Growth Rate Comparison of Longfin Smelt (*Spirinchus thaleichthys*) Between Wet and Dry Years Through Otolith Analysis

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The San Francisco Bay-Delta is host to the southernmost population of longfin smelt (*Spirinchus thaleichthys*), which is listed as a threatened species in California. Fall Midwater Trawl (FMWT) catch show the abundance of age-0 longfin smelt is correlated with freshwater flow, however, the mechanism behind the pattern is unknown. We hypothesized that growth rates would be higher during high freshwater flow years. As in many estuaries, high freshwater outflow is associated with increased primary production and zooplankton prey availability thus potentially fueling increased growth of longfin smelt. We tested this hypothesis using otolith aging techniques to back-calculate size at age-1 for adults, otolith increment widths for juveniles, and estimated growth rates from age-length keys. We found that longfin smelt were larger at age-1, however, growth for juveniles was slower during dry years. Furthermore, we found a persistent reduction in mean length from the September survey of the FMWT over the years suggesting long-term climate patterns and shorter-term hydrology may be interacting to influence growth and survival of longfin smelt. Consistent dry years, lack of freshwater flows, and the threat of increased extremes due to climate change will put the longfin smelt in a more precarious position then they are currently. If freshwater flows are important to longfin smelt abundance and growth, management options that provide adequate freshwater flows will provide a necessary component for longfin smelt population recovery.

Keywords: Longfin Smelt, *Spirinchus thaleichthys*, drought study, growth rate, otolith analysis

Poster Topic: Fish Biology, Ecology and Protection: Smelt

Temperature Tolerance and Metabolism of Threatened Smelt

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Increases in water temperature due to climate change and drought are of great concern for managers of the San Francisco Estuary. Several native fishes are in decline; however, it remains unclear how further temperature stress may contribute to these declines. The threatened Longfin Smelt (*Spirinchus thaleichthys*) and the critically endangered Delta Smelt (*Hypomesus transpacificus*) are of particular concern in California. In efforts to forecast how increased temperatures may impact these fishes, we measured upper temperature tolerance (CTMax) and whole-fish oxygen consumption rates (MO_2) at 14ºC and 20ºC, in both species, at 50 days post hatch (dph). Delta Smelt had a higher CTMax (27.6ºC) compared to Longfin Smelt (24.8ºC). MO_2 was greater in Delta Smelt exposed to 20ºC compared to 14ºC, reflecting an increased energetic cost at warmer temperatures. In contrast, Longfin Smelt MO_2 was similar at 20ºC and 14ºC, suggesting that these fish may have limited capacity to adjust their physiology to elevated temperatures and there may be a mismatch between oxygen demand and supply at this early larval stage. Understanding the thermal limits and physiological responses to increases in temperature can help identify species-specific sensitivities and vulnerabilities of native, ecologically important California fishes to projected increases in water temperature.

Keywords: Delta Smelt, Longfin Smelt, temperature, tolerance, metabolism, endangered fishes

Poster Topic: Fish Biology, Ecology and Protection: Smelt

Putting Extreme Drought into a Long-Term Context: Growth Rate Variability and Recruitment Success in Response to Environmental Conditions

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The Delta Smelt (*Hypomesus transpacificus*) was once abundant among the pelagic fish assemblage inhabiting the upper SFE and Delta until the 1980's when the population began to decline. Recruitment theory suggests growth in the early life is a strong predictor of year class abundance. We hypothesize that the recent drought conditions have reduced growth rates and survival in the early life. In this study we use otolith age-length relationships from Delta Smelt collected during the Summer Townet Survey to develop an age-length model. The model was applied to fish collected during the 20-mm survey from 1995 to present to estimate growth and survival. Growth and survival varied considerably over the time series and tended to be lower and more variable during dry years when fish were less abundant. However, temperature and prey availability contributed to growth rate variability confounding trends between growth, survival and freshwater outflow. This study highlights the importance of incorporating multiple environmental drivers over long timescales to understand recruitment success for Delta Smelt. The recent, unprecedented drought represents a period where environmental conditions are converging to significantly limit recruitment success.

Keywords: Delta Smelt, growth rates, survival, otoliths

Poster Topic: Fish Biology, Ecology and Protection: Smelt

Growth and Life History of Delta Smelt Utilizing the Yolo Bypass

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Problem Statement: Our research aims to examine the differences in growth rates and life history strategies observed between Delta Smelt captured in the Yolo Bypass versus those captured throughout the Delta.

The Yolo Bypass, located adjacent to the Sacramento River near the city of Sacramento, is one of the largest managed flood plains in California and has been documented to provide beneficial habitat for many native fishes. Since 2009, the abundance of Delta Smelt, an endangered species endemic to the Sacramento-San Joaquin Delta, has increased dramatically in the Yolo Bypass. Concomitantly, the abundance of zooplankton prey for the Delta Smelt in the Yolo Bypass has also increased. We hypothesize that the growth rate of Delta Smelt utilizing the Yolo Bypass will be greater than individuals occupying other freshwater and low-salinity habitats. We tested this hypothesis using otolith growth increments from Delta Smelt collected by rotary screw trap in the Yolo Bypass Toe Drain from 2010-2014 and compared their growth to individuals collected throughout the rest of the estuary from the same time period. Growth rates of juvenile fish utilizing the Yolo Bypass were elevated compared to the rest of the estuary, suggesting that this managed floodplain habitat provides better feeding conditions for the species and that the region may be a freshwater refuge for the endangered Delta Smelt.

Relevance: This research helps refine our understanding of how an endangered native species can exhibit unique life history strategies and make use of new habitat in response to changing conditions in the Sacramento-San Joaquin Delta.

Keywords: Delta Smelt, Yolo Bypass

Poster Topic: Fish Biology, Ecology and Protection: Smelt

Development and Evaluation of Using Environmental DNA Sampling to Detect and Monitor Wild Delta Smelt

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The Delta Smelt is a threatened species endemic to the Sacramento/San Joaquin Delta (Delta) and other parts of the upper SF Estuary whose population has collapsed within the past few decades. Surveys in recent years found very few remaining fish, a sharp and alarming decline for an annual species. Even when the Delta Smelt populations are healthy, traditional surveys (e.g. Spring Kodiak Trawl (SKT)) have several limitations in their ability to monitor Delta Smelt over the large area that comprises their native range. Unsurprisingly, as the population has declined, effective monitoring of Delta Smelt has become even more difficult. Environmental DNA (eDNA) sampling is a technique where the presence/potential absence of organisms is detected in environmental samples, such as water. Two major benefits of using eDNA is 1) eDNA sampling does not require visual identification, and 2) eDNA sampling has little to no risk of sampling-related mortality that is typical with traditional surveys. Therefore eDNA is a promising potential complement to traditional surveys for detecting the increasingly rare Delta Smelt. We are currently in Phase I of a pilot project designed to develop an eDNA sampling technique specifically designed to detect Delta Smelt in the Delta using a targeted qPCR assay. We present initial results of a pilot study designed to develop and test the feasibility of an environmental DNA protocol for detecting Delta Smelt in the San Francisco Estuary. Initial results include filtration and extraction protocols, Delta Smelt DNA shed rate, assay sensitivity, and an analysis of presence of PCR inhibition. We will also present information on the pros and cons of eDNA sampling in general, as well as future work plans for this project.

Keywords: eDNA, Delta Smelt, sampling, protocol development

Poster Topic: Fish Biology, Ecology and Protection: Smelt

Phenotypic Effects of Domestication on Captive-Bred Cultured Delta Smelt

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The Fish Conservation and Culture Lab (FCCL) is currently culturing the 9th generation of endangered Delta Smelt (*Hypomesus transpacificus*). These fish have been removed from the wild since 2007. In order to understand the effect of domestication on the captive-bred cultured Delta Smelt, the growth and survival of larvae with both parents from the wild were compared to the larvae of parents from the 8th generation of the refuge population (control group) under two different turbidity environments (5.5 and 9 NTU). The results show the larvae with wild parents were slightly smaller than the control group till they were 80 days post hatch (dph), and the survival of the ones with wild parents was lower at 40 dph than the control groups, especially for the group with low turbidity (84% vs 92% at 9 NTU; 53% vs 80% at 5.5 NTU). In addition, phenotypic parameters including fork length, body weight, and fecundity from both refuge and wild-born populations (they were brought in the lab from the wild at the sub-adult stage) were compared when they were sexually mature for spawning. The results show in the past six years, the wild-born populations were getting smaller, especially in the past two years, while the refuge population have maintained a similar size. The fecundity of wild-born population also decreased with the fish size.

Keywords: Delta Smelt, domestication, phenotype, refuge population

Poster Topic: Fish Biology, Ecology and Protection: Smelt

The Search for the Spawning Habitat of Delta Smelt

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The Delta Smelt (*Hypomesus transpacificus*) is a federal and state ESA-listed fish that is endemic to the San Francisco Bay–Delta. Delta Smelt population abundance has been in decline for decades, yet some aspects of their life history are still a mystery to the scientific community. This study aims to gain an improved understanding of their preferred spawning habitat. We address this question by comparing the distribution of newly-hatched larval (5-6 mm FL) Delta Smelt and ready-to-spawn adult Delta Smelt, and subsequently analyzing habitat attributes of areas where both life stages occur. Our study draws on data from three long-term monitoring surveys: the Smelt Larval Survey, the20-mm Survey, and the Spring Kodiak Trawl. We focus on years 2009 to 2015 to capture a variety of environmental conditions in our dynamic and ever changing Delta ecosystem.

We found 'hot spots' where both ready-to-spawn adult and newly-hatched larval Delta Smelt were present in spatial and temporal proximity to each other, indicating spawning habitat. Using those areas, we explore where spawning is likely occurring, where spawning is not likely occurring, and identify habitat attributes common to those areas. With this information we can start to pin-point the specific spawning substrate that Delta Smelt are using, and in the future could conduct egg surveys in those locations. At the management level, gaining a better understanding of suitable Delta Smelt spawning habitat would better guide habitat restoration efforts and could eventually lead to more favorable Delta Smelt habitat.

Keywords: Delta Smelt, Habitat Spawning, Mature Juvenile

Poster Topic: Fish Biology, Ecology and Protection: Smelt

Maternal effects on egg quality in Delta Smelt (*Hypomesus transpacificus*)

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Maternal effects have the potential to influence important early life-history traits of offspring, such as egg and larval quality and survival. In this study, the relationship between maternal traits (i.e body weight, fork length, and condition factor) and indicators of egg quality (i.e. egg size, and quantity of fatty acids) and larval quality (i.e. larval total length at hatch, oil globule size, and yolk size) were investigated in the endangered estuarine fish Delta Smelt (*Hypomesus transpacificus*). Results show a trend for larger females to produce larger eggs in the first clutch, but this relationship diminishes in the second clutch of eggs, which were generally smaller than the first clutch. Using mixed effect linear models to analyze relationships between maternal traits and indicators of offspring quality revealed that the condition factor of the female, egg size, and clutch (first or second) were predicting variables of the quantity of important fatty acids (Omega-3's) required for larval growth and survival. This study highlights that factors affecting adult female size and condition may have transgenerational effects, as offspring from larger females may have an advantage in growth potential (e.g. via more nutritional resources in the egg) and thus a higher survivorship. These findings have long-term implications at the population level for the Delta Smelt, as sub-optimal environmental conditions (e.g. reduced food availability) in the San Francisco Estuary Bay-Delta may impact the growth of adult fish and in turn indirectly affect the offspring fitness leading to negative consequences for the population after multiple generations.

Keywords: Delta Smelt, maternal effects, egg quality, larval survival

Poster Topic: Fish Biology, Ecology and Protection: Smelt

Longfin Smelt Distribution, Abundance and Evidence of Spawning in San Francisco Bay Tributaries

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The Longfin Smelt Project Work Team has identified various studies that would expand our current understanding of Longfin Smelt distribution, abundance, abundance trends, spawning location(s), and the relationship between Delta outflow and longfin smelt abundance (e.g., Kimmerer 2002). The UCD Fisheries Research Team launched a field survey in 2015 to document the geographic extent of longfin smelt adult distribution and larval rearing in San Francisco Bay tributaries. In four tributaries, (Napa River, Sonoma Creek, Petaluma River, and Coyote Creek) adults were sampled using an otter trawl while larvae were sampled using CDFW's Smelt Larval Survey sled biweekly from January-March. In the pilot study year 2015, adult longfin smelt were found at the upstream extent of each bay tributary, with Coyote Creek having the highest catch. Larval longfin smelt were found at various areas along Napa River, Sonoma Creek, and Petaluma River. No larval longfin smelt were found in Coyote Creek. In the second year of the study the team was able to expand with extended fresh water areas into San Pablo bay as well as extending the sampling time frame through use of the 20mm net from March to June. In 2016 longfin smelt were caught in all three gear types at various life stages. Through expanded sampling locations and gear types, UCD is gaining additional information on water quality features coinciding with larval longfin smelt presence.

Keywords: Longfin Smelt Project Work Team, San Francisco Bay Tributaries

Poster Topic: Fish Biology, Ecology and Protection: Smelt

Field Calibration of the SmeltCam

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The SmeltCam functions as an open-ended codend that automatically collects information on the number and species of fishes that pass freely through a trawled net without human handling. The SmeltCam captures high speed images of object passing through it and a computer algorithm attempts to differentiate fish from other objects and to identify the species of fish. Recent research has indicated that the SmeltCam is an effective tool for field studies of Delta Smelt and other fishes. Here, we report on a field calibration study of the SmeltCam. The study involved placing a closed codend on the back of the SmeltCam during day and night sampling and comparing the species and numbers of fishes cpatured in the codend with those observed by the SmeltCam. This field calibration compliments previous laboratory flume studies and provides information that improves the functionality of the SmeltCam. Continued development of the SmeltCam will provide an effective tool to study rare and sensitive species in the Bay-Delta.

Keywords: smeltcam, delta smelt, sampling methods

Poster Topic: Fish Biology, Ecology and Protection: Smelt

Identification of Individual Cultured Delta Smelt Using Visual and Automated Analysis of Natural Marks

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Given the limited availability of tagging methods for individual small fishes, we evaluated the feasibility of external natural marks to identify subadult-adult Delta Smelt (*Hypomesus transpacificus)* produced at the Fish Conservation and Culture Lab (FCCL). As potential natural marks we selected the dorsal head area (DHA) where external pigmentation is particularly abundant. To verify the effectiveness of natural marks, fish were individually tagged using Visible Implant Alpha tags. Three photo sessions were conducted beginning 230 and 244 days post-hatch in two fish groups over two periods, respectively (January-May 2013 and October-April 2014-15), with the latter group including low and high light treatments to evaluate the influence of light on natural marks. We used a digital camera to acquire DHA and evaluated their effectiveness as natural mark using visual (naked eye) and automated image recognition (TinEye's Match Engine API). Shorter intervals between photo sessions (nearly 56 days in 2013 and 90 days in 2014-15) resulted in higher correct matching for both visual recognition (100% in 2013 and 70-100% in 2014-15) and automated recognition (59-89% in 2013 and 19-33% in 2014-15). Pigmentation generally became less apparent under the high light treatment, leading to a marginally lower percent of automated recognition relative to fish under low light. Unlike visual recognition for the 2014-15 sessions, the percent of correct visual matching in the 2013 sessions remained constant (100%) as a function of the number of days between sessions, suggesting a smaller change in pigmentation during the maturation and spawning periods (winter-spring) than before maturation (fall-winter). These results suggest natural marks may be more reliable to track cultured Delta Smelt at the adult stage than from the sub-adult to adult stage. Application of natural marks in wild fish requires further testing as preliminary observations revealed significantly lower DHA pigmentation in field-caught adult Delta Smelt.

Keywords: Delta Smelt, tagging, pigmentation, image recognition, natural marks

Poster Topic: Fish Biology, Ecology and Protection: Smelt

Can We Tag Delta Smelt? Feasibility of PIT and Acoustic Tagging of Cultured Adults

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Delta Smelt abundance has declined to a record low, resulting in major resource management issues and increased demand for better information. To date, information on the movement, survival, and behavior of Delta Smelt has been principally inferred from collection of fish during trawling and salvage monitoring. Recent advances in miniaturization of passive integrated transponder (PIT) tags and Juvenile Salmon Acoustic Telemetry System (JSATS) transmitters now allow these technologies to be considered for smaller fishes such as Delta Smelt. The ability to track individual Delta Smelt would substantially improve knowledge of the species' habitat use, migration routes, and entrainment vulnerability. Building on a growing body of juvenile salmonid telemetry research, this study investigated 28-day survival and tag retention of cultured Delta Smelt (>70 mm) intracoelomically fitted with PIT tags (8.4 mm, 33 mg) and prototype JSATS transmitters (15.0 mm, 220 mg). Survival of PIT-tagged individuals was high (95%). Survival of individuals with injected and surgically inserted dummy acoustic tags was lower (50-60%). Tag retention was high in all tag treatments (95-100%). These results indicate that Delta Smelt fitted with PIT tags can be used to examine management actions, subject to additional behavioral and physiological studies, but acoustic tags must be made smaller. Logistic regression suggests that survival of >90% would require a maximum tag mass/body mass ratio near 0.02.

Keywords: Acoustic telemetry, Passive integrated transponder, Delta Smelt, JSATS, Tagging techniques

Poster Topic: Fish Biology, Ecology and Protection: Smelt