Physical Processes Influencing Spawning Migrations of Delta Smelt
YEAR 2 – Water Year 2012
Figures

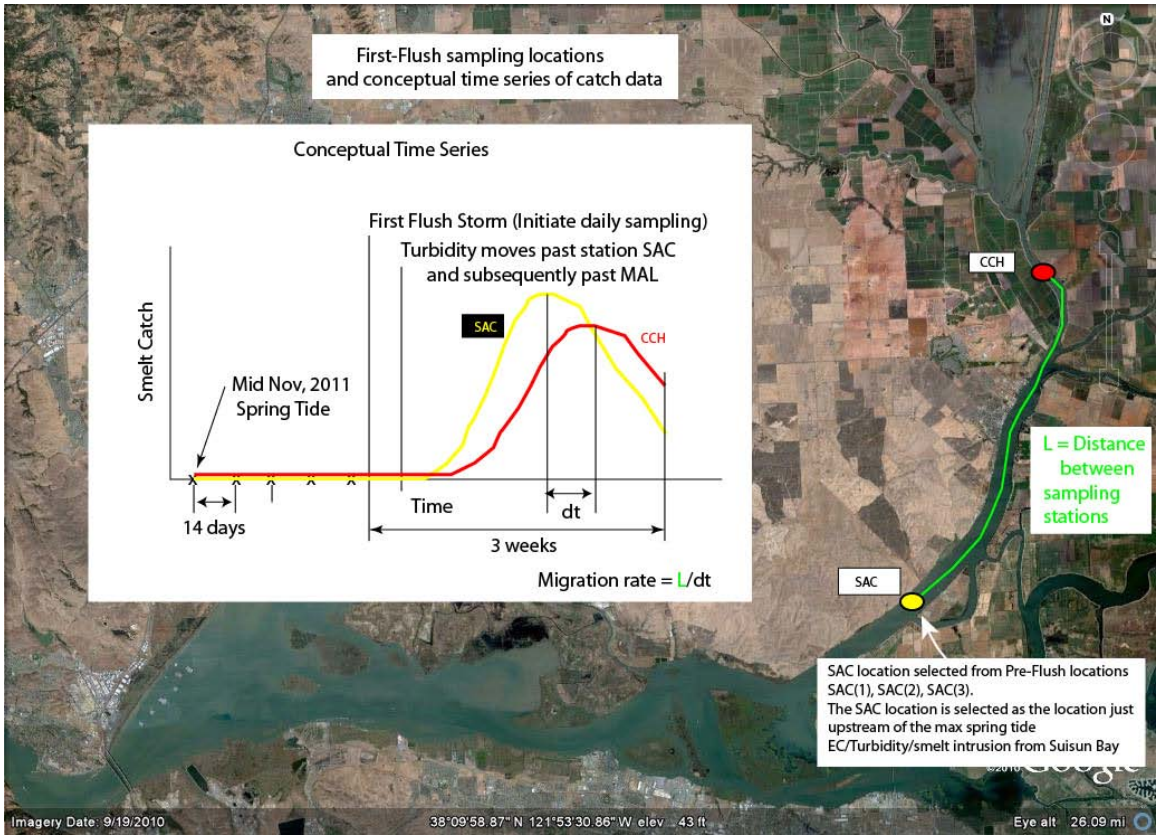


Figure 1 – Study region showing approximate sampling locations with conceptual temporal pattern of delta smelt catch during the proposed study period (inset). Actual locations of stations SAC (yellow) and CCH (red) will be determined during the Pre-Flush sampling. Conceptually, we anticipate fish catch will be very low during the Pre-Flush period at both stations; whereas, after the First-Flush, we anticipate an increase in catch first at station SAC and then sometime later at station CCH as smelt migrate from Suisun Bay into the north Delta. We may be able to compute a migration rate, assuming there is a delay between stations represented by distinct peaks, as shown here.

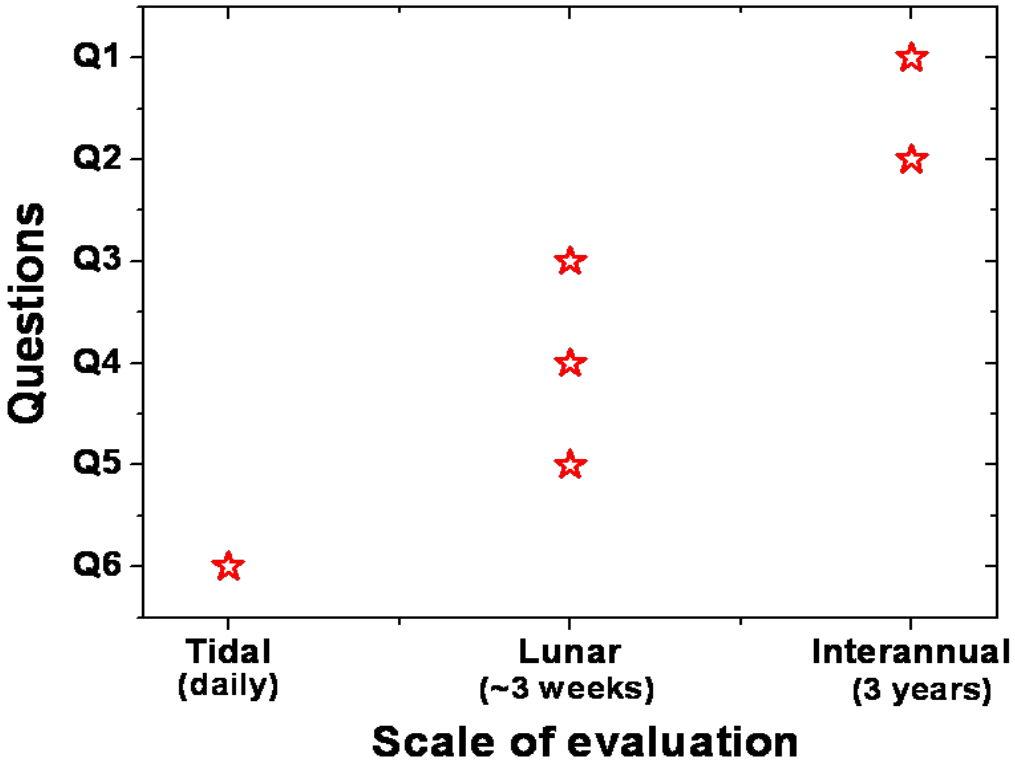


Figure 2 – Process time scales of the proposed study questions indicating the minimum level of field sampling required for assessment.

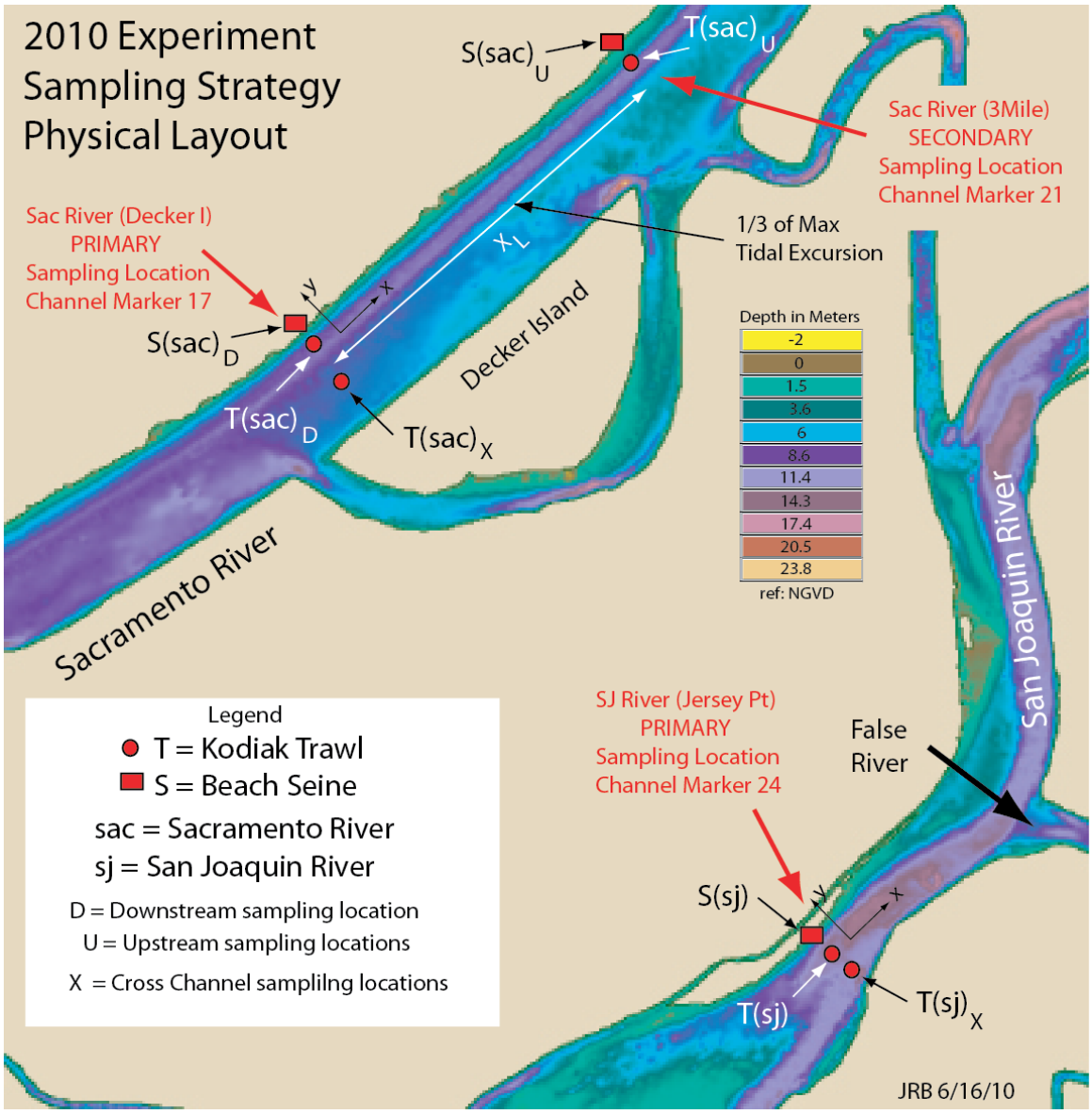


Figure 3 – WY2011 sampling locations and western Delta bathymetry. Sampling alternated daily between the Sacramento River and the San Joaquin River. Five Kodiak trawling locations were sampled overall: three in the Sacramento River near Decker Island – two sites $T(sac)_D$ and $T(sac)_X$ were adjacent to Channel Marker "17" and $T(sac)_U$ was located adjacent to Channel Marker "21"; two locations were sampled in the San Joaquin River near Jersey Point adjacent to Channel Marker 24 (T(sj) and $T(sj)_X$). Beach seine hauls were made near the shoreline in conjunction with trawls at locations $S(sac)_D$ and $S(sac)_U$ in the Sacramento River, and a purse seine was used in the San Joaquin River at location S(sj). Velocity data collected by the USGS at Jersey Point can be downloaded in real time from CDEC (http://cdec.water.ca.gov/cgi-progs/queryF?s=sjj). DWR collected water quality data at this site can be obtained from CDEC at (http://cdec.water.ca.gov/cgi-progs/queryF?s=jer). Velocity and water quality data collected in the Sacramento River near Decker Island (Channel Marker "17") can be found at (http://cdec.water.ca.gov/cgi-progs/queryF?s=sdi).

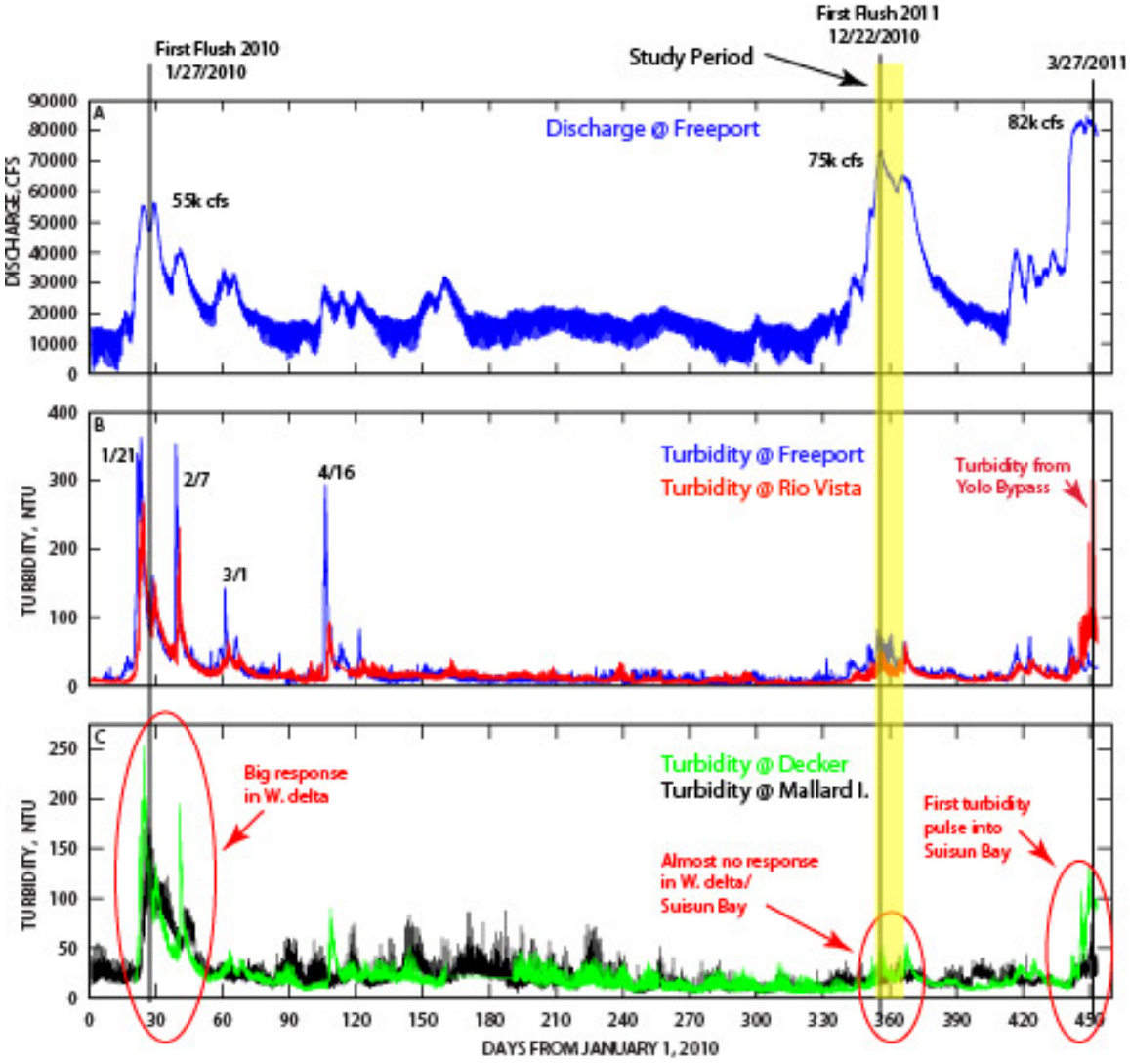


Figure 4 – Time series plots of (A) Sacramento River discharge at Freeport, (B) turbidity measured at Freeport (blue) and Rio Vista (red), and (C) turbidity measured at Decker Island (green) and at Mallard Island (black). Note that turbidities were very low during late December 2010 compared to the previous winter and then in late March 2011 due to runoff from the Yolo bypass that was transported into Suisun Bay and past Mallard Island.

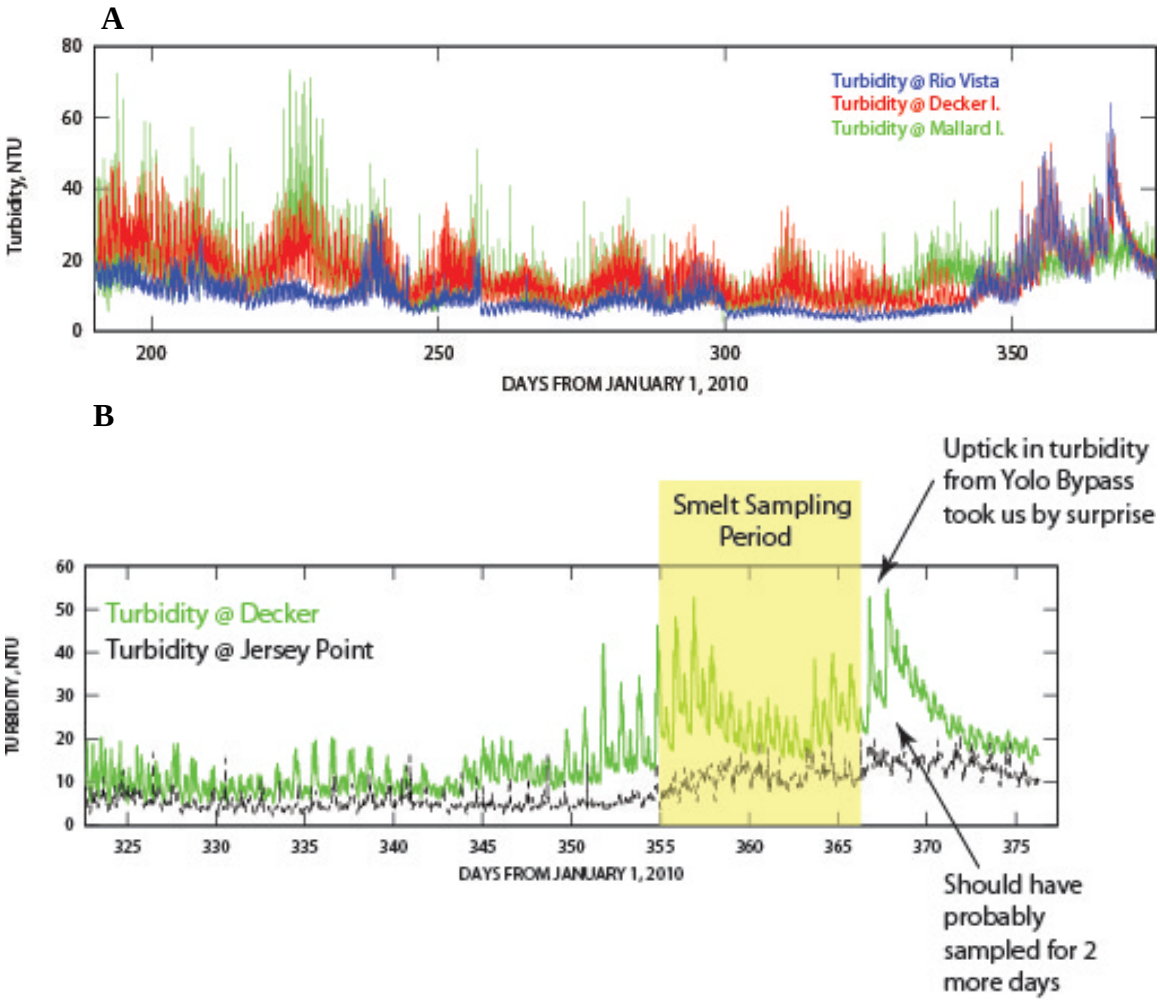


Figure 5– Time series showing turbidity measured at (A) Rio Vista (blue), Decker Island (red) and Mallard Island (blue), and (B) at Decker Island (green) and at Jersey Point (black) in the San Joaquin River. Note that a large turbidity gradient (high variability) existed in the lower Sacramento River due to the intrusion of Suisun Bay water on flood tides which routinely exceeded 12 NTU. Turbidities at the Mallard (green) and Decker Island (red) stations are higher overall and more variable than at Rio Vista, suggesting that the eastern margin of delta smelt habitat regularly extends up into the lower Sacramento River during the Pre-Flush period. Also note that an region of slightly elevated turbidity was moving back and forth through our sampling location at Decker Island while they remained very low at Jersey Point. The transparent yellow box indicates the sampling period of the WY2011 study.

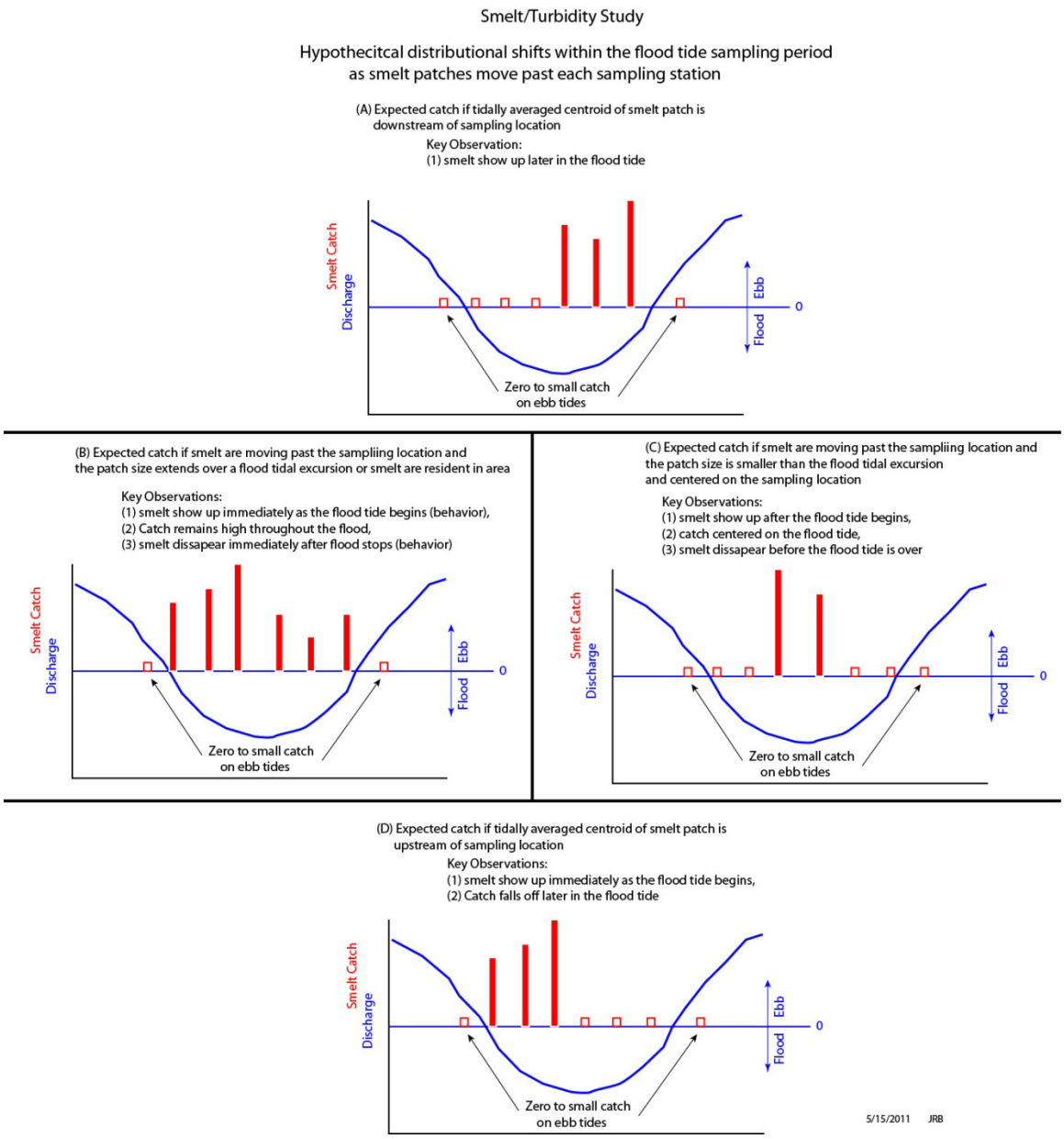


Figure 6 – Hypothetical catch sequence at stations SAC and CCH. From our conceptual model we expect to get very low catches at stations SAC and CCH during the Pre-Flush period (not shown). Then as smelt respond to the first flush (changes in turbidity, salinity, whatever) and we begin to sample daily we expect to see the following sequence of catch histories (which assumes that we have very low catches during ebb tides due to behavioral responses): (A) smelt begin to move into the study area and we see them on the end of the flood tide only, which means the centroid of the patch is downstream of the station, (B) a patch size larger than the flood tidal excursion is moving past the study area (or, is resident, which is what we observed in WY2011), (C) the patch size is smaller than the flood tide tidal excursion, (D) the centroid of the patch has moved past our sampling location. If we can track individual patches, and fish were moving down estuary (say because the river flows were REALLY high or the resident smelt in the Liberty region were moving into Suisun Bay) then the reverse pattern would occur D-A. With daily

sampling we may be able to track individual patches as they move past our sampling locations as well as document the distributional shift of the population as a whole over the 3-week sampling period.

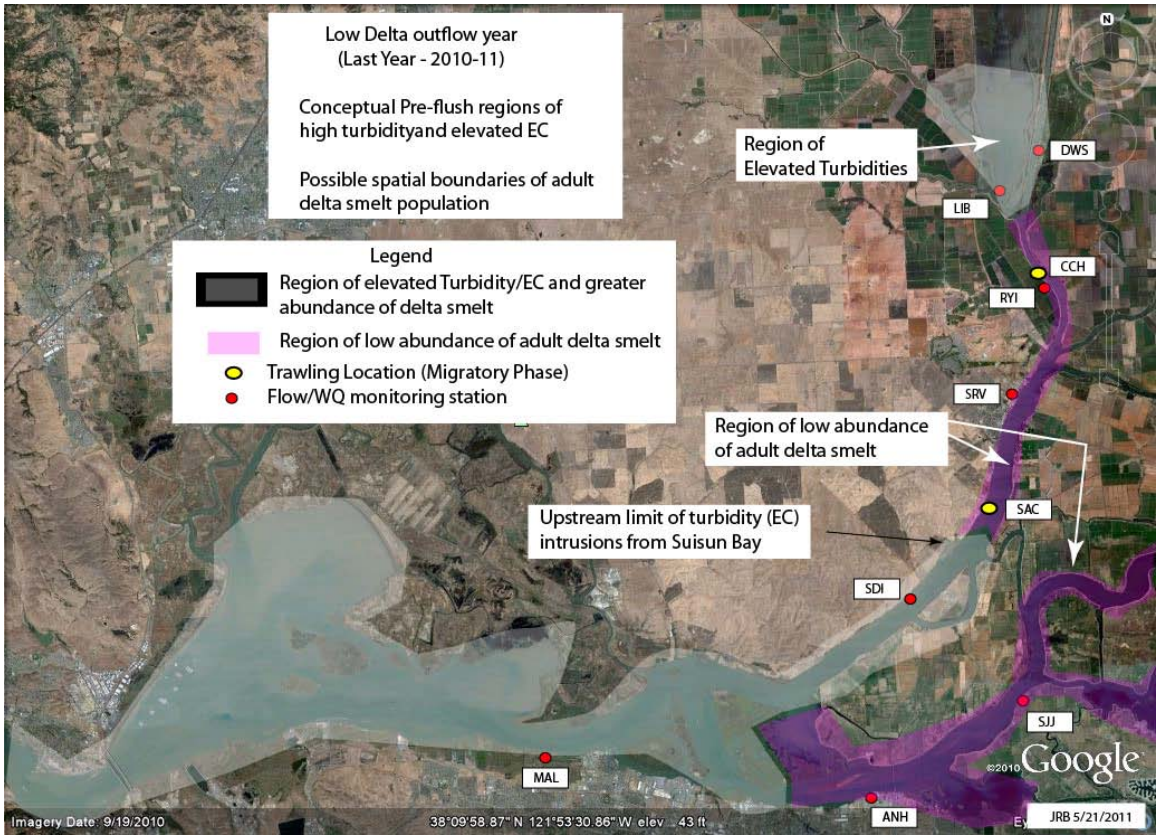


Figure 8 – Conceptual drawing, for the low delta inflow (e.g. last year) of (1) the region of elevated turbidity/EC and smelt abundance (grey region), (2) region of low delta smelt abundance (pink region), (3) USGS flow and water quality stations (red dots),(4) trawling locations (yellow dots) under low delta outflow conditions (e.g. SAC site well upstream)

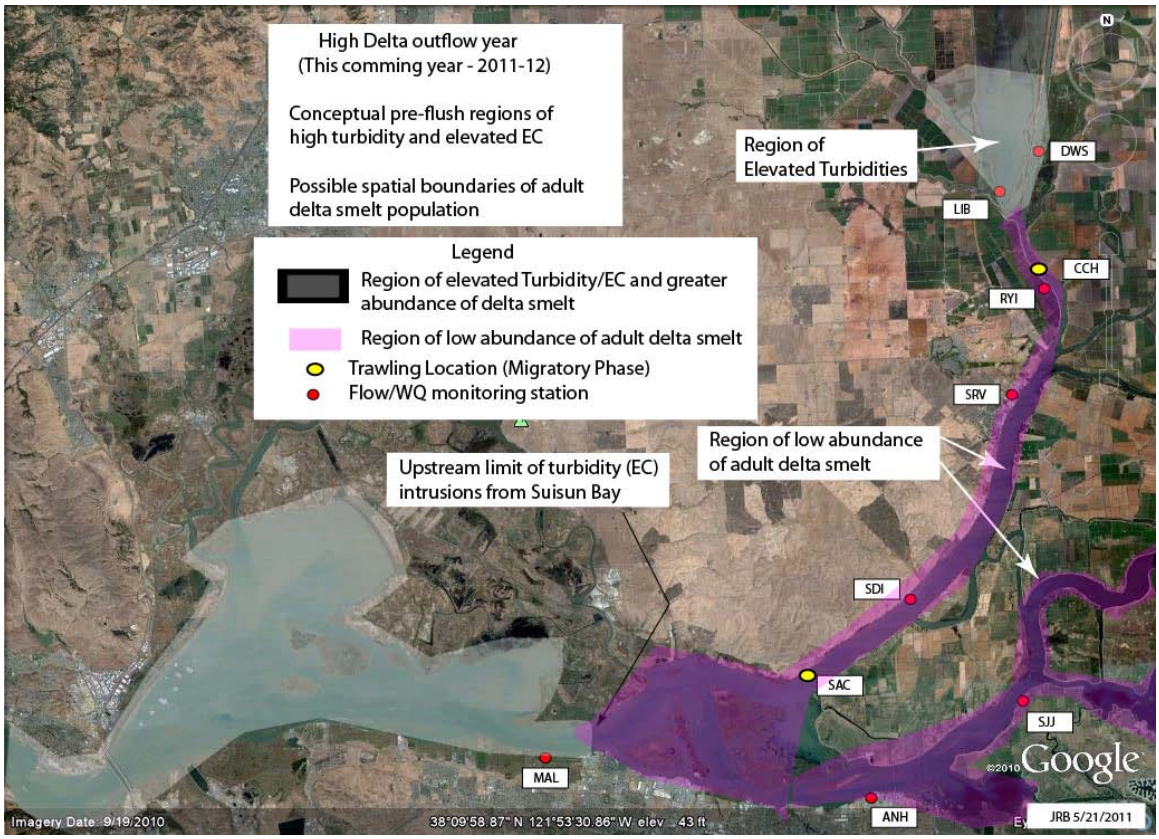


Figure 9 - Conceptual drawing, for the high delta inflow (e.g. this upcoming year) of (1) the region of elevated turbidity/EC and smelt abundance (grey region), (2) region of low delta smelt abundance (pink region), (3) USGS flow and water quality stations (red dots),(4) trawling locations (yellow dots) under high delta outflow conditions (e.g. SAC site well downstream).

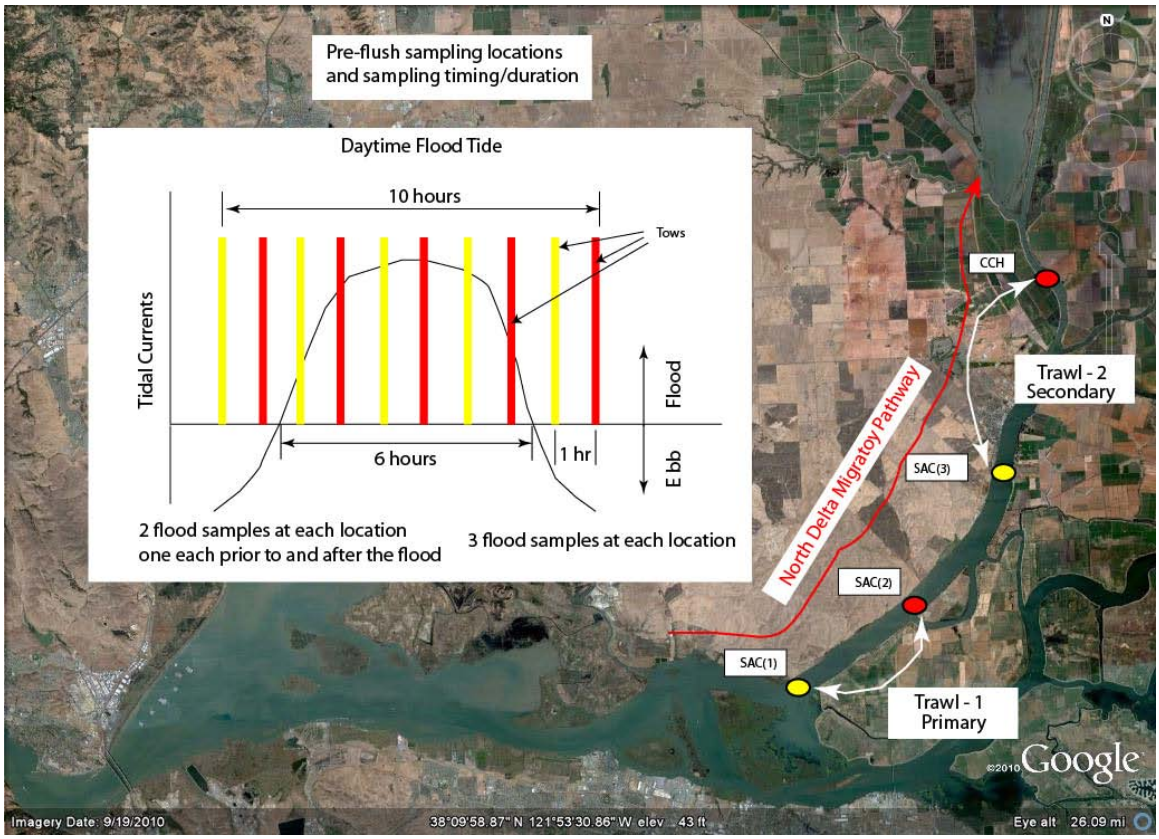


Figure 10 – Map of the Pre-Flush sampling locations and a graphic showing the sampling time and duration. Essentially two trawls sampling hourly will be used: one trawl will alternate between stations SAC(1) and SAC(2) and the second trawl will alternate between stations SAC(3) and CCH. We propose to sample hourly during daytime flood tides continuously for ten hours so that we get an ebb tide sample before and after each flood tide at each location. This sampling strategy will give us three flood tide samples, once every two hours, at each location.

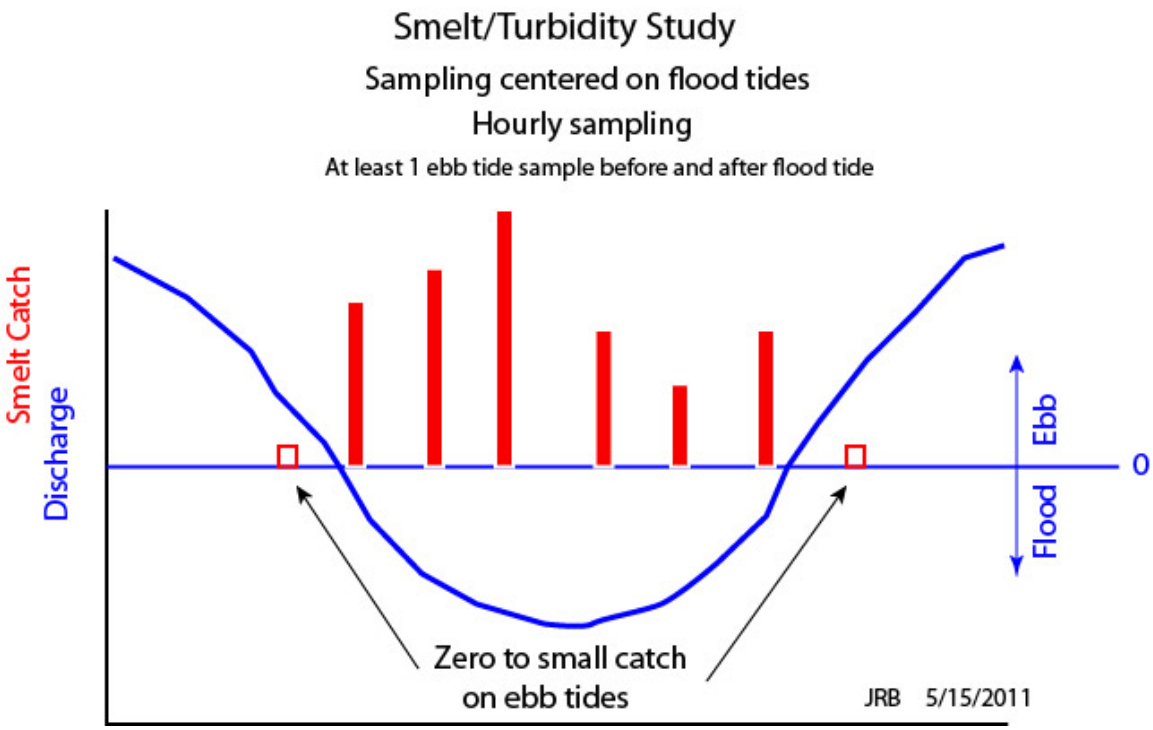


Figure 11 – First-Flush sampling Scheme. Schematic of the "typical" smelt catch based on hourly sampling centered on the daytime flood tide with at least one ebb sample before and after the flood tide, as is shown.

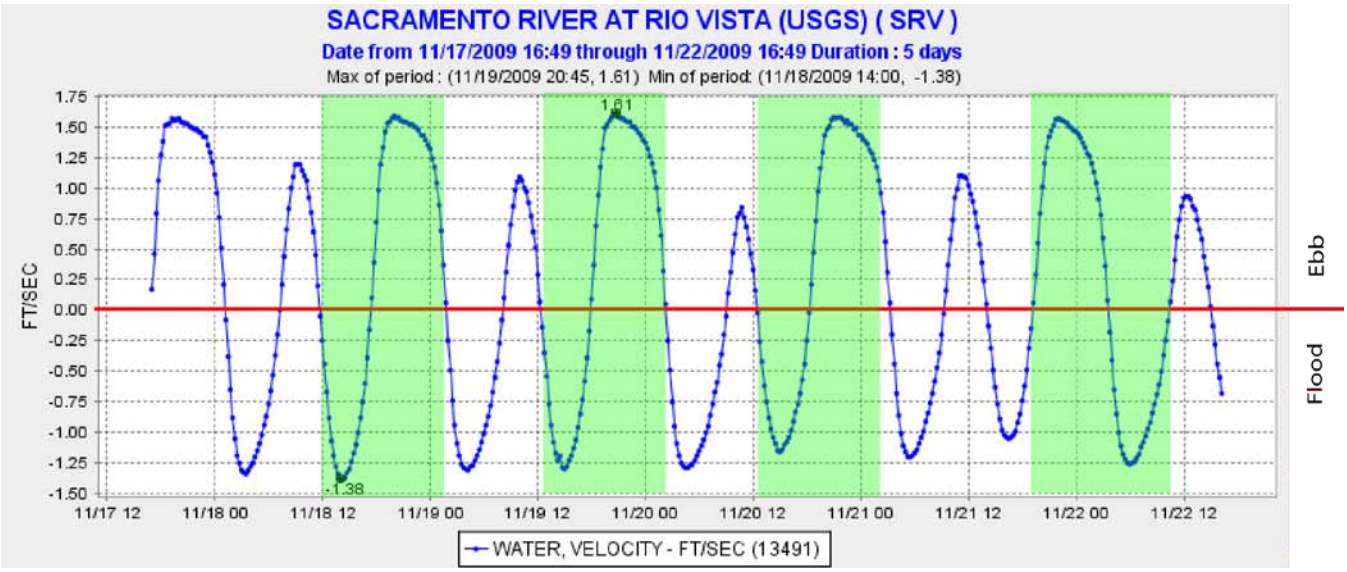


Figure 12 – Velocity data measured in the Sacramento River at Rio Vista by the USGS obtained from CDEC in real-time. As an example, the green regions indicate periods when trawling would occur if this were the study period. Note: the tides shift by roughly an hour each day and the "big" ebbs generally occur at night during the fall-winter period. Also, at the beginning of this record, sampling begins at noon on 11/18 on slack before flood tide, whereas for the last sampling period, sampling begins on slack before

ebb tide (15:00 11/21) to capture the larger flood tide which occurs after the big ebb later in the period shown.

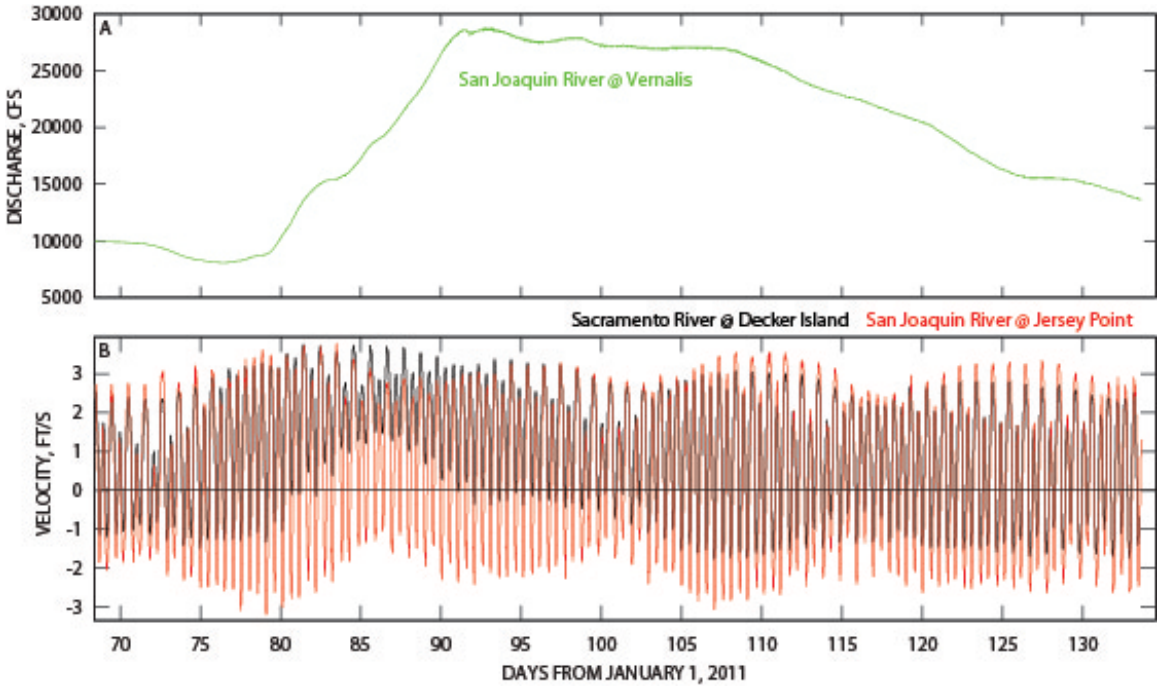
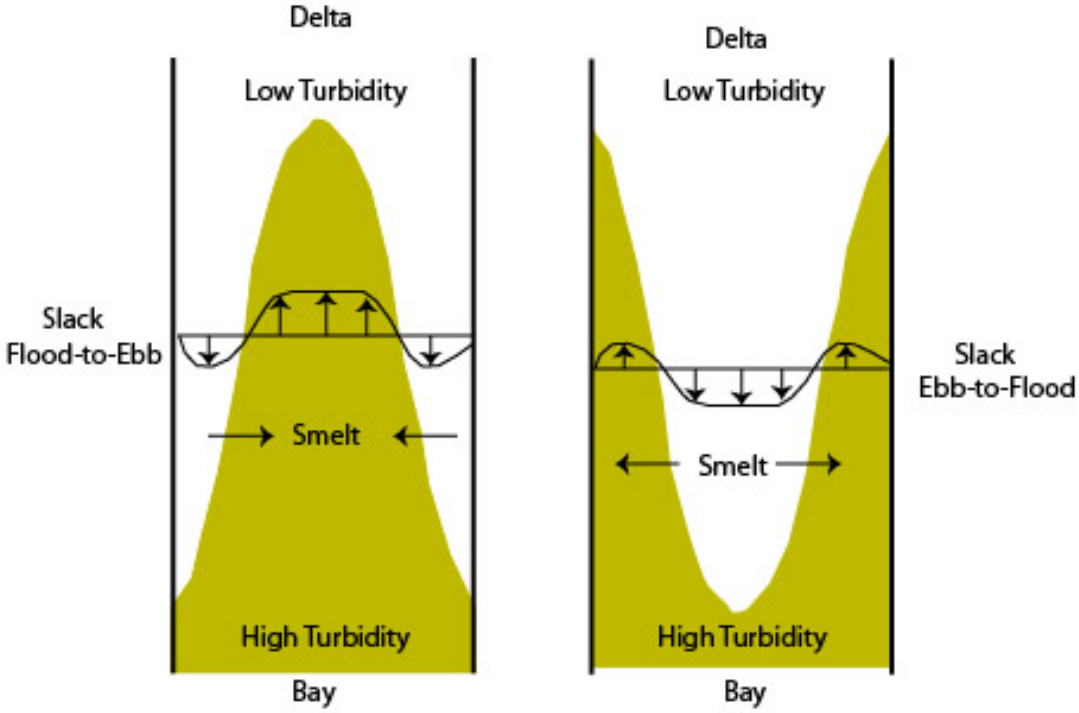


Figure 13 - Time Series plots of (A) Discharge in the San Joaquin @ Vernalis and (B) the ADCP index velocity measured in the Sacramento River @ Decker Island (black) and in the San Joaquin River @ Jersey Point (red). From this figure we see that despite persistent large input flows on the San Joaquin River (~27k cfs), the flood tide remains on the San Joaquin River at Jersey point despite the fact that the flood tide on the Sacramento River at Decker Island was non-existent for a period of ten days staring on Julian Day 85.

Lateral gradients from along-channel Gradients in a tidal channel

(A) Case where turbidity is higher in Bay than in Delta (Pre-Flush Conditions)



(B) Case where turbidity is higher in Delta than in Bay (First-Flush Conditions)

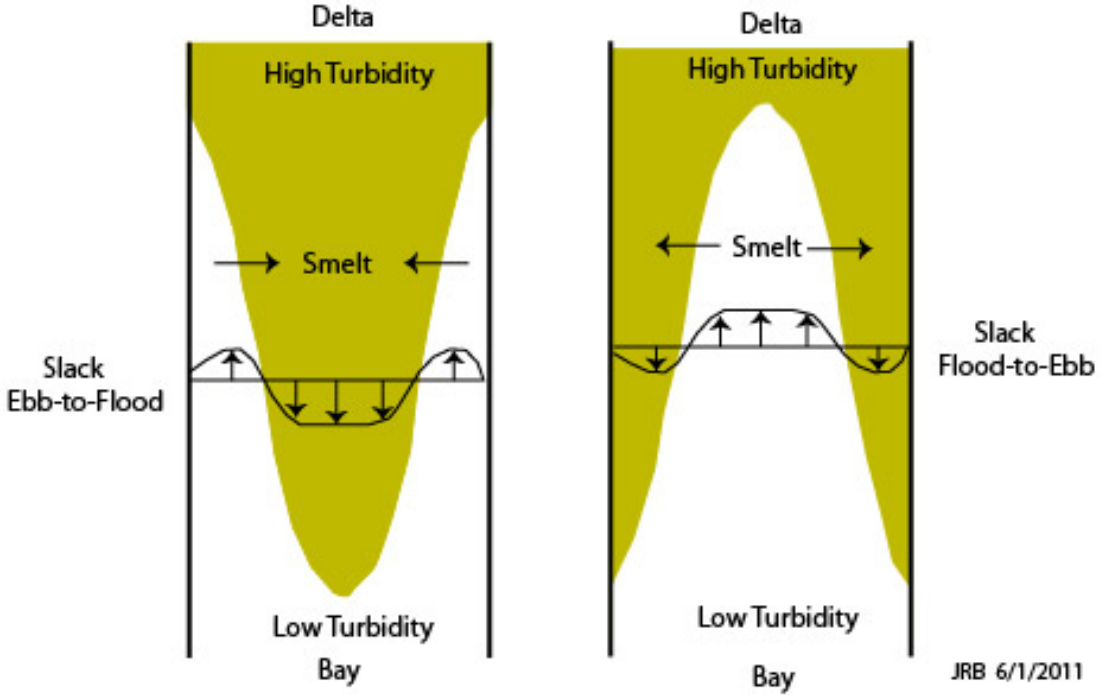


Figure 14 – Conceptual diagram showing how cross-channel gradients are created from along-channel gradients in a tidally driven channel. Increased friction near the shoreline creates lateral shear causing the currents to be slower than in the center of the channel.. Near slack water, when the water changes direction, the slower moving water nearshore changes direction first (sometimes about an hour) before they reverse in the center of the channel where they are stronger and have greater. (A) During the Pre-Flush turbidity conditions - a turbidity gradient from the bay to the Delta - the tide changes from ebb to flood, creating a situation where the turbidities are higher at the edges and lower in the center of the channel. When the tides change from flood to ebb, it creates the reverse - lower turbidities on the edges and higher in the middle. (B) During the First- Flush, turbidities are higher in the Delta than in the bay, and the timing of the lateral gradients is reversed. Thus, in order to **both** maintain position in the low salinity zone during the Pre-Flush period AND migrate into the delta during the First-Flush, smelt merely need to swim **laterally** towards the higher turbidity within the channel margins at each slack water, as is shown. Finally, this conceptual model only works on the lower Sacramento River - not in the San Joaquin - because the primary source of turbidity in the San Joaquin River comes up from Suisun Bay due to Sacramento River discharge.