Interagency Ecological Program 2022 Annual Workshop

POSTER ABSTRACTS

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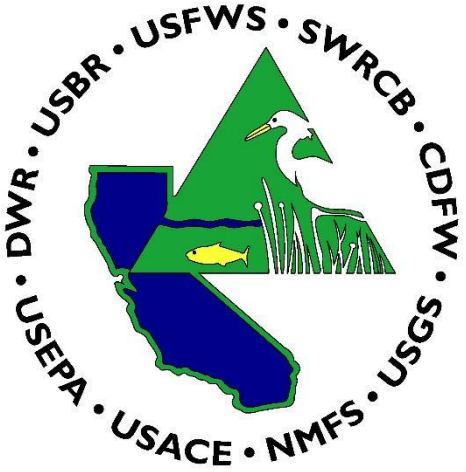

Interagency
Ecological Program

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Listed alphabetically by category and last name of presenting author.

*Denotes presenting author
+Denotes eligibility for early career scientist award

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Delta Smelt & Longfin Smelt

Wakasagi in the San Francisco Bay Delta: Comparative trends in distribution and life-history traits with native Delta Smelt (J. Adams)

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Introductions of non-native fishes can have major consequences on native fish communities. Wakasagi Pond Smelt (*Hypomesus nipponensis*, hereafter Wakasagi) are native to Japan, and were previously separated from their congener the endangered Delta Smelt (*Hypomesus transpacificus)* of the San Francisco Estuary (hereon 'estuary') California (CA) until they were introduced into CA reservoirs in the 20th century as bait fish. Wakasagi have since expanded their range downstream to the estuary, though current knowledge of Wakasagi distribution status and biology in the estuary and negative influences on Delta Smelt is limited. Our study used a comparative approach, synthesizing long-term field monitoring surveys, modeling environmental associations, and quantifying phenology, growth, and diets of Wakasagi and Delta Smelt to describe abundance and range, trends of co-occurrence, and shared ecological roles between smelt species. Wakasagi abundance was higher in northern regions of the estuary, where most co-occurrence with Delta Smelt was found, and below source reservoirs; however, their distributions also extended to western regions of the estuary. Additionally, we found evidence of an established Wakasagi population in the estuary. We noted similar ecological roles for both smelt species, demonstrated by overlapping habitat use (e.g., an association with higher turbidities and higher outflow), phenology, growth, and diets. However, earlier hatching and rearing of Wakasagi during cooler months and reduced

growth during warmer drought years suggest this species is unlike typical non-natives (e.g., Centrarchids), and may exhibit similar sensitivity to environmental variability as Delta Smelt, potentially explaining why Wakasagi abundance remains relatively low in the estuary.

Sex determination of Delta Smelt: Some ways to distinguish captive adults (M. Aghnolaghi)

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Sex determination techniques are important for the successful breeding of captive fish, but these are not always easily accomplished particularly when working with species that have weakly dimorphic secondary sexual traits. The Delta Smelt (*Hypomesus transpacificus*) are endangered fish in California that do not exhibit outward gender identifying traits, and their sexual identity cannot be revealed until they reach spawning conditions. Considering this issue, we carried out a study to explore the morphometric traits as a way to distinguish the sex in Delta Smelt at the UC Davis Fish Conservation and Culture Lab (FCCL). The skin structure was observed in female and male with the scanning electron microscope (SEM), different morphological traits and geometric-morphometrics from the captured photos were measured using ImageJ, Thin-Plate-Spline and MorphoJ through winter to spring, 2013 in the early adult stage (230 dph, n = 34 male, 25 female) and post-spawning stage (342 dph, n = 33 male, 20 female). The 10 most morphological traits were measured (total length: TL, fork length: FL, standard length: SL, post-adipose fin length: Post-Adip, pre-anal fin length: Pre-AFL, post-anal fin length: post-AFL, minimum caudal peduncle depth: CPD, head length: HL, body height: BH, and Pre-dorsal fin length: pre-DFL). The regression slopes were obtained between the variables and the difference of slopes between males and females were tested by ANCOVA which showed CPD and pre-AFL were significantly different between the two sexes. Also, the SEM images revealed that male scales are rougher than female scales due to the presence of ridges and convex grooves. This study confirmed some morphological traits, particularly the variation between CPD and pre-AFL could be a potential tool to determine the sex of adult Delta Smelt before the spawning season in hatchery operations and field monitoring.

Experimental evaluation of alternate spawning strategies to produce Delta Smelt for supplementation (M. Badger)

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To support the Delta Smelt Supplementation Strategy, the UC Davis Fish Conservation and Culture Laboratory (FCCL) has expanded its mission from maintaining a refuge population as insurance against extinction to also encompass production of fish for release to the wild. This large-scale production requires a spawning strategy that harnesses production-efficiency gains, for producing large numbers of fish for release, and adheres to robust conservation genetic principles, to retain genetic diversity and bolster effective population size, N_e. We performed spawning experiments at the FCCL to evaluate relative costs and benefits of alternate spawning strategies: 1) a pooled strategy where we combined eggs from three dams and milt from three sires in one container at the fertilization step and 2) a modified 3 x 3 factorial strategy where eggs from three dams were admixed then apportioned among three containers *prior* to the fertilization step; each container then received milt from a single sire to eliminate potential for sperm competition. We used genetic parentage analysis of offspring (larvae) to determine the reproductive success of dams, sires, and spawns under each strategy. Here, we present preliminary results from four replicates of the pooled spawning strategy and ten replicates of the factorial spawning strategy. Contributions of parents to offspring were more even under the factorial strategy and consequently resulted in higher N_e (average N_e = 5.50 ± 0.38 for factorial; average N_e = 3.86 ± 1.30 for pooled; expected N_e = 6.0 for both). The steep reduction of N_e under the pooled strategy suggests that competition for fertilization increased variance in reproductive success and that this strategy exacts a high risk to conservation objectives. The factorial strategy, however, yielded a high average N_e, which suggests that this strategy strikes a practical balance between production and conservation genetic demands on culture of delta smelt for supplementation.

Too hot to handle? The potential effect of global warming on Longfin Smelt in the Delta and Suisun Bay (E. Chen)

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The Delta and Suisun Bay are important spawning and rearing habitats for Longfin Smelt. Utilizing climate change projections for these regions presents a suitable analysis on how global warming may affect spawning and rearing as well as the species abundance as a whole. By establishing known thermal physiological and behavioral thresholds for Longfin Smelt at the larval, juvenile, and adult phases, we can project the approximate timing when locations within the Suisun Bay and Delta may become too warm for the species at each life stage under two different climate change scenarios. The results suggest that increased water temperature will be the most pronounced in Suisun Bay, where the number of days above the adult thermal threshold could more than double by the end of the century. In addition, the larval thermal threshold is projected to be exceeded throughout all of the Delta and Suisun Bay during the winter by the end of the century, which could lead to extirpation of the species based on water temperature alone. Our analysis suggests that without significant efforts in curbing greenhouse gas emissions, the Delta and Suisun Bay could become inhospitable for Longfin Smelt and other native fish species within the foreseeable future.

New, small-scale Delta Smelt culture system is effective in producing early-stage larvae, but not late-stage larvae (T.C. Hung)

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The Fish Conservation and Culture Laboratory (Byron, CA) cultures a refuge population of Delta Smelt (*Hypomesus transpacificus*) on a large scale, which includes rearing multiple family groups within the same tanks. However, the ability to rear fish on a small scale, such as in individual family groups, would provide greater flexibility to Delta Smelt production and associated research projects. To address this need, we developed a new culture system and modified culture practices for rearing small groups of larval Delta Smelt. We 1) determined the performance of this system from embryo to 80 days post-hatch (dph) and 2) tested whether its performance met the standard set by the large-scale, "refuge" system at key culturing life stages in terms of embryo hatching rate (10 days post-fertilization) and larval survival, length, and weight (40 and 80 dph). We found that the experimental system produced a mean ± SE of 376 ± 44 late-stage larvae per 1000 embryos. The hatching rate of embryos incubated in the experimental system did not differ from that of the refuge system. Early-larval survival also did not differ between systems. However, early-stage experimental larvae were longer and heavier than refuge larvae. In contrast, late-stage larvae reared in the experimental system had poorer survival and were shorter and lighter than refuge-reared larvae. Thus, the experimental system met the refuge-system benchmark for embryo hatching and exceeded the benchmark in early-larval production, but could be improved for late-larval rearing.

Evaluation of Visible Implant Elastomer as a Tagging Method to Inform Experimental Release and Supplementation of Delta Smelt (C. Long)

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As part of the Delta Smelt supplementation strategy, the UC Davis Fish Conservation and Culture Lab and the U.S. Fish and Wildlife Service conducted two tagging experiments to validate the use of Visual Implant Elastomer (VIE) tags in Delta Smelt. In our first experiment, we examined whether VIE color (red, orange, green, blue, and yellow) differed in terms of its retention and effects on fish growth and survival. In our second experiment, we tested whether the tagged body location (posterior dorsal, anterior dorsal, and mid-lateral, relative to dorsal fin) differed in tag retention or its effects on growth and survival. Over the 165-day span of the first experiment, there was no significant difference in growth or survival between any of the colors or the control. Across all color groups, mean tag retention was 96% (range = 87-100%) and mean fish survival was 68% (range = 63-77%) at 165 days post-tagging. Over the 120 days of the second experiment, we found no difference between the different tag locations in growth and survival for fish. We also found that mid-lateral tags were lost at a higher rate than tags at other locations at 120 days post-tagging (84% mean retention in mid lateral tags compared to 98% and 99% for anterior and posterior dorsal tags, respectively). The information gained from these experiments will inform our use of VIE tagging in Delta Smelt for experimental releases and supplementation and provides the extended benefit of application to a variety of future experiments.

FCCL Spawning Methods: Alternative spawning methods for production of cultured Delta Smelt *Hypomesus transpacificus* for supplementation (K. Kelvas)

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Supplementation of hatchery-origin delta smelt to the wild will require a spawning method that balances the need for large-scale production, to increase abundance in the wild, and robust genetic management, to retain genetic diversity and a large effective population size. This will require an alternative to the method used for maintaining the refuge population, which is produced under strict genetic management. To meet this new need, the UC Davis Fish Conservation and Culture Laboratory (FCCL), in partnership with UC Davis Genomic Variation Laboratory and the US Fish and Wildlife Service, is developing an alternative spawning method for supplementation production. In this poster, we describe operational methods for the two alternatives that the FCCL tested in 2021 (see posters by Badger et al. and Rahman et al. for experimental results). Both were based on a 3 x 3 (dam x sire) spawning design. The first method used a modified factorial design that eliminated the potential for sperm competition among sires. Eggs from three dams were admixed then apportioned among three containers prior to the fertilization step, when each container received milt from a single sire. The second method allowed for sperm competition among genetically selected broodstock. Milt from three sires was admixed prior to fertilization of an admixture of eggs from three dams. Compared to the standard pair-cross strategy used for production of the refuge population, the alternate spawning methods tested offer the potential to decrease the time and effort needed for supplementation production.

Assessing sperm quality and competition for paternity success in Delta Smelt (*Hypomesus transpacificus*) (M. Rahman)

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To support the Delta Smelt Supplementation Strategy, the UC Davis Fish Conservation and Culture Laboratory (FCCL) has expanded its mission from maintaining a refuge population as insurance against extinction to also encompass production of fish for release to the wild. This large-scale production requires a spawning strategy that delivers production-efficiency gains while minimizing variance in reproductive success, which will depend in part on use of high-quality gametes (eggs and sperm). To advance identification of an appropriate spawning strategy, we investigated the influence of sperm quality and competition on variance in reproductive success of cultured delta smelt. Using a blocked (n = 5), 3 x 3 full-factorial breeding experiment, conducted at the FCCL, we explored relationships between sperm quality and body size (sire), fertilization rate, offspring (larvae) number, and reproductive success of cultured delta smelt. Per block, eggs from each of three dams were apportioned into three containers (two for replication and one for estimation of egg number per dam) and fertilized with an admixture of sperm from three sires. Thus, each block received eggs and milt from three dams and three sires only, for a total of 15 dams and 15 sires contributing gametes over five blocks. Prior to fertilization sperm quality was assessed based on velocity and linearity. At 8 days post-hatch (dph), larvae were collected, counted, and preserved for parentage analysis. Relationships between sperm quality and fertilization rate and offspring number were significantly positive, whereas correlation between sperm quality and body size was non-significant. Our study demonstrates that reproductive outcomes of delta smelt can differ significantly depending on sperm quality and competition. This contribution will facilitate identification of a spawning strategy to support production and conservation genetic imperatives for delta smelt supplementation and, furthermore, will facilitate increased larval production for associated conservation purposes.

What's got you down? Declining Longfin Smelt abundance and the search for environmental factors that affect vital rates (V. Tobias)

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The Interagency Ecological Program's suite of monitoring surveys has documented increases and decreases in Longfin Smelt abundance over several decades in the San Francisco Estuary. In recent years, Longfin Smelt abundance has declined to the lowest levels on record. We investigated what habitat conditions contribute to high and low abundance for Longfin Smelt using a conceptual model in which environmental conditions affect abundance by influencing the rates of transition from one age class to the next (i.e., vital rates). We fit an age-based, state space model to estimate parameters related to recruitment and survival based on data from the San Francisco Bay Study. We also compiled environmental data from several sources to describe temperature, salinity, food availability, and flow regimes in the estuary as well as conditions in the ocean. Our model used stochastic search variable selection to identify factors that are likely to explain variation in vital rates over time. For some vital rates, we found a few environmental variables that were most likely to be important predictors, but for others a suite of factors was equally likely. Understanding the conditions that can influence specific transitions may help inform strategies for management of Longfin Smelt habitat in the estuary.

Invasive Species

Comparing Fish Sampling Methods in the Sacramento-San Joaquin Delta (M. Arndt and M. Talley)

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The Sacramento-San Joaquin Delta supports diverse fish communities. The Lodi Fish and Wildlife Delta Juvenile Fish Monitoring Program (DJFMP) is a long-term fish monitoring program that uses a variety of gear types to capture fish species across different habitats. While DJFMP focuses primarily on salmonids, centrarchids have increasingly become a family of interest due to their success in outcompeting native fish species. Beach seines are often used to sample unobstructed shorelines (boat ramps, exposed shorelines, etc.), while boat electrofishing allows sampling of more obstructed areas (dense vegetation, banks, and undercuts). We compared catch data from DJFMP seine and electrofishing surveys in order to measure each method's value in obtaining a comprehensive picture of centrarchid and salmonid population health. Beach seines yielded significantly higher counts ($p < 0.01$) of salmonids than electrofishing did, with very low occurrence of centrarchids. Electrofishing, however, was significantly better at catching centrarchids ($p < 0.01$), with very few salmonids caught overall. While some of these differences may be due in part to differences in life cycles and habitat preference, it does suggest that each gear type plays a unique role in measuring the health of the Sacramento-San Joaquin Delta. Going forward, resource managers may want to consider implementing longer-term boat electrofishing surveys alongside robust seining programs in order to expand our understanding of local fish populations.

Invasion of the Water Body Snatchers! *Tridentiger spp.* Stomach Contents and Competition with Native Smelt (T.D. Malinich)

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The San Francisco Estuary has experienced significant ecosystem changes and stressors resulting in declines in all native fish species, such as the endangered Delta (*Hypomesus transpacificus*) and Longfin Smelt (*Spirinchus thaleichthys*). Efforts to restore native habitats and species are challenged by ongoing ecosystem stressors, including non-native invasive fish species. Non-native species are regularly monitored by long-term monitoring surveys conducted by the California Department of Fish and Wildlife, part of the Interagency Ecological Program (IEP). Here we focus on two invasive *Tridentiger* goby species: Shimofuri, (*T. bifasciatus*), and Shokihaze (*T. barbatus*). *Tridentiger* gobies have been present in the upper San Francisco Estuary since the late 1980s. However, following introduction of the Shokihaze Goby in the late 1990s and the pelagic organism decline in the early 2000's, *Tridentiger* spp. larvae have become one of the most abundant fish in the estuary. In 2021, we highlighted the importance of these growing populations, which now vastly outnumber native fish species. We aim to extend this work and highlight the competitive impacts of larval gobies on other fishes in the Upper Estuary. *Tridentiger* gobies have a long-protracted spawning season with the potential to compete with native fishes for prey resources during their pelagic larval phase. To examine how growing goby populations may impact fish their and prey resources, we are examining the stomach contents of larval and juvenile *Tridentiger* gobies collected in 2008. Specifically, we will be comparing the diversity of prey within goby stomachs temporally and spatially within the Estuary. We further compare *Tridentiger* stomach contents with larval and juvenile Striped Bass, Longfin Smelt and Delta Smelt. Overlap in stomach contents could indicate greater competitive stress on native species, in an already food limited environment.

Preliminary data suggest that Wakasagi spawn similarly to Delta Smelt, but during the day and far more frequently (Y.J. Tsai)

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Hybridization is known to occur between native Delta Smelt (*Hypomesus transpacificus*) and invasive Wakasagi (*H. nipponensis*) and may be a threat to the genetic integrity of the imperiled Delta Smelt population. The first step to identifying pre-zygotic mechanisms that may help explain how and to what extent hybridization occurs in the wild is to characterize the spawning behavior of Wakasagi. Wild Wakasagi were collected from the San Francisco Estuary. Five ripe females and five mature males were introduced into spawning tanks and video recorded for four days. Videos were analyzed for spawning behavior, and eggs resulting from spawning were counted. We compared the spawning of Wakasagi in this study to that of cultured Delta Smelt documented in previous studies. We found that Wakasagi spawning was similar to, but more exaggerated than, that observed in Delta Smelt. Preliminary data also suggest that Wakasagi spawn far more frequently and release many more eggs during spawning compared to Delta Smelt. These findings help explain how hybridization may occur behaviorally between Wakasagi and Delta Smelt, as well as how Wakasagi might reproductively outcompete Delta Smelt and succeed as an invasive species. Mixed-species behavioral trials are forthcoming.

Wakasagi (*Hypomesus nipponensis*) Abundance Trends (S. Staiger and V. Mora)

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The Sacramento Shipping Channel has been an important target area for Delta Smelt capture due to optimal environmental conditions in past years. Wakasagi abundance in the shipping channel has also increased during the same period, but 2021 has marked an increase of an alarming rate. This trend appears to correlate with declining populations of endemic Delta Smelt (*Hypomesus transpacificus*). It was believed that Wakasagi were rarely found in the same habitat as Delta Smelt, but new data suggest that these osmerid species are commonly found coexisting in the same habitats (Fisch, K., 2014). Wakasagi have been found to tolerate greater extremes in regards to salinity and temperature when compared to Delta Smelt (Swanson, C., 2000). Thus, Wakasagi might be taking up a niche that is no longer suitable for Delta Smelt. This research evaluates population trends of Wakasagi in the Sacramento Shipping Channel and water quality trends from 2016-present. Water quality analysis will focus on turbidity, temperature, and salinity to better understand long term trends that might affect increasing abundance of Wakasagi.

Lower Food Webs

Monitoring, Modeling, Prediction (MMP), a project with the objective of predicting the likelihood of enhanced chlorophyll (bloom) occurrences in the Bay/Delta ecosystem (R. Dugdale)

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The decline and potential extinction of the Delta Smelt in the Bay/Delta ecosystem has been linked to the low and declining primary production of the ecosystem, which has been related to increasing elevated ammonium discharge from sewage treatment plants and alternatively to grazing by the invasive clam, *Potamocorbula amurensis*. Even so, sporadic occurrences of elevated phytoplankton biomass (blooms) are observed in the Bay/Delta ecosystem, but their timing and location is not well understood. Using a combination of historical data analysis, modeling and real-time observations, a framework has been constructed for the objective prediction of spring and fall blooms in the Bay/Delta ecosystem. The framework is based on a set of criteria for key parameters that must all be positive for a bloom to be predicted. The criteria include historical flow ranges associated with blooms and a river flow range low enough to avoid washout of the phytoplankton, but high enough to dilute effluent ammonium to the low values required to allow nitrate uptake by the phytoplankton. A set of boundary conditions, e.g. chlorophyll and ammonium concentrations at the upper end of the ecosystem at Rio Vista are also evaluated. This boundary criterion determines if there is a sufficient phytoplankton population entering the system to reduce the ammonium concentration and be seed for a bloom. The boundary conditions are applied to the SCHISM-CoSiNE coupled hydrodynamic-biogeochemical model to produce a model-based criterion. Application of the framework will be presented for fall 2020 and spring 2021, using data from weekly river transects measuring ammonium, nitrate and carbon uptake, landscape- based high-speed mapping and from fixed installations, to ascertain whether an observed bloom developed in situ or was advected from upstream.

Nutrient and Chlorophyll Variation between the Yolo Bypass and Sacramento River (P. Farman)

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The Yolo Bypass is the largest remnant floodplain of the Sacramento River, and provides essential flood management and wildlife habitat within the Sacramento - San Joaquin Delta. In 1998, the California Department of Water Resources implemented the Yolo Bypass Fish Monitoring Program (YBFMP) to collect baseline data on hydrology, water quality, lower trophic organisms, and fish within the Yolo Bypass. To understand how nutrient and chlorophyll concentrations vary between the Yolo Bypass and lower Sacramento River, the YBFMP collects nutrient and chlorophyll samples twice a month at two sites within the Yolo Bypass's perennial Toe Drain canal and an adjacent site in the Sacramento River. We analyzed nutrient and chlorophyll data from October 2016 to September 2019, and found that in the lower Sacramento River, there were lower concentrations of chlorophyll, dissolved ammonia, dissolved nitrate-nitrite, and dissolved orthophosphate, and higher concentrations of dissolved silica compared with the Yolo Bypass. Model results also showed that chlorophyll concentration increased in the spring, dissolved nitrate-nitrite concentration increased in the winter, and dissolved orthophosphate concentration increased in the summer. These differences between sites and seasons are likely driven by precipitation, flooding, agricultural input, and hydraulic residence time, as these abiotic factors have the potential to contribute, dilute, or flush away nutrients and chlorophyll. These results highlight the Yolo Bypass's ability to provide higher concentrations of nutrients and chlorophyll, key components to the base of the food web, as compared to the Sacramento River.

What to Expect When Expecting: Investigation of Mysid Fecundity in the Upper San Francisco Estuary (U. Ikeme)

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For more than 40 years the Zooplankton Study under the Environmental Monitoring Program (EMP) has collected mysid and zooplankton abundance data in the upper San Francisco Estuary (SFE). In addition, mysid length, sex, and fecundity data has also been recorded, but fecundity dataset has yet to be published and has not been analyzed in several decades. We have recently done quality control on the fecundity dataset and performed preliminary analysis for three mysid species from the upper San Francisco Estuary. For *Hyperacanthomysis longirostris*, an introduced mysid species first detected in 1993, there is a trend of higher egg counts at shorter body lengths compared to the native species, *Neomysis kadiakensis* and *Neomysis mercedis*. We also observed a decline in the average number of eggs per gravid *N. mercedis* since the mid-1990s, which corresponds to a general decline in its population that began in the mid-1980s. We captured gravid individuals of all three species throughout the year, with peaks generally in late spring and early summer. Mysids play a key role in the estuarine food chain, being an important food item for several imperiled fish species, and this investigation provides new insight into their population dynamics within the region.

Hydrodynamics structure zooplankton-phytoplankton interactions over a seven year period in the Sacramento Deep-Water Ship Channel (A.P. Smits)

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Drivers of phytoplankton and zooplankton dynamics vary spatially and temporally in estuaries, complicating efforts to understand changes in food web productivity. We conducted ~monthly (2012 – 2019; n = 74) sampling at ten fixed stations along the Sacramento deep water ship channel (DWSC), characterized by seaward to landward gradients in water residence time, nutrient concentrations, and plankton community composition. We used multivariate autoregressive state space (MARSS) models to quantify environmental and biotic controls on phytoplankton and zooplankton biomass across major taxonomic groups. The importance of specific environmental drivers (e.g. water temperature, turbidity, nutrients) and trophic interactions differed significantly among hydrodynamic zones with different mean residence times. Environmental (abiotic) drivers explained more variation in phytoplankton and zooplankton dynamics than a model including only trophic interactions, but individual phytoplankton-zooplankton interactions were stronger than effects of individual environmental drivers. Interactions between zooplankton and phytoplankton were strongest in landward reaches with the longest residence times and the highest zooplankton biomass. Interactions between cryptophytes and zooplankton were stronger than interactions between bacillariophytes (diatoms) and zooplankton, despite contributing less biovolume in all but the most landward reaches. The importance of specific trophic interactions in our models, coupled with the weak associations between zooplankton and chlorophyll-a or total phytoplankton biovolume, suggest that efforts to quantify resource availability for pelagic food webs may benefit from sample collection or sensor measurements that distinguish among algal taxa.

How do nutrient and phytoplankton conditions in Suisun Bay compare before and after EchoWater implementation by Regional San? (F. Wilkerson)

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With EchoWater implementation by Regional San, it is unclear how the waste-water treatment upgrade resulting in changes in nutrient loads, forms and proportions will affect phytoplankton and ultimately the pelagic food web of the northern San Francisco Estuary. The aim of our study is to compare nutrients, phytoplankton community composition and productivity results from prior to upgrade with conditions after the upgrade was complete. A series of stations were sampled from above Regional San in the Sacramento River south through Suisun Bay. As expected, after the upgrade, ammonium and nitrate concentration decreased throughout the transect. A peak in ammonium concentrations was observed in western Suisun Bay in proximity to the Central San WWTP discharge. During transects we also measured productivity versus irradiance of the dominant phytoplankton groups using a Phyto-PAM II and how they responded to short-term ammonium and nitrate additions. Finally, phytoplankton conditions were also studied in experimental enclosures exposed to varying light and using water from selected stations to which nitrate, ammonium and effluent enrichments were made to resemble the pre-upgrade conditions. These data will aid in understanding the light and nutrient drivers of pelagic primary production in the upper estuary in order to help management actions in the Delta that aim to re-establish historic food web processes.

Potpourri

Review of the Monitoring Enterprise in the Sacramento-San Joaquin Delta (S. Brandt)

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The 2009 Delta Reform Act directs the Delta Independent Science Board (ISB) to review scientific research and monitoring that support adaptive management of the Delta. Recognizing the need for a comprehensive review of Delta monitoring activities, the ISB reviewed the suite of monitoring programs in the Sacramento-San Joaquin Delta (referred to as the monitoring enterprise). The purpose of this review was to assess if information collected from monitoring is meeting the needs of the management agencies; if coordination, efficiencies, data quality, and data accessibility could be improved; and how monitoring data can better support the implementation of adaptive management. This review includes a comprehensive inventory of all monitoring activities and was informed by a literature review, public comments, brown bag seminars and panels, a monitoring workshop, a survey, and subsequent interviews with experienced scientists and managers involved in Delta monitoring. The Delta ISB developed an adaptive management framework for monitoring that would better meet the needs of management and stakeholders and apply the five best practices identified in the review: (1) formally tie monitoring to goals, objectives, and questions; (2) be informed by stakeholder needs and capabilities and include alternative forms of data and knowledge; (3) adapt as new information, science, and technology become available; (4) include data management, analysis, storage and synthesis; and (5) ensure that data are accessible. In addition, the Delta ISB recommends the following three transformative changes for the monitoring enterprise to better link monitoring to management: (1) develop priority management-informed science needs and questions for the monitoring enterprise and synthesize information around these questions in biennial reports or at a summit, (2) reimagine monitoring designs that are guided by priority management-informed science needs and a system-wide conceptual model; and (3) strengthen the integration, organizational and funding structure to support monitoring, analysis, and adaptive management.

Assessing prevalence, pathways, and impacts of selenium exposure for fish species of concern in the Sacramento-San Joaquin Delta (F. Feyrer)

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The prevalence, pathways, and population-level consequences of selenium (Se) exposure in fishes of the Sacramento-San Joaquin Delta is uncertain. Historically, a lack of observable direct mortality of fishes in the environment has prevented consensus that Se or other contaminants are important drivers of fish population dynamics. However, recent observations of deformed fish linked to high Se concentrations in adult tissues and juvenile otoliths have raised concerns that Se exposure may continue to pose a considerable risk to fish populations. Because of the dynamic nature of the Delta and the complicated life histories of its native fish fauna, examining the effects of contaminants such as Se on specific life stages in different seasons and salinity zones is critical to identifying how interacting stressors contribute to exposure and imperilment of fish species of concern. Comprehensive, ecologically based investigations are needed to elucidate the individual and population-level impacts of Se on native fishes. This presentation will summarize our work to date and describe ongoing efforts to study effects of Se in Delta fishes.

2022-2026 Science Action Agenda: A Vision for Integrating Delta Science (R. Klopfenstein)

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Unique for the Delta science enterprise, the Science Action Agenda (SAA) prioritizes and aligns science actions to meet management needs. This four- to five-year iterative agenda, published by the Delta Stewardship Council's Delta Science Program, is developed by and for the Delta science community. The SAA is organized around pressing management needs and the highest priority science actions responsive to those needs. The 2022-2026 SAA, anticipated by Spring 2022, also includes a list of top management questions to better link broader management needs to science actions. The content of the SAA was created through an iterative and collaborative process of engaging participants through meetings, workshops, and surveys. The development of the 2022-2026 SAA began in early 2020 with the engagement of over 30 collaborative groups to develop the list of top management questions. These questions led to the development of broader management needs and, later, responsive science actions. Over 125 workshop participants and 150 survey responses across multiple workshops and surveys informed the SAA development process. The 2022-2026 SAA was also informed by research relevant to the 2017-2021 SAA. The 2017-2021 SAA Progress Summary was created to track progress made on the 2017-2021 SAA science actions and to identify gaps. The Progress Summary was informed by a synthesis of activities that contributed to addressing the 2017-2021 SAA science actions and public input on the draft Progress Summary. The existing gaps identified in the Progress Summary informed the development of the science actions. The draft 2022-2026 SAA was released for public comment in fall 2021, and feedback on the draft informed the final SAA. As a distillation of input from scientists, managers, and those with stake across the Delta, the Delta Science Program and other agencies use the SAA as a guide for science funding and to promote collaboration and transparency.

Restoring the Heart of a Healthy Estuary: A Synthesis Of Restoration In The Sacramento–San Joaquin Delta And Suisun Marsh (J. Moffat)

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Effective adaptive management of ecosystem restoration at the landscape-scale requires a detailed understanding of current conditions to support science-based decision making (Delta ISB 2013; Delta ISB 2016). To this end, the Delta Independent Science Board identified a need for "a comprehensive map and accompanying database to show where habitat restoration activities are being conducted or planned in the Delta, accompanied by essential information on these projects" (ISB 2013). To support achievement of restoration goals and implementation of adaptive management, we are examining the history and future of active and passive process-based ecological restoration in the Delta and Suisun Marsh. Using EcoAtlas and supplemental sources, we present a synthesis of planning and implementation of restoration to date using a coordinated description of restoration types, their processes, and goals, categorized into four project types: tidal wetlands, non-tidal wetlands, riparian habitats, and floodplains. For each of these types, we provide background, a description of restoration processes, and a quantification of the area covered across all projects identified in the Delta and Suisun Marsh. For each project, we identify acreage, whether the restoration was intentional or unintentional, lead agencies, funding sources, and project phase (completed, in-progress, and planned). In total, we identified 30 tidal wetland restoration projects totaling 18,799.1 acres; 12 unintentional levee breaches that have passively restored 7,650 acres of fully tidal and muted wetlands; 20 riparian projects totaling 1,132.86 acres; 9 floodplain projects totaling 1,898.14 acres; and 17 non-tidal wetland projects totaling 3,601.71 acres. We plan to use the 2022 Interagency Ecological Program Workshop to gather further feedback from practitioners and scientists on this project list.

Resident Fishes

Lamprey diversity within California watersheds: Genomic approaches for disentangling an understudied multispecies complex (G. Auringer)

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Lampreys, a group of jawless, eel-like fishes, are extant representatives of the first known vertebrates. At least six species of lamprey (*Entosphenus* spp. and *Lampetra* spp.) occur in California watersheds. All are listed as California Species of Special Concern, yet little is known about interspecific and intraspecific genetic structure of lamprey populations throughout the state. Genomic approaches are well-suited to fill fundamental knowledge gaps concerning California's native species of lamprey, including determining species identification, phylogenetic placement, and assessing lamprey passage at dams, weirs, and other potential barriers. Larval lamprey are very challenging to identify to the species level using morphological features, and the larval phase is the longest portion of the life span (3-9 years). In this study, we applied restriction-site associated DNA sequencing (RADseq) to lamprey samples collected opportunistically through several ongoing fish monitoring surveys in 2018-2019. Our preliminary dataset captures individuals from various species, life stages, and geographic locations throughout northern California. Analysis of 480 individuals genotyped at variable SNPs (single nucleotide polymorphisms) throughout the genome revealed genetically distinct clusters of individuals that allowed us to infer species identity for unidentified samples. Two anadromous species, Pacific lamprey *(Entosphenus tridentatus)* and River lamprey (*Lampetra ayresii),* are highly genetically divergent. We observed novel species distribution patterns, shedding light on undescribed species diversity in California. For many sampling locations, multiple lamprey species were found at the same site during the same sampling period, suggesting sympatry is common for lamprey in California. Ongoing research efforts aim to generate a SNP monitoring panel specific to lamprey populations in the SF Bay-Delta, Klamath, Sacramento, and San Joaquin watersheds.

Liberty Island: The Rise of the Non-Natives (G. Steinhart)

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Liberty Island, historically a tidal freshwater wetland, was converted to agricultural lands in the early 20th century. After decades of farming, the levees surrounding the island failed during high water in 1997-1998. The island flooded and was left alone in hopes that it would again provide wetland habitat for native fishes. After flooding, Liberty Island was used by several native fishes (see accompanying poster "Liberty Island: A New Hope for Natives"), but it also created available habitat for non-native species. The U.S. Fish and Wildlife Service (USFWS) monitored the fish community in Liberty Island from 2002-2005 and again from 2009-2019 using various methods. Here, we examine trends non-native black bass (*Micropterus* spp.) and sunfish (*Centrarchid* spp.) by comparing abundances from inside Liberty Island, adjacent to Liberty Island, and across the entire Delta. We examined larval trawl data from the USFWS and the California Department of Fish and Wildlife Smelt Larval Survey. In addition, we used beach seine data from the USFWS and the California Department of Water Resources Yolo Bypass monitoring. During this time, non-native bass and sunfish increased in abundance across the Delta and were present in variable abundance near Liberty Island. Inside Liberty Island, abundance of bass and sunfish was initially low, but began to increase around 2010 and peaked around 2015, which corresponded with the dramatic increase in non-native aquatic vegetation inside Liberty Island. However, density of non-native fishes was rarely higher inside Liberty Island than elsewhere, except for very young Centrarchids caught in USFWS larval tows. Although Liberty Island may have provided habitat for native species when it first flooded, through time non-native fish and vegetation increased in abundance which could reduce benefits for native species.

Liberty Island: A New Hope for Natives (C. Macfarlane)

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Liberty Island was a tidal freshwater wetland that was reclaimed in the 1900s for agriculture. In 1997, after multiple levee breaches during high flows, the island flooded and was left to passively restore to wetland habitat with the goal of providing habitat for declining native species. The U.S. Fish and Wildlife Service (USFWS) monitored the fish community in Liberty Island from 2002-2005 and again from 2009-2019 using a variety of techniques. Here, we examine trends in native Delta Smelt (*Hypomesus transpacificus*) and Sacramento Splittail (*Pogonichthys macrolepidotus*) by comparing abundances inside Liberty Island with adjacent sample sites and sites across the Delta. We examined larval trawl data from the USFWS and the California Department of Fish and Wildlife Smelt Larval Survey. We also compared beach seine data from the USFWS and the California Department of Water Resources Yolo Bypass program. Delta Smelt were sometimes more abundant inside Liberty Island than outside, but significantly declined after 2015 across the Delta and in all sampling programs. At the same time, non-native vegetation and non-native fishes increased inside Liberty Island (see accompanying poster “Liberty Island: The Rise of the Non-Natives”). Sacramento Splittail were periodically abundant with high annual variation both within and outside Liberty Island. Sacramento Splittail abundance did not decline as non-native species increased inside Liberty Island. Instead, peaks of abundance were associated with high water years that increased access to floodplains used for reproduction. Data from Liberty Island suggests flooded island habitat may be used native fishes for foraging, nurseries, or refuge and demonstrates benefits of increasing tidal wetland habitat. These benefits, however, can be temporary if the flooded island is invaded by non-native vegetation and fish, although the effects likely differ by species based on habitat needs of different life stages.

Distribution and habitat use of Tule Perch (*Hysterocarpus traskii*) in the Sacramento-San Joaquin River Delta (E. Sharkey)

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Tule Perch (*Hysterocarpus traskii)* are a native fish species inhabiting the San Sacramento-San Joaquin River Delta (Delta). As with many native fishes within the Delta, Tule Perch habitat preferences and distribution across the Delta are not well studied and could provide valuable information for ongoing habitat restoration efforts for native fishes. In this study, we conduct a preliminary analysis using boat electrofishing datasets collected by the California Department of Fish and Wildlife (1980s and 2000s) and the U.S. Fish and Wildlife Service (2018 to current) to assess the spatial and temporal distribution and habitat use of Tule Perch within the Delta. More specifically, we attempt to answer the following study questions: 1) Has the distribution of Tule Perch changed in the Delta since the 1980's? 2) What environmental parameters are best at predicting Tule Perch presence in nearshore habitats? Since 2018, the U.S. Fish and Wildlife Service has conducted a nearshore boat electrofishing survey to supplement its long-term beach seine monitoring program and gather information on juvenile Chinook Salmon and nearshore fish assemblages throughout the Delta. This study provides an example to the IEP scientific community of how the publicly available data from this survey may be used to inform native fish conservation initiatives in the future.

Salmon & Sturgeon

Every pathogen counts: Transcriptional response to co-infection in juvenile fall-run Chinook Salmon (*Oncorhynchus tshawytscha)* (S. Abdelrazek)

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Infectious diseases are regarded as one of many factors contributing to the decline of wild salmon populations. This study aimed to elucidate the mechanisms underlying Chinook salmon (*Oncorhynchus tshawytscha*) response to infectious agents via 1) determine the prevalence and abundance of infectious agents, and 2) determine the expression profiles of immune, stress, and brain derived neurotrophic factor genes. To achieve these goals, juvenile Chinook salmon were deployed in cages, at the Red Bluff Diversion Dam, California, USA. Fish gill, kidney, and intestinal tissues were sampled at 0-, 7-, 14-, and 21-days post deployment (dpd) to determine pathogen prevalence and abundance, and host transcriptional response, via qPCR. Intestinal tissue was evaluated for presence of *Ceratonova shasta*, using a specific PCR assay. On day 21, kidneys were collected for histopathological assessments to determine impacts of *C. shasta* in intestine and *Parvicapsula minibicornis* in kidney.

Co-infection was common with *C. shasta* and *P. minibicornis* being the two predominant pathogens. Five of the eight target pathogens were detected in the gills, indicating that this tissue serves as an important entry point. Transcriptional responses were detected in the gills (by 7 dpd) before they were detected in the kidneys. *C. shasta* detection in kidney was relatively consistent with the detection in the intestine. *C. shasta* and *P. minibicornis* trophozoites were observed within lamina propria and glomerulus with a moderate degree of glomerulonephritis. Results indicate that Chinook salmon are exposed to a wide range of infectious agents, resulting in complex host-pathogen dynamics. This study provides conservation managers with information on the effects of infectious diseases and their impact on out-migrating Chinook salmon in California's Central Valley and elsewhere. It also establishes the foundation for future research into the most prevalent infectious agents, and their potential pathogenicity, which could jeopardize out-migrating Chinook salmon in the Sacramento River.

Evaluating Historical and New Potential DJFMP Beach Seine Sites (J. Buxton and J. Gronemyer)

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The Delta Juvenile Fish Monitoring Program (DJFMP) has utilized beach seines to sample juvenile Chinook salmon in the Sacramento-San Joaquin Delta (Delta) since the mid-1970s. Fifty-eight sampling sites, located in seven sampling regions, exist throughout the Delta and San Pablo Bay. Thirteen current locations have been sampled regularly since the program's beginning and many additional sites were added in the 1990s. DJFMP is currently reevaluating the seine sampling methods based on findings from a 2013 IEP program review. The review determined it is unlikely that fixed-site sampling is representative of the different habitats found throughout the Delta. In addition, numerous historical seine sites are unable to be consistently sampled for a variety of reasons such as accessibility and changes in environmental conditions. To address these issues DJFMP aims to incorporate a hybrid stratified random design which will continue to include historical sites while also incorporating new sites. This study aims to evaluate and quantify the reasons that lead to not sampling historical sites and highlight ongoing efforts to identify new seine sites. From 2005 to 2019, we calculated the frequency of code-4's (unable to sample) at historical sites and for each seine run we identified the site with the highest frequency and evaluated the reasons that it could not be sampled. Preliminary results from evaluating historical site code-4's indicate water level issues, muddy sites, and multiple factors as the top reasons a site is unable to be sampled. Satellite imagery is being utilized to locate new potential sites. Field crews are then evaluating these sites in-person while annotating key factors including ease of access, water velocity, and substrate type. Incorporating new sites into the program is proving challenging as most potential beach sites are located on privately-owned land, inaccessible due to riparian vegetation, or are in deeply channelized locations.

New green sturgeon population estimate and assessment of bycatch impact (P.N. Dudley)

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NOAA fisheries classifies the green sturgeon southern distinct population as threatened. This population resides in California waters, migrating between the Sacramento River to spawn and the San Francisco Bay/coastal waters to feed. Each year in April through August, a subset of adults migrates up the Sacramento to spawn in between Chico, and Redding. Tracking this population as it hopefully recovers will allow managers to take smaller corrective actions before more severe measures are required if they see decreases in the population. This work presents and updated population estimate based on an annual spawner acoustic census, a new integrated population model, and a life table model. This method uses data from the annual acoustic survey, telemetry data from the BARD database, and literature data. This method uses a stochastic approach, sampling from data sets and parameter values to attempt to display and accurate degree of uncertainty in the population estimate. This stochastic approach also permits us to use these data sets to simulate the effect bycatch in the California halibut trawl is having on the population. We find that the green sturgeon population in 2018 was approximately 11,000 with a wide range of uncertainty and that bycatch at the level currently experienced would reduce a stable population by 4% every 10 years. Early action to prevent a species decline is much more successful and less costly and restrictive than delayed efforts to build back an already degraded population. Thus, tracking this population is crucially important.

The Tunnel at the End of the Light: Could reducing artificial nighttime illumination benefit native fish? (B.M. Lehman)

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The Sacramento–San Joaquin Delta has been invaded by several species of non-native predatory fish that are presumed to be impeding native fish population recovery efforts. Since eradication of predators is unlikely, there is substantial interest in removing or altering manmade features in the Delta that may exacerbate predation on native fish (contact points). Manmade features such as artificial lighting at night (ALAN) may contribute to increased levels of predation by attracting predators to prey, increasing predator reaction distance, and foraging success. Field experiments in the Delta have found ALAN to attract both large and small fish, and to increase predation rates on juvenile salmonids by non-native predators. Removing, altering, or reducing the intensity of artificial lights that illuminate waterways is a feasible and potentially beneficial restoration action to improve the fate of native fish. However, to date there has been no inventory of ALAN in the Delta and quantifying light levels that are relevant at small spatial scales is difficult with existing remote sensing data. To inform the potential of reducing ALAN to benefit salmon, we surveyed all major channels in the legal Delta and created an inventory of illumination sources that cast measurable light onto waterways. We combine this with experimentally gathered information on predation rates as a function of ALAN and other environmental covariates to prioritize light sources that could be addressed to benefit salmon.

Water Quality

Old and Middle Rivers Harmful Algal Bloom Monitoring (HAB): Visual Observation vs. Direct Sampling (B. Jones)

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Harmful Algal Blooms (HAB) are becoming a more common occurrence throughout the Sacramento - San Joaquin Delta. The most prevalent cyanobacteria and producer of harmful toxins in the central and south Delta in recent years is *Microcystis aeruginosa*, a known producer of harmful toxins called microcystins. Starting in late 2017, the Department of Water Resources North Central Region Office's Water Quality Evaluation Section as part of the South Delta Temporary Barriers Project (TBP), started recording visual index values of surface *Microcystis* blooms during standard water quality stations visits every 3-4 weeks across the region year-round. Visual index values range from no visible *Microcystis* to very high concentration of contiguous colonies of *Microcystis*.

Starting in 2019, during peak Visual Index periods of June-September, additional HAB sampling is conducted at specific sites of concern in the south Delta to provide additional support for the Delta Regional Monitoring Program (RMP). Additional sampling includes subsurface phytoplankton taxa identification, and surface *Microcystis* tow net sampling analyzed with a Fluid Imaging Technologies FlowCam. Specifically looking at 3 of our additional sampling sites; Old River near Head (OH1), Old River above Mountain House Creek (ORM), and Middle River and Howard Road (MHO), we want to better define what our visual index score indicates for concentration value of *Microcystis*, by comparing visual index scores with *Microcystis* tow net sample biovolumes and Phytoplankton taxa biovolume samples from additional discrete sampling efforts. By defining our visual index scores, we will be better equipped in the future to quickly and more accurately estimate concentration values of HABs throughout the Delta.

The response of phytoplankton and nutrient composition to an upgrade of a major wastewater treatment plant (S. Randall)

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The northern San Francisco Estuary (nSFE) is described as a high nutrient, low growth system where the low productivity may be a causal factor in the population decline of pelagic fish species, including the endangered delta smelt (*Hypomesus transpacificus*). Anthropogenic nitrogen (N) loading, including that originating from treated wastewater, is a major nutrient source for this region. Regional San, a wastewater treatment plant that discharges to the Sacramento River at Freeport, serves 1.6 million residents and is the largest inland wastewater treatment plant in California. Previously, it had been discharging ammonium-N as a product of its effluent at a rate of 15 tons/day. Starting in late 2020 and completed in April 2021, Regional San upgraded its wastewater treatment process through the EchoWater Project to include tertiary treatment, or biological nutrient removal (BNR). To study the effect of Regional San's upgrade on nutrients and phytoplankton in the nSFE, biweekly water samples have been collected since March 2021 at Rio Vista, CA, a city located on the Sacramento River and downstream from Regional San. These samples are being used to create a data time series of nutrient concentrations, chlorophyll-*a*, and associated phytoplankton productivity and nitrogen uptake. Preliminary data shows a decrease in ambient ammonium-N concentration at Rio Vista following the upgrade and ammonium-N has remained low, around 1µM, until the November 2021 atmospheric river. After this storm, nutrient concentrations in the nSFE increased, with ammonium-N increasing to 6µM and nitrate-N increasing to 65µM. The time series data will be compared with historical Rio Vista data collected prior to the upgrade. The results of this study will contribute data necessary for interpreting post-upgrade estuarine responses to nutrient management at Regional San, and more generally to the growing understanding of anthropogenic impacts on estuarine nutrients and phytoplankton.

A Tale of Two Rivers: Water Quality and Zooplankton Abundance in the Low-Salinity Zone (L. Richardson and D. Finger)

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The entrapment zone (EZ) is a phenomenon that occurs at the transition between saltwater and freshwater in an estuary. It is defined by the Department of Water Resources' Environmental Monitoring Program (EMP) as the zone at which bottom specific conductance measures between 2000 and 6000 µS/cm, where mixing and recirculation of freshwater and saltwater currents locally increase turbidity and concentrations of suspended sediment and nutrients. Abundance of phytoplankton and zooplankton is also enhanced within the EZ, and EMP began monitoring discrete water quality and the location of the EZ in 1996 because of its ecological significance. The EZ's location fluctuates both seasonally and between years depending upon the level of freshwater outflow. When outflow is high, the EZ is typically located downstream of the confluence of the Sacramento and San Joaquin rivers. During low-flow conditions, the EZ moves upstream of the confluence and splits into two geographically distinct areas in the Sacramento and San Joaquin rivers.

The ecological implications of these split EZs are not well understood, but it has been shown from monitoring data that community composition of zooplankton differs between the Sacramento and San Joaquin EZs. The purpose of this analysis was to compare water quality parameters between the three main EZ positions (below the confluence, in the Sacramento River, and in the San Joaquin) since 2014 to help determine whether water quality is driving differences in zooplankton abundance or composition. While the San Joaquin EZs averaged lower values for turbidity, most physical and chemical water quality parameters did not differ greatly between the EZ locations. Therefore, we cannot assume that local water quality factors are causing differences in zooplankton between the EZs. Further analysis is needed to determine what different characteristics of these two rivers determine their lower trophic communities.

Salinity monitoring in and around the Frank's Tract region during presence of the 2021 West False River Barrier (T. Salman)

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Installation of the West False River Emergency Drought Salinity Barrier (EDB)by the Department of Water Resources (DWR) was initiated on June 3, 2021 in accordance with the Governor's emergency drought proclamations issued on April 21 and May 10, 2021. The 2021 EDB is a temporary rock fill barrier that has the primary goal of preventing salinity intrusion by seawater into the interior central and south Delta waterways, allowing for the State Water Project (SWP) and Central Valley Project (CVP) to meet water quality objectives outlined in State Water Resources Control Board water quality control plans. To meet EDB permit compliance, the DWR along with agency partners are responsible for monitoring and reporting on the water quality conditions in response to the installation of the EDB. Continuous data from several water quality monitoring stations in and around this region of the Delta were used to help identify any potential changes in water quality during the presence of the barrier with a focus on specific conductance (as a surrogate for salinity). The water quality monitoring stations in closest proximity to the barrier: False River near Oakley (a station immediately upstream from the barrier) and San Joaquin River at Jersey Point (a station about 1 mile downstream from the barrier) provide a useful gauge of localized barrier effects on salinity, and we further looked at the broader network of stations in and around Franks Tract to determine the impacts and success of the barrier in minimizing salinity intrusion.