Do Hatchery Chinook Salmon Supplement Naturally Produced Fish, or Replace Them?

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Hatcheries are intended to increase populations. To the extent that hatchery fish replace rather than supplement naturally reproducing fish, hatcheries are at best ineffective. Data on adult returns of fall Chinook salmon to the upper Sacramento River and Battle Creek, and to the Yuba River, show that populations have varied strongly over time, but returns before the recent population collapse were about the same as half a century ago. However,the spatial distribution of spawning (Sacramento River v. Battle Creek) and recent coded-wire tag data show that many of the fish spawning in the upper Sacramento and Yuba rivers are now hatchery fish (about 50 and 70% respectively in 2010, estimated from fresh carcasses only). This strongly suggests that hatchery Chinook have replaced rather than supplemented naturally produced fish in these streams, as has been suggested elsewhere. Moreover, naturally produced fall Chinook in these rivers seem not to be reproducing themselves, or barely doing so, despite the recent reduction in fishing pressure and overall increase in returns. These results raise questions regarding the effectiveness of hatchery production of fall Chinook in the Central Valley, and whether the existing hatchery programs are consistent with the objectives of the Central Valley Project Improvement Act.

Keywords: Chinook, hatcheries, hatchery effects

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Key Uncertainties Surrounding Predation at Diversion Structures

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Large-scale water diversions have made possible the development of much of the arid western United States. Regulatory agencies now routinely require the screening of large diversion structures, which has greatly reduced direct entrainment mortality of listed fish species, but concerns remain over the potential they have for increasing juvenile mortality by congregating predators and increasing predation efficiency. We reviewed the literature on survival and predation at large diversion structures such as GCID and Red Bluff Diversion Dam, and found that significant mortality has been documented to occur at diversion structures, much of which is likely due to predation. However, major questions remain about the impact of this mortality, and how it can be managed. Acoustic technology allows for accurate measurements of both prey fish survival and the behavior of piscivorous fish at diversion structures. Key questions that need to be examined include:

Do predators congregate around diversion structures?

Do structures create more predation or just re-distribute predators?

Are there indirect effects from reduced flows below the diversions? E.g., reduced velocity and turbidity may impact predation efficiency. Studies have shown that river turbidity is strongly related to predation rate.

How can structures be designed to minimize predation? Recent screen designs include refuges for fish built into the screen at specific intervals, but no field studies have been conducted on their success.

Can predator numbers at a structure be suppressed enough to reduce overall predation rates?

Studies are underway to help answer these questions, including a NMFS study of predation at diversion structures in the Sacramento River at Sacramento and Freeport, but more focused studies and intensive monitoring will be needed.

Keywords: water diversion structures, predation, survival, uncertainty, monitoring

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The History of the Spawners: Juvenile Delta Use by Adult Winter- and Spring-Run Chinook Salmon

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Out migrating juvenile Chinook salmon are observed throughout the Sacramento-San Joaquin Delta, but little is known about the extent of Delta use as a rearing habitat for juveniles that successfully return as adults to spawn. In this study, we use Sr isotopes in otoliths to reconstruct Delta use as juveniles by the 2007-2009 Sacramento River Winter-andSpring-run Chinook salmon spawning adults. The Sr isotope history of the juvenile period of an adult salmon can be reconstructed with ~2 week resolution, presenting the potential to reconstruct the juvenile rearing history for the fish that successfully return to spawn. Inferring patterns of movement from isotopic data necessitates comparing the isotope of the fish with an isoscape, a map of the isotope signatures of the area through which an animal might move. To specifically enable Delta use reconstruction, we have identified a downstream gradient in Sacramento River Sr isotopes that allows the northern Delta (Freeport to Decker Island) to bedelineated from the upstream Sacramento River. From the northern Delta, Sr isotopes change rapidly with salinity, enabling departure from the Delta to be easily identified. Use of the South Delta can also be inferred, though it has not been observed. We compare otolith Sr isotopes to those of the Sr isoscape to infer the patterns of habitat use. Initial results show a range of outmigration strategies for Winter-run, with more limited behavior for Spring-run, but most fish spend the majority of their juvenile rearing period in the Sacramento mainstem. We observe little indication of outmigration as yearlings in either group. Finally, we show how this qualitative approach commonly used for inferring movement of animals across isoscapes can be improved by implementing a state-space model to quantify the movement and the uncertainty about those movements to recreate probabilistic migration scenarios.

Keywords: Chinook salmon; otoliths; Delta; strontium; juvenile habitat use

Thursday, October 18, 2012: Room 311-313, Salmonid Life History and Biology (I) – Order 3

Using Size, Growth Rate and Rearing Origin to Evaluate Selective Mortality of Juvenile Chinook Salmon across Years of Varying Ocean Productivity

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One of the most challenging aspects in understanding population declines of anadromous fish species is determining how processes occurring in freshwater, estuarine, and marine habitats influence growth, survival and reproductive success. Individual variation in growth rates and body size during early life history stages can have significant population level consequences. For example, an elevation in size-selective mortality due to poor ocean conditions is believed to be the driver behind the collapse of Central Valley fall-run Chinook salmon in 2007. However, empirical data quantifying where within the life stage smaller individuals may have greater mortality, and under what environmental conditions, are difficult to obtain.

Here we provide trends in reconstructed growth rates (otolith increment widths), fish condition (K factor), fork length, triacylglycerol lipid content (TAG), and the proportion of hatchery and wild individuals (otolith sulfur isotopes) for salmon collected in the San Francisco Bay and coastal ocean. We compare sub-yearlings that emigrated in 2000and 2001 (years of good ocean productivity) with the cohort in 2005 (a year of poor ocean productivity). Preliminary findings show that significant size and growth rate selective mortality occurred in the spring of 2005 when juvenile salmon first entered the coastal ocean to feed. Fish that were larger upon exit from the San Francisco Bay survived more than the smaller, slower growing fish during this same time. The findings in 2005 were in stark contrast to fish in 2000 and 2001where no significant size or growth rate selective mortality was detected. Although hatcheries generally release larger juveniles, our study did not find preferential selection for hatchery fish. Our data suggest that size selective mortality can be strong, favoring larger juveniles when food is limiting in the ocean and may be one of the mechanisms that contributed to the low number of returning adults in 2007.

Keywords: size selective mortality, growth rates, ocean conditions, otoliths

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Did San Francisco Bay Previously Provide Rearing Habitat for Juvenile Salmonids?

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In May we held a symposium entitled: "Beyond Suisun - estuarine ecology of juvenile salmonids". Through a review of the ecology of juvenile salmonids in estuaries, the traditional wisdom was questioned that juveniles of Central Valley salmon populations do not use San Francisco Bay proper as rearing habitat (the majority of the estuary lies west of Carquinez Strait). Although data are surprisingly limited for such a critical issue, studies to-date support the idea that juvenile salmonids do not dwell long in the middle and outer estuary, moving quickly between Suisun Bay and the ocean. This poses the question whether juvenile salmonids ever used the Bay for rearing and, if so, what restoration options should be considered. Changes in the last two centuries may have shifted suitable habitat from west of Carquinez to east - specifically the landward intrusion of salinity associated with lower levels of freshwater flow and the loss of marshes west of Carquinez. The counter view is that juveniles always moved rapidly from the vegetated refuges and food-rich waters of the delta and Suisun Bay to the deep, food-rich waters west of Golden Gate and in the northern Gulf of Farallones (a region fueled by upwelling and replete in planktonic food). The Gulf thus provides habitat typical of estuaries, allowing rapid growth of juveniles to sizes that can access typical ocean prey. Nevertheless, the Bay remains a habitat for passage between river and ocean. Juvenile tagging studies will inform on the rate and pattern of migration and thus help define questions relating to survival and growth during migration through the Bay and Gulf. Understanding the current and historic estuary are critical for choosing future management scenarios, but it is not sensible and probably not possible to try to go back to a prior ecological state.

Keywords: salmonid, San Francisco Bay, juvenile migration, Gulf of Farallones, management

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Flow, Gates, Trucks, and Chinook salmon: Collaborative Approaches to Adaptive Management in the Lower Mokelumne River

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The lower Mokelumne River (LMR) produces a substantial Chinook salmon return that significantly contributes to the Central Valley salmon population and associated commercial and sport fisheries. In fall 2008 ocean conditions were identified as being one of the key factors in the decline of fall-run Chinook salmon escapement. However, an additional factor contributing to low returns in the LMR appears to be high straying rates to other rivers. During 2008 and 2009, over 50% of the total number of Mokelumne River origin Chinook salmon returning to Central Valley tributaries strayed into the American River.

The Lower Mokelumne River Partnership (Partnership) is made up of representatives from CDFG, USFWS and EBMUD. The Partnership identified several factors that can influence straying including flow operations, Delta water management (including Delta Cross Channel operations), temperature, and planting practices for hatchery fingerlings and smolts. Working with operators from EBMUD, DWR, and USBR the Partnership has developed a number of adaptive management actions to test their effect on stray rates and total escapement. These actions include closures of the Delta Cross Channel gates and attraction releases from Camanche Reservoir. Additionally, CDFG and EBMUD biologists and hatchery managers reviewed historic release sites for Mokelumne River Fish Hatchery production and identified Sherman Island as a site that potentially reduces stray rates while maintaining an acceptable rate of return to the river and fisheries.

Since implementation of various adaptive management actions, straying of Mokelumne River salmon has been reduced compared to years when no actions are taken. In fall 2011 the Chinook salmon escapement to the river was the highest observed since 1940. Based on the initial results, a five-year study plan is being developed to further evaluate the multiple management actions along with developing a protocol to support decision making about actions involving Delta water management.

Keywords: Mokelumne River, Delta Cross Channel, Attraction Flows, Straying Rates, Salmon

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Juvenile Chinook Salmon Entrainment into Unscreened Water-Diversion Pipes: Can Behavioral Fish-Deterrent Devices Decrease Their Entrainment Rates?

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Emigrating, juvenile Chinook salmon risk entrainment (removal from the river) via water-diversion pipes associated with municipal water or agricultural-irrigation withdrawals from the California Central Valley. Most water-diversion pipes are unscreened, providing no entrainment protection. Fish entrainment susceptibility may vary under different river currents, water intake diversion rates or light levels. We investigated the daytime entrainment risk of Chinook salmon (length range: 7 - 15 cm) in a large-sized (24 m L x 3.3 m W x 3.3 m H; 501,000-l) outdoor flume over a range of river currents (0.15, 0.38 and 0.61 m/s) and water diversion rates (0.34, 0.42 and 0.57 m^3/s) through a 45-cm-diameter pipe during the day. We also tested the ability of behavioral fish-deterrent devices to reduce the number of fish entrained into the pipe, without decreasing the total amount of water diverted. Fish entrainment was higher at 0.15 (50%) than at 0.61 m/s (12%) river currents, due to increased fish movement at slower river speeds. Fish deterring devices were tested at 0.15 m/s river current and 0.57 m^3/s water diversion rate. Compared to control experiments, fish entrainment rates increased significantly (by 61%) with strobe lights, were unaffected by a velocity cap, and decreased significantly (by 68%) when a metal ring was vibrated at 12 Hz in front of the pipe during the night. Most strikingly, fish entrainment rates were greatly reduced using a widened box with louver bars attached to the pipe inlet (97%) and when a perforated diffusing cylinder was used (94%). Our findings suggest that unscreened water diversions may pose a significant threat to juvenile Chinook salmon in the Delta and behavioral fish-deterrent devices may decrease their entrainment risk, without disrupting water extraction practices. Research was funded by the Anadromous Fish Screen Program.

Keywords: fish, diversions, screens, louvers, guidance, swimming, entrainment, behavior, hydraulics, flume

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How Do Inflow, Outflow, Water Export, and Tides Affect Salmonid Loss in the Delta's Fish Facilities?

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There are long-term monitoring data available for Deltain flow, outflow, OMR flow, water export, and fish loss to the SWP and CVP fish collection facilities. These data sets have been analyzed by many researchers, in an attempt to shed light on what factors control the fish loss to the fish facilities. Some suggested that OMR flow or water export was the major factor while others indicated that tide or Delta outflow exhibited more influence than other factors. While each of the analyses may not be invalid to some degree, these studies are focused on individual factors. Our analysis presented here will use a holistic approach to evaluate these factors individually and collectively. We will provide the methods and framework we have developed and present and discuss some of the preliminary results.

Keywords: fish salvage, Delta outflow, OMR, SWP, CVP, salmonids

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Factors Driving Variation in Salvage and Survival of Juvenile Chinook in the Delta

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Fish salvage at the Delta pumps has been used as the primary index of fish losses associated with export pumping, and is also the longest term, consistent data set on fish passing through the Delta. I will present results of our newest analyses of salvage data to sort out the key factors that drive the numbers of juvenile Chinook arriving at the pumps. Correlations of salvage to catches in the Chipps trawl, both for unmarked Chinook and for CWT groups, show that salvage increases as survivorship through the Delta increases. After including Chipps trawl catches as an independent variable reflecting smolt abundance, the remaining variation in salvage rates is related to Sacramento flow, San Joaquin flow, and water temperature. Export pumping volume shows little or no relationship to salvage density. We are extending this analysis to incorporate a mechanistic accounting of route selection and route-specific survival for smolts passing through the Delta. Route specific parameters are derived from acoustic telemetry studies, which also enable quantitative linkage of smolt behavior to flow dynamics through the Delta. We combine the results of Delta hydrodynamics models with those of smolt passage models to test the relative influence of various water operations on fish salvage at the export pumps and on smolt survival through the Delta. Results can be used by managers to weigh the merits of variations to Delta operations for protecting ESA-listed Chinook smolts.

Keywords: Delta, Chinook, survival, salvage, abundance, pumping

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Using Acoustic Telemetry to Assess Hydrodynamic Factors Influencing the Migration Behavior and Route Selection of Juvenile Salmonids in the Interior Delta

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In January 2012, plaintiffs, plaintiff-intervenors, and Federal defendants in the litigation relating to the Biological Opinion on long-term operations of the State Water Project (SWP) and Central Valley Project (CVP) issued entered into a joint stipulation regarding project operations during April and May 2012. Part of this stipulation agreement called for an intensive acoustic telemetry study to assess how South Delta exports may alter the behavior and route selection of juvenile salmonids (particularly steelhead smolts) migrating along the mainstem San Joaquin River. To meet this objective, more than 500acoustically tagged hatchery steelhead smolts were released downstream of Stockton and dozens of additional telemetric receivers were placed at strategic locations in the Central, South and Western Delta. Releases were conducted every two weeks at three different levels of South Delta exports (or OMR flows). Within-season analyses showed that a relatively large fraction (~25%) of acoustically tagged smotls arrived at receiver arrays located along Old and Middle River corridors just north of Woodward Island (Railroad Cut). However, subsequent analysis showed the proportion of fish arriving at Railroad Cut was consistent with survival rates observed in previous acoustic studies and with fish routing following15-minute flow proportions. The rate of acoustically tagged fish arriving at Railroad Cut did not appear related to South Delta export levels, but these results were preliminary. Detailed analysis relating fish behavior to channel specific DSM2 Hydro and particle tracking model results will provide a robust assessment of hydrodynamic factors which may influence migrating juvenile salmonids in the interior Delta. The 2012 stipulation telemetry study is the first to focus on quantification of juvenile salmonid behavior rather than on estimating survival rates. Results reported for this study are expected to strongly influence planned Delta water project operations for 2013.

Keywords: Delta, salmon, steelhead, entrainment, exports, OMR, hydrodynamics, OCAP, BiOp, behavior

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