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

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

Keywords: Selenium, Sacramento splittail, exposure, fish populations, bioaccumulation, toxicity
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Unraveling Sources and Pathways of Se Exposure in Wild Sacramento Splittail with Spinal Deformities

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

Keywords: Sacramento splittail, contaminant, otolith, Selenium, isotope, San Joaquin
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Fish Nursery Areas and Migratory Corridors in Suisun Marsh

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

Keywords: Fish nursery, tidal wetland, habitat complexity, migratory corridor, Suisun Marsh
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Rearing Habitat of Larval Pacific Herring (*Clupea pallasi*) in Shallow Open Water and Tidal Marsh Habitats of San Pablo Bay and the Western Delta

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

Keywords: Pacific Herring, larval, rearing, survival, recruitment, shallow water habitat, marsh
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Native Submerged Aquatic Vegetation in the San Francisco Estuary: Causes and Implications of Morphological Variation and Phenotypic Plasticity

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

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

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

Keywords: Potamogeton, Pondweeds, SAV, Stuckenia, Flow, Plasticity, Mesocosm, Invertebrate, Low-salinity zone
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