North Delta Hydrodynamics from a Fish Perspective

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Juvenile salmon, and in fact all organisms that reside in the water column (i.e., pelagic), swim within a reference frame that moves with the water—the Lagrangian reference frame. Yet we typically characterize hydrodynamics from an Eulerian, fixed site perspective. In river deltas and estuaries, transport within the spatial domain can be quite complex, creating a divergence between the Eulerian and Lagrangian representations. The network of canals that comprise the Sacramento -- San Joaquin Delta offer an array of possible migration routes, and thus a great deal of travel time and distance variation within the system. These concepts are not limited to fish but apply equally well to anything that is moving with the water, such as abiotic constituents like suspended sediment, nutrients, and pollutants.

We will discuss results obtained from numerical hydrodynamic model simulations in RMASim, and particle tracking methods, where we have characterized transport in the north Delta from a pelagic fish (Lagrangian) perspective, focusing on the out-migration of juvenile salmon from the Sacramento River watershed. Comparisons of the metrics developed from the particle tracking study will allow us to directly assess the impacts of changes in the Lagrangian environment. Additionally, this study provides the hydrodynamic baseline prior to implementation of any significant changes proposed by Bay Delta Conservation Plan (BDCP). Accordingly, the metrics developed as a result of this study could be used to quantify the effect of changes from BDCP actions on the hydrodynamics that out-migrants experience as they traverse the north Delta.

Keywords: particle tracking, hydrodynamics, modeling, outmigration, survival
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Estimating Habitat Based Movement and Mortality of Winter-Run Chinook in the Central Valley

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Management of the Sacramento River and San Francisco Estuary requires models that can reflect population responses to alternative actions, such as timing of water releases, exports, and habitat restoration. We developed a population life cycle model that is sensitive to management variables in both the aquatic and marine stages of the life cycle. Freshwater hydrologic variables, such as Sacramento River flow and exports, and habitat characteristics such as channel morphology and tidal marsh inundation affect the survival and movement rates of juveniles rearing in river, floodplain (Yolo bypass), delta, and bay habitats. Similarly, marine variables such as ocean productivity and harvest affect the survival of ocean life history stages. The general model structure runs on a monthly time step and provides a rich set of rearing options as a function of hydrologic decisions that affect flow and habitat availability, while also accounting for the effect of ocean variability. To apply the model to winter-run Chinook we estimated the coefficients in a Bayesian statistical framework. The model predictions of abundance were compared to observed abundances (adult escapement and juvenile abundance at Red Bluff Diversion Dam, Knights Landing, and Chipps Island). Furthermore, CWT study results (Newman 2003) were used as informative priors on survival rates of juveniles in the river, floodplain, and delta habitats. Modeling results from the first version indicated that winter-run habitat use is primarily in the river and to a lesser degree delta and floodplain habitats with some variability in timing among years. Future work on the second version will incorporate additional survival information (e.g., derived Particle Tracking Model outputs) and temperature relationships to reflect proposed actions and reasonable alternatives in the BDCP and OCAP decision-making processes.

Keywords: Life Cycle Model, Bayesian Estimation, Winter-Run Chinook, Movement
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How Do Habitat Restoration, Flow, and Temperature Affect Salmon and Steelhead Populations? Conclusions from a Based Model

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Predicting the benefits to salmon and steelhead of channel restoration or changes in flow and temperature regime is a critical problem for project planning and evaluation. This problem is practically impossible to address using only field studies or simple population models, so our approach was to develop inSALMO, an individual-based simulation model. InSALMO represents stream habitat as a series of reaches, each made up of cells varying in depth, velocity, and several cover types. Salmon are represented from the arrival of adults at spawning streams through spawning, egg incubation, juvenile rearing, and outmigration. We applied inSALMO to 17 reaches of Clear Creek below Whiskeytown Dam, representing 17% of the actual stream length. Results for fall Chinook salmon include that an existing restoration project did not increase total numbers of outmigrating juveniles but did increase production of larger juveniles that appear more likely to survive to adulthood. A potential future restoration project was predicted to further support large juveniles, in part because its downstream location makes it useful to most juveniles as they migrate out. Concerning how management affects the production of anadromous steelhead vs. resident trout, inSALMO predicted that steelhead smolt production was highest under conditions of relatively high survival and high growth, conditions that also produce large numbers of resident trout. We conclude that models like inSALMO are valuable for organizing information and field studies in a way that clearly leads to well-documented and reproducible decision support. InSALMO led to clear results about the relative (and sometimes conflicting) effects of alternative management actions such as spawning gravel injection, re-shaping channels, providing cover, reducing temperatures, and altering flow regimes. The model is useful both for planning new actions and evaluating finished actions.

Keywords: habitat restoration, salmon, steelhead, population effects, modeling
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Where and Why are the Fish? Investigating the Relationship between Hydrodynamic Complexity and Delta Smelt Abundance in Suisun Bay

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We determined the extent to which delta smelt catch in the Fall Midwater Trawl (FMWT) survey can be correlated to specific hydrodynamic conditions. The three-dimensional UnTRIM Bay-Delta model was used to determine habitat complexity metrics, such as the current speed gradient, around each of 49 stations in Suisun Bay. These physical metrics were related to delta smelt catch at the time and location of each trawl. A station index, normalized with regard to historic delta smelt catch, was developed using the entire FMWT dataset to determine the relative consistency of smelt catch at each of the FMWT stations in Suisun Bay. Hydrodynamic, topographic, and salinity variables from the model were used to determine the general characteristics of each of the FMWT stations. The stations with consistent catch were located in regions with relatively slower current speeds and reduced seabed variability, relative to the lower quality stations. However, at the medium quality stations, on a tow-by-tow basis delta smelt catch was more likely when the hydrodynamic conditions at the time of the trawl were more energetic, relative to the conditions over the preceding 25 hours. In this way the FMWT data combined with the model results suggest that delta smelt broadly prefer relatively less energetic and less variable areas of Suisun Bay, but were more likely to be caught when the tidal currents were flowing. Numerical models can be combined with long-term data sets to improve the understanding of the observed biological data, but results differ on different spatial and temporal scales.

Keywords: Delta Smelt, Habitat Complexity, Numerical Modeling
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DSM2 PTM, an Open Source Platform for Delta Fish Migration Behavior Research and Model Development

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Can hydrodynamics, water project operations, and water quality (e.g., turbidity) explain and predict route choice, travel time and survival of juvenile Chinook Salmon migrating through the Sacramento – San Joaquin Delta? To answer this question, numerous field studies have been conducted and large amount of acoustic telemetry fish tag data have been collected, on the basis of which various agencies and organizations have begun to make efforts in fish behavior modeling. Facing the need for a collaborative effort among agencies and organizations to tackle the question and to conduct efficient and effective fish migration behavior research and model development, DWR is teaming up with USGS to build an open source platform so that these efforts can be shared and future work can be better coordinated.

The effort for building such a platform is started from DSM2 PTM, a model that has been used to simulate the transport and fate of individual neutrally buoyant particles through the delta. Because the original model only simulates neutrally buoyant particles, the model has limitations when used to simulate fish migration through the delta. To overcome these limitations, DWR is working with USGS to develop swimming, route selection and survival modules, which are statistically inferred/developed from wide ranges of multi-year, multi-station acoustic telemetry fish tag data. DWR has also started the structural changes of the original DSM2 PTM to make it more suitable for an open source platform. The modified model will allow behavior modules developed outside of DWR to be easily integrated into the model without cracking open the existing code. In this presentation, we highlight how telemetry data is being used to improve DSM2 PTM as a model for predicting fish behavior and survival.

Keywords: Modeling, Fish Behavior, Salmon, PTM, Open Source, Telemetry Data, Ecohydraulics
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