# INTERAGENCY ECOLOGICAL PROGRAM
# 2022 ANNUAL WORKSHOP

## TALK ABSTRACTS

### March 22-24, 2022

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Interagency
Ecological Program

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# Abstracts

This booklet contains abstracts for the workshop presentations. There is a separate booklet available for the posters, which can be found in the Poster Discussion Forum located on the IEP Annual Workshop page.

Abstracts were optional and not all presenters provided one. Available abstracts are listed by session and speaker.

## Contents

# Session III: Drought Impacts

## A Hard Rain's [Not] A-gonna Fall: A synthesis of drought impacts on the Delta ecosystem

**Rosemary Hartman[1] , David Bosworth[1], Arthur Barros[2], Peter Nelson, Keith Bouma-Gregson[3], Leela Dixit[1], Laura Twardochleb[1], Christina Burdi, Jereme Gaeta[2], Nick Rasmussen[1], Jenna Rinde[2], Peggy Lehman[1], Evan Sawyer[4]**

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The extreme drought of 2020-2021 came fast on the heels of the 2014-2016 drought. The unexpected lack of runoff in 2021 forced water resource managers and IEP scientists to re-examine how the ecosystem responds to multi-year droughts. The IEP Drought Synthesis Team was formed in the spring of 2021 to describe how the Delta ecosystem responds to extended dry conditions as well as describe the impacts of drought management actions in 2021. The synthesis team, made up of IEP scientists from across multiple agencies and areas of expertise, compiled data from a wide range of IEP surveys; collecting data on hydrology, water quality, nutrients, harmful algal blooms, chlorophyll, aquatic vegetation, zooplankton, jellyfish, clams, and fish. They compared abundance, timing and/or distribution of these ecosystem constituents during droughts (multiple "dry', "critically dry", or "below average" years in a row) versus wet periods (multiple "wet" or "above normal" years in a row) for 1975-2021. They also took a closer look at data from 2011-2021, comparing data between individual years to see how the current drought compares to the previous drought. They found that some constituents responded negatively to drought, others responded positively, and others differed by region. Abundance of Longfin Smelt and Striped Bass decreased. Secchi depth, salinity, temperature, aquatic vegetation, and Microcystis all increased with drought. Zooplankton and chlorophyll increased during droughts in the South Delta but decreased during droughts in Suisun Marsh and Suisun Bay. Jellyfish were confusing and Delta Smelt were inconclusive. The Emergency Drought Barrier may have exacerbated a dense cyanobacterial bloom within Franks Tract in the summer of 2021, but no other effects of the Barrier or TUCP could be measured above the impact of the drought itself.  These analyses will help inform future drought management actions to balance ecosystem and human beneficial uses.

**The Effect of Hydrometeorological Forecast Errors on Temperature Management Projections for the Sacrament River: A 2021 Drought Case Study**

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The intensification of drought throughout California in 2021 highlighted the impact of seasonal hydroclimatic forecasts on a range of water resources management decisions. One such set of decisions entailed management of cold water held at Shasta Dam to provide instream spawning habitat for the endangered Winter Run Chinook salmon while meeting constraints imposed on Shasta Reservoir by system-wide demands. Advance planning to prevent exceeding certain levels of temperature-dependent egg mortality (TDM) requires a suite of forecasts: reservoir inflow, agricultural demand, valley floor hydrology, meteorology, reservoir and conveyance facility operations, and salmon spawning distribution. Each of these has considerable uncertainty, especially at the long lead times required for early decision-making. Yet the relative importance of errors in each forecast in affecting projected TDM outcomes is not well-characterized. To address this, we present a retrospective analysis of the 2021 Sacramento River temperature management season to evaluate the sensitivity of different projections of interest (e.g., water temperatures at Shasta, downstream, seasonal TDM) to errors in each forecast component. The analysis considers original forecasts of reservoir inflow, meteorology, spawning distribution, and reservoir operation at monthly increments throughout the spring planning period along with the actual realized conditions. Outcomes are evaluated through the use of a simulation framework representing reservoir, river, and egg incubation processes in the upper Sacramento River system. Results will help inform and direct efforts to improve forecasting methods for better advanced decision-making in drought years like 2021.

**Influence of salinity on pyrethroid toxicity: an analysis of neurotoxicity and osmoregulation in a model estuarine fish (*Menidia beryllina*)**

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Climate change is causing changes in precipitation patterns and as well as increased sea levels. These alterations are linked with increased salinity in estuaries, making the potential differences in toxicity across a salinity gradient a topic of increasing interest in assessing risk to estuarine species. As ionic concentration increases the log $K_{OW}$ and water solubility of a compound has been shown to increase and decrease respectively. Pyrethroid insecticides are commonly used in agricultural, industrial, and household settings and have been detected in watersheds globally. Several recent studies have shown that pyrethroid toxicity can change across a salinity gradient. Early life exposures in fish to pyrethroids has been found to cause toxicity at environmentally relevant concentrations and alter behavior, reproduction, and gene expression. Therefore, Inland Silversides (*Menidia beryllina*), a commonly used euryhaline, model fish species, were exposed from 5 days post fertilization (approximately 1-day pre-hatch) for 96 hours to six pyrethroids: bifenthrin, cyfluthrin, cyhalothrin, cypermethrin, esfenvalerate, and permethrin. Exposures were conducted at three salinities relevant to brackish, estuarine habitat (0.5, 2, and 6 PSU) and 3 concentrations, either 0.1, 1, 10, and/or 100 ng/L, determined from previous experiments to be sublethal and environmentally relevant. After exposure, Inland Silversides underwent behavioral assays and were subjected to a dark and light cycle to determine behavioral toxicity. Additionally, Inland Silversides exposed to bifenthrin, cyfluthrin, and cyhalothrin at 6 and 10 psu and 1 ng/L, were placed in clean water and are being reared until reproductive age. F0 larvae, F0 adults, and F1 larvae will undergo behavioral analysis and gene expression analysis to inform on the potential multigenerational effect of pyrethroids. These results indicate that there may be different behavioral responses to pyrethroids depending on exposure salinity and concentration. There was developmental toxicity observed from cypermethrin exposure at 0.5 PSU, but not from other compounds. This suggests behavioral differences are related to neurological effects rather than developmental impacts. Results show different behavioral responses in each pyrethroid at different salinities. These data will provide knowledge to managers and environmental planners to help further protect threatened and endangered fishes in estuarine and bay regions.

## Years in their ears: what can fish earbones tell us about the success of vulnerable salmon populations in an increasingly volatile and warming climate?

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To track changing climate regimes, many species have shifted their phenology, distribution, and abundances. For salmon populations, life history diversity is one way to buffer themselves against natural or anthropogenic perturbations. Plasticity in migration timing may be particularly important, as their ability to respond spatially to adverse ambient conditions is constrained by the configuration of the stream network. In the Central Valley, land-use changes have fragmented river corridors and restricted access to high-elevation habitats that would have otherwise provided thermal refugia for Chinook salmon populations. Therefore, restoring local landscapes that support climate-adapted behaviors is critical to increase salmon resilience to future climate changes.

To investigate how life history diversity may allow threatened Central Valley spring run Chinook (CVSC) salmon populations to persist in a warming climate we used otolith strontium isotopes to reconstruct the juvenile migratory strategies of adults sampled in Mill and Deer Creeks (self-sustaining CVSC populations) between 2003 and 2018. We found that yearling migrants, an increasingly rare phenotype, were critical to cohort success during drought years. Cool summer temperatures, critical for supporting the yearling strategy, were only found in a few accessible Central Valley tributaries. Providing access into high elevation habitats might be vital to allow these populations to persist in a rapidly changing climate. Our findings are an important step towards identifying the management strategies that will protect and promote expression of life-history diversity that contributes to CVSC recovery and stability in California's warming climate.

# Session IV: Lightning Talks

### Hydroclimatic variability and density dependence influence Pacific Herring population dynamics

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Pacific Herring (*Clupea pallasii*) is an essential forage fish for coastal and estuarine ecosystems, linking basal resources to higher trophic levels. In this study we characterized how historic hydroclimate variability in the San Francisco Estuary, California, USA has driven Pacific Herring population dynamics. In particular, we focused on 1) the environmental effects of salinity and temperature on age class abundance and spawning stock biomass (SSB), and 2) the strengths of biotic drivers (spawning, recruitment, and density dependence). We used Multivariate Autoregressive State-Space (MARSS) models on multiple long-term monitoring data sources from 1980 to 2015, and compared model support for different competing hypotheses on the drivers of Pacific herring dynamics. Our results show that (i) age-0 fish were common in four regions: Central Bay, South Bay, San Pablo Bay, and Suisun Bay; that abundance was associated with cooler, saltier conditions; and that population growth occurred in several regions over the time series; (ii) age-1 fish were also most abundant during saltier conditions in Central Bay, which is directly connected to the Pacific Ocean; and (iii) SSB was not influenced by temperature or salinity. In addition, evidence of density dependence suggests that biological factors (e.g., spawning substrate, food) were limiting population growth for juvenile life stages. Overall, our results indicate that Pacific herring benefited from drought conditions and cool temperatures, but also face challenges with increased frequency and severity of marine heat waves. We recommend that ecosystem-based fisheries and management focus on improving the carrying capacity of the estuary via habitat restoration and food web recovery and reducing harvest during poor ocean conditions via fishery closures.

# Sessions V-VII R Training

**2022 IEP Workshop R Micro-Training Sessions**
**(Basic Statistics, Regression in R, and Advanced Analyses)**

Whether fresh out of school or a seasoned scientist, this year's R workshop should have a training session that can help you take your science to the next level. We will have 13 micro-trainings that will help guide attendees through a range of topics from data exploration to non-linear regression. Each micro-training will include 15-minute talks guiding attendees through a specific data analysis step or method followed by a short question and answer period.

Each micro-training will also include an IEP-based dataset to analyze, an R script that attendees can use to replicate the presented analysis, and a document that is a companion text to the talk. The users can download these for future reference and to serve as a foundation for future analyses.

The first session, titled "*Basic Statistics in R*", will include five micro-trainings to help guide the pre-analysis process and introduce users to several univariate and multivariate approaches to analyze categorical data. The second session, titled "*Regression in R*", will have five micro-trainings that introduce users to numerous regression approaches from simple linear regression to handling zero-inflated catch data. The final session, titled "*Advanced Analytical Topics in R*", will cover mixed-effects regression, and introduce users to regression in a Bayesian framework. We encourage attendees to stick around after the last talk for an open Q&A period.

Overall, we hope this workshop will provide tools that can help attendees promote to the next level, increase the impact of their next publication, or just provide a baseline understanding of a suite of commonly used analytical approaches. We look forward to seeing you at our micro-trainings on March 23, 2022.

# Session VIII: Careers in State and Federal Agencies

**Bios of Panel Members**

**Mike Beakes**

Supervisory Fish Biologist
U.S. Bureau of Reclamation, Bay-Delta Office

Mike's background is in river ecology with over eighteen years of experience working in academia, state and federal government, and the private sector. He completed his undergraduate studies at Northern Arizona University and started my PhD at UC Santa Cruz before transferring and completing my degree at Simon Fraser University in British Columbia, Canada. His research spans topics include steelhead life-history diversity, the effects of wildfire on California coastal streams, and salmon habitat modelling of rivers in California, Washington, and British Columbia. He has been working as a senior Biologist at the Bureau of Reclamation Bay-Delta Office since 2018 and recently assumed a supervisory role in the Science Division, where he provides programmatic support for the Central Valley Project while managing a team of biologists that oversee and implement projects focused on water-resource management.

**Henry DeBey**

Environmental Program Manager
Delta Stewardship Council

Henry DeBey works to foster and fund collaborative science and peer review in the Delta. Previously, he was a fishery officer at the United Nations Food and Agriculture Organization, where he managed sustainable development projects in coastal communities ranging from Tunisia to Bangladesh. He holds a Bachelor of Arts in geography, environmental studies, and design from the University of California, Los Angeles and a Masters of Environmental Science from Yale University. He loves to ride bikes, play soccer, and paint.

**Erin Foresman**

Environmental Program Manager,
State Water Resources Control Board, Bay-Delta Section of the Division of Water Rights

Erin Foresman joined the State Water Board in 2017 to lead the final stages of State Water Board consideration and approval of updates to the Bay-Delta Water Quality Control Plan (Bay-Delta Plan) addressing southern Delta salinity and environmental flows on the Lower San Joaquin, Stanislaus, Tuolumne, and Merced rivers. Current work is focused on implementing the new and revised objectives, drought response, compliance with existing water quality requirements, and monitoring, assessment, science, and reporting needed to review and complete ongoing updates to the Bay-Delta Plan. Prior to joining the State Water Board, Erin was an Environmental Scientist at the United States Environmental Protection Agency (USEPA) for 15 years as a member of the San Francisco Bay-Delta Team and the Wetlands Regulatory team. Erin has a Master of Science degree in Ecology from UC Davis, Bachelor of Science degree in Geology, and Bachelor of Arts degree in Communications from the University of Iowa.

**Karen Gehrts**

Branch Manager
Department of Water Resources, Ecosystem Monitoring, Research, & Reporting Branch

Karen Gehrts is the manager for the Ecosystem Monitoring, Research, and Reporting Branch in the Department of Water Resources. The Branch's mission is to develop and implement collaborative science including compliance monitoring, innovative research, technological advancements, and adaptive management. They produce and communicate the best available information to support resource management in the San Francisco Estuary.

**Dan Kratville**

Senior Environmental Scientist
CA Department of Fish and Wildlife, Fisheries Branch

Dan Kratville has worked for the Department of Fish and Wildlife for 15 years with a focus on fisheries biology, water operations and scientific permitting. He's had both field jobs and desk jobs, and both are rewarding and challenging in their own way.

**Cathy Marcinkevage**

Assistant Regional Administrator
NOAA Fisheries' California Central Valley Office

Cathy manages the division's regulatory and scientific efforts to protect and recover listed salmonids and sturgeon. She has been in lead roles for several complex ESA consultations, and she has been involved in adaptive management, development and review of analytical tools and models, and restoration planning. Cathy joined NMFS in 2011 as a biological modeler after working in the private sector environmental modeling community, and she still occasionally enjoys the more-rare opportunity to dig into a dataset. A native east coaster, Cathy has degrees in Environmental Engineering from the University of Illinois and Columbia University but has enjoyed all that California has to offer her and her family, including three active kids.

**Jeffrey McLain**

Project Leader
U.S. Fish and Wildlife Service, Lodi Fish and Wildlife Office

Jeff began his fisheries biology career in 1992 working for the U.S. Fish and Wildlife Service as part of the Interagency Ecological Program office on Wilson Way in Stockton. Over the past 29 years, Jeff has worked in more than 10 positions with the federal government as a biological science technician, fisheries biologist, biologist, and natural resource management specialist in supervisory and non-supervisory capacities. One of the favorite parts of his job is hiring and has had the privilege of hiring countless talented federal employees into NOAA Fisheries and the U.S. Fish and Wildlife Service over the years, some of which have stayed in the federal government and some moving on to other opportunities. He holds a bachelor's degree in aquatic biology from Sonoma State University and a master's degree from San Francisco State University in Marine Biology.

**Anke Mueller-Solger, PhD**

Associate Director
USGS, California Water Science Center

Anke leads and oversees a great team of more than 180 scientists who conduct cutting-edge research and monitoring with many partners on diverse water science topics throughout California, including in the Bay-Delta. Prior to coming to the USGS, Anke was the first Lead Scientist for the Interagency Ecological Program. Anke also worked on Bay-Delta science topics in prior positions with the California Department of Water Resources and at UC Davis. Anke grew up in Germany and has lived in California since 1990. She has German degrees in Biology and a Ph.D. in Ecology from UC Davis.

**Brian Thompson**

Environmental Protection Specialist
U.S. Environmental Protection Agency, Southwest Regional Office (Region 9)

Brian has worked at EPA's national and regional offices in the watersheds and water quality standards programs as an Environmental Protection Specialist and Physical Scientist. He currently serves as the EPA staff co-lead in coordinating water quality programs in the Delta and California within EPA and with state partners. The technical aspects of his work focus on how adverse temperature and flow conditions are impacting aquatic life.

# Session IX: Experimental Release of Delta Smelt

### History in the making: Updates on the first experimental release of captive-reared Delta Smelt

**Trishelle Tempel**

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Between December 2021 and February 2022, captive-reared Delta Smelt were released into the upper San Francisco Estuary for the first time in history as part of an experimental release program. This management action was made possible through a high level of coordination and collaboration between a large, interagency and academic team. The primary goal of these experimental releases was to develop best practices for tackling the complicated logistics associated with releasing captive-reared Delta Smelt, including the feasibility of two release mechanisms: (1) soft release, in which fish are placed into large enclosures and given time to acclimate before being released into the wild and (2) hard release, in which fish are released directly into the wild. After thorough planning, the team successfully released cultured Delta Smelt using both release mechanisms. Captive-reared Delta Smelt were subsequently recaptured during routine monitoring efforts within the upper San Francisco Estuary, showing that these captured fish were able to survive and disperse following release. Ultimately, these experimental releases are meant to inform the design of a supplementation program, as mandated in the most recent USFWS Biological Opinion.

# Session X: Longfin Smelt

### Transferable approaches to evaluate the health of early life stages of a threatened anadromous fish species, the Longfin Smelt.

**Mauduit F., Segarra A., Yanagitsuru Y., Sherman J., Hung T.C., Fangue N.A., Connon R.E.**

Conservation efforts are sometimes constrained by lack of knowledge about the species' biology and the impact of environmental stressors upon them. Longfin Smelt (*Spirinchus thaleichthys*) is a threatened anadromous fish species found in estuaries and lakes along the northern Pacific coast of North America. To evaluate potential contributions of anthropogenic activities to their decline, we aimed to 1) transfer tools and approaches commonly used on model species and/or later life stages to assess the health of Longfin Smelt larvae and 2) apply these tools to determine effects of an exposure to a frequently detected pyrethroid insecticide; Bifenthrin. For this, we tested the relevance of the light/dark stimuli induced behavior test and of the thermal susceptibility test for the Longfin Smelt larvae. Movement tracking of 1 to 4 dph larvae during alternating light-dark periods revealed a pattern of increased larvae's locomotion in the light followed by resting state in the dark, allowing the establishment of a behavioral model for this species. In addition, we tested larvae's thermal tolerance by monitoring the heart rate of anesthetized individuals submitted to a stepwise temperature increase. We observed that larvae heart rate gradually increased with temperature until becoming arrhythmic. Combined, these two tests allow for the assessment of Longfin Smelt larvae health and provide sensitive endpoints to evaluate the impact of environmental stressors upon this species. Exposure to environmentally relevant concentrations of bifenthrin for 96h induced hyperactivity but did not affect cardiac thermal tolerance of the 1-4 dph Longfin Smelt larvae.

## Assessment of Environmental Factors on Apparent Growth in Longfin Smelt

**Bryan Matthias and Vanessa Tobias**

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There is very little published information about the growth rates of Longfin Smelt (*Spirinchus thaleichthys*; hereafter LFS) and most work has focused on growth during the first year of life. Here, we focus on assessing the effects of abiotic factors on LFS apparent lifetime growth. Length data were obtained from multiple long-term monitoring surveys spanning from 1981-2020 (a total of 311,180 observations) and age (in months) was assigned using length-frequency distributions. We used a biphasic growth model that incorporated both fixed (environmental) and random (unobserved) effects to quantify temporal variation in length-at-age patterns. Outflow, temperature, conductivity and the temperature-conductivity interaction were all significant and the effects of these covariates differed between juvenile and adult growth phases. Effects of outflow were negative across both juvenile and adult growth phases, suggesting slower growth during periods of high outflow. For juveniles, growth rates are similar across the range of conductivity when temperatures are low, but at high temperatures we predict large declines in growth as conductivity increases. We predict similar trends with adult growth, highest growth at the lowest conductivity (which increases with temperature) and slower growth at high conductivity, regardless of temperature). The general patterns in growth predicted from this model reflect those earlier studies on LFS growth. Results presented here represent a preliminary look at factors affecting LFS apparent growth. Future model development and directions will include incorporating biotic effects (e.g., density dependence, prey availability, etc.).

## What causes longfin smelt abundance to vary 100-fold with freshwater flow?

**Wim Kimmerer[1], Ed Gross[2], Levi Lewis[3], Jillian Burns[1,4], Lenny Grimaldo[5]**

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For over 4 decades, a strong relationship has existed between freshwater outflow in spring and the subsequent fall abundance index of longfin smelt. Efforts to develop theories for the causal mechanisms underlying this relationship have been fragmentary, and no clear understanding has yet emerged.

We used weight of evidence to compare among eight candidate mechanisms for the relationship of longfin smelt abundance with flow (or X2). To plausibly contribute to this relationship, mechanisms must meet several constraints including magnitude (100-fold range of abundance with X2), persistence (since ~1978), timing (spring to early summer), locus (salinity of ~2), and specificity. Candidate mechanisms that failed at least one constraint include variation with X2 in: extent of habitat (fails magnitude constraint), proportional losses to diversions (magnitude), dispersion mitigating density-dependent effects (timing and locus), food availability (persistence), ocean conditions (timing), and habitat complexity (not specific enough to identify a causal linkage).

The mechanism with the greatest support involves the movement of developing larvae and its interaction with the movement of water. Larvae hatch in January-March in fresh to brackish waters and drift seaward with the net flow. The Smelt Larva Survey catches larvae mostly smaller than 10mm (mean age ~7d), implying the larger, older larvae are outside the survey's range. Particle tracking shows that passive behavior moves most larvae far seaward of the survey's extent. To remain in the estuary the larvae must remain deep in estuarine channels, which moves them toward the Low-Salinity Zone (LSZ) where most of the larger larvae rear. This movement is most effective when X2 is low (high flow), as the LSZ oscillates tidally through Carquinez Strait where gravitational circulation is amplified by the greater depth. This movement happens around May, when catches in the 20mm survey begin to show evidence of a relationship with X2.

Why does the mechanism matter? By pinpointing the timing and location of the mechanism it becomes possible to better focus management actions where and when they will be most effective. Specifically, the existing X2 standard which now applies from January to June could be modified experimentally to focus on ~May, using the same amount of water to achieve a much higher outflow during this critical period. Moreover, interannual variability in losses of longfin smelt to diversions may contribute less to the X2 relationship than previously believed.

# Session XI: Delta Salmon

## Quantifying the role of predation by piscivorous fishes as a source of juvenile Chinook Salmon mortality in the Sacramento-San Joaquin Delta

**Frederick Feyrer[1], Russel Perry[2], Matthew Young[1], Brock Huntsman[1], Veronica Larwood[1], Justin Clause[1], Ethan Enos[1], Cyril Michel[3], and Thomas Reid Nelson[3]**

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Healthy, viable Chinook Salmon populations are vital to the economy and water supply of California. Unfortunately, all runs of Chinook Salmon in California's Central Valley are in low abundance and are the focus of resource intensive management and conservation efforts. Numerous factors have impacted Chinook Salmon throughout their lifecycle. Of particular concern is the survival of juvenile Chinook Salmon as they emigrate from natal tributaries through the Sacramento-San Joaquin River Delta, a maze of natural and manmade channels linking the Sacramento river to San Francisco Bay and the Pacific Ocean. Predation by piscivorous fishes is thought to be a primary source of mortality of juvenile Chinook Salmon in the Delta. To address this issue, we sought to determine if variation in reach-specific predation dynamics covary with survival as estimated from acoustic tracking studies. We will present preliminary results on species composition, size structure, abundance, and prey consumption of piscivorous fishes in three key migratory pathways in the northern Delta and compare those data to expectations based on what is known about survival.

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## Salmon smolt survival through the Sacramento River during the late-spring outmigration

**Jeremy Notch[1], Flora Cordoleani[1], Alex McHuron[1], Rebecca Robinson[1], and Cyril Michel[1]**

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In California's Central Valley, recent drought conditions and water supply management have led to unfavorable outmigration conditions for juvenile salmon during the spring (April-May). In particular, a significant portion of juvenile spring-run Chinook salmon smolts are known to outmigrate through the Sacramento River during this time due to extended rearing and slowed tributary outmigration from their high elevation rearing habitat. While these later migrants may be numerically inferior to the earlier fry or parr outmigrants, recent studies have shown they have an outsized contribution to adult returns. From 2019 to 2021, we acoustic tagged and released fall-run Chinook salmon smolts as spring-run surrogates from Coleman National Fish Hatchery during the late spring (n=2184) to better understand survival dynamics during this period. Survival through the Sacramento River (Red Bluff to Knights Landing) ranged from 54% (±3.1 S.E.) during a wet year (2019) to 0.6% (±0.3 S.E.) during a critically dry year (2021). Survival through the Sacramento River was strongly correlated with flow and water temperature at the Wilkins Slough gauge. In some release groups, survival was low despite moderately high flows but warmer than average water temperature (18 degrees Celsius), suggesting that water temperature may have been a significant factor as temperature increased above a critical threshold.

**Characterizing neuroendocrine and neurotoxic effects of bifenthrin to salmonids and influence of climate change to toxicity: An integration of omic profiles to apical endpoints**

**Jason T. Magnuson and Daniel Schlenk**

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An increase in urban and agricultural application of pyrethroid insecticides in the San Francisco Bay Estuary and Sacramento San Joaquin Delta has raised concern for the populations of several salmonids. Bifenthrin (BF), a type I pyrethroid, is among the most frequently detected pyrethroids in the Bay-Delta watershed, with surface water concentrations often exceeding chronic toxicity thresholds for several invertebrate and fish species. Predicted climate change effects, such as increasing water temperature in fish rearing habitats, are additional stressors to salmonids in the Delta. To better characterize the effects of BF and influence of changing environmental conditions, salmonids were exposed to concentrations of BF detected in the Delta (30 ng/L-1.5 µg/L) under various water temperatures (11, 16.4, and 19 °C) as predicted by recent climate change models. Chinook salmon and steelhead trout had altered neuroendocrine effects following BF exposure, with a decrease in the levels of sex steroid hormones, dopamine, and a dysregulation of genes involved in dopaminergic processes. When co-exposed to BF under increased water temperature scenarios, there was a heightened decrease in dopamine levels with increasing temperature. These changes were further reflected when Chinook were assessed for olfactory function and placed in a Y-maze behavioral assay to assess responses of fish to predatory cues, with BF exposed fish less deterred from the odorant, relative to controls. Rainbow trout exposed to BF under conditions of increased temperature and salinity also exhibited neuroendocrine effects, with an increased temperature-dependent response. To better understand the underlying effects of BF to neuroendocrine function, non-targeted metabolomic studies were conducted on Chinook salmon and steelhead trout. Alterations in the levels of several metabolites in the brains of exposed fish were predicted to induce an apoptotic, inflammatory, and reactive oxygen species response. Transcriptomic analysis revealed that BF exposed trout had predicted pathways involved in gonadotropin releasing hormone signaling, reduced extracellular matrix stability and adhesion, as well as cell death. Histopathological analysis subsequently showed an increased number of TUNEL positive, apoptotic cells in the brains of BF exposed fish. Non-targeted metabolomic and transcriptomic profile analyses were integrated to better characterize a common target of BF in the brains of exposed salmonids. Pathways involved in the metabolism of triglycerides were predicted to be a novel target of BF in the brains of exposed fish. Lipidomic analysis was further conducted and a dose dependent decrease in the abundance of triglycerides was observed by BF. Overlaying multi-omic level molecular responses and subsequently linking them to histopathological and behavioral effects has allowed us to find specific targets of BF in the brains of exposed salmonids.

## Occupancy modeling using contiguous spatial replicates: an application to electrofishing samples in the Delta

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Sampling a wider variety of fish habitats to obtain estimates of habitat occupancy was proposed in a review of the Delta Juvenile Fish Monitoring Program. Sampling via electrofishing can address the first issue, but to model the probability of occupancy, repeated samples at a given site are needed to obtain replication. In the classic occupancy modeling framework, replicates are obtained from repeated visits to the site, thus creating temporal replicates. In many sampling designs, there is a need to substitute spatial replicates for temporal replicates due either to using historical data sets that did not include temporal replicates or due to minimizing travel costs by sampling replicates in close proximity. As a result, replicates may lack independence due to spatial autocorrelation, which can lead to biased parameter estimates in the occupancy model. Approaches to deal with such correlated designs among replicates explicitly model the local occupancy, which is the probability of occupancy at the replicate level. Statistical methods that account for correlation use a Markovian structure, which assumes that animals move through the replicates in a specific order. While this structure may be appropriate for large mammals that move along paths, it may not be appropriate for animals that are shifting among replicates randomly. To address this limitation, we developed a statistical approach that accounts for autocorrelation among contiguous spatial replicates by using autocovariates without the assumption of directionality. We applied this approach to estimate spatio-temporal patterns in occupancy of juvenile Chinook Salmon (*Oncorhynchus tshawytscha*), Hitch (*Lavinia exilicauda*), and Largemouth Bass (*Micropterus salmoides*) obtained from electrofishing data in 2018 and 2019. Juvenile Chinook Salmon showed spatio-temporal patterns in occupancy with the highest probabilities of occupancy estimated in the northern Delta and in April. Hitch had the highest occupancy in Cache Slough across all months, whereas Largemouth Bass had high occupancy throughout the Delta, but had particularly high occupancy in the central and south Delta. Our statistical approach using autocovariates can be applied generally to sampling designs beyond the 1-dimensional shoreline electrofishing, and we will discuss how to expand our approach in sampling designs of higher dimensions.

**Rapid, CRISPR-based genetic identification of run-type enables new opportunities for management of threatened Chinook salmon**

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Chinook salmon in California's Central Valley consist of four run types (fall, late-fall, winter, and spring), which differ in the time of year they migrate up river to spawn. Two of the runs, winter and spring, are listed as endangered and threatened, respectively, under the Endangered Species Act. Understanding run-specific status, distribution, and migration patterns is vital for conservation; therefore, accurately and efficiently distinguishing between Chinook salmon runs is important. Currently, the methods used for run type identification can be unreliable or take time and molecular expertise. However, we have developed SHERLOCK assays, a CRISPR-Cas system, that can genetically identify spring run, winter run, and fall/late fall-run in less than 30 minutes and can be performed in the field with minimal training or equipment.

Initially developed for point-of-care disease diagnostics, we are using SHERLOCK to distinguish Chinook salmon runs by targeting run-specific differences in the genome. However, a single SNP does not distinguish all four run-types, so we use a tiered approach. First, we distinguish between the listed early migrating (spring and winter) and non-listed late migrating (fall and late fall) Chinook salmon by targeting SNPs and indels in the Greb1L region, a gene associated with run timing in Chinook salmon. Then, if identified as an early migrating Chinook, we perform a second set of SHERLOCK assays to distinguish between spring-run and winter-run by targeting SNPs on chromosome 16. All spring and winter-run samples were detected with the early migrating assay and all fall and late fall-run samples were detected with the late migrating assay. Amplification and detection of the target run type is very rapid, with reliable assay results in less than 30 minutes. We also determined that the early and late migrating assays are extremely sensitive and can detect less than 10 copies of target DNA in a reaction. SHERLOCK can work on extracted tissue samples, unextracted mucus samples put directly into the reaction, or with environmental DNA (eDNA) samples. SHERLOCK is poised to become a routine method for genetic identification due to its accuracy, speed, sensitivity, ease of use, and affordability.

# Session XII: Resident Fishes

### Heritability of maturation timing in captive Delta smelt

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Captive spawning programs can aid in fish conservation by preventing extinction of a species or by producing individuals to supplement a declining wild population. However, captive spawning can lead to unintended physical or genetic changes that make fish more successful in captivity and less successful when reintroduced into the wild. The University of California, Davis Fish Conservation and Culture Laboratory has supported a refuge population of Delta smelt (*Hypomesus transpacificus*) for over a decade, employing a variety of practices to maintain genetic and phenotypic similarity to wild fish. Previous research found that captive Delta smelt with higher levels of hatchery ancestry had more surviving offspring than Delta smelt with more recent wild ancestors, providing some evidence of genetic adaptation to captivity. When selecting breeding pairs of Delta smelt, we aim to maximize the retention of genetic diversity and minimize inbreeding, but our ability to optimize genetic matches is limited by the availability of mature fish each week during the spawning season. The timing of maturation in captive Delta smelt therefore influences which fish are selected for spawning. With these logistical constraints in mind, we expanded on previous evidence of genetic adaptation to captivity by investigating temporal patterns and heritability of maturation timing in captive Delta smelt. We used a decade of spawning season data and a genetic pedigree to elucidate maturation timing variables (e.g., time from fertilization to maturity). We assessed variation in maturation timing across years and relative to hatchery ancestry (i.e., how many generations a fish family has been in captivity). Using the pedigree, we also estimated the heritability of maturation timing across generations. Our study enhances previously limited understanding of what drives maturation in Delta smelt and can inform future captive spawning practices.

## Assessing Biological Homogenization of the Sacramento-San Joaquin River Delta

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The worldwide decline in biodiversity due to the extinction of endemic species and spread of cosmopolitan species is a well-recognized phenomenon. For many places, native species are being replaced by highly successful invaders that can tolerate a broader range of environmental conditions and human activities. In California, the overall fish fauna has been homogenized at a broad scale and invasive species have become the dominant component of the Sacramento-San Joaquin River Delta (Delta) fish assemblage; however, the extent of biotic homogenization that has occurred over time and space in the Delta is not known. Here we use nearshore fish assemblage data that have been collected over multiple decades in beach seine surveys to assess biodiversity patterns in the Delta and areas directly upstream. More specifically, we attempt to answer the following study questions: 1) Has the nearshore fish assemblage homogenized through time? 2) What species are associated with these changes and how have their populations changed through time? Higher diversity of fish species can be observed in the nearshore-littoral habitat of the Delta than the open water, and this habitat has played a dominant role in the food web over the past several years. Overall, we found that biological homogenization has not occurred at a broad level across the Delta, but regional levels of homogenization were detected in the South and West Delta. These shifts in biodiversity were associated with an increase in the distribution of warm-water Centrarchids and other invasive species. These results suggest that biodiversity across space remains relatively high across the Delta, but the continued spread of warm-water invasive species throughout the Delta may lead to further homogenization in the future.

# Session XIII: Invasive Species

### Ecosystem Engineering Impacts of Water Primrose in the Delta

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Water primrose (*Ludwigia* spp.) is a highly invasive, non-native floating macrophyte in the Sacramento-San Joaquin Delta that has recently extended its historical invasive range from aquatic habitats into tidal freshwater marshes, leading to the mortality of dominant plant species such as tules (*Schoenoplectus* spp.). This presentation will first discuss the goals of the CDFW Prop 1 Project entitled "Ecosystem Engineering Impacts of Water Primrose in the Delta" to investigate this novel behavior of water primrose habitat expansion. Objectives of the project include quantifying marsh loss and the spatial trajectory of water primrose invasion from 2004-2020, as well as identifying marshes that are most vulnerable to water primrose invasion. We are investigating water primrose traits, such as growth strategies, allelopathic properties that may drive water primrose's infestation in tidal freshwater marshes, as well as the role of biodiversity in marsh resistance to invasion. Preliminary analysis of plant trait data collected from our summer and fall 2021 field campaigns reveal differences in water primrose plant height between tidal marsh and aquatic habitats, but not leaf area or leaf weight. Results suggest that water primrose is allocating resources to vertical growth over horizontal canopy expansion, possibly as a mechanism to compete with tules/cattails for light access in marsh habitats. The results of this project will help increase understanding of the mechanisms driving water primrose invasion and expansion into tidal marshes. Results will also be valuable for land/conservation managers and Delta policy makers to develop informed initiatives to successfully manage water primrose expansion and prevent marsh and biodiversity loss in the Delta.

## Boom, Busts, and Enigmas – Stories of Introduced Crustaceans in San Francisco Estuary

**Kathy Hieb**

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Several species of crabs and shrimp were introduced into the San Francisco Estuary within the past 3 to 4 decades, including the European green crab (*Carcinus maenas*), the Chinese mitten crab (*Eriocheir sinensis*), the Siberian Prawn (*Palaemon modestus*), the Mississippi grass shrimp (*Palaemonetes kadiakensis*), and the Asian mud shrimp (*Upogebia minor*). All these species became established in the estuary and are still present, but their spread, population trends, and current status are vastly different. Population trends have included “booms” and apparent busts, “booms” followed by steady or slowly increasing populations, and a slow spread with occasional detections.

IEP monitoring surveys collect all of these species, but none are targeted and well sampled. This is due to several factors, including depth distribution (intertidal and shallow subtidal), association with structure or vegetation, burrowing behavior, and distribution outside of the monitoring surveys’ sampling areas. In addition, incorrect identification of the first specimens collected contributed to delayed detection. In this presentation I will review the introduction, detection, population trends, impacts, and current status of these introduced crustaceans.

## Nutria eradication progress in California, from 2017 to the present

**Jared Barr**

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California Department of Fish and Wildlife (CDFW) are currently reviewing trends and progress toward the eradication of invasive nutria (*Myocastor coypus*) in California, from the initial discovery through the first two years of a dedicated eradication program. Management strategies were modeled after the Chesapeake Bay Nutria Eradication Project, which successfully eradicated nutria from over 250,000 acres of the Delmarva peninsula. As of 2021, CDFW has conducted surveys on approximately 243,000 acres of suitable nutria habitat. Nutria have been detected and removed within 23,880 and 13,320 acres of habitat, respectively, for a total of 2,842 nutria removed from the landscape. Methods critical for the early detection of nutria include dedicated field staff to conduct surveys, a robust network of baited monitoring stations, and targeted means of detecting small and/or localized metapopulations. We have seen positive results in sites that have been monitored across years, with an average of 7.9 and 4.8 nutria taken per trapped site per year and 1,242 and 702 total nutria taken in 2020 and 2021, respectively. This talk will explore the progress and challenges of the nutria eradication effort in California from 2017-2021. To help tell that story, we will review annual trends for survey and trapping effort, numbers taken and average densities among infested sites, land access, population demographics and reproductive rates, geographic distribution, and progression of infested sites through the 5-phases of the eradication strategy.

# Session XIV: Data Synthesis

### Identifying Drivers of Food Web Dynamics through Data Integration and Synthesis

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The Delta Science Program, in partnership with the National Center for Ecological Analysis and Synthesis (NCEAS), organized a collaborative synthesis working group focused on drivers of food supply and food web dynamics in the San Francisco delta ecosystem. Understanding these drivers and their relative influence is important for understanding declines in forage fish abundance and designing possible management interventions. Participants from federal, state, and academic institutions collaborated to compile and synthesize data from multiple sources. One group used long-term data to examine the relative influence of biotic and abiotic drivers on different components of the delta food web using structural equation modeling. This was done at several spatio-temporal scales, so that interactions could be compared across different regions of the estuary and at different time scales. Another group conducted a meta-analysis on how hydrological connectivity affects primary productivity in estuarine and freshwater ecosystems. This group then used high-resolution data to examine relationships between connectivity and primary productivity in the San Francisco delta, with the goal of understanding the food web impact of different flood and restoration scenarios.

**Change is Here: *climate change in the San Francisco Estuary***

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The IEP Climate Change Project Work Team set out to improve the current understanding of climate change in the estuary and to help anticipate current and future impacts. Through an extensive review of climate related literature, the team identified current and potential future impacts to three main ecosystems of the San Francisco Estuary: floodplain, tidal marsh, and open water. A conceptual model was developed to help explain how the estuary currently functions in relation to climate variables. Then, for each ecosystem the status of abiotic factors and select species was evaluated, as well as the potential impacts of climate change on these ecosystems and individual species. The IEP Climate Change Technical Report is the result of this review and is available on the IEP website.

### Water Temperature-Inflow Relationships in the Upper San Francisco Estuary

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Water temperature and inflow are key environmental drivers in aquatic systems that are linked through a causal web of factors including climate, weather, water management, and their downstream linkages. However, we do not yet fully understand the relationship between inflow and water temperature, especially in complex managed systems such as estuaries. The San Francisco Estuary is the center of a critical water supply infrastructure and home to a deteriorating ecosystem with several declining fish species at the warm edge of their thermal range. We used generalized additive modeling of long-term monitoring data to evaluate the relationship between inflow and water temperature along with its spatio-seasonal variability. Most commonly, we found a negative temperature-inflow relationship in which water temperatures increased as inflow decreased, up to 2 °C from high to low-inflow years. However, the opposite (positive) relationship was observed in the winter months, and in the western (downstream) regions from July-September, up to -1.2 °C from high to low-inflow years. These results were upheld by models that included the long-term temperature trend or used salinity as a proxy for location. Upstream factors likely played the biggest role in the summer when local precipitation is negligible, whereas local precipitation and the related weather conditions may drive much of the winter pattern. Although further mechanistic studies are needed to infer the direct effect of dam releases on water temperatures, these results provide a broader understanding of the impacts of flood and drought dynamics for those tasked with managing estuarine ecosystems.

# Session XVI: Harmful Algal Blooms

### Cyanobacteria Blooms in San Francisco Estuary

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Toxic cyanobacteria blooms have occurred in the upper San Francisco Estuary since 1999. The initial blooms were small, local, and comprised of a single species. Today these blooms form a complex “Phycosphere” that stretches across the upper estuary and can produce dangerously toxic conditions. These blooms now threaten the health of humans and aquatic species, as well as the economy of the Delta. This talk will summarize the field and laboratory research we have done in the Delta since 2003 to address key questions including: How has the species composition and potential toxicity changed over time? What makes the bloom more dangerous today than before? What factors control growth? How does the bloom affect other aquatic species? What do we need know? And where do we go from here?

## Accumulation of Microcystin in Delta Invertebrates

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Filter-feeding invertebrates compound risks associated with cyanobacteria harmful algal blooms (CHABs) by biomagnifying cyanotoxins; as such, shellfish can serve as both time-integrated samplers of toxin levels in the water column and bio-sentinels of health risks through the food web. Little work has been done to characterize microcystin (MC) concentrations in Delta shellfish, but these organisms are consumed by native species, including sturgeon, and humans. Our **primary goal** is to analyze Delta shellfish and water samples to determine when MCs enter the Delta food web, their geographic distribution, and the magnitude and duration of impairment. Sampling began in August 2020 and is continuing to occur monthly. We have collected Asian clams (*Corbicula fluminea*) from 10 sampling sites throughout the Delta and crayfish (*Pacifastacus leniusculus*) from a subset of these sites. Although sampling will continue through August 2022, we have gathered enough data to begin characterizing MC shellfish contamination. MCs in shellfish frequently exceeded the EPA Tolerable Daily Intake for humans at all locations except for Cache Slough sites and Sacramento River at Isleton during the months of July through November. Further, the lowest MC concentrations were consistently measured at Cache Slough sites and the Sacramento River at Isleton. Sherman Lake is the “most” important site for sturgeon rearing/feeding in our study and MC was consistently present in clams at this site. MCs in discrete water grab samples have remained relatively low at all sites (i.e., max <5 µg/L). Ultimately, this work will fill an important data gap concerning MC contamination in brackish and freshwater shellfish and the implications for managed species, their communities, and human health risks.

**A Study of a *Microcystis* Bloom and Toxin Mitigation in Discovery Bay, CA Using an Eco-Friendly Approach**

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Discovery Bay is a community in Contra Costa County whose identity is strongly connected to the Sacramento-San Joaquin River Delta. In recent years, Discovery Bay waterways have suffered from recurring and often-severe toxic cyanobacterial blooms (cyanoHABs). Remediation and prevention of cyanoHABs in the waterways of DB will require the assessment of internal nutrient loads and the identification and characterization of nutrient sources and sinks in order to devise a suitable long-term management plan to reduce nutrient levels in the water. In the meantime, short-term mitigation approaches, preferably ones that leave no chemical residue or nutrient element, are essential for reducing the severity of cyanoHABs in Discovery Bay. We conducted a two-week pilot study during summer 2020 involving mesocosms (1.5 $m^3$ enclosures) that utilized natural, bloom-impacted water from Discovery Bay to assess the effectiveness of hydrogen peroxide as a mitigative strategy for reducing cyanoHABs and cyanotoxins (microcystins). Peroxide based products have begun to receive more attention recently as mitigative tools because 1) cyanobacteria tend to be more susceptible to peroxide than beneficial eukaryotic algae, 2) peroxide decomposes into water and molecular oxygen ($O_2$) leaving no chemical residue, and 3) peroxide can decompose cyanotoxins at appropriate concentrations. Two treatment concentrations and appropriate controls were tested in enclosures for their effectiveness in reducing an existing *Microcystis* bloom. A low concentration reduced the bloom but did not immediately reduce total microcystins. A high concentration greatly reduced both cyanobacteria as well as particulate and dissolved microcystins. Overall, while optimal dosing amounts and schedule still need to be determined, our results indicate that peroxide is an effective means of bloom reduction and toxin destruction and should become a focus for the development of mitigative approaches as alternatives to more deleterious methods and algaecides.

## Coordinated California: HAB Programs across the state to coordinate monitoring and health risk communication

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Photosynthetic cyanobacteria and eukaryotic algae capable of creating toxins, often called harmful algal blooms, are recurring and escalating issue across California. In the upper San Francisco Estuary, toxic cyanobacterial blooms have occurred since 1999. Special studies and monitoring efforts to assess impacts of harmful agal blooms have occurred but often weren't mandated. With the passage of the Freshwater and Estuarine Harmful Algal Bloom Program bill by the California Legislature, AB 834, the Water Board was tasked to develop a statewide framework and strategy. In this presentation, we will give an overview of the framework and strategy to show how partner agencies can apply it to the San Francisco Estuary. Additionally, we'll provide information on other statewide programs that may be of interest to the Interagency Ecological Program.