Aerobic Scope Reveals High Thermal Performance in Juvenile Chinook Salmon, *Oncorhynchus tshawytscha*

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Defining suitable thermal habitat for fishes is of fundamental importance to ensure population persistence, but translating laboratory measures of thermal performance into regulatory numeric criteria remains difficult. The mechanisms driving population declines due to changes in environmental temperature are poorly understood, yet they are essential for effective management of California native fishes. In an effort to provide valuable physiological temperature data that can be used by conservation managers, we tested the thermal performance of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) across a range of environmentally relevant temperatures. Fish (initial size ca. 8.8 cm FL, 9 g) were acclimated to 14 or 20°C, and swim tunnel respirometers were used to measure routine metabolic rate (RMR) and maximum metabolic rate (MMR) at test temperatures ranging from 12 to 26°C. Absolute aerobic scope (AAS=MMR-RMR) and factorial aerobic scope (FAS=MMR/RMR) were calculated to determine the capacity of each fish to supply oxygen to tissues above and beyond the basic routine need. MMR, AAS, and FAS did not differ significantly between the two thermal acclimation groups, while RMR was lower in fish acclimated to 20°C. Overall, RMR, MMR, and AAS increased as test temperatures increased, and AAS was maintained until mortality rates abruptly increased at 25°C. These data are critical for managers seeking to link the survival of fishes with environmental temperature regimes, to identify temperature ranges optimal for survival, and to help determine future restoration sites that will be important for the recovery of native fish populations.

Keywords: salmon, metabolic rate, climate change, oxygen consumption

Poster Topic: Fish Biology, Ecology and Protection: Salmon

2016 South Delta Chinook Salmon Survival Tag Retention Study: Increased Tag Burden Results in Increased Tag Expulsion

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The 2016 South Delta Chinook Salmon Survival Study was part of an ongoing telemetry study that was conducted to better understand the survival and route selection of emigrating Chinook Salmon *Oncorhynchus tshawytscha* smolts through the south Delta. In order to better interpret the artificial impact of survival introduced through the surgical tagging procedure, we also conducted a companion study to assess tag retention and fish survival after tagging. This consisted of surgically implanting a dummy acoustic transmitter into the abdominal cavities of 50 juvenile Chinook Salmon, and assessing the condition of each fish after a 30-day holding period. The 2016 survival and tagging effects studies contrasted previous years in that the tag burden (i.e., the ratio of the transmitter weight to body weight) was higher than the 5% maximum limit adhered to in past years for both released study fish (average tag burden in 2016 Week 1 = 6.3%; Week 2 = 5.2%) and tagging effects fish (average tag burden = 7.6%). Despite the increased tag burden, we observed 100% survival and an average of 85.8% increase in weight of tagged fish after the 30-day holding period. However, we also observed a decrease in tag retention compared to previous years of the study that remained below the maximum 5% tag burden limit (tag retention in 2016 = 88.0%; 2015 = 98.6%; 2014 = 100%). The tag expulsion observed in 2016 occurred only within the smallest 31.3% of held fish (average size of all 2016 held fish at Day 0 = 4.8 g, range = 4.5–6.9 g). These results generate insight regarding possible limitations in using smaller fish in future telemetry studies and help correct survival estimates for potential bias associated with tag expulsion rates.

Keywords: Chinook Salmon, acoustic telemetry, survival

Poster Topic: Fish Biology, Ecology and Protection: Salmon

Calculating Potential Fish Benefits from NMFS Delta Actions

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Calculating the benefits from the NMFS RPA Delta Actions is difficult because the available fish sampling data is limited; there are several conceptual models for fish behavior at Delta channel junctions or diversions; and there are limited measurements of survival in each major Delta channel. The calculation of fish benefits requires the following information: Delta inflows and channel flows; daily fish migration pattern; flow fractions and corresponding fish fractions for each Delta junction; and survival in each Delta channel.

Calculations are shown for estimating two benefits from closing the DCC; the fraction of migrating fish that enter the SJR pathway with reduced survival to Chipps Island and the fraction of fish that are salvaged and lost at the CVP and SWP exports. Calculations are shown for installing a fish screen or a fish exclusion device in Georgians Slough. Calculations are shown for shifting exports from SWP (20% salvaged, 80% lost) to CVP (60% salvages, 40% lost). Calculations are shown for reducing reverse OMR flow to -5,000 cfs, and for further reducing OMR flows to -2,500 cfs based on salvage loss triggers. Calculations are shown for reducing the April and May exports to a fraction of the SJR inflow, and for installing the Head of Old River barrier. Calculations are shown for increasing the SJR inflow in April and May, and for separating the SJR inflow from the CVP and SWP exports by routing the SJR down Old River while routing the export flows in Middle River and Victoria Canal. The calculation framework is based on the historical Delta flows (DAYFLOW) and the changes in Delta flows that would result from each RPA action. An expanded DAYFLOW, which includes daily estimates of each D-1641 objective and each RPA action should be created with a cooperative project between the WOMT agencies.

Keywords: Delta Fish Benefits, Salvage Loss Calculations, Flows and Diversions

Poster Topic: Fish Biology, Ecology and Protection: Salmon

Dynamic Visualization of Tethered Salmon Smolt and their Predators in San Joaquin River Habitats

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Many non-native predatory fishes (e.g. striped bass, largemouth bass, white catfish, and channel catfish) are known to prey upon salmon smolt in the San Joaquin River (SJR) system. The locations, densities, and dynamics of these predators and quantitative impact on smolt are unknown. During 2014 and 2015 a study was conducted to examine effects of manipulated predator densities and prey transit time on juvenile salmon survival. In support of this, repeated active acoustic surveys were conducted to detect and estimate predator densities throughout the SJR from Port of Stockton to Lathrop. Additionally in 2015 parts of Clifton Court Forebay and the Stockton Deepwater Channel of the SJR were surveyed. This electronic-poster presents dynamic three-dimensional visualizations of results from these surveys and experiments, including: maps of riverbed bathymetry, backscatter, and SAV; sonar-detections of fish as they were encountered during the surveys; tethered smolt tracks and predation events; and estimated densities and abundances of predatory fish over time (March through May, 2014 and 2015).

Keywords: 3D animated visualization, non-native fish, salmon-smolt predation, novel methods

Poster Topic: Fish Biology, Ecology and Protection: Salmon

Monitoring for Pathogens and their Effects on Out-Migrating Chinook Salmon in the Delta

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Water temperatures in the Sacramento-San Joaquin River Delta are postulated to rise over the next decades as a result of global climate change. A side effect of elevated water temperatures is the facilitation of disease spread and infection in fish. Recently observed elevated water temperatures coincided with juvenile Chinook salmon migration timings, potentially enhancing susceptibility to disease. We conducted multiple-endpoint assessments to evaluate the health status of out-migrating Chinook salmon juveniles throughout the Delta. First we exposed caged hatchery-origin to ambient waters to assess the types of pathogens present in the San Joaquin River that may potentially impact migration success and rearing survival. Second, we evaluated field caught wild juvenile fish and hatchery origin (released) juvenile fish to assess potential differences in disease status. We examined gill, brain, and kidney to determine pathogen presence and abundance, as well as the expression of immune-response genes to assess the relative impact of infection on the fish. In the caged fish, *Ichthyophthirius multifiliis,* Rickettsia-like Organism, and *Flavobacterium psychrophilum* were identified as pathogens of potential concern for Chinook salmon. *Ichthyophthirius multifiliis* was the most commonly detected pathogen and the pathogen with the highest loads. Gill tissue had the highest levels of detection for the pathogens, highlighting the utility of the gill for pathogen detections in wild fish. We will present comparative data for hatchery origin (caged), hatchery origin (released), and wild out-migrating Chinook salmon, and discuss how this data, and developed tools can be incorporated into monitoring programs in order to provide comprehensive health status assessments of out-migrating salmon. Understanding the dynamics of pathogens in Pacific salmon systems will improve resource manager`s ability to predict successful smolt migration and rearing survival during periods of high water temperatures or extreme drought.

Keywords: Elevated water temperatures, Drought, Disease, Pathogens, Out-migrating Chinook salmon, Monitoring

Poster Topic: Fish Biology, Ecology and Protection: Salmon

Emigration Rate and Survival of Winter-run Chinook Salmon

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Sacramento River Winter-Run Chinook salmon are locally adapted to escape summer heat in the Central Valley by navigating farther than other runs earlier in the year to cold, refugial tributaries above Shasta Reservoir, where they spawned and reared throughout the summer. This unique life history strategy of extended instream residence is found nowhere else on the West Coast. The decline of Winter-Run Chinook Salmon is largely attributed restricted spawning and juvenile rearing to the mainstem of the Sacramento River, with early life stages reliant on controlled flows released from Shasta Reservoir. We evaluated the response of juveniles to managed flow conditions by tracking movement patterns and emigration survival of hatchery Winter Chinook. Fish were tracked from the spawning area below Keswick dam to the ocean from 2013-2016, all of which were drought years. An array of 120 receivers was deployed throughout the Sacramento River and San Francisco Estuary, terminating at the Golden Gate Bridge. Up to 570 fish per year were surgically implanted with Juvenile Salmon Acoustic Telemetry System (JSATS) transmitters and released. Despite drought conditions and generally low flows, fish movement and survival varied with the magnitude of flows. Low flows corresponded with long in-river residence and low survival whereas strong peak flows corresponded to rapid emigration and high survival. Extended periods of Winter-Run Chinook Salmon holding under low flow conditions have not been observed in other runs and thus may reflect a residual life history behavior. Overall, this study highlights the importance of pulsed flow conditions for promoting higher survival of juvenile Winter-Run Chinook Salmon emigrating to the ocean, which will inform future management of the species.

Keywords: Winter-run Chinook Salmon Central Valley Sacramento River Acoustic telemetry juvenile

Poster Topic: Fish Biology, Ecology and Protection: Salmon

Differential Impacts of Outmigration, Survival, and Biocomplexity for the Central Valley Chinook Salmon Population

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Traditionally, conservation management has focused on maximizing species abundance, while more recent discussions have focused on biocomplexity and resilience. Which is more important for salmon in the California Central Valley? Here, we modeled expected adult return abundance to the Stanislaus River under different scenarios of juvenile migration strategies and survival based on empirical data. We estimated survival probability by size (selection functions) by comparing juvenile outmigrant size distributions from rotary screw trap sampling with those reconstructed in the surviving adults using otolith chemistry. We then separated the data into four dimensions (total number of outmigrants, total survival probability, outmigrant size distributions, survival size distribution) and ran all possible combinations to identify the factors having the largest effect on the number of adult returns. Our results suggest that the total number of outmigrants and total survival probability were the most important factors explaining the number of returns (explaining 50% and 30% of the variance, respectively). Diversity in life history traits (i.e. the size distribution of outmigrants and survival rates) explained most of the remaining variability (about 10% each). Our results suggest that maximizing the total number of outmigrants is the best strategy to maximize population size, but that variable migration strategies should be maintained for population stability and resilience.

Keywords: biocomplexity, portfolio effect, size-specific survival

Poster Topic: Fish Biology, Ecology and Protection: Salmon

Central Valley Passive Integrated Transponder (PIT) Tag Array Feasibility Study

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NOAA led a collaborative pilot study in 2015-16 to develop and test a variety of Passive Integrated Transponder (PIT) tag detection systems to assess the potential for using PIT tags to monitor the movement and survival of listed salmonids in the Central Valley and Sacramento-San Joaquin Delta. Detection array approaches were developed for 4 sites that represent the range of channel sizes and structures present in the Delta, in increasing level of challenge: (1) shielded circular antenna array on a pipe in a high RF noise environment; (2) prototype pontoon-mounted vertical fin array with 6-ft long hydrofoil fins on the upper Mokelumne River, representing tributary rivers; (3) larger pontoon-mounted vertical fin array with 12-ft long fins on the mainstem San Joaquin River, representing large, tidally-fluctuating channels; and (4) towed arrays for trawl-type surveys in the largest channels where the lower Delta meets San Francisco Bay. Arrays at sites 1-3 were installed and operated March through May 2016 and detection rates were estimated by releasing PIT-tagged hatchery Chinook salmon smolts. Evaluation of the towed array consisted of fabricating and field testing a prototype array in the Northwest and then combining the performance results with environmental data (bathymetry, salinity, flow, etc.) from the lower Delta to estimate various scenarios for sampling effort and potential detection rates. Results from this initial feasibility study will help inform deliberations about how PIT tags might provide an additional tool to complement existing approaches, such as acoustic tagging, to advance research and monitoring of listed fish in the Central Valley and Delta. Partners in the project include California Department of Fish and Wildlife, California Department of Water Resources, East Bay Municipal Utility District, US Bureau of Reclamation, US Fish and Wildlife Service, and Biomark.

Keywords: PIT tags, antennas, salmon, San Joaquin River, Mokelumne River

Poster Topic: Fish Biology, Ecology and Protection: Salmon

Migratory Behavior and Survival of Reintroduced Spring-Run Chinook Salmon Smolts in the San Joaquin River and Delta

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Along with actions to reconnect and restore habitat in the San Joaquin River, there is a concurrent spring-run Chinook salmon reintroduction effort underway. Chinook salmon smolts have been released in the spring near the confluence of the Merced River with the San Joaquin. However, there is little information available on the migratory behavior and survival of these fish as they exit the river and traverse the San Francisco Estuary before entering the Pacific Ocean. We are planning to release two groups of salmon smolts outfitted with injectable-sized JSATS (juvenile salmon acoustic telemetry system) transmitters to assess movement rates, behavior, and reach-specific survival in relation to environmental parameters. One group will be released upstream of where the Merced River flows into the San Joaquin, in a similar manner as the hatchery produced spring-run smolts used in the reintroduction effort. A second group of tagged fish will be released at the entrance to the Sacramento-San Joaquin Delta, near Durham Ferry.

An array of acoustic receivers in the San Joaquin River and San Francisco Estuary will permit us to reconstruct encounter histories of individual fish and subsequently derive survival estimates, detection probabilities, and movement rates of the salmon smolts, as well as relate these estimates to changing environmental conditions. The results of this study will inform us survival rates of these reintroduced fish as they emigrate the river, how survival is affected by changing environmental conditions, how water operations may affect the survival, and will allow us to focus future studies on reaches of river that have consistently low survival. The survival estimates will also be incorporated in life cycle models to forecast future abundance of spawners returning to the San Joaquin River. Information learned throughout the course of this study will also be useful in gauging the effectiveness of the reintroduction effort.

Keywords: Telemetry, Spring-run, Chinook salmon, Survival, San Joaquin River, Delta, JSATS

Poster Topic: Fish Biology, Ecology and Protection: Salmon

A Brief History of Central Valley Hatchery Releases in Time and Space

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Salmon hatcheries play a complex role in the California Central Valley. Originally established to mitigate upstream habitat loss, they now dominate Chinook salmon fall run production and have a significant impact on the dynamics and genetic diversity of the entire stock complex. Here, we follow on from the study of Huber & Carlson (2015) by geolocating the release locations of all fall-run Chinook salmon releases in the Central Valley since 1946. We examine how management practices have evolved over the past 70 years, focusing on the timing and location of hatchery releases. We also explore the relationship between straying index and trucking distance for each of the five main hatcheries. Over the past 70 years, hatchery salmon have been trucked increasing distances from the hatchery-of-origin, while variation in date at ocean entry has been truncated. The major implication of increased trucking distances lies in the increased probability of these individuals straying to other rivers to spawn, reducing genetic diversity and opportunities for local adaptation. Reduced diversity in ocean entry timing increases the chances of a mismatch with optimal ocean conditions. This simplification of the Central Valley "portfolio" has the potential to reduce the resiliency of both wild and hatchery populations, and should be considered in future management decisions.

Keywords: Hatchery practices, salmon, straying, life history diversity, portfolio effect, trucking

Poster Topic: Fish Biology, Ecology and Protection: Salmon

Fall Run Chinook (*Oncorhynchus tshawytscha*) Salmon Upstream Migration Behavior in San Joaquin River Basin

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Acoustic telemetry has evolved and improved over several decades enabling researchers and agencies to more accurately study the movements of a variety of fish species. These improvements allow researchers to explore important aspects of anadromous fish behavior relating to streamflow management, stressors and restoration actions. In California's Central Valley, researchers have deployed an array of acoustic hydrophones in conjunction with acoustic tags to study anadromous fishes such as sturgeon (*Acipenser spp.*), Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*Oncorhynchus mykiss*). These acoustic arrays of receivers cover the entire length of freshwater rivers in the Central Valley to the Golden Gate Bridge and in the Pacific Ocean. California Department of Fish and Wildlife (CDFW) conducted an adult Chinook salmon tracking study in San Joaquin River from 2012 to 2015. Sixty-eight Chinook salmon were implanted with acoustic tags and released in the San Joaquin River upstream of Mossdale County Park. Using the detection data that is shared by researchers and agencies, we were able to construct migration timing, pattern, and speed of each tagged Chinook salmon.

Adult Chinook salmon spawning migration is poorly understood in California's Central Valley despite working beginning as far back as the 1960s (Hallock et al, 1970). Limited data has been collected about adult salmon spawning migration, timing, movement behavior, and travel speed. Scientists hypothesize adult fall-run Chinook salmon hold in the Delta or river, migrating to spawning grounds when river conditions improve as a result of increasing river flow and decreasing river temperature. Results indicate adult Chinook salmon are capable of traveling between Sacramento and San Joaquin River Basins before they arrive at their final spawning ground. Detection data shows migration behavior related to river flow changes. Salmon exhibit complex searching patterns during their upstream migration and similar patterns have been demonstrated in studies within the Columbia River Basin.

Keywords: San Joaquin River, Fall run Chinook salmon, telemetry study

Poster Topic: Fish Biology, Ecology and Protection: Salmon