Preliminary Analysis of Suspended-Sediment Concentration and Turbidity in the Fall Low Salinity Zone of the San Francisco Estuary

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During fall, delta smelt occupy the low salinity zone (salinity 1-6) of the San Francisco Estuary which is located in eastern Suisun Bay or landward at the confluence of the Sacramento and San Joaquin Rivers. Delta smelt also occupy the freshwater Cache Slough complex. Delta smelt favor more turbid water and turbidity is primarily a function of suspended-sediment concentration (SSC) in the Estuary. The USGS California Water Science Center has continuously monitored turbidity and SSC in the Cache Slough complex since 2008 and SSC in eastern Suisun Bay at Mallard Island since 1994. In fall 2011, we deployed instruments to measure hydrodynamics, turbidity, and SSC at two Suisun Bay sites, Grizzly Bay and Suisun Cutoff, where we made similar measurements in fall 1995. Preliminary findings are that 1) the position of the salinity 2 isohaline (X2) does not affect fall SSC at Mallard Island, 2) mean fall SSC at Mallard Island decreased by about one-half from 1994 to 2011 and in Grizzly Bay and Suisun Cutoff it was 45% and 9% less in 2011 than in 1995, 3) Suisun Bay was usually more turbid than the confluence in fall 1994-2011, 4) Suisun Bay was usually more turbid than the Cache Slough complex in fall 2011, and 5) turbidity at Mallard Island was greater in fall 2011 than 2010 but in the Cache Slough complex the opposite was observed with turbidity being greater in fall 2010 than 2011. Factors affecting the fall turbidity may include wind, salinity, clearing of estuarine waters, tides, and prior wet season flow and sediment supply.

Keywords: delta smelt, habitat, turbidity, suspended sediment, low salinity zone,

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Comparison of Seston Composition and Sources in the Delta during Two High-Flow Falls, 2006 and 2011

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We have been using a multi-tracer, multi-isotope approach to assess biogeochemical processes and sources of organic matter, nutrients, and water at several score main-channel and tributary sites in the Delta 2005-2012. Since this large dataset overlaps the three main fall habitats of delta smelt, we are evaluating whether the additional biogeochemical insights provided by a multi-fingerprinting approach might explain more of the variance in smelt presence-absence than the X2-habitat curve approach. For this comparison, we analyzed bulk seston (POM) for $\delta^{13}C$, $\delta^{15}N$, $\delta^{34}S$, and C:N. Samples were also analyzed for ammonium, nitrate, DOC, and water isotopes to further evaluate habitat conditions; these latter analyses for 2011 are in progress. Splits of all samples were analyzed for nutrients, chlorophyll, and other constituents.

Sacramento River flow was relatively high in the falls of both 2006 and 2011 as a result of the preceding wet springs, with fall 2011 having slightly higher flow. These two high-flow falls had very different biological, chemical, and isotopic responses; in specific, 2011 had lower nutrient concentrations, higher NO3/NH4, and much more frequent and larger phytoplankton blooms. POM composition is sensitive to changes in salinity, nutrient sources, extent and type of C-N-S cycling, geographic sources of the POM, and quality of the organic matter. The two years showed huge differences in POM sources and quality, and biogeochemical processing of C-N-S. For example, POM in 2011 had a much lower percent of terrestrial POM and showed a steeper downstream gradient of C cycling, less uptake of marine SO4, and N that was more affected by nitrification. The POM in 2011 was higher-quality than in 2006, and was derived in part from the Cache/Yolo region. Therefore, small differences in flow between fall 2006 and 2011 resulted in huge changes in the sources and quality of organic matter.

Keywords: isotopes, POM, seston, habitat-quality, nutrients, organic-matter-quality

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Modeling Fall LSZ Habitat Using the UnTRIM Bay-Delta Model

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The UnTRIM Bay-Delta model is a three-dimensional hydrodynamic and salinity model of San Francisco Bay and the Sacramento-San Joaquin Delta, which extends from the Pacific Ocean through the entire Sacramento-San Joaquin Delta. The UnTRIM Bay-Delta model has been used in studies of San Francisco Bay and the Sacramento-San Joaquin Delta for California DWR, USBR, USGS, and the US Army Corps of Engineers. The model calibration and validation conducted as part of these studies demonstrate that the UnTRIM Bay-Delta model is accurately predicting flow, stage, and salinity in San Francisco Bay and the Sacramento-San Joaquin Delta under a wide range of hydrologic conditions.

The UnTRIM Bay-Delta model was applied to characterize the areal and volumetric extent of estuarine habitat in the Low Salinity Zone (LSZ) over a range of historic conditions between 1994 and 2011. The area, volume, and average depth of the LSZ was related to the position of the 2 psu isohaline (X2) on each simulation day to establish relationships between the position of X2 and the location and extent of the LSZ. The percentage of time per day the LSZ resides in a given location of the Bay-Delta was also evaluated. This approach unifies the 1-D approach employed by the State Water Resources Control Board since 1995 to manage the location of X2 with a 3-D characterization of LSZ habitat, and demonstrates how the physical characteristics of the LSZ are influenced by the distribution of shallow habitats along the axis of the estuary.

Keywords: Low Salinity Zone, UnTRIM, X2, hydrodynamic modeling

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FLaSH: Health Status of Delta Smelt*, Hypomesus transpacificus*

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The Fall Low Salinity Habitat (FLaSH) study examined the potential effects of habitat quality on the health, nutrition, and reproductive status of delta smelt, *Hypomesus transpacificus*, in the San Francisco Estuary (SFE). In collaboration with California Department of Fish and Game (CDFG) long-term fish monitoring surveys, the Summer Tow Net, Fall Midwater Trawl and the Spring Kodiak Trawl, the FLaSH has been investigating delta smelt health occupying the SFE. This study examined the potential effects of habitat quality on the growth, nutritional, and reproductive status of delta smelt. We compared the effect of habitat quality on morphometric indices, otolith analyses and nutritional status of the 2011-2012 delta smelt year class and the indices relationship with reproductive status. Preliminary results indicate that the 2011 was a 'good' habitat year when examining growth rates and condition indices. RNA/DNA ratios increased from fall to winter while triglyceride concentrations were variable. Indications for reproductive performance will be discussed in regards to growth, condition, and nutritional status. Preliminary results show that gonadosomatic and hepatosomatic indices increased from fall 2011 to spring 2012.
Relevance: Information presented in this study examines the concepts outlined by the FLaSH to determine the effect of habitat quality on the health of delta smelt and potentially other species of management concern in the upper San Francisco Estuary.

Keywords: Delta smelt, nutrition, otolith, habitat

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Water and Particle Properties as Measures of Habitat Quality

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Aquatic habitat quality in the Delta is determined by interactions between nutrients, suspended sediment, water, and light. Together, these habitat attributes affect the food supply by controlling algal production and species distribution; affect the food web structure by influencing energy transfer and grazer community composition; and affect fish distributions by altering foraging behavior and predation. The variation in these attributes across the Delta is commonly observed as variations in, for example, chlorophyll, turbidity, and secchi depth, which have been related to algal, zooplankton, and fish abundance. Our project examines these relationships in greater detail using a suite of new optical techniques that directly measure light transmission properties as well as algal and particle size and abundance. One purpose of the study is to identify the simplest optical water quality measurements that may best be used in a continuous real-time in-situ monitoring network of habitat quality.

We conducted profile measurements and collected samples at 25 stations from Suisun Bay to Cache Slough in conjunction with the2011 Fall Mid-Water Trawl and Spring Kodiak Trawl programs, sampling at the same time and location as the fish collection activities. We found a large tidal dependency and large spatial variability for the parameters measured. For example, the chlorophyll concentration and median size of large suspended particles (including algae and flocs) increased upstream, in contrast to turbidity and salinity which showed the opposite trend. Distributions and interactions between measured parameters will be presented in combination with results of more traditional water quality measurements and from analysis of discrete water samples. The optical measurements will be used as part of an effort to establish relationships between readily-measured habitat quality indices and direct measurements of fish and community structure.

Keywords: Habitat Quality, Particles, Algae, Sediment, Turbidity, Phytoplankton

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Response of the Delta Smelt Population to the Fall Outflow Conditions in 2011: Insights from Qualitative Modeling

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The role the low salinity habitat (LSH) to the ecology of the Sacramento-San Joaquin Delta (Delta) and the biological response of the LSH to the high outflows in 2011 is an area of active research and management interest, mainly in terms of the likely benefits to the delta smelt (*Hypomesus transpacificus*) population. How the hypothesized flow-induced responses in the LSH are integrated at community level remains a central ecological question. Signed digraph qualitative modeling was used to evaluate potential ecological interactions and underlying feedback mechanisms operating in the LSH delta smelt subsystem. The objectives of this research were: 1) to develop alternative models for the delta smelt subsystem during the fall 2011 and 2) compare the observed patterns in the fall 2011 with the hypothesized and predicted changes in the delta smelt subsystem. The modeled subsystem was composed of 5 community variables, including species (sub-adult delta smelt and the introduced overbite clam *Potamocorbula amurensis*), trophic groups (phytoplankton, zooplankton and delta smelt predators) and fall outflow. Models assumed negative effect of outflow on overbite clam and either positive or no direct effect of outflow on phytoplankton, zooplankton and delta smelt. The predictions of FLaSH hypotheses and qualitative models were compared to the 2011 field results for the Fall Low Salinity Habitat Program (FLaSH). Model predictions showed: 1) A consistently positive influence of outflow on the delta smelt population and zooplankton under all scenarios, 2) a generally positive influence of flow on phytoplankton and 3) a generally negative influence of outflow on the overbite clam. The consistency of model predictions and observed field patterns points out the coherence of FLaSH hypotheses and inherent ecological interactions. Model predictions support the adaptive management of fall outflows to enhance the quality of the LSH for sub-adult delta smelt.

Keywords: Primary zone economy, employment, industry clusters, agriculture, recreation, infrastructure

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FLaSH: Enzymatic Biomarkers and Pathogens as Stress Indicators on the Health of Delta Smelt, *Hypomesus transpacificus*

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The Fall Low Salinity Habitat (FLaSH) study examined the potential effects of habitat quality on the health, nutrition, and reproductive status of delta smelt, *Hypomesus transpacificus*, in the San Francisco Estuary (SFE). In collaboration with California Department of Fish and Game (CDFG) long-term fish monitoring surveys, the Summer Tow Net, Fall Midwater Trawl and the Spring Kodiak Trawl, the FLaSH has been investigating delta smelt health occupying the SFE. The main goal is to investigate the effects of habitat quality on the general health status of delta smelt. Fish health in this context is broadly defined and measured in terms of growth, reproduction, and survival from the adverse effects of multiple stressors (biological, environmental, and chemical) present in the estuary.

Delta smelt and other species were collected in collaboration with various Interagency Ecological Program (IEP) fish monitoring surveys including the Summer Tow Net, Fall Midwater Trawl, and the Spring Kodiak Trawl. Fish health measurements are in progress and results will be analyzed within and across data sets. The presence of xenobiotics (OP pesticides, carbamates, metal contamination, PAH, and PCBs) was determined for the 2011-2012 delta smelt year class by using several biochemical biomarkers such as Acetylcholinesterase (AChE), Sodium Potassium Adenosine Triphosphatase (Na^+/K^+ ATPase), and Ethoxyresorufin O-Deethylase (EROD). The potential relationships among the biomarkers, presence of pathogens/disease, and reproductive status are being examined. Preliminary results showed that there were significant depression in AChE and Na^+/K^+ ATPase for some of the fishes collected at certain regions. Pathogen analysis showed a significant interaction of water temperature, location, and surface conductivity to cause *Mycobacterium* DNA presence in delta smelt.

Relevance: Contaminants and pathogens are important stressors affecting fish health in the SFE. These findings will provide management protocols for delta smelt and other species of concern in the upper San Francisco Estuary.

Keywords: Delta smelt, contaminants, enzymes, disease, habitat Quality

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Opposing Seasonal Biomass Cycles Influence the Grazing Effects of Corbicula and Potamocorbula.

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Potamocorbula amurensis and *Corbicula fluminea* have both been shown to be capable of reducing phytoplankton biomass in San Francisco Bay and the Delta. Therefore both bivalves have the potential for further stressing the base of an already strained foodweb and for derailing restoration plans that include increased phytoplankton production. Our goals are to understand the population dynamics of both bivalves in the system and to uncover environmental factors that might limit their success. Here, we use the California Department of Water Resources spatially intensive benthic sampling program (GRTS) to examine the grazing rate distribution of both bivalves in spring and fall of 2009 through 2011.

Population distributions of *Potamocorbula*, an estuarine clam, and *Corbicula*, a freshwater clam, overlapped in the ecologically sensitive X2 region except in the wet year, 2011, when they overlapped upstream of the X2 region, particularly in spring. Maximum grazing rate occurred in October of all years in Suisun and Grizzly Bays, due to *Potamocorbula* populations that peak in biomass in fall and drop to a minimum in spring. The confluence region and most of the Delta had higher grazing rates in May than in October in all years. The spring dominance was strongest in regions most influenced by the Sacramento River. A consistent exception to this pattern was observed in Mildred Island and the historic Sacramento River where *Corbicula* had higher grazing rates in fall than in spring.

Bivalve grazing rates were sufficiently high in fall of 2009 and 2010 to potentially limit phytoplankton biomass accumulation in the low salinity zone. Grazing rates were low enough in spring of all years and in fall 2011 that bivalve grazing alone could not account for observed phytoplankton biomass levels. The increased freshwater flow in 2011 is likely the cause of the reduced bivalve grazing impact in 2011.

Keywords: bivalve, grazing, foodweb, *Corbicula potamocorbula*, biomass

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The Food Environment for Delta Smelt in Fall: A Synthesis of Recent Findings

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The low-salinity zone (LSZ) of the San Francisco Estuary provides habitat for juvenile delta smelt and several other fish species. Decades of monitoring coupled with several intensive studies of this region have yielded important insights that provide a context for the ongoing fall habitat studies. The aim of these studies is to determine how freshwater flow influences this habitat; however, because of the myriad influences of flow on the estuary, this effect is elusive. I summarize some of the key findings that have emerged from our studies of the LSZ, particularly in the last several years. The LSZ is not a production hot-spot as once believed; rather, in many years grazing by clams depresses abundance of phytoplankton, the copepod *Pseudodiaptomus forbesi*, and probably microzooplankton. Populations of these organisms must be subsidized by transport from other parts of the estuary. I show evidence of this transport from the deficit in production within the LSZ and from measurements of chlorophyll and zooplankton abundance made during transects across the LSZ. Elevated freshwater flow increases the transport of phytoplankton and zooplankton into the LSZ, but to some extent it also uncouples the plankton from benthic grazing. The result is higher copepod abundance in the LSZ when flow is high during spring and sometimes into fall, whereas abundance in the freshwater source region is nearly invariant with flow. As these results are developed further using coupled hydrodynamic-ecological models, they will prove useful for understanding and predicting how feeding conditions for delta smelt in their fall habitat may vary with flow.

Keywords: delta smelt; low-salinity zone; copepod; foodweb; hydrodynamics;

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The Rise in Fall of Northern Estuary Phytoplankton During the FLaSH Study

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Most efforts to understand the delta smelt ecosystem have focused on studies in spring. We have been measuring conditions in the low salinity zone (LSZ) and the Sacramento and San Joaquin Rivers during fall since 2010. Fall blooms are rare. In 2010 chlorophyll in all regions was low (< 4 μg/L) compared to spring. In Fall 2011 there was excess freshwater and the fall low salinity habitat (FLaSH) program was put into place to maximize fall ecosystem studies when there was a more seaward location of X2 (or LSZ). As part of this we sampled water from Suisun Bay/confluence from September to early November 2011 to evaluate the response of nutrients and chlorophyll. A transect of nine stations within the Sacramento River and Suisun Bay between Rio Vista and Avon Pier was sampled eight times for nutrients, dissolved inorganic carbon, chlorophyll, phytoplankton community composition and rates of primary production and nutrient uptake. On 26 October and 2 November a phytoplankton bloom (chlorophyll ~30 μg/L) was observed at Sacramento River stations. The bloom was dominated by the diatom *Aulacoseira* that had long chains, typically 15-20 cells per chain. At these stations, nutrients were lower with ammonium concentrations < 2 μM and nitrate ~15 μM, and the percent nitrate uptake contributing to primary production was high. The role of light availability was unclear as Secchi depths were similar between bloom and non-bloom stations. The 2011 bloom may have been a consequence of the increased freshwater flow. The interaction of flow and nutrients, in particular anthropogenically derived ammonium, will be developed. The results could be used in adaptive management of fall outflow for delta smelt protection

Keywords: diatom, nitrate, ammonium, phytoplankton, bloom, chlorophyll, low salinity zone

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