Oral Abstracts

2018 Bay-Delta Science Conference

Abstracts for oral sessions presented at the 2018 State of the Bay-Delta Science Conference are compiled in this document. Abstracts are listed in the order that they appear in the program and are sorted by day, room, and time. Names of presenting authors are underlined. Asterisks (*) indicate the presenter is competing in the student presentation awards competition.

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Plenary Session

Bay-Delta Science: Looking Towards 2020

John Callaway, Delta Science Program, John.Callaway@deltacouncil.ca.gov

While the Bay-Delta system already is a “devilishly wicked problem”, it faces growing challenges moving into the next decade including climate change and more. In order to address these challenges, we need to continue conducting science that provides insight for decision making and that improves our overall understanding of the system so that we can identify upcoming challenges on the horizon. Some important steps towards improving our scientific vision include: providing stable funding for science, addressing science governance issues, engaging social scientists, and crossing the Bay-Delta watershed divide. Progress is being made in each of these areas; however, major challenges remain. Science funding must be sustainable and dependable in order to provide useable science, both immediately and with a longer term vision. Governance issues are being incorporated into the updated Delta Science Plan, but this issue will need broader discussion and a long-term commitment to achieve meaningful improvements. Incorporating social sciences into the research agenda within the Delta is critical on a variety of fronts, and recent efforts address this issue, including the Delta Science Program’s newly proposed Social Science Task Force. Connecting science from the Sierra to the Sea has many supporters but coordinating efforts in a meaningful way will require identifying strategic areas for collaboration given funding and resource constraints across the entire system.

Session Title: Plenary Session
Session Time: Monday, September 10th, 9:00 AM - 12:10 PM, Rooms 308-313

Policy Leadership in the Glen Canyon Dam Adaptive Management Program: Stakeholders or Science?

Jack Schmidt, Utah State University, jack.schmidt@usu.edu

The Glen Canyon Dam Adaptive Management Program (GCDAMP) was created in 1997 as a federal advisory committee whose purpose is to make recommendations to the Secretary of the Interior regarding operations of Glen Canyon Dam. Stakeholders who serve as official committee members represent the seven Colorado basin states, 5 tribes with spiritual or cultural connection to the Grand Canyon, and representatives of river-based recreation, hydropower consumers, and environmental advocacy. Stakeholders have many different perspectives regarding the goals of ecosystem management and have articulated different desired future conditions for the river corridor in Grand Canyon National Park. The different goals offered by different stakeholders lead to differences of opinion regarding the most significant scientific questions that ought to be addressed by the GCDAMP and its science support arm – the USGS/Grand Canyon Monitoring and Research Center. Because the interests of some stakeholders benefit by significant changes in reservoir operations and the interests of other stakeholders benefit by maintenance of the status quo, tension and disagreement arises as to what questions in applied science are the most significant and ought to be addressed. To date, most major policy initiatives began as issues identified and pursued by river scientists. Thus, scientists play an important role in interpreting the policy concerns of stakeholders and translating those concerns into tractable questions that can be addressed within reasonable time frames. Scientists also have an obligation to help stakeholders understand that some policy concerns cannot be answered within the existing framework of water supply agreements or within the time frames of stakeholder concerns. A dynamic tension will always exist between the river science community who is expert in the identification of critical uncertainties that limit the effectiveness of management actions and the stakeholder community that has many different values and objectives for the outcome of management actions.

Session Title: Plenary Session
Session Time: Monday, September 10th, 9:00 AM - 12:10 PM, Rooms 308-313

Government Science at a Crossroad: Creating a Future of Enhanced Relevancy and Impact

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Government-based science is at a fundamental crossroad, both in the Bay-Delta and across the Nation. Never have the tools of science been so powerful in terms of the amount and diversity of data that can be measured, our ability to transmit and analyze that information, and the variety of ways that we can communicate the findings. On the other hand, our science agencies and efforts are faced with ever-greater demands and challenges. The questions being asked in order to understand and solve problems are growing more complex, at the same time agencies are facing growing budget pressures. At a societal-scale, we see declining public trust in science, greater expectations for fast answers and return on investment (ROI), and increased questioning and challenging of findings. New laws and policies require greater transparency, data sharing, and review. These drivers and opportunities affect our science policies, practices, and people. Moving forward, we must find ways to continue delivering independent, high-quality science and to do so more rapidly and broadly, and communicate in ways that are more understandable and applicable. For a variety of reasons, these tasks are not inherently easy for scientists or science organizations, and may make any given science effort take longer and cost more. But if done right, such an approach will increase the relevance and impact of science. It can provide a foundation for more effective solutions and greater decision space for resource and management agencies, without straying into advocacy for specific policy or management actions. And importantly, it can demonstrate the very positive return that science can provide as we move into an increasingly complex and dynamic future.

Session Title: Plenary Session
Session Time: Monday, September 10th, 9:00 AM - 12:10 PM, Rooms 308-313

Integrating Social Science in Large Estuarine Restoration

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The need to integrate social science for restoration is no longer a debate. How to do so, however, remains an enigma to many. Dr. Biedenweg will present her work with Washington State's Puget Sound Partnership to integrate social science in planning and monitoring the restoration of the Puget Sound basin. The work includes identifying, adopting, and monitoring indicators of human wellbeing along with ecological metrics of restoration success; using decision tools with watershed and basin planning groups to integrate best available social science when developing strategic plans; and supporting research to better inform linkages between social and ecological trends. The presentation will describe the thinking and process for achieving these goals, and the successes and pitfalls along the way. Throughout the talk, Dr. Biedenweg will identify key social scientific concepts relevant to large-scale ecosystem restoration.

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Communicating science in a post-truth world

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Communicating your science is often intimidating to scientists, but in the post-truth era we find ourselves in now, it is more important than ever. What makes people more or less likely to accept new information? How can you, as a scientist, build trust when there is political polarization or when trust has broken down? How can you engage in meaningful dialogue and communicate across differences? In this engaging and lively talk, we'll discuss these themes, highlight stories of scientists who have effectively engaged, and focus on skills to successfully communicate with various audiences.

Session Title: Plenary Session
Session Time: Monday, September 10th, 9:00 AM - 12:10 PM, Rooms 308-313

Why Integrated Modeling? Examples from the Field

USGS Coastal Storm Modeling System: Integrating Across Models and Communities

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The USGS Coastal Storm Modeling System (CoSMoS) is a dynamic modeling approach that integrates a suite of models to provide detailed predictions of coastal flooding due to both future sea level rise and storms integrated with long-term coastal evolution (beach changes and cliff/bluff retreat) over large geographic areas. CoSMoS models all the relevant physics of a coastal storm, which are then scaled down to local flood projections for use in community-level coastal planning and decision-making. For emergency response applications, CoSMoS is also being linked with NOAA's National Water Model to form a two-way coupled system termed Hydro-CoSMoS to provide up to 72-hour forecasts of watershed and ocean based flood forecasts.

An important priority for the modeling team is to ensure that the results are developed with the needs of the end-user in mind, particularly when for emergency response. Throughout the development of CoSMoS in both the San Francisco Bay Area and in Southern California, the USGS partnered with place-based boundary organizations to engage local stakeholders to understand their modeling needs. To complement this, two web-based tools have been developed to make the CoSMoS information easily accessible. The Our Coast Our Future flood viewer (developed by Point Blue) allows varied audiences to explore the 40 combinations of sea level rise and storms that have been modeled throughout the CoSMoS regions. The Hazard Exposure Reporting & Analytics tool (HERA, developed by USGS) translates flood exposure into socioeconomic impacts. Similarly, initial modeling results of Hydro-CoSMoS were utilized in a tabletop exercise by local water managers in Napa to gain valuable insight into what final products would be most helpful to managers and emergency responders. In this session, we will discuss the importance of engaging end-users in developing modeling products and to demonstrate that integrated stakeholder engagement is as equally important as integrated modeling.

Keywords: CoSMoS, flood, hydrological, integrated, modeling, sea level rise, emergency response
Session Title: Why Integrated Modeling? Examples from the Field
Session Time: Monday, September 10th, 1:35 PM - 3:15 PM, Room 306

Translating Process-Based Restoration Strategies into Spatially-Explicit Restoration Opportunities in the Delta

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In a previous report titled "A Delta Renewed" we offered a collection of guidelines for science-based ecological restoration in the Sacramento-San Joaquin Delta that emphasized restoring or emulating natural processes, anticipating future landscape and climate changes, establishing appropriate configurations of habitat types at the landscape scale, and utilizing a variety multi-benefit management strategies. In this talk, we will present on our recent work to support regional restoration planning efforts by developing a repeatable process for using these guidelines to identify spatially-explicit restoration opportunities. The process is largely GIS-based and utilizes spatial data on existing land cover and conservation status, habitat configuration (including patch sizes and distances), surface elevations (including depth of subsidence), and future changes in tidal elevations associated with sea-level rise. By distilling generalized guidelines into spatially-explicit opportunities, it is our hope that the process provides a practical tool for incorporating science into planning. To that end, these new methods are currently being piloted through planning efforts focused on the Central Delta Corridor and the McCormack Williamson Tract, and are also being used to assist with the quantification of ecological restoration potential in the Delta Plan Ecosystem Amendment (the subject of the final talk in this session).

Keywords: Delta, resilience, restoration, planning tool
Session Title: Why Integrated Modeling? Examples from the Field
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Anticipating and Communicating Regional Effects of Reconfiguration of Delta Geometry

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The contemporary Delta has evolved from a complex natural marsh to a highly managed channel network through two centuries of human intervention. In the decades to come the evolution of Delta geometry will continue through planned restoration actions, and possibly through unplanned levee failures. Changes in Delta geometry, particularly addition of new areas open to tidal inundation, can have both local and regional hydrodynamic effects that are important to many stakeholders. Because of the complexity of the Delta channel network, regional hydrodynamic effects can be non-intuitive. There needs to be a better way to understand regional impacts and improve the conversation of opportunities and tradeoffs when considering restoration actions and investment in levee systems. Detailed multi-dimensional modeling of the Bay-Delta System has been used extensively to examine effects of planned restoration actions and potential levee failures. This current work builds on those studies by selecting a representative range of previously modeled geometry changes, and generating spatial metrics from new simulations with consistent hydrology and operation assumptions. Spatial metrics include changes in water level, net flow, tidal prism, and tidal excursion. The resulting spatial metrics demonstrate distinct patterns when geometry changes are focused in Suisun Marsh, northwest Delta, northeast Delta, or south Delta. These patterns vary in sign, magnitude, and spatial extent of the metrics' responses to new tidal inundation. Under some circumstances, summing the effects of individual geometry changes provides a reasonable estimate of the effects shown when simulating combinations of geometry changes. This approach may help develop improved general understanding of regional impacts and quantitative means of assessing tradeoffs in meeting stakeholder objectives. It is relevant to planned restoration actions, levee investment, and planning for accommodation of climate change.

Keywords: Delta, modeling, geometry, restoration, levees, multidimensional, metrics, spatial
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Franks Tract Hydrology, Landscape, and Stakeholder Views

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Franks Tract is a flooded island situated at the intersection between the San Francisco estuary and the Delta freshwater corridor. The Tract has been the subject of numerous restoration and salinity control proposals, most recently the 2015 False River Emergency Drought Barrier installation by the California Department of Water Resources (DWR) and the 2018 Franks Tract Restoration Feasibility Study led by the California Department of Fish and Wildlife under the Delta Smelt Resiliency Strategy. For these projects, DWR used the Bay-Delta SCHISM (Semi-implicit Cross-scale Hydroinformatics Model) package to perform well-resolved 3D studies of the hydrodynamic and water quality response to the drought barrier and restoration designs at near field and far field scales. The studies confirmed the prevailing understanding of how Franks Tract affects tides and central Delta salinity intrusion, but also suggested that submerged aquatic vegetation (SAV) plays an important role modulating regional circulation. The combination of constructive disruption of the system, new monitoring, remote sensing of vegetation abundance by UC Davis and ultimately collaborative embedding of a vegetation model in the SCHISM hydrodynamic model allowed us to better characterize these dynamics and anticipate how/when similar considerations might affect future restoration designs. The integrated modeling concepts featured in this talk include hydrodynamic

decision making at two scales using water project operational criteria, coupling of the SAV model, and use of draft results as a basis for stakeholder discussion. As model users, we will describe how our use of a community-driven, high performance modeling suite affects our notion of what "integrated modeling" means and what types of sharing and interaction seem most fruitful for us.

Keywords: Integrated Modeling, Restoration, Drought, Franks Tract, Hydrodynamic Modeling
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Understanding Impacts of Water Management on Salmon Using Integrated Physical and Biological Models

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California's complex water projects are operated to achieve a balance among myriad competing societal objectives, including how operations modify the freshwater and estuarine habitats of salmon. To prevent the extinction and promote the recovery of endangered salmon, resource managers need tools to help them understand how water project operations impact salmon. We are developing a growing collection of decision support tools that integrate hydrologic, hydraulic, water quality, and biological models to link water management actions to salmon endpoints; two of which are briefly reviewed in this presentation. In our integration of models of hydraulics, water temperature, salmon embryo survival, and data on egg-to-fry-survival for Sacramento River winter-run Chinook, we discovered that laboratory-based temperature criteria were not as protective of developing salmon eggs as had previously been believed. In our integration of hydrologic, hydraulic, water quality and salmon population models and application to California WaterFix scenarios, we found that the net effect of changes to Delta hydrodynamics are expected to be negative for Sacramento River winter-run Chinook, even though some effects would be beneficial to a segment of the population. Some key general insights of our work include 1) that careful selection and integration of models allows for clear linkages to be made from management actions to the biological endpoints of concern; 2) while model integration can take considerable time and effort, the process can be expedited by including talented computer programmers in the team, and 3) it is critical to integrate not just the models with each other, but also the models with data.

Keywords: Chinook salmon, integrated models, hydrology, water quality, population dynamics,
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Conservation of Wetland Birds

The Relative Importance of Agricultural and Wetland Habitats to Waterbirds in the Sacramento–San Joaquin River Delta of California

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Biodiversity loss from agricultural intensification underscores the urgent need for science-based conservation strategies to enhance the value of agroecosystems for birds and other wildlife. California's Central Valley, which has lost over 90% of its historic wetlands and currently is dominated by agriculture, still supports waterbird populations of continental importance. A better understanding of how waterbirds use available habitat is particularly needed in the Sacramento–San Joaquin Delta, an ecosystem under threat. From 2013 to 2015, we studied waterbird habitat associations in the Delta during fall migration and winter. Waterbird use of cover types (agricultural crops and managed wetlands) varied substantially among guilds, by season, and among geographic subregions of the Delta. Overall, wetlands were particularly important to waterbirds in fall. In winter, wetlands and flooded rice and corn were important to many guilds, and non-flooded corn and irrigated pasture to geese and cranes. The factors that influenced waterbird abundance and distribution also varied substantially among guilds and differed at various geographic scales. In both seasons, most species had a positive association at the field level with flooded ground and open water and a negative association with vegetation. Given the great uncertainty in the future extent and pace of habitat loss and degradation in the Delta, there is an urgency to prioritize conservation actions needed to maintain robust waterbird populations in this region. For the Delta to retain its importance to waterbirds, it will be necessary to maintain a mosaic of wetlands and wildlife-friendly crops that accounts for the value of the surrounding landscape. This includes restoring additional wetlands and maintaining corn, rice, alfalfa, and irrigated pasture, and ensuring that a substantial portion of corn and rice is flooded in winter.

Keywords: Alfalfa, agroecosystems, corn, irrigated pasture, rice, waterbird conservation, waterbird habitat
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The Importance of Managed Wetlands to Multiple Waterfowl Species in the Suisun Marsh

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Managed wetlands comprise a significant proportion of the wetland habitat present in the San Francisco Bay Estuary and plans to restore tidal action to some of these lands are underway. Given the significant loss of all types of wetland habitat within California and the Pacific Flyway, it is critical that we understand the value of our remaining wetland habitats to wildlife. We examined the relative importance of managed wetland and tidal wetland habitats in the Suisun Marsh to multiple species of waterfowl. We monitored the movements of both wintering and breeding waterfowl in the Suisun Marsh using GSM-GPS backpack transmitters on Mallard (Anas platyrhynchos, n=149), Gadwall (Anas strepera, n=60), Cinnamon Teal (Anas cyanoptera, n=24), Northern Pintail (Anas acuta, n=104), American Wigeon (Anas americana, n=41), Northern Shoveler (Anas clypeata, n=26), and Canvasback (Aythya valisineria, n=32). Transmitters were programmed to provide GPS quality location data for individual marked birds at a rate of between 4 and 48 locations per day depending on solar recharge of the transmitter. We compared habitat selection for these marked individuals by marsh type (tidal vs managed), time of day (day or night), ownership (public or private) and season. Waterfowl did utilize tidal marsh habitats under certain conditions and timing but the overwhelming majority of habitat use by waterfowl occurred on managed wetlands. The Suisun Marsh is an important resource use area for Pacific Flyway waterfowl and careful planning and management will be needed to maintain that status into the future.

Keywords: managed wetland, tidal, waterfowl, Suisun Marsh
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Time Series Remote Sensing Of Waterfowl Food Resources and Productivity in Central Valley Managed Wetlands

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Approximately 90% of the Central Valley's naturally occurring wetlands (including the Sacramento-San Joaquin Delta) have been lost due to land use change, yet the Central Valley remains a critical landscape for migratory waterbirds through a complex system of managed wetlands and post-harvest flooded agriculture. In present-day managed wetlands, moist soil seed plants provide an essential food resource for waterfowl, but the regional distribution and productivity of these resources have not been quantified. We coupled Landsat time series and field data to map distributions and quantify productivity of important moist soil seed plants: watergrass, smartweed and swamp timothy for the years 2007 - 2017. Vegetation field data were collected during the summer of 2017 at over 200 60x60m plots extending from the Sacramento Valley in the north to the San Joaquin Valley in the south. The surveys were conducted at four National Wildlife Refuges and three State Wildlife Areas, plus a private duck club. We also collected swamp timothy seed head samples from 70 Landsat pixel footprints (350 samples total) across the Central Valley to generate Landsat-based biophysical models of seed yield following methods by Rahilly and others (2012). Preliminary models show high correlation between seed yield and the green chlorophyll index [(NIR/G) - 1] (R2 = 0.50, percent normalized RMSE = 10%). Wetlands were also ranked by relative productivity using Landsat-based monthly composite greenness indices. Final models and moist soil seed maps will be used to highlight areas that have consistently high yield and those that may be more variable. Maps of food resource extents and productivity will aid conservation planning and monitoring at refuges. In addition given extreme fluctuations in water availability, these maps will provide an annual record of how wetlands were managed historically, serving as a reference for what is feasible in future years.

Keywords: managed wetland, waterfowl, satellite remote sensing, productivity
Session Title: Conservation of Wetland Birds
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Does Diet Composition or Habitat Biogeochemistry Drive Mercury Concentration in a Threatened Wetland Bird?

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The San Francisco Bay has been heavily impacted by methylmercury (MeHg) contamination putting waterbirds at risk of adverse effects from MeHg toxicity. Variation in MeHg concentrations among individuals of the same species may be driven by variation in the biogeochemical pathways involved in MeHg production or by differences in diet composition among individuals. We examined diet composition, trophic structure, and MeHg biomagnification in the food web of a state-threatened, wetland bird, the California black rail (Laterallus jamaicensis coturniculus), along with 12 measures of sediment biogeochemistry, to determine whether differences in MeHg concentrations among rails from three adjacent wetlands were driven primarily by differences in diet or habitat biogeochemistry. Black rails were dietary generalists with similar diets among wetlands (percent similarity indices > 70%). The trophic structure of the black rail food web was also similar among wetlands. Trophic magnification slopes for MeHg did not differ significantly (all p > 0.12) and ranged from 0.18 to 0.28. The concentration of MeHg and the percent of MeHg to total Hg in sediments differed significantly among wetlands (p = 0.047 and 0.021, respectively), and differences in MeHg concentrations of rails and their prey mirrored differences in sediment MeHg. Further, we identified five sediment measurements that contributed significantly to a discriminant function explaining differences in sediment biogeochemistry among wetlands: loss on ignition, dry sediment MeHg concentration, percent of MeHg in sediment, percent of Fe(II) to total Fe, and concentration of total reduced sulfur. Given the similarities in diet composition, trophic structure, and MeHg biomagnification among wetlands, we concluded that variation in habitat biogeochemistry and associated sediment MeHg production was the primary driver of differences in MeHg concentration among rails from different wetlands. Future changes in sea-level and weather patterns could alter tidal wetland biogeochemistry thereby affecting MeHg production and availability to wetland food webs.

Keywords: Mercury, Food webs, California black rails, Biomagnification, Wetland biogeochemistry
Session Title: Conservation of Wetland Birds
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Diving Duck Response to Restoration of North Bay Salt Ponds: Managed vs. Breached Ponds

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The San Francisco Bay (SFB) estuary is important wintering and stopover habitat for over 700,000 waterfowl, and is especially significant for diving ducks that use its intertidal and shallow subtidal habitats. Supratidal areas, such as managed ponds, can supplement the needs of waterfowl. In northern SFB, the Napa-Sonoma Marshes Wildlife Area comprises 6100 ha of wildlife habitat, including former commercial salt production ponds that are the focus of intense restoration efforts. Tidal flow has been restored to 61% of pond area, with the remainder maintained as managed ponds. A challenge central to tidal restoration is to balance the needs of obligate marsh species with those that rely on open water habitats, such as divers. To evaluate the response of divers to restoration efforts, we used our 19-year (1999-2018) dataset of monthly high tide waterbird and water quality surveys of each pond. We compared seasonal use of breached and managed ponds for abundant diver species (scaup, Aythya spp.; canvasback, A. valisineria; and ruddy duck, Oxyura jamaicensis). Species abundances were positively associated with each other, and all species were more abundant on larger, lower salinity, lower temperature ponds. Canvasbacks were most abundant in winter, on breached ponds, and in association with dabbling ducks. Scaup and ruddy ducks were most abundant on managed ponds. Scaup were more abundant in winter than fall and on ponds with more dissolved oxygen (DO), while ruddy duck abundance did not differ among seasons and was not associated with DO. Our analysis identifies key differences in habitat associations among diving duck species, suggesting species specific management strategies may be useful, and highlights the importance of maintaining long-term surveys to evaluate response to restoring habitats. Managers may incorporate these findings into management strategies to better maintain appropriate habitat and resources for these three species of diving ducks.

Keywords: diving ducks, canvasback, scaup, ruddy ducks, salt ponds, habitat restoration
Session Title: Conservation of Wetland Birds
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Flow Alteration Studies: Lessons Learned and Preliminary Synthesis From Lower Trophic and Delta Smelt Studies in 2017

Directed Outflow Project

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Requests and plans for water management actions related to augmentation of Delta outflow are ongoing and are expected to proceed in the future. However, there is uncertainty and disagreement regarding the relationship of Delta outflow during the rearing period to Delta Smelt vital rates and habitat, and the hypothesized benefit of outflow alteration for Delta Smelt. Delta outflow has experienced reductions in recent years, coinciding with the collapse of the Delta Smelt. Reduced outflow has been linked to reductions in habitat suitability in Suisun Bay and Marsh and movement of the LSZ to the Confluence of the Sacramento-San Joaquin River where little connection to shallow open water habitats exists. The Directed Outflow Project (DOP) is a collaborative multi-year effort among roughly a dozen state, federal and non-governmental groups seeking to evaluate hypotheses related to the rationales provided for Delta outflow management actions to benefit Delta Smelt. To augment ongoing surveys and known datawithin the DOP study area, during the fall of 2017 we paired data collections (same location and time) of abiotic and biotic habitat constituents (i.e., fish, plankton, chlorohyl, harmful algal constituents, contaminants, physico-chemical measures, diet, smelt health and condition, smelt growth, salinity and thermal history) to assist in reducing shortcomings of using data collected for different studies/hypotheses and/or across variable spatial/temporal scales.Here we provide key results and synthesis of the DOP study aspects in relation to associated hypotheses/predictions,with comparisons and discussion to the current Delta Smelt knowledge base.

Keywords: outflow augmentation, Delta smelt, fall X2, suisun marsh
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Delta Smelt Prey Dynamics in Response to Managed Outflow

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The Delta Smelt population decline throughout the prolonged drought did not appear to rebound in response to a record wet year in 2017. During fall of 2017, lower trophic investigations were conducted in conjunction with the USFWS Enhanced Delta Smelt Monitoring (EDSM) Program to determine how Delta Smelt prey responded to managed outflow per the USFWS Biological Opinion. These data were also be used to assess how Delta Smelt feeding habitats during the fall compare with prey availability. We present biweekly spatial and temporal macrocrustacean data collected from three different habitats at EDSM monitoring stations. Our data show that mysid shrimp abundance, dominated by Hyperacanthomysis longirostris and Neomysis kadiakensis, varied spatially (across habitats and regions) and temporally (monthly) during the fall. The most abundant amphipod was Gammarus daiberi, and it also varied temporally and spatially, but tended to aggregate at higher densities in Suisun Bay and the lower Sacramento River. These data suggest that water quality and habitat are important factors that affect abundance and distribution of macrocrustacean prey in the upper San Francisco Estuary. Ultimately, improved understanding of the distribution and abundance of these organisms relative to outflow and associated water quality may feature prominently in recovery efforts for endangered Delta Smelt.

Keywords: Delta Smelt, mysids, amphipods, outflow,
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The Influence of Summer Temperature on Delta Smelt Habitat during Wet Water Years

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The summer of 2017 was characterized by favorable salinity for Delta Smelt in Suisun Bay and the Sacramento-San Joaquin River confluence region; however, water temperatures in the confluence region and parts of the North Delta approached stressful levels between July and September. These conditions corresponded to reduced catches near the confluence of the Sacramento and San Joaquin Rivers in the summer, followed by a reduction of catch in the North Delta in the late summer and fall. To investigate the influence of temperature on Delta Smelt catch and distribution, we analyzed similarities and differences between conditions in the summer of three recent wet years: 2017, 2011, and 2006. Water temperatures during the summer of 2011 were lower than in 2017, while summer water temperatures in 2006 were also relatively high from late June through July. A 3-D hydrodynamic model was applied to simulate salinity and temperature during the summer of each of these 3 years. The model predictions of salinity and temperature were compared to available fish catch data for each year from the Bay Study, Fall Midwater Trawl, and Enhanced Delta Smelt Monitoring (2017 only). The goal of this analysis is to better understand the influence of summer temperature on Delta Smelt distribution during the summer and fall.

Keywords: Delta Smelt, habitat, hydrodynamic modeling, temperature
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Smelt in Hot Water: Is Thermal Stress the Final Blow for Delta Smelt?

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Managing freshwater outflow in late winter-early spring to maintain the Low-Salinity Zone in Suisun Bay has been one of the primary management strategies for supporting Delta Smelt and their habitat. Meanwhile fall flows have declined over time due to freshwater exports and the Low-Salinity Zone has been located upstream where physical habitat is thought to be poor quality. As a result, fall flows in wet/above normal years are now mandated by the 2009 BiOP to maintain the Low-Salinity Zone no less than 74km in September and October. This management action has occurred twice (2011 and 2017) since 2009, and Delta Smelt experienced strong recruitment in 2011 but did not in 2017. Summer water temperatures in 2017 were near the Delta Smelts thermal limit throughout the Estuary, while 2011 was much cooler, thus temperature may be an important driver of recruitment success. To explore how temperature influences growth and recruitment of Delta Smelt we used otolith microstructure and microchemistry to quantify growth, hatch-date distributions, and movement history of fish collected in the wet years 2011 and 2017 and the drought years 2012-2016. Temperature in the spring had a strong influence on hatch-date distributions, 2011 having the longest period of successful hatching. Temperature also had a positive effect on growth up to 19°C, after which growth decreased significantly. Finally, temperature exceeding 20°C in freshwater corresponded with movement of Delta Smelt into brackish water. Our results suggest temperature may be the critical driver of the life history and recruitment success of Delta Smelt.

Keywords: Delta Smelt, Outflow, X2, Temperature, Otolith, Climate Change, Drought, HobbsLab,
Session Title: Flow Alteration Studies: Lessons Learned and Preliminary Synthesis From Lower Trophic and Delta Smelt Studies in 2017
Session Time: Monday, September 10th, 1:35 PM - 3:15 PM, Room 308-310

Examining Phytoplankton Responses During the USFWS Delta Smelt Fall Outflow Action: How did the Base of the Food Web Respond to a Change in X2?

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How are phytoplankton in Suisun Bay and the Sacramento River Delta affected by delta flow management? Microalgae are an important part of the Bay-Delta trophic system, and assemblages can change rapidly in response to environmental conditions. Management actions, like the recent fall outflow action, may affect the quantity of phytoplankton, the nutritional quality of the assemblage, and promote blooms of both beneficial and harmful taxa. From late September through November 2017, we collected data on phytoplankton, water quality, nutrient concentrations, and chlorophyll a in conjunction with the Enhanced Delta Smelt Monitoring program to determine how phytoplankton varied temporally and spatially.

Phytoplankton biomass was low: chlorophyll concentrations averaged 2.6 µg/L, but were significantly higher in the Sacramento River Deep Water Shipping Channel. These low concentrations continued throughout the season and were comparable to chlorophyll data collected since phytoplankton biomass sharply declined three decades ago. Early in the season, diatoms and cyanobacteria were both common, and diatoms became proportionally more abundant as the season continued. Nutritionally rich diatoms appeared to dominate in the upper delta, with more cyanobacteria downstream. Nutrient concentrations varied between sampling locations; the shipping channel had high phosphate and low combined nitrogen concentrations, Suisun Bay and the lower Sacramento River had high combined nitrogen and low phosphate, the upper Sacramento River had high ammonium, and nutrients in the Cache Slough Complex were variable.

Spatial and temporal shifts in nutrients and the microalgae community may change habitats' suitability for native fish as flows are managed. More research is needed to understand the effects of Fall Outflow management on the phytoplankton community, and to predict the quantity and nutritional quality of food for zooplankton and delta smelt.

Keywords: Phytoplankton, Directed Outflow Project, Food Webs, Nutrients, Species Assembages
Session Title: Flow Alteration Studies: Lessons Learned and Preliminary Synthesis From Lower Trophic and Delta Smelt Studies in 2017
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Life and Death of Phytoplankton

The Etiology of Phytoplankton Productivity and Bloom Formation in the Northern Delta

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In the Sacramento-San Joaquin Delta, the separate and combined effects of landscape-scale engineering, flow diversions, the introduction of nutrients and other contaminants, along with changes in sediment supply, are thought to have altered patterns of phytoplankton primary production. Changes in phytoplankton production have in turn been linked to declines of native pelagic fish species in the system.

It is widely believed light limitation is the strongest control on productivity in the Delta, owing to elevated turbidity. However, turbidity has been declining over the past decade with no concomitant rise in phytoplankton biomass. It is generally assumed that nutrients (nitrogen, phosphorus, silica) are not limiting to primary production in the Delta, but elevated ammonium concentrations have been shown to affect total rates of phytoplankton productivity, chlorophyll biomass, as well as phytoplankton community structure. Other anthropogenic actions that may have affected formation of phytoplankton blooms include introduction of invasive clams – which can crop production before the bloom stage – changes to water residence time – which can leave insufficient time for blooms to form, and altered flowpaths – which can isolate zones that can initiate blooms from zones in which the blooms can expand.

We have aggregated data of many different types to explore the etiology of phytoplankton bloom formation in the northern Delta with the objective of highlighting management options for improving aquatic habitat conditions. The effects of environmental factors such as light, flow, residence time, temperature, nutrient forms and ratios on bloom incidence, bloom intensity and phytoplankton community composition were investigated. Early results show that inception of large-scale blooms occur at only a few locations, and under hydrologic conditions that promote propagation. At the current stage of analysis, nutrients do not appear to be a factor in bloom formation. The analysis is ongoing; we will present our latest findings.

Keywords: Phytoplankton, Productivity, Blooms, Northern Delta, Chlorophyll, Residence time, Nutrients
Session Title: Life and Death of Phytoplankton
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Nutrient Limits Phytoplankton Bloom during a Historical Spring Bloom Event in San Francisco Bay

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We present modeled chlorophyll a concentration for San Francisco Bay during a historically high spring bloom event in 2013. A finite volume biogeochemical transport & cycling model DWAQ (Deltares Water Quality) was offline coupled to a validated three-dimensional hydrodynamic model DFM (Deltares Flexible Mesh). The model was successful in capturing the historical bloom event, when biogeochemical processes including nitrogen cycling, phytoplankton dynamics and pelagic grazing were enabled. The peak of the bloom was essentially controlled by nutrient limitation, whereas the generally high-nutrient, low-chlorophyll condition for all other periods was maintained by zooplankton grazing. The modeling results emphasize that nutrient limitation can play an important role in controlling phytoplankton bloom during high chlorophyll events, although phytoplankton biomass in San Francisco Bay is generally not nutrient-limited.

Keywords: phytoplankton bloom; biogeochemical model; zooplankton grazing; nutrient cycling
Session Title: Life and Death of Phytoplankton
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Toxicity Evaluation of the Effects of Fluridone Formulations on Delta Phytoplankton

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Submerged, floating and emergent species of invasive aquatic vegetation have expanded in the Delta, particularly during the recent drought, and now occupy the majority of shallow-water and littoral areas of the system. There are multiple adverse effects of aquatic weeds including reduction of open-water habitat, negative effects on water quality, as well as hazards for boating. Other potential deleterious effects of invasive macrophytes include negative effects on phytoplankton and possible facilitation of Microcystis blooms. The herbicide Fluridone is used for the control of submerged aquatic vegetation in the Delta, however multiple herbicide formulations exist, including liquid and time-released pellets. Given the prevalent use of Fluridone in the Delta, and the implications of non-target effects on local phytoplankton communities, we evaluated the sensitivity of the diatom Thalassiosira pseudonana to various formulations of Fluridone. Research has indicated the toxicity of adjuvant components in herbicide formulations; therefore we included an examination of pellets without Fluridone to determine any differences in toxicity among the formulations. These experiments are in progress, the results of which will provide important insight to whether invasive aquatic weed control has the potential to negatively impact food web habitat, and can have greater implications for programs such as the Delta Smelt Resiliency Strategy and the numerous restoration activities currently underway in the Delta.

Keywords: Phytoplankton, herbicides, toxicity, Fluridone, Delta, foodwebs
Session Title: Life and Death of Phytoplankton
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Monitoring Cyanobacteria in Mixed Algal Populations in an Effort to Predict the Onset of Cyanohabs

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Global occurrence of CyanoHABs is increasing at an alarming rate sparking a need for development of new methods and tools to rapidly quantify, monitor, and mitigate bloom events. Countless annual timelines have been recorded showing increased bloom activity at a certain time of the year, "hot" season, followed by relaxation period. During a "hot" season, when bloom activity is expected to peak, we're preparing for sampling and analysis in an effort to better characterize the factors leading to the onset of HABs. During the relaxation period there may also be short lived HAB events stemming from changes such as increased anthropogenic input or anomalous heat spikes. These off-peak bloom events may offer better information for determining the driving factors behind HABs, but are hard to catch using in situ fluorometers that specifically monitor cyanobacterial marker pigments such as phycocyanin (PC), which only provide a partial answer to the question, "Is a HAB fast approaching?" A more detailed approach using high frequency, field-ready tools such as the CyanoFluor or PhytoFind, which use pigment ratios, allows us to rapidly monitor cyanobacteria populations WITHIN total algal populations providing information which can be used to predict the onset of HABs and offering valuable data for building predictive models. This is the best approach to help further our understanding of why HABs occur.

Keywords: Cyanohabs, monitoring, predicting fluorescence ratios, algae fluorometer, phycocyanin, chlorophyll, cyanobacteria
Session Title: Life and Death of Phytoplankton
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From Algal Toxins to Environmental DNA: Passive Samplers as a Tool to Help With Multiple Management Objectives

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Climate changes are expected to affect water-quality, ecosystem health, and species viability within the San Francisco Bay-Delta (Delta). As these changes occur, it will be necessary to streamline data collection protocols so that sampling tools can simultaneously address multiple management objectives while saving time and money. One existing tool that shows promise for meeting multiple management objectives are Solid Phase Adsorption Tracking (SPATT) samplers. SPATTs were developed as an economical tool to passively monitor algal toxins that may be missed by discrete grab sampling. SPATT's have proven useful in the Delta and will continue to be used to monitor future algal toxins. We found SPATTs can also be used to monitor for Environmental DNA (eDNA). The eDNA method is an efficient, non-invasive, and relatively rapid process that can determine species presence and organism occupancy. Typically, eDNA monitoring involves collecting a discrete grab sample. However, traditional sampling methods may limit the spatial and temporal scale of eDNA monitoring. In a pilot study, we used SPATT and grab samples to determine if imperiled freshwater mussels (Unionidae) were present in the Delta. We deployed six SPATTs at two Delta locations. Anodonta Californiensis were detected in all six SPATT samples and 33 grab samples in the San Joaquin River near Mossdale. No mussel eDNA was detected in any SPATT samples at the I street bridge, but A. Californiensis was detected in 2 of 11 grab samples. This is the first time we are aware that SPATT samplers have been used to monitor for eDNA. Although we successfully used SPATTs, additional eDNA investigations and modification of the method may further improve upon our results. We believe this is a promising tool to meet future management objectives by cost effectively detecting cryptic species such as Delta Smelt, while simultaneously monitoring for algal toxins.

Keywords: algal toxin, environmental DNA, freshwater mussels, multiple management objectives
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Sea Level Rise Effects and Adaptations I

Vulnerabilities to Sea Level Rise in Eastern Contra Costa County: Communities and Assets at Risk of Flooding

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Situated at the intersection of rising sea levels and stream flows from California's 2 largest river systems, the agricultural, ecological, and urban landscapes of the Sacramento – San Joaquin Delta require an assessment of their vulnerability to climate change. To date, regional climate vulnerability investigations have largely focused on water resource management and have not included stakeholders in the process of identifying vulnerable assets and adaptation options. The San Francisco Bay Conservation and Development Commission's Adapting to Rising Tides (ART) program and the Delta Stewardship Council are engaging local governments, communities, non-profits, and the private sector to conduct a vulnerability assessment and adaptation planning of current and future flood risk from climate change. This investigation focuses on eastern Contra Costa County, from Pittsburg to Clifton Court. Technical work includes refining flood maps by modeling the combined hydraulic influences of riverine inputs and Bay tidal effects impacted by sea-level rise. These maps follow the ART "One Map=Many Futures" – which depicts different combinations of sea-level rise and storm conditions on single maps – enabling a distilled yet comprehensive understanding of risk. Results identify communities and a range of assets including transportation and utility infrastructure at risk from current flooding and from flooding that will be exacerbated by sea-level rise. Using the ART approach this project mobilizes a people-centered and equitable planning process resulting in the identification of adaptation strategies to be integrated with ongoing regional efforts, such as the ART Bay Area Project, and broader planning across the Delta region. This presentation introduces the results of the modeling and initial vulnerability assessment, and describes the next steps in the ART approach.

Keywords: Sea Level Rise; climate change; flooding; resilience; community; planning; modeling
Session Title: Sea Level Rise Effects and Adaptations I
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The State of the Mouse: Conserving SMHM in Our Modern and Changing Estuary

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Recent research has redefined our understanding of the ecology of the endangered San Francisco Estuary endemic, the salt marsh harvest mouse (SMHM, Reithrodontomys raviventris). These new data can, and should, inform, conservation and management of the species. Though as our knowledge of this relatively understudied species grows, so do some of the most pressing threats the mouse faces. In this talk we present a synthesis of some of the most recent research developments, a summary of the most important threats to the species, and a list of the potentially most impactful future research endeavors. While some of the newest research on SMHM is promising for species recovery, some paints a more dire picture. For example, while the species has been managed as a relatively strict habitat specialist for decades, recent work indicates that their habitat requirements are quite flexible, and expands greatly the know habitat extent of SMHM. On the other hand, recent genetic work shows that the genetic diversity of the southern subspecies is much lower than the northern, making it vulnerable. In light of these developments, current recovery strategies, and future threats, our primary recommendations are to investigate the potential effects of climate change on SMHM, investigate range-wide SMHM population dynamics and genetics, investigate the demographic response of SMHM to habitat restoration, and to place a stronger emphasis on the importance of the community context of SMHM ecology. With improvements to genetic analyses, electronic research equipment, and advanced computer modeling capabilities, our capacity for large-scale, coordinated, research programs is greater than ever, and we recommend increased cooperation among entities throughout the species range.

Keywords: salt marsh harvest mouse, conservation, management, research, behavior, genetics, wetlands
Session Title: Sea Level Rise Effects and Adaptations I
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Preventing an Ecological Trap from Tidal Restoration with Sea-Level Rise: Incorporating Managed Wetlands in Climate Adaptation Strategies

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Sea-level rise (SLR) scenarios indicate that tidal wetlands on the lower Pacific coast of the U. S. are highly vulnerable to submergence resulting in extensive loss of habitat. Under higher SLR scenarios, all high and mid marsh habitats are lost with 83% of current tidal wetlands transitioning to unvegetated habitats by the end of the century. Even under conservative scenarios, 95% of high marsh and 60% of mid marsh habitats are lost. In the San Francisco estuary, upland migration is constrained in most areas by low vertical accretion, steep topography, and urban development resulting in coastal squeeze. Thus, tidal wetland loss may be inevitable with climate change, and a return to historical extent of tidal marshes is not possible. Instead, novel ecosystems are being managed within a highly urbanized estuary to maximize biodiversity and abundance. Collaborative decision analyses have suggested that rapid tidal restoration may bolster endemic tidal marsh populations (including endangered species) in the short-term; however, these actions may create an ecological trap where populations are concentrated in restored areas that become unsustainable with rising sea levels and increasing storm events. In contrast, managed wetland techniques, used effectively in the estuary to manage former salt pond habitats and Suisun Marsh brackish marshes, may provide durable and resilient refugia for tidal marsh species. Although not often discussed as a climate adaptation strategy, incorporating managed wetland impoundments is consistent with developing a mosaic of wetland habitats often sought under large-scale restoration landscapes (e.g., South Bay Salt Pond Restoration Project). Management of levees and water control structures may not be cost-prohibitive if techniques from current managed wetlands are applied and when the alternative may be extirpation. Here, we discuss how managed wetlands could be used as a climate adaptation tool to provide refugia for conserving source populations of tidal marsh species.

Keywords: tidal restoration, sea-level rise, managed wetland, climate adaptation, ecological trap
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Projected Impacts of Sea-Level Rise and Geomorphic Change on Intertidal and Subtidal Foraging Habitat Availability for Migratory Birds in San Francisco Bay

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Nearly one million migratory waterbirds along the Pacific Flyway rely on intertidal flat and shallow subtidal foraging habitat of the San Francisco Bay each year. These important habitats are threatened by increased tidal inundation and altered sediment transport caused by sea-level rise, increased storm frequencies, and habitat alterations, such as damming and levee construction. Loss of intertidal flats and shallow habitat may force waterbirds to search for alternative foraging habitat, potentially influencing energetic costs and increasing the risk of mortality. To inform sea-level rise mitigation strategies for waterbird habitat, we compared current availability of flats and shallows to habitat availability during three future time periods (2030, 2050, and 2100) by modeling geomorphic change and sea-level rise at two shoals in South San Francisco Bay: Eden Landing and Dumbarton. Differences in the shape and slope of these shoals affected the rate and magnitude of habitat loss; we observed greater and faster loss at Eden Landing where the shoal was shorter and flatter than at Dumbarton. Foraging habitat availability from 5 to 25 cm water depth decreased over time at both sites, with nearly 100% of habitat lost at Eden Landing and approximately 60% of habitat lost at Dumbarton by 2100. At Eden Landing, four times more habitat was lost in the first half of the century from 2005 to 2050 than in the last half of the century from 2050 to 2100. In contrast, habitat availability declined steadily throughout the century at Dumbarton. Our results demonstrate that without mitigation, projected sea-level rise could dramatically reduce the availability of tidal flat and shallow foraging habitats in South San Francisco Bay by the end of this century, and that shoal shape and slope are important factors in determining the rate and magnitude of habitat loss as sea-level rises.

Keywords: Sea-level rise, Waterbirds, Mudflats, Coastal habitat loss
Session Title: Sea Level Rise Effects and Adaptations I
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Modeling the Implications of Sea Level Rise for X2 Standards Compliance

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Sea level rise (SLR) will increase salinity intrusion into the Bay-Delta estuary, potentially causing adverse ecological impacts. X2, the upstream distance of the near-bottom 2-isohaline from the Golden Gate Bridge, is a measure of salinity intrusion that has been linked to ecological health and is used to determine when reservoir releases are needed to push saline water seaward. We used a hydrodynamic model of the estuary, D-Flow FM, to simulate the effects of a range of SLR values (0 to 240 cm) on X2 for a recent wet water year (WY), 2011, and a dry WY, 2012. Preliminary results indicate that as SLR increases, X2 regulatory requirements would be increasingly violated without additional inflows. For an SLR of 100 cm, X2 increased by 6.4 km in the wet WY and 6.1 km in the dry WY. We fit the Jassby (1995), Monismith (2002), and MacWilliams (2015) X2 equations to our simulation results for a range of SLR values. The MacWilliams equation performed the best, and the SLR-dependent parameters that we determined for that equation may be used to estimate SLR impacts on X2 for any SLR value by interpolating between the X2 calculated for the SLR values we evaluated. Using these parameters, we developed an algorithm to determine the minimum additional outflow needed to satisfy the primary X2 requirements. For an SLR of 100 cm, the minimum additional outflow needed was 0.27 km3 (0.22 maf) in the wet WY and 2.13 km3 (1.7 maf) in the dry WY. Compared to historical flows for these WYs, these are increases of 1% in the wet WY and 16% in the dry WY.

Keywords: sea level rise, salinity, X2, management, net delta outflow
Session Title: Sea Level Rise Effects and Adaptations I
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Integrated Modeling to Support Salmon Management

Real-Time Modeling of the Effects of Shasta Reservoir Operations on Winter-Run Chinook Salmon Incubation Can Increase Management Flexibility and Fish Survival

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Problem Statement: In 2013-2015, Sacramento River temperatures exceeded 54F and egg-to-fry survivals of winter-run Chinook were historically low. A paper by Martin et al. (2017) implicated mortality to temperature-elevated metabolism exceeding oxygen supply to redds. These findings prompted NOAA to consider lowering the temperature control criteria. However, in dry/warm years Shasta Reservoir may contain insufficient cold-water to maintain a lower temperature forcing managers to target a higher temperature or reduce the duration of temperature control. Determining which strategy yields higher fry survival requires preseason information on redd locations and real-time information on the physiological response of developing eggs and fry to temperature.

Approach: Impacts of alternative temperature control strategies on egg-to-fry survival can be evaluated with linked models. Redd location can be inferred from historic patterns of redd locations, the onset of spawning and temperature gradients prior to and during spawning. Laboratory studies show embryo sensitivity to oxygen stress is greatest just prior to hatching and then declines as fish switch from diffusive oxygen uptake to gill respiration. These mechanisms were modeled in Egg Kill (www.cbr.washington.edu/sacramento/egg/index.html) to estimate the effect of temperature on winter-run Chinook incubation survival. The current web-based system predicts egg-to-fry survival as a function of redd distributions and temperature. New model additions will generate probabilistic forecasts of temperature effects on redd locations and egg-to-fry survival.

Results: Targeting cold-water to the July-August hatch allows managers time and flexibility to plan reservoir operations while increasing fry survival in years with low cold-water resources as occurred in 2014. Challenges of real-time temperature management are discussed from our experience in the 2018 incubation season.

Conclusion/Relevance: Biologically based models that characterize the effects of water temperature on the behavior and physiology of salmonids from spawning through incubation can make a significant contribution to efficient real-time management of Shasta Reservoir.

Keywords: winter-run Chinook Salmon, egg mortality, temperature control, Shasta Reservoir, model
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A Decision Support Tool Linking Physical Models of Water Temperature with Biological Models of Salmon Health in the Shasta/Sacramento System

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Water flow and temperature play a critical role in salmon health, especially during early life stages where exposure to high water temperature in spawning grounds can drive high mortality rates. In the Sacramento River of California, federally endangered winter-run Chinook salmon are reliant on cold-water from Shasta Reservoir, an important component of the federal and state water project and supply of fresh water to the Delta. To better understand the dynamics of cold-water resources for the Sacramento system and how this relates to salmon health, we are integrating a series of linked mechanistic models simulating water temperature dynamics in Shasta and Keswick Reservoirs and the Sacramento River, and a biological model that simulates the thermal effects of water temperature on developing salmon eggs. We developed a web-based decision support tool, the Central Valley Temperature Mapping and Prediction (CVTEMP), to deliver the outputs from the physical and biological models on a daily basis. This tool allows users to evaluate model predictions of water temperature and temperature-dependent salmon egg survival over time and under different scenarios of hydrological and meteorological conditions of the system.

Keywords: Water Temperature, Salmon Health, Linked Models
Session Title: Integrated Modeling to Support Salmon Management
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Interactive Decision-Support Models for Assessing Effects of Alternative Water Management Actions on Juvenile Salmon Migrating through the Delta

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Problem Statement: Because water management actions may be costly to fisheries or water resources, managers increasingly need quantitative tools for assessing the effect of potential water management actions. Decision-support models may be used to understand the effect of large-scale infrastructure projects, such as California WaterFix. They may also be used to help understand the potential effect of in-season actions and near real-time decisions, such as required under the 2016 Water Infrastructure for the Nation Act.

Approach: To provide quantitative decision-support tools for juvenile salmon, we developed the Delta Survival, Travel time, and Routing Simulation (STARS) model. The Delta STARS Model is an individual-based simulation model that predicts survival, travel time, and routing of juvenile salmon migrating through the Delta. The model's structure and parameters are based on a Bayesian analysis that relates individual survival, travel time, and routing of acoustic-tagged late-fall Chinook salmon to daily Sacramento River flows at Freeport and Delta Cross Channel operations.

Results: We illustrate two applications of the STARS model. First, we implemented the STARS model as part of the proposed DREAMS (Delta Real-time Enhanced Acoustic Monitoring System) project and the Interagency Ecological Progam - Enhanced Acoustic Telemetry (IEP EAT) project. This application produced near real-time simulations of daily survival, travel time, and routing for the current water year, providing managers with an in-season assessment of expected survival and migration dynamics. Second, we added “management knobs” to the STARS model to allow managers to modify routing at key river junctions to simulate how implementation of behavior guidance structures affect routing, and ultimately, through-Delta survival.

Relevance: Our applications show how thoughtful design of field studies, statistical modeling, and interactive visualizations can be used to develop decision-support tools to aid water and fisheries management in the Delta.

Keywords: decision support models, water management
Session Title: Integrated Modeling to Support Salmon Management
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Confronting Jagger's Law: Improving Multi-Objective Ecological Flow Management with Flexible Priorities and Turn-Taking

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Management of the Sacramento River and Sacramento–San Joaquin Delta (SRD) is one of California's greatest challenges, requiring trade-offs between valued components that serve a multiplicity of conflicting purposes. We demonstrate an improved method for multiple objective allocation of water: "turn-taking" optimization (TTO) within a multi-model cloud computing framework. We apply TTO to an array of physical hydrologic models that are linked with the Ecological Flows Tool (EFT), a multi-species decision support framework for evaluating how specific components of the flow regime promote and balance favorable habitat conditions for 15 representative species and 31 indicators within the SRD. The application of the TTO approach incorporates the existing modelled representation of socio-economic water management criteria, priorities and constraints and optimizes water release patterns each water year using a dynamically shifting set of EFT indicators. Rather than attempting to optimize conditions for all ecological indicators every year, turn-taking creates flexibility and opportunities for different indicators to be successful in different years, informed by the frequency each species' ecological needs should be met. As an individual EFT indicator is successful in a particular year, its priority in one or more subsequent years is reduced (and vice versa). Comparing TTO to a Reference case scenario based on current management practices, 12 EFT indicators are improved, 14 show no change and 5 show a reduction in suitability. When grouped into 9 species and life-history groups, there was improved performance in 4 (late-fall Chinook, winter Chinook, spring Chinook and Fremont cottonwood), no change in 4 (fall Chinook, Delta smelt, splittail and longfin smelt), and worse performance in 1 group (steelhead).

For a deeper look at study methods and results please see ourarticle (https://doi.org/10.15447/sfews.2018v16iss1/art2) in theSan Francisco Estuary & Watershed Science.

Keywords: multi-objective optimization, endangered species, trade-offs, environmental flow, real-time, turn-taking
Session Title: Integrated Modeling to Support Salmon Management
Session Time: Monday, September 10th, 3:35 PM - 5:15 PM, Room 306

A Machine Learning Model for Predicting Salmonid Take at the SWP and CVP in Real-Time

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The rate of incidental take at the SWP and CVP pumping facilities is potentially influenced by a dynamic set of environmental, behavioral and water operations variables. Many of these variables are also highly correlated and interact with each other. As such, the assumptions of commonly used, parametric modeling approaches, such as ordinary least squares regression, are violated, and the potential for spurious results arising from complex and difficult-to-interpret interactions is high. In order to circumvent these issues in multi-dimensional situations, a range of machine-learning techniques are gaining favor in ecology and natural resource management. We developed a machine learning model trained on 15 years of historical data in order to predict weekly salvage of salmonids based on a suite of variables that can be forecasted one month into the future. We apply two related classes of models. The first is Random Forest (RF) regression, a modeling technique based on regression trees that split data sets incrementally based on one predictor variable at a time. This approach seeks to minimize variance within each new group of data while maximizing variance between groups. The second is Quantile Forest regression (QRF), a generalization of the RF model that returns the complete conditional distribution of the response variable while RF regression only returns mean values. Most importantly, QRF can be more informative in management scenarios where levels of risk are of interest. A drop-one analysis was performed by fitting each model to data with one water year excluded and then predicting the excluded year and predicted years were aggregated to examine overall model performance variable between populations. Despite substantial uncertainty, observation-prediction points fell quite evenly around a one-to-one line, suggesting reasonable predictive ability for incidental take of listed salmonids that occurs as a result of implementing state and federal water export operations.

Keywords: Incidental Take, Delta, Random Forest, Machine Learning
Session Title: Integrated Modeling to Support Salmon Management
Session Time: Monday, September 10th, 3:35 PM - 5:15 PM, Room 306

Restoration and Vegetation

Ensuring a Resilient Tidal Marsh Ecosystem Through Healthy Upland Transition Zones: Assessment and Recommendations

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For wildlife dependent on a healthy tidal marsh ecosystem in the San Francisco Estuary, the transition zone between the marsh and surrounding upland is critically important. This habitat provides refuge for wildlife from the effects of extreme tides and storm events and provides for marsh expansion due to climate change. Scant natural transition zone remains and, thus, extensive restoration efforts are under way. Yet there is little information on which characteristics of transition zones ensure healthy tidal marsh ecosystems and promote the recovery of species of concern, such as the endangered Ridgway's rail. This lack of information inhibits our ability to design restoration strategies that maximally benefit target species and limits our ability to assess the effectiveness of management actions. Through partnerships with practitioners, we have carried out a broad-scale study in San Francisco Bay and San Pablo Bay to identify key features of the transition zone that best support species recovery and ecosystem resilience. We collected field data on the winter and breeding season diversity and abundance of tidal-marsh associated birds in relation to vegetation and physical characteristics of the transition zone and adjacent land use at 17 study sites. We test the hypotheses that the abundance of marsh-dependent birds within adjacent marshes and use of the transition zone by marsh-dependent birds during high water events is associated with: (1) dense vegetation structure ≥50 cm in height, (2) density of gumplant (Grindelia stricta), and (3) broad, gradually-sloped transition zones. In this multi-partner project, we have developed an initial set of integrated protocols for studying the biotic and physical features of transition zones. Results provide a basis for a comprehensive monitoring framework for the transition zone—to be integrated into regional monitoring efforts—that will help support recovery and promote stability of wildlife dependent on tidal marsh ecosystems.

Keywords: extreme tides; monitoring framework; tidal marsh-dependent wildlife; transition zone
Session Title: Restoration and Vegetation
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Mapping Arundo donax across the Central Valley to Prioritize Watershed Restoration

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Arundo donax is an invasive plant that damages riparian ecosystems across California, including coastal watersheds and in the Central Valley. Its tall canes grow densely, consuming substantial water, crowding out native vegetation and altering hydrology. Cal-IPC and partners have mapped infestations, analyzed impacts, prioritized sites and are in the process of building partnerships to eradicate Arundo donax (giant reed) in Central Valley watersheds, an area in excess of 14 million acres in size. Arundo impacts water availability through high levels of transpiration. As measured in coastal watersheds, an acre of Arundo can use as much as 20 ac-ft/yr/ac more than native. Thus, a net water gain of 20 ac-ft/yr/ac may be realized for every acre of Arundo that is permanently removed from a watershed. To successfully achieve this long-term benefit, projects must start at the top of a watershed and proceed downstream because Arundo spreads from plant fragments floating downstream). To implement top-down control, a complete mapping of the plant in invaded areas must occur. Then groups may systematically implement control programs, as has already occurred in numerous coastal watersheds in California. This type of project—mapping, impact analysis, prioritization and program preparation—provides an effective foundation for later implementation,and has already been accomplished for coastal watersheds from Monterey to Mexico by Cal-IPC. Systematic eradication of Arundo also restores fluvial processes and riparian habitat, reduces flooding and erosion, and lowers fire risk. Our long-term goal is to eradicate all Arundo in both the Sacramento and San Joaquin valleys. This will protect the Delta Region, which is already initiating its own mapping, prioritization and control program for Arundo. Work in the Delta will be far more sustainable if upstream Arundo sources are eliminated. This talk or paper will discuss mapping, field-checking, and project design by watershedin the Central Valley beyond the Delta.

Keywords: Arundo donax, invasive plants, watershed-scale, water use, landscape-level effort
Session Title: Restoration and Vegetation
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Screening Herbicides for Management of Waterhyacinth in the California Bay Delta

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Waterhyacinth is a worldwide aquatic weed that has become a significant nuisance in the Sacramento/San Joaquin River Delta (hereafter the Delta). Glyphosate and 2,4-D have been the predominant herbicides used for management. While these chemicals have been effective for control, additional herbicides need to be evaluated to address concerns over herbicide resistance management, environmental restrictions, and reduction in total active ingredient applied. We performed three trials in floating quadrats in the Delta. Treatments were applied in four replications using a 3-nozzle boom, with a standard spray volume of 100 GPA and Agridex surfactant at 3 pt/A. In the first (2016), we applied two rates each of 2,4-D (15.2 and 30.4 oz ae/A), glyphosate (24 and 48 oz ae/A), imazamox (8 and 16 oz ae/A), and penoxsulam (0.75 and 1.25 oz ai/A). The highest rates of all four herbicides provided satisfactory control (2,4-D, 82%; glyphosate, 87%; imazamox, 93%; and penoxsulam, 94%). In the second trial (2016), we compared the lower rate of glyphosate (24 oz ae/A) to four rates each of imazamox (2.7 to 21.3 oz ae/A) and penoxsulam (0.2 to 1.4 oz ai/A). The highest rates of imazamox and penoxsulam provided excellent control (96% and 95%, respectively). In the third trial (2017), we applied other low-rate chemicals, carfentrazone and flumioxazin, alone and in tank mixes with imazamox or glyphosate. We also applied glyphosate (24 oz ae/A) in three spray volumes (25 GPA, 50 GPA, and the standard volume of 100 GPA). The tank mix of flumioxazin + imazamox (1.35 g ai + 5 g ae/A) and the 50-GPA application of glyphosate each produced better than 95% control. Imazamox and penoxsulam appear to be effective alternatives to 2,4-D and glyphosate for controlling waterhyacinth with reduced rates of active ingredient. Their availability also will facilitate management for herbicide resistance.

Keywords: waterhyacinth, control, management, herbicides, invasive
Session Title: Restoration and Vegetation
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The Promise of Remotely Sensed Phenology for Wetland Restoration Monitoring

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Phenological information on seasonal change in wetland vegetation may provide important clues about ecosystem functioning, such as carbon sequestration, and responses to climatic variability, disturbance and invasions. Such information, however, is difficult to collect in the field in comprehensive and spatially explicit manner at regional scales. Alternatively, time series of repeatedly collected remote sensing data can be used to evaluate landscape-level phenological indicators representing ecosystem schedules governing functional processes and restoration outcomes. Our study demonstrates the potential of such remotely sensed phenology to elucidate ecological characteristics of different-aged restored marshes in San Francisco Bay and west Sacramento-San Joaquin Delta using satellite imagery at medium (30m) and high (5m) spatial resolution. Results indicate that at early stages since restoration, phenological indicators may be more sensitive to initial site design and landscape setting than time since restoration per se; however, longer-term phenological characteristics more strongly reflect transformations of canopy structure and their feedbacks with local ecosystem processes. Our findings also highlight remote sensor-specific caveats that need to be considered in generalizing among different sources of phenological data. Collectively, these outcomes illustrate the potential of remotely sensed phenology to cost-effectively monitor post-restoration wetland dynamics and assist in regional-scale upscaling of ecosystem properties and services.

Keywords: Restoration, remote sensing, marsh, monitoring, phenology, succession
Session Title: Restoration and Vegetation
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Leveraging Free Remote Sensing Data for the Landscape-Scale Assessment of Vegetation Dynamics in Restored Wetlands

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Current scientific literature reports a significant variability in the outcomes of wetland restoration, with projects sometimes falling short of ecological targets. A consistent monitoring of wetlands could pinpoint the causes of this variability but is often limited by a lack of funding or difficult field access. Remote sensing analyses can complement field monitoring at low costand facilitate landscape-scale site comparison for a better identification of factors promoting vegetation recovery. Yet remote sensing data remain underutilized in post-restoration assessments. We seek to address this gap by developing a methodological framework leveraging free remote sensing data for the long-term tracking of restoration progress. Specifically, we constructed time series of vegetation greenness for a subset of 21 restored wetlands and 5 reference sites in the Sacramento-San Joaquin Delta of California using NASA's Landsat archives. We identified breakpoints within these site-level time series to detect changes in vegetation dynamics. We then used a higher resolution dataset from USDA's National Agricultural Inventory Program to delineate vegetated patches within each site. From the resulting classification, landscape metrics were generated to relate fluctuations in site greenness to changes in the geometry and spatial distribution of vegetated patches. Preliminary results suggest a significant effect of site age, initial restoration design, and connectivity on vegetation dynamics, but a substantial variability among restored and reference sites. Younger wetlands and sites with a greater patch density showed a more rapid increase in site greenness. Meanwhile, older sites with a high vegetation to water ratio and clustered vegetated patches were more likely to experience a decrease in site greenness. These results show the serious potential of leveraging free remote sensing data to explore patterns of vegetation development. Studying these patterns offers important clues on the effect of landscape dynamics and site characteristics on vegetation recovery.

Keywords: wetland, restoration, remote sensing, landscape metrics, trajectories, Landsat, NAIP, breakpoint.
Session Title: Restoration and Vegetation
Session Time: Monday, September 10th, 3:35 PM - 5:15 PM, Room 307

Hardly Strictly Smelt Genetics

Experimental Work Informs Delta Smelt Environmental DNA (eDNA) Protocol Development

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Traditional monitoring of Delta Smelt currently detects very few individuals. More sensitive detection may be achieved with indirect sampling of Delta Smelt using environmental DNA (eDNA). Although the field of eDNA is developing rapidly, estuarine systems are underrepresented. Estuaries pose challenges for eDNA detection due to turbidity, variable flow, and tidal exchange. In particular, high and variable turbidity requires adjustments to filtration and detection protocols. Here we report on recent experimental work designed to improve eDNA detection of Delta Smelt and interpret Delta Smelt eDNA detections in a biological context. Small amounts of eDNA from a tank of cultured Delta Smelt were combined with field water and filtered. The same experiment was replicated with field water from different,biologically relevant turbidities. The experiment was designed to reproduce the challenges of detecting eDNA from a small, rare fish in turbid water. The likelihood of eDNA detection was affected by filter type and filtration volume. This work helps to determine best practices for eDNA sampling in dynamic estuarine systems. Refining methods for Delta Smelt eDNA sampling increases the value of eDNA for management of Delta Smelt and other San Francisco Estuary species. eDNA sampling enhances ecosystem sustainability because it allows for increased sampling of sensitive populations in habitats that cannot be sampledusing traditional methods and with fewer adverse impacts such as mortality due to sampling.

Keywords: Delta Smelt; DNA; eDNA; management; conservation
Session Title: Hardly Strictly Smelt Genetics
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Assessing the Genetic Diversity of Sacramento Perch (Archoplites interruptus) for Development of a Captive Breeding Program

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The California endemic Sacramento Perch (Archoplites interruptus) was once widely distributed throughout the Sacramento-San Joaquin drainage. Anthropogenic activities have resulted in the extirpation of this species from its native range with a handful of remnant populations confined to isolated reservoirs and lakes in California and Nevada. Left unmanaged, these translocated populations risk further genetic diversity declines and threats to the species continued persistence. The California Department of Fish and Wildlife is interested in developing captive breeding programs in partnership with private aquaculture farms for Sacramento Perch to promote native species conservation, which could provide individuals for a conservation supplementation program. To determine the genetic health of the species and determine candidate populations for use in captive breeding programs, we conducted a range-wide genetic assessment of previously surveyed (2008) and newly discovered populations using 12 microsatellite markers. We found two primary genetic clusters, each containing sub-structure. Pairwise FST estimates showed that all populations were highly differentiated from each other, even within the same genetic cluster. Most of the populations surveyed showed evidence of past bottlenecks, likely founder effects resulting from transplantation and unsuccessful recruitment due to competition with non-native fish species. Measures of effective population size (Ne) for many of the populations fell below the minimum recommended value to prevent further genetic diversity loss. Most of the populations surveyed will need managed supplementation to persist and as a result, are not candidates for use as captive broodstock. Identification of genetically diverse, healthy populations for use in supplementation efforts will aid management efforts to prevent further declines in this species.

Keywords: Population structure, Managed populations, Captive breeding, Bottlenecks, Genetic Drift, Isolation
Session Title: Hardly Strictly Smelt Genetics
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Evidence of Domestication Selection in a Delta Smelt Conservation Hatchery

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When a species is critically endangered, captive breeding programs are often used as a last resort to prevent extinction. For the Delta Smelt (Hypomesus transpacificus), a forage fish species endemic to the San Francisco Estuary that experienced a steep abundance decline in the past few decades, one such program exists in the form of the Fish Conservation and Culture Laboratory (FCCL) at Byron, California. However, captive populations can often experience domestication selection, which may result in reduced fitness when said populations are reintroduced into the wild. Here, we examined evidence of domestication selection for the endangered Delta Smelt using genetic monitoring data from the FCCL. The FCCL has been genetically managed intensively since its initiation in 2008, with parentage assignment for spawning adults and incorporation of wild fish each year. Genetic monitoring results indicate little loss of genetic variation and low differentiation between the wild and refuge populations. Yet we have found increasing recovery rates (where offspring survive to become reproductively mature during the subsequent spawning season) of crosses where cultured fish comprise one or both parents in a cross. Results indicate that crosses with higher levels of hatchery ancestry tend to produce a greater percent of offspring that are recovered the following year. We also found evidence that recovery rate of any particular cross decreases when it is raised in a tank composed of fish with high levels of hatchery ancestry. As the potential use of FCCL Delta Smelt for reintroductionis becoming more likely, we suggest changes in fish rearing at the FCCL to reduce genetic adaptation to captivity and further research into mechanisms of genetic adaptation to captivity.

Keywords: Delta Smelt; domestication selection; genetics; hatchery
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Delta eDNA Part 1: Investigation of eDNA Methodology to Detect Delta Smelt

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The loss of historical habitat within the San Francisco Bay Delta estuary for has resulted in extirpations or serious declines of Delta smelt (Hypomesus transpacificus) throughout its former range. Management actions are sub-optimal if current distribution and occupancy information is unreliable. Enhancing survey method sensitivity would improve compliance monitoring under the Endanger Species Act, recovery planning for Delta smelt. Current environmental DNA methodology, sampling recommendations, and models for DNA transport are primarily for use within uni-directional riverine and lacustrine systems, however, little or no models exist for the transport of eDNA within a tidally mixed system like that of the San Francisco Bay Delta estuary. With the goal of creating a SF Bay delta eDNA transport model live car experiments using hatchery Delta smelt were conducted over the past two years in coordination with the US Bureau of Reclamation and the Central Valley Projects (CVP) Tracy Fish Collection Facility. Samples were taken at fixed distances along a sampling array within the CVP channel. The biomass of hatchery Delta smelt was varied to determine the probability of detection from a known biomass at a fixed distance within a given sample volume. Quantitative PCR was used as the means for identifying target DNA within filtered samples using published techniques (Bergman et al. 2016; Blankenship and Schumer 2017). This presentation will provide an overview of sampling techniques including sample timing, equipment, and filter types. In addition data from live car experiments and initial model input and results will be discussed within the context of sampling for Delta smelt and other salvaged species at the Central Valley Project.

Keywords: eDNA, Delta smelt, monitoring, water management
Session Title: Hardly Strictly Smelt Genetics
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Delta eDNA Part 2: Applying eDNA Procedures to Detect Delta Smelt at Salvage

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The rarity of Delta Smelt has made monitoring quite difficult. EDNA is a valid technique and is in widespread use across the planet for the detection of cryptic, rare, and invasive species. EDNA is extremely sensitive, lends itself to automation, and is scalable. EDNA is non-invasive and does not require permitted “take”. In January 2018, an expedited request was made to survey for Delta Smelt in the South Delta using eDNA. Given investigation of eDNA procedures had been underway (see Delta eDNA Part 1), a modest alteration of sampling using existing partnerships was employed. The goal for the application was to obtain information on ability of an eDNA survey to detect the presence of Delta Smelt within the South Delta and relate those data to ambient conditions and water operations at South Delta water diversions. Field sampling occurred at three places in the South Delta, the bridge to Bacon Island (Middle River), D&L Farm (Old River), and at the Central Valley Project (CVP) trash rack. Both the Old River and Middle River sites were sampled on in-coming (flood) tides in order to mimic a unidirectional system, to the extent possible, thus allowing for the application of existing eDNA detection models. CVP was sampled twice daily (in duplicate) irrespective of tide. Field sampling and analysis followed published methods(Bergman et al. 2016; Blankenship and Schumer 2017), with two species surveyed for using quantitative Polymerase Chain Reaction (qPCR), Delta Smelt and a common salvaged species, Threadfin Shad. While detected rarely, Delta Smelt were observed at all three sites and more commonly than physical capture at salvage. Threadfin Shad were observed at a majority sampling events, although non-detects were present during incidents of low density. Web-based data visualization were developed as part of project to enhance potential communications and information delivery.

Keywords: eDNA, Delta smelt, monitoring, water management
Session Title: Hardly Strictly Smelt Genetics
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Lower Trophic Food Webs

What Controls Food Availability to Pelagic Fishes during Summer–Fall in the Low-Salinity Zone of the San Francisco Estuary?

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Between 1987 and 1993 the food web of the Low-Salinity Zone (LSZ) was reshuffled by a series of species introductions, notably those of the clam Potamocorbula amurensis and several copepod species. This food web has since remained remarkably stable, without extirpations or further introductions. Here we synthesize results of studies of this estuarine food web and describe our current understanding of the limits to productivity. The LSZ is a low point in the estuary for phytoplankton biomass and abundance of copepods and fish. The phytoplankton minimum is clearly related to grazing by clams, particularly Potamocorbula amurensis. For copepods the situation is more complex, as P. amurensis is both a competitor and a predator that imposes substantial mortality on early life stages of copepods. Each copepod species has found a way to accommodate the combination of low phytoplankton biomass and high mortality. For example, early stages of the tiny cyclopoid Limnoithona tetraspina are eaten by clams and predatory copepods, but the population remains abundant because of low mortality of adults, indicating little consumption by fish. Pseudodiaptomus forbesi is most abundant in a freshwater refuge from predation, but makes up ~half of the summer diet of delta smelt in the LSZ. However, mortality rates of all life stages are high there, so P. forbesi can persist in the LSZ only through a subsidy mediated by mixing from freshwater regions of the Delta, bolstered by advection during high-flow periods. These copepods are food limited, with low reproductive and growth rates, and growth rates increase at times in response to some, but not all, phytoplankton blooms.

Relevance: Few options exist for restoring the once-high productivity of the LSZ, and current attention to off-channel, spatially and temporally variable regions seem most promising for maintaining and restoring the pelagic ecosystem of the upper estuary.

Keywords: productivity; copepod; spatial subsidy; food limitation; mortality rate; growth rate
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24 Hour Bugs – Testing Zooplankton Tidal and Diel Distributions

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The Fish Restoration Program is tasked with restoring tidal wetlands to increase food web support for listed fish species, particularly Delta Smelt and Longfin Smelt. However, zooplankton, the largest components of smelt diets, exhibit tidal and diel vertical migrations that make it difficult to fully characterize fish food availability. Because it is logistically infeasible and prohibitively expensive to sample zooplankton at all tidal stages during both day and night on a regular basis, we conducted a study of zooplankton vertical and horizontal distribution over a single 24 hour period in June of 2017. The goal of the study was to determine whether zooplankton abundance and composition during the day can be used to estimate overall zooplankton abundance and composition during regular monitoring of restoration sites. We found that both tidal stage and time of day had a highly significant effect on zooplankton community composition and total catch-per-unit-effort, with abundance being higher at night and on high slack tides. However, during a given time frame, major differences between channel and shallow-water zooplankton were not evident. This study supports the findings of other researchers in the estuary that have shown diel and tidal migration to be important for Pseudodiaptomus forbesii, a key component of Delta Smelt diets. In the future, we need to take tidal and diel distribution into account when making conclusions about monitoring of zooplankton in wetland restoration sites.

Keywords: Zooplankton; Smelt; vertical migration; copepoda; cladocera; food web; tides
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The Contribution of Terrestrial Particulate Organic Carbon to Estuarine Copepod Diet

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In the San Francisco Bay-Delta (SFBD), phytoplankton primary production is perceived as a major food source for zooplankton, thereby fueling higher trophic level energy needs. Yet algal resources are by no means abundant in this estuary due to turbidity – limiting the photic zone – and the introduction of Potamocorbula amurensis – causing grazing competition. In fact, the SFBD is classified among the lowest 15% of estuaries worldwide in terms of phytoplankton primary production, raising the question: what other food resources are supporting the lower aquatic food web in the SFBD? Terrestrial organic matter (OM) is a non-trivial component of particulate organic carbon (POC) in this estuary, and despite its relatively low nutritional content, terrestrial POC has been identified as a significant food resource for copepods in other estuaries. In order to clarify the role of terrestrial POC in the SFBD lower aquatic food web, we designed a zooplankton feeding experiment that used a combination of chemical biomarkers (lignin, chlorophyll a) and DNA amplicon metagenomics to track Suisun Marsh POC water chemistry and Eurytemora affinis gut content after feeding. We also investigated the impact of terrestrial OM on zooplankton survivability using observational laboratory feeding experiments with E. affinis across a spectrum of algal and terrestrial POC food treatments. Our results suggest that terrestrial POC alone is insufficient to support zooplankton, but in the presence of phytoplankton terrestrial POC enhances survival more than phytoplankton alone. This synergy between terrestrial POC and phytoplankton emphasizes the value of landscape diversity for food web management, particularly in light of current and future restoration efforts in the SFBD.

Keywords: zooplankton, phytoplankton, food web, metagenomics
Session Title: Lower Trophic Food Webs
Session Time: Monday, September 10th, 3:35 PM - 5:15 PM, Room 311-313

Growth Rates of a Dominant Calanoid Copepod in the Yolo Bypass of the Upper San Francisco Estuary

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Freshwater flow pulses through the Yolo Bypass are being tested as a mechanism to stimulate copepod growth rate and thereby enhance the lower food web of the northern Delta. Copepod growth is the key rate process in zooplankton secondary production. We conducted a total of 38 growth-rate experiments within the toe drain of the Yolo Bypass during summers 2015-2017. Experiments were performed on copepods collected from four sites: Lisbon Weir, Screwtrap, Prospect Slough, and Ryer Island, in Cache Slough near the confluence with the Sacramento River (2017 only). These experiments were done using the artificial cohort method with image analysis to estimate volume per copepod. Volume was then calibrated against carbon, and growth rate was calculated as the rate of change of log-transformed carbon per copepod. In addition to copepod growth rate, analyses of lipids, pigments, and chlorophyll in particulate matter were performed to assess the influence of food quantity and quality on copepod growth rate. On average copepod growth rate was highest at Lisbon (0.40 day-1), the northernmost station, and lowest at Ryer Island (0.23day-1). Growth rate was positively related to chlorophyll concentration, a relationship that has been absent or weak in our previous studies, and total lipids. Copepod growth rates were consistently higher in the Yolo Bypass and adjacent waters than in other parts of the San Francisco Estuary; however, they were still lower than maximum laboratory growth rates, indicating persistent food limitation. In addition, they overlap in range with previous measurements in the Cache Slough complex. These results support our findings of relatively high growth rates in this region. It appears that flow pulses do not directly affect copepod growth rate but can potentially facilitate the transport of this productive water further downstream which should support higher consumption by planktivorous fishes including the endangered delta smelt.

Keywords: Copepod, growth rate, Pseudodiaptomus forbesi, Yolo Bypass, food web
Session Title: Lower Trophic Food Webs
Session Time: Monday, September 10th, 3:35 PM - 5:15 PM, Room 311-313

Patterns of Nekton Abundance and Food Web Structure in the Sacramento Deep Water Shipping Channel

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The Sacramento Deep Water Shipping Channel (SDWSC) is a 42 km long man-made channel connecting Rio Vista to the Port of Sacramento for shipping traffic. It functions as a terminal tidal channel, as closed radial gates disconnect the upstream end of the SDWSC from the Sacramento River. The uniform central section of the SDWSC is approximately 9 m deep with shoals on either side. An apparent mixing zone has been observed in the middle reaches of the SDWSC at the extent of tidal excursion. During the high flow event in winter to spring of 2017, the mixing zone dissipated, likely due to diminished effects of tidal forces during extremely high river flows. Here, we describe spatiotemporal patterns in water quality, nekton community, and food web structure upstream, within, and downstream of this mixing zone. The goal is to further understand the physical and hydrodynamic features that drive the biological outcomes in the SDWSC.

Keywords: Food Web Structure, Nekton Abundance, Sacramento Deep Water Shipping Channel
Session Title: Lower Trophic Food Webs
Session Time: Monday, September 10th, 3:35 PM - 5:15 PM, Room 311-313

Sea Level Rise Effects and Adaptations II

Adapting to Rising Tides (ART) Bay Area Sea Level Rise Analysis and Mapping: Communicating Current and Future Flood Risk in San Francisco Bay

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During the Bay Conservation and Development Commission'sfirst sea level rise adaptation process, called Adapting to Rising Tides (ART) Alameda County, the project's cross-sector working group encountered challenges in applying the regional scale sea level rise models and maps that were available at the time. For example, the group identified topographic errors in the available maps and models and found it difficult to apply the maps when planning for both temporary and permanent flood scenarios. In response, the ART team, working group, Metropolitan Transportation Commission, and AECOM developed higher resolution maps for the nine-county Bay region that addressed these challenges. First, an intensive local stakeholder review process was used to groundtruth the new maps and correct topographical errors. Second, the maps were designed to include sea level rise and extreme tide combinations through a unique total water levels approach that communicates both temporary and permanent flooding, thus supporting development of thresholds for action. In addition, the mapping team incorporated data identifying low points on the shoreline that may lead to inland flooding, and tidal datums for over 900 locations along the shoreline, leveraging the FEMA San Francisco Bay Area Coastal Study. This mapping resource has already supported vulnerability assessments and adaptation planning efforts in four counties—aiding county staff and asset managers in identifying protections for human and natural communities in the Bay. This session will review the development of the maps and provide a live demonstration of an interactive web-map that will go live Summer 2018. The session will also describe the anticipated updates to the maps, including emerging science on delta-bay combined modeling (ART has new work in this area) and on-the-ground storm records.

Keywords: sea level rise, flooding, modeling, adaptation planning, science communication
Session Title: Sea Level Rise Effects and Adaptations II
Session Time: Monday, September 10th, 3:35 PM - 5:15 PM, Room 314

Phenotypic Plasticity of Pacific Cordgrass Under Varying Tidal Inundation Regimes

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San Francisco Bay (SF Bay) tidal marsh restoration relies on a nimble integration of natural processes and active restoration efforts. Active restoration can include manipulation of marsh elevations, targeted breaching of hydrologic barriers, channel redesign or other approaches. Over the last decade, active restoration in SF Bay has increasingly relied on directed plantings to accelerate habitat establishment beyond that typically provided by natural processes alone. Chief amongst foundation species in SF Bay is Pacific cordgrass (Spartina foliosa), which is consequently widely used for restoration. Sea level rise (SLR) estimates for SF Bay suggest that much of the current expanseof tidal marsh will be inundated by end of the century, and plants like S. foliosa, which provide marsh-accretion services and habitat for endangered species, figure prominently in any assessment of future SF Bay tidal marsh habitat survival. The focus of this work is to examine the potential of regionally dispersed populations of S. foliosa to differentially adapt to sea level rise. Individuals from nine populations of S. foliosa derived from the Carquinez Strait, San Pablo Bay, inner Marin shoreline and the outer coast at Bolinas Lagoon and Tomales Bay were collected. Collected propagules (rhizome plus shoot) were then out-planted in a modified 'marsh organ' mesocosm design at two sites: Sears Point Restoration Project marsh in San Pablo Bay, and at North Creek Marsh in the Eden Landing Ecological Reserve. Individual mesocosms were each placed at increasingly lower elevations from current natural S. foliosa stands to simulate tidal inundation regimes predicted from sea-level rise. Morphological metrics and growth rates for each population were collected, and populations were genetically analyzed to examine any potential ecotypic development. Identification of inundation-influenced, population-specific plasticity in S. foliosa allows for targeted propagation of this iconic tidal marsh plant species to maximize active restoration outcomes.

Keywords: sea level rise, mesocosm, marsh organ, Spartina foliosa, tidal marsh
Session Title: Sea Level Rise Effects and Adaptations II
Session Time: Monday, September 10th, 3:35 PM - 5:15 PM, Room 314

Integrating Natural Resources into Sea Level Rise Vulnerability Assessments: San Mateo County Tidal Wetlands Case Study

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Coastal vulnerability assessments are becoming more common in California as a result of state and local government led climate adaptation efforts. Due in part to the proliferation of fine-scale coastal flood models, standardized approaches have been developed for assessing vulnerability of built assets (e.g., roads, infrastructure) based on likelihood of exposure to flooding and potential for adverse consequences to human health and safety. However, changes in habitats and ecosystem services are more difficult to quantify because (1) ecosystems are dynamic, requiring more sophisticated analyses of projected temporal changes, and (2) there is no consensus on which services should be quantified or what metrics to use. The disparity makes it challenging for decision-makers to integrate natural and built assets into coastal adaptation planning. Risk to natural systems can be underrepresented, skew prioritization of vulnerable assets toward the built environment, and fail to adequately account for benefits derived from natural ecosystems (e.g., coastal protection, carbon sequestration). Together with San Mateo Countyin the San Francisco Bay Area, we are quantifying projected changes in four tidal marsh functions and services (marsh habitat, bird indicator species populations, carbon sequestration, and wave attenuation) under different sea level rise/storm scenarios by leveraging existing models, data, and literature. Composite maps of projected future changes allow identification of wetlands with high current value that are projected to remain highly valuable under a range of future conditions (i.e., resilient) as well as those likely to degrade in the near-term (i.e., vulnerable). In partnership with San Mateo County and the California Coastal Conservancy, the results will be integrated into coastal adaptation and climate action planning processes at the county-level and in the broader San Francisco Bay region, and disseminated more broadly as a case study.

Keywords: sea level rise, climate, vulnerability, wetlands, tidal marsh, ecosystem services
Session Title: Sea Level Rise Effects and Adaptations II
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Effects of Sea Level Rise on Shallow Groundwater in the San Francisco Bay Area

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The threats sea level rise (SLR) poses to coastal development from direct inundation are better understood than the threats due to rising groundwater levels. Rising sea level will raise the level of groundwater in coastal aquifers, resulting in damage to buried infrastructure and increased potential for flooding from groundwater inundation. This paper provides a preliminary investigation of potential regional impacts of SLR on coastal aquifers of the San Francisco Bay Area. Here, some of California's densest and most economically valuable development is built on unconsolidated sediment, with an already-high water table that will be lifted higher as sea level rises.

Depth to water data from groundwater monitoring wells and a digital elevation model of the Bay Area were used to model minimum depth to water within one kilometer of San Francisco Bay. A linear model of SLR-induced groundwater rise in the coastal aquifer was employed to locate areas likely to be inundated by emergent groundwater or newly vulnerable to shallow groundwater issues as sea level rises. The model reveals widespread shallow groundwater conditions in the study area.

Though more refined hydrologic models are needed to fully understand groundwater conditions at a local scale, this mapping effort provides a useful regional tool. Many of the at-risk areas identified in this study will likely be inundated directly by SLR before or at the same time that groundwater emergence becomes an issue. However, groundwater emergence means flooding may be inevitable in some areas, even if levees are constructed to prevent direct inundation.

This research is valuable for decision-makers because it identifies areas where groundwater flooding may render levee projects ineffective, places where sewer pipes may be subject to higher rates of inflow and infiltration, and areas with greater potential for liquefaction in a seismic event due to a rising water table.

Keywords: Groundwater; Sea level rise; Inundation; Coastal aquifer; GIS
Session Title: Sea Level Rise Effects and Adaptations II
Session Time: Monday, September 10th, 3:35 PM - 5:15 PM, Room 314

Emergent Groundwater and Sea Level Rise, the Silent and Largely Unknown Underground Threat

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Big ideas are needed to adapt to the triple flooding threat of sea level rise, extreme precipitation, and emergent groundwater. Of these threats, emergent groundwater is the least

understood, which could be detrimental for climate adaptation planning. San Francisco Bay has significant developed, low-lying areas near the shoreline, including many

built on fill over historic marshes and mudflats. The shallow groundwater layer lurks just below the surface, and with sea level rise, emergent groundwater could flood this area from below before the end of the century. Groundwater monitoring wells in Alameda and Oakland were used to investigate the depth of the shallow groundwater layer during both dry and wet seasons. This layer is highly dynamic, responding to both tidal fluctuations and precipitation events. After this baseline was established, the response of this layer to sea level rise was examined and areas of emergent groundwater were mapped. These areas were paired with their respective sea level rise scenario from the Adapting to Rising Tides program, creating a more robust assessment of potential future flood risk. Rising groundwater levels near the surface can contribute to flooding in basements and below-grade structures, impacts to the structural stability and integrity of below-grade infrastructure and foundations, and an increased risk of liquefaction during earthquakes. Most commonly,

high groundwater levels are mitigated using pumps. However, in developed areas built on fill, groundwater pumping and extraction could increase subsidence risks and enhance differential settling of roadways and structures. Communities located at the intersection between rising groundwater and rising seas will require innovative solutions to address these increasing risks. Currently, future increases in precipitation intensity are not included in this study; therefore, the triple flooding threat may be underestimated. This key data gap is the subject of another collaboration working to reduce uncertainties and improve resilience efforts.

Keywords: Groundwater, Sea Level Rise, Flood, Inundation Mapping, Adaptation, Alameda, GIS
Session Title: Sea Level Rise Effects and Adaptations II
Session Time: Monday, September 10th, 3:35 PM - 5:15 PM, Room 314

Complementary Models for Structured Decision Making in the Central Valley and the Delta

CVPIA SDM Modeling Process Update

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Problem statement:

CVPIA implemented a Structured Decision Making process in 2012. CVPIA called for charters beginning in 2016 that were responsive to priorities developed in the SDM process. The scientific framework for decision making has developed into a robust process for evaluating the state of the fish, assessing the best science, and developing priorities for annual expenditures. That framework will soon be able to assess results from the initial prioritizations and 'close the loop' in a true adaptive management approach. Maintaining support for the program will be critical to firmly establish adaptive management as the decision making process for CVPIA.

Approach:

Since 2012 Structured Decision Making (SDM) has been the process for prioritizing the funding measures thought most limiting to the natural production of anadromous fish in the Central Valley and Bay-Delta. Adoption of SDM provides a framework of actions and objectives linked together with an explicit scientific foundation explaining these linkages and incorporating uncertainty and adaptive management. SDM includes development of numerical Salmon Population Models, regular coordination with a Science Integration Team, visualization of data and results to support decision-making, and integration with other data efforts in the Central Valley. Over time, as the salmonid aquatic system is better understood, the approaches and prioritization will likely change to reflect the growing knowledge base developed by the process.

Results: The SDM effort is building the fourth iteration of the model for Fall run chinook, integrating the first iteration of population models for winter-run, spring-run, and green sturgeon, continuing to connect project monitoring directly to future forecasts of the numerical population model.

Conclusions/Relevance: By using the SDM process we are improving the CVPIA Fish Program's science-based framework, increasing our transparency and accountability, and reinvigorating our collaboration with agencies and stakeholders in the Central Valley.

Keywords: Modeling Fish Biology Structured Decision Making CVPIA
Session Title: Complementary Models for Structured Decision Making in the Central Valley and the Delta
Session Time: Tuesday, September 11th, 8:20 AM - 10:00 AM, Room 306

An Integrated Population Model to Estimate Survival, Growth, and Movement Transition Probabilities for Juvenile Salmonids

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Managers invest a substantial amount of resources to promote recovery of anadromous fish. Recovery strategies are manifold and typically include management actions designed to stimulate growth, increase in-river survival, and motivate outmigration during favorable conditions for juvenile fish. Evaluating the efficacy of these management actions is difficult, however, because monitoring data that explicitly track individuals from egg deposition to juvenile outmigration are lacking. We developed a new parameterization for integrated population models that links two different, but often collected, types fish monitoring data: adult escapement estimates and juvenile screw-trap capture data. Specifically, this model fits hidden process models to both sources of data to account for observer error and links parameters from these models using a multistate framework. We evaluated the efficacy of this model by fitting it to simulated data under a range of conditions and estimating the associated bias associated with juvenile survival, growth, and movement parameters. As an example application, we also fit this model to data collected for Chinook salmon (Oncorhynchus tshawytscha) in California's Central Valley. Simulation results suggest the model is able to estimate juvenile parameters with no-to-minimal bias under a range of conditions. By fitting this model to real-world monitoring data we were able to evaluate the influence of environmental conditions often hypothesized to influence juvenile population dynamics (i.e., flow, temperature, amounts of habitat, etc.). We demonstrated that integrated population models allow for the estimation of transition probabilities that are typically inestimable for naturally produced juvenile fish when using traditional statistical approaches. Furthermore, the structure of our integrated population model serves as a useful foundation for decision-support models within adaptive management programs by making the direct link between management actions, monitoring efforts, and decision-support-model predictions.

Keywords: Adaptive management, Demographic estimation, Integrated population model, Population dynamics
Session Title: Complementary Models for Structured Decision Making in the Central Valley and the Delta
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Defining a Modeling Baseline, Backcasting and Forecasting Restoration Projects

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Problem statement: Structured Decision Making requires development of a baseline condition in order to assess various management alternatives. When applied to a large geographic area like California's Central Valley, this can become a difficult task due to variability in records and reporting as well as the spatial variability across landscapes. The challenge becomes more difficult when considering a temporal scale. In the case of CVPIA, restoration efforts have been implemented over more than twenty years. As the SDM considers a twenty year horizon, how can a reasonable baseline be established? Should there be decay in the viability of habitat enhancements and how could that decay be addressed in the salmon population model?

Approach: We have assembled records of all available CVPIA restoration efforts conducted since inception of the program. These projects have been standardized to the degree possible through development of a spatial / temporal database that will be used to inform CVPIA modeling efforts.

Results: Initial results indicate that habitat decay estimates should be included in the various population models. Regular maintenance and assessment of habitat enhancements could be tied to decision matrices that would provide scheduled management actions in response to environmental and population responses.

Conclusions/Relevance: Development of a historical database of CVPIA projects has enhanced the program in two meaningful ways: (1) it has provided a more robust baseline condition that supports a better comparison of management alternatives; and (2) it supports the development of decision matrices that allow for flexible management over the twenty-year horizon of the salmon population model.

Keywords: Modeling CVPIA Fish Biology Structured Decision Making Backcasting Forecasting Baseline
Session Title: Complementary Models for Structured Decision Making in the Central Valley and the Delta
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Open Source Technology for Better Collaboration

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Problem statement: Multi-party, interdisciplinary teams are increasingly asked to model and assess natural resource problems. The traditional approach has been for each subject-area expert to use the tools at hand to collect data, conduct analyses, and present conclusions. The result has been a hodgepodge of siloed data, calculations, and outputs; which impedes collaborative efforts and shared understanding across disciplines, programs, and interests. Lack of understanding leads to “black box” criticism, and lack of support for conclusions. Often, it is difficult to support something you do not understand.

Approach: Using open source software concepts common in other technical sectors, we have been able to standardize data inputs for complex modeling efforts and provide a platform for building simple, interactive, and shareable visualizations. The open-source approach was used to support collaborative efforts between local watershed-level experts, specialized systems experts, and policy-level managers to prioritize a range of projects ranging from monitoring and reporting studies to implementing habitat restoration in the Central Valley.

Results: Tidy data approaches improve understanding of data inputs, analyses, and outputs. These open data approaches foster a better understanding of the model and the underlying data, thus supporting a more collaborative approach to analysis and prioritization. Our tidy data approach has resulted in a repeatable foundation to expand the modeling efforts to address multiple species and alternatives, while maintaining shared understanding of data inputs, modeling approaches, and outcomes.

Conclusions/Relevance: Tens of millions of dollars are directed to fish restoration every year; however, the effectiveness of many projects are not well understood. Through the implementation of standard approaches common to other sectors, we can build a repeatable, understandable, supportable foundation for decision-making in an increasingly complex world.

Keywords: modeling, open data, tidy data, fisheries, resource management, decision support
Session Title: Complementary Models for Structured Decision Making in the Central Valley and the Delta
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Structured Decision Making in the Delta: Application of SDM to management decisions for Delta smelt

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Problem statement: The Collaborative Science and Adaptive Management Program (CSAMP) is a forum where agencies, water contractors, and NGOs come together with the purpose of collaborating to improve performance from both biological and water supply perspectives. CSAMP's diverse membership enables it to act as a catalyst for more effective management of species of concern and water supply in the Delta. In this role, CSAMP recently sponsored a demonstration project that explored how Structured Decision Making (SDM) could be used to support decision making on management actions for Delta smelt. This process explicitly considered a broad range of ecological, learning, economic and social objectives, and therefore illustrated an alternative to standard management approaches for species of concern that typically focus on a narrow set of ecological objectives.

Approach: Using SDM principles, this project examined the expected costs and benefits of the thirteen management actions identified in the state's Delta Smelt Resiliency Strategy with the goal of testing the value of an SDM approach for informing priorities and next steps. Compass Resource Management (Graham Long and Sally Rudd) led the implementation of the process and facilitated a Technical Working Group comprising representatives from state and federal agencies and water contractors. The project used a combination of quantitative and qualitative approaches to evaluate management actions, including application of a Delta Smelt Population Simulation Model to estimate the relative benefits of actions to Delta smelt growth and survival.

Results: The project methods demonstrate how multiple lines of evidence and expert opinion can be brought together to provide an overall perspective of the expected consequences of management actions, identify important information gaps, and identify trade-offs across ecological, economic and social objectives. The project succeeded in reaching consensus recommendations within the working group on a prioritization of the Delta Smelt Resiliency Strategy management actions and the project methods were supported by the members of the CSAMP Policy Group (composed of senior representatives of the CSAMP member organizations). The process was useful for better understanding the costs and benefits of various Delta Smelt management actions, but the findings are limited due to the coarse level of evaluation and more work is needed to fully understand the benefits of a number of the resiliency strategy actions.

Conclusions/Relevance: SDM processes have the potential to help navigate conflicts and differences of opinion across both scientists and stakeholders to produce decisions that are more informed, defensible and transparent. These processes however are not appropriate for all decisions and their success depends on many factors such as the willingness of stakeholders to collaborate, a decision maker that is willing/able to consider the recommendations from the process, and sufficient resourcing to manage coordination across participants. Discussion is welcomed on the opportunities, benefits and challenges for applying SDM in the Delta for the management of species of concern and water supply..

Keywords: Modeling CVPIA Fish Biology Structured Decision Making
Session Title: Structured Decision Making, Delta smelt, Water supply
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Restoration at the Crossroads

Successes and Challenges of Salmon and Steelhead Passage Facilities

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Adult fishways and juvenile passage structures to accommodate salmonid migration at hydroelectric projects date back to the early 1900s. Engineering, monitoring, and evaluation of fish passage facilities expanded considerably as thirteen large hydroelectric projects (i.e., 660 to 2,485 megawatt) were constructed on the mainstem Columbia River between 1933 and 1975. Research and adaptive management increased exponentially at these projects following the listing of several salmon and steelhead stocks under the Endangered Species Act in the 1990s. In addition, multiple hydroelectric project licenses were renewed in the late 1900s, leading to innovative passage facilities at multiple high head dams throughout the Pacific Northwest. Based on two decades of experience spanning research at about 20 of these facilities, we will provide specific examples of ecological, environmental, structural, hydraulic, and operational conditions that have facilitated or impeded successful passage at various projects. In addition to condition changes we will provide insight on monitoring techniques that have worked and haven't worked to assist in validating changes.

Keywords: Salmon, Steelhead, Passage, Dams, Migration, FERC ESA, Hydroelectric Telemetry, Anadromous
Session Title: Restoration at the Crossroads
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Floodplain Rehabilitation for Multiple Species on the Fringe of the Delta: Maximizing Ecological Function and Mitigation Credits

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Studies have hypothesized that there is very little remaining floodplain in California's Central Valley due to the combination of flow regulation, channel incision and levee construction. Areas where floodplains can be restored should be high priorities for the restoration community, presenting the opportunity to increase essential ecosystem functions and provide anadromous fish habitat. The Southport Levee Improvement Project is one such opportunity. The multi-purpose project, situated along 5.6 miles of the right bank of the Sacramento River in West Sacramento, includes a major levee setback that is under construction. This project is an important step toward combining flood-risk reduction with significant ecological restoration.

The levee setback will create 150 acres of reconnected floodplain habitat. The restoration design creates riparian, perennial marsh and floodplain habitat and accommodates compatible public recreation. The design will reduce habitat fragmentation, spatial/temporal losses, provide ecological uplift, and incorporate a watershed scale approach to ecosystem enhancement and flood protection. The establishment of ecological and physical design criteria are necessary to ensure creation of high-value habitat is maximized, species benefitting from restoration are maximized, and restoration design observes constraints of the Southport Project.

We will review the multi-disciplinary approach employed to integrate hydrodynamic modeling with ecological design to maximize the habitat enhancements of the restoration design. Our approach utilized a 2-dimensional hydrodynamic and morphological model as an analytical tool for assessing floodplain inundation dynamics to support restoration recommendations and optimization of ecological benefits. We will emphasize the benefits of using a 2-dimensional hydrodynamic model as a tool to describe hydrodynamic and ecological processes, inform restoration design, and satisfy ecological criteria and constraints.

We will also discuss how levee setback projects represent a significant opportunity for achieving increased flood protection and restoration of critical habitat for Delta and anadromous fish species and in turn, providing multiple benefits to society.

Keywords: Floodplain, flood, restoration, habitat, levee, setback, anadromous, ecosystem, hydrodynamic model
Session Title: Restoration at the Crossroads
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North Delta Grizzly Slough Floodplain Restoration Project: Synthesizing Science for Multi-Benefit Restoration Planning

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The Grizzly Slough Floodplain Restoration Project is one of two main elements of the North Delta Flood Control and Ecosystem Restoration Project that consists of flood management and habitat improvements where the Mokelumne River, Cosumnes River, Dry Creek and Morrison Creeks converge. The site (489 acres on the lower Cosumnes River) is a rare place where elevation, unregulated flows, intact sediment supply, and public ownership provide opportunities to restore floodplain processes. This project will restore sustainable floodplain and riparian habitat in the Cosumnes River corridor by reintroducing tidal exchange and seasonal flooding (through levee breaching) and restoring vegetation to create seasonal wetlands and riparian forest. The project will also provide an agricultural zone established at higher elevation to allow cultivation of irrigated crops (corn) for wildlife benefits (Sandhill crane and Swainson hawk) and revenue.

Science-based restoration planning informed the design of the Grizzly Slough Project where a need to balance multiple project objectives and existing constraints was superimposed on the need to minimize environmental impacts and project costs. Historic and recent research in the Cosumnes Preserve floodplain including Grizzly Slough was synthesized to support project planning. Landscape, geomorphic, hydrologic, vegetation and wildlife studies and hydrologic modelling provided the analytical underpinnings for the project design. This research and lessons learned demonstrate how the growing body of science in the northeast Delta supports and informs restoration, monitoring and adaptive management planning. For example, a single breach concept and limited grading plan replaced a two breach design, when hydrologic modeling depicted limited benefits of the more complicated design approach. Studies on native fish and birds support predictions of benefits for Chinook salmon, Sacramento splittail, Swainsons's hawk and Sandhill crane. Stressor identification from adjacent restoration/mitigation projects, has resulted in project measures to reduce potential adverse impacts from mercury and invasive species.

Keywords: ecosystem restoration, floodplains, seasonal wetlands, riparian forest, Cosumnes, multi-benefit project
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Restoration in the Cache Slough Complex: The Yolo Flyway Farms Restoration Project

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The Yolo Flyway Farms Restoration Project involves restoring and enhancing approximately 278 acres of tidal freshwater wetlands at the southern end of the Yolo Bypass within the Cache Slough Complex. The Project seeks to partially restore historical ecological functions in this highly altered regional landscape. The primary goals of the Project are to 1) improve habitat conditions for Delta smelt by enhancing regional food web productivity; 2) improve habitat conditions for salmonids by providing access to rearing habitats for out-migrating juveniles and migratory habitats for adults; 3) support a range of other aquatic and wetland-dependent species; 4) provide habitat for establishment of native plant communities; 5) minimize potential for colonization by aquatic weeds; and 6) preserve existing topographic variability to allow for habitat succession and climate change resilience.

The Project will involve minimal excavation of approximately 65,000 cubic yards of soil to provide access to emergent marsh and floodplain habitats connected to the adjoining tidal system via breaching of existing agricultural berms and the creation of an interior tidal channel network. The excavated material will be placed on existing upland areas on the project site. Following excavation, the site will be planted with salvaged emergent marsh vegetation. Construction is scheduled to begin in summer 2018.

Keywords: Yolo Flyway Farms, Delta Smelt, Salmonids, Habitat Restoration
Session Title: Restoration at the Crossroads
Session Time: Tuesday, September 11th, 8:20 AM - 10:00 AM, Room 307

Restoring Regulation: BCDC's San Francisco Bay Plan Amendment to Address Allowing Bay Fill for Habitat Projects

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The San Francisco Bay Conservation and Development Commission (BCDC) is a California state planning and regulatory agency with regional authority over the San Francisco Bay, the Bay's shoreline band, and the Suisun Marsh. BCDC was created in 1965 with the mission of protecting and enhancingSan Francisco Bay and encouragingthe responsible and productive use of the Bay for this and future generations.The San Francisco Bay Plan is the regulatory framework that guides BCDC's permittingdecisions for proposed development in theBay and its shoreline band, andincludespolicies that provide guidance for balancingdevelopment with protecting natural resources and the public's right to access the shoreline. Formerly,Bay Plan policies limited Bay fill for habitat restoration projects to a "minor amount," a stricter standard thanthe "minimum amount of fill necessary for the project" required by lawfor other types ofdevelopment projects. Yet, increasing amounts ofsediment will be needed to ensure that Bay ecosystemsare not inundatedby rising sea level. In some projects, BCDC's public access requirements also conflicted with wildlife protection goals. Finally, the Bay Plan dredging policies limited the beneficial reuse of sediment dredged from the Bay.Over the past year, BCDC staff have collaborated with restoration expertsto amend the Bay Plan to address these issues. Policy changes that have been explored include creatinga more nuanced approach for allowing greater than a 'minor amount' of Bay fill to protect Bay ecosystems from inundation over time, balancing public access and wildlife protection, and allowing the beneficial reuse of dredged sediment. This session will be useful to Bay restoration professionals who manage projects requiring BCDC permitsand to those who are generally interested in how we canadapt our policies and regulations to reflect the reality of a rising Bay.

Keywords: habitat restoration; sea level rise; adapting regulation; BCDC; public access
Session Title: Restoration at the Crossroads
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Modeling Delta Smelt I

Delta Smelt Life Cycle Modeling: Findings and Reflections on Synthesis Efforts

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Life cycle modeling provides a quantitative approach to measure the effects of abiotic and biotic factors on a species' recruitment and life-stage specific survival. Synthesizing information from different historical surveys, each with their own origins and methods, represents the current best hope for life cycle modeling of wild delta smelt (Hypomesus transpacificus). But moving synthesis beyond conceptual models to quantitative ones is hard because of disparate, survey specific biases and sampling variability which requires complicated statistical procedures for fitting even a single model, while multiple hypotheses per vital rate results in an explosion of hypotheses to sift through and compare using methods at the frontier of statistical ecology. Here we build a quantitative model that describes delta smelt post-larval recruitment from adults, and the survival of post-larvae, juvenile, and sub-adult life stages, where each modeled vital rate can depend on several covariates. Model inputs used information collated from Interagency Ecological Program surveys, with which indices of delta smelt abundances, predators, prey, and salient abiotic conditions were derived. A Bayesian hierarchical modeling approach was used to draw inference on each model while accounting for observation error in delta smelt abundances, and a number of model comparison and diagnostic strategies were employed to identify any factors that had the most effects on delta smelt population dynamics above and beyond random year effects. In general covariates impacting recruitment were identified as having the most evidence for an effect on any given vital rate. Population viability analyses were carried out to provide a measure of effect size by these covariates, as well as the consequences of management actions relying on applying these findings.

Keywords: Delta smelt; life-cycle model; population viability analysis; state-space model
Session Title: Modeling Delta Smelt I
Session Time: Tuesday, September 11th, 8:20 AM - 10:00 AM, Room 308-310

Analysis of Limiting Factors Across the Life Cycle of Delta Smelt (Hypomesus transpacificus)

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We developed a mechanistic life-cycle model derived from the elicitation of multiple factors influencing the success of individual life-stages of the imperiled delta smelt (Hypomesus transpacificus). We discuss the relevance of limiting factors in population ecology and problems with additive models in detecting them. We identify limiting factors and assess their significance using a non-linear optimization routine, combined with traditional metrics to assess the value of covariates and model performance. After reviewing previous conceptual models and multivariate analyses, we identified a set of factors that were consistent with conceptual models and useful in explaining the erratic fluctuations in a common abundance index: food at certain times in certain locations, predation by introduced species primarily in the spring, and entrainment. The analytical approach provides a transparent and intuitive framework in which to consider the contribution of covariates and consequences for population trends, and has the potential to assist with the evaluation of proposed recovery measures.

Keywords:
Session Title: Modeling Delta Smelt I
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Estimation of Adult Delta Smelt Distribution for Hypothesized Swimming Behaviors Using Hydrodynamic, Suspended Sediment, and Particle-Tracking Models

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A set of related modeling and analysis tasks were scoped by the Delta Smelt Scoping Team of the Collaborative Adaptive Management Team (CAMT) to provide insight to factors that affect entrainment of delta smelt by water exports and the population effects of that entrainment. As part of these studies, the distribution and entrainment of delta smelt has been estimated through application of hydrodynamic, sediment transport, and particle tracking modeling with alternative swimming behavior rules. The hypothesized behaviors range from passive transport to active swimming triggered by salinity and turbidity conditions. The physical process and swimming behavior modeling informs a population dynamics model that is used to fit parameters including initial abundance (population) and natural mortality and compare the predicted delta smelt distribution to available Spring Kodiak Trawl and salvage observations. The match between observed and predicted distribution is quantified in a single log likelihood, allowing the relative performance of alternative behaviors to be quantified and ranked. In this first step of two steps in evaluating behaviors, a fixed initial distribution of delta smelt in the lower Sacramento River is assumed for both water year 2002 and 2004. Multiple potential start times of the spawning migration were considered in the 2002 simulation period. In related work funded by CAMT, the initial distribution assumption is relaxed and two additional water years are simulated. In both evaluations, the predicted distribution and fate of particles varies greatly with specified swimming behavior. The simpler hypothesized delta smelt behaviors generally lead to less realistic predicted distributions. The more successful behaviors involved tidal migration triggered by high or increasing salinity and often included some form of holding behavior triggered by high turbidity.

Keywords: delta smelt, modeling, hydrodynamics, turbidity, sediment, entrainment, swimming, population dynamics
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Reconciling Data Availability with Objectives for Testing Ecological and Management Hypotheses

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Advances in statistical methods and computing power make it possible to apply increasingly rigorous analyses to address hypotheses about ecology and management of delta smelt (Hypomesus transpacificus). However, lack of robust data on the distribution and abundance of delta smelt, and spatial and temporal inconsistencies in data on delta smelt and physical, biological, and social attributes of its environment, make it difficult to draw strong inference that can guide management. We applied multiple forms of quantitative analysis, derived from both natural and social sciences, to reduce uncertainty in both input data and outputs of these analyses. For example, we applied variants of occupancy models to understand environmental associations with the presence and relative abundance of delta smelt. We also applied expert elicitation to gain inference into potential predation intensity. Expert elicitation encompasses a rigorous set of methods for synthesizing expert knowledge to inform decision-making, and has proven reliable and practical when field data are limited; it is not synonymous with asking people what they think. Ultimately, maximizing ecological and societal confidence in management options may require investments in new data-collection methods, and collection of new types of data.

Keywords: response variable, expert elicitation, strong inference, uncertainty
Session Title: Modeling Delta Smelt I
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Revisiting Relationships between Delta Smelt Abundance and Salinity

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Salinity distribution represents the response of the San Francisco Estuary to different combinations of river discharge, water diversions and withdrawals, tidal regime, and channel geometry in the Estuary. However, X2, a surrogate for salinity, has been used as the policy-relevant estuarine habitat indicator and assumed to have meaning for nonspecialists. X2 cannot be directly measured and is estimated using either estimated Delta outflows or surface salinities converted from electrical conductivity measurements. Both methods for estimating X2 are subject to substantial errors, leading to subsequent large uncertainties for estimated X2 values. Previous studies indicated weak or no correlations between Delta Smelt abundance and X2. To avoid X2 related uncertainties, we used salinity to examine its correlations to Delta Smelt abundance and their vital rates. Using long-term monitoring data, we found that salinity is not only strongly correlated to Delta Smelt abundance, but also to annual population growth rate and recruitment. Salinity can be measured accurately and continuously, has ecological significance, and integrates a number of important estuarine properties and processes. It seems appropriate to use salinity as an estuarine habitat indicator.

Keywords: Salinity, Delta Smelt abundance, population growth rate, recruitment, electrical conductivity
Session Title: Modeling Delta Smelt I
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New Developments in Suisun Marsh Water Quality and Some Ecological Implications

A New Way to Assess Dissolved Oxygen Conditions in Suisun Marsh

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Dissolved oxygen (DO) is a key component of water quality and one of the most essential elements in protecting fish in Suisun Marsh sloughs. The San Francisco Bay Water Board adopted a Total Maximum Daily Load (TMDL) for Suisun Marsh which includes new DO water quality objectives. Some sloughs in Suisun Marsh are prone to low DO due to a mixture of natural and anthropogenic sources contributing large loads of organic material. Over the past century, the marsh has been extensively managed, including land use change, channelization of sloughs, altered freshwater delivery, and creation of a network of privately- and publicly-owned managed wetlands, which all affect water quality. Managed wetlands play an important role in providing wintering habitat for waterfowl on the Pacific Flyway and support resident and migratory shorebirds. However, operations at managed wetlands can be a source of organic-rich nearly hypoxic discharges resulting in significant DO depletion in the receiving sloughs, which serve as vital fish habitat in the estuary. We evaluated how these discharges affect aquatic organisms, developed a TMDL which is a water quality attainment strategy to improve DO, and derived water quality objectives specific to Suisun Marsh. This is the first effort since 1975 to refine DO water quality objectives. Development of the objectives included evaluation of the sensitivity and oxygen requirements of Suisun Marsh fish and the application of the U.S. EPA Virginian Provence Approach to develop both chronic and acute DO thresholds. The new DO objectives are intended to protect against the adverse effects of low DO on survival, growth, reproduction, and behavior of fish in the marsh and to accommodate both spatial and temporal aspects of low oxygen events. The approach taken to develop these site-specific objectives for Suisun Marsh sloughs may be applicable to other sloughs around the Bay.

Keywords: Suisun Marsh, water quality, dissolved oxygen, new site-specific objectives
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Evaluating the Effects of Managed Wetland BMPs on Receiving Slough Water Quality in Suisun Marsh

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Sloughs in Suisun Marsh have historically experienced episodic low dissolved oxygen (DO) and high methyl mercury (meHg) events, adversely affecting aquatic life and other beneficial uses, leading to a Clean Water Act Section 303(d) impairment listing by the Regional Water Quality Control Board under clause 303(d) of the Clean Water Act. Siegel et al. (2011) created conceptual models of DO and meHg processes in managed wetlands and receiving sloughs using their 2007-2008 empirical data, from which they developed a suite of best management practices (BMPs) for managed wetlands aimed at reducing impairment. BMP implementation started afterwards and has since expanded. An in-progress study intensively monitored 2016 and 2017 water quality conditions in Peytonia and Boynton sloughs, both with a history of water quality impairment, to characterize managed wetland discharge and receiving slough water quality in response to BMP implementation. Monitoring included continuous wetland stage and slough stage and water quality (temperature, DO, conductivity, and pH) and discrete grab sampling for organic carbon, biochemical oxygen demand in water and sediment, and meHg. In parallel, the RWQCB has continuous water quality monitoring in Goodyear and lower Cordelia sloughs where low DO problems have also occurred. Findings help explain slough biogeochemical processes in relation to wetland discharges. Year-to-year changes allow assessment of BMP efficacy. These data, combined with previous monitoring data, indicate that slough water quality has improved since with BMP implementation though problems still occur. These data are also being used to develop a modeling framework for evaluating potential water quality response to different scenarios of BMP implementation, in support of implementing the Total Maximum Daily Load program the RWQCB recently adopted. This study is the first systematic field effort to test BMP efficacy in Suisun Marsh sloughs and provide support to managers and regulators for identifying specific BMPs for broader implementation.

Keywords: Water quality, dissolved oxygen, methylmercury, best management practices, Suisun Marsh
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Modeling the Dissolved Oxygen Response in Suisun Marsh Sloughs to Managed Wetland BMPs

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Problem statement: The Suisun Marsh landscape includes areas of managed and tidal wetlands, connected to Suisun and Montezuma sloughs that exchange flows with the open waters of Suisun Bay. Incidences of low dissolved oxygen (DO), which can be associated with discrete discharge events from managed wetlands and other possible sources, can potentially impair the aquatic habitat in the sloughs of Suisun Marsh and have historically been observed.

Approach: Over the past five years, a number of best management practices have been explored in several managed wetlands to reduce their impact upon tidal slough DO conditions . Here, we present the findings of a HEC-RAS water quality model, developed and calibrated with field data collected in 2016 and 2017, to better understand the interactions between organic carbon and nutrient loading from managed wetlands, tidal exchange, and external inflows such as from the Fairfield Suisun Sewer District effluent. HEC-RAS is a public domain model that allows unsteady flow hydraulic calculations and water quality analysis at spatial and temporal scales consistent with intensive field monitoring, and is a novel application in the San Francisco Estuary.

Results: We used the model to perform analysis of temperature, DO, biochemical oxygen demand, organic carbon, and nutrients in the sloughs. We then used these model analyses to characterize the role of managed wetland discharge (volume and quality) on the water quality in the sloughs and to evaluate the effectiveness of changes to management practices that would minimize low DO impacts during periods of managed wetland discharge activity.

Relevance: The model identifies BMP strategies to minimize low DO events, going beyond conditions tested in the field. This tool will be available for wetland managers and others considering or taking actions intended to or that may affect Suisun Marsh DO water quality conditions and thus habitat suitability.

Keywords: HEC-RAS, water quality model, dissolved oxygen
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Assessing the Impacts of Suisun Marsh Salinity Control Gates' Summer Operation on Delta Water Quality

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Problem statement: The Delta Smelt Resiliency Strategy calls for summer operation of the Suisun Marsh Salinity Control Gates (SMSCGs) to reduce salinity and improve habitat in the Marsh during summer months in Above Normal (AN) and Below Normal (BN) years. This study aims to assess the impacts of this operation on Delta water quality as well as the corresponding water cost to meet Delta's water quality standards at key compliance locations including Jersey Point and Collinsville.

Approach: First, the Delta Simulation Model (DSM2) is set up to consider gate operation in August in historical surrogate years (AN and BN) to evaluate the feasibility of implementing this action. Next a forecast model for 2018 is developed using forecasted hydrology and historical facility operations of previous similar years. Different gate operation scenarios are explored, including operating through the entire August, first half of the month, and second half of the month, as well as via two gates (with the third gate closed). and all three gates. Finally, a water cost optimization method is applied to identify the minimum extra freshwater outflow required to meet the Delta standards; in this way it can approximate the real-time operation under forecast or hypothetical conditions.

Results: The results show that gate operation in August increases salinity from mid-August through late October. For Jersey Point, increases in peak salinity range from 14%-18%. Salinity increase from September to early October in Collinsville is also evident. The water cost to offset the standards violation is less than 30 thousand acre-feet assuming 2018 being a BN year.

Conclusions/Relevance: These findings indicate that additional freshwater outflow is required so that the proposed operation would not lead to unintended salinity changes in the Delta. This study is meaningful in terms of providing information for the seasonal planning incorporating this year's SMSCGs' operation.

Keywords: Suisun Marsh, salinity control, gate operation, Delta water quality standards
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Hydrodynamic Influences on Food Webs in Tidal Wetlands of Suisun Marsh

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Native fishes of the upper San Francisco Estuary evolved under highly variable hydrodynamic and water quality conditions in an environment of 400,000 acres of tidal marsh, 100,000 acres of seasonal floodplains and 1,000 miles of tidal sloughs in the Delta and another 65,000 acres of tidal marsh and 30,000 acres of tidal sloughs and bays in Suisun Marsh. Today, most tidal marsh and floodplains are gone, sloughs shifted from a complex network of highly varied residence times to a simple network with fairly uniform residence times, invasive species are prominent, freshwater flows are reduced and their timing highly altered, sediment regimes have been altered extensively, and humans load waterways with municipal, agriculture and industrial wastewater discharges. Though the scientific community has documented life cycles and life history movements for resident and marine transient species in great detail, the role of the remnant tidal wetlands as nearshore rearing habitat is still an area of active research. We hypothesized that dominant food web pathways utilized by juvenile fishes in Suisun Marsh, an important nursery area, would be driven by seasonal changes in hydrodynamics according to residence time, marsh plain exchange, and local watershed inputs. Using multi-parameter sondes and automatic water samplers, we collected water quality and nutrient data across spring-neap lunar cycles that co-occurred with juvenile fish recruitment during spring and summer 2017 and 2018. Our study provides preliminary evidence that food webs respond to geomorphic and hydrodynamic interactions that create variability in stage, velocity, and exchange across the land-water interface. This study directly informs our understanding of benthic and pelagic food webs and the propagation of organic matter to juvenile fishes.

Keywords: Hydrodynamics, food webs, rearing, nursery, emergent wetlands, benthic, pelagic
Session Title: New Developments in Suisun Marsh Water Quality and Some Ecological Implications
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Climate Change Resilience

Impacts of an Extreme Wet Winter on Invasion Prevalence and Community Structure in Soft Sediment and Hard Substrate Habitats in San Francisco Bay

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Invasions by non-native species are well-known drivers of significant ecological change worldwide. Despite considerable available information on marine invasions in California, and particularly the San Francisco Bay region, it remains challenging to detect new invasions and estimate actual changes in invasion patterns, such as rate and spread. These data are key to understanding invasion processes and informing management and policy. We address this issue for two key habitats in the San Francisco Estuary: hard substrate-dwelling sessile invertebrate (fouling) communities and the soft sediment (infaunal) community. We conducted repeated, standardized surveys of fouling and infaunal communities in the estuary over a number of years spanning a wide range of environmental conditions (2000–2018 for fouling; 2012–2018 for infauna).

We characterized fouling communities using settlement panel surveys, and we sampled infaunal communities using a Young-modified Van Veen grab. These years spanned recent dry and wet extremes, with two major droughts and several wetter winters including record extreme precipitation in the winter of 2016–2017.

Non-native species were prevalent throughout the estuary, but achieved greater dominance following dry winters. Hard substrate community composition at any given site during the summer period was predicted by environmental conditions, especially the previous winter's precipitation, which is linked to salinity levels. Infaunal community composition was relatively stable by comparison, even through the 2014–2015 marine heat wave, but shifted significantly following the 2016–2017 wet winter. Rarefaction analyses and richness estimators indicate that the number of species detected in both habitats varied both as a function of the number of sites sampled in a given year and with environmental conditions. These results suggest that standardized sampling across a broad range of conditions over time is needed.

Keywords: invasions climate precipitation drought fouling infauna

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Drought Resistance and Resilience in the Delta Fish Community over Five Decades

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The 2012-2016 California drought was unprecedented in severity. In the San Francisco Estuary (SFE), this drought was characterized by elevated nutrient loads, depressed zooplankton densities, enhanced Microcystis blooms, and an expansion of invasive aquatic vegetation coverage. Did wet conditions in 2017 allow the system to return to pre-drought conditions? Furthermore, has the capacity for drought resilience in the SFE changed over the last 5 decades during which we have been collecting ecological data? To assess these questions, we drew on long-term IEP datasets (Fall Midwater Trawl, Delta Juvenile Fish Monitoring Program beach seine data) to assess patterns in the likelihood of presence for eight fish species across five drought cycles, spanning a 51-year time series (1976-2017). We developed Bayesian-based indices of drought resistance and recovery to assess patterns in the ability of species to both resist the drought stressor, and to recover once wet conditions returned. While the species we assessed included both pelagic and nearshore species, and natives and non-natives, drought resistance was low across all species. In contrast, drought resilience (recovery after drought) was highly variable across both species and drought cycles. For example, both Delta Smelt and Sacramento Splittail (sampled in the Fall Midwater Trawl) showed evidence of resilience in 2011 when wet conditions returned after the 2007-2010 drought. However, the same recovery signals were not observed in 2017. In the most recent drought cycle, Delta Smelt had significantly lower resistance to drought and a reduced rebound after drought compared to previous drought cycles. These results are informative to management, as a return to wet conditions after drought now may not allow for the same level of population rebound as may have occurred under historical conditions.

Keywords: Drought, Resilience, Resistance, Delta Smelt, Longfin Smelt, Largemouth Bass
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Drought, Climate Change and Restoration Resiliency

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Many non-local factors affect the success of aquatic restoration plans in the California Delta. These include connectivity to corridors for fish migration, availability of tidal energy, availability of fresh water flows, water management decisions, conditions of drought and flood, and global warming. I look at the results of several studies across periods of intense drought and recovery, and evaluate the possibilities for mitigating against climate change in restoration efforts. Predicted changes in climate for California include higher temperatures, changing temporal patterns of precipitation and decreasing snowpack, all of which conditions were seen in the 2012-16 drought. These changes will be hard on native fish species, but options for mitigation exist because of the constructed way in which water moves across California. Reservoirs can manage cold water pools through controlled releases; floodplains can be inundated adaptively through weirs; riparian shading, emergent vegetation, and deep pools can maintain lower temperatures in rivers; natural tidal wetlands can have cooling properties that affect adjacent channels; and managed wetlands may create highly controlled refuges for food production and multi-species refuges.

Keywords: Drought, climate change, native fish, novel ecosystems, habitat restoration
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Restoration Planning for the Sacramento – San Joaquin Delta and Suisun Marsh: Considering the Implications of Climate and Land-Use Change

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The Delta Reform Act requires "taking into consideration the physical changes that have occurred in the past and the future impact of climate change and sea level rise" for restoration planning. Re-establishment of tidal marsh is critical to restoring food web function and increasing the extent of habitat for fish and wildlife within the Sacramento – San Joaquin Delta and Suisun Marsh (Delta). Land subsidence, sea level rise, and urbanization significantly constrain where tidal reconnection is possible in the future. We use new information on sea level rise, island and water elevations, levee failure probability, regional subsidence estimates, and land-use projections to identify potential restoration constraints. To do this, we used a state-and-transition simulation model (STSM) to conduct stochastic simulations of land-use in the Delta for three scenarios through 2100. The STSM uses a grid-based framework to represent landscape units and simulates state transitions (i.e. land use change, inundated vs. not) of each grid cell stochastically across time. Selected scenarios compare future subsidence and levee management actions within the framework of historic land-use change. We compare 1) current levee conditions and subsidence continues through 2100, 2) levees are improved and maintained and subsidence reversal action is taken across the entire study area through 2100, and 3) selected levees are improved and maintained and targeted subsidence reversal action is taken in areas with the potential to achieve suitable intertidal elevations by 2100. These scenarios are presented in an interactive display and suggests that strategic subsidence reversal and levee maintenance allows for spatially explicit intertidal marsh restoration opportunities within a landscape experiencing significant land-use pressures.

Keywords: sea-level rise, subsidence, land use, restoration, tidal marsh
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Restoring Tidal Habitats for Climate Resilience

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Growing recognition of the rates of future sea-level rise and other climate changes associated with global warming have prompted a shift in the approaches to tidal habitat restoration and types of restoration projects pursued. Early wetland restorations in the Bay Delta were generally tidal marsh restorations and involved setting the right elevations, planting native vegetation and then breaching levees to restore tidal inundation. Later restorations incorporated restoration of natural processes to create desired wetland features. Both restoration approaches provided benefits, but had limitations in terms of resilience to sea level rise and climate change such as lack of physical and biological complexity (for the early era) and reliance on sedimentation to outpace sea-level rise (for the later era).

As restoration practice has evolved, approaches have expanded. In line with the recommendations of the Baylands Ecosystem Habitat Goals Update (2015), projects now cover a broader range of habitats from subtidal oyster reefs to upland ecotone slopes, incorporate more extensive wetland to upland ecotones to allow room for coastal habitats to migrate upslope with sea level rise, emphasize habitat diversity, and connect habitats across gradients (such as salinity and temperature) that are likely to shift with climate change to increase climate resilience. This talk provides examples of projects in the San Francisco Bay Delta that are using climate resilient restoration approaches and identifies emerging lessons and management needs. Project examples draw on restoration of tidal creeks and extensive wetland-upland transition zones (Lower Walnut Creek Restoration), oyster reef and eelgrass beds, seasonal wetlands, and beaches as living shorelines. Review of emerging restoration approaches indicates a need to build capacity of restoration contractors, coordinate regional monitoring, and to identify a consistent funding stream for ongoing site management.

Keywords: wetland restoration, sea-level rise, climate change
Session Title: Climate Change Resilience
Session Time: Tuesday, September 11th, 8:20 AM - 10:00 AM, Room 314

Improving Hydrologic Measurements and Predictions

Effect of Salinity Control Gate Operation on the Salinity Field in Suisun Marsh

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Suisun Marsh is the prime location of low salinity water suitable for native fish such as Delta Smelt and salmon. The California Department of Water Resources (DWR) continuously monitors the salinity in the Suisun Marsh through a network of 16 water quality stations. The Suisun Marsh Salinity Control Gates (SMSCG) were constructed in 1988 to lower the salinity in the marsh by preventing the upstream flow of Montezuma Slough during flood tides and allowing the downstream flow during ebb tides. The SMSCG are operated to meet the standards of D-1641 and the Suisun Marsh Preservation Agreement (SMPA) in the fall and winter months. These standards were developed to meet the needs of landowners who irrigate managed wetlands to grow food for ducks. However, low salinity zones in the marsh are also beneficial for fish and other aquatic organisms. As part of the Delta Smelt Resiliency Strategy, DWR is investigating operation of the SMSCG during summer months. The Gates may be able to freshen the water of the Marsh all year around, helping native fish populations by expanding their habitat and making it more attractive. The presentation analyzes the capability of the SMSCG and shows how much salinity can be lowered by modified operation to benefit the fish population.

Keywords: fish population, water quality, salinity control, low salinity zone
Session Title: Improving Hydrologic Measurements and Predictions
Session Time: Tuesday, September 11th, 10:20 AM - 12:00 PM, Room 306

What Happens During a Minor Flood Pulse: Observations of Bedload Transport in the San Joaquin River Using New Methods

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The question of “does the streambed change over a minor flood pulse” does not have a clear answer due to lack of measurement methods during high flows in rivers downstream of dams. The mobility of gravel and fine sediments is necessary to maintaining a loose streambed, which allows Chinook salmon to construct a redd (egg nest) of sufficient depth for intragravel egg incubation and survival in rivers draining to the San Francisco Bay Delta.We seek to inform our understanding of bedload transport by linking field measurements using fiber optic distributed temperature sensing (DTS) cable, calculations of disentrainment over time and distance, and in situ measurements of streambed permeability with sediment transport theory and an existing explicit analytical solution to predict depth of sediment deposition and one-dimensional fluid velocity from amplitude and phase information. The method facilitates the study of gravel transport by using near-bed temperature time series to estimate rates of sediment deposition continuously over the duration of a minor flood coinciding with bar formation, including (1) a field method for measuring local rates of deposition and bed elevation change during a minor flood to compute rates of bedload transport, (2) use of an existing analytical solution to quantify the depth of sediment deposition over distance and time from temperature amplitude and phase information, and (3) observational and theoretical evidence that incipient motion occurs during a minor flood. These observations of partial bedload transport, taken along a 2 km gravel bed reach of the San Joaquin River, CA, USA during a managed pulse flow release, suggest that the discharge needed to create the boundary shear is lower than previous estimates, and that partial transport of grain sizes on the bed, including the median particle size, occurs during a minor flood with a current recurrence interval of approximately 1-2 years.

Keywords: rivers, sediment, physical processes, bedload transport, temperature, flow, dams, salmon
Session Title: Improving Hydrologic Measurements and Predictions
Session Time: Tuesday, September 11th, 10:20 AM - 12:00 PM, Room 306

AQPI: Improved Monitoring and Forecasts of Precipitation, Streamflow, and Coastal Flooding in the San Francisco Bay Area

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When big storms hit California, current technology does not provide forecasters with the detailed information needed to inform reservoir operations, flood protection, combined sewer-stormwater systems and emergency preparedness. Standard weather radars are often unable to give an accurate picture of what is happening in the complex landscape of California's coastal mountains.

The Advanced Quantitative Precipitation Information (AQPI) System is a regional project awarded to NOAA and collaborating partners by the California Department of Water Resources. The AQPI System consists of improved weather radar data for precipitation estimation and short-term nowcasting; additional surface measurements of precipitation, streamflow and soil moisture; and a suite of forecast modeling systems to improve lead time on precipitation and coastal Bay inundation from extreme storms.

AQPI observing assets include a coastal Doppler C-band weather radar along the Sonoma County coast which will point offshore to improve tracking of incoming storms and four gap-filling Xband radar units strategically located to provide high-resolution coverage over-populated and flood prone urban areas throughout the San Francisco Bay region. The radar data will be assimilated by atmospheric models to improve short-term prediction of precipitation. The AQPI System also will improve runoff and coastal flooding predictions in and around the Bay. To address climate change and sea level rise with possibly more extreme storms the System will implement the Coastal Storm Modeling System (CoSMoS). This system will forecast flooding around the San Francisco Bay coastline.

The AQPI System can aid water managers in securing water supplies while mitigating flood risk and minimizing potential water quality impacts to the Bay from storm runoff and combined sewer overflows. The system can be expected to provide benefits exceeding costs by a ratio of at least 4:1. This presentation provides an overview of AQPI, setting the stage for a poster cluster on this topic.

Keywords: Forecasts, Precipitation, Streamflow, Coastal Flooding, Gap-filling radar
Session Title: Improving Hydrologic Measurements and Predictions
Session Time: Tuesday, September 11th, 10:20 AM - 12:00 PM, Room 306

Ensemble Flow Forecasts for Risk Based Reservoir Operations of Lake Mendocino: An Adaptive Approach to Reservoir Management

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Forecast informed reservoir operations (FIRO) is a methodology that incorporates short to mid-range precipitation and flow forecasts to inform the flood operations of reservoirs. The Ensemble Forecast Operations (EFO) alternative is a probabilistic approach of FIRO that incorporates ensemble streamflow predictions (ESPs) made by NOAA's California-Nevada River Forecast Center (CNRFC). With the EFO approach, release decisions are made to manage forecasted risk of reaching critical operational thresholds. A water management model was developed for Lake Mendocino, a 111,000 acre-foot reservoir located near Ukiah, California, to evaluate the viability of the EFO alternative to improve water supply reliability without increasing downstream flood risk. Lake Mendocino is a dual use reservoir, which is owned and operated for flood control by the United States Army Corps of Engineers and is operated for water supply by the Sonoma County Water Agency. Lake Mendocino releases water into the Russian River which provides habitat to endangered and threatened salmonid species. Due to recent changes in the operations of an upstream hydroelectric facility, this reservoir has suffered from water supply reliability issues since 2007. The EFO alternative was simulated for Lake Mendocino using a 26-year (1985-2010) ESP hindcast generated by the CNRFC. Model simulation results demonstrate that the EFO alternative may improve water supply reliability for Lake Mendocino to meet downstream demands and increase cold water pool storage to maintain cold water releases for improved summer and fall habitat conditions for juvenile and adult salmonids. Additionally simulation results do not demonstrate an increase in flood risk for areas downstream of Lake Mendocino. The EFO alternative provides a management framework that could be adapted and applied to other flood control reservoirs such as those in the Bay Delta System.

Keywords: Forecast, Reservoir, Operations, Water, Supply, Flood, Risk, Adaptive, Ensemble
Session Title: Improving Hydrologic Measurements and Predictions
Session Time: Tuesday, September 11th, 10:20 AM - 12:00 PM, Room 306

High Resolution Water Velocity Measurements Using Infrared Quantitative Imaging Velocimetry

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Infrared Quantitative Imaging Velocimetry (IR-QIV) is a novel technique that accurately measures the instantaneous surface velocity field, including turbulence metrics, in natural flows. Sequences of infrared images of flowing water are captured, from which a high temporal and spatial resolution record of velocity is calculated over a large area of up to tens of meters by tens of meters.

The IR-QIV method, developed in a collaboration between Cornell University, DWR and USGS, was utilized during the 2014 Georgiana Slough Floating Fish Guidance Structure Study, and more recently during November 2017, on the Sacramento River and Sutter Slough. We present measurements from these studies, showing excellent agreement between the IR-QIV measurements, and ADV (Acoustic Doppler Velocimeter) and ADCP (Acoustic Doppler Current Profiler) water column velocity and discharge measurements.

Commonly used velocimetry methods (ADCPs and ADVs) measure either a high temporal resolution velocity record at a single point or mean velocity along a 1D transect. In contrast, IR-QIV can make both high spatial and high temporal resolution measurements over a large 2D area, resolving turbulence scales in both time and space. Furthermore, IR-QIV does not require any contact with the water or any seeding markers in the flow, and can operate during any lighting conditions and most weather conditions.

Using both the turbulent velocity field measured by IR-QIV and length scales derived directly from the infrared images we are able to estimate local bathymetry, which means we can estimate discharge can by this single, non-contact measurement method.

This type of measurement opens many possibilities for both resource management and hydrodynamic model verification. The large spatial coverage coupled with the high resolution of the measurement are ideal for characterizing flow conditions in transition regions (e.g., sidewall boundary layers or near obstacles), making it a uniquely suited tool for fish behavior studies.

Keywords: PIV, infrared, hydrodynamics, flow, turbulence, measurement, boundary layer, QIV, physical
Session Title: Improving Hydrologic Measurements and Predictions
Session Time: Tuesday, September 11th, 10:20 AM - 12:00 PM, Room 306

Defining and Quantifying Floodplain Fish Habitat

Developing Rearing Habitat Objectives to Support Salmon in the Central Valley

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Over the past century, water management and habitat degradation have led to significant declines in Chinook salmon in the Central Valley of California. Efforts have been made to restore the declining health of riverine habitats and anadromous fish. However, the Sacramento River, San Joaquin River, and their tributaries continue to suffer from declining fish populations. Scientists working on Central Valley rivers have made recent efforts to develop quantitative biological objectives for restored anadromous fish populations. An additional set of environmental objectives are necessary to define the design criteria for restored rivers; i.e., quantitative targets for habitat types and water quality metrics that are hypothesized to support biological objectives. Evidence has determined that, beyond typical instream rearing habitat, seasonally-inundated side channels and floodplains provide food production and rearing habitat necessary to support target populations of juvenile Chinook salmon. Providing an adequate quantity and quality of rearing territory during emigration can reduce the negative effects associated with competition for space on a population level. We have applied the Emigrating Salmonid Habitat Estimation (ESHE) modeling framework that simulates the movement, growth, survival, and territory requirements of cohorts of juvenile Chinook salmon to estimate rearing habitat needs across time and space to sustain target abundance levels of Chinook salmon in the Sacramento and San Joaquin Rivers, including all major tributaries. This modeling approach provides the first comprehensive spatially and temporally explicit targets for rearing habitat for all Central Valley rivers. By estimating where habitat is most needed within a watershed, and at what times during the rearing season, management actions can be better designed to achieve quantitative biological objectives.

Keywords: Chinook salmon, rearing habitat, floodplains, modeling, Central Valley, river restoration
Session Title: Defining and Quantifying Floodplain Fish Habitat
Session Time: Tuesday, September 11th, 10:20 AM - 12:00 PM, Room 307

Dark Carbon and a Return to Abundance: How Detrital Floodplain Food Webs Can Help Recover Endangered Fish

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Recovery of endangered fish populations will likely be impossible without first recovering the landscape-scale ecological processes which once supported historic abundances of native species. In the pre-development Central Valley Each winter and spring flooding once created a vast mosaic of productive wetland habitats that teemed with fish and wildlife. A major driver of this wildlife abundance was terrestrial carbon made available to aquatic food webs when floodplains inundated. Nineteenth and twentieth-century investments in drainage and a network of dams, canals, and levees transformed the Central Valley's fertile floodplains into one of the world's most productive agricultural regions. This system of water infrastructure also sped water off the landscape and cut off over 95% of the Central Valley's floodplains from river channels. As a consequence, aquatic ecosystems no longer recruit the carbon (stored solar energy) needed to sustain robust food webs build abundant fish and wildlife populations. Put simply, levees starve aquatic ecosystems.

This presentation will demonstrate how multi-species, multi-benefit floodplain management can help cultivate ecological solutions on working agricultural landscapes to increase diversity, resilience and abundance of native aquatic species. In particular, we will explore a portfolio of solutions aimed at reconnecting floodplain carbon sources to river food webs and beginning to restore natural ecological processes within the extensively altered and highly managed landscape of the Central Valley.

Keywords: floodplain, dark carbon, productivity, managed ag floodplains, rice, salmon
Session Title: Defining and Quantifying Floodplain Fish Habitat
Session Time: Tuesday, September 11th, 10:20 AM - 12:00 PM, Room 307

The Opportunity of Floodplain Habitat Quantification

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Reconciling the needs for species and habitat conservation, flood management, agriculture and water supply in the Central Valley and Bay Delta necessitates land and resource stewardship approaches that achieve multiple benefits simultaneously. Designing and implementing effective multi-benefit flood projects requires a transparent, replicable, and transferable approach for quantifying floodplain habitat function. This presentation examines the conceptual approach for habitat quantification use by the Central Valley Habitat Exchange Habitat Quantification Tool (HQT). In this case, habitat quality and suitability are defined for individual species using a common set of parameters and quantitative metrics in an outcomes-based framework. The HQT enables quantification of the relative habitat value of extant landscape, and can serve as a basis for recommending specific actions that would increase habitat quality in a given location. An additional effect of this habitat quantification approach is to make transparent the relationship between habitat needs for multiple species in a single location. In doing so, this approach to habitat quantification additionally opens up the possibility of more reconciled forms of species management such as mitigation for multiple species in a single location.

Keywords: Salmon, Floodplain, Chinook, Habitat, Quantification, Multi-Benefit
Session Title: Defining and Quantifying Floodplain Fish Habitat
Session Time: Tuesday, September 11th, 10:20 AM - 12:00 PM, Room 307

Quantifying Spatiotemporal Habitat Benefits of Floodplain Restoration

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Floodplain environments support some of the most diverse and productive ecosystems globally, but are also some of the most threatened due to multiple interacting stressors. The loss of connectivity between rivers and their floodplains in California's Central Valley and Bay-Delta has eliminated valuable spawning and rearing habitat and food production for native fish including juvenile salmonids and Sacramento splittail. Determining habitat restoration and flow management alternatives that best meet habitat requirements for native fish requires improved methods for quantifying potential habitat benefits in space and time. The objective of this research was to apply hydrospatial analysis of floodplain inundation patterns to quantify physical habitat for Sacramento splittail before and after levee-removal restoration along the lower Cosumnes River. Spatially-resolved flow-depth and flow-velocity relationships were established via 2D hydrodynamic modeling and subsequently combined with daily flow time series and habitat suitability indices relating to depth, velocity, inundation duration, timing, and connectivity. Spatially-resolved daily habitat suitability was computed as weighted usable area and summarized at the flood event and water year scale. Results suggest that the levee-removal had the overall effect of nearly doubling splittail habitat availability, with considerable variability in space and time. Habitat improvements varied depending on flow, indicating that intermediate flood flows provided the greatest relative benefits and suggesting that flow-habitat relationships are not linear or one-to-one in complex floodplain environments. A central contribution of this work is that it allows for consideration of spatially- and temporally-dependent habitat criteria, such as inundation duration and connectivity. As water resources and floodplain landscapes in the Bay-Delta and beyond are increasingly managed to improve conditions for native species while also providing multiple other benefits, this research offers an inclusive quantitative approach for evaluating management alternatives. Overall, research findings point to the substantial habitat benefits possible through management actions promoting river-floodplain interaction.

Keywords: floodplain, habitat suitability, spatiotemporal, modeling, restoration, Cosumnes River, Sacramento splittail
Session Title: Defining and Quantifying Floodplain Fish Habitat
Session Time: Tuesday, September 11th, 10:20 AM - 12:00 PM, Room 307

The CVHE Chinook Salmon Habitat Quantification Tool

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Habitat Quantification Tools (HQTs) were developed for multiple species by the Central Valley Habitat Exchange to facilitate investment in restoration of Central Valley habitat. The HQTs are designed to quantify habitat benefits in a consistent way that can be used as a basis to evaluate credits and impacts. The Chinook Salmon HQT is a predictive spatially and temporally resolved method to estimate the amount of suitable salmonid rearing habitat expected to be provided on an annual basis by floodplain restoration projects. The approach uses two-dimensional hydrodynamic modeling in conjunction with habitat suitability criteria for factors such as depth, velocity, connectivity, and cover, as well as the duration, timing, and frequency of flood events. The HQT uses the historical flow record combined with hydrodynamic modeling output and habitat suitability criteria to estimate daily spatially-distributed habitat, which is used to generate annual exceedance probability curves for qualifying habitat in acre-days per year. One advantage of this method, compared to other methods typically used in the design process to estimate the amount of suitable habitat, is that it accounts for habitat provided over all qualifying flood days, and is not based on index flow rates generated through flood frequency analysis. The HQT can be used iteratively during the design process to better understand when and where within restoration sites benefits accrue and to quantitatively compare scenarios to maximize the provision of suitable habitat during design. The method was tested for a recent levee-removal restoration project along the lower Cosumnes River, using a 20-year historical flow record. Qualifying habitat was provided in all years, with availability increasing substantially in wet years. Habitat availability was highly related to annual flow, though not directly correlated. The Chinook Salmon HQT is currently being testing and refined at several floodplain restoration sites that are in initial design stages.

Keywords: floodplain restoration, salmonid habitat suitability, habitat quantification, spatiotemporal hydraulic modeling
Session Title: Defining and Quantifying Floodplain Fish Habitat
Session Time: Tuesday, September 11th, 10:20 AM - 12:00 PM, Room 307

Modeling Delta Smelt II

Understanding How Abiotic and Biotic Factors and Management Actions Affect Delta Smelt: What Do We Need to Know?

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Using the findings of available research and analysis to inform management decisions often requires intermediate steps, such as decision-support tools or conceptual models, to make the link between knowledge and need. For Delta Smelt an increasing body of scientific papers and reports provide a solid foundation of information but quantification of how and why Delta Smelt, and the food and other resources on which they depend, may respond to specific management actions is limited. To begin to address this need the Collaborative Adaptive Management Team has initiated the development of a Science Plan that increases understanding of abiotic and biotic factors and management actions affecting on Delta Smelt specifically to support decision-making. This work is underway and is being conducted in coordination with other ongoing activities relevant to Delta Smelt and will leverage data and research findings from multiple sources. The focus will be on understanding the role of actions such as seasonal flow management, Toe Drain flows to enhance food web, managed wetlands and Suisun water management, in the context of ambient environmental conditions. It is expected that the framework applied in the plan could be extended to include other management decisions. This presentation will provide an opportunity to discuss progress, but more importantly to receive input from scientists and managers about they think the emphasis should lie, and what specific challenges need to be overcome to implement such proactive scientific activities in advance of and following flow events and management actions.

Keywords: Delta Smelt; management decisions; monitoring; experimentation; synthesis
Session Title: Modeling Delta Smelt II
Session Time: Tuesday, September 11th, 10:20 AM - 12:00 PM, Room 308-310

Is it Maybe, Just Maybe Possible that Striped Bass had Long Been a Fundamental Limit on Delta Smelt Population Growth?

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Fishes of the family Osmeridae are forage fishes and the morphology and life history of Delta Smelt Hypomesus transpacificus, suggest it too was historically a forage fish. The life history of Delta Smelt also suggests that like Striped Bass and Longfin Smelt, it should be a species whose abundance or survival correlates positively with interannual variation in Delta outflow. However, a persistent 'fish-flow' relationship for Delta Smelt has not been forthcoming despite seven decades of increasing monitoring intensity. There are two possible reasons that a 'fish-flow' relationship for Delta Smelt has not been forthcoming: (1) the species is not sensitive (or only very weakly sensitive) to interannual variation in Delta outflow, or (2) some other factors were already limiting the species' response to Delta outflow when the major California Department of Fish and Wildlife trawl surveys began. This presentation uses historical monitoring and research data to set up the hypothesis that Striped Bass was that limiting factor, and then describes a plan to use an individual-based life cycle model for Delta Smelt to test one of three potential limiting mechanisms, the direct predation of Delta Smelt by Striped Bass.

Keywords: Delta Smelt, Striped Bass, Life Cycle Model, Predation
Session Title: Modeling Delta Smelt II
Session Time: Tuesday, September 11th, 10:20 AM - 12:00 PM, Room 308-310

Updates to Delta Smelt Life Cycle Model 3: A State-Space Model Separating Entrainment and Natural Mortality

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The existing management strategy for the Sacramento-San Joaquin Delta's endangered delta smelt population places a high conservation value on management of water operations, specifically prevention of delta smelt entrainment during water extraction by the Central Valley and State Water Projects; however, variation in entrainment mortality over time has not been quantified. Management of the species is limited by not knowing the effect of active hydrodynamic management over the last decade and the relative contribution of entrainment to total delta smelt mortality. The Delta Smelt Life Cycle Model (LCM) is an effort by the United States Fish and Wildlife Service to assess present and past delta smelt population status, quantify drivers of population dynamics, and find long-term, resilient solutions to conserve delta smelt. The LCM is a state-space model that separates state and observation processes and quantifies the relative effects of water operations on delta smelt abundance by incorporating time series of Central Valley and State Water Project entrainment estimates. Four surveys were used to estimate delta smelt abundance at four life stages, and environmental and trophic covariates were used to estimate annual variation in survival and reproduction. Merits of this approach were the separation of entrainment from other sources of mortality, assessment of the relative contributions of different sources of mortality, and the derivation of entrainment observation probability as a function of mortality rates. Results suggested that active management of hydrodynamic conditions has been successful in reducing delta smelt entrainment mortality. A step decline in entrainment mortality over multiple life stages was observed beginning in 2005, concurrent with the advent of hydrodynamic management.

Keywords: delta smelt, entrainment, state-space, management, mortality
Session Title: Modeling Delta Smelt II
Session Time: Tuesday, September 11th, 10:20 AM - 12:00 PM, Room 308-310

Impacts of Salinity on Mechanisms of Development and Life History Transitions in Embryos of the Delta Smelt (Hypomesus transpacificus)

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The delta smelt (Hypomesus transpacificus) is a critically endangered species endemic to the San Francisco Estuary (SFE). Of particular interest for conservation of the species is to identify the physiological and ecological impacts contributing to their population decline in recent decades. Transitions between early life history stages are particularly sensitive to and tightly coupled with salinity for the delta smelt and therefore may be sensitive to changes in patterns of salinity due to climate change. Yet, most studies examine the health of this species without incorporating information from early development that may influence later life stages. Here, we describe the embryonic development of the delta smelt in great detail, allowing the identification and morphological measurement of critical structures. Additionally, we investigate development and survival at ecologically relevant salinities: 0, 4, and 8ppt. Delta smelt embryos had similar hatch success among treatments and demonstrated no significant difference in eye, yolk, and egg size across salinities, which may indicate a tolerance to salinity stress at this stage, a common feature in euryhaline teleosts. To investigate this further, we explore the mechanisms that contribute to the transitions between life stages such as egg activation, fertilization, hatching success, and survival upon hatching that may be affected by salinity. Results from this investigation may lead to lasting improvements on our conservation practices and management of this species and further enhance our understanding of embryonic development exposed to salinity stress.

Keywords: Delta smelt, salinity, embryonic development, morphometrics, hatching success
Session Title: Modeling Delta Smelt II
Session Time: Tuesday, September 11th, 10:20 AM - 12:00 PM, Room 308-310

Combined Effects of Warming and Pollutants on Temperature-Dependent Sex Determination, Survival, and Development across Generations

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Understanding anthropogenic impacts, such as climate change and pollution, on aquatic ecosystems is critical for preserving biodiversity and maintaining water quality. The pyrethroid pesticide bifenthrin is a known endocrine disrupting compound (EDC) that enters watersheds through urban and agricultural runoff. Ethinylestradiol (EE2) is a common pharmaceutical that enters watersheds via wastewater effluent. Little is known about how elevated temperatures associated with climate change may affect the estrogenic activity of bifenthrin and EE2, particularly in species that exhibit temperature-dependent sex determination (TSD), such as the estuarine species Menidia beryllina. This study investigated the effects of temperature and bifenthrin exposure on development, reproductive output and gene expression in M. beryllina across multiple generations. Fish in the parental generation were exposed to environmentally relevant concentrations of bifenthrin and EE2 (positive control), as well as methanol (solvent control) at 22°C and 28°C for 14 days prior to spawning. Embryos in the F1 generation were exposed to EDCs as larvae (until 21 dph) and then reared to adulthood (8 months) in clean water at experimental temperatures. In all F1 treatments, elevated temperature resulted in fewer viable offspring. Sex ratios of the F1 generation were influenced by both elevated temperature and EDCs, resulting in alteration of adaptive TSD. Fish exposed to bifenthrin during development exhibited developmental deformities. Changes in gene expression were observed in larval fish across generations, suggesting the potential for transgenerational effects of EDCs at higher temperatures. Findings from this study will be useful in determining how EDCs will impact organisms and community structure in the face of global climate change.

Keywords: multiple stressors, multigenerational, bifenthrin, Menidia beryllina, endocrine disruption, climate change,
Session Title: Modeling Delta Smelt II
Session Time: Tuesday, September 11th, 10:20 AM - 12:00 PM, Room 308-310

On the Horizon

Progress in Establishing a Nonnative Predator Research and Pilot Fish Removal Program on the Stanislaus River

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Federal legislation (Water Infrastructure Improvements for the Nation [WIIN] Act; passed December 16, 2016) requires the Oakdale and South San Joaquin Irrigation Districts and NOAA Fisheries to jointly establish a nonnative predator research and pilot fish removal program in the Stanislaus River to investigate whether a removal program is an effective strategy to improve overall conditions for native fish, specifically the survival of juvenile salmonids. Throughout 2017 and early 2018, we collaborated with NOAA Fisheries and the California Department of Fish and Wildlife to develop study plans, obtain permits, and implement the studies. Goals for 2018 include efforts to: (1) gather data on the abundance, composition, and distribution of both native and nonnative piscivorous fishes in the Stanislaus River; and (2) gather age composition and diet information from fish predators. The study area spans the lower 40 miles of the Stanislaus River from the confluence with the San Joaquin River to just below the Oakdale Recreation Area. The sampling design allows for information to be gathered on both temporal and spatial aspects of predation in the Stanislaus River. Randomly selected sampling locations will be revisited multiple times during the study period. Mark-recapture using PIT tags will be used in a robust design framework to account for the ability of tagged fish to move into and out of the study locations (i.e., an open population). Data collected in this fashion can provide insight on how predation risk (e.g., the number of Chinook salmon consumed by predators) may change through time and space as well as how predator populations may change throughout the study period. Information gathered in the early phases of the study will better inform the future study design and implementation of the removal phases in 2019 and beyond.

Keywords: predation, fish removal, Stanislaus River, WIIN Act, abundance, diet, age
Session Title: On the Horizon
Session Time: Tuesday, September 11th, 10:20 AM - 12:00 PM, Room 311-313

A New Tool for Prioritizing and Planning Gravel and Large Woody Debris Augmentation in Urban Streams

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Problem: Steelhead in the San Francisco Bay Watershed are threatened. Human impacts, including ubiquitous reservoirs, roads, and development have altered streams in the Santa Clara Valley. Besides flows, human activities modify downstream sediment flux and alter recruitment of large woody debris (LWD). Most gravel and LWD augmentation has taken place on large rivers, with large wood. This work presents a site prioritization tool and concept development approach that synthesizes the latest science to prioritize locations best suited to gravel and LWD augmentation to support steelhead spawning and rearing in the logistically challenging setting of smaller urban streams.

Approach: To prioritize stream reaches well suited to gravel and LWD augmentation we crafted a multi-criteria decisional analysis matrix which articulates criteria deemed applicable to local channels by stakeholders.

Results: Reaches were delineated using geomorphically relevant metrics from easily available public sources. Criteria selected to prioritize locations for gravel and LWD augmentation are: Presence of water-supply dams upstream; degree to which sediment and wood source areas protected and managed open space; level of observed sediment accumulation; degree of bed and bank manipulation; proximity to upstream and downstream sediment sinks, fisheries mapping, presence of regulatory floodways and elevated episodic risk (here – large wildfires and floods), access and easement. The Team developed a site assessment Standard Operating Procedure specific to evaluating potential gravel and LWD augmentation sites (SOP) which was used to evaluate and further prioritize sites in the field. The SOP outlines evaluation steps as well as ecologic and geomorphic metrics to collect for future evaluations.

Relevance: This tool is needed to help water managers in urban watersheds address the challenge of balancing water supply and habitat needs. Climate change is expected to bring more widespread hardwood conversion, and this work presents tools and design concepts which can help managers facing land-cover conversion.

Keywords: gravel augmentation, LWD augmentation, streamwood, geomorphology, hydrology, fisheries, habitat restoration
Session Title: On the Horizon
Session Time: Tuesday, September 11th, 10:20 AM - 12:00 PM, Room 311-313

Durability of Environment-Recruitment Relationships in Aquatic Ecosystems: Insights from Long-Term Monitoring in a Highly Modified Estuary and Implications for Management

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The environment can strongly influence the survival of aquatic organisms and their resulting dynamics. In part owing to simplicity and ease, our understanding of physical-ecological relationships are often based on correlations which are sometimes used to underpin resource management actions. However, these statistical relationships can break down over time as ecosystems evolve. Even when durable, some may not be useful for management if they exhibit high variability or non-stationarity. California's San Francisco Bay Delta provides an ideal model system for testing the durability of such relationships, many of which continue to inform regulatory actions and constraints for species of concern. We systematically reviewed 55-peer reviewed publications containing 420 environment-recruitment relationships for aquatic taxa from the Bay Delta to first identify general trends and gaps across this body of work. We then retested 23 of these relationships, spanning 9 species and 16 environmental variables, using the original analytical approach with long-term monitoring data that have accumulated in the years since they were first published to determine whether they persisted. Most relationships tested remained robust (i.e., 20 of 23 were the same or stronger in magnitude and goodness-of-fit as measured by R2) to the addition of new data. However, prediction error associated with each generally increased over time and in some cases very rapidly. Our results suggest that more data will not further improve the predictive ability of these statistical relationships and management and regulatory questions that require higher precision will require alternative methods and a more explicit accounting of uncertainty (e.g., machine learning, real-time approaches). We conclude by exploring sources of uncertainty that might drive increasing error in the Bay Delta and synthesizing insights from the literature on best practices for the analysis, use, and refinement of environment-recruitment relationships.

Keywords: environment-recruitment, long-term monitoring, correlation, fish, regime shift
Session Title: On the Horizon
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Illegally Moored Vessels Lead to Loss of Native Eelgrass (Zostera marina), an Essential Fish Habitat and Food Source for Birds in San Francisco Bay

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Seagrass beds are the lungs of the ocean, providing valuable ecosystem services across the globe. Human impacts threaten seagrass beds worldwide, prompting conservation efforts at local and regional scales. Eelgrass (Zostera marina) is a seagrass native to the North America and benefits humans and marine biota. It is National Marine Fisheries Service's policy to recommend no net loss of eelgrass function in California, yet anthropogenic disturbances continue to threaten eelgrass. San Francisco Bay is home to the largest eelgrass bed along the Pacific flyway and supports a rich diversity of prey for migratory birds. One of the largest eelgrass beds in San Francisco Bay, found in Richardson Bay, has experienced a severe reduction in extent due to the presence of illegally moored vessels. We conducted an aerial survey of eelgrass in Richardson Bay, and quantified the extent of eelgrass damage using a GIS classification. We produced a Highly Conservative Damage Assessment and a Moderately Conservative Damage Assessment to quantify the range of eelgrass loss within the Richardson Bay anchorage. Results indicate that moored vessels have damaged 25% – 41% of eelgrass within the anchorage. On average, a single boat caused between 1,712 ± 951 m2 and 2,833 ± 1,012 m2 of damage to eelgrass. In total, 19.95 – 33.95 ha of eelgrass have been lost in Richardson Bay due to illegally moored boats. To our knowledge, this is the first study to quantify direct human impacts to eelgrass in San Francisco Bay. Our results will help inform management decisions aimed at reducing loss to eelgrass. To prevent future declines in this critically important ecosystem, eelgrass mitigation is urgently needed in Richardson Bay.

Keywords: Human impacts, Seagrass, Anchoring, Aquatic vegetation, Ecosystem conservation
Session Title: On the Horizon
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Discovery of Invasive Nutria in California's Sacramento-San Joaquin Delta Watershed

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Following eradication in the 1960s, a reproducing population of invasive nutria (Myocastor coypus) has again been discovered in California's San Joaquin Valley and the Sacramento-San Joaquin River Delta. Nutria are large, semi-aquatic rodents, reaching up to 20 pounds in size and resembling beavers and muskrats. Native to South America, nutria were introduced in the U.S. for the fur-trade and successfully farmed in California during the 1930s-60s. Collapse of the fur market led to nutria releases and feral populations, which were declared eradicated from California in the 1970s. However, In March 2017, a pregnant, female nutria was trapped in a private wetland in Merced County. Since that time, over 40 additional nutria have been taken from private and public wetlands, adjacent to the San Joaquin and Merced Rivers, ponds, and irrigational canals, with additional confirmed and potential sightings, damage, and sign in Stanislaus, Merced, San Joaquin, Tuolumne, and Fresno Counties. If allowed to persist, nutria will severely impact California's ecosystems and resources, including the loss of wetlands, severe soil erosion, increased sedimentation, damage to agricultural crops and levees, and reduced stability of river banks, dikes, and roadbeds, as they have done in Louisiana, Chesapeake Bay, and the Pacific Northwest. Nutria also degrade water quality and can contaminate drinking supplies with parasites and diseases transmissible to humans, livestock, and pets. The California Department of Fish and Wildlife and project partner agencies seek to eradicate nutria from the State for the prevention of significant environmental, agricultural, and economic impacts in the Sacramento-San Joaquin River Delta watershed. CDFW is conducting local outreach, pursuing landowner access permissions, developing an eradication strategy, and has deployed survey and trapping teams to delineate the population and initiate eradication efforts. Up to date needs, progress, and direction of future efforts of the California Nutria Eradication Project will be presented.

Keywords: Invasive, nutria, Myocastor coypus, eradication, wetlands, non-native
Session Title: On the Horizon
Session Time: Tuesday, September 11th, 10:20 AM - 12:00 PM, Room 311-313

Climate Variability Effects on Salmonids

Harvest, Hatchery Returns and Straying of Fall Chinook Salmon from Coleman National Fish Hatchery Released at Bay and Delta Sites During California's Drought

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The U.S. Fish and Wildlife Service's Coleman National Fish Hatchery (NFH) is the largest salmon hatchery in California, annually producing 12 million fall Chinook Salmon smolts that substantially contribute to California's ocean and inland fisheries. Standard practice at Coleman NFH is to release smolts on-site into Battle Creek. On-site releases typically achieve the hatchery's goal of 1% overall contribution, distributed across the ocean and inland fisheries and returns of adults to the hatchery and Battle Creek, while reducing straying of hatchery-origin fish into non-natal spawning areas.

During the severe drought of 2014 and 2015, degraded water quality throughout the Sacramento River and Delta raised concerns that fish released on-site would not survive their emigration to the ocean, thereby failing to achieve the hatchery's contribution goals. Consequently, the decision was made to transport a large percentage of fall Chinook Salmon smolts for release at off-site locations in the Delta and San Pablo Bay to increase smolt survival by bypassing poor in-river conditions. An unintended consequence of releasing juvenile salmon off-site is decreased returns to the hatchery because of increased straying.

Evaluation of Coleman NFH releases of fall Chinook Salmon during the drought revealed the following effects of transporting smolts to the Bay-Delta: 1) increased contributions to the ocean commercial and recreational fisheries; 2) redistributed contributions to the inland sport fishery; 3) increased straying of adults to non-natal spawning areas, and; 4) decreased returns to Coleman NFH. High stray rates and apparent low survival of off-site releases resulted in the lowest escapement to Battle Creek in 40 years and was insufficient to meet the hatchery's broodstock needs in 2017. Despite additional efforts to collect eggs from Coleman NFH-origin strays at the California Department of Fish and Wildlife's Nimbus Fish Hatchery, juvenile production goals were not met at Coleman NFH in 2017.

Keywords: Fall Chinook Salmon, Hatchery, Drought, Harvest, Straying, Off-site Release
Session Title: Climate Variability Effects on Salmonids
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Living to Tell the 2012-2015 Drought Story as Told by the Otoliths of the Endangered Sacramento River Winter-Run Chinook Salmon

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The coexistence of alternative life history strategies results from evolutionary processes to maximize individual fitness, providing species with an extraordinary adaptive tool enabling them to persist in varied and unpredictable environments. Chinook salmon exhibit a range of ocean-entry timings that buffer the population to the unpredictable timing of the marine upwelling period. Likewise, alternative strategies that take advantage of a diversity of freshwater rearing habitats may be important in highly variable hydroclimates like California's Central Valley.Recent studies show the endangered Sacramento River winter-run Chinook salmon uses the mainstem Sacramento River and its tributaries as rearing habitats. Prior to the 2012-2015 drought, winter-run juveniles used the available rearing habitats evenly. However, we hypothesized that during the 2012-2015 drought juveniles may have 1) used different rearing strategies (shorter freshwater residence), 2) coped with higher temperatures, and/or 3) used fewer non-natal habitats due to tributaries being inhospitable or inaccessible. To test these hypotheses, we reconstructed juvenile habitat use and thermal histories in adult winter-run fish using otolith strontium and oxygen isotope ratios, respectively. These data were combined with hydrologic, temperature, and satellite data to quantify the accessibility and water quality conditions between the Sacramento River and its tributaries (including intermittent streams) during the drought compared to non-drought years (2005-2007). During the drought, most juveniles used the mainstem Sacramento River for rearing (up to 64%) and size at freshwater exit was 10% smaller than during non-drought years. The numbers of wild winter-run that returned to spawn in 2017 from the 2014 drought cohort was at historic lows. This suggests that the few surviving winter-run reared and outmigrated through the Sacramento River mainstem corridor and did not use tributaries as a thermal refuge as juveniles. Droughts will continue to be a primary stressor for multiple life stages of winter-run and to their long-term persistence.

Keywords: Chinook salmon, winter-run, climate change, drought, Sacramento River, tributaries, otoliths
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Snowpack and Air Temperature Influences Residence and Emigration Timing and Size of Juvenile Anadromous Fish across a Large, Hot, Dammed Watershed

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Migration often places juveniles in environments that promote development and survival. Anadromy is a common migratory life history whereby adults inhabit marine waters but juveniles rear initially in watersheds. There they can grow before migrating to sea where survival depends on size. Watershed conditions (e.g., flow, temperature) vary among seasons, and migratory fishsync juvenile phases with temporarily optimal habitats. Snowpack likelyinfluenceswatershed conditions. Where cool water is limiting, melting snowpack may keep waters cool and flowing longer into spring,determiningthe annual persistence of appropriate conditions for fish. Here we examined the timing of heat-sensitive fish in a warm watershed to understand how habitat use is constrained by regional environmental conditions. We quantified the effect of (1) mountain snowpack and reservoir releases on springtime watershed flow and temperature and(2) temperature on the end date of seasonal fish presence and maximum size of juveniles emigrating to sea. When snowpack was high, cool, flowing waters persisted late into spring, fish resided longer into spring, and the maximum size of fish emigrating to sea was larger. Higher snowpack also increased inflows to the system's major reservoir, which distributed water collected in the spring during the summer. Its water outflow resulted in detectable increases in downstream flow and, to a lesser extent, decreases in temperature. Thus, snow appeared to ultimately constrainthe close of an annual window for juveniles to rear in the watershed, which was somewhat modifiable by dam practices. Given widespread expected decreases in snowpack, springtime rearing in some species may become compromised, limiting life histories that rear late in spring and diminishing portfolio benefits supported by life history diversity. Moving forward, reservoir managers may consider targeting cool conditions for juveniles in the spring and researchers may explore snowpack as a predictor of fitness in anadromous fish.

Keywords: Dams, drought, flow, migration, phenology, salmonids, reservoirs, snow, thermal tolerance
Session Title: Climate Variability Effects on Salmonids
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Opening the Black Box: Delta Rearing by Juvenile Fall Run Chinook Salmon in Droughts and Floods

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Historically, the Sacramento-San Joaquin Delta was dominated by floodplain, riparian and wetland habitats that wereideal for juvenile salmon rearing. Less than 3% of these habitats remain today, and the extent to which juvenile Chinook salmon use the Delta for rearing (vs. solely as a migratory corridor) is poorly resolved. Every year, large numbers of juvenile salmonleave their natal rivers as fry, yet fryare rarely sampled leaving freshwateror in the estuary, begging the question – do they rear or perish in Deltahabitats?Here, fall and late-fall run sized juvenile Chinook salmon were collected by the Delta Juvenile Fish Monitoring Program from upstream (Sherwood Harbor, Mossdale), within, and downstream (Chipps Island and the Bays) of the Delta in 2014-17. We used otolith strontium isotopes to reconstruct their natal origin and primary rearing reaches (e.g. natal stream, Sacramento or San Joaquin Rivers, the Delta). We then used otolith microstructure to estimatereach-specific growth rates, and paired these data with gut content analyses and condition indices from the same individuals. We also reconstructed juvenile rearing patterns of post-spawned (i.e. “successful”) adult salmon from multiple populations. Together, these datashow that Delta rearing can be an important strategy, both in drought and flood conditions.By distributing juveniles across a broader array of habitats and growth opportunities, early dispersers may be critical to the long-term persistence of Central Valley salmon in an increasingly unpredictable climate.

Keywords: Juvenile salmon, life history diversity, migration, rearing, otolith isotopes, Delta
Session Title: Climate Variability Effects on Salmonids
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Impacts of El Niño on Adult Chinook Salmon (Oncorhynchus tshawytscha) Weight in the Gulf of the Farallones

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Chinook salmon (Oncorhynchus tshawytscha), is a species that has evolved to cope with the highly variable oceanic and freshwater environments of the Pacific Northwest, and responds to large changes in those environments in equally dramatic fashion. Here, some of the effects of El Niño on Chinook as they migrate through the Gulf of the Farallones (GoF), central California Current System, are examined. We tested the hypotheses that the strength and occurrence of an El Niño event would be linked with (1) Chinook seasonal dressed mean weights from the commercial fishery from May to June between Bodega Bay and Monterey, and (2) the Sacramento Index. El Niño events were defined by use of the Oceanic El Niño Index reflecting the winter of t-1 through t (which we assign to year t for correlation analysis). Commercial landed Chinook dressed weight was lower during El Niño compared to non-El Niño years. During strong El Niño winters (1982-1983, 1997-1998, and 2015-2016), as well as the moderate El Niño winter (1991-1992), Chinook dressed weight was 69% of mean weights from other years. Chinook dressed weight was also correlated with the Sacramento Index. The reduced Chinook dressed weight during El Niño was likely due to a disrup-tion in their normal feeding cycle in the GoF. For Central Valley fall Chinook, the vast majority of Chinook in the GoF, the impact of reduced weight and Index numbers related to El Niño on the overall long-term population dynamics is small since fall Chinook reproduction occurs largely in hatcheries. However, the situation with ESA and CESA-listed spring and winter Chinook is different since these two runs rely more heavily on natural production of juveniles.

Keywords: Chinook Salmon, El Nino Impacts, weight
Session Title: Climate Variability Effects on Salmonids
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Untangling Effects of Water Movement and Water Quality

Checking Assertions with Data: Untangling Factors that Constrain Water Exports from the San Francisco Bay Estuary

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Conflicts surrounding management of endangered species may be intense, especially when the species involved rely on resources that are scarce relative to human demand. Managing or resolving these conflicts requires access to information that helps characterize the problem; where information is lacking or perceived by stakeholders differently, conflicts over endangered species management may become intractable. We studied water management practices and constraint that affect the flow of water into and through the San Francisco Bay's estuary, which is home to six imperiled fish species and water export facilities owned by the state and federal governments that serve millions of people and large expanses of agricultural land. Frequent media reports reflect the widely-held beliefs that environmental regulations, and protections for the endangered fish species in particular, frequently and dramatically reduce water diversions in this system and increase freshwater flow to San Francisco Bay. However, data necessary to evaluate such claims are not synthesized in publicly available form. Using several public data sources, we analyzed the long-term trend in the net effect on Delta outflow of water diversions in the estuary's Central Valley watershed, and the frequency and magnitude of specific regulatory and infrastructural constraints on the two water export facilities. We found that the percentage of freshwater runoff from the Central Valley watershed that reaches San Francisco Bay has declined over the past several decades such that the Bay's estuary experiences extreme drought conditions in most years. Protections for endangered fish species constrained daily water exports less frequently than other environmental safeguards and operational constraints during a six-year period that included a prolonged and severe natural drought. We found that although data regarding constraints on water exports are available, they are not synthesized or contextualized in a way that facilitates public access or understanding; this may perpetuate misconceptions that foster conflict.

Keywords: exports, salinity, regulations, endangered species, flow, operations, public perceptions, drought
Session Title: Untangling Effects of Water Movement and Water Quality
Session Time: Tuesday, September 11th, 1:35 PM - 3:15 PM, Room 306

How Sweet is It: Early 20th Century Delta Salinity Regime as Recorded by C&H Sugar Barge Travel Data

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The San Francisco estuary has been highly modified since exploration and settlement by Europeans in the mid-18th century. Although these hydrologic alterations supported the growth of California's economy, they have been accompanied by significant declines in native aquatic species and subsequent efforts to reverse these declines through flow management. To inform ongoing deliberations on management of freshwater flows to the estuary, the author has collaborated with others to characterize both pre-development conditions (circa 1850) and changed conditions over the last century (i.e. since the early 1920s). The new work presented here bridges these earlier efforts by evaluating an interesting and unique data setthat, through proxy measurement, characterizes the salinity regime in the early 20th century prior to systematic monitoring beginning in the early 1920s.

The California and Hawaiian Sugar Refining Corporation (C&H), whose sugar refinery is located at Crockett, obtained its fresh water supply from barges that traveled upstream on the Sacramento and San Joaquin Rivers. C&H maintained a record of its barge travel beginning in 1908, recording both the distance traveled and the quality of water obtained. These records serve as a surrogate for the prevailing salinity conditions in the Delta during a period prior to regular water quality monitoring. Previously-developed flow-salinity methodologies were used to evaluate the C&H data, in tandem with concurrently available flow and salinity data, and characterize estuarine salinity intrusion during a period of declining runoff when several anthropogenic changes were underway. Salinity intrusion during the 1908-18 period was found to be similar to thesubsequent 1922-41 periodfor similar water year conditions, particularly in wet years.This work provides a foundation for future efforts to more broadly characterize the dynamic hydrologic and hydrodynamic changes that occurred in theestuary from pre-development conditions to the 1920s.

Keywords: salt intrusion, hydrologic change
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Effects of Extreme Freshwater Disturbance During the 2016-17 Wet Winter on San Francisco Bay Mudflat Infaunal Macroinvertebrates

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Intertidal mudflats of San Francisco Bay (SFB) are habitats for many organisms including infaunal macroinvertebrates that are prey for foragers at higher trophic levels. These organisms with limited to no mobility must withstand the conditions of the overlying water column at all times unlike nekton and mobile fauna that may relocate to areas with favorable conditions. Extreme precipitation during the wet winter of 2016-2017 produced very low salinities in SFB. The effects of such low salinity events are poorly known for mudflat infauna, including both native and non-indigenous species (NIS). A field study was conducted in three regions along the salinity gradient of northern SFB to compare mudflat infauna assemblages during and after the wet winter. Early observations from the field indicated a higher abundance of the invasive bivalve, Gemma gemma, in the more saline outer reaches of SFB compared to regions with greater freshwater influence further north. Experiments in the laboratory were conducted on the highly invasive G. gemma to determine the effect of extreme depression of salinity on the burrowing activity of the clam. Findings from the field survey helped characterize the differences in assemblages between regions that differed in the magnitude of freshwater disturbance. This study provides a first examination of the changes in frequency of NIS in SFB mudflat infaunal assemblages with respect to freshwater disturbance and time since disturbance. Results from the laboratory experiments provide the first look into the tolerance of the G. gemma to sudden drops in salinity understanding their distribution, abundance, population biology, and community impact in SFB. The results of this work will contribute to the understanding of the impacts of extreme freshwater disturbances on mudflat communities, and particularly the susceptibility or resilience of NIS in SFB.

Keywords: keywords go here
Session Title: Untangling Effects of Water Movement and Water Quality
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Stable Isotope Characterization of C, N, P, and S Compounds in Treated Wastewater Effluent Discharging to the Sacramento-San Joaquin Delta Region

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The Sacramento-San Joaquin Delta receives large inputs of biologically important C, N, P, and S compounds from wastewater disposal. These inputs can affect water quality and influence fundamental biological processes in the aquatic environment. To better understand the ecological consequences of C, N, P, and S inputs to the Delta from wastewater sources, it is necessary to characterize the C, N, P, and S compounds delivered by these sources in a manner that facilitates tracing their subsequent transport, biochemical transformation, uptake, and fate. Stable isotope values of organic and inorganic C, N, P, and S compounds can be powerful tools for understanding sources, sinks, and biogeochemical processes affecting these compounds. A lack of source characterization data is a major factor limiting the explanatory power of studies of the Delta utilizing stable isotope values of C, N, P, and S compounds to assess biogeochemical and ecological impacts of wastewater inputs of these compounds.

To rectify this lack of source characterization data, in June 2017 we began quarterly sampling of final treated effluent from four wastewater treatment plants (Sacramento Regional Wastewater Treatment Plant, Contra Costa Sanitary District Treatment Plant, White Slough Water Pollution Control Facility, and Manteca Wastewater Quality Control Facility) in and near the Delta representing a range of treatment processes and discharge volumes. While sampling and analysis of stable isotope values of C, N, P, and S compounds for this project is ongoing, preliminary results indicate that several of these stable isotope tracers will be useful in differentiating between final treated effluent from the wastewater treatments plants sampled as well as tracing the discharged effluent through the Delta environment. These findings are a step towards a better scientific understanding of the effects of wastewater discharge on the Delta environment and the formulation of regulatory strategies to best manage these effects.

Keywords: Wastewater, Wastewater Treatment, Carbon, Nitrogen, Phosphorous, Sulfur, Stable Isotopes, Biogeochemistry
Session Title: Untangling Effects of Water Movement and Water Quality
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Contribution of Utility Vault Water to Pollutant Loadings into San Francisco Bay

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Utility vaults and underground structures are essential to modern utilization of energy and technology, but often accumulate water and contain equipment (e.g., copper wiring) that could cause contamination. The National Pollutant Discharge Elimination System Utility Vault Permit administered by the California State Water Resources Control Board (SWRCB) allows the release of water from these structures to Waters of the State and has mandated broader characterization of utility vault water. In this study, we report the concentrations of 126 priority pollutants in 20 utility vault water samples collected throughout California by Pacific Gas and Electric Company (PG&E). Twenty-one priority pollutants were detected, metals most common. Two constituents (copper and zinc) exceeded water quality criteria, with maximum concentrations of 791 and 386 µg/L, respectively, which are typical of urban stormwater runoff. To assess the relative impact of utility vault water, we estimated volume and calculated loads. By compiling industry records and permit applications, we were able to show that the volume of water discharged from utility vaults is two orders of magnitude less than a single urban tributary that drains into San Francisco Bay, CA.For the San Francisco Bay watershed, the median loading of Cu and Zn from utility vault water was 0.06 and 0.5kg/yr, respectively, which was insubstantial compared to a previous estimate of Cu and Zn loading (74,000 and 320,000 kg/year, respectively). These are the first reported values of priority pollutants in utility vault water and provide evidence for the SWRCB that utility vaults do not have a reasonable potential to contribute to an exceedance of water quality objectives.

Keywords: Utility vault water discharge, Copper, Zinc, Stormwater, Water quality criteria
Session Title: Untangling Effects of Water Movement and Water Quality
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Tidal Marsh Responses to Sea-Level Rise in San Pablo Bay and the Delta: Implications for Wetland Change and Management

Modeling Approaches to Evaluating Marsh Resiliency to Sea-Level Rise in the San Francisco Bay Estuary

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Tidal wetlands are sensitive to changes in surface elevation relative to sea level and are likely to be substantially impacted by accelerating sea-level rise. Marsh accretion occurs through feedback mechanisms between suspended sediment deposition and organic matter accumulation. Planning for the effective conservation and management of tidal marshes requires the use of predictive modeling to evaluate effects of increased sea-level rise, sediment availability, and plant productivity on accretion. A variety of marsh accretion models have been used to predict tidal marsh response to these factors. We modeled century-level changes in elevation at two historic wetlands in San Francisco Bay, China Camp and Rush Ranch, that differ in the relative importance of sediment and organic matter for accretion. We utilized three accretion models (Marsh98, WARMER and MEM), four sea-level rise rates, and three site-specific suspended sediment concentrations, along with three starting elevations representative low, mid, and high elevations. We compared model results by looking at a specific year, comparing elevation trajectories over time, and spatially explicit results across scenarios. Responses between sites were generally similar but key subtle differences were observed. As expected, elevations were less likely to shift to mudflat elevations as sediment concentrations increased, particularly as the magnitude of SLR increased. Rush Ranch, the site with the highest plant productivity, showed little response to changes in sediment at the two lowest SLR scenarios compared to China Camp, which is likely due to the increased influence of organic material on marsh accretion at Rush Ranch. The largest difference in models was with the lowest initial elevation. The MEM consistently predicted higher future elevations, most notably at Rush Ranch. In summary, we were successful in improving understanding of marsh dynamics by evaluating similarities/differences in model calibration and predictions, ultimately aiding managers in understanding model applicability under different circumstances.

Keywords: tidal wetlands, accretion, sea-level rise, model, suspended sediment concentration
Session Title: Tidal Marsh Responses to Sea-Level Rise in San Pablo Bay and the Delta: Implications for Wetland Change and Management
Session Time: Tuesday, September 11th, 1:35 PM - 3:15 PM, Room 307

Using Surface Elevation Tables (SETs) to Monitor Marsh Elevations along a Tidal and Salinity Gradient

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Sea-level rise, changes in storm frequency and intensity, shifting patterns in freshwater flow and precipitation will impact marsh habitats and wildlife communities. Marsh elevation is a balance between local suspended sediment delivery to the surface for vertical accretion, subsidence, organic matter production, and tidal flooding. To better assess stability of tidal marshes over the near and long-term we deployed Surface Elevation Tables-Marker Horizon (SETs-MH) monitoring stations at five marsh sites along a salinity gradient within San Pablo Bay, Suisun Bay and the Delta in February, 2016. We installed 20 SETs-MHs across sites that included Petaluma marsh, San Pablo Bay NWR, Rush Ranch, Browns Island, and Miners Slough. Since deployment, elevation change between sites and within sites varied greatly. Between the November 2016 reading and the February 2017 reading there was a large increase in elevation at Miners slough (45.1 mm) and Browns Island (14.2 mm). At the next reading in May 2017, San Pablo Bay NWR experienced a large increase in elevation (22.0 mm). When comparing SET data from the San Francisco Bay-Delta to other locations throughout California two results are clear. First, elevation gains are relatively low (<5mm/yr) in most marshes in California where we are monitoring SETs. With sea-level rise rates from 2-5mm/yr in California this highlights that many of these areas are not “keeping pace” with current local rates of sea-level rise. Secondly, the storm season of 2016/2017 provided sediment to the marshes of the Delta (Browns Island and Miners Slough) and north San Pablo Bay that rapidly increased their elevations. This preliminary data highlights the importance of storms and high-river flows for sediment delivery to Delta marshes that makes them more resilient to sea-level rise. However, our preliminary data also shows that similar trends were not measured in San Pablo Bay and the rest of California.

Keywords: marsh, accretion, storms, San Pablo Bay, Delta, sea-level rise
Session Title: Tidal Marsh Responses to Sea-Level Rise in San Pablo Bay and the Delta: Implications for Wetland Change and Management
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Spatial Differences in Mineral and Organic Matter Deposition across a Salinity Gradient in San Francisco Bay-Delta Tidal Marshes

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Sediment deposition is an important component of accretion processes that allow tidal marshes to maintain their relative elevation as sea-levels rise. Interactions among suspended sediment concentration (SSC), inundation, and distance to sediment source influence deposition rates across the marsh. Seasonal variation in SSC and sediment transport processes, may also affect short-term deposition rates. Determining spatio-temporal patterns of sediment deposition across tidal marsh landscapes is thus key to understanding wetland vulnerability to sea-level rise. We sought to determine the amount of sediment deposition and the influence of abiotic drivers on sediment flux by measuring sediment deposition over the course of one year. We deployed sediment traps along transects perpendicular to large and small tidal channels in two tidal marshes in the San Francisco Bay estuary (salt marsh at Petaluma River and brackish marsh in northern Suisun Bay), replacing traps at 1-2 month intervals to capture seasonal variation. Similar to previous studies, we found sediment deposition was highest close to channels and at lower elevations. Marsh areas with larger channels had greater sediment deposition than smaller channels. Accretion rates and mineral deposition rates were greater at the brackish site. Organic matter deposition was 2.6 times greater at the brackish site, and reflected the differences in plant composition and the salinity gradient. We also found that deposition was greater from January through June, peaking in May and June, which corresponded to an increase in wind speed. Our study suggests salt marshes are at greater risk to sea-level rise than brackish marshes in San Francisco Bay, and will inform modeling efforts to incorporate seasonality and spatial heterogeneity into projections of marsh elevation under future climate scenarios. In addition, our results can be used as a guide for future efforts to measure sediment flux by identifying the period most representative of annual deposition rates.

Keywords: Marsh accretion, sea-level rise, sediment deposition
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Developing Functional Relationships between Marsh Processes and Abiotic Gradients in the San Francisco Bay-Delta Estuary to Update an Ecosystem Model

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Tidal marshes are vulnerable to drowning by sea-level rise if they cannot accrete vertically or migrate upslope. In the San Francisco Bay-Delta Estuary, significant shoreline development often limits the potential for migration; thus vertical accretion is critical to marsh survival in much of the region. Factors that affect elevation change over time in marshes include sediment supply, in situ marsh productivity, and decomposition. To project long-term elevation change across the region, it is critical to quantify spatial variation in these processes. In this presentation we summarize results from recent field and greenhouse experiments to determine how these elevation-related processes vary across inundation and salinity gradients in the estuary. One key finding of our work is that major plant species had different functional responses to inundation. Pickleweed, common in saline marshes, had the greatest sensitivity to greater inundation. Spartina foliosa, Juncus balticus, and several sedge species were more tolerant of inundation. In a greenhouse growth experiment, increasing salinity negatively impacted biomass of several brackish marsh species. Litter type (plant species identity) appeared to have little importance to decomposition rates, but we found decreasing plant decomposition associated with more saline conditions in the field and greenhouse. We discuss how development of these functional relationships between important marsh processes and major estuarine gradients are being used to update an ecosystem model of marsh vulnerability to sea-level rise. More broadly, our work highlights the important role of species composition and salinity in determining the magnitude of ecosystem processes that affect long-term elevation change in tidal marshes.

Keywords: Climate change, decomposition, inundation, productivity, salinity, sea-level rise
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Monitoring and Managing Sea-Level Rise Impacts on Tidal Marshes in the San Francisco Estuary

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Once upon a time, we were confident that if we protect and carefully manage mature tidal marsh remnants, these ecosystems will persist for the foreseeable future and provide sanctuary for tidal marsh species known to be at-risk due to habitat loss and fragmentation. This confidence is now regarded as more "fairy tale" than reality. A series of recent, independent studies have demonstrated that mature marshes are vulnerable to marsh drowning due to the combination of reduced sediment supply and increased rates of sea-level rise. Further, changing salinity, prolonged droughts, violent storm events, and erosion from extreme flooding add further risk to the viability of these habitats. Uncertainties abound! These insights have prompted additional studies that focus on the dynamics of mature tidal marsh habitats in response to extreme perturbations. The studies profiled in this special session shed additional light on these concerns. If mature marshes are vulnerable to uncertainties, imagine the level of risk associated with tidal marsh restoration projects underway and in the planning stages. These restoration projects may not reveal their vulnerability for years because they lack high marsh vegetation and marsh accretion signals that provide the most precise indicators for timely evaluation of these risks. Environmental uncertainties and renewed institutional commitment to tidal marsh restoration create the need to establish an effective and efficient regional tidal marsh 'observing system' (monitoring) that assesses tidal wetland restoration progress, triggers needed management actions, and maximizes interventions that help sustain these habitats. There is currently an EPA-funded effort underway designed to address this issue. Regardless, we need to refine our questions and continue to support the kind of research tools and studies profiled in this session well into the future. Let us not be lulled by a fairy tale that ultimately turns out to be an unpleasant reality.

Keywords: sea-level rise, wetland impacts, mature tidal marsh monitoring, management alternatives,
Session Title: Tidal Marsh Responses to Sea-Level Rise in San Pablo Bay and the Delta: Implications for Wetland Change and Management
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Fish and Flood in the Central Valley I

Unplanned Inundation at the McCormack-Williamson Tract Provides Informative Pre-Restoration Zooplankton Community Data

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The restoration of marsh and intertidal habitat in the Delta aims to provide productive high-quality habitat to native species. In February of 2017, McCormack-Williamson Tract flooded due to levee failure from high flows in the Cosumnes River. This unintentional flooding allowed for a four-month observational period where zooplankton community structure on the tract and surrounding habitats during high flows were monitored. The results from cluster and indicator species analysis demonstrate that the tract supported a productive zooplankton community different from that of surrounding habitats. This unique community included high value food resources such as Daphnia pulex, a large bodied cladoceran that is an important food resource to juvenile fish. Zooplankton biomass on the tract was over a hundred times higher than surrounding habitats during inundation. Additional results demonstrate that the tract had a high degree of community similarity to the downstream site suggesting outflows subsidized the downstream zooplankton community and biomass. This export of zooplankton biomass likely increased the amount of available food resources for higher trophic levels in downstream habitats. Analysis of data collected from the four months of unintentional flooding has provided information that will guide restoration and monitoring efforts and has informed our knowledge of zooplankton communities in flooded habitats in the northeast Delta.

Keywords: zooplankton biomass, restoration, community analysis, pre-restoration data
Session Title: Fish and Flood in the Central Valley I
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Banding, Bugs, and Phytoplankton: Spatial and Temporal Patterns Across the Yolo Bypass Floodplain During 2017

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Previous work by Ted Sommer et al.found that that the Yolo Bypass, the vast primary floodplain of the lower Sacramento River, consistently exhibits hydraulic banding during inundation events. Distinct bands are visible in imagery, representing each of the major inputs to the floodplain; the Sacramento River, Knights Landing Ridge Cut, Cache Creek, and Putah Creek. Bands remain visually separated along the entire 61 km north-south length of the Yolo Bypass, indicating that latitudinal mixing across inputs is limited. In this study, we examine spatial and temporal patterns of hydraulic banding as reflected in chemical, physical and lower trophic samples collected on an east-west transect throughout the extended and unusual flooding of 2017. Results indicate that turbidity, specific conductance, and pH varied spatially from east to west reflective of the visual banding patterns observed in Sommer et al. 2008. Chlorophyll concentrations, zooplankton abundances and drift invertebrate abundances were spatially heterogeneous, often differing several-fold between sample sites on the same date. Chlorophyll a and zooplankton were generally highest on the shallower western side of the floodplain, decreasing eastward toward the primary flow path. Temporally, a synchronous and distinct peak in phytoplankton, zooplankton and drift invertebrates was observed 3 weeks after flooding began, and during the first descending limb of the floodplain hydrograph. Although phytoplankton biomass and zooplankton densities varied spatially and temporally, they were consistently higher than the adjacent Sacramento River at the westernmost floodplain sites, and across all floodplain sites during drainage. Drift invertebrate densities were dominated by chironomids, and were always 10 to 100 times higher on the floodplain in comparison to the Sacramento River. Ultimately, this study will help elucidate how different hydraulic inputs and flooding duration relate to the high productivity that is generated on the floodplain and exported to the downstream San Francisco estuary.

Keywords: Floodplain, Yolo Bypass, banding, lower trophic productivity, hydrology
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Floodplain Habitat Enhancement Increases Juvenile Salmonid Rearing Duration and Growth on the Merced River

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In response to salmon habitat loss due to numerous anthropogenic stressors on the Merced River, two restoration projects were implemented to enhance rearing and spawning habitat. These projects created approximately 21 acres of seasonally inundated floodplain habitat to provide refuge from predation and high flows in the main channel and increase habitat complexity and prey productivity.

We used seining, fyke traps, and PIT tag antennas to compare habitat use, residence time, and growth rates of juvenile Chinook Salmon rearing in restored and unrestored reaches. We captured and PIT tagged a total of 1240 wild juvenile salmonids during seining events in March and April. In addition, we released 987 hatchery Chinook Salmon in late April.

At restored sites, 13.9% of tagged fish (n = 693) were recaptured at the site of original capture; average minimum rearing duration was 14.9 days (SD ± 9.8, range 1-48 days). At unrestored sites, 3.6% of tagged fish (n = 139) were recaptured at the site of original capture; all fish recaptured at unrestored sites had a 7 day minimum rearing duration. Growth rates were similar in restored reaches (0.82mm/day ± 0.11) as unrestored reaches (0.79mm/day ± 0.14). Average total growth was significantly greater at the Henderson Park restoration site (13.4mm ± 7.8) than in unrestored reaches (6.3mm ± 2.04). Average total growth at the Merced River Ranch restoration site was highly variable (11.5mm ± 10.9) and was not significantly different from either Henderson Park or unrestored sites. Chinook Salmon densities remained high later in the rearing season in restored reaches.

This study demonstrates that floodplain habitat restoration projects can extend in-river juvenile Chinook Salmon rearing duration, leading to higher total growth. Because larger juvenile salmon body size at out-migration is correlated with higher survival to adulthood, longer rearing duration may improve Chinook Salmon population viability.

Keywords: floodplain, restoration, juvenile salmon, rearing, growth
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The Flood Pulse Concept in a Managed Bypass-Floodplain

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A flood pulse is the lateral exchange of water, nutrients and biota within a river-floodplain. In a natural floodplain, there are several stages of interactions which create a flood pulse: (1) the aquatic/terrestrial transition zone (ATTZ) is flooded and aquatic organisms benefit indirectly from the transport of terrestrial resources, (2) a "moving littoral" of biota utilizing the ATTZ results in high productivity on the floodplain, and (3) at floodplain drainage primary production exported off the floodplain is much higher than that of permanent water bodies (Junk et al. 1989). However, it has been theorized that unnatural floodplains, which have been leveed and drain quickly, such as the Yolo Bypass, produce unpredictable pulses. The biota within these augmented systems are thought not to be able to use the ATTZ, precluding the formation of a "moving littoral" (i.e., only stage one occurs), reducing the benefits to fish that are thought to occur on floodplains. However, Sommer et al. 2001 found that in prolonged flooding periods (e.g. 1998 and 1999), the Yolo Bypass becomes highly productive, providing enhanced growth benefits for juvenile salmon. In this study, we examined how the flood pulse concept applies to the Yolo Bypass during both short duration (2016 and 2018) and prolonged flooding events (2017). We analyzed the prey community and diet contents of juvenile salmon and smelt (Oncorhynchus sp. and Hypomesus sp.) weekly, to understand the flood duration required to produce a flood pulse in the Yolo Bypass. Particularly for dipteran flies, it appears that short duration floods result in a truncated or less productive flood pulse, whereas prolonged flooding in the Yolo Bypass provides benefits for fish more characteristic of a natural floodplain.

Keywords: Yolo Bypass, prey community, juvenile fish diet, floodplain duration
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Isotope Tools to Track Floodplain Rearing of Native Fish

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Previous research shows that juvenile salmon and other native fishes that gain access to floodplains grow faster than those that remain in the river. This is due to a relatively productive food web created by a longer residence time of water, lower water velocities, and the decomposition of plant matter compared to the extremely channelized Sacramento River, California. Yet, little is known about how floodplain rearing may contribute to greater in-river or early ocean survival. Here, we test the feasibility of using sulfur isotopes in juvenile salmon eye lenses and/or otoliths to link the extent to which floodplains have population-level benefits to multiple salmon populations and other native fishes. We observed fish from the Yolo Bypass floodplain having isotopically light and distinct sulfur isotopes (34S/32S) in their prey content and muscle tissue. Juvenile salmon on the floodplain were depleted in 34S/32S (δ34S= -1.7±2.9,1999; δ34S=-1.67±1.1, 2016) in muscles relative to salmon collected in the Sacramento River (δ34S 4.3±4.7, 2012; δ34S=7.2±1.04, 2016), consistent with the trend in particulate organic matter between the two adjacent habitats. Microbial decomposition of plants (e.g., rice) fractionates sulfur isotopes which are incorporated into the invertebrate prey items of salmon, their muscle tissue, and permanently recorded in their eye lenses and otoliths. We apply this isotopic marker to identify floodplain reared fish that naturally recruited to the Yolo Bypass during floods in 2017 and estimate their duration of floodplain rearing.

Keywords: isotopes, floodplain, salmon, sulfur, yolo bypass, rearing habitat, eye lenses
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The Growing Science on Delta Aquatic Vegetation: Understanding Vegetation Effects on Habitat and Development of Areawide Management Strategies I

Operational Aquatic Invasive Plant Management in the Delta

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Aquatic invasive plant management in the California Sacramento-San Joaquin Delta (Delta), and its tributaries has been conducted since 1982 by the California Parks and Recreation Division of Boating and Waterways (DBW). Controlling aquatic invasive plants is challenging, but new and useful tools can improve efficiency and impact of the control program. This year, the program will utilize chemical, physical and biological control methods as a part of Integrated Pest Management (IPM) in the Delta, which is approximately 101,000 acres. New tools allow the program to have operational resiliency to changing field conditions. DBW targets nine invasive aquatic plant species including Eichhornia Crassipes and Egeria densa. Increased number of target invasive plants, trends in target plants and environmental conditions such as high or low water flow years have further emphasized the importance of adaptive management and a flexible toolset to control target invasive plants in the Delta due to constantly changing field conditions. Improvements to hydroacuostic mapping and the use of aerial imagery have aided the program and are seeing increased utilization due to adaptive management. Using aerial data provides valuable information for decisions made for the control of aquatic invasive plants in the Delta.

Keywords: Invasive
Delta
adaptive management
control
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Growth of Water Hyacinth, Brazilian Waterweed, and Curlyleaf Pondweed in the Delta

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The Delta is a 26,000hectare network of waterways that constitute the transition of the free-flowing Sacramento River and San Joaquin River to the brackish Suisun Bay. A freshwater tidal estuary, the Delta is a critical habitat for numerous freshwater and migratory species. The Delta has a diverse assemblage of native aquatic plant species, as well as several invasive aquatic plants. As part of ongoing aquatic plant management in the Delta, the seasonal growth of water hyacinth (Eichhornia crassipes (Mart.) Solms), Brazilian waterweed (Egeria densa Planch.), and curlyleaf pondweed (Potamogeton crispus L.) were studied. For each species, three separate sites were sampled monthly from May 2015 through December 2017. At each site, twelve biomass samples were taken with either a 0.1 m2 quadrat (floating plants) or a 0.023 m2 Eckman dredge (submersed plants). Air and water temperature were recorded continuously at 15 minute intervals using a Hobo temperature sonde. Samples were sorted to relevant plant parts, dried at 70C, and weighed to determine plant biomass. Waterhyacinth regrowth began in April-May of each year, and peaks in fall or early winter. Maximum biomass averaged almost 3,000 gDW m-2. Brazilian waterweed abundance reached a peak of over 400 gDW m-2, but typically did not vary greatly in abundance or in canopy height. Curlyleaf pondweed abundance reached 400 g DW m-2. While turion production was not synchronous between sites or years, turion sprouting was consistently occurring between late fall and late winter, with a peak in January. This provides a possible phenological event to target for management of this species. Water temperature is an important driver for plant growth of all three species. Low flow years tend to have more plant growth in part because of the earlier onset of adequate temperature for growth, and higher water temperatures throughout the growing season.

Keywords: Eichhornia crassipes, Egeria densa, Potamogeton crispus, phenology, aquatic macrophyte
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Using Remote Sensing to Assess of Growth and Distribution for Floating Invasive Plants and Growth Response Times to Altered Environments

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Management of aquatic weeds in complex watersheds and river systems present many challenges to assessment, planning and implementation of management practices for aquatic invasive plants. The Delta Region Areawide Aquatic Weed Project (DRAAWP), a USDA sponsored area-wide project, is working to enhance planning, decision-making and operational efficiency of invasive plant management in the California Sacramento-San Joaquin Delta. Satellite and airborne remote sensing are used to map area of plant coverage and estimate biomass density to aide operations and assess management impacts on plant communities. Modeling at local and watershed scales using the SWAT modeling tool provides insight into land-use effects on water quality. Environmental variability in the Delta occurs across a range of time scales from long-term climate and seasonal trends to short-term water flow mediated variations. Controlled environment growth studies have been conducted to quantify the growth response of invasive aquatic plants to water quality and other environmental factors. Response time for invasive species response are examined at time scales of weeks, day, and hours using a combination of study duration and growth assessment techniques to assess water quality, temperature (air and water), and light effects. These provide response parameters for plant growth models in response to environmental variation and interact with management and economic models associated with aquatic weed management. Plant growth models are to be informed by remote sensing and applied spatially across the Delta to balance location and type of aquatic plant, growth response to altered environments and phenology. Initial utilization of remote sensing tools developed for mapping of aquatic invasive plants improved operational efficiency in management practices. These assessment methods provide a comprehensive and quantitative view of aquatic invasive plant communities in the California Delta.

Keywords: Invasive aquatic plants, remote sensing, plant response to altered environments
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Implementation and Assessment of New Biological Control Tools for Water Hyacinth and Arundo in the Delta

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Water resources in the Sacramento-San Joaquin Delta are impacted by invasive aquatic and riparian plants that threaten water conveyance, access for recreation, and conservation. Floating water hyacinth, Eichhornia crassipes (Mart.) Solms., occupies over 1,000 ha, and the giant riparian grass arundo (Arundo donax L.) invades levees and wetlands. Biocontrol involves the release of insects that feed only on the targeted weed to reduce its survival, density, and spread. As part of the USDA-ARS Delta Region Areawide Aquatic Weed Project (DRAAWP), four insects are being released and evaluated for biocontrol of water hyacinth. Surveys of 16 Delta locations revealed that only one of three insects released in the early 1980s was established throughout the Delta: the leaf-chewing/crown-boring weevil Neochetina bruchi. Highest annual populations were observed in September. A closely-related weevil, Neochetina eichhorniae, was present on the Tuolumne River in the San Joaquin watershed. The third agent, the leaf and crown-boring moth Niphograpta albiguttalis, was not observed. A fourth agent, the leaf-sucking planthopper Megamelus scutellaris, has been released since 2012 and is present at one site each in the American and Merced River watersheds. The planthopper was released at 24 new Delta sites in 2018, with evidence of reproduction in the field. The moth N. albiguttalis was released at sites just upstream of the Delta. The weevil N. eichhorniae has been confirmed as host-specific and will be released in the near future. Prior feeding tests with Delta smelt and rainbow trout had demonstrated that these insects pose no hazard to listed fish. For biocontrol of arundo, two insects, a shoot-galling wasp, Tetramesa romana, and a shoot- and root-feeding armored scale, Rhizaspidiotus donacis, were released, and the armored scale is established. Biological control has the potential to improve weed control and aquatic ecosystem management in the Delta, providing opportunities for restoration.

Keywords: Water hyacinth, arundo, biological control, insect, invasive aquatic weed, assessment,
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Modeling Nitrogen Export from Sacramento and San Joaquin River Basins to Bay Delta Estuary: Current Status, Ecological Implications, and Possible Mitigation Strategies

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Bay Delta Estuary and its waterways have recently been infested by invasive aquatic weeds, which impede water flow, impair commercial navigation and recreational activities, degrade water quality, and alter animal community interactions. Nitrogen loadings exported from upstream watersheds, which have intense agricultural activities are deemed as one important abiotic factor to facilitate the rapid growth of invasive aquatic plants. Therefore, quantifying the nitrogen loadings entering the bay, understanding its seasonal patterns, and exploring relative N contribution of different landuse types in upstream watersheds are quite critical for designing appropriate watershed management plans to reduce nitrogen runoff and in turn constrain the booming of invasive aquatic weeds in Bay-Delta waterways. To address all these concerns, this study aims to model nitrogen fate and transport from Sacramento and San Joaquin River basin to the Bay-Delta Estuary via Soil and Water Assessment Tool (SWAT) model, under the support of the USDA-ARS Delta Region Area-Wide Aquatic Weed Project (DRAAWP). Calibrated SWAT models with proper flow transport modules (Tile drain in San Joaquin, and flood conveyances in Sacramento River basins) are employed to reconstruct the historical daily continuous N exports from the entire upstream river basins, which are then linked with downstream plant growth model to investigate the effect of current nitrogen status on weed growth. Relative N contribution of different landuse types inside the watershed will also be investigated, so high nitrogen yield places can be identified. Different Best Management Practices (BMPs) are then applied in high nitrogen yield places via SWAT simulations to explore their effect in reducing nitrogen runoff, and corresponding mitigation on weed growth in downstream waterways.

Keywords: SWAT, Nitrogen modeling, Sacramento River Basin, San Joaquin River Basin
Session Title: The Growing Science on Delta Aquatic Vegetation: Understanding Vegetation Effects on Habitat and Development of Areawide Management Strategies I
Session Time: Tuesday, September 11th, 1:35 PM - 3:15 PM, Room 311-313

Altered Nutrient Inputs to the Bay-Delta: Anticipating the Effects of the Sacramento Regional Wastewater Treatment Plant Upgrade

The EchoWater Project: Upgrades to the Sacramento Regional Wastewater Treatment Plant

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Regional San serves more than 1.4 million people throughout the region and is responsible for treating wastewater at the Sacramento Regional Wastewater Treatment Plant (SRWTP) near Elk Grove. The treated wastewater is discharged into the Sacramento River near Freeport. SRWTP was built in the late 1970s and became fully operational in 1982. In 2010, new water quality regulations issued by the State required new wastewater treatment processes, including biological nutrient removal, filtration, additional disinfection, and more. The upgrade for nutrient removal and reduction of ammonia (nitrification and denitrification) must be completed by May 2021, and new filtration and disinfection capabilities must be completed by May 2023. Our effluent limit for ammonium (NH4-N) will change from 47 mg-N/L year-round to 1.7 mg-N/L from April to October, and 3 mg-N/L from November to March. Due to the conversion of ammonium to nitrate, our effluent nitrate (NO3) concentration will increase from <1 mg-N/L to a limit of 10 mg-N/L. Based on the typical current—and anticipated future—performance of the treatment plant, we anticipate there will be a > 65% reduction in our total inorganic-N load to the Sacramento River. The EchoWater Project will also substantially increase water recycling opportunities by producing highly treated water that meets Title 22 water reuse standards. The EchoWater Project is the largest public works project in Sacramento's history, with 20 separate construction projects and numerous construction contractors on site through 2023. The total cost is estimated between $1.5 and $2.1 billion. To fund it, customer rates are expected to gradually increase annually to the high $30s per month by 2023. The project was approved to receive nearly $1.6 billion in low-interest financing from the State of California's Clean Water State Revolving Fund, which will save ratepayers more than a half billion dollars in interest costs.

Keywords: water quality, wastewater, water treatment, infrastructure, nutrients, ammonia, Sacramento River
Session Title: Altered Nutrient Inputs to the Bay-Delta: Anticipating the Effects of the Sacramento Regional Wastewater Treatment Plant Upgrade
Session Time: Tuesday, September 11th, 1:35 PM - 3:15 PM, Room 314

Changing Nitrogen Loads to the Northern San Francisco Estuary: Framework for Identifying Science Opportunities and Constraints

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Anthropogenic activities have resulted in elevated ambient concentrations of nitrogen (N) and phosphorus (P) in many regions of the Sacramento/San Joaquin Delta and northern San Francisco Bay (Bay-Delta). While, in general, the Bay-Delta does not experience some of the classic symptoms of nutrient over-enrichment -- e.g., large phytoplankton blooms and hypoxia -- other nutrient-related impacts have been hypothesized, including: excessive growth of invasive aquatic vegetation; harmful algal blooms (HABs); and other impacts on phytoplankton-related primary production. By 2021, nitrogen loads to the Bay-Delta will decrease substantially due to upgrades to the Sacramento regional wastewater treatment plant (Regional San), currently one of the Bay-Delta's largest N sources. The upgrade is expected to cut Regional San's total N loads by >65% and shift the predominant form of N in its effluent from NH_4^+ to nitrate (NO_3^-). This large change in nutrient inputs provides a unique opportunity to study ecosystem-scale responses in the Bay-Delta to an altered nutrient regime. This presentation will describe a conceptual framework, under development by a multidisciplinary team of Bay-Delta scientists, for identifying anticipated changes to ambient nutrient concentrations and potential ecosystem responses to the altered nutrient regime. The project's primary goal is to inform planning for monitoring and special studies, pre-and post-upgrade, that will help maximize what we can learn from this substantial decrease in nutrient inputs, both to inform adaptive management of Bay-Delta ecosystem health, and contribute to deepened fundamental understanding of nutrient dynamics.

Keywords: nutrients, nitrogen
Session Title: Altered Nutrient Inputs to the Bay-Delta: Anticipating the Effects of the Sacramento Regional Wastewater Treatment Plant Upgrade
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Tracing the Fate and Effects of Effluent-Derived Nutrients to the Bay-Delta using Stable Isotopes: Establishment of Pre-Upgrade Baseline Conditions to Facilitate our Understanding of Post-Upgrade Food-Web Changes

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Planned upgrades to the Sacramento Regional wastewater treatment plant (WWTP) starting in 2019 will reduce total N inputs and shift the dominant form of N entering the Delta from NH4 to NO3, greatly reducing the extent of nitrification of NH4. The upgrades are expected to affect aquatic ecosystems and water quality in unknown ways. Our ability to predict the effects of the changes is limited by our understanding of the fate and cycling of the WWTP-derived effluent. Since different sources of nutrients and/or processes often have distinctive isotope “fingerprints” that can provide a better understanding of the system than just chemical data, a multi-isotope approach has proved useful for tracing spatial and temporal changes in sources of nutrients, biogeochemical processes, and linkages between nutrients and algae in this ecosystem. Current efforts are focused on completing the analysis and interpretation of archived isotope samples collected at dozens of sites in the Delta 2006-2017, including samples collected during 11 of the 12 falls 2006-2017 and 10 of the 11 spring/summers 2007-2017. This dataset provides a detailed characterization of the impact of pre-upgrade effluent on sites during a wide range of hydrological conditions. Since nitrification of effluent is responsible for the isotopic-labeling of residual effluent NH4 and the resulting newNO3, isotopes are expected to be powerful and reliable tools for distinguishing between the effects of pre-upgrade and post-upgrade nutrients and other effluent-related inputs on aquatic food webs once nitrification is greatly reduced. We will present our current perspectives on the relative merits of various isotope tools for tracing pre- and post-upgrade conditions in the ecosystem. Thetimely evaluation of the success of various isotope and other tools for assessing temporal and spatial variations in the linkages between nutrients and algae, will permit appropriate monitoring to begin as the WWTP upgrade starts.

Keywords: nutrients, effluent, isotopes, food webs, WWTP, upgrade, algae
Session Title: Altered Nutrient Inputs to the Bay-Delta: Anticipating the Effects of the Sacramento Regional Wastewater Treatment Plant Upgrade
Session Time: Tuesday, September 11th, 1:35 PM - 3:15 PM, Room 314

Measuring Biogeochemical Rates Affecting Nitrogen Concentrations in a Hydrodynamically Complex Delta

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The concentration, form, fate and thus effects of many nutrients in aquatic systems is largely determined by biogeochemical processes. Quantifying the rate at which these processes occur and the relationship of environmental drivers (e.g., salinity, turbidity, sediment properties, plant biomass, etc.) to those rates, is needed to build, calibrate, and validate models across space and time. Reliable modeling of nutrient concentrations in aquatic systems enables managers to run scenario testing and improves ecological forecasting. While measurements made under controlled laboratory conditions can provide a fundamental understanding of biogeochemical processes and rates, they can frequently diverge from environmental rates. Field measurements of biogeochemical rates in tidal, hydrologically complex systems like the Delta adds an additional layer of complexity because nutrient concentrations can also be altered through mixing. This is the case for nitrogen, which is present in many forms (e.g., nitrate, ammonium, dissolved organic nitrogen, particulate organic nitrogen, nitrogen gas), occurs in different ecosystem compartments (water, sediment, live and dead biomass, atmosphere), and is associated with diverse sources such wastewater, agriculture, and urban inputs. Interest in nitrogen cycling within the Delta is particularly relevant because there will be a large reduction in nitrogen inputs when Sacramento's regional wastewater treatment plant is upgraded in 2021. We will present results from several field approaches we are using to measure biogeochemical rates related to nitrogen cycling. The approaches include: using paired, high frequency fixed station measurements to quantify changes in nitrate concentration between two locations and estimate nitrification rates; mapping nutrient concentrations concurrent with water age to calculate net ecosystem uptake of nitrate, ammonium and dissolved organic nitrogen; measuring changes in nitrogen concentrations using benthic and water column chambers; and collecting high resolution vertical profiles of nutrient concentrations to examine the effects of aquatic vegetation on nitrogen concentration and form.

Keywords: biogeochemistry, nutrients, nitrogen, rates, water quality,
Session Title: Altered Nutrient Inputs to the Bay-Delta: Anticipating the Effects of the Sacramento Regional Wastewater Treatment Plant Upgrade
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Continuous Simultaneous Measurement of Phytoplankton Taxonomy and Nutrient Concentrations in the San Francisco Estuary to Evaluate the Effects of Wastewater-Derived Nutrients on Phytoplankton Community Structure

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One potential outcome of lowered ammonium concentrations in the Delta resulting from the Sacramento regional wastewater treatment plant upgrade scheduled for 2021 is a shift in the phytoplankton community structure to taxa more amenable to support pelagic food webs. However, most historical information about phytoplankton abundance and community structure in the Delta has been gleaned from monthly sampling at fixed locations, and it is broadly recognized that the abundance of phytoplankton species – and nutrient concentrations and forms – often varies over short temporal and spatial scales, and that multiple drivers besides nutrients play a role. This makes it difficult to make conclusive statements about ecosystem responses to a change in nutrients. Here we discuss results from using a commercially available instrument designed to continuously quantify major algal taxa in situ, based on fluorometric quantification of primary and accessory pigments. First, we will show how well the instrument compares to laboratory measurements made on grab samples (e.g., chlorophyll-a and phycocyanin concentrations, phytoplankton enumeration and HPLC pigments). We will also show how data from high-frequency (15-min) monitoring of algal pigments, nutrients (nitrate, ammonium and orthophosphate) and ancillary water quality at a fixed station can provide insights into drivers of phytoplankton abundance and community structure. We will also show how high-speed (5 to >10 m s−1) boat mapping at high sampling frequencies (1 Hz) can provide additional insights into drivers of phytoplankton, help us resolve differences attributable to mixing of different water sources, while also allowing us to calculate biogeochemical rates (e.g., phytoplankton uptake) and explore the complex linkages among time-dependent hydrologic and biogeochemical processes in the Delta.

Keywords: algal pigments, composition, foodwebs, nutrient forms and ratios
Session Title: Altered Nutrient Inputs to the Bay-Delta: Anticipating the Effects of the Sacramento Regional Wastewater Treatment Plant Upgrade
Session Time: Tuesday, September 11th, 1:35 PM - 3:15 PM, Room 314

What Difference Does it Make? The practice of Art and Ecology in Collaboration

Historical Perspectives and Present Collaborations of the Art and Ecology Partnership

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Throughout history, art and ecology have merged together to compliment and contradict one another. The environmental artist movement in the 60's was about relating to nature, however, works created with that motivation, did not necessarily live in harmony with their environment. This session explores the evolution of the art and ecology movement, its various movements and forms that have taken place in the last 60 years. IT explores the current movement of ecological art, which integrates the deeper understanding of landscape to evolve a project. It asks the question, is there more to the collaboration of science and art than making something intellectual, beautiful or graphically presentable? How can present day ecological artist be integrated into projects to improve the success of an ecological restoration project, and what does that success look like? This will include examples from a recent redesign of Bxybee Park, and Emily Renzel Wetlands in the San Francisco Bay Area.

Keywords: art ecology collaboration history
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Documenting Ecosystems: Soundscapes and Percussion

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Musicians, composers, and artists have valuable insight and perspective to contribute to ecological research, conservation and restoration efforts. The fields of soundscape ecology and acoustic ecology have begun to even the playing field so that sonic variables get as much attention as do studies based on visual data. We can create an even more fruitful platform for sound studies by creating opportunities for musicians and sound artists to collaborate with ecologists. It is bound to be mutually beneficial to ecologists and artists/musicians, and offer a more holistic and fresh view that is necessary when considering all-encompassing climate issues. Not only is there potential for fresh perspectives during research, but results and information could be presented to a much wider audience through a combination of both traditional scientific and arts and music infrastructures. I am a musician, composer and percussionist with a background in ecology and entomology, and my work lies in the intersection of these fields.I have studied topics such as the endangered Hylaeus Hawaiian bees, logging in national forests, and ants and climate change in Brazil, and have used music, writing and art in order to bring attention to these important environmental topics. My work has been presented in multiple albums of music and in the books "The Hylaeus Project: The Endangered Hawaiian Hylaeus Bees" and "FieldGuided". I will present information on the goals, techniques, and results of my work, and describe the programs, funding organizations, non-profit organizations, and artist residencies that have provided opportunities for my work to be carried out.

Keywords: percussion, soundscapes, collaboration, interdisciplinary, art, music, drums, acoustic ecology, entomology
Session Title: What Difference Does it Make? The practice of Art and Ecology in Collaboration
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Creek College - A Project Bridging the Arts and Ecological Restoration

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Creek College is a project that was founded on these questions; what can the arts do to make the broadest impact in aiding restoration efforts? We wondered, can a poem benefit a creek? How can art practices bring attention to the needs of a particular environment?

Creek College is a project bridging art and environmental conservation. We offer a range of art classes and experiences in exchange for activities that aid in the restoration of watersheds suffering from environmental degradation.Analternative approach to traditional education models, it aims to generate collaborative engagement and to create a platform for challenging conversations surrounding the state of our environment.

The project strives to discover some of the inherent healing aspects to exploring/finding nature through art—physically, psychologically, spiritually. Art allows us to explore the horrific, beautiful, peaceful, threatening, in observation or through the creative process. Therefore art has a certainpotential that perhaps traditional environmental education lacks.

The project works like this;We choose a body of water at a given location and invite artists to submit proposals to teach there (literally there! on the creek).

There is no monetary exchange for participating.Instead, each class is paired with a restoration barter activity. The needs of each site dictate the restoration activity, and are determined by the watershed council or organization overseeing the site.The classes are dependent on the interests of each artist. Past classes have included; sculpture, written word, graphic design, sound, dance, and more experiential offerings.

This talk will examine collaborations between artists and ecologists, and their relationships to thesites that host Creek College. It will reflect on successes and failures that have aided the project in its development.

Keywords: art, collaboration, social practice, creek college, ecological restoration
Session Title: What Difference Does it Make? The practice of Art and Ecology in Collaboration
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Translating the Animal

Melody Owen, Artist - represented by Elizabeth Leach Gallery in Portland, Oregon - http://melodyowen.net, info@melodyowen.net

Perception is at the heart of reality. I am interested in perceived divides and intersections between humans, nature and technology. My current artistic research is on animal communication and perception, on the notion of the Umwelt (the individual embodied experience), as well as the interconnectedness of everything. We are loosing species and ecosystems at an alarming rate. For this reason, I believe disciplinary lines must be crossed. Artistic thinkers are of value to scientists, not only to illustrate their research but also to challenge and expand ways of thinking about the natural world. Inspiration, insight and peer review are common to both practices and with some effort, each mode of research has great potential to enrich the other. In light of the environmental crisis we face, it is time to not just think outside the box but to dismantle the box and use the parts to build something new... perhaps a platform where we can meet and work on common goals. I will present my thesis work for my masters degree in environmental humanities. It is about the trifecta of human/animal/digital and how artists translate or explore the animal as entity through artistic mediums such as installation, animation and sound.

Keywords: animal, digital, art, empathy, extinction
Session Title: What Difference Does it Make? The practice of Art and Ecology in Collaboration
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Ecological Imagination as a Tool for the Future

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As a sculptor practicing in the field of art, landscape, architecture and design, the tool of imagination has created works the reveal the truth of the impact of the past on the present landscape. In this session, Elise Brewster will share her experiences as a founding instigator and lead researcher for the Historical Ecology Program of the San Francisco Estuary Institute in providing regional science to shape planning and restoration. She will share how she helped to shape other's imagination of their local landscape throughart/science collaboration called STILLHERE to reveal the forgotten landscapes of the San Francisco Bay Area. She will describe how she developed expertise in solar site development having worked on the largest solar development [at its time] in Bavaria Germany with Landscape Architect Helmut Wartner. Then with Wartner , and Paul Kephart, RANA CREEK, she inspired the Light on Land approach for solar fields and tested this approach in the Carisso Plains: the largest field in the US, and other sites.

Elise has designed and built installations in Israel, Africa, Japan and Europe. Most recently, she was the Tinshop Artist in Residence: Breckenridge Colorado, where she created Blue River etched drinking glasses for the Breckenridge Water Division, illustrating the towns water supply. Her drawings, paintings and sculptures are in numerous private and public collections and publications. She is currently working on a film called THE BOATRIGHT about a woman re-generating a 47' wooden sloop, dreaming of sailing into a resurrected ocean.

Keywords: boatright art sculptor
Session Title: What Difference Does it Make? The practice of Art and Ecology in Collaboration
Session Time: Tuesday, September 11th, 1:35 PM - 3:15 PM, Room 315

Modelers at the Crossroads

Spatially distributed Bayesian uncertainty analysis to improve trash reduction tracking

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Trash is a pervasive environmental problem with readily apparent environmental impacts that are closely related to runoff from urban areas. Stormwater managers are increasingly being required to provide an objective, quantitative basis to justify decisions for how to mitigate the impacts of urban runoff. Recently, the California State Water Board issued aggressive municipal trash reduction requirements, mandating the elimination of trash inputs to waterways within the next decade. Communities must demonstrate compliance via a standardized set of visual observations for areas not covered by full capture devices. Currently, there are no systems in place to efficiently translate these visual observations into spatial metrics that can be used for robust quantification of progress towards the zero trash goal. In response to this technology gap, we've developed a trash compliance reporting system that that includes mobile apps for field data collection and a web-based interface for spatial data processing, analysis, and progress reporting. With very few trash assessment data available, there is not a sound basis for determining sampling requirements or levels of confidence associated with trash condition. A Bayesian statistical approach provides a practical means to quantify spatial patterns of uncertainty in trash assessments that is tied to the observed variability of trash accumulation at specific locations. It allows trash compliance to include quantifiable degrees of certainty, even when very few data are available, and municipal resources to be focused on areas with persistent trash problems. The trash compliance system is integrated with a stormwater modeling platform designed to efficiently satisfy NPDES permit requirements (https://www.2nform.com). Through examples in several Central Coast communities, we illustrate the value of integrated mobile data capture and science-based analytics to improve understanding of trash accumulation patterns. Also, we demonstrate the appropriateness of a Bayesian statistical framework and uncertainty quantification to improve action prioritization.

Keywords: trash, stormwater, urban , runoff, modeling, bayesian
Session Title: Modelers at the Crossroads
Session Time: Tuesday, September 11th, 3:35 PM - 5:15 PM, Room 306

Modeling Economics in the Sacramento-Sacramento San Joaquin Delta

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The Sacramento-San Joaquin Delta (SSJD) supports about half a million acres of irrigated agriculture, mostly in its primary zone, providing most of the employment and income in this agricultural subregion. In contrast, the secondary zone supports most non-agricultural sectors, which represent more than 95 percent of the employment and income in the Legal Delta. This complex system affected by multiple ecosystem stressors and man-made alterations may face some challenges to support agriculture and other sectors. These may have an impact on the socioeconomic structure of the SSJD and constitute the central issue in this presentation. A compilation of recent economic analysis case studies for the SSJD is presented including agricultural and non-agricultural economic sectors, and ecosystems management. Findings indicated that vulnerabilities that while vulnerabilities for agriculture exist, these are more related to flood than to water quality. Opportunities in recreation and non-agricultural sectors are also discussed. Case studies outlay potential transitions in the SSJD economy as it balances economic and environmental objectives using as systems analysis approach. The framework presented provides a basis for quantifying economic tradeoffs between ecosystem management and economic development and aid in policy making.

Keywords: Economic tradeoffs, Sacramento-San Joaquin Delta, ecosystems management, agriculture, development
Session Title: Modelers at the Crossroads
Session Time: Tuesday, September 11th, 3:35 PM - 5:15 PM, Room 306

Recommendations for a Modeling Framework to Answer Nutrient Management Questions in the Sacramento-San Joaquin Delta: Modeling Science Workgroup White Paper

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Management actions in the Delta related to nutrients could cost billions of dollars to implement in the coming decades depending on decisions that will come before the Central Valley Regional Water Quality Control Board (Water Board). The complexity of the Delta ecosystem and the range of questions to be addressed demand that numerical, processed-based water quality modeling be part of Delta management efforts. In 2015 the Water Board convened the Modeling Science Workgroup to advise the development and use of water quality models as one component of the Water Board's Nutrient Research Plan. The Charge to the Modeling Science Workgroup was to provide advice to the Water Board on types of models needed, modeling organization and approach, and cost. Key findings included that comprehensive numerical models are necessary to address research and management questions, multiple models will be necessary to address spatial and temporal variability of various processes, data requirements (monitoring and data management) are critical to supporting modeling activities, and an overall framework or governance structure to guide the process and make decisions regarding best allocation of resources will be necessary for successful implementation. Further, a multi—disciplinary team of chemists, biologists, hydrologists, engineers, statisticians, and other relevant scientists is needed to develop conceptual models and evaluate numerical model output in light of the body of scientific knowledge about the Delta.

Keywords: Water Quality, Model, Delta, multi—disciplinary, numerical
Session Title: Modelers at the Crossroads
Session Time: Tuesday, September 11th, 3:35 PM - 5:15 PM, Room 306

Development of Stage-Frequency Curves in the Sacramento – San Joaquin Delta for Climate Change and Sea Level Rise

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Future changes in hydrologic patterns and sea level rise will impact water levels in the Sacramento-San Joaquin Delta, the hub of California's water supply system and an important ecosystem and agricultural area. An important tool for flood management is stage-frequency curves which indicate how often certain water levels (or stage) occur.

The Delta poses inherent complexity in the determination of stage-frequency and requires a number of considerations. One needs to account for river flows coming into the Delta, as well as the effect of tides from the Delta's connection to the ocean through San Francisco Bay. During storms, Delta water levels are also affected by tidal surge from the advancing storm fronts coming from the Pacific Ocean. Under climate change, Delta water levels will also be affected by rising sea levels and expected changes in hydrology such as shifts in timing and amount of precipitation and runoff and changes in how much of our precipitation falls as rain or snow (referred to as climate change hydrology in this paper).

With these taken into consideration, this study lays out the assumption and methodology to develop stage-frequency curves in the Sacramento-San Joaquin Delta for three different conditions; one for current hydrology conditions, one for current hydrology with sea level rise and one for mid-century climate change hydrology with sea level rise. In addition, water surface elevation profiles along the Sacramento and San Joaquin rivers for various magnitudes of flood events were compared to the top of levee elevations.

Both the stage-frequency curves and the water surface elevation profiles comparisons to top of levee elevations provide valuable information to water resources planners and was applied to inform life and flood risk analysis for the Delta in the 2017 Central Valley Flood Protection Plan Update.

Keywords: Flood, climate change, sea level rise, stage-frequency curves, 2017CVFPP, California
Session Title: Modelers at the Crossroads
Session Time: Tuesday, September 11th, 3:35 PM - 5:15 PM, Room 306

The Importance of Engaging Cross-Disciplines in Modeling and the Role of CWEMF

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Long term sustainability of the Bay-Delta system and areas affected presents many challenges, with no easy answers or straightforward solutions. Studies and assessments of metrics, measurable objectives, uncertainty, risks, and system resiliency, are necessary in the on-going search for potential alternatives and long-term solutions. It requires more scientific dialogue and cooperative efforts across lines defining both disciplines and sectors. Science based modeling is an indispensable tool in this effort, often requiring different levels of educational background, training, and expertise. Yet few can claim proficiency in disciplines outside their own. This often leads to participants belonging to separate groups with their own studies, organizations, and conferences. More cross-discipline coordination between scientists, stakeholder, and organizations can go a long way in achieving common goals to address problems and solutions of the Bay-Delta system. The California Water and Environmental Modeling Forum CWEMF just held its 24th annual meeting of bringing together modelers to share their efforts in addressing California's complex water and environmental systems. Yet there is a noticeable lack of participation by members from the biological, fisheries, and ecosystem sectors. This presentation will review CWEMF's history, mission, accomplishments, explore the variety of disciplines and their focus on selected programs, and then suggest ways to facilitate more cross-discipline informational and technical discussions towards achieving long term solutions.

Part of Session: Modelers at the Crossroads

Keywords: CWEMF, Sustainability, Modeling, Cross-Disciplines, Coordination
Session Title: Modelers at the Crossroads
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Managing Land for Humans and Wildlife

Exploring the Human Dimension of Suisun Marsh: Implications for Waterfowl and Wetland Habitat Management

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The Suisun Marsh Plan calls for the restoration of up to 7,000 acres of tidal marsh and the enhancement of more than 40,000 acres of managed wetlands over a 30-year period, while maintaining the heritage of waterfowl hunting and other recreational opportunities, and increasing the surrounding communities' awareness of the ecological values of Suisun Marsh.

Complex management objectives like these require careful decision-making and communication strategies that are sustainable over time and maintain stakeholder and resource user support. By developing comprehensive information on how people use Suisun Marsh, what they value, and how they participate in conservation practices, resource management agencies can better develop, implement, and evaluate restoration opportunities and management programs that contribute to maintaining or increasing participation in waterfowl hunting and recreational opportunities, and promote public education and support for waterfowl and wetland habitat management.

To evaluate opportunities, a mixed methods research approach was implemented that included in-person interviews of Suisun Marsh representatives and users, secondary data content analysis, and over 2,400 multi-modal surveys with statewide waterfowl hunters, Suisun Marsh users and Suisun Marsh landowners and duck club members. Factors such as waterfowl hunting heritage, user preferences, recreation satisfaction, barriers to implementation of conservation practices on private land, agency image, and demographics were explored.

The findings of the research have broad implications for the implementation of the Suisun Marsh Plan that could inform future conservation decisions and support further development of multi-stakeholder approaches for the restoration of tidal wetlands and the management of managed wetlands in Suisun Marsh. Recommendations for conducing further research, considering Suisun Marsh user preferences, values and behaviors during the implementation of the Suisun Marsh Plan, and enhancing communication and engagement of various Suisun Marsh user groups are provided.

Keywords: human dimensions, waterfowl hunting heritage, recreation, environmental values, wetland management
Session Title: Managing Land for Humans and Wildlife
Session Time: Tuesday, September 11th, 3:35 PM - 5:15 PM, Room 307

Incorporating Nature-Based Adaptation Strategies into Shoreline Planning in Marin County

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The County of Marin has recently completed a vulnerability study along its Bay shoreline that identifies places and people at risk from rising seas. As the program moves into its adaptation and resilience phase, the next logical step is to identify strategies, particularly those including “living shorelines” or “nature-based” techniques to reduce exposure to flooding and erosion hazards and to increase the resilience of the shoreline. Together with Point Blue Conservation Science and the San Francisco Estuary Institute, the County of Marin is developing a framework to identify, evaluate and prioritize nature-based climate adaptation strategies, ensuring decision-makers can maximize benefits to the public and ecosystem using the best available science. The effort leverages SFEI’s bay-wide Operational Landscape Unit framework. It is an on-the-ground test case for planning using nature’s jurisdictions, with the intent that the framework developed will be applicable around the entire bay and beyond. Lastly, the project will provide a framework for understanding the broader suite of benefits and potential trade-offs that go beyond the cost of construction for different adaptation strategies, which is a critical need in transitioning from community vulnerability assessment to action.

Keywords: nature-based, adaptation, shoreline, climate, sea level rise, planning, ecosystem services
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Agriculture, Subsidence and Carbon in the Sacramento-San Joaquin Delta

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Draining Delta lands for agriculture exposed the organic soils to oxidation, the primary cause of subsidence. Since the late 1800s, more than 2.4 billion m3 of organic soils have disappeared, lowering island surfaces to as much as 8 m below sea level. This has increased the risk of levee failure and threatens the State's water supply system. At the same time oxidation of the peat soils results in substantial greenhouse gas (GHG) emissions.

Restoring wetlands and/or converting traditional crops to rice on drained Delta organic soils provides a GHG benefit, mitigates subsidence, and reduces risk to levees. GHG fluxes have been monitored on both current crops and restored wetlands, and data were used to build models able to predict GHG emission and emission reduction resulting from restoring wetlands and rice. Changes in soil elevation have been monitored before and after wetland restoration. The recent approval of a new carbon protocol Restoration of California Deltaic and Coastal Wetlands enables access to long-term carbon revenue. Delta landowners are making progress towards the application of the protocol.

We report on Delta land-owner progress in engaging the carbon protocol and how the conversion to wetlands and rice can improve GHG budgets, subsidence, and economy in the Delta. Over 12,000 acres have been listed with American Carbon Registry for potential participation in the carbon market and we are moving forward with verifying and validating emissions reductions for over 1,700 acres of wetlands on western Delta islands. Our analysis indicates that mosaics of carbon-sequestration wetlands, rice,and other alternate land uses on Delta islands can provide revenue commensurate with current land uses

Keywords: GHG mitigation, carbon, wetlands, carbon market, subsidence, rice, protocol, restoration,
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Land Evaluation and Site Assessment (LESA) in the Cache Slough Complex Region of the Sacramento-San Joaquin Delta, California

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The Cache Slough Complex watershed lies in the northwest quadrant of the Sacramento-San Joaquin Delta. The Delta landscape is at the center of California's water conflicts and the region embodies competing values of water use for agriculture, wildlife habitat, and urban development. Because of its lack of urban development, the Cache Slough Complex is the focus of competition for land between and among flood protection, ecosystem restoration, and agricultural uses. The value of the land for agriculture has not been well understood, nor is it adequately reflected by Prime Farmland or similar designations.

Agricultural activities dominate land use in the Cache Slough Complex, and include the production of food and forage crops and livestock grazing. A Land Evaluation and Site Assessment (LESA) system was developed for the Cache Slough Complex to better inform County and State land use planning processes that may impact agriculture in the region. The factors that comprise the LESA system are developed by local stakeholders to measure suitability of parcels for agricultural use in a specific geographic area. Typically, LESA models address the threat of urban development to agriculture; in this case the project is responding to a somewhat novel threat.

The Cache Slough Complex LESA was developed through a stakeholder-driven process with guidance from technical experts; the process was facilitated in a manner so that intersecting, divergent issues were discussed and tradeoffs were informed by a shared understanding between local and technical communities. The Geographic Information Systems (GIS) tool development was integrated into the project design from inception. The project resulted in a shareable, updatable GIS tool to evaluate projects that convert agricultural lands to other uses, a clear understanding of the value of agriculture to the local economy and agricultural system, and a way to inform ecosystem restoration and flood planning efforts currently underway.

Keywords: land use, planning, ecosystem restoration, agriculture, sustainability, modeling, GIS, habitat
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Trends in Cropping Patterns and Economic Impacts in Delta Agriculture

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Agriculture is the economic foundation of the Delta communities, and this paper will describe how the composition and contribution of Delta agriculture has changed over the past decade and look forward to how it might continue to evolve over the next decade. Primarily utilizing field-level time-series data on cropping patterns from pesticide use data, we estimate the economic impact of Delta agriculture and related food and beverage processing sectors and use maps to illustrate changes in cropping patterns from 2001 to 2016.

Preliminary results show Delta farming revenue grew about 25% between 2009 and 2016, and now exceeds $1 billion. Delta farming directly and indirectly supports about 13,000 jobs in the 5-Delta counties, and about 23,000 jobs across California when including closely linked processing sectors such as wineries. Delta wine grapes are about 5% of total state wine grape production, but the local economic impact of this production has increased as wineries have expanded in and nearby the Delta.

Since 2009, wine grapes have surpassed processing tomatoes as the highest value Delta crop, while alfalfa has replaced corn as the leader in acres. In addition to wine grapes, acreage increases of more than 3,000 acres are seen in almonds, safflower, potatoes, rice and wheat. Since 2009, there has been a large decrease in corn acreage, as well as significant declines in alfalfa and asparagus. These changes are mostly due to economic factors, but environmental change could also play a role. We close with a discussion of what these trends mean for the future of Delta agriculture, and their implication for future economic and environmental change in the region.

Keywords: agriculture, economic impact, cropping patterns
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Fish and Flood in the Central Valley II

Movement and Migratory Behavior of Acoustically-Tagged Adult Chinook Salmon in the Yolo Bypass in Wet and Dry Years, 2013-2017

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The ecological success of a migratory species may vary with life stage, migratory route, and response to passage barriers. We investigated the movement behavior of Chinook Salmon in different water year types in the Yolo Bypass, an intensely altered seasonal floodplain in the Sacramento-San Joaquin Delta of California. Chinook Salmon (Oncorhyncus tshawytscha) navigate the floodplain during their spawning migrations each year, although the Yolo Bypass migratory corridor is only connected to spawning habitat in the Sacramento River when the river reaches stages greater than 9.8 m (32 ft NADV88) and overtops Fremont Weir in the Yolo Bypass. Fish that enter the Yolo Bypass in drier years, when the weir is not overtopping, must exit the Bypass at its southern end and continue up an alternative suitable migratory corridor if they are to spawn successfully. Understanding how these animals move through their environment under different hydrological conditions is thus a fundamental part of determining how the migratory landscape is best conserved, managed, or reconciled. This presentation synthesizes five years of data from acoustically-tagged adult Chinook Salmon migrants in the Yolo Bypass and contrasts their movement behavior and indices of migratory success between wet and dry years in the Delta, including residence time, behavior around barriers to passage, movement rates, milling behavior, and detection at spawning grounds in Putah Creek and the Sacramento River.

Keywords: Chinook, migration, behavior, spawning, telemetry, Bayesian
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Evaluating floodplain benefits to juvenile salmonids using long-term monitoring data on the lower Mokelumne River

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Over a decade of reach scale habitat restoration on the LMR has reconnected several acres of seasonal floodplain habitat for juvenile salmonid rearing. Although the physical and biological benefits of these specific project areas have been well documented, the benefits at a population scale are often difficult to detect. Additionally, levee failures have created incidental floodplain inundation. In this presentation, we utilize over twenty years of fisheries and hydrologic monitoring data to evaluate the population scale trends of juvenile Chinook salmon in relationship to the frequency and duration of floodplain inundation on the LMR. Floodplain area to discharge relationships and variations in gaged and in-situ temperature are used to describe patterns of juvenile salmon outmigration timing, weekly abundance, size and condition, and life stage specific migration. In addition, we use long-term juvenile fish community data to examine potential changes in spatial and temporal utilization of rearing habitats along the LMR.

Keywords: salmonids, floodplain, monitoring
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Nursery, Migration Corridor, and Refugia: Twenty Years of Rotary Screw Trap Sampling in the Yolo Bypass

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A seasonal floodplain is one of the most variable and diverse habitats to be found in an estuary. Tidal slough and off-channel habitat can be fully inundated during flood season, and such inundation can vary by amplitude, frequency, timing, and duration across the landscape. Here we examine the environmental factors that structure juvenile fish communities in the Yolo Bypass, primary floodplain of the Sacramento River in California's Central Valley, using twenty years of data collected from our rotary screw trap at the Yolo Bypass Toe Drain. Generally, we found greater numbers of native fish species in flood years; however, the timing of catch and types of floodplain inundation these fishes are associated with vary by species. Juvenile Sacramento Pikeminnow and Sacramento Sucker are typically observed in March and April, respectively, in years when Sacramento River water overtops into the Yolo Bypass in early Spring. Juvenile Sacramento Blackfish are observed between May and July, but only in years when there is overtopping into the Yolo Bypass in late spring (April-May). Meanwhile, Splittail and Chinook Salmon are observed every year but are more abundant in wetter years. Although overall catch numbers are typically lower in drier years, we have also observed relatively high numbers of Delta Smelt during the recent severe drought of 2012-2015. This indicates that Delta Smelt can use dead-end tidal slough such as the Yolo Bypass Toe Drain and that the north Delta region may act as a refuge for the species during less than ideal conditions. Our results illustrate the importance of flood dynamics and habitat complexity to the fish community of the San Francisco Bay-Delta.

Keywords: Floodplain; Native Fishes; Fish Community; Habitat Connectivity
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Juvenile Salmon Growth, Movement and Survival from Butte Creek to the San Francisco Bay - A Look at Past and Present Tagging Studies in the Sutter Bypass

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Spring-run Chinook salmon were once a major component of the Central Valley Chinook salmon stock, with over two million adults returning annually to spawn. Today, wild populations thought to be self-sustaining persist in only three tributaries to the Sacramento River: Mill, Deer and Butte Creeks. Of these streams, Butte Creek consistently supports the largest run of spring-run Chinook salmon by an order of magnitude. It has been suggested that some of the success attributed to this population is due to the productive rearing habitat in the Butte Sink and Sutter Bypass, which allows juvenile salmon to grow to exceptional sizes before heading out to sea, and potentially increasing their survival to the ocean. To study the growth and rearing potential in lower Butte Creek, California Department of Fish and Wildlife (CDFW) tagged out-migrating juveniles with coded wire tags (CWT) in upper Butte Creek between 1995 and 2008 and re-captured them downstream, obtaining growth and residence time for juveniles rearing in the Sutter Bypass. In 2015, we implemented an acoustic tagging experiment in the Sutter Bypass to provide information on movement and survival rates for wild smolts out-migrating throughout the Sutter Bypass, Sacramento River, Delta and San Francisco Bay. Between 2015 and 2018 we collected data from over 700 smolts acoustically tagged during drought and high water events, allowing for the assessment of movement and survival in relation to a range of environmental conditions. We will present the results from the CDFW CWT study and the acoustic tagging study, and discuss the implications for the Sutter Bypass as an important rearing habitat for juvenile salmon, as well as the survival rates of wild Chinook salmon smolts from the Sutter Bypass to the Golden Gate.

Keywords: salmon, floodplain, Butte Creek, spring-run, Sacramento River, Sutter Bypass
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Data Gaps and Uncertainties in Modeling Yolo Bypass Benefits to Juvenile Salmonids

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Significant modifications have been made to California's Central Valley floodplains for mining, agriculture, urban development, water supply, and flood control. The resulting loss of off-channel rearing habitat, migration corridors, and food web productivity has significantly impacted native fish species whose life history strategies depend upon seasonal inundation of floodplain habitat. The Yolo Bypass still retains many characteristics of historic floodplain habitat that are favorable to a suite of fish species. Over the last several years, we have developed a model that incorporates the costs and benefits for juvenile salmonids emigrating through the Yolo Bypass. The central tradeoff in the model is between growth and survival on the floodplain. Longer floodplain residence time yields higher growth but greater mortality. Floodplain rearing is only beneficial if the increased size at ocean entry increases ocean survival enough to outweigh the mortality rate on the floodplain. Through the model development process, we have identified gaps and uncertainties in data on salmonid use of the Yolo Bypass, such as movement and survival of small juveniles (< 100 mm FL), spatial and temporal variation in growth and survival across the Yolo Bypass, factors influencing floodplain residence time, and interaction between floodplain residence duration and ocean entry timing. In this talk, we will describe how the existing data limitations influenced our modeling assumptions and illustrate the implications of these limitations on our modeling results. Future modeling progress depends on narrowing these data gaps and reducing parameter uncertainty.

Keywords: model, salmonid, floodplain, Yolo Bypass, growth-survival tradeoff
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The Growing Science on Delta Aquatic Vegetation: Understanding Vegetation Effects on Habitat and Development of Areawide Management Strategies II

Treating Submerged Aquatic Vegetation with Herbicides to Improve Delta Smelt Habitat

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Aquatic vegetation now covers approximately 30% of the Sacramento-San Joaquin River Delta. Dense beds of non-native plants render large areas of habitat unusable by Delta Smelt. As part of the Delta Smelt Resiliency Strategy, we are conducting a two-year pilot study (2017-2019) to investigate the effect of submerged aquatic vegetation (SAV) on water quality and plankton and to determine the ecological effects of SAV treatment with herbicide. Since June 2017, we have monitored vegetation biomass and coverage, water quality, and plankton communities at two treated sites (Decker Island, Little Hastings Tract in the Cache Slough Complex) and one untreated site (French Island in the Cache Slough Complex). We present findings from the first year of study. To date, vegetation response to the herbicide (Fluridone) is variable between treated sites and not yet clearly discernible from seasonal variation that may be unrelated to herbicide treatment. However, Fluridone is slow acting and commonly requires more than one year of application to achieve significant biomass reduction. Preliminary results do not indicate clear differences between treated and untreated sites in phytoplankton or zooplankton, but there is evidence that zooplankton communities differ between SAV habitats and more open water habitats. We have not observed strong effects of SAV on water quality as compared to more open water habitats, which suggests that tidal dynamics in the Delta overwhelm the effects that vegetation might otherwise have on water quality. We will continue herbicide treatment and monitoring until at least Spring 2019, by which time we anticipate significant SAV reduction at treated sites. Results of this study will be used to inform protocols for managing SAV in the Delta using herbicides. Strategically clearing vegetation to reclaim productive open water habitats represents a key action for recovery of Delta Smelt.

Keywords: fish, habitat restoration, invasive species, phytoplankton, plants, water quality, zooplankton
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Testing the Waters: Fluridone Fate and Toxic Effects After Application to Submerged Aquatic Vegetation

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In a multi-agency collaborative effort, the Department of Water Resources has implemented the Delta Smelt Resiliency Strategy's action for enhanced aquatic vegetation control in the Delta during treatment seasons of 2017 and 2018 to reduce the negative impacts of invasive aquatic vegetation on Delta Smelt habitat. Fluridone, the most common herbicide used in the Delta for submerged invasive vegetation, was applied by the State Parks, Division of Boating and Waterways to submersed vegetation in 2017 (June - September), and again in 2018 (March - June). The action is taking place at Decker Island, a planned tidal wetland restoration site, and in the Cache Slough Complex where both a treated and untreated site are being monitored. While fluridone is applied widely in the Delta every year, there are unanswered questions regarding the potential toxicity of the herbicide in ambient Delta waters, and its concentrations in the sediment after application. Water chemical analysis, sediment chemical analyses, and toxicity tests were conducted on samples collected prior to, during, and after treatment, to assess the fate and non-target toxic effects of fluridone in Delta water bodies. Initial results show that water concentrations of fluridone are very low or not detectible; however, sediments accumulate fluridone, which is detected at much higher levels than in the water. Water samples from the untreated site that were amended with fluridone caused reduced growth in the native diatom, Thalassiosira pseudonana, at 60 ppb, approximately 20 times field detected concentrations, and native copepod, Eurytemora affinis, survival was significantly affected at approximately 2000 times field detected concentrations (2.5 ppm). Preliminary results suggest that, though toxicity can occur at high concentrations of fluridone, environmental water concentrations are not toxic to characteristic diatoms and copepods found in ambient waters.

Keywords: submersed aquatic vegetation, herbicide, toxicity, diatom, zooplankton, delta smelt, fluridone
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Growth Patterns of Submerged Aquatic Vegetation at Wetland Restoration Sites within the San Francisco–San Joaquin Delta

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The San Francisco–San Joaquin Delta (the Delta) is in a degraded state due to a multitude of anthropological factors including: physical habitat alteration, altered freshwater discharges, toxic contamination, and the introduction of non-native aquatic species. Ongoing efforts to restore wetlands in the Delta to benefit state and federally-listed fish species seek to avoid the detrimental effects which submerged aquatic vegetation (SAV) can have on wetland habitats. In the Delta, SAV provides foraging habitat for non-native predators and competitors of listed fish species. While the available literature documents the negative effects that wetlands dominated by non-native SAV face, few studies have set out to understand how SAV will respond to restoration in wetland habitats spread across the Delta. In this study, field collections were carried out at future restoration and reference sites to better understand how SAV species composition and areal coverage respond to wetland habitat restoration. SAV sampling was carried out at four sites; Liberty, Prospect, Browns, and Winter islands in March, June and August of 2018 and will be continued in October 2018 and January 2019. The patterns of SAV growth we found prior to restoration have implications for restoration projects in the Delta. Standardized procedures for sampling SAV are suggested for other researchers interested in assessing SAV in the delta.

Keywords: submerged aquatic vegetation, SAV, restoration, tidal wetland, habitat, food production
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Water Quality Impacts of Water Hyacinth at a Hydrologic Crossroads

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Water hyacinth is a major invasive species that has modified ecosystem functioning in the Sacramento-San Joaquin Delta. Studies in lakes show that water hyacinth can alter water quality under patches and in rivers water hyacinth impacts water quality downstream. In this study, we asked whether the presence or treatment of water hyacinth with herbicides resulted in changes in water quality in a tidal freshwater system. We combined existing datasets that were originally collected for permit compliance and for long-term regional monitoring into a dataset that we analyzed with a before-after control-impact (BACI) framework. This approach allowed us to describe the effects of presence as well as treatment, while accounting for seasonal patterns in water quality. We focused on temperature, dissolved oxygen, and turbidity because these parameters are important drivers of the distribution of fish species of management concern. This study showed that water hyacinth effects water quality differently in a tidal estuarine system than systems with either static or flowing hydrology. We found that although effects of treatment were not detectable when compared with water immediately upstream, impacts of water hyacinth presence and treatment on dissolved oxygen and turbidity were detectable when compared to regional averages. Both parameters differed from regional averages before treatment, but became more similar to regional water quality averages after treatment. Temperature was similar to regional averages before treatment, and became slightly less similar to the regional average after treatment. Together, these results suggest that tidal sloshing expands the effects of water hyacinth upstream, creating a buffer of altered water chemistry around patches. It also suggests that although water hyacinth impacts dissolved oxygen and turbidity, these parameters recover to regional averages after treatment, which is important for managing water quality for fish habitat.

Keywords: invasive, water quality, management, habitat, dissolved oxygen, turbidity, temperature, vegetation
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Sediment Trapping by Submerged Aquatic Vegetation in the Delta

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Submerged aquatic vegetation (SAV) dominated by Brazilian waterweed (Egeria densa) acts as an ecosystem engineer in the Sacramento-San Joaquin Delta by trapping sediment within and beneath the vegetation. We hypothesize that widespread presence of SAV in the Delta is reducing vertical accretion on adjacent marshes and impacting fish habitat by reducing water column turbidity. To test these hypotheses, we are (1) studying the effect of SAV on sediment flux and trapping using (a) transecting measurements of net sediment flux around SAV patches and (b) fixed time-series measurements of velocity and suspended-sediment concentration (SSC) within and outside SAV patches, and (2) measuring the impact of SAV on rates of inorganic sedimentation by collecting gravity cores beneath SAV and short cores in marsh sedimentation plots and long cores on the marsh platform adjacent to SAV.

To date, we have conducted sediment flux measurements, vegetation sampling, and gravity coring beneath SAV in our study sites at Lindsey Slough, the lower Mokelumne River, and Middle River below Mildred Island. Time-series data from a fixed deployment at Lindsey Slough show that within the vegetation, tidal currents were damped by more than 90% compared to the adjacent un-vegetated channel. Average SSC was 19% lower and tidal peaks in SSC were reduced by 50% within the vegetation compared to outside. In eight 0.25 m2 quadrats of biomasssamples collected at Lindsey Slough, E. densa, the main constituent had a mean stem diameter of 2.45 (sd = 0.09) mm and mean dry weight of 596 (sd=157) g m-2. These plant measurements will be used to determine the horizontal leaf area index of SAV in Delta channels. All data collected on vegetation and sediment dynamics in the three study sites will be used to estimate the sediment trapping ability of SAV in the entire Delta.

Keywords: invasive aquatic vegetation, Egeria densa, sediment, suspended sediment concentration
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Biogeochemical Processes and Effects

North Delta Restoration on the Horizon: Balancing Ecosystem & Municipal Water Quality

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The Sacramento – San Joaquin Delta is a major water conveyance hub for both the State Water Project and Central Valley Project. Biological Opinions for both Salmon and Delta Smelt have called for the restoration of thousands of acres of habitat principally in the North Delta Arc Region (i.e. Suisun Marsh, Cache Slough Complex (CSC), and Yolo Bypass). While the predominant focus has been on ecosystem productivity, there has been very little attention on the potential for municipal water quality impacts associated with large and small scale habitat restoration projects.

To help address this issue, the Department of Water Resources in partnership with the Solano County Water Agency developed an adaptive biweekly monitoring program for the CSC starting in September 2013. A total of 11 discrete water quality stations were established within the CSC including Lisbon Weir in the Yolo Bypass. Sites were selected to complement existing monitoring efforts by State, Federal and local agencies as well as establish pre and post water quality conditions for existing and planned habitat restoration projects.

The results of the study show that water quality is highly segmented by region within the CSC. Locations at the upstream boundary of the CSC including Lisbon Weir show the highest levels of primary productivity (as measured by chlorophyll) as well as the highest levels of nutrients, organic carbon, turbidity, EC and trihalomethane formation potential (THMFP), all indicators of poor municipal water quality. The results also show that localized inputs, particularly those from the Toe Drain and other CSC tributaries, may be significantly more important to ecosystem productivity and municipal water quality than small scale habitat restoration. Lastly, recent monitoring during managed pulse flows down the Toe Drain (as part of the Delta Resiliency Strategy), showed significant increases in local productivity with minimal municipal water quality impacts.

Keywords: Cache Slough Complex, Ecosystem and Municipal Water Quality, Habitat Restoration
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Nitrogen Cycling in Bay-Delta Tidal Wetlands

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Increasing exports of human-derived nitrogen (N) have degraded coastal, estuarine and riverine aquatic ecosystems worldwide. As sites of intense N cycling, tidal wetlands in regions such as the Bay-Delta may importantly mediate the connection between N inputs and aquatic food webs. N exports are posited as having a major impact on the function and makeup of the Bay-Delta marine food web, potentially impacting native pelagic fish species. The objective of this study was to quantify high-frequency (sub-hourly) N dynamics at two wetland sites (in Suisun Marsh, San Francisco Bay Estuary; Cache Slough Complex, northern Sacramento San-Joaquin River Delta) to evaluate the capacity for wetlands to act as dissolved N sinks or sources. To explore how short- and long-term drivers (from tidal cycles to inter-annual climatic changes) interact to shape patterns of N movement (measured as nitrate; $NO3^{-}$) into- and out of wetlands, we will present findings from a combination of data sets of dissolved N measurement spanning multiple timescales (hourly to inter-annual). Ultimately, this study will help to provide a broader understanding of the role that tidal wetlands play in coastal and estuarine N biogeochemistry, and will help to define the potential effects that management decisions (e.g., wetland restoration, nutrient reduction strategies) will have on Bay-Delta food webs, N cycling and coastal exports.

Keywords: tidal wetland, nitrogen, nitrate, eutrophication, food web
Session Title: Biogeochemical Processes and Effects
Session Time: Tuesday, September 11th, 3:35 PM - 5:15 PM, Room 314

Biophysical Controls on CO2 and CH4 Atmospheric Fluxes from Suisun Marsh, San Francisco Bay Estuary

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Suisun Marsh represents one of the largest brackish tidal marsh systems on the West Coast of the United States. Although well monitored for vegetation dynamics, changes in fish and invertebrate populations, and water quality, the understanding of long-term exchanges of atmospheric (vertical) and hydrological (lateral) carbon (C) fluxes remains limited. Studies in comparable ecosystems around the world are limited in both number and scope, due to methodological challenges posed by the dynamic nature of tidal wetlands. As a result, very few studies have measured C fluxes on a continuous, annual basis and relationships between C fluxes and key biophysical controls such as inundation, temperature, radiation, and salinity are not well defined. Increasing the number of direct measurements of vertical and lateral C fluxes is a critical first step to developing a better understanding of biophysical controls and sensitivities of C sequestration and greenhouse gas (GHG) mitigation potential of coastal wetlands. Here we present 4 years (2014-2018) of near-continuous eddy covariance measurements of atmospheric CO2 and CH4 fluxes.

CO2 fluxes showed significant interannual variability, with low net CO2 emissions in the first year of the study (27 ± 29 g C m-2 yr-1), moderate uptake in the second and third year (184 ± 28 and 193 ± 29 g C m-2 yr-1, respectively) and much higher uptake in the last year (391 ± 32 g C m-2 yr-1; April 2017 – April 2018). Conversely, annual CH4 fluxes were similar across years, ranging from 1.04 ± 0.11 to 1.27 ± 0.11 g C m-2 yr-1. We investigated the primary biophysical controls of year-to-year variability in C sequestration at the marsh and found that much of the variability in net CO2 fluxes was explained by changes in salinity concentrations over the course of the study.

Keywords: Brackish Tidal Marsh, Greenhouse Gases, Atmospheric Carbon Fluxes, Interannual Variability
Session Title: Biogeochemical Processes and Effects
Session Time: Tuesday, September 11th, 3:35 PM - 5:15 PM, Room 314

Detection of Free and Covalently Bound Microcystins in Sediment and Clam Samples from the Sacramento-San Joaquin Delta

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Microcystins, a class of hepatotoxins produced by a variety of cyanobacteria species, significantly impact the health of both animal and human populations utilizing surface waters for drinking water, daily living, and recreation worldwide. Cyanobacterial blooms are predicted to become more severe due to rising surface water temperatures and increasing eutrophication of water bodies. Elevated water temperatures and increased UV exposure also encourage growth of toxigenic species. Analytical techniques must allow for accurate quantification of microcystins in biological and environmental specimens, yet this task is challenging as microcystins can become covalently bound to proteins. Thus, methods solely based on solvent extraction may lead to false negative results as they are unable to liberate bound microcystin residues. Here we developed an analytical method where microcystins are oxidized via the Lemieux reaction causing cleavage of the Adda amino acid moiety and releasing the compound 3-methyl-2-methoxy-phenylbutric acid (MMPB), allowing indirect detection of microcystin concentrations. This method was then used to analyze sediment and clam samples taken from twelve sites in the Sacramento-San Joaquin Delta during May and October of 2017. Our results showed that 40% of the sediment samples tested positive for microcystins with concentrations ranging from 16.3 - 151.0 ng/g. All clam samples had microcystin concentrations below limit of detection. The method's limit of detection is 10 ng/g. Microcystin positive soil samples were mainly found along the San Joaquin River, suggesting this water body being a potential source for microcystin exposure to the benthic community. Water samples from the sites were analyzed for microcystins via enzyme linked immunosorbent assays (ELISA) and were below limit of detection. Our data is important for the Bay-Delta management because microcystins may compromise the health of aquatic life and information on their detection and distribution is imperative when implementing policy for toxic cyanobacteria bloom reduction and environmental restoration.

Keywords: Cyanotoxins, microcystins, clams, sediment testing, analytical chemistry, Sacramento-San Joaquin Delta
Session Title: Biogeochemical Processes and Effects
Session Time: Tuesday, September 11th, 3:35 PM - 5:15 PM, Room 314

You're Gonna Dig This

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Active alterations of earth's biogeophysical processes are increasingly being scrutinized in the Anthropocene, as dense human settlements and hinterlands alike grapple with a rapidly changing biosphere. The challenges of a global population approaching 10 billion and the built and natural environments required to sustain it are framing critical questions about climate adaptation measures and the scope, scale and sustainability of approaches aimed at increasing societal and ecosystem resilience. As coastal societies evolve to support larger, more densely concentrated populations, accurate analyses of the of these regions will reveal opportunities for resource optimization for adaptation endeavors.

Human societies have extensive assets threatened by sea level rise, and shoreline ecosystems are critically imperiled by rising waters, because upland migratory pathways are impeded by development. The ecological, economical and societal value of "green infrastructure" for shoreline adaptation have been repeatedly demonstrated, and are increasingly attractive for their multi-benefit returns.

These applications are already being contemplated and examined by planners and engineers for their potential as sea level rise mitigation approaches, but their physical construction requires a very large volume of material. This volume — the Coefficient of Excavation (CoE) — of material gleaned in urban development practices has not been accurately quantified, nor has it been assessed in consideration of various growth/development trends.

As populations rise on developed shorelines, soils and sediment excavated in urban development processes can be used to build multi-benefit adaptation landforms.

These materials, often treated as waste products and bound for landfilling as daily cover, represent valuable physical resources for aiding in societal resilience, ecological restoration and coastal zone hazard mitigation. Multi-disciplinary efforts should are needed for measuring and modeling the potential of these key resources — materials active in the "urban metabolism" of developed and developing shoreline societies and regions globally.

Keywords: climate adaptation; sediment; flood mitigation; ecological resilience; resource management; sustainability
Session Title: Biogeochemical Processes and Effects
Session Time: Tuesday, September 11th, 3:35 PM - 5:15 PM, Room 314

Longfin Smelt from the Coast to the Delta I

Long-Term Food Availability for Juvenile Longfin Smelt Within Regions and Seasons of the Delta Based on Chlorophyll Concentration and Zooplankton Abundance

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Chlorophyll concentration and zooplankton abundance are indicators of food availability at the base of the aquatic food web needed to support juvenile Longfin smelt in the Delta and Suisun Bay. Chlorophyll concentration and zooplankton abundance measured between 1969 and 2015 were used to address the hypotheses that food availability within regions of the Delta and Suisun Bay and seasons used by juvenile Longfin smelt: 1) decreased in 2000 coincident with the Pelagic Organism Decline (POD) in fish abundance, 2) varied over time with ecological periods, and 3) was dependent on the variation of both chlorophyll and zooplankton. The IEP data used for analysis were collected bi-monthly to monthly at 13 stations in the Delta and Suisun Bay. Data were stratified into regions and seasons matching juvenile Longfin smelt distribution. The potential impact of long-term ecological change was examined by Kruskal-Wallis tests after further stratifying the data into ecological periods (Pre-Clam (PC), Pre-POD (PP), and POD). Chlorophyll concentration decreased after 1986, and was accompanied by a decrease in Eurytemora and increase in Pseudodiaptomus abundance in the 1990s for all regions during the summer and fall. During the POD, Pseudodiaptomus abundance increased for most regions and seasons, while chlorophyll concentration and Eurytemora abundance increased during the winter and spring. Within most regions, Eurytemora abundance was correlated with chlorophyll concentration, but the correlations were more positive for PC and PP than POD periods. We conclude that long-term changes in chlorophyll concentration and zooplankton abundance co-varied and could have contributed to the long-term decline in Longfin smelt, but the availability of food was not responsible for the Longfin smelt decline measured during the POD. This information is needed by managers to develop management plans that address factors controlling the long-term decline in Longfin smelt and other fishes of interest, including Delta smelt.

Keywords: Longfin smelt, chlorophyll, zooplankton, POD, food web
Session Title: Longfin Smelt from the Coast to the Delta I
Session Time: Wednesday, September 12th, 8:20 AM - 10:00 AM, Room 306

Examining Spatial and Temporal Variability in Diets and Prey Selection of Larval Longfin Smelt Collected From Shallow and Deep Areas of the Northern San Francisco Estuary

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Longfin smelt, a historically abundant native forage fish in the San Francisco Estuary, population abundance has declined by over an order of magnitude in the last two-three decades partly due to a decrease in zooplankton abundance, or food availability. Shoals and tidal marshes are important rearing habitat for larval longfin smelt and until recently use of these habitats has been neglected. Do these areas provide high quality habitat for longfin smelt? To answer this question, larval fish and zooplankton were sampled concurrently in 2016 and 2017 in shoals, tidal marshes, and channels (2017 only) in the brackish northern estuary for identification and gut content analysis. Larvae distribution reflected hydrology of 2016 (dry year) and 2017 (wet year). To date, Eurytemora affinis, Limnoithona tetraspina and other cyclopoids are the most abundant copepods in the environment and guts. Longfin smelt larvae eat all life stages of Eurytemora affinis and larger cyclopoids. Environmental conditions, sampling sites, regions, and years, among different sampling sites will be analyzed to help determine how the covariates relate to food availability and diets. Examining longfin smelt diets in littoral and channel areas will reveal the most productive habitat type in the northern estuary and inform management decisions for the species.

Keywords: longfin smelt, zooplankton, diet, prey availability, shoal, tidal marsh
Session Title: Longfin Smelt from the Coast to the Delta I
Session Time: Wednesday, September 12th, 8:20 AM - 10:00 AM, Room 306

Spatial Variation in the DNA-Based Diets of Young Longfin Smelt

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Food limitation is a likely constraint on the abundance of several species of fish in the San Francisco Estuary and is particularly important for survival through early development. Here, we used high-throughput DNA-sequence analysis on the guts of longfin smelt (Spirinchus thaleichthys) to describe the diversity of prey important to this threatened species in greater detail and greater taxonomic resolution than was previously possible. Larval fish were collected in shoals, tidal marshes, and channels during February through June 2017. Through sequencing the mitochondrial cytochrome oxidase I gene from the guts of 155 fish using primers that block amplification of longfin smelt DNA, we are able to describe the full diversity of organisms ingested by longfin smelt, with Pacific herring larvae examined for comparison. In addition to comparing diets across habitats, we will also compare what was ingested to the available zooplankton assemblage, which includes over 20 phyla of organisms present in the water column according to our DNA sequencing results. This work will provide a better understanding of what longfin smelt feed on in the estuary, which will help inform management actions intended to improve the availability of those food items as well as advise existing aquaculture efforts directed at conservation and research on longfin smelt.

Keywords: longfin smelt, food web, diet, DNA sequencing, zooplankton, mtCOI, juvenile
Session Title: Longfin Smelt from the Coast to the Delta I
Session Time: Wednesday, September 12th, 8:20 AM - 10:00 AM, Room 306

Novel Investigations into the Distribution, Growth, and Origins of Longfin Smelt throughout the SFE

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The Longfin Smelt is an iconic forage fish that once thrived in the San Francisco Bay Estuary. In the last 30 years, the population has crashed to less than 1% of historic levels, suggesting the ecosystem has become unsuitable for this native species. However, little is known about the ontogenetic niche (physical habitat characteristics required for successful spawning and rearing) within the Estuary. Here we describe results of a 3-year interdisciplinary study of the life-history of Longfin Smelt. By surveying new habitats and conducting microstructural and microchemical analysis of fish otoliths (ear bones), we are transforming our understanding of the habitat requirements of this severely threatened native species. Our expanded surveys show that this species utilizes and spawns within habitats previously omitted by long-term surveys, and our otolith microchemical analyses reveal wide diversity in individual life history strategies that likely facilitates population resilience within a highly dynamic environment. These results may change our fundamental understanding of the population dynamics of this species, and we are working directly with resource managers to integrate these results into current management strategies aimed at conserving and restoring Longfin Smelt populations in San Francisco Bay.

Keywords: Longfin Smelt, conservation, otoliths, geochemistry, endangered, water, survey, fish, ecology
Session Title: Longfin Smelt from the Coast to the Delta I
Session Time: Wednesday, September 12th, 8:20 AM - 10:00 AM, Room 306

Examining Variability in Hatching and Rearing Habitat for Key Forage Fish in the Upper San Francisco Estuary During Wet and Dry Periods from An Unmined IEP Dataset

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The San Francisco Estuary supports a number of forage fish species of commercial and ecosystem importance. New targeted research of larval Longfin Smelt and other forage fish in shallow habitats and tributaries around San Francisco Bay show they are hatching and rearing over far more expansive areas of the estuary (seaward and inland) than previously recognized. In this study, we examined California Department of Fish and Wildlife's historic Bay Larval Survey data (1980-1989) to identified key relationships with water quality variables that determine how larval forage fishes varied in abundance and distribution among bay regions. Our analyses show that larval Longfin Smelt were distributed seaward in average to wetter year types. In contrast, larval Pacific Herring were more abundant in inland stations during drier years. Northern Anchovy appear to have multiple spawning events, and given the abundance of small larvae observed in the bay, may be spawning inside San Francisco Bay. Overall, the analyses presented from this relatively unmined data set suggests that water quality and freshwater flows (Delta outflow and local tributary flow)may be important in shaping conditions that support larval forage fish rearing habitat throughout the estuary.

Keywords: Longfin smelt, forage fish, IEP, Bay Survey
Session Title: Longfin Smelt from the Coast to the Delta I
Session Time: Wednesday, September 12th, 8:20 AM - 10:00 AM, Room 306

Future Restoration Changing the Delta

Franks Tract Feasibility Study Applying the Guidance of a Delta Renewed

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Assessing the feasibility of restoring Franks Tract is an element of the 2016 Delta Smelt Resiliency Strategy. The initial step in the process was the development of a conceptual restoration design guided by A Delta Renewed and expert elicitation. Then working with collaborators assess the feasibility of implementation.

The restoration concept focused on shifting the habitat composition of Franks Tract from shallow subtidal habitat, dominated by submerged aquatic vegetation (SAV), with unconstrained tidal flow to a mix of intertidal and deep subtidal habitat. The approach also focused on reducing the inter-connectedness of channels in the area, primarily by blocking False River to re-establish circulation patterns similar to the historic condition. The conceptual restoration design was used to assess the hydrodynamics associated with construction to inform engineering feasibility and assess the near and far field effects of the restoration.

The primary biological objectives of the restoration approach are achievable:

- Create and enhance habitat to support Delta Smelt and other pelagic and native species.
- Reduce entrainment of Delta Smelt into the south Delta.
- Enhance foodweb support and increase residence time within dead end channels.
- Reduce SAV.
- Reduce habitat for introduced predatory species.

The restoration approach reduces salinity intrusion into the central and south Delta particularly during periods of low outflow, in essence functioning as a permanent drought barrier.

The engineering assessment concluded that construction of the conceptual restoration design was feasible, although expensive, and could be implemented using material primarily from on site.

While the restoration concept addressed biological objectives it raised significant concerns among the local community and elicited a locally proposed design. These concerns tie directly to how we achieve restoration of the Delta, while protecting and enhancing the unique values of the Delta as an evolving place, by applying concepts ofreconciliation ecology and novel ecosystems.

Keywords: Franks Tract, novel ecosystems, Delta Smelt, Delta Renewed, feasibility, restoration
Session Title: Future Restoration Changing the Delta
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3-D Hydrodynamic Modeling to Support Restoration Planning

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California Department of Water Resources performed three-dimensional hydrodynamic and particle tracking simulations in support of the restoration feasibility study. The work was done with the Bay-Delta SCHISM model, a well-resolved 3D model of the Bay-Delta that had been extensively exercised in the Franks Tract region during the 2015 drought. Simulations allowed participants to visualize dynamics under various designs and describe how the system responds at both a local and system scale. The main working proposal included just under 1000 acres of intertidal habitat in west Franks Tract, including dendritic channels and a berm that reduces tidal connectivity between False and Old Rivers. The far field effects included diversion of tidal energy around Franks Tract and the interruption of tidal pumping, the main mechanism of salinity intrusion into the central Delta. Particle tracking simulations suggest entrainment of from the West Delta towards the export region is reduced. Exchange between the San Joaquin River and the Central Delta is increased under lower flow regimes. Two sensitivities were studied. First, the role of submerged aquatic vegetation (SAV) in modulating flow and transport was explored because SAV was found to play a significant role in regional circulation during the installation of the 2015 Emergency Drought Barrier. SAV has less effect under the restoration proposal, because gradients are more gradual and Franks Tract circulation plays a smaller role in the larger system. The second sensitivity was project interaction. The restoration was studied coupled with other contemporary projects at Dutch Slough, Prospect Island and McCormack-Williamson Tract which were considered interrelated due to proximity or a shared dependence on Delta Cross Channel performance. The coupled system produces slightly poorer water quality than Franks Tract restoration alone, but the central Delta is still freshened overall, and Franks Tract project is a beneficial contributor to the portfolio.

Keywords: Multi-dimensional model, Delta Smelt, Habitat Restoration, Franks Tract, Salinity Transport.
Session Title: Future Restoration Changing the Delta
Session Time: Wednesday, September 12th, 8:20 AM - 10:00 AM, Room 307

Redesigning Franks Tract: Community, Stakeholder and Public Outreach

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Franks Tract has been vast, open water in the central Delta since 1938, when a levee breach went unrepaired and flooded reclaimed agricultural lands. Since that time, a shallow, lake-like ecosystem has developed within in it, alongside shoreline communities and recreational users. As a component of the Delta Smelt Resiliency Strategy, Franks Tract may be reclaimed again to improve water quality and restore tidal marsh habitat. Any proposed changes to Franks Tract (a designated State Recreation Area) will differently affect those who live, work and play in the area. Thus restoration design and planning efforts should include careful consideration of the interests of its owners, neighbors, local communities, and different state agencies.

This presentation will share the methods and findings of the community, stakeholder and public outreach effort of the Franks Tract Feasibility Study. Our mixed-methods approach included a user survey, in-person interviews, fieldwork, stakeholder workshops, participatory mapping, and a review of past and existing plans for the area. We found that human uses of Franks Tract and Little Franks Tract are numerous and occur throughout the year. It is one of the most populated and publicly used tracts in the Delta. Usage is highest in the summer months, primarily associated with boating. Recreational and economic value is directly tied to water navigability and proximity to “fast water”, which was the primary concern expressed by stakeholders with respect to the feasibility study plans.

Through our outreach process, we worked directly with residents and stakeholders to identify ways to improve restoration design, mainly by minimizing negative impacts and designing amenity features for residents and recreational users. Going forward, we recommend that these initial efforts be further advanced through an integrative,in-depth design process with stakeholders, local communities, agencies and experts.

Keywords: restoration, Delta as Evolving Place, subsidence, recreation, navigability, dredging, codesign
Session Title: Future Restoration Changing the Delta
Session Time: Wednesday, September 12th, 8:20 AM - 10:00 AM, Room 307

The Delta Conservation Framework: Realizing a Vision for a Sustainable Delta by 2050

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Bridging the often-disparate paths of human and wildlife needs is essential for lasting conservation success. The Delta Conservation Frameworkoffers context and guidance for implementation of practices toward a collective long-termvision of the Delta as “a mosaic of towns, agricultural landscapes, managed wetlands, and resilient ecosystems where people prosper and healthy fish, wildlife, and plant communities thrive.” In 2016, CDFW committed tolead state, federal, and local agencies and the Delta stakeholder community in an inclusiveplanning effort to advancetheconservationof theSacramento-San Joaquin Delta, Yolo Bypass and Suisun Marshfollowing the pivot away from theBay Delta Conservation Plan effort. Building on prior Delta planning efforts,and cognizant of uncertainties related to climate change and other impending land use changes, the Framework provides a collective vision and long-term, landscape-scale goals. The term conservationin this framework means achieving protection, enhancement, and restoration of ecological function of Delta ecosystems,integrated within a mosaic ofagricultural sustainability, flood protection, recreation, and otherhuman interests. Goal-based conservation strategies and objectives, suggested for implementation by 2050, aim at increasing public awareness, involvement, communication, and advancing science-informed,ecosystem-function oriented conservation practices and processes. It suggests a forum for planning partnerships like the Central Delta Corridor Partnership, with broad collaborative engagement to integrate stakeholder concerns into regional-scale goal setting within Regional Conservation Strategies or Regional Conservation Investment Strategies. It helps inform long-term continuation of existing restoration initiatives, such as EcoRestore, and address challenges, potential regulatory conflicts, and other barriers to implementation of projects like Franks Tract. It serves as one foundation for the amendment of the Delta PlanChapter 4, and helps guide State funding priorities. The Delta Conservation Framework offers approaches for stakeholder integration to achieve conservation outcomes and adaptive managementof Delta ecosystems system-wide benefitting both human and natural communities.

Keywords: Restoration, conservation, partnerships, landscape-scale, long-term, collaboration, human dimension, ecological function
Session Title: Future Restoration Changing the Delta
Session Time: Wednesday, September 12th, 8:20 AM - 10:00 AM, Room 307

Developing a Delta Habitat Restoration Adaptive Management Program

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Habitat restoration is a key strategy in the Delta Plan to achieve the coequal goal to protect, enhance and restore the Delta ecosystem. Various efforts including the California EcoRestore initiative and Proposition 1 grants administered by the Delta Conservancy and Department of Fish and Wildlife will advance the restoration and enhancement of habitat in the Delta, Suisun Marsh, and Yolo Bypass regions of the California Delta. Recognizing that past Delta restoration efforts have rarely covered the full adaptive management cycle, the Delta Science Program initiated a comprehensive, science-based adaptive management approach to support achievement of Delta habitat restoration goals and increase restoration success. The Interagency Adaptive Management Integration Team (IAMIT), comprising agency and stakeholder scientists and technical management staff, developed a white paper describing existing adaptive management resources, how those resources link together, and what resources are currently lacking. The white paper concludes with a series of recommendations for developing a complete, integrated, and financially supported habitat restoration adaptive management program. The desired outcome of implementing these recommendations is a program that 1) supports individual restoration projects, 2) considers local and system-scale effects, 3) sets a stage to evaluate impacts of restoration actions at multiple time and spatial scales, and 4) supports effective communication of acquired knowledge for management. The Delta Habitat Restoration Adaptive Management Program will provide a strong foundation for robust, long-term adaptive management for habitat restoration in the region.

Keywords: adaptive management, habitat restoration, EcoRestore, decision making, science-based management
Session Title: Future Restoration Changing the Delta
Session Time: Wednesday, September 12th, 8:20 AM - 10:00 AM, Room 307

Physics to Fish in the North Delta: How Physical and Biological Processes Influence Habitat Quality for Fish I

Hope We Can Believe In: Why Understanding the North Delta Is So Important

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The northern region of the Sacramento-San Joaquin Delta (North Delta) extends from Cache and Lindsey Sloughs north through the Yolo Bypass to the Feather River confluence with the Sacramento River. Land use is dominated by agriculture; urban areas flank its eastern margin. The aquatic system consists of interconnected channels, dead-end sloughs, shallow open water areas, and tidal and seasonal wetlands. As the northern end of the “North Delta Habitat Arc,” the North Delta has long been considered a prime target for habitat restoration. Examples of recent strategies and programs that include North Delta restoration are the Delta Plan, California EcoRestore, Fish Restoration Program, and the Delta Smelt and Salmon Resiliency Strategies. Hopes are high for the effectiveness of restoration actions in the North Delta because it retains more historical characteristics in its landscape and flow patterns, has higher elevation and inflows and better water quality, continues to harbor native species, and provides more restoration opportunities than most other parts of the Delta. Additional hopes revolve around the idea that restoration benefits will extend beyond the North Delta, for example through export of food and sediments to low-productivity and sediment-starved downstream areas. But how justified are these hopes? What needs to be considered and what can be done to make them come true? Finding answers to these questions is the goal of a set of interdisciplinary studies "from physics to fish” currently underway in the North Delta. Important results from these studies will be presented in a special session. This presentation provides an introduction to this session, discusses some of the conceptual underpinnings of the studies, and explains how results can help restoration planners and practitioners base restoration actions less on hope and more on a solid understanding of how the North Delta really functions, now and in the future.

Keywords: North Delta, Habitat, Ecosystem, Restoration, Integrated Science, Management Applications, Experiments
Session Title: Physics to Fish in the North Delta: How Physical and Biological Processes Influence Habitat Quality for Fish I
Session Time: Wednesday, September 12th, 8:20 AM - 10:00 AM, Room 308-310

North Delta Hydrodynamics with Emphasis on Habitat Connectivity

Jon Burau, USGS
Paul Stumpner, USGS

Specific landscape features within the Cache Slough Complex (CSC) create tidal and net flow patterns that are demonstrably different from the narrow, steep sided, riprapped, leveed network of canals that is typical of aquatic habitats in the Sacramento-San Joaquin Delta (Delta). The effect that the interaction between these landscape features and the flow dynamics that they create have on the quality of native fish habitat is uncertain, but is a topic of great interest.

We studied two sub-regions in the CSC to investigate the effects of landscape shape on ecosystem function —Wildlands and Little Holland Tract—because these regions have distinctly different landscape shapes but are similarly hydrodynamically forced. Wildlands is a small (~100 acres) dendritic marsh system similar to the historic Delta, which experiences marsh plain inundation at higher tidal stages during spring tides; in contrast, Little Holland Tract is a larger (~1500 acres) shallow water pelagic habitat (< 6 feet mean depth at high tide) that has extensive mudflats at low tide. These landscapes create differences in flow and water quality patterns that, in turn, create distinctly different habitats, even though they are less than a mile apart.

In this talk, we examine the tidal and net flow characteristics in these habitats as part of a USGS interdisciplinary “flux study”, conducted in July and August of 2017. The overall objective of this investigation was aimed at understanding the physical drivers of habitat quality in the CSC through concurrent measurement of high frequency physical, chemical and biological data (phytoplankton, zooplankton, and fish). While an important aspect of this study focused on the transport of material within and through these habitats, we also examined the connection between these habitats and their surrounding channels with the aim of understanding how these specific landscape features effect ecosystem function in the CSC as a whole.

Keywords:
Session Title: Physics to Fish in the North Delta: How Physical and Biological Processes Influence Habitat Quality for Fish I
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Sacramento-San Joaquin Delta Sediment Characteristics Following the Extremely Wet Conditions During 2017

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Over the last few decades we have observed a trend of declining sediment supply to the Sacramento-San Joaquin Delta along with a decline in turbidity. Sediment supply to the Delta is important to understand, especially when the focus is on better habitat sustainability, sediment demands from the Eco-Restore projects, and the potential for sediment removal from the system via the Delta tunnel(s). We analyzed suspended-sediment load into the Delta, bed sediment characteristics Delta wide, turbidity dynamics, and Delta sediment export to San Francisco Bay. The Sacramento River flow in 2016 was above average; however, it was the sediment supply from the Sacramento River watershed in 2017 that was significant. The flow volume and suspended-sediment load observed at Freeport were on par with 2006, and with annual flow volume through the Yolo Bypass into the North Delta on par with 1983. The provisional bed sediment data appears consistent with other years, with medium sand observed in the Sacramento River channel, Sutter and Steamboat Sloughs, and silt/mud observed in Lindsey Slough, the Deep Water Ship Channel, Upper Cache Slough and Cache at Ryer Island. Though data indicate some deposition within the Cache Slough region in 2017, the average March through September turbidity in the vicinity of Liberty Island and Little Holland Tract was 40% less in 2017 than in 2016. Sediment data indicate sediment erosion through Yolo Bypass, some deposition in the Cache Slough Complex, and substantial export to the Bay. The downward sediment trend we observed suggests a smaller sediment load for 2017 than we observed; but sediment likely was supplied from the Feather River because a larger than typical fraction (nearly 20%) of the total Sacramento River discharge was due to emergency releases from the Oroville reservoir. More than 80% of the sediment inflows were exported to San Francisco Bay.

Keywords: physical processes, north delta, sediment, turbidity
Session Title: Physics to Fish in the North Delta: How Physical and Biological Processes Influence Habitat Quality for Fish I
Session Time: Wednesday, September 12th, 8:20 AM - 10:00 AM, Room 308-310

Influence of Flood and Drought on Bed Erodibility and Turbidity in Two Flooded Agricultural Tracts in the North Delta

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The north Delta is considered a promising area for habitat restoration for fish, including the endangered Delta smelt. In an effort to improve habitat, some subsided agricultural tracts flooded by levee breaches have been retained as tidal shallows, and additional breaches are planned. The objective of this study was to determine what physical configurations of shallow basins produce elevated turbidity suitable for Delta smelt. We investigated the dynamics of suspended sediment (which controls turbidity) in two adjacent flooded tracts, Liberty Island (LB) and Little Holland Tract (LHT). LB is larger than LHT (1757 vs. 590 ha) and deeper. Time series of suspended-sediment concentration (SSC), water level, wind-wave height and period, and tidal currents were collected in LHT and LB from August 2015 to October 2017, spanning both drought and historic high Delta outflows. Bed sediments were sampled every 60 days and analyzed for grain size distribution. SSC was greater in LHT (median 50-55 mg/L) than LB (median 30-35 mg/L). The difference was caused by greater mobilization of bed sediments in LHT by both wind waves, because LHT is shallower, and tidal currents, which are stronger in LHT than LB. We also found that bed erodibility, which influences the amount of sediment suspended by a given level of bed shear stress, varied with hydrologic conditions. Erodibility was lower during drought conditions and increased following elevated Delta outflow, indicating that episodic influx of new sediments is necessary to maintain elevated turbidity. Our results show that turbidity in tidal shallows is influenced by basin morphology and proximity to river-borne sediments, factors which can be taken into account in selecting and designing restoration sites. Our finding that drought has the potential to suppress turbidity within tidal shallows shows that indirect effects of hydrologic variability may influence the success of restoration efforts.

Keywords: turbidity; Delta smelt; habitat restoration; erodibility; sediment dynamics
Session Title: Physics to Fish in the North Delta: How Physical and Biological Processes Influence Habitat Quality for Fish I
Session Time: Wednesday, September 12th, 8:20 AM - 10:00 AM, Room 308-310

The Effects of Transport Processes on Phytoplankton and Nutrient Dynamics in the Cache Slough Complex: Observations over Spatial and Temporal Scales

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Water quality constituents vary on temporal and spatial scales in the Cache Slough Complex (CSC) an area of considerable landscape complexity. Landscape features in shallow water environments near the Stair Step area have been shown to influence transport processes and thus phytoplankton and nutrient gradients important to native fish habitat. High net flow (advective transport) from the Toe Drain during the wet season, particularly during Yolo Bypass flooding events, often introduces water high in nitrate, chlorophyll-a, and turbidity, to the region. In the dry season, during periods of low advection, transport of water is accomplished primarily through tidal processes (dispersive transport) and water residence time is higher in the landward direction of backwater sloughs. Higher chlorophyll-a fluorescence and nitrate drawdown has been observed coincident with higher residence time in the Stair Step region during the dry season. As a result, steeper gradients of chlorophyll-a fluorescence and nitrate have been measured landward along Shag Slough and Liberty Cut during these periods of low advective transport. Water-quality measurements at high temporal and spatial resolution, coupled with an understanding of transport processes, can offer insights into phytoplankton abundance and nutrient dynamics over seasons and water years. We will present results of in-situ water-quality measurements at continuous monitoring stations at the mouth of Liberty Island, Liberty Cut, Toe Drain, and the main breaches of Wildlands and Little Holland Tract North, along with analyses of discrete samples. Finally, we will show our results from high-resolution mapping, which further demonstrates how transport processes may affect the spatial gradients and exchange of nutrients, organic material and phytoplankton that is necessary for to support the pelagic food web.

Keywords: water quality, high-resolution, North Delta, nutrients, phytoplankton
Session Title: Physics to Fish in the North Delta: How Physical and Biological Processes Influence Habitat Quality for Fish I
Session Time: Wednesday, September 12th, 8:20 AM - 10:00 AM, Room 308-310

Science on Salmonids I

Challenging Juvenile Chinook Growth Models with Empirical Data - Implications for Fish and Water Management

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Bioenergetics models to address growth or consumption by Chinook Salmon use a standard set of coefficients to relate metabolic process to temperature for any population of the broad-ranging species. However, recent studies have shown varying temperature tolerances in salmonids, which may suggest that populations in the southern end of the range likely tolerate higher temperatures than more northern populations. Generalization about predator and prey energy densities may also affect and bias simulated growth and consumption estimates. Our approach uses several lines of evidence to better understand relationships between temperature and salmonid growth. We focus this effort on juvenile Chinook Salmon in the San Joaquin River Restoration Program, which seeks to restore the southern-most run in North America, as well as other populations in the San Joaquin-Sacramento drainage. We used data from wild and hatchery cohorts along the SJR, meta-analyses for other populations, and simulations with inSTREAM and bioenergetics models. Multiple lines of evidence suggest that juvenile Chinook Salmon growth rates in southern rivers are quite robust, despite the degraded conditions of these ecosystems. We found that estimated scope for growth and consumption rates differ by ca. 35% by using direct versus published energy densities of juveniles. Implied growth performance is greatly affected by assumptions of juvelines' thermal history. Our broader main objectives are to generate population and habitat specific bioenergetics algorithms and encourage a broader use of population-specific relationships of temperature and growth rate. A focus on these approaches can help fisheries managers set realistic expectations for restoration projects and better inform conservation goals of water management in California.

Keywords: juvenile Chinook Salmon, bioenergetics, fish restoration, water management
Session Title: Science on Salmonids I
Session Time: Wednesday, September 12th, 8:20 AM - 10:00 AM, Room 311-313

Listening to the Signal in the Noise: Insights into Hidden Diversity in Spring-Run Chinook Salmon at the Southern Species Range Using Genetic and Isotope Tools

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Historically, spring-run Chinook salmon were the most abundant salmon in the Central Valley, and supported the early California fishery until high elevation spawning habitats became degraded and inaccessible behind high head dams. Presently, spring-run salmon populations have been extirpated from their historical habitats in San Joaquin River and its tributaries, and considered threatened with extinction under the US Endangered Species Act. Here, we highlight the results of three case studies that apply new genetic and otolith isotope tools to reveal hidden diversity relevant for managing spring run at the southern margin of the native species range. First, we analyzed the genetics of archived scales from juveniles that were large-at-date (e.g., yearlings) from the Stanislaus River suggesting the presence of spring run ancestry. Secondly, we show that adult spring run that successfully return to spawn on Mill, Deer, and Butte Creeks employed different freshwater outmigration patterns as juveniles (fry, smolt, yearlings) among creeks and years. Lastly, we determined the natal origins of spring-running adults on the Yuba River using otoliths and found evidence that some originated and returned to the Yuba River. These data suggest the potential for a self-sustaining spring run population on the Yuba River. Collectively, these findings highlight remnant behaviors occurring in multiple populations that are contributing to the resiliency of spring run, and provide insights into their conservation and recovery.

Keywords: Spring run, otolith, genetics, isotopes, resiliency, salmon, San Joaquin, Yuba
Session Title: Science on Salmonids I
Session Time: Wednesday, September 12th, 8:20 AM - 10:00 AM, Room 311-313

Ancestry and Adaptation in Rainbow Trout Above Barriers to Anadromy: Implications for Recovery of Central Valley Steelhead

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Steelhead/rainbow trout (Oncorhynchus mykiss) are found in all of the major streams of the California Central Valley but anadromous steelhead are currently limited by impacts such as dams, water diversions, and high temperatures. Widespread stocking of hatchery rainbow trout strains has also impacted populations throughout California for over 100 years, primarily using trout strains derived from the Central Valley lineage. Analysis of genetic data can identify patterns of population structure, determine ancestry of populations isolated above barrier dams, and detect introgression by out-of-basin stocks. In addition, evaluation of adaptive genomic variation can provide insights into the evolution of migratory life-histories among above-barrier populations, particularly above dams that form reservoirs. Although native lineages of O. mykiss remain dominant in most above-barrier populations, evidence of stocking with hatchery rainbow trout strains is present in some populations. We also find evidence for life-history diversity in above-barrier populations associated with reservoirs. These results highlight the importance of local adaptation and the potential for trout populations above barrier dams to contribute to the recovery of anadromous O. mykiss through re-establishment of migratory connectivity between upstream spawning and rearing habitats and the ocean.

Keywords: Genetics, Ancestry, Adaptation, Anadromy, Steelhead, Fish Passage, Migration, Dam Removal
Session Title: Science on Salmonids I
Session Time: Wednesday, September 12th, 8:20 AM - 10:00 AM, Room 311-313

What Makes a Successful Hatchery Fish? Using Microhaplotypes to Understand Correlates of Broodstock Reproductive Success in Winter-Run Chinook Salmon

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Supplementation hatchery programs are designed to conserve and recover the receiving population, yet adaptation to captivity is pervasive in Pacific salmon and can reduce reproductive success of hatchery-reared fish spawning in the wild. Understanding the correlates of reproductive success in hatchery-origin fish is important to inform conservation practices and to further understand adaptation to captivity. Using a novel panel of microhaplotype markers in a GTseq framework, we evaluate 5 brood years of winter-run Chinook salmon from the Livingston Stone National Fish Hatchery and identify broodstock traits that correlate with reproductive success. Determining the traits linked to adaptation to captivity will give hatchery managers, biologists and conservationists a more thorough understanding of population dynamics in hatchery cohorts and potentially inform the best use of hatchery-reared fish for the conservation and recovery of Winter Chinook salmon in the Sacramento River.

Keywords: conservation, hatcheries, salmon, parentage, supportive breeding
Session Title: Science on Salmonids I
Session Time: Wednesday, September 12th, 8:20 AM - 10:00 AM, Room 311-313

Differences in Thermal Performance between Populations of Chinook Salmon, Oncorhynchus tshawytscha

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Fish populations, and salmonids specifically, are known to match their physiology to the local thermal environment. This physiological plasticity can be a result of acclimatization and local adaptation. Chinook salmon exist across a large latitudinal range, with individual populations experiencing a variety of temperature regimes. Within California Chinook salmon, those living at the southern range boundary appear to be quite thermally tolerant; however, without direct comparisons with other populations and iterated across acclimation regimes, our understanding of the thermal capacity of Chinook salmon remains limited. Our work directly compares the thermal physiology of Central Valley Chinook populations with those from more northern latitudes to investigate adaptive or acclimation differences. We reared juvenile Chinook salmon from three populations[NAF1] spanning the coast of California and Oregon. Each population was reared at three acclimation temperatures to explore interpopulation variation in acclimation capacity and thermal physiology. Physiological thermal performance metrics included growth, critical thermal maximums and aerobic scope. Preliminary results indicate that populations do differ in their thermal capacity and acclimation response, suggesting that larger biogeographical patterns may become apparent with future research. Our work is relevant to the management of California, and more broadly West-coast, salmonid populations undergoing rapid environmental change. Understanding the differences between populations, and their capacity to acclimate or adapt to future climate conditions is essential to effectively managing these vulnerable stocks.

Keywords: Chinook Salmon, Temperature, Aerobic Scope, Central Valley, Interpopulation Variation, CTM
Session Title: Science on Salmonids I
Session Time: Wednesday, September 12th, 8:20 AM - 10:00 AM, Room 311-313

Mercury and Contaminants

Simulation of Biogeochemical Processes Driving Methylmercury Production in Different Sediment Habitats of the Delta and Its Tributaries

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Fish and birds in the San-Francisco Bay-Delta and its tributaries are contaminated with monomethylmercury (MeHg), which poses a significant threat to human and ecological health. Management of waterbodies could help to reduce MeHg concentrations. To make informed decisions, resource managers need a working understanding of biogeochemical processes affecting MeHg production. Computational models that simulate the net production of MeHg in sediments can be a useful tool in this regard. A biogeochemical reaction model using the PHREEQC program was modified to improve the description of net MeHg production in sediments. Rate equations to describe different pathways of mercury (Hg) methylation and MeHg demethylation were implemented and coupled to redox reactions. Based on a comprehensive literature review, we determined ranges of (de)methylation rate constants derived from Hg-isotope assay measurements, estimated the relative contribution of different pathways to (de)methylation, and estimated the rate of organic matter degradation under different environmental conditions. It was found that it is important to choose internally coherent data sets because incubation conditions and assumptions in the literature can differ between studies. Simulations investigated how net MeHg production changed depending on different habitats and seasons. Results were evaluated by comparing simulation output with field data sets. A comprehensive sensitivity analysis was conducted to assess drivers in different habitats. The simulated habitats were Lake Combie, Cache Creek Nature Preserve, Cache Creek Settling Basin, and permanent wetlands in the Yolo Bypass. The significance of this work lies in assessing interacting processes with the computational model. For example, the simulation of legacy Hg that provides a small but steady pool of Hg available for methylation, in combination with (de)methylation reactions coupled to redox processes, can help to inform managers about dominant pathways, which makes it possible to identify environmental conditions that should be avoided to reduce net MeHg production.

Keywords: mercury, biogeochemical reaction model, sediments, net methylmercury production
Session Title: Mercury and Contaminants
Session Time: Wednesday, September 12th, 8:20 AM - 10:00 AM, Room 314

Headwater Mercury Source Reduction Strategy: 2018 Update

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The Headwater Mercury Source Reduction (HMSR) Strategy is a multi-disciplinary and cross-regional approach for assessing and addressing contamination in the context of four strategic targets for mercury: (1) hydraulic mines and mine features, (2) mercury-contaminated sediment in reservoirs, (3) mercury exposure, and (4) mercury and forest management. The Strategy builds on over a decade of research, actions, and methods, providing a cohesive platform for technical experts to share, revise, and integrate best-practices for the assessment and mitigation of mercury. This effort is coordinated through a HMSR Technical Advisory Committee (TAC) that meets quarterly to document and update an informed approach to reduce headwater sources of mercury. The development of an effective regional strategy to address mercury can be leveraged toward the identification and execution of future projects in the headwaters to the benefit of the downstream Bay-Delta, contributing to watershed-wide management of mercury. The Sierra Nevada is the source of 60% of the State's developed water supply but historic mining activities have left the headwaters with a legacy of mercury contamination that persists over 150 years after the 19th century Gold Rush. Clean Water Act Section 303(d) listings for mercury impairment as well as the issuance of site-specific fish consumption advisories by the Office of Environmental Health Hazard Assessment (OEHHA) indicate that mercury is present in the aquatic food web from the Sierra to the sea. Mercury contaminated sediment from legacy gold mines in the Sierra continues to be a source of inorganic mercury (Hg) to the environment, and furthermore, continues to be transported during storm events to downstream systems including reservoirs, where conditions are conducive for methylation. MeHg in aquatic ecosystems enters the food web, and biomagnifies and bioaccumulates in fish, posing an imminent exposure risk to humans and wildlife.

Keywords: Headwaters, mercury, sediment, forests, hydraulic mines, reservoirs, fish, human exposure
Session Title: Mercury and Contaminants
Session Time: Wednesday, September 12th, 8:20 AM - 10:00 AM, Room 314

Sediment Scour and Legacy Mercury Remobilization in Alviso Slough, South San Francisco Bay

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The remobilization and transport of legacy mercury (Hg) deposits has been a primary concern of the South Bay Salt Pond Restoration Project since its inception, particularly in the far South San Francisco Bay. Elevated Hg concentrations reside in the sediments of Alviso Slough and the surrounding ponds as a result of historic mining operations in the upstream watershed. Alviso wetland restoration began in 2010 when the levees surrounding Pond A6 were breached, and muted tidal action was restored to the Pond A8 complex through an adjustable tidal control structure (TCS), allowing for progressively increased magnitudes and durations of tidal flushing. As part of the adaptive management process, we collected a baseline high-resolution bathymetric survey of the study area during 2010, followed by semi-annual surveys ever since. A total of 13 bathymetric surveys were used in combination with Hg concentration data from 12 deep sediment cores (up to 230 cm) to estimate the amount of legacy Hg remobilized as a result of sediment scour within Alviso Slough since restoration began. Approximately 50 kg of Hg was remobilized between 2010 and March 2017. Scour along the portion of slough adjacent to the Pond A6 breaches, where Hg concentrations are lower, began to slow and approach a new equilibrium after just three years. In contrast, the upper slough near the TCS, where Hg concentrations are higher, is still actively eroding and poses a greater threat of increased Hg remobilization in the future. These surveys provide unprecedented detail on the evolution of Alviso Slough bathymetry in response to natural seasonal variability of flow, breaches, and TCS operations and will inform both ongoing and future wetland restoration projects.

Keywords: mercury, bathymetry, restoration, Alivso Slough, South San Francisco Bay
Session Title: Mercury and Contaminants
Session Time: Wednesday, September 12th, 8:20 AM - 10:00 AM, Room 314

The Effect of 2015 Wildfires on Particulate Total Mercury Concentrations in Cache Creek

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Cache Creek (CC) is a major source of mercury (Hg) to the Yolo Bypass, the region of the northern Sacramento-San Joaquin Delta with the highest concentrations of toxic methylmercury (MeHg) in water, sediment, and fish (Wood et al., 2010). Ongoing efforts by DWR and USGS to model Hg cycling in the Yolo Bypass using the DSM2 and CASCADE models, respectively, depend on data for Hg and MeHg from CC. USGS is monitoring total mercury (THg) and MeHg in the Cache Creek Settling Basin (CCSB) inflow and its outflows (Water Year (WY) 2010-) and at Rumsey (55 km upstream of CCSB) (WY2015-). During summer 2015, the Rocky and Jerusalem fires burned more than 28,000 hectares of the CC watershed upstream of Rumsey, providing an opportunity to characterize wildfire effects on THg concentrations. Average pre-fire concentrations (+/- std. dev.) of partculate THg (p.THg) were 317 +/- 132 ng./g at Rumsey druing WY2015 (n=11), 254 +/- 117 ng/g in CCSB inflow during WY2010-15 (n=77), and 302 +/- 101 ng/g in CCSB outflows during WY2010-15 (n=79). During the first post-fire wet season (WY2016), p.THg was significantly lower at all three locations: 169 +/- 92 ng/g at Rumsey (n=30), 186 +/- 79 ng/g in CCSB inflow (n=17), and 215 +/- 47 ng/g in CCSB outflows (n=29). Decreases in p.THg were likely caused by the fires, which caused Hg loss from soil by volatilization. WY2017 was very wet; 10 storms caused flows in CC above 10,000 cfs. By the fifth storm peak of the season in late January 2017, p.THg concentrations at all three sites had rebounded to about 250 ng/g, indicating waning wildfire influence. These observations provde a useful dataset for modeling of wildfire effects on Hg transport.

Keywords: mercury, wildfire, Cache Creek, Rumsey, Settling Basin, Yolo Bypass, water
Session Title: Mercury and Contaminants
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Source and Dispersal of Sediment and Contaminant Runoff from the Atlas and Nuns Fires in Northern San Francisco Bay

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Wildfires followed by intense storms can result in enhanced erosion in burned catchments, and downstream transport of eroded sediment and contaminants to coastal environments. The Atlas and Nuns Fires of October 2017 burned a wide variety of landscapes ranging from urbanized to agricultural to wildlands throughout Napa and Sonoma counties, and there may be specific spatial variations in the type and toxicity of associated contaminants. Catchments that are underlain by rocks of the Sonoma Volcanics or Franciscan Complex have soils with distinctive geochemical compositions. Therefore both the geology and land-use of areas burned by the Atlas and Nuns fires could potentially confer unique geochemical signatures that can be used to identify wildfire sedimentation and contaminant loading in downstream environments. Suites of petrogenic, biogenic, and pyrogenic hydrocarbon contaminants, potentially toxic anthropogenic metals, and geochemical compositions will be characterized in soils in burned areas and in sediments from San Pablo and Suisun Bay to identify sources and dispersal of wildfire runoff of sediment and contaminants to the estuarine ecosystem. Sedimentation and contaminant loading from land affect the quality of habitat in coastal and estuarine environments, and can impact the health of resident and migratory wildlife. This study lays the groundwork for understanding how an extreme intermittent event (wildfire+storm) can affect ecosystems in the Bay-Delta, and in a changing climate that could see more droughts, wildfires, and floods.

Keywords: Wildfire, flood, erosion, sediment, contaminants, PAHs, metals, Napa, Sonoma.
Session Title: Mercury and Contaminants
Session Time: Wednesday, September 12th, 8:20 AM - 10:00 AM, Room 314

Longfin Smelt from the Coast to the Delta II

Comparison of Acoustic and Trawl-Based Estimates of Small Fish Distribution and Abundance in San Pablo Bay

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In late October and early November 2017, four 12-hour fish sampling sessions were conducted in southern San Pablo Bay, as a part of Prop 1 funded Longfin Smelt study. During each session, simultaneous sampling was conducted with a midwater trawl, an otter trawl, and a BioSonics DT-X scientific echosounder using three different vessels in close proximity. Two of the four sessions were conducted at night, and all sessions covered a full tidal cycle. Daytime acoustic returns showed the vast majority of small fish (40-110mm length) in schools, often within the bottom half of the water column. At night, fish schools dispersed and individual fish were more evenly-distributed vertically, however the acoustically-estimated densities of air-bladdered fish were 1-2 orders of magnitude greater than densities derived from fish trawls. Different horizontal fish distributions found using trawl and acoustic methods could lead to conflicting ecological conclusions. For example, trawl-based fish densities indicated fish preferred sloped bathymetry at channel sides, while acoustics showed higher densities near the channel center. We urge further integration of acoustic with trawl and optical methods to better inform pelagic organism studies in the San Francisco Estuary.

Keywords: Fish, anchovy, longfin smelt, echosounder, trawl, distribution, habitat
Session Title: Longfin Smelt from the Coast to the Delta II
Session Time: Wednesday, September 12th, 10:20 AM - 12:00 PM, Room 306

The Demographic Importance of the San Francisco Estuary Population of Longfin Smelt

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The San Francisco Estuary (SFE) population of longfin smelt (Spirinchus thaleichthys) has experienced a dramatic decline in recent decades. Longfin smelt are estuarine and anadromous, with breeding populations ranging from Alaska to the SFE. To determine how unique the SFE population of longfin smelt is, we evaluated the range-wide demographic and genetic structure of longfin smelt populations using genomic data generated by RAD sequencing. Using a probabilistic framework, we estimated diversity indices for each population. Population structure was determined by PCA and admixture analysis, while genetic distances between populations were calculated using the Fst metrics. To examine population connectivity, simultaneous estimates of effective population sizes and the migration matrix of populations were determined using an approximate Bayesian approach based on the joint site frequency spectrum between populations.

We found evidence of ongoing gene flow from the SFE estuary north into the Columbia River, Humboldt, and Pitt and Harrison Lakes. Fst values, admixture analysis, PCAs, and migration analyses also support a close relationship between the SFE population, Columbia River, Humboldt, Pitt Lake, and Harrison Lake. The other populations analyzed, Lake Washington, Yakutat Bay (AK), the Skeena River were all genetically distinct. We conclude that the SFE population is currently a source of genetic diversity for populations to the north.

Keywords: longfin smelt, Genetics, Conservation, San Francisco Estuary
Session Title: Longfin Smelt from the Coast to the Delta II
Session Time: Wednesday, September 12th, 10:20 AM - 12:00 PM, Room 306

Historic and Contemporary Distribution of Longfin Smelt (Spirinchus thaleichthys) along the California Coast

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Longfin smelt (Spirinchus thaleichthys) was listed as threatened under the California Endangered Species Act in 2009. This anadromous fish exhibits complex life history patterns, using a variety of habitats from nearshore waters, to estuaries and lower portions of freshwater streams. While consistent data collection efforts in the greater San Francisco Bay region provide much information regarding this species, little is known throughout its remaining range in California. To help address this gap in knowledge, the objectives of this review were to gather, synthesize and analyze existing data for this species from areas outside of San Francisco Bay, and to identify areas of historic and contemporary presence, and habitat use along the northern and central California coasts. Observations were gathered from existing published articles, technical reports, museum collections and field observations. Longfin smelt captures were noted dating from 1889 to 2016 in a diverse range of habitats, including coastal lagoons, bays, estuaries, sloughs, tidal freshwater streams and nearshore habitats. Longfin smelt were found throughout northern and central California in 15 watersheds spanning from Moss Landing Harbor north to Lake Earl near the northern California border. Spawning was noted in both the Eel River and in tributaries to Humboldt Bay, with pre-and post-spawn individuals observed in tributaries to Humboldt Bay in more recent years. Use of nearshore waters was also noted with most longfin smelt collected in shallow waters relatively close to shore in the vicinity of known spawning areas. This paper provides a comprehensive look at the current and historical presence data available for this species along the California coast, highlights current data gaps, and identifies additional information needed to improve management and enhance recovery of the species within the State.

Keywords: Anadromous, California Endangered Species Act, Habitat, Humboldt Bay, Longfn Smelt
Session Title: Longfin Smelt from the Coast to the Delta II
Session Time: Wednesday, September 12th, 10:20 AM - 12:00 PM, Room 306

Go West (and South) Young Smelt: Mapping the Habitats Associated with Juvenile Longfin Smelt and their Prey

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and conservation of listed species requires an understanding of the environmental characteristics associated with trends in species distribution and abundance. Previous research in the San Francisco Estuary has emphasized the importance of spring freshwater outflow to support the Longfin Smelt (LFS) population, in part, because their abundance in the fall increases by approximately two orders of magnitude between low and high spring outflows. Despite this well-established relationship, mechanisms underlying why age-0 LFS respond favorably to higher flow remain unclear. To improve our understanding of factors associated with age-0 LFS distribution and abundance in the San Francisco Estuary, we examined the LFS and zooplankton (prey) catch data from California Department of Fish Wildlife 20-mm survey from 1995 to 2015 using Boosted Regression Tree (BRT) analysis, a powerful ensemble tool for examining large data sets. An initial list of over 130 predictor variables was compiled consisting of water quality variables measured concurrently with the survey, landscape attributes, and indexes of ocean conditions. Turbidity, conductivity, and temperature dominated the relative importance of predictor variables, consistent with other studies of LFS catch. Predictive performance of the BRT model on out-of-bag samples suggests the model may perform well in areas beyond the survey's spatial extent. Thus, we generated maps of predicted daily age-0 presence throughout the entire San Francisco Estuary and Delta for 6 years selected to represent contrasting conditions of LFS spawning stock abundance and water year types. The maps consistently identify habitats associated with LFS presence downstream of the 20-mm survey footprint (e.g. San Pablo Bay and the South Bay), particularly in wet years. Our work suggests LFS may be occupying habitats not currently sampled by the 20-mm survey and that targeting these habitats for additional sampling to test the predictions of our model is warranted.

Keywords: Habitat suitability; habitat mapping; calanoid copepod; 20-mm survey; hydrodynamic model
Session Title: Longfin Smelt from the Coast to the Delta II
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Multistate Occupancy Estimation for Longfin Smelt

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Long term monitoring data collected in San Francisco Bay-Delta system are used to assess the population status and trends in fish populations, including Longfin Smelt. Typically, not all fish are collected or species detected during sampling, which can systematically bias data and affect inferences. We used multistate occupancy estimators to evaluate the distribution, abundance, and detection probability of Longfin Smelt collected during 1995-2015 with three long-term surveys. Smelt occupancy and abundance was related to salinity, day of the year, and water temperature, but the nature of the relations (positive or negative) varied among surveys. There were strong spatial and temporal effects on occupancy and abundance that changed through time and were unrelated to the covariates used in the analysis. Detection of smelt was greatest for the 20 mm survey, averaging more than 50%, and was much lower for the summer townet and midwater trawl employed during the Bay study. As a result, Longfin Smelt occupancy and abundance were systematically underestimated by as much as 45%. Correlations revealed relatively strong positive associations between commonly used abundance indices and occupancy and abundance estimates for the 20 mm survey data, but weak associations for the summer townet survey and bay study data. These results emphasize the importance of accounting for incomplete detection of fish during sampling to ensure data quality. Further, the relatively large spatial and temporal effects suggest that unknown or unmeasured factors exert a strong influence on smelt population dynamics that if not understood, may reduce the effectiveness of management actions for conserving Longfin Smelt.

Keywords: sample bias, occupancy estimation, spatial dependence,
Session Title: Longfin Smelt from the Coast to the Delta II
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Human Dimensions of Restoration

Working With Nature across the Land-Use Spectrum: A Holistic Approach to Ecological Resilience

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Many approaches to ecological restoration and enhancement of ecosystem services focus on particular parts of the landscape – open spaces high in watersheds, urban areas in valleys, waterways or shorelines. This cookie-cutter approach to dividing up large physical and ecological systems is more tractable, but may fail to maximize benefits across the full system. Across the land use gradient from open space high in watersheds, to urbanized and farmed valleys, to the shoreline, nature-based interventions can provide multiple benefits to people and wildlife. This presentation will highlight several novel initiatives across the land-use spectrum that are working toward this holistic approach to restoration of ecological functions and ecosystem services in the San Francisco Bay Delta region. They stem from a synthesis of the scientific literature on ecological resilience, and they focus on shorelines, creeks, urban areas, working landscapes, and open spaces. While the entire complex equation of how to optimize ecosystem services and ecological functions across the landscape is not yet solvable, these initiatives begin to point toward a path for a new approach to resilience focused on working with nature to benefit from natural processes.

Keywords: ecological resilience, climate adaptation, ecosystem services, nature-based solutions
Session Title: Human Dimensions of Restoration
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Science-Based Regulatory Permitting for Resilient Tidal Habitat Restorations

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The acquisition of environmental permits is a major cost item for tidal wetland restoration, and causes substantial restoration implementation delays. Meanwhile, tidal marsh-dependent endangered species such as Ridgway's rail and salt marsh harvest mouse are increasingly under threat by sea level rise in the San Francisco Estuary. Given the accelerating nature of sea level rise, restoration of tidal habitats should be implemented on a large scale and soon to have any chance of contributing to the recovery of these species. The rates of future sea level rise and salinity increase are highly uncertain, and their interaction with other processes such as sediment deposition, plant growth, decomposition, species distribution shifts, colonization by invasive species remains largely unknown. We found that designs for restoring resilient tidal habitats require the use of the most current predictions of sea level rise and other manifold interacting effects of climate change. Restoration designs should not only consider habitat establishment within the foreseeable future, but also evolution of the habitat over the course of many decades. Implementation of such resilient designs faces regulatory challenges. Regulatory agencies tend to focus on crediting immediate habitat establishment, but may not be able or willing to acknowledge benefits of resilience in the face of long-term climate change. We review several recent concepts and tools (e.g., projections of the California Ocean Protection Council and progress on biophysical feedbacks) that can be used to develop resilient designs for tidal marsh restorations, and we provide examples of resilient designs from recent projects, including planned restorations at Tule Red, Bay Point, and Lower Walnut Creek. Although recent plans for regulatory integration teams could allow for some streamlining of permitting, these efforts should also include a mechanism to consider the latest climate change data and modeling in evaluating permit requirements of resilient wetland restoration designs.

Keywords: Resilience, restoration, climate, permitting, tidal marsh
Session Title: Human Dimensions of Restoration
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The Lower Walnut Creek Restoration Project: Sustainable Flood Management and Ecosystem Restoration in Southern Suisun Bay

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The tidal reaches of many creek channels entering San Francisco Bay experience high rates of sediment deposition due to the combined fluvial and estuarine sediment supplies and the mild channel slopes. Sediment that accumulates within the creek channel reduces conveyance capacity and increases flood risk to adjacent properties. Historic flood management practices for these tidal creeks relied heavily on environmentally-disruptive channel dredging to maintain flood capacity. Our study explores the opportunities and limitations of a nature-based approach to flood protection as an alternative to dredging along the lower reaches of Walnut Creek near Martinez, CA.

The Lower Walnut Creek Restoration Project is a multi-benefit habitat and flood protection project along the lower 4 miles of Walnut Creek and Pacheco Creek. The project proposes a nature-based approach to flood protection by setting back levees and reconnecting historic floodplains and tidal marshes to the creek channels.

We present hydraulic and geomorphic analysis to evaluate the near term and future flood protection benefits that can be achieved with a natural infrastructure project. The analysis of future conditions includes the consideration of anticipated sea-level rise and geomorphic changes due to marsh accretion as well as the effects of tidal and fluvial channel scour.

The results of this analysis indicate the potential for significant reductions in flood levels during small to moderate (2-year and 10-year) flood events, however hydraulic constrictions at existing transportation infrastructure downstream of the project site limit the potential reduction in flood levels during extreme (100-year) flood events.

We also present outcomes from the project's outreach and collaborative planning efforts with adjacent landowners. This collaborative planning process aims to improve the understanding of existing flooding issues and infrastructure vulnerabilities, consider feasible solutions, set realistic expectations for levels of flood protection into the future, and identify new public-private partnerships.

Keywords: Lower Walnut Creek, nature-based flood protection, multi-benefit project, hydraulics, geomorphology
Session Title: Human Dimensions of Restoration
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How Community Science Collected Data Benefits Research and Increases Public Awareness - Stevens Creek and Permanente Creek Water Quality Monitoring Project

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Grassroots Ecology is a nonprofit organization based in Palo Alto that leverages the power of volunteers to create healthy ecosystems across Silicon Valley. We restore native habitat in open spaces and neighborhoods, steward creeks and watersheds, and provide hands-on nature education. Observing the lack of public knowledge about local creek water quality and little data being collected, Grassroots Ecology (formerly Stevens and Permanente Creek Watershed Council) developed a pilot water quality monitoring program in the Stevens and Permanente Creek watersheds (Santa Clara Co., CA) in 2004 to address the issue. After obtaining additional funding in 2006, we expanded our water quality sampling to eight locations along Stevens Creek and one location at Permanente Creek and included a new volunteer biomonitoring program surveying benthic macroinvertebrates. Water quality data is collected in accordance with CA SWAMP methods. . In addition to having volunteers learn how to use scientific equipment and collect water quality data, we discuss the different types of nonpoint source pollutants that are most commonly found in Stevens Creek. Since monitoring Stevens Creek in 2004, we have continuously seen high turbidity at the reservoir outlet and as far as 9.5 miles downstream. In 2011 we started partnering with the City of Cupertino, Los Altos and Sunnyvale to host World Water Monitoring Challenge events to bring further awareness of nonpoint source pollution to the public. In the past 3 years, we have held over 75 community science events and engaged over 800 volunteers. This type of community involvement is a great way to bring scientific knowledge to the public, which in turn leads to behavioural change. The importance of our program has been highlighted in articles published by the San Jose Mercury News and the Cupertino Courier.

Keywords: water quality, community science, nonpoint source pollution, data
Session Title: Human Dimensions of Restoration
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The Science, Practice, and Benefits of Regional Long-Term Monitoring

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Tidal wetland monitoring in the San Francisco Estuary has generally been viewed through the lens of regulatory mitigation requirements for restoration projects. However, as tidal wetland restoration has shifted from small-scale mitigation to large-scale, publicly-funded restoration for public benefit, wetland monitoring has taken on new significance. It is now critical that we evaluate “restoration success” in the context of this massive public investment. We must objectively compare which approaches are working, which are not, and how we can improve our restoration practices. Further, we need to organize our monitoring approach to become both efficient and effective. Working at regional scales makes this challenge more achievable. The recent prominence of environmental uncertainty (e.g., sea-level rise, sediment deficit, drought, flooding) adds additional urgency to the need for regional monitoring. It is critical that we strategically assess mature tidal marshes and their threatened species now that we realize their vulnerability to rapid environmental change in the foreseeable future. Further, what we learn from mature tidal wetlands will significantly help to evaluate trajectories of restoration projects and provide early warning of negative environmental effects in the future. Lastly, we need to institute actions to protect our shorelines, promote adaptive success of restorations, and help to sustain our mature tidal marshes. All of these actions will require careful monitoring to assess their effectiveness. The National Estuarine Research Reserve System (established in the 1970’s), a NOAA program that partners with state agencies such as San Francisco State University, is grounded on long-term tidal wetland monitoring for public benefit. Some examples illustrating the benefits of coordinated regional monitoring will be cited to illustrate the value of this approach, and the importance of applying these principles to a regional tidal wetland monitoring program for the San Francisco Estuary will be discussed.

Keywords: regional tidal wetland monitoring, climate change, sea-level rise, coastal intelligence
Session Title: Human Dimensions of Restoration
Session Time: Wednesday, September 12th, 10:20 AM - 12:00 PM, Room 307

Physics to Fish in the North Delta: How Physical and Biological Processes Influence Habitat Quality for Fish II

Success and Potential Impacts of Corbicula in Varying Habitat Types and Restoration Sites in the North Delta

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The benthos was sampled in Little Holland Tract (LHT) and its surrounding sloughs, Wildlands (W), Cache and Lindsay Sloughs (CS, LS) in summer-fall 2017. Our goals were (1) to determine the bivalve grazing rate, coincident with flux studies, in order to estimate the loss rate of phytoplankton to the bivalves during the study period in LHT and W, and (2) to examine Corbicula recruitment and success in varying North Delta habitats towards improving our understanding Corbicula's potential impact on restoration success. Corbicula biomass, recruitment, and grazing rate turnover (GRTO, grazing rate normalized for depth= /d) were estimated at all locations.

Habitat types included flooded island (LHT), restored small meandering slough (W), and two sloughs with a history of geographic and environmental alterations (CS, LS).

We used Corbicula recruitment and growth as indicators of habitat favorability. The highest Corbicula biomass was in CS and the lowest in LHT and W. Recruitment was present in all months except in CS, and was consistent through the seasons in W. GRTO was highest and consistent through the seasons in CS and lowest in LHT.

Corbicula biomass displayed a high to low gradient from North to South in LHT, CS and W. The LHT population likely benefitted from southward transport of food from surrounding sloughs.

GRTO within LHT was at or near zero in the north and increased to >1 m3/m2/d in the south. Results within LHT show that grazing was not likely to be a factor in phytoplankton growth in the north during the flux study. In W, the Corbicula population in the south peaked in July with GRTO >0.5 m3/m2/d. These GRTO values may have locally influenced the biomass of phytoplankton and, potentially, its export from W.

Keywords: Corbicula, Biomass, Grazing Rate, North Delta
Session Title: Physics to Fish in the North Delta: How Physical and Biological Processes Influence Habitat Quality for Fish II
Session Time: Wednesday, September 12th, 10:20 AM - 12:00 PM, Room 308-310

Nitrogen and Light Limitation of Primary Production in the Northern Sacramento-San Joaquin Delta

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Open waters of the Sacramento-San Joaquin Delta support relatively low phytoplankton biomass compared to other aquatic ecosystems despite ample nitrogen (N) and phosphorus (P) concentrations in many locations. These high nutrient, low productivity dynamics suggest there are alternative physical, chemical, or biological controls of pelagic primary productivity. We assessed controls of algal biomass and primary production in space and time by analyzing variation in physical, chemical, and biological conditions in the Sacramento Deep Water Ship Channel and conducting incubation experiments to test for nutrient limitation. Routinely, the greatest algal biomass occurred in the uppermost sections of the channel in early summer followed by N depletion and reduced algal biomass later in the year. In downstream regions, light appeared to be the most important control of algal biomass as turbidity and nutrient concentrations remained elevated year-round. Results from incubation experiments aligned with the historical dataset as only the upper channel responded to N additions after the summer depletion of available N. Together, these results suggest that controls of primary production vary spatially and temporally, including both light and N limitation. Thus, bottom-up strategies to boost the pelagic food web and promote secondary production of zooplankton and/or fisheries should recognize the spatial and temporal heterogeneity of multiple physical and chemical properties that regulate ecosystem functions in the northern Delta.

Keywords: primary production, nitrogen, light, ecosystem
Session Title: Physics to Fish in the North Delta: How Physical and Biological Processes Influence Habitat Quality for Fish II
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Yolo Bypass Adaptive Management: Managing Summer and Fall Outflows to Improve the Downstream Pelagic Food Web

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The Yolo Bypass/Cache Slough Complex is a region in the Delta that is known to still be relatively richer in plankton. However, the food web benefits of this region may be limited by a lack of flow during dry months to subsidize downstream areas in the Delta. Research by our team suggests that even modest agricultural flows through the Yolo Bypass can improve local and downstream plankton production. For example, in the fall of 2011 and 2012, agricultural drainage flows appear to have been responsible for the first fall plankton blooms in over twenty years in the Delta. Hence, we posited that enhanced flow through the Yolo Bypass could benefit pelagic food availability in this region and downstream during a critical time period for Delta Smelt sub-adult growth and development. Towards this goal and in response to the CA Natural Resources Agency identifying North Delta flow augmentation as a Delta Smelt Resiliency Strategy, DWR along with other State and Federal agencies collaborated with local water agencies and landowners to generate a flow pulse through the Yolo Bypass in summer 2016. The results from this study showed a significant increase (ANOSIM p< 0.05) in the downstream phytoplankton biomass in the lower Yolo Bypass and Cache Slough Complex in response to the modest flow pulse. Based on SIMPER analysis the species contributing to this shift in biomass was primarily from large-celled diatoms Aulacoseira sp. (36%) and Cyclotella sp. (14%). We also observed a modest increase in calanoid copepod densities, with growth and reproductive rate experiments of these calanoid copepods showing a positive correlation to increasing phytoplankton biomass. This managed flow pulse not only provided positive benefits to Delta Smelt habitat, but was also a successful example of adaptive management that will now guide us to facilitate a fall flow pulse in 2018.

Keywords: Yolo Bypass, Cache Slough Complex, Delta Smelt, phytoplankton, zooplankton, flow
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Fish Communities of the Cache Slough Complex: Marshes, Macrophytes, and Liberty Island

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The Cache Slough Complex, a network of tidal sloughs in the northwest Sacramento-San Joaquin Delta, contains a diverse array of habitat types, including tidal marshes, remnant riparian hardwood forest, intertidal embayment, and agricultural floodplain. This physical habitat is overlain by hydrologic variability, with tidal fluctuations, seasonal runoff from Ulatis, Putah, and Cache Creeks, and infrequent floodplain inundation via the Yolo Bypass. This milieu supports a diverse fish community, including many native species uncommon in the rest of the Delta. This diversity provides an opportunity to learn about the habitat associations of both native and non-native fishes. Using multiple gear types and years of sampling we explicitly evaluate the distribution of little-studied native and select non-native fishes with respect to physical and hydrologic features within the Cache Slough Complex. In this talk we discuss the value of different habitat types to different fish communities, and potential outcomes of future habitat restoration actions.

Keywords: Fishes, community, habitat
Session Title: Physics to Fish in the North Delta: How Physical and Biological Processes Influence Habitat Quality for Fish II
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Integrating Multiple Data Types to Improve Understanding of the North Delta

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Complex interdisciplinary studies yield complex data streams and the North Delta studies are no exception. However, to be useful to the largest number of people, these complex results must be integrated across disciplines and then distilled down to straightforward messages applicable to important management questions. Ongoing studies in the North Delta have highlighted a number of such messages. Large-scale events are important at multiple scales. Atmospheric pressure and wind can influence water level sufficiently to effect flooding of a marsh plain at the local level. Sediment transport through the North Delta during large flooding events is important in moving sediment into the lower Delta and bays but is also important in re-setting characteristics of bed sediments at the local habitat level, so that resuspension processes continue to generate adequate turbidity. During periods when Yolo Bypass is not flooding, the upper region of the North Delta is poorly connected to the lower region because of limited mixing and landward net flow during much of the year. The result is long water residence times, which promote increased phytoplankton abundance, but largely of smaller and less nutritive blue-green algae. Fish food organisms (primarily zooplankton) may similarly be retained. However, fish can likely only take advantage of long residence time if they move into these areas via active swimming. So, fish utilization of favorable habitat areas (natural or restored) may well depend on multiple factors that influence fish occupancy and movement (e.g., water temperature, turbidity, food density). Observational studies are useful for advancing understanding of ecosystem function in the North Delta; however, experimental studies can more directly address questions about effective management strategies. Continued habitat restoration in the North Delta provides opportunities to experimentally address management questions about project design and function and provide results applicable throughout the Delta.

Keywords: North Delta, interdisciplinary studies, habitat restoration
Session Title: Physics to Fish in the North Delta: How Physical and Biological Processes Influence Habitat Quality for Fish II
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Science on Salmonids II

Survival and Movement of Hatchery Winter-Run Chinook Walmon Juveniles

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Successful management of winter-run Chinook salmon requires a mechanistic understanding of factors that influence survival. The freshwater outmigration of juvenile salmon is a journey through habitat heavily altered by humans. Detailed data on movement and survival of outmigrating juvenile winter-run Chinook is necessary to manage this endangered species. Juvenile Chinook salmon produced at Livingston Stone National Fish Hatchery were implanted with small acoustic transmitters (JSATS: Juvenile Salmon Acoustic Telemetry System) and tracked by receivers placed throughout their migration from Redding to the Golden Gate Bridge. High resolution receiver spacing allows identification of movement behaviors and areas of increased mortality. Repeating the study over several years (2013-2018) allows comparisons among years with different flow conditions. Comparing the outmigration among the Sacramento River, Delta and Bay showed that transit time was longest and most variable for the River, shorter and less variable through the Delta, and shortest through the Bay. Extended in river holding behavior was seen in some fish for certain years. Survival was variable for the River (18-55%), consistent for the Delta (35-42%) and variable for the Bay (30-70%). A section of the River between Mill Creek and Colusa had high mortality for some years. Generally high flows had higher River survival but one year had high survival during relatively low flows. Total outmigration success to the ocean varied among years from 2-25%. High resolution data on movement and survival during the juvenile outmigration will increase understanding of basic biology, provide real data to inform life cycle models, and guide management actions to yield the best outcome.

Keywords: Winter-run Chinook Salmon Survival Acoustic Telemetry Tagging Juvenile
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Movement and Survival of Reintroduced Juvenile Spring-Run Chinook Salmon in the San Joaquin River and South Delta

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Human activity has transformed the Sacramento San Joaquin Delta from a shallow river characterized by tidal wetlands and riparian vegetation into a gauntlet of channels reinforced with levees and water diversion pumps. Imperative to the reestablishment of spring-run Chinook salmon populations isunderstanding movement patterns and survival of fish during critical life stages.Our goal is to better understand the response of out-migrating juvenile Chinook salmon across multiple years of varying water flows and environmental conditions in an effort to gain insight on areas of high fish mortality. In March of 2017 and 2018, 700 juvenile spring-run Chinook salmon were implanted with 0.217g acoustic transmitters and their emigration from the restored reaches of the San Joaquin River to the Pacific Ocean was tracked. High flows in 2017 provided access to floodplains and juvenile fish delayed out-migration for 6-11 weeks from the upper reaches of the study area. A mark-recapture model was used to estimate reach-specific survival, transition probabilities at junctions, and detection probabilities at receiver stations. Survival through the restoration area to the entrance of the Delta was relatively high (31%), however survival through the Delta to the Pacific Ocean was very low (4%). A comparison of reach-specific survivalbetween years will be conducted upon final removal of the 2018 array. Theseinitial resultssuggest that restoration efforts are benefittingjuvenile salmon in years with ample runoff, but that regardless of high observed river discharge,the Bay-Delta estuary remains a perilous place for juvenile Chinook salmon. In the near future, pulse flows that create turbid water to aid in predator avoidance by juvenile salmon will be an important sustainable practice by Bay-Delta management. Over the long term, habitat restoration through the Delta will be crucial for the survival of fish in the last leg of their journey to the ocean.

Keywords: Conservation, telemetry, spring-run Chinook Salmon
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Effects of Static and Dynamic Environmental Factors on Reach-Specific Movement and Survival Rates of Outmigrating Hatchery-Origin Sacramento River Winter-Run Chinook Salmon

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Sacramento River Winter-run Chinook Salmon have experienced a precipitous population decline in recent years, prompting increases in supplemental hatchery production from 200,000 to 600,000 pre-smolts from a small conservation hatchery. Over the last five years escapement dropped from 6,400 to less than 1,000 individuals with increasing reliance on hatchery supplementation as the proportion of hatchery-origin fish climbed from 6% in 2013 to 86% in 2017. Much of the decline has historically been attributed to loss of spawning habitat, but to understand the mechanisms for recent declines, our goal was to determine what environmental conditions might be associated with in-stream mortality during smolt migration to sea. We used the Juvenile Salmon Acoustic Telemetry System (JSATS) technology to estimate reach-specific survival rates for hatchery-raised winter-run released below Keswick Dam. Fish were tracked by receivers placed every 10-50 river kilometers throughout their 550 km migration route to the sea, ending at the Golden Gate Bridge. Average fish size ranged from 93-100 mm Fork Length, with 148 fish released in 2013 up to 570 released in 2016 and 2017. Overall survival to the ocean ranged from 4 to 22%, depending on release year and group. For each year, we assessed reach-specific survival in relation to modeled flow and temperature data, off-channel habitat availability, reach length and area, the number of tributaries and diversions per reach, river sinuosity, and the percent of shaded riverine cover. Preliminary results suggest a strong positive relationship between survival and flow, which in turn reduces instream residence time; however, low survival estimates associated with one of the wettest years on record in 2017 suggest other factors may be important to consider for managing hydrology to recover winter-run in the Sacramento River.

Keywords: Sacramento River winter-run Chinook Salmon reach-specific survival mark-recapture
Session Title: Science on Salmonids II
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A Hybrid Study Design Combining Acoustic Telemetry and Coded Wire Tagging to Estimate Trawl Gear Efficiency and Run-Specific Abundance of Juvenile Salmon Entering and Exiting the Delta

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Problem Statement: Abundance estimates of juvenile salmon populations entering and exiting the Delta have been identified as a key management parameter. However, coded wire tagging (CWT) experiments alone yield imprecise estimates of trawl gear efficiency and population abundance owing to low recapture rates and uncertainty about the number of tagged fish available for capture.

Approach: Here, we analyze data from a novel study design that pairs acoustic tagged (AT) fish with releases of coded wire tagged (CWT) hatchery Chinook salmon. In this hybrid design, a multistate mark-recapture model applied to AT fish is used to estimate survival to trawl sites at Sacramento and Chipps Island. In turn, survival estimates allow us to estimate 1) the abundance of CWT fish available to be captured by trawls, 2) trawl gear efficiency, and 3) abundance of different genetic races passing trawl sites.

Results: We found the hybrid study design allows trawl gear efficiency to be estimated over weekly time periods (e.g., 5-10 days) providing multiple estimates of efficiency. Furthermore, we found that tow-level covariates can be incorporated into the model to quantify tow-to-tow variation in gear efficiency. We also found that trawl location (north, middle, south channel of Chipps Island) and tow direction (upstream or downstream) had significant effects on trawl gear efficiency.

Relevance: Devising methods to estimate abundance of juvenile salmon entering and exiting the Delta is critical for developing long-term monitoring data for assessing population status, informing life cycle models, and guiding management actions affecting endangered populations.

Keywords: Chinook salmon, trawl gear efficiency, acoustic telemetry, coded wire tags
Session Title: Science on Salmonids II
Session Time: Wednesday, September 12th, 10:20 AM - 12:00 PM, Room 311-313

Movement and Survival of Acoustic-Tagged Juvenile Chinook Salmon Released Upriver of Shasta Dam, 2017

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Problem Statement: Stake holder interests have spurred the reintroduction of the critically endangered population of winter-run Chinook salmon to tributaries upriver of Shasta Dam, northern CA. Towards this effort, two groups of acoustic-tagged juvenile hatchery late-fall Chinook salmon were released at the mouth of the McCloud River as surrogates to determine how the fish would distribute and survive.

Approach: We measured travel times to the dam, and the fractions of fish that moved between locations within Shasta Reservoir and to the dam. We also fit a Cormack-Jolly-Seber model to determine average detection rates and apparent survival probabilities of the tagged fish over the two 3- month studies.

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Results: In our first (February) release of 262 tagged fish, 182 fish (70%) were detected at least once at the dam, 41 tagged fish (16%) were detected at least once downstream of Shasta Dam, and 3 fish (1%) traveled as far as San Francisco Bay. During the second (November) release of 355 tagged fish, 4 fish (1%) were detected at Shasta Dam and one fish was detected below Shasta Dam. Fish detections were so sparse that detection and survival probabilities were inestimable for the second release group of tagged fish.

Relevance: The first release of fish was fortuitously exposed to exceptionally high river flows and dam discharges, which may have contributed to the successful downstream migration and detection of these fish. The reported fish travel times, detection, and survival rates are the first estimates of juvenile salmon emigration from locations above Shasta Dam in more than 70 years, and should help inform managers how to best assess juvenile winter-run Chinook salmon and assist in their reintroduction to watersheds upriver of Shasta Dam.

Keywords: Salmon reintroduction
Shasta Dam
Movement and survival
Session Title: Science on Salmonids II
Session Time: Wednesday, September 12th, 10:20 AM - 12:00 PM, Room 311-313

Pesticides and Contaminants

A Review of Water Quality Science in the Delta: Part 1, Chemical Contaminants and Nutrients

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As part of its charge to review science activities that support adaptive management in the Delta, the Delta Independent Science Board (DISB) has completed a review of the scientific basis for assessing water quality in the Delta. Focusing this review on chemical contaminants and nutrients, we also assessed how water quality information is being used in management decisions, especially for supporting adaptive management. Our analysis of the state of water quality science in the Delta is based on information gathered from: (1) a literature review of recent publications on the topic of water quality, (2) responses to a questionnaire distributed to several agencies, (3) in-person interviews with individuals involved in different aspects of water quality, and (4) comments received on a draft released for public comment. We also invited presentations to the DISB, and members of the DISB attended meetings of several working groups involved with water quality in the Delta. We have now published our review, where we report four main findings, along with ten general findings that are accompanied by specific recommendations. This presentation will summarize our findings and recommendations, outline next steps in disseminating the review and assessing its effectiveness, and describe and seek input on the DISB's plan for our next phase of water quality science review. Recommendations include continued and expanded use of water quality data in support of management decisions and policies. We also suggest that more aspects of Delta water quality be managed adaptively and that additional resources be directed to support coordinated and integrated water quality monitoring and science efforts.

Keywords: water quality, selenium, mercury, nutrients, drinking water, pesticides, CECs
Session Title: Pesticides and Contaminants
Session Time: Wednesday, September 12th, 10:20 AM - 12:00 PM, Room 314

Data Driven Evaluation of Pesticide Concentrations Observed in the Aquatic Environment

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Data Driven Evaluation of Pesticide Concentrations Observed in the Aquatic Environment

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We propose to develop a data driven geospatial model that can interpret the pesticide monitoring data compiled from many programs. Due to differences in study objectives and practical constraints, those programs may monitor sites located anywhere in the hydrological system-from the edge of the field to tributary or main stem sites. With varying pesticide contribution from their corresponding drainage areas, contaminants at the monitoring sites may display different behaviors, such as range of concentration, variation over time, frequency of detection and exceedance over water quality thresholds. In addition, because sites located downstream also integrate the signals from sites located upstream and other unmonitored region, signals at those sites are interrelated. This dependency is difficult to characterize due to variation in the lag-time resulted from off-site transport, hydrologic flow, and degradation. Utilizing all available monitoring data to assess statewide pesticide occurrence and trends thus requires an understanding of the hydrologic conditions and contributing area to any given sampling site. We propose to build a database with extensive list of geomorphological, hydrological, climatic and anthropogenic attributes for any surface water locations and develop data-driven model that can link the differing behaviors in pesticide concentrations at various monitoring sites to the large array of the attributes values. The ultimate goal is to use this model to predict pesticide concentrations for any surface water location in California, which can then be utilized in risk assessment and management decision making.

Keywords: pesticide, watershed attributes, data-driven model
Session Title: Pesticides and Contaminants
Session Time: Wednesday, September 12th, 10:20 AM - 12:00 PM, Room 314

Understanding Inputs of Current-Use Pesticides to Cache Slough, Liberty Island, and the Yolo Bypass

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The Cache Slough complex and the Yolo Bypass are areas of critical habitat for several Delta fish species including the threatened Delta Smelt, and multiple habitat restoration projects are planned in these areas. In addition, recent research suggests that the Yolo Bypass can serve as an important source of phytoplankton and zooplankton, benefitting fish downstream in the Cache Slough complex and the wider Delta. However, these areas are impacted by agricultural and urban runoff containing mixtures of current-use pesticides which may have direct, harmful effects on fish as well as on plankton production and quality.

As part of several ongoing studies and in collaboration with State and regional partners, the USGS Pesticide Fate Research Group collected and analyzed water samples from multiple inflows to, and sites within the Cache Slough complex and Yolo Bypass during 2015-2017. Samples were collected during a range of flow conditions, including baseflow, storm runoff, and managed pulse flow conditions and were analyzed for over 150 current-use pesticides and pesticide degradates. A total of 112 samples were analyzed from 11 sites, and all samples contained mixtures of from 6 to 29 current-use pesticides. Overall, the numbers of pesticides detected and their concentrations were generally greater in samples collected from inflow sites versus sites within the Cache Slough complex. Pesticide concentrations varied seasonally and tended to be higher during the winter and spring months especially during storm events. Thirty-three samples contained at least one pesticide with a concentration exceeding an Environmental Protection Agency established aquatic life benchmark, and most of these exceedances were for the insecticides bifenthrin, dichlorvos, fipronil, and imidacloprid, and the fungicide carbendazim. Knowledge of the composition and timing of occurrence of these pesticide mixtures is critical to understanding and mitigating any potential detrimental environmental effects in critical habitats of the North Delta.

Keywords: Pesticides, Water quality, Contaminants
Session Title: Pesticides and Contaminants
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Identifying Unknown Chemical Toxicants Using Nontarget Analysis and Suspect Screening

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Over 2300 miles of stream and river reaches in California in 119 watersheds have been identified as impaired by unknown causes of toxicity (California 2012 303(d) list). Identification of the chemical(s) responsible for toxicity is challenging, and conventional approaches often fail to isolate causes, restricting the potential for source reduction or targeted treatment. Episodic toxicity toward sensitive aquatic species is observed in urban tributaries and in wastewater treatment plant effluents. Combining whole organism and/or in vitro toxicity tests with high-resolution mass spectrometry provides a broad-scope method to identify toxic agents without the requirement of presupposing the responsible chemicals or chemical classes. This presentation summarizes Bay-Delta relevant case studies that illustrate how these techniques are combined and deployed in ambient waters and wastewater effluents to identify potential toxic agents. A unified workflow using solid phase extraction to capture and concentrate constituents from water, followed by gas chromatography quadrupole time-of-flight mass spectrometry (GC-QTOF-MS) and liquid chromatography quadrupole time-of-flight mass spectrometry (LC-QTOF-MS) has been developed and validated. The methods used vary with project objective, but typically include quantification of over 100 target compounds, screening of over 5000 suspect compounds in mass spectral databases, and analysis of thousands of additional “nontarget” compounds that may not appear in databases because they are environmental degradation products, human metabolites, impurities introduced during manufacturing, or are relatively new to commercial use. Strategies for broad incorporation of nontarget chemical analysis in toxicity monitoring efforts are outlined.

Keywords: Contaminants, Pesticides, Pharmaceuticals, mass spectrometry, wastewater, monitoring, toxicity testing, watershed
Session Title: Pesticides and Contaminants
Session Time: Wednesday, September 12th, 10:20 AM - 12:00 PM, Room 314

Trihalomethane Precursors in the Delta and Beyond: Comparison of Major Regional Sources and Transport in Central Valley Rivers and the State Water Project

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California's water purveyors face increasing pressure to provide potable water that meets high standards for municipal supply and public health. Removal of trihalomethanes (THMs), a regulated category of organic carbon-derived disinfection byproduct (DBP), from municipal water supplies requires costly treatment steps. Limiting or reducing the capture / uptake of THM precursors from waterways into municipal treatment systems can therefore be economically preferable to deploying and operating additional water treatment technologies and systems. Development of management actions that reduce THM precursors at their source, or through optimization of water withdrawal procedures, would be enhanced by additional knowledge surrounding THM precursor concentrations, their sources, and their fates within the Sacramento-San Joaquin river system and its tributaries. We evaluated THM precursor sources from multiple land use categories and hydrologies, demonstrating potential for urban land use to release water with very high THM formation potential (THMFP; median 618 µg L-1) that was greater than storm water (median 460 µg L-1), irrigation (357 µg L-1) releases from agricultural systems, or a natural watershed (median 123 µg L-1). While individual storm events released high THM precursor concentrations over short periods, dry season agricultural irrigation has the potential to release elevated THM precursor levels for several months. Experimental bioassays and sampling along 333 miles of the California Aqueduct confirmed bioavailability and photoxidation potential of less than 10% for THM precursors. The longevity of THM precursors suggests that rivers have strong potential to act as conduits for THM precursors, enabling near-conservative transfer of THM precursors from hundreds of miles upstream to municipal water intakes in and south of the Delta.

Keywords: trihalomethanes, disinfection by-product precursors, Delta, dissolved organic carbon, DOC
Session Title: Pesticides and Contaminants
Session Time: Wednesday, September 12th, 10:20 AM - 12:00 PM, Room 314

Crossing Bay-Delta-Watershed Intersections: Science, Management, and Policy Issues

Crossing Bay-Delta-Watershed Intersections: Science, Management, and Policy Issues

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Despite the direct connection of the San Francisco Bay and the Sacramento-San Joaquin Delta within a single estuarine system, as well as the clear ecosystem linkage to the watershed, scientific research, management, and policy across the regions are not well coordinated. This panel, including scientists, managers, and policy makers, will discuss challenges to improved integration across the Bay-Delta estuary from their different perspectives.

Session Title: Crossing Bay-Delta-Watershed Intersections: Science, Management, and Policy Issues
Session Time: Wednesday, September 12th, 1:15 PM - 2:55 PM, Room 306

Restoration Lessons Learned

Restoration on Putah Creek Provides Home for Chinook Salmon

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Lower Putah Creek in the Central Valley of California flows from Lake Berryessa through Yolo and Solano counties, into the Yolo Bypass. The number of adult fall-run Chinook Salmon spawning in Putah Creek has increased from fewer than 10 in 2013 to over 500 in each of the past four years. Restoration efforts have provided access to habitat that was not available to salmon for decades. Attraction flows and minimum flows were established, and spawning gravel that had been buried by years of siltation and compaction were uncovered. During the drought of 2012-2016, Central Valley hatcheries trucked juveniles downriver for release in the estuary to increase the number of fish surviving to the ocean. This action increased straying across the waterways of the region when these "trucked" fish returned as adults. Coded wire tag recoveries from adult carcasses in Putah Creek show that all of the marked fish sampled in Putah Creek were trucked to locations far downstream from hatcheries. Otolith microchemistry has revealed that unmarked adult salmon in 2016 originated from at least five hatcheries and that some fish may have be the result of natural spawning in Putah Creek. A rotary screw trap deployed in the spring of 2017 has confirmed that spawning is successful and Putah Creek offers the habitat necessary for producing juveniles. These findings indicate the potential for re-establishing Chinook Salmon in a creek that hasn't supported a run since the mid-twentieth century.

Keywords: Restoration, Putah Creek, Chinook Salmon, Otolith
Session Title: Restoration Lessons Learned
Session Time: Wednesday, September 12th, 1:15 PM - 2:55 PM, Room 307

Process-Based Restoration to Benefit Juvenile Salmonids on the Lower Yuba River: The Hallwood Side Channel and Floodplain Restoration Project

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Anthropogenic actions on the Lower Yuba River dating back to the Gold Rush altered geomorphic and hydraulic conditions, and subsequently the available habitat for rearing juvenile salmonids. The Hallwood Side Channel and Floodplain Restoration Project was developed to address the United States Fish & Wildlife Service Anadromous Fish Restoration Program's goal to double natural production of anadromous fish in Central Valley rivers. Specifically, the Project was designed to restore and enhance ecosystem processes, focusing on juvenile rearing fall and spring-run Chinook Salmon and California Central Valley Steelhead. The Project is supported by numerous agencies, stakeholders, and relationships with aggregate mining landowners to facilitate economically efficient habitat enhancement. Through several years of planning, design, permitting, pre-project monitoring, Phase 1 begins implementation in summer 2018. The design process targeted increasing inundation frequency and duration during the rearing period in a network of perennial and seasonally inundated side channels, and removing large, unnatural constraints separating the main channel from its floodplain. Focused riparian planting was paired with predictions for natural recruitment in an experimental setting. The full Project will proceed over 4 to 6 years and will create or enhance up to 165 acres of seasonally inundated floodplain habitat, 2 miles of perennial channels, and 6 miles of seasonal side channels and alcoves. Two-dimensional hydraulic models and habitat suitability indices were used to predict habitat benefits, such as an increase in inundated acreage by up to 37%. Weighted usable area is expected to increase by up to 64%, and wetted edge habitat would increase by up to 74%. Due to a design based on restoring lateral connectivity and removing unnatural constraints that is coupled with a robust monitoring program, the Project will provide a wealth of information regarding restoration success at a large scale with application in upslope and Bay-Delta settings alike.

Keywords: process-based habitat restoration, hydraulics, design, Chinook salmon, steelhead, riparian, floodplain
Session Title: Restoration Lessons Learned
Session Time: Wednesday, September 12th, 1:15 PM - 2:55 PM, Room 307

Patterns of Fish Community Composition and Abundance Across an Open Water-Tidal Wetland Interface in the Upper San Francisco Estuary Provide a Recipe for Habitat Restoration

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A large amount of habitat restoration is planned for the upper San Francisco Estuary and Sacramento - San Joaquin Delta to, among other things, benefit native fish species of interest. To help guide the process by projecting likely emergent biological properties (as expressed by fishes) of habitat restoration, we studied patterns of fish community composition and abundance across an open water-tidal wetland interface in the low salinity zone of the upper San Francisco Estuary. Fishes were sampled at Ryer Island, an isolated tidal wetland in Suisun Bay, for approximately 18 months across three habitat strata: deep open water channel, shallow water shoals adjacent to the wetland, and within the wetland. Preliminary results suggest strong variability in the occupancy of various species of interest across the habitat strata. For example, some species such as Sacramento Splittail, Tule Perch, and Sacramento Pikeminnow are strongly affiliated with the wetland while other species such as White Sturgeon apparently do not readily occupy the wetland. Variability in physical and biological properties of habitat across the strata likely drive the patterns seen in fishes, which together provide strong scientific support for the likely outcome of various habitat restoration scenarios.

Keywords: fish, community, Suisun bay, restoration
Session Title: Restoration Lessons Learned
Session Time: Wednesday, September 12th, 1:15 PM - 2:55 PM, Room 307

Physical, Chemical, and Biological Differences Across Two Habitat Types in the Cache Slough Complex

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Habitat restoration in the Sacramento-San Joaquin Delta is thought to be an important conservation tool for aiding imperiled native species. The value of these different habitats to target species is largely anecdotal, lacking empirical evaluation and configurations for potential habitat restorations are myriad, making it difficult to completely forecast the impact of these scenarios on fishes. In our study, we compare the physical and biological characteristics of two habitats which exemplify two extremes of potential restoration configurations in the north Delta: Little Holland Tract (a shallow flooded polder) and the Liberty Island Conservation Bank (a tidal wetland). Our study seeks to resolve how site-specific differences in geomorphology and hydrodynamics influence ecological outcomes on tidal and spring-neap timescales. We took part in multidisciplinary efforts to measure fluxes of flow, water quality, phytoplankton, and zooplankton, along with larval and adult fishes at hourly intervals across an entire tidal cycle. Each of these sampling efforts was followed by several days of intensive gill net and otter trawl sampling to assess the adult and juvenile fish populations supported by each site. Throughout our sampling, we found clear differences between the two sites. This type of knowledge is necessary to identify desirable restoration outcomes, isolate mechanistic causes, and ensure that restoration efforts achieve their target conservation goals.

Keywords: Habitat restoration, fish communities, zooplankton
Session Title: Restoration Lessons Learned
Session Time: Wednesday, September 12th, 1:15 PM - 2:55 PM, Room 307

Reconstructing an Estuarine Beach at Aramburu Island - Shoreline Design Performance Five Years Post-Construction

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The Aramburu Island Shoreline Enhancement Project in Richardson Bay, Marin County serves as a demonstration of a “living shoreline” approach to sea-level rise adaptation. The overarching goals of the project were to inhibit wind-wave erosion of an unstable, retreating shoreline and improve shorebird habitat on a man-made island managed by Marin County Parks for wildlife habitat and recreational uses. The shoreline enhancement design was based upon data collected on beach slope, sediment size, and wind fetch at reference beaches around San Francisco Bay. Three different beach designs were implemented on the island to reflect different combinations of slope, grain size, and material type. Construction occurred in fall 2011 by grading back the shoreline profile, building low "micro-groins" from small boulders and woody debris to provide partial barriers to longshore drift, and depositing different mixtures of sand, gravel, cobble, and oyster shell hash along the shoreline in ratios based upon estimated incident wave energy. Monitoring of shoreline geomorphology and bird use at the site has been ongoing since construction to assess design performance and to understand sediment transport dynamics, resilience of the constructed beach forms, and changes in habitat values. This talk will present the monitoring results at five-years post-construction, assess design performance relative to the project goals and objectives, and provide recommendations for future estuarine beach restoration and creation projects. Despite notable changes in shoreline geomorphology since project construction, the enhancements have provided protection against the high rates of pre-project erosion along most of the shoreline and have provided valuable habitats for shorebirds and other bird guilds. Beach restoration and creation presents a promising approach for managing shoreline erosion and adapting to sea level rise. In this context, Aramburu Island can be used as a precedent for future projects at similar sites around San Francisco Bay.

Keywords: Beach restoration, shoreline stabilization, sea level rise adaptation, managed retreat
Session Title: Restoration Lessons Learned
Session Time: Wednesday, September 12th, 1:15 PM - 2:55 PM, Room 307

Modeling Fish Movement

Juvenile Salmon 2-D Trajectory and Passage Patterns at the Georgiana Slough and Sacramento River Junction Emerge From Swim Orientations Based on Their Recent Past Flow Field Experience

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Decades of work has not yet provided a robust and broadly applicable explanation for fish movement that can operate with such fidelity and accuracy that it can be reliably applied for designing waterways infrastructure, even in cases where consequences are severe for 'getting it wrong'. Rivers are used in many ways to meet society's needs. Humans must more rapidly develop methods and solutions to de-conflict the competing needs of society and maintaining fish resources that are valuable commercially, recreationally, and culturally. Specifically, solutions are needed for directing fish swim paths in rivers to specific locations near infrastructure where individuals can be collected, passed, or redirected for their continued safe travel. We investigate salmon movement trajectory and passage patterns at the tidal junction of the Sacramento River and Georgiana Slough using CFD and a fish behavior modeling technique known as ELAM modeling. We focus on the accumulated experiences that a salmon encounters as it moves through a river flow field and how these experiences may explain observed movements and resultant passage into Georgiana Slough. We test our hypothesis by means of an ELAM behavior model using a version of salmon decision-making rules at the individual level, with CFD modeling as input for hydraulic stimuli across the space and time scales that it takes these fish to transit this river section. The behavioral repertoire described reproduces the predominate salmon movement and passage patterns observed in the tidal flow environment of the junction as well as juvenile salmon trajectory patterns observed in very different environments present behind Columbia and Snake River hydropower dams. This corroborates our discussion on the potential for engineering actions to influence salmon movement behavior. Our findings represent a nuanced, more complex middle ground between findings from prior studies dating back 20 years that used fewer and simpler data sets.

Keywords: ELAM model, individual based model, salmon movement, fish passage
Session Title: Modeling Fish Movement
Session Time: Wednesday, September 12th, 1:15 PM - 2:55 PM, Room 308-310

Numerical Modeling as a Fish Passage Prediction Tool at the Yolo Bypass: Flow Hydrodynamics

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Increased inundation within the Yolo Bypass is deemed necessary to improve rearing habitat for listed juvenile salmonids. It is being achieved by constructing a notch in the vicinity of Fremont Weir on the Sacramento River. A critical component of the notch is the approach channel and the associated flow pattern that will be necessary to maximize fish passage from the Sacramento River to Yolo Bypass through the notch. In this study, a numerical modeling tool is developed that integrates the flow hydrodynamic model with an agent-based numerical fish movement model. The purpose is to use the numerical model to predict the fish passage at the Yolo Bypass project site; the proposed notch alternatives cannot be measured in the field. This is part one of the talk, focusing on the flow characteristics as the fish movement modeling relies on the availability of reliable flow hydrodynamics. In a separate part two talk, the agent-based fish movement modeling is presented. First, the hydrodynamic models are validated against the ADCP velocity data in multiple years. Such comparisons shed light on the appropriateness of each model under practical and complex river environment. Next, the model is applied to selected notch alternatives. Flow patterns are discussed in lieu of the fish tracking data and fish passage at the notch, along with what can and cannot be simulated by the numerical models.

Keywords: Fish Passage; Modeling Fish; Flow Hydrodynamics; Yolo Bypass; Fremont Weir
Session Title: Modeling Fish Movement
Session Time: Wednesday, September 12th, 1:15 PM - 2:55 PM, Room 308-310

Calibration of an Individual-Based Model Simulating Juvenile Chinook Salmon Migration and Survival through the Sacramento River Delta to Inform Water Resources Management Actions

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Problem Statement: Individual-based models (IBMs) are increasingly used as a fast an inexpensive alternative to field studies in order to predict the response of key species of interest to various alternative management scenarios in the Sacramento River Delta. However, underlying behavioral parameters for these IBMs are often taken from studies conducted elsewhere or from expert opinion and may not be applicable to the Delta.

Approach: We used data from studies on juvenile late-fall run Chinook salmon in the Delta to parameterize three facets of the ECO-PTM, an individual-based juvenile salmon migration model developed by California DWR. Behavioral parameters were calibrated through Particle Swarm Optimization of a likelihood function via output from the ECO-PTM fit to travel time data; survival parameters were estimated by fitting the XT survival model to acoustic telemetry data, and migration routing parameters at key junctions were estimated through a GLM using near-field telemetry data at those junctions.

Results: We present here the estimated survival, routing, and behavioral parameters to be used in the ECO-PTM. These parameter estimates are biologically reasonable and similar to those for other studies of late-fall juvenile Chinook salmon in the Delta. Running the ECO-PTM for various flow regimes using the estimated parameters yields survival and migration estimates through the Delta that agree well with established estimates.

Relevance: Because we have used data from the species and area of interest to calibrate these parameters, results from the ECO-PTM simulations can be relied upon as reflecting movement and survival of juvenile salmon in the Delta. This tool should provide managers with a method to quickly assess effects of management actions on this critical resident species.

Keywords: Individual-based model, statistical calibration, particle swarm optimization
Session Title: Modeling Fish Movement
Session Time: Wednesday, September 12th, 1:15 PM - 2:55 PM, Room 308-310

Numerical Modeling as a Fish Passage Prediction Tool at the Yolo Bypass: Fish Movement Tracking

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The United States Bureau of Reclamation and the California Department of Water Resources are investigating notching the Fremont Weir on the Sacramento River. The notch is intended to provide access to the Yolo Bypass floodplain for juvenile salmon across a range of flows and to provide upstream passage for adult anadromous fishes. This study estimated the fish entrainment rate of 6 separate notch scenarios of varying size and configuration. Notches were modeled based on engineering drawings and existing bathometry using 2D hydrodynamic models as described in part 1 of this talk. Fish entrainment estimates vary from approximately 1 to 25% across a range of flows and stages. Across all scenarios larger notch flows entrain greater fish numbers, although not proportionally to the volume through the notch. Notch entrainment varies by location along the Fremont Weir. Entrainment estimates are comparable to measured entrainment rates elsewhere in the Sacramento River suggesting that the modeled estimates are reasonable. The results further suggest that improving entrainment rates estimates will require shifting the cross sectional distribution of fish.

Keywords: Fremont weir, entrainment, Yolo Bypass
Session Title: Modeling Fish Movement
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Individual-Based Juvenile Salmon Migration Model to Prioritize Water Resources Management Actions

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water resources management actions have been planned to protect and restore salmon populations for a healthy Delta ecosystem. Currently evaluating the effectiveness of these actions mainly relies on field studies, which can be costly and may not provide a complete assessment over a range of applications due to limited study area, duration, and river conditions. To supplement field studies, the California Department of Water Resources developed an ecological modelling tool, ECO-PTM. ECO-PTM is an individual-based juvenile salmon migration model that is based on a random-walk particle-tracking method, but with fish-like behaviors attached to the particles. The behavioral parameters are estimated from acoustic telemetry tag data from various field studies. A stochastic optimization tool, Particle Swarm Optimization, is used to calibrate the swimming behavior parameters. ECO-PTM can simulate salmonid migration timing, routing, and survival. The presentation will describe the model features and its capabilities as well as its limitations. A case study of the model application will be presented to illustrate how the model can be used to quantitatively evaluate the salmon protection benefits of various fish barriers and guidance structures in the Sacramento River and help managers prioritize management actions. For the case study, a historical hydrodynamic simulation for the entire Delta from 1990 to 2017 was performed to generate a fine-scale (15-minute timestep) flow regime. Under the flow regime, various scenarios were evaluated, including those that prevent juvenile salmon from entering the central Delta or that guide the fish to more favorable survival routes. We will present the results of the evaluation, including the comparison of the survival rates from Freeport, past several major junctions in the Sacramento River, to Chipps Island.

Keywords: salmon, migration, survival, fish barriers, hydrodynamic, modeling, behavior, particle tracking
Session Title: Modeling Fish Movement
Session Time: Wednesday, September 12th, 1:15 PM - 2:55 PM, Room 308-310

Predation Management and Predators I

Habitat, Hatcheries, and Predators Affect Salmon Migration and Survival

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Predators can influence both survival and behavior of migrating prey, and predator impacts can depend on habitat, environment, and prey attributes. Juvenile Chinook salmon (Oncorhynchus tshawytscha) experience high predation pressure as they migrate from freshwater to marine environments. These predator-prey interactions occur across various habitats and environmental conditions, and among hatchery and wild salmon. Understanding how habitat, hatcheries, and predators interact to influence juvenile salmon survival and behavior will help inform conservation efforts. To examine these factors, we conducted a series of field experiments where we placed hatchery and wild juvenile salmon in enclosures with predators and measured their survival and migration speed. In our first behavioral assay, we found that predator cues caused wild salmon to slow down, whereas hatchery salmon did not change their speed. Additionally, across all groups, salmon with higher body condition and moved faster than those in poorer condition. Our results indicate that predators may reduce prey migration speed, but that this effect depends on prey traits. Our second experiment will expand this framework to additionally assess how predation rates and migration behavior vary with habitat structure and will take place over a larger scale. Our findings suggest that, predators not only affect the survival of juvenile salmon, but they also may affect migratory behavior. Thus, trait-dependent changes in migration speed should be considered when evaluating the effects of predators on migrating prey. Relevant to Bay-Delta management, if nonnative predator consumption of juvenile salmon depends on habitat structure, then habitat restoration may be a strategy to increase salmon survival. Furthermore, if predators cause delays in salmon migration this could have subsequent consequences on salmon survival in subsequent life stages.

Keywords: salmon, migration, predation, habitat, behavior, movement, hatchery
Session Title: Predation Management and Predators I
Session Time: Wednesday, September 12th, 1:15 PM - 2:55 PM, Room 311-313

Spatial Patterns and Environmental Associations of Piscivorous Predation throughout the South Sacramento-San Joaquin River Delta in 2017

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It is currently not clear what proportion of juvenile salmonid mortality can be directly attributed to fish predation, and it is difficult to interpret results regarding population-level salmonid predation in the Delta because empirical data have only been collected at limited spatial scales. Spatial patterns and environmental associations of predation on salmonids are often investigated at discrete locations, limiting our ability to extrapolate to larger regions. During the spring of 2017, we quantified predation mortality rates, predator abundance and composition, and relevant environmental covariates in 21 randomly selected 1-km long field sites in the south Delta and lower San Joaquin River, using the generalized random tessellation stratified selection protocol. This site selection protocol will allow us to infer relationships between the environment and predation across a broader spatial scale than previous studies. Predation mortality rates were quantified through the use of Predation Event Recorders (PERs; standardized predation monitoring devices), and predator densities were quantified through the use of Dual-Identification Sonar (DIDSON) cameras.

Preliminary results from this hydrologically wet year indicate a general increase in predation rates through time, with a positive correlation between water temperature and predation rates. Future analyses will relate predation mortality rates and predator densities to in-situ measured environmental variables and habitat characteristics, as well as hydrodynamic variables as estimated from the Bay-Delta SCHISM model. Ultimately, we will determine statistical relationships between predation mortality rates and environmental conditions. This will enable robust predictions of spatially-explicit predation mortality risk, which can then be incorporated into acoustic tag salmonid survival models to elucidate the role of predation in juvenile salmonid mortality.

Keywords: predation, predator-prey, salmon
Session Title: Predation Management and Predators I
Session Time: Wednesday, September 12th, 1:15 PM - 2:55 PM, Room 311-313

Experimental Quantification of Piscivore Density and Habitat Effects on Juvenile Chinook Salmon Survival

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Predation on special-status fishes by non-native piscivores is hypothesized as a major impediment to population recovery. High predation on juvenile Chinook salmon (Oncorhynchus tshawytscha) in the Delta is suspected of contributing to low through-Delta survival estimates. However, these estimates are made over large spatial scales complicating attempts to link predation risk with specific habitats, and/or piscivore aggregations. To begin addressing these uncertainties, experimental enclosures were used to test relationships between largemouth bass (Micropterus salmoides) density and habitat type on juvenile Chinook salmon survival. Three contiguous 15.2 by 6.1 by 1.2 m enclosures were constructed in the South Fork Mokelumne River adjacent to Bouldin Island. Enclosures were separated with mesh sizes that allowed salmon, but not pisivores, to move between enclosures. We monitored salmon survival and movement among enclosures with a series of PIT tag antennas between each enclosure and double antennas on each end. The first experiment varied piscivore density by stocking 3, 6 or 12 largemouth bass into each enclosure. Thirty five juvenile salmon implanted with PIT tags were then introduced into each enclosure. Three replicates of the density experiment were performed with densities rotated among enclosures. The second experiment varied habitat type while predator density was held at the median level (6 bass). Habitats were submerged aquatic vegetation, dock pilings and no habitat. Three replicates of the habitat experiment were performed with habitats rotated among each enclosure. Results of this study highlight implications for the success of predator removal and habitat restoration as strategies to reduce predation on juvenile Chinook salmon in the Delta.

Keywords: Experiment, Habitat, Survival, Chinook salmon, Largemouth bass, Restoration, Telemetry
Session Title: Predation Management and Predators I
Session Time: Wednesday, September 12th, 1:15 PM - 2:55 PM, Room 311-313

Estimating Delta Predatory Fish Abundance with DIDSON Acoustic Cameras

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The relationship between predatory fish abundance and predation of juvenile salmonids in the Sacramento - San Joaquin Delta (the Delta) has been obscured by the relatively unknown populations and distributions of predator fish. This study focuses on an experimental approach to estimate predator fish density in multiple habitats within the Delta using DIDSON acoustic cameras. Using two boat-mounted DIDSON cameras, we surveyed 21 randomly selected 1-km sites throughout the Delta between 3 April and 15 May 2017. Systematic line transects were conducted at each site and footage was processed to identify, measure, and locate individual predator fish. Electrofishing was conducted at three sites, once at the start of the season and once at the end, to ground truth acoustic estimates and collect specimens for an acoustic reference library used in species differentiation analysis. We used Linear Discriminant Analysis to discern species from acoustically-derived morphometric data and found that piscivorous fish could be distinguished from non-piscvorous fish with 98.1% accuracy. We will build linear models incorporating environmental covariates to analyze predator distributions and expand density estimates to broader spatial scales. Results from this study will be used to analyze relative predation rates measured on tethered smolts collected concurrently with the acoustic data. We anticipate that our results will have high resolution capable of identify key environmental and biological components resulting in predation “hot-spots.” This information can be used to advise management and restoration decisions that may affect juvenile salmonid survival.

Keywords: predation, piscivore, delta, didson, predator
Session Title: Predation Management and Predators I
Session Time: Wednesday, September 12th, 1:15 PM - 2:55 PM, Room 311-313

Every Fish That Dies Gets Eaten

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Outmigrating juvenile salmonids in the San Joaquin Basin experience low survival. One suite of possible management actions includes efforts at reducing impacts from predators on these juvenile fish. Several studies have been undertaken on the Stanislaus River in an effort to understand factors influencing mortality in juvenile salmonids. Both flow and habitat have been identified as significant factors influencing mortality during rearing and migration of juvenile salmonids. A better understanding of relationship between flow, habitat, and predation will greatly assist in effectively managing limited resources to support self-sustaining populations of salmon and steelhead. Multiple factors influencing mortality will need to be addressed to achieve any lasting improvement in survival of juvenile salmonids. Come to the presentation for more detail on this important topic.

Keywords: salmon steelhead predation migration juvenile survival mortality
Session Title: Predation Management and Predators I
Session Time: Wednesday, September 12th, 1:15 PM - 2:55 PM, Room 311-313

Sediment Monitoring and Modeling

Quantifying the Effect of Accumulating Sand on Salmonid Egg Survival

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The habitat quality within a salmon nest, called a redd, can vary over the course of the egg incubation period. When measured, incubation habitat quality indicators, such as sand abundance or redd permeability, typically only provide an instantaneous indication of habitat quality, thereby implying a static condition. However, these indicators may change overtime as they are affected by changes in the physical environment (e.g., streamflow and sand supply) that may be managed. I performed artificial redd experiments to monitor its accumulation of sand and hydraulic conductivity with time. I found that hydraulic conductivity decreases by as much as two orders of magnitude during an incubation period. Hydraulic conductivity and sand accumulation vary with cumulative sand bedload transport as simple power function relationships that are meaningfully generalized for describing the effect along a 12-mile gravel-bedded salmon spawning reach of the San Joaquin River. The resultant trend in cumulative transport versus hydraulic conductivity is coupled with an empirically-based relationship between hydraulic conductivity and salmonid egg survival that demonstrates a seven fold difference in percent survival depending on typical incubation season streamflow levels and sand supply. A useful conclusion of this study is the provision of a management tool for predicting the effect of sand accumulation on percent egg survival as a function of streamflow. These findings thereby quantifiably demonstrate significant incubation habitat quality variability and the importance of managing streamflow and sand supply for salmonid fry production; a key component to their sustainability.

Keywords: Salmonid Incubation Habitat, Intragravel Flow, Egg Survival, Sand Accumulation, Redd
Session Title: Sediment Monitoring and Modeling
Session Time: Wednesday, September 12th, 1:15 PM - 2:55 PM, Room 314

Impacts of Sediment-Induced Stratification in Shallow-Water Estuarine Environments

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Direct numerical simulation is used to investigate the effects of sediment-induced stratification on wave-and current-driven flows for conditions relevant to shallow-water, estuarine environments. Wave properties are held constant while currents are varied. Stratification modifies flow by suppressing the exchange of high- and low -momentum fluid by sweeps and ejections, which leads to a reduction in the vertical component of the Reynolds stress. Reduced turbulent mixing causes bottom drag to decrease and currents to accelerate. However, stratification does not affect the wave velocity profiles for the conditions tested. Suppression of the Reynolds stress also reduces shear production of turbulent kinetic energy near the bed, while higher in the water column it increases because of increased mean shear. As a result, the streamwise turbulent intensity is reduced near the bed but increases above the viscous sublayer. This increase creates a feedback loop acting to restore the vertical Reynolds stress to its unstratified magnitude higher in the water column. Stratification also suppresses vertical turbulent sediment fluxes, reducing the depth-averaged suspended sediment concentration by as much as 8%. The results aid in better understandingturbulent, near-bed sediment transport processes, and thus are important to Bay-Delta management.

Keywords: DNS; wave- and current-driven flows; Effects of sediment-induced stratification
Session Title: Sediment Monitoring and Modeling
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Remote Sensing of Turbidity in San Francisco Bay Using UAVs

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Recent improvements in satellite-based imaging technology have enabled more accurate, higher-resolution monitoring of coastal oceans and estuaries over very large spatial scales. However, limitations in temporal and spatial resolution and cloud coverage limit the effectiveness of remote sensing for studying many estuarine dynamical processes. In particular, sediment transport in San Francisco Bay is driven by the combined effects of tides and winds, processes with time scales of the order of hours that cannot be fully resolved using Sentinel or Landsat imaging systems with overpass times of the order of days to weeks. To fill this temporal gap, we developed a low-altitude remote sensing platform for estimating surface sediment concentrations (SSC) using an unmanned aerial system (UAS). The platform consists of UAS-deployed multispectral imagery combined with an algorithm for extracting SSC and removing distortion caused by wind-generated waves and sun glint, sources of measurement error not present in traditional satellite imagery. During the summer of 2017 and spring of 2018 we used the system to observe SSC near the Dumbarton Bridge in South San Francisco Bay. We show that, after calibration, this system can be used as an effective tool for developing maps of SSC with high resolution in both time and space.

Keywords: Sediment, Turbidity, Remote sensing, UAS, drones, UAV
Session Title: Sediment Monitoring and Modeling
Session Time: Wednesday, September 12th, 1:15 PM - 2:55 PM, Room 314

Opportunistic Biophysical Monitoring of McCormack Williamson Tract Elucidates Potential Pathways for Ecosystem Recovery under Flooded Conditions

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The largely unregulated hydrograph of the Cosumnes River provides the necessary hydrologic and suspended sediment variability to sustain natural physical processes. The confluence of the Cosumnes and Mokelumne rivers at the McCormack-Williamson Tract (MWT) has provided a dynamic site for both time dependent baseline monitoring and episodic event based monitoring of water quality and isotopic conditions in the Delta. This is one of the few places within the Delta where the gradient from subtidal, intertidal, and seasonal floodplains is present and connected to fluvial processes and where multiple restoration projects are being connected at the larger landscape scale. In situ monitoring of water quality and isotope sampling was conducted over 30 events in both 2017 and 2018 water years, targeting both seasonal flows and flooding events across the MWT area. The Cosumnes flows of 2017 were 5.3 times higher between Oct1-Mar31 than 2018 with additional, frequent large releases from the Camanche Dam into the Mokelumne River during February and March. As expected, greater flows resulted in greater turbidity in the system, including the Mokelumne. Despite the closing of the Delta Cross Channel at the same time of year, salinity was found at higher levels deeper into the MWT system, particularly the riverine systems in the Cosumnes. Although tidally influenced, the greater flows in the Cosumnes during precipitation driven runoff tended to bring a greater influx of freshwater and upstream organic matter, which was reflected in isotopic mapping within the complex channel network. This research continues to shed light on the fine-resolution flux of dissolved organic materials and the impact of annual flows on water quality.

Keywords: river, turbidity, salinity, organic matter, floodplain, Cosumnes, Mokelumne, restoration
Session Title: Sediment Monitoring and Modeling
Session Time: Wednesday, September 12th, 1:15 PM - 2:55 PM, Room 314

An Effective Suspended Sediment Transport Model for the Sacramento-San Joaquin Delta

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The ability to model sediment transport in the Delta is important for effective management of Delta resources. The Delta Simulation Model 2 Sediment Transport Model (DSM2-STM) is a time-efficient tool to estimate the suspended sediment concentrations (SSC) in the Sacramento-San Joaquin Delta. The sediment module is an extension to DSM2 General Transport Model (DSM2-GTM), a numerical model that utilizes Eulerian fixed grid and has been verified for generating reasonable salinity results for Delta historical simulations. DSM2-STM incorporates advection, dispersion, resuspension and deposition mechanisms, thus physically-based simulation of the sedimentation process is based on hydrodynamics, model boundaries, and assumptions of sediment properties. Model results provide suspended sediment spatial distributions and temporal variabilities which are important for the ecology of the estuary.

This development is benefited from the 15-minutes continuous SSC monitoring network established by U.S. Geological Survey (USGS). Those data are valuable for model boundaries and calibration. The preliminary results of calibration from 2010 to 2012 and validation for the period of 2012-2016 show good agreement between observed data and modeling outputs. Overall, the model reproduces the SSC peaks, timing and duration as well as the trends when concentration falls. Based on sampling assumptions, suspended sediment is highly correlated to turbidity. Therefore, the sediment model can serve as a surrogate to predict turbidity levels. A further calculation of sediment fluxes provides a quantitative and qualitative approach to conduct sediment budget analyses by evaluating either annual sediment load at a specific location or trapped sediment through a sediment pathways analysis. Being able to numerically simulate sediment for the Delta provides options to assess impacts of possible scenarios and support management decision-making. There is also an ongoing effort to integrate with a mercury cycling model to support the open-water Total Maximum Daily Load requirements from the Delta Mercury Control Program.

Keywords: suspended sediment concentration, sediment transport model, DSM2, sediment budget, turbidity
Session Title: Sediment Monitoring and Modeling
Session Time: Wednesday, September 12th, 1:15 PM - 2:55 PM, Room 314

A Comparative Study for Consumptive Use in the Sacramento-San Joaquin Delta: Models and Field Data to Inform Water Management and Policy Decisions

Water Management and Policy Insights from the Sacramento-San Joaquin Delta Consumptive Study

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Consumptive water use by crops, often referred to as evapotranspiration (ET), is frequently the largest component of an agricultural region's water balance. In this presentation, results and policy insights from a comparative study on the Sacramento-San Joaquin Delta (SSJD) are presented for two water years (2015 and 2016) using modeling methods and field data. Seven methods: CalSIMETAW, DETAW, DisALEXI, ITRC-METRIC, SIMS, UCD-METRIC, and UCD-Priestley Taylor. In addition, field-based estimates and measurements of ET using eddy covariance and estimates with surface renewal stations were developed over bare soil during the fall of 2015 and over three predominant crops in the Delta (alfalfa, corn, and pasture) in the 2016 irrigation season. Results indicate that crop consumptive use in the SSJD is around 1.4 MAF/yr, with estimates falling within11% of the ensemble mean. Field-based estimates give generally lower measures of ET for the three crops analyzed. With 12% area in non-agricultural vegetation and 18% in open water, consumptive use from these land uses is substantial and in some cases higher than the average crop ET. Yet these estimates need refinements as most models in the study are rather suited to estimate crop ET. A consortium approach involving agencies, academics and consultants with standardized dataset and modeling tools exchange may improve transparency, accuracy and effectiveness in estimating ET in the SSJD and elsewhere in California.

Keywords: remote sensing, evapotranspiration, consumptive use, Bay Delta, agriculture, energy balance
Session Title: A Comparative Study for Consumptive Use in the Sacramento-San Joaquin Delta: Models and Field Data to Inform Water Management and Policy Decisions
Session Time: Wednesday, September 12th, 3:15 PM - 4:55 PM, Room 306

Evapotranspiration from Three Crop Types and Fallow Lands in the Sacramento-San Joaquin River Delta

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Our research addresses the question, “What is the consumptive water use of major crops and some fallowed lands in the Delta?” Evapotranspiration (ETa) field measurements and estimates were taken at 5 sites in 2015 and 14 sites in 2016 and 2017, representing three major Delta crops: pasture, alfalfa, and maize (corn), and fallow lands with elevations above sea level. We used several major, internationally well-established methods: eddy covariance, eddy covariance with energy budget residual, and surface renewal with energy budget residual. Our results compare well with a few previous field measurement and estimate based studies for the Delta for these crops. Fallow fields in this study, all above sea level elevation, and kept mainly weed-free, showed very low amounts of evaporation. Crop evapotranspiration was compared with the reference evapotranspiration (ETo) taken from nearby California Irrigation Management Information System-based stations. Our research, overall, suggests some crops, in the context of the unique climatic and soil characteristics of the Delta, may have lower consumptive water loss than in other areas of California and other states. These results are generally supported by some other limited studies in the Delta. The uncertainties between our methods are analyzed and discussed, but these uncertainties are neither of high enough magnitude, nor exhibit sufficient mean bias, to compromise our conclusions. This information is important to water managers and other stakeholders considering water usage patterns in the Delta.

Keywords: evapotranspiration, sacramento-san joaquin delta, eddy covariance, surface renewal
Session Title: A Comparative Study for Consumptive Use in the Sacramento-San Joaquin Delta: Models and Field Data to Inform Water Management and Policy Decisions
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Satellite Remote Sensing of Evapotranspiration over Agricultural Land: An Improved Priestley-Taylor Approach

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Given the challenges of already-stressed water resources and groundwater regulation in California, a cost-effective, timely, and consistent spatial estimate of crop ET, from the farm to watershed level, is becoming increasingly important. The semi-empirical Priestley-Taylor (PT) approach, calibrated with field data and driven by satellite observations, shows great promise for accurate ET estimates across diverse ecosystems. In this study we improved the robustness of the PT approach in agricultural lands, to enable growers and farm managers to tailor irrigation management based on in-field spatial variability and in-season variation. We optimized the PT coefficients for each crop type with available ET measurements from eddy covariance towers and surface renewal stations covering six crop types (Alfalfa, Almond, Citrus, Corn, Pasture, and Rice) in California. Estimates of net radiation and ET based on Landsat and MODIS satellite observations agreed well with field measurements. The RMSE of the estimated ET was less than 1.3 mm/day. The calibrated algorithm was applied to the Sacramento-San Joaquin Delta region to map daily and monthly ET at 30 m resolution during 2015 and 2016 water years. It captured well the seasonal dynamics and spatial distribution of ET in Sacramento-San Joaquin Delta. This approach, once calibrated, is relatively easy to implement for the whole state. A continuous monitoring of the dynamics and spatial heterogeneity of canopy and consumptive water use at a field scale, will help prepare and inform to adaptively manage water, canopy, and grove density to maximize yield with least amount of water.

Keywords: priestley-taylor model, evapotranspiration, water management, comparative study, remote sensing
Session Title: A Comparative Study for Consumptive Use in the Sacramento-San Joaquin Delta: Models and Field Data to Inform Water Management and Policy Decisions
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Using DETAW and CALSIMETAW as Comparative Models for Estimating Actual Evapotranspiration in the Sacramento-San Joaquin Delta

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DETAW (Delta Evapotranspiration of Applied Water) is a mathematical model that estimates the actual evapotranspiration (ETa) and root zone water balance in the Sacramento – San Joaquin Delta Service Area (DSA). ETa is estimated using a two-step crop coefficient approach for 15 different land use categories in 168 subareas within the Delta. In DETAW v2.0, the crop coefficients of these land use categories were calibrated by comparing model results to two SEBAL applications in the Delta (2007 and 2009). Both depth and volumetric daily ETa and ETaw are estimated for 11 crop categories, native vegetation, riparian vegetation, urban, and open water areas. As a model developed to inform Delta modeling and water management, DETAW v2.0 model was one of seven models in the 2018 Delta Water Master crop consumptive use study. CalSIMETAW is a new soil-water balance model for estimating daily soil water balance to determine crop evapotranspiration (ETc) and evapotranspiration of applied water (ETaw) for 20 agricultural crop categories and 4 land use categories using a two-step crop coefficient method in California Water Resources Planning. ETaw is a seasonal estimate of the water needed to irrigate a crop assuming 100% irrigation efficiency. The model requires weather data, soils, crop coefficients, rooting depths, seepage, etc., that influence crop water balance. It provides spatial soil and climate information, and uses crop category information to provide seasonal water balance estimates by combinations of county and detailed analysis units (DAU/County) over the State. CalSIMETAW employs near-real-time daily ETo information from Spatial CIMIS to provide a statewide grid of ETo information. The model uses daily air temperature data from PRISM that covers California on a 4 km x 4 km grid spacing to determine ETo, using the calibrated Hargreaves-Samani equation. ETc is estimated as the product of ETo and a crop (Kc) coefficient value.

Keywords: modeling, comparative study, evapotranspiration, delta model
Session Title: A Comparative Study for Consumptive Use in the Sacramento-San Joaquin Delta: Models and Field Data to Inform Water Management and Policy Decisions
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2015-2016 Delta Consumptive Use Analysis – Remote Sensing Approaches

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Accurately estimating consumptive use of water through evapotranspiration (ET) in the Bay-Delta can have important benefits for water management and support improvements in hydrologic modeling. Satellite mapping of ET provides a cost-effective and promising solution for operational monitoring of ET, especially for the Bay-Delta where quantifying consumptive use can be difficult using ground-based meters and other instrumentation. This talk will describe two different approaches for remote sensing of ET and discuss progress towards automation of these approaches.

For the Delta Consumptive Use Analysis, the ITRC modified Mapping Evapotranspiration at High Resolution with Internal Calibration (ITRC-METRIC) was used to examine spatially varied actual evapotranspiration (ETc) from fields throughout the California Delta (SSJD). The analysis also examined the value of utilizing spatial ETo in the interpolation of ETc over the Delta and sensitivity of the ETc estimates to ETo corrections at weather stations within or close to SSJD. Results show that the correction process had minimal impact (~2%) on annual ETc in 2015 and 2016, while the use of spatially varied ETo had an important impact on regional and combined ETc (5-6%).

The Satellite Irrigation Management Support (SIMS) framework integrates satellite data with information from the California Irrigation Management Information System (CIMIS) to map field-scale crop canopy development and basal crop evapotranspiration (ETcb). The SIMS framework developed in partnership between NASA and DWR, provides a fully automated approach for ET mapping, though the current approach employed by SIMS is less sensitive to intermittent deficit irrigation and may underestimate soil evaporation. This presentation will discuss strengths and limitations of the SIMS approach and will summarize results from accuracy assessments conducted to date. We will also introduce the OpenET platform, and describe progress towards automation of multiple satellite-based approaches for ET mapping.

Keywords: consumptive use, modeling, evapotranspiration, remote sensing, Sacramento San Joaquin Delta
Session Title: A Comparative Study for Consumptive Use in the Sacramento-San Joaquin Delta: Models and Field Data to Inform Water Management and Policy Decisions
Session Time: Wednesday, September 12th, 3:15 PM - 4:55 PM, Room 306

Ecological Research Supporting Novel Restoration Design

Managed Wetland Rearing Benefits Juvenile Chinook Salmon Growth in Suisun Marsh

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Suisun Marsh, in the San Francisco Bay Estuary, has been altered by urban development and the creation of managed wetlands for waterfowl hunting. These managed wetlands comprise forty-five percent of Suisun Marsh's total area, though tidal restoration of several properties is imminent. To better inform future management and to understand how this novel ecosystem currently affects native fish of special concern, juvenile Chinook salmon, Oncorhynchus tshawytscha, (~63 mm FL) were reared in cages for seven weeks between March and April of 2017 in three discrete habitat types: a small managed wetland, a leveed slough adjacent to managed wetlands, and a slough surrounded by historic marsh preserve. Growth rates over the seven-week study differed significantly between the managed wetland and the two slough locations. Fish reared in the managed wetland demonstrated strong growth (7.7 mg/day) whereas both sloughs saw low or negative growth (-0.4 – 1.0 mg/day). We used a multimodel inference approach to evaluate the contribution of different environmental drivers towards variation in growth. Among direct drivers, temperature and food abundance explained growth differences best. The tidally muted managed wetland experienced less diel fluctuation in temperature compared to the slough and remained cooler on average, likely reducing thermal stress. In addition, the managed wetland had the highest zooplankton density and fish with the fullest stomachs, contributing to fast growth rates which may have helped offset the costs low dissolved oxygen levels in the managed wetland. These results highlight the potential of managed wetlands in Suisun Marsh as valuable rearing habitats. Future projects should consider incorporating pond-like elements into restoration design and improving existing managed wetlands with gate structures that enable volitional access and the adjustment of draining cycles to supplement in-slough food resources.

Keywords: managed wetlands, chinook salmon, novel ecosystem, restoration, tidal marsh
Session Title: Ecological Research Supporting Novel Restoration Design
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Primary Production across a Managed Wetland-Slough Complex

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Phytoplankton production rates in Suisun Marsh are an important food web process that are relatively understudied. Managed wetlands are typically flooded in the fall to provide habitat for overwintering ducks, and then drained in the spring. This management schedule is followed by roughly 150 duck clubs throughout the marsh, creating a periodic flux of primary production into adjacent tidal channels.

We investigated whether there were differences in primary production rates between novel and naturalistic habitats. Phytoplankton growth rate measurements were conducted twice a week, and water quality transects were conducted once a week, in a managed wetland and an adjacent terminal slough of northeastern Suisun Marsh during Spring 2018. We tracked production rates and their associated parameters through 3 phases of wetland management: drawdown, flood-up, and holding period.

Results suggest management regimes have important control over the rate of primary production. Understanding the factors that control production in managed wetlands may inform a framework for enhancing lower food web production in a food-limited system and may help further characterize the Suisun Marsh as a nursery habitat for native fishes.

Keywords: Suisun Marsh, primary production rates
Session Title: Ecological Research Supporting Novel Restoration Design
Session Time: Wednesday, September 12th, 3:15 PM - 4:55 PM, Room 307

McCormack-Williamson Tract’s 2017 Failure as a Chance to Improve Hydrodynamic Modeling Linkages to Restoration Targets

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To anticipate the effectiveness of restoration actions to islands within the California Delta, hydrodynamic and water quality models are used to predict changes in primary and secondary production. One of our primary goals with the hydrodynamic and water quality models is to predict the magnitude and export of increased zooplankton productivity in the MWT region as a result of planned restoration. The McCormack-Williamson Tract (MWT) will be restored as tidal floodplain in 2020, but recently flooded due to levee failure in the winter of 2017. Pre-restoration flooding created the opportunity to collect hydrologic and ecologic data that can be used to inform our models. We built a two-dimensional model of the MWT and surrounding areas to evaluate specific restoration scenarios using Deltares’ Delft 3D coupled with the DELWAQ engine. This gives us a coupled hydrodynamic and water quality model to evaluate parameters such as temperature and salinity in the region. The data collection campaign during the 2017 “restoration preview” allowed for an adaptive modeling strategy in order to fine-tune our modeling methods in linking model output with zooplankton abundance and distribution. The data showed increased production within the Tract as well as export downstream of the flooded MWT. With the improved methodology, our modeling will better predict the habitat effects of proposed restorations of Delta islands.

Keywords: Hydrodynamic Model, Floodplain, Adaptive Management, Restoration
Session Title: Ecological Research Supporting Novel Restoration Design
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Modeling Water Age in the Upper San Francisco Estuary

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Transport time scales are commonly used in hydrodynamic and ecological studies to provide insight into the rate of transport processes relative to ecological processes, such nutrient uptake rates. Transport time scales can be estimated both from field observations and from hydrodynamic modeling. Recently, continuous underway measurements have been used to detect isotopic signals of evaporation. These are used to estimate the distribution of a transport time scale which is conceptually analogous to water age, as defined in modeling studies. We apply a modeling approach to estimate both the evaporation to inflow ratio and water age of Sacramento River water. The model utilizes predicted hydrodynamics from a version of the RMA San Francisco Estuary UnTRIM model which incorporates a high-resolution grid of the Cache Slough Complex developed at UCD. Several tracers are introduced in the model in order to estimate the fraction of Sacramento River water at any location, the fraction of the Sacramento inflow that has evaporated, and mean Sacramento River water age. We compare model predictions with information derived from continuous underway measurements in the Cache Slough Complex during October of 2014 and evaluate sources of uncertainty in both the modeling approach and measurement-based estimates of water age. The comparison is a major step in establishing confidence in both modeling and observation-based approaches to estimate ecologically relevant transport time scales. Application of the validated model will allow much larger spatial and temporal extents of estimated transport time scales relative to current observational approaches and can be used in conjunction with observation data to provide insight to biological and chemical rates in the estuary.

Keywords: Hydrodynamic, model, transport, age, evaporation, Cache Slough, Sacramento River
Session Title: Ecological Research Supporting Novel Restoration Design
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Novel Rearing Habitat for Native Delta Fish Species

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The San Francisco Estuary's salmon and smelt are going extinct, with climate change and non-native species increasingly limiting opportunities for classic restoration schemes. Reconciliation ecology – supporting native species within human-dominated landscapes – has benefitted declining native species beyond that envisioned by classic restoration. However, application of reconciliation ecology in the watershed has been limited to the estuary and flood bypasses despite potential of other habitats. For example, Sacramento perch would be extinct had they not been planted into reservoirs. Reservoirs hold promise for smelt and salmon, too. First, presence of kokanee and wakasagi suggest plenty of both cool water and zooplankters. Second, self-sustaining landlocked Chinook salmon populations intimate that endangered runs could complete their life histories without trap-and-haul in reservoirs. Third, populations closest to wild, native Central Valley steelhead are above the dams. Fourth, presence of at-risk Delta fishes in State Water Project (SWP) reservoirs indicates the chance that smelt may be present, too. To minimize extinction probability of these unique species, I recommend (1) stocking delta smelt into reservoirs either containing kokanee or having similar features to wakasagi reservoirs; (2) designating key reservoirs for native salmonid conservation; and (3) instituting a standardized monitoring program in SWP reservoirs.

Keywords: smelt salmon kokanee reservoirs temperature zooplankton reconciliation ecology Sacramento perch
Session Title: Ecological Research Supporting Novel Restoration Design
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As the Smelt Fares

Indicators of Reproductive Health of Delta Smelt

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The physical habitat, health, and nutritional indices of Delta Smelt, Hypomesus transpacificus were studied in relation to reproductive status among regions of the San Francisco Estuary. Adult Delta smelt were collected during the Spring Kodiak Trawl by the California Department of Fish and Wildlife from 2012 to 2015. Health indices of fish consisted of morphometric indices, gill pathology, and liver indices. Nutritional indices consisted of RNA/DNA and liver glycogen. Reproductive variables included GSI, oocyte developmental stage, clutch size, oocyte size, oocyte weight, and estrogen level. Examined spatial and temporal factors as well as migratory status on the reproductive endpoints. Hepatosomatic index and liver lesion severity correlated with reproductive indices, suggesting that liver health is a driver of reproductive status. Liver glycogen was found to positively correlate with reproductive indices suggesting that good nutritional status was important for good reproductive status. Reproductive status of Delta smelt in Suisun Bay was poorer than Delta smelt found in the Cache Slough Complex and Suisun Marsh which is consistent with the hypothesis that these areas are important for spawning.

Keywords: Delta smelt, Reproduction, Nutrition, Histopathology,
Session Title: As the Smelt Fares
Session Time: Wednesday, September 12th, 3:15 PM - 4:55 PM, Room 308-310

Hot and Bothered: Warming Effects on Delta Smelt Behavior Lead to Increased Predation

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Drought induced warming and increasing periods of high temperatures pose major threats to fish communities in the Sacramento-San Joaquin Delta. Of particular concern is how increasing frequency and duration of warming events may impact the endangered Delta Smelt (Hypomesus transpacificus). To help address this issue, we tested the effects of warming (fluctuating [17-21°C] and warm [21°C] treatments) on juvenile Delta Smelt individual and group behavior, response to chemical alarm and predator cues as well as a real predator. After 7 days temperature exposure, Delta Smelt in the warm treatment increased swimming velocity, decreased turning angle capacity, and altered group structure with larger inter-individual distances (IID) compared to fish in the control treatment (17°C). These alterations in individual and group behaviors were not seen in the fluctuating treatment. Following conspecific and predator-derived chemical alarm cues, Delta Smelt showed anti-predator responses, but responses and recovery varied by temperature treatments. Control and fluctuating fish responded to conspecific cues with increased swimming speeds, decreased IID and near-neighbor distances, and after 15 min fish recovered back to baseline behaviors. However, fish in the warm treatment had not recovered after 15 min, and swimming speeds reached close to maximum aerobic swimming capacity. Fish in control and fluctuating treatments showed minimal responses to predator-borne cues whereas warmed Delta Smelt significantly increased swimming speeds and decreased turning angle. Predation by Largemouth Bass (Micropterus salmoides) was greatest under the warm treatment correlative of altered behaviors. This study provides novel insight into the group behavior of Delta Smelt, their response to predation, and how prolonged warming may induce negative individual and group behaviors causing alterations in predator-prey dynamics. Lastly, this work highlights the importance of testing ecologically realistic temperature fluctuations in experiments as Delta Smelt had significantly altered responses to warm exposures.

Keywords: temperature, Delta Smelt, behavior, predation
Session Title: As the Smelt Fares
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After Nine Years of Survey Data, What Can We Learn About Larval Longfin Smelt?

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After Nine Years of Survey Data, What Can We Learn About Larval Longfin Smelt?

Longfin smelt (Spirinchus thaleichthys) are a species of high conservation concern within the San Francisco Estuary (Estuary). The California Department of Fish and Wildlife (CDFW) long-term monitoring surveys indicated a significant decline in their population overtime, which ultimately lead to their 2009 listing as 'threatened' under the California Endangered Species Act. In response to their listing, CDFW deployed the Smelt Larval Survey (SLS) to inform resource managers of their potential entrainment risk at the South Delta state and federal water export facilities. The SLS samples each year (2009-2017) from January to March throughout the upper Estuary, and thus covers a majority of the LFS spawning season and habitat in most years. Therefore, we can use these data to answer questions about Smelt life history: 1. What is the distribution of newly-hatched (4-6 mm) and larval (7-12 mm) Longfin Smelt in the upper Estuary, and 2. What are the abiotic habitat attributes associated with those size classes of Longfin Smelt? Our results indicate that spawning is widespread throughout the upper Estuary, but appears to shift with changing conditions. Although Smelt are found in a variety of environmental conditions, there seem to be trends in habitat use for spawning and rearing.The SLS most frequently captures larvae 7 mm in size and an increased understanding of the habitat requirements of that life stage can guide us on managing their early life history.

Keywords: Longfin larvae SLS entrainment distribution smelt
Session Title: As the Smelt Fares
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Estimating Effective Population Size of Delta Smelt using RAD-seq

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Problem Statement: Recently there has been discussion over whether or not the population decline of Delta Smelt (Hypomesus transpacificus) has affected its genetic diversity.

Approach: Genetic effective population size (Ne) is one useful parameter to quantify the number of breeding individuals in an idealized population to result in the degree of genetic drift as observed in the wild Delta Smelt population. Currently, there are several approaches available to estimate Ne including temporal methods (NeT), which use samples from different generations, and a linkage disequilibrium method (NeLD), which samples individuals from a single generation. Previous studies have estimated the NeT and NeLD of the wild Delta Smelt population using 12-15 microsatellite markers but these estimates had wide confidence intervals and the sparsity of markers leaves entire portions of the genome unexamined. It is possible that with genomic data generated using next generation sequencing we may gain significant power and be able to more precisely estimate the Ne of the wild Delta Smelt population. Here we describe the development of a bioinformatics pipeline to estimate Ne values using RAD sequencing data. By utilizing thousands of loci in our estimation of Ne, we hope to develop a pipeline that sensitively and accurately estimates NeT across 23 generations and utilize an established linkage map to estimate NeLD within a single generation.

Results: Analysis of effective population size of Delta Smelt is currently underway and results are expected in the early summer.

Conclusion/Relevance: An accurate estimation of effective population will provide a useful component for conservation efforts aimed at maintaining genetic diversity with the Delta Smelt population. More broadly, the bioinformatics pipeline will allow a streamlined effort to estimate Ne in other fish with RAD-seq data.

Keywords: population genetics, effective population size, RAD-seq, bioinformatics, Delta Smelt
Session Title: As the Smelt Fares
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Experiments to Fill Critical Knowledge Gaps About Cultured Delta Smelt (Hypomesus transpacificus)

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The Delta Smelt is a state and federally listed species that is in decline throughout its range in the Sacramento-San Joaquin Delta. Recent abundance indices of Delta Smelt have been the lowest on record and indicate that proactive recovery measures must be undertaken to prevent species extinction in the wild. One option is to supplement the wild population with cultured Delta Smelt from the refugial population reared at the University of California Davis Fish Conservation and Culture Laboratory (FCCL). However, before such action can be considered by regulatory agencies, critical knowledge gaps must be filled regarding the efficacy and safety of supplementation using cultured fish. The California Department of Water Resources has funded several studies that are currently underway to support this effort. In collaboration with agency partners, scientists at UC Davis are crafting a Hatchery and Genetic Management Plan outlining best practices for Delta Smelt supplementation as well as recommendations for genetic monitoring and methods to evaluate recovery. UC Davis researchers have designed enclosure prototypes that can be used to conduct experiments on Delta Smelt biology in the field or for captive propagation. UC Davis scientists have also performed pathogen screening of wild and cultured Delta Smelt as well as environmental samples using quantitative PCR and a BioMark detection assay to evaluate the potential for pathogen transmission with supplementation. Finally, it may be possible to release Delta Smelt at the fertilized egg stage to avoid effects of domestication selection that could hinder supplementation success. Staff at the FCCL have investigated physical methods to mark Delta Smelt eggs as well as the functionality of hatching frames, that are used to spawn Wakasagi eggs in estuaries in Japan, for Delta Smelt. Results of these complementary research studies will provide critical information that can guide future population supplementation efforts in Delta Smelt.

Keywords: Delta Smelt, recovery, supplementation
Session Title: As the Smelt Fares
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Predation Management and Predators II

Machine Learning Techniques for Identifying Predation Events from Salmon - Predator Acoustic Tracking Data in the Sacramento-San Joaquin River Delta

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Animals perform a variety of behaviors as they go about their daily lives. Biologists often think of these behaviors as being distinct from one another and the set of distinct behaviors an animal can execute is often referred to as that animal's "behavioral repertoire." Defining the behavioral repertoire of a given individual or species is a challenging and often subjective task. Here, we implement new unsupervised machine learning techniques to discover the behavioral repertoire of freely moving animals directly from tracking data. We further apply a dynamical machine learning approach to determine when animals transition from one distinct behavior to another using time series data. To demonstrate these methods, we apply them to data from a study of acoustically tagged salmon and salmon predators conducted in the Sacramento-San Joaquin River Delta, California. We first applied unsupervised machine learning for the quantitative classification of salmon and predator movement behavior from acoustic tagging data. This allows us not only to map the behavioral repertoires of the salmon and their predators, but also to define a transition probability of behavioral patterns between two observed time points. In the second step, we applied a statistical machine learning technique to identify predator attacks and predation events using a change-point detection algorithm. The change-point detection allows us to qualitatively determine if the behavior of the time series of the salmon changes and to identify the time point when this change occurs.

Keywords: Machine Learning, Change-point detection, acoustic tagging, Sacramento-San Joaquin, salmon, predators
Session Title: Predation Management and Predators II
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Identifying Predation of Outmigrating Juvenile Salmonids Using Characteristics of Two-Dimensional Telemetry Tracks

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Consumption of telemetered fishes by piscivores is problematic for telemetry studies because tag detections from the piscivore could introduce bias into the analysis of telemetry data. We illustrate the use of multivariate mixture models to estimate group membership (smolt or predator) of telemetered juvenile Chinook salmon (Oncorhynchus tshawytscha), juvenile steelhead trout (O. mykiss), striped bass (Morone saxatilis), smallmouth bass (Micropterus dolomieu) and spotted bass (M. punctulatus) in the Sacramento River, CA, USA. First, we estimated two types of track statistics from spatially explicit two-dimensional movement tracks of telemetered fishes: the Lévy exponent (b) and tortuosity (τ). Second, we hypothesized that the distribution of each track statistic would differ between predators and smolts. To estimate the distribution of track statistics for putative predators and smolts, we fitted a bivariate normal mixture model to the mixed distribution of track statistics. Lastly, we classified each track as a smolt or predator using parameter estimates from the mixture model to estimate the probability that each track was that of a predator or smolt.

Keywords: Chinook salmon, predation, striped bass, smallmouth bass
Session Title: Predation Management and Predators II
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Clifton Court Forebay Predator Removal Electrofishing Study, Final Reporting

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The Clifton Court Forebay (CCF) Predator Reduction Electrofishing Study (PRES) was implemented in response to the National Marine Fisheries Service letter dated April 9, 2015, requiring that the California Department of Water Resources immediately implement interim measure (a) of condition 3 as part of the larger effort to comply with Reasonable and Prudent Alternative Action IV.4.2(2) of the 2009 Biological Opinion and Conference Opinion on the Long-term Operations of the Central Valley Project and State Water Project. The PRES was a 3-year study, beginning with a pilot year effort in 2016, a 2017 effort to refine methods and determine the main factors affecting predator catch, particularly spatial patterns, and a 2018 effort focused on maximizing predator removal based on knowledge gained during the 2016 and 2017 campaigns. The PRES involved electroshocking and removing predators from CCF and transporting them to Bethany Reservoir. The goal of the study was to decreasing predation on protected fish species with an emphasis on an increase in Chinook Salmon (Oncorhynchus tshawytscha) and steelhead (Oncorhynchus mykiss) survival. A concurrent study, Skinner Efficiency and Improvement Study, was conducted to evaluate survival of Chinook Salmon in CCF. This study used detections of Passive Integrated Transponder tagged juvenile Chinook Salmon and acoustic tagged juvenile Chinook Salmon that were released into CCF and monitored during the PRES.

Keywords: Clifton Court Forebay Salmon Steelhead Striped Bass Predation Electrofishing Survival
Session Title: Predation Management and Predators II
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Predation Management in the Sacramento-San Joaquin Watershed

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Understanding the impacts predatory fishes have on native fish populations, especially salmonids, has been identified as an important action to support the recovery of special-status species in the Sacramento- San Joaquin Delta (Delta)(Grossman et al. 2013). Numerous research studies have looked at the influence of non-native predators on juvenile salmonids. However, there has been less focus on the effects of predator management strategies in the Delta. Through literature synthesis and professional communications, this presentation will synthesize research findings (e.g. Michel et al. 2017; Sabal et al. 2016; Cavallo et al. 2013) and explore relevant management actions that influence predator-prey dynamics in the Delta. In addition, current predation-management research underway in the Delta will be characterized. For example, the research design of the Fish Release Site Predation Monitoring (cooperative project of the DWR and USBR) project will be described to show how hypothesis testing is being used to determine the more effective of two management/salvage release strategies. The project description will show how juvenile Chinook Salmon tethering experiments are taking place at a federal and state fish salvage release site (Curtis Landing on Sherman Island) and at a control site (1.7 km (1.1 mi.)) away.

Keywords: Sacramento-SanJoaquin, predator management, fisheries
Session Title: Predation Management and Predators II
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NMFS Salmon Recovery Planning Perspective on Predation

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Predation is one of several key stressors impacting the survival and recovery of Central Valley salmon. It is likely the proximate mechanism of low juvenile salmon survival rates observed in the Sacramento and San Joaquin riversrelative to other west coast salmon rivers such as the Snake and Yakima, even though those rivers have substantially longer migration corridors. Predation is clearly an important and complicated stressor for juvenile salmon. However, the ultimate causes limiting Central Valley salmon population viability include habitat loss, habitat degradation, extensive flow modification, and an ecosystem altered by non-native species. This presentation will cover NMFS' approach of addressing these underlying causes and better understanding predation in order to identify and take targeted actions to improve juvenile salmon survival through the Sacramento-San Joaquin river system and Delta.

Keywords: Salmon, Predation, Salmon predation, Striped bass
Session Title: Predation Management and Predators II
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From Science to Implementation: Treating Sediment as a Critical Resource

Status and Trends of Sediment Supply to San Francisco Bay, Water Years 1995 through 2016

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The status and trends of sediment supply in the San Francisco Bay-Delta system is critical information for management decisions about dredging, marsh restoration, flood control, contaminants, water clarity (primary production), and sea level rise. Yet, no synthesis of recent studies on sediment supply was available. Now, addressing this need for San Francisco Bay, a jointly funded study was recently completed by the Regional Monitoring Program for Water Quality and the USGS.

Net sediment supply to San Francisco Bay from terrestrial sources during water years [WY] 1995-2016 was 1.9±0.8 Mt/yr (million metric tonnes/year). Small tributaries draining directly to the Bay contributed 63%of the sediment supply; the balance being derived from the Central Valley (Sediment delivery points are Mallard Island for the Delta and the head of tide of each small tributary or outfall for small tributaries around the Bay). Bedload supply (0.19 Mt/yr), after accounting for removals by dredging activities, storage in flood control channels, and errors in measurements was negligible.

In terms of trends, since the step decrease in suspended-sediment concentrations in the Delta in WY 1999, there appears to be a slight downward trend (not statistically significant) largely driven by decreasing discharge associated with the drought during the latter part of the study period. For small tributaries around the Bay, trends for individual tributaries or as a whole group could not be determined due to sparse and incomplete datasets. For the Delta, the flood of WY 2017 was rather significant and will provide an interesting reference point for trends assessment once data are published in 2018. Consistent monitoring of sediment loads over the next decade at Mallard Island and at a subset of representative watersheds around the Bay—to augment existing data—could be used in the future to evaluate trends and for predictive modeling.

Keywords: Suspended load, coarse bed load, sediment supply, trend
Session Title: From Science to Implementation: Treating Sediment as a Critical Resource
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Sediment for Survival: Understanding the Need of San Francisco Bay Tidal Marshes and Mudflats

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Sediment is a critical resource that is essential for sustaining tidal wetlands and mudflats (i.e., baylands) around San Francisco Bay that will be resilient under a changing climate. Developing an understanding of anticipated bayland sediment need in the coming decades and how it compares to anticipated sediment supply requires sediment science to be integrated across the watershed, bayland, and bay components of the ecosystem, considering scenarios of sea level rise, large storm frequency, baylands restoration, and management choices in both the baylands and watersheds. Such integration is needed for discrete Bay shoreline regions to enable determination of areas with the greatest overall sediment need and development of localized sediment management strategies.

There is currently an effort underway to develop a science-based regional sediment strategy to inform decision-making for the resilience of San Francisco Bay wetlands. The regional sediment strategy is being conducted in close coordination with other regional efforts to: 1) assess projected bayland sediment demand, sediment supply, and associated long-term resilience for discrete shoreline regions for climate change-bayland restoration-land use change scenarios; 2) develop sediment management guidelines for bayland resilience (including key tradeoffs); and 3) develop a monitoring strategy aimed at collecting data to improve our ability to manage sediment delivery to and movement within the Bay. This presentation will provide initial findings from the study, focusing on the predicted future bayland sediment demand for discrete shoreline units around the Bay under varying degrees of sea level rise and bayland restoration. Funding for this work is being provided by the EPA Water Quality Improvement Fund and the San Francisco Bay Regional Monitoring Program.

Keywords: climate change, sediment demand, bayland resilience, sea level rise
Session Title: From Science to Implementation: Treating Sediment as a Critical Resource
Session Time: Wednesday, September 12th, 3:15 PM - 4:55 PM, Room 314

Developing a Resilient Landscape Vision for the Pond A8, Calabazas Creek, and San Tomas Aquino Creek Interface

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Flood control channels at the Bay edge are facing increasing concerns of aging infrastructure, regulatory restrictions for dredging, high maintenance costs, and future challenges of increased water levels with rising seas. In addition, there is an increasing need in the region for utilizing sediment that gets trapped in these channels as a resource to allow existing and restored tidal habitats to keep pace with sea-level rise. There exists a unique opportunity to rethink the design and management of these channels to meet required levels of flood risk management while helping restore bayland habitats.

This presentation will provide an overview of a collaborative effort in Santa Clara County, CA aimed at developing a multi-benefit landscape vision to reconnect Calabazas and San Tomas Aquino creeks to Pond A8 (a restored commercial salt pond) to benefit both flood management and wetland habitat restoration. This vision is an element of the EPA-funded project Healthy Watersheds Resilient Baylands, which seeks to integrate watershed planning and redevelopment with baylands restoration to create healthier and more resilient aquatic systems and communities. Healthy Watersheds Resilient Baylands team members and project partners worked with the Santa Clara Valley Water District and South Bay Salt Pond Restoration Project to explore a range of opportunities for restoring physical processes and integrating ecological benefits into flood risk management. A landscape scale vision was developed that included strategies for: 1) improving the delivery of freshwater and sediment out of the creeks and into Pond A8; 2) creating a pathway for marsh migration with sea-level rise; and 3) improving ecosystem functioning and resilience through the creation of estuarine-terrestrial transition zones irrigated with treated wastewater. Upon implementation, this case study could be used to inform future reconnection projects in similar landscapes around the Bay and guide responsive policies to climate change challenges.

Keywords: Sediment reuse, wetland restoration, creek-Baylands reconnection, resilient landscape vision
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Public Sediment: Unlocking Alameda Creek

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The Resilient by Design Bay Area Challenge (RBD) is a design competition (2017-2018) that brought together public officials, Bay communities, and local, national and international experts to develop innovative solutions to issues brought on by accelerated climate change in the Bay region. One of the RBD design teams, Public Sediment, focused their efforts on sediment supply and management as ecological infrastructure for the Bay's vulnerable marshes, mudflats and coastal communities.

Recognizing the importance of the Bay's tributaries for sediment supply, Public Sediment pursued a strategy for Unlocking Alameda Creek. This strategy consisted of an integrative and systemic approach to redesigning the Alameda Creek sedimentshed, which is the largest in the Bay, as well as one of the most altered and engineered. In this presentation, we discuss three main components of the Unlocking Alameda Creek proposal. The first is the systemic integration of multiple projects and design interventions along the creek, from uplands to the Bay. These interventions include the release and redistribution of sediments from behind dams, structural redesign of the 12-mile federal flood control channel for improved sediment and fish passage, and tidal-fluvial reconnection of the Creek to The Eden Landing South Bay Restoration Project, achieved through decommissioning a portion of the flood control channel at the bay interface. The second component describes the team's efforts to reconcile the disparate and seemingly conflicting agendas of many projects, stakeholders and public agencies encountered in this effort, including flood management, ecological restoration, public access and regulatory protocols. Third, for projects like these to be supported and successful, will describe efforts to make sediment public, through outreach, sensing, and the design of public pathways and outdoor mudrooms within the creek itself. In closing, we will reflect on the strengths and limitations of this tributary design and describe next steps in the project.

Keywords: Sediment, Baylands, flood management, restoration, wetlands, infrastructure, climate change, creeks
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Interpreting Spatial and Temporal Turbidity Patterns in Suisun Bay Using a 3-D Model, Continuous Monitoring, Remote Sensing, and Monthly Sampling Data

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Turbidity patterns in Suisun Bay are characterized by high variability and sharp gradients over short spatial and temporal scales. However, it is difficult to fully characterize the spatial and temporal variations in turbidity throughout Suisun Bay for inclusion in fish habitat models using the field observations that are currently available. Continuous measurements of turbidity at fixed locations in Grizzly Bay and Honkey Bay can be used to characterize temporal variability at two fixed locations but offer little information on spatial distribution. Monthly sampling of turbidity as part of fisheries surveys provides information on spatial variability, but these measurements are not synoptic. Combining these data sets with remote sensing data and 3-D modeling provides a more detailed assessment of the spatial and temporal turbidity patterns in Suisun Bay. We used a hydrodynamic, wave, and sediment transport 3-D numerical model of the Bay-Delta to estimate the spatially and temporally varying turbidity throughout the system. We analyzed the model results in combination with continuous monitoring time series data, turbidity data at discrete locations from regional monitoring fisheries surveys, remotely-sensed turbidity maps, and prior published findings to develop a comprehensive understanding of turbidity throughout Suisun Bay. Seasonal variations in wind-wave resuspension and sediment supply from the Delta combine with advection by tidal currents to create a large amount of temporal turbidity variability. The interplay of broad shallow areas and deeper channels results in a large amount of spatial variability in the turbidity. This analysis provides a comprehensive understanding of the processes driving both turbidity magnitude and variability in Suisun Bay, which can be used to better understand sediment transport and turbidity and their potential implications on fish habitat.

Keywords: Turbidity, Susuin Bay, Numerical Modeling, Habitat, Sediment Transport
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