**DRAFT**

# SUPPLEMENTAL INFORMATION
# For
# CALFED EWA Review Panel

## POTENTIAL ACTIONS TO REDUCE THE EFFECTS OF WATER MANAGEMENT ON DELTA SMELT REPRODUCTION, GROWTH AND SURVIVAL INTENDED TO INCREASE DELTA SMELT ABUNDANCE

### Assumptions

- Overall working hypothesis is that
  - Adult delta smelt entrainment risk and spawning distribution are influenced both by fall hydrodynamics/water quality (salinity) AND winter hydrodynamics/water quality encountered during spawning migrations;
  - Larval delta smelt entrainment risk is influenced by adult spawning distribution AND hydrodynamics during hatching and early rearing/transport;
  - Summer/fall carrying capacity is influenced by food availability AND physical/chemical habitat suitability.

- Actions involving manipulation of water project operations that can potentially be implemented in the coming year that
  - May improve delta smelt habitat, survival and reproductive success
  - May increase food organism productivity and food availability

- Actions have been ranked based on available information using best professional judgment that the action will have the intended result and produce a favorable change in some aspect of the delta smelt population. (The November draft matrix listed potential actions based on this ranking. Here they are presented chronologically.)

- Each action includes a list of response variables with which to evaluate the effectiveness of the action and the validity of the underlying hypotheses. Many of these variables can be measured from existing sampling programs and analytical work that is expected to be carried out in the coming year in conjunction with the POD investigation.

- Each response variable is rated high, medium or low with regard to our confidence in the ability to detect a real change in the response variable.
  - Some response variables measure the immediate effects of the action on some aspect of the life stage present during the action, e.g. entrainment of adult delta smelt.
  - Other response variables assess effects on characteristics of the population at a later stage, such as the hatch dates of the population sampled the following fall.
  - Whether an assumed immediate response persists through time and remains evident in later measures of the population depends on conditions affecting the intervening

life stages. For example, reduced entrainment and hence increased survival of larval delta smelt from early in the spawning period should be manifested as a broader range of hatch dates in fish sampled from the population in the fall. On the other hand, increased survival may not result in increased abundance in the fall if there were a bottleneck in survival between spring and fall (e.g. food supply limitation or some other source of increased mortality).

- Time to detection is an estimate of how long it may take for the action (if continued) to affect the response variable to a degree that can be detected. In most cases detection times are estimates based best professional judgment.
  - For example, if earlier spawning fish produce *more* larvae or if the progeny *survive better* to reproductive age, then the effect of reducing water management-related mortality for these fish should compound over successive generations, and be more apparent after several years.

- Some foundational information is preliminary. Additional information could confirm or refute the supporting evidence for each action/hypothesis.

- Details are lacking with regard to how compliance with the action would be defined and how results would be evaluated.

**May-December**

Hypothesis: *Higher Delta outflow in the summer and fall will increase the amount of habitat for delta smelt. If smelt use this habitat and their distribution is wider and shifted downstream, subsequent entrainment in the winter will be reduced. Food availability also may be improved.*

Potential Action: maintain an average $X_2$ position seaward of Broad Slough (80 km) [Collinsville 81 km] during May-December

Trigger: Implement if the current water year type is “above normal” or wetter (largely determined by precipitation/runoff in the previous winter and spring). If the water year is a “below normal” or drier year, then this action is not attempted.

Primary Response Variables [confidence in detection, time to detection]:

Improved Environmental Quality (EQ index) (turbidity, ec), $X_2$ position [high, 1 year]
Wider geographic distribution of delta smelt in current Fall Mid-water Trawl (FMWT) [high, 2-5 years]

Secondary responses:

Decreased adult delta smelt entrainment (as indicated by salvage) in following winter months [low, unknown]
Increased percentage of early-spawned cohort (lengths in next 20MM survey and back-calculated hatch dates from next FMWT) [low; 1 year, 2-5 years]

Other possible outcomes:

Decreased *Corbula* grazing rate

Increased fish food supply: Calanoid copepod density
Improved fish health – from histopathological analyses
Reduced larval delta smelt loss due to entrainment (as estimated e.g. by Kimmerer method) based on spawner distribution.
Increased salvage post-VAMP if Delta inflow from the San Joaquin River decreases and diversions increase because post-larval/juvenile population may be larger

Supporting evidence: correlative evidence with hypothesized causation
(1) Stronger stock-recruit relationship from the fall to following summer when fall salinity included as a covariate;
(2) Correlation between mean fall $X_2$ position and fall environmental quality index;
(3) Salinity influences delta smelt distribution, creating a linkage between water project operations and fall salinity in the Delta.

Scientific uncertainty: High.

Effectiveness depends on fish behavior in reaction to changed habitat conditions and most responses pertaining to increased population numbers are expected well after the period of action implementation.

**January-February**

Hypothesis: *Increased Old and Middle River flows will reduce entrainment losses of adult delta smelt.*

ORMR flow in this period is primarily a function of San Joaquin River flow and export pumping rate.

Potential Action: Limit the upstream (i.e. reverse or southward) flow in Old and Middle Rivers to a minimum of -3,500 cfs.

Trigger: Implement beginning in January if and when water temperature has declined to < 13 degrees C and flow in the Sacramento River at Freeport reaches 25,000 cfs. Full effect would be achieved if this action were continued until a subsequent action is triggered.

Primary Response variables:
Adult delta smelt entrainment at low end of established ORMR flow v. salvage relationship [high, 1 year]

Secondary Response variables:
Increased occupancy of stations in Spring Kodiak Trawl sampling
Increased percentage of early-spawned cohort (20mm Survey and FMWT back-calculated hatch dates) [low, 2-5 years]
Increased mean length of FMWT fish [low, 2-5 years]
Increased 20 mm, TNS, and FMWT abundance later that year [low, 2-5 years]

Other possible outcomes:
Increased salvage post-VAMP if as is typical inflow from the SJR decreases and diversions increase, because the zone of entrainment expands and the post-larval/juvenile population in the affected portion of the Delta may be larger.

Reduced larval delta smelt loss due to entrainment (as estimated e.g. using Kimmerer method).

Supporting evidence: hydrodynamic linkages to salvage fairly well-described; estimates of population effect vary widely
(1) Relationship between adult delta smelt salvage and net January-February Old and Middle river flows (Smith, 2006 CALFED Science Conference);
(2) Estimates of the percent of the population lost to entrainment. Estimates range widely depending on assumptions selected by different individuals for several factors needed to estimate entrainment loss from salvage data for which no information specific to delta smelt exists (e.g., pre-screen mortality and louver efficiency).
(3) Adult delta smelt spawning migration appears to be cued by a combination of environmental factors. Appearance of these fish in fish facility samples is most consistently associated with water temperature falling to below about 13 degrees C and a flow pulse into the Delta.

Scientific uncertainty: High

The relationship between net flow in Old and Middle Rivers and adult delta smelt salvage may not be linear. Average flow for the two months may not be the best predictor of salvage; antecedent conditions and events over shorter time periods in January and February may determine the outcome. Salvage range is fairly wide at flow close to selected target. Migration behavior of delta smelt is not currently described (timing, destination).

If entraining fewer adult delta smelt results in more smelt spawning in the southern Delta, entrainment of the newly hatched larvae may increase. No data are presently available to assess this outcome because these larval smelt are not detected in current fish facility sampling. Avoiding upstream flow on Old and Middle rivers once spawning has begun (see below) should increase the survival of larvae produced in the southern Delta.

**March-May**

Hypothesis:

*Favorable $X_2$ location during the spawning period reduces the exposure of delta smelt to effects of reverse flow in the southern Delta channels*

*With less favorable X2 location, avoiding upstream flow in Old and Middle Rivers once smelt have begun spawning in the central or southern Delta will reduce entrainment losses of larval smelt.*

ORMR flow in this period is primarily a function of San Joaquin River flow into the Delta, export pumping rate and deployment of barriers in southern Delta channels. Because San Joaquin River inflow is usually less than the export flow, ORMR flow is often is in the reverse or upstream direction. Decreases in exports have a greater effect on ORMR flow compared to equivalent increases in San Joaquin River flow, but ORMR flow implementation will be at the discretion of the Projects.

In mid- to late-April, a barrier is constructed in upper Old River near the San Joaquin River and three others are constructed at other locations in southern Delta channels as part of the Vernalis Adaptive Management Plan (VAMP) experimental design. These barriers dramatically alter flow patterns in the southern Delta, blocking the flow of water from the San Joaquin River through upper Old River to the CVP and SWP diversion facilities so that exported water must flow from north to south in Old and Middle Rivers from the central Delta. During the 31-day VAMP period combined SWP/CVP export pumping is relatively low, typically 1,500, 2,250 or 3,000 cfs per the VAMP design. Local diversions for irrigated agriculture also operate in this season. Positive ORMR flow cannot be achieved unless the export flow is provided from the San Joaquin River via the upper reaches of Old and Middle Rivers (Note: At San Joaquin River flows above 5,000 cfs the barrier at the head of Old River cannot be constructed safely. A decision may be made to not construct the barrier if flows are forecasted to exceed about 7,000 cfs during the VAMP period because of concerns about scouring and flooding at this and higher flows.)

<u>Potential Actions</u>:
1) Maintain downstream (positive or northward) flow in Old and Middle Rivers once delta smelt spawning begins unless on March 1 the 14-day running average X2 position is west of 65 km.

2) Postpone installation of barriers in the southern Delta until June 1; San Joaquin River flow and export pumping as per VAMP protocol.

<u>Trigger</u>:

Implement Action 1 when ripe or spent females are found in the Spring Kodiak trawl or within ten days of water temperature in the southern or central Delta increasing to12 degrees C, unless on March 1 the 14-day running average X2 position is west of 65 km. Continue for at least two weeks or if possible until the start of the VAMP period.

Implement Action 2 with the flow and pumping conditions in the VAMP period and further defer barrier operation thereafter until June 1

<u>Primary Response variables</u>:

Increased 20 mm abundance and distribution [low, 1 year]
Increased percentage of early-spawned cohort based on lengths in 20mm survey [medium, 2-5 years]

<u>Secondary Response variables:</u>

Increased percentage of early-spawned cohort based on back-calculated hatch dates from fish in FMWT [medium, 1 year]
Increased mean length of FMWT fish [low, 2-5 years]
Increased TNS and FMWT abundance [low, 2-5 years]

<u>Other possible outcomes</u>:

Increased salvage in the post-VAMP period if, as is typical, inflow from the SJR decreases and diversions increase, because the zone of entrainment expands and the change in the post-larval/juvenile population in the affected portion of the Delta may be large enough to detect in routine salvage operations.

Reduced larval entrainment loss during the action (as estimated by Kimmerer method).

<u>Supporting evidence</u>: Hypothesized substantial influence of hydrodynamics on entrainment and estimated loss of larval delta smelt

(1) Combined particle tracking and 20 mm distributions (Kimmerer method) suggest population losses are directly correlated with $X_2$ position and can exceed 20% when $X_2$ moves landward of 65 km;
(2) DSM-2 particle tracking modeling suggests the south Delta barriers substantially increase central and south Delta particle entrainment risk under VAMP San Joaquin River flow and export pumping rate conditions;
(3) Delta smelt hatch dates back-calculated from otoliths suggest most fish surviving to summer-fall were hatched during the VAMP period when SJR flow is typically augmented, export pumping is relatively low and consequently ORMR flow is from south to north (downstream). Ripe and spent adult smelt are commonly observed well in advance of the VAMP period, suggesting early-spawned fish have high mortality, including loss due to entrainment. Early-spawned fish were recently hypothesized to have high natural survival rates (Bennett 2006 CALFED Science Conference).
(4) Based on otolith strontium chemistry, fish surviving to summer/fall have high proportions of central Delta origins in recent years (Hobbs 2006 CALFED Science Conference) as contributions from other areas have declined, suggesting increased vulnerability of the population to the effects of entrainment episodes.
(5) At 12 degrees C, time to hatching for delta smelt eggs is about 10 days.

Scientific uncertainty: Medium-high. Immediate effect on survival of delta smelt larvae seems certain. Effect on age composition at later life stages seems likely. Subsequent effects on fish size or abundance depend on intervening factors like food availability.

**June-October**
Hypothesis 1: *Increased San Joaquin River flow to Suisun Bay will deliver more phytoplankton and zooplankton to support juvenile delta smelt.*

Potential Action: Increase San Joaquin River flows enough for productivity to reach the western Delta.

Potential Action: Dredge Clifton Court Forebay to maximize its storage capacity, and then use the extra storage capacity to allow for reduced frequency of gate opening to take water in.

The second action could be implemented in conjunction with the first. More PTM modeling will be required to evaluate the merits and potential effectiveness of the second potential action. At this time it is unknown if any benefit afforded by decreased frequency of radial gate operations would be offset by increased velocities and volumes taken in when the gates are opened. The underlying goal of both actions is to increase downstream transport of primary and secondary production from the southern delta.

Trigger: Implement in summer months

Primary Response variables:

Increased Calanoid copepod flux into the western Delta and Suisun Bay smelt-food co-occurrence.

Calanoid copepod demographics in western Delta and Suisun Bay conform more to in-delta demographics.

Secondary Response variables:

Increased delta smelt survival from summer through fall [low, 5 years]
Increased FMWT abundance, condition, size, energy density [low, 5 years].

Supporting evidence: Correlative evidence and histopathology suggest summer food limitation
1) *Pseudodiaptomus* abundance in western Delta/Suisun Bay is likely subsidized by advection from the Delta. The subsidy is evident in spatial changes in copepod demographics (Durand – 2006 CALFED Science Conference)
2) summer-fall stock-recruit relationship for delta smelt apparent when co-occurrence of fish and food organisms is considered;
3) food limitation suggested by incidence of liver glycogen depletion during summer;
4) fall fork lengths chronically lower than long-term average (note: possible explanations other than food limitation);

Scientific Uncertainty: High.

Hypothesis 2: *Increased flow from the Yolo Bypass (inflow or managed wetlands) will deliver more phytoplankton and zooplankton to the Delta to support young delta smelt.*

Potential Action: Provide flows through Yolo Bypass into Cache Slough to provide for net downstream transport of productivity

Trigger: Implement during summer months

Response variables:

Fish – increased FMWT abundance, condition, size, energy density. [2-5 years]
Food supply – enhanced Calanoid copepod flux, chlorophyll a, smelt-food co-occurrence [2-5 years].

Supporting evidence: Correlative evidence and histopathology suggest summer food limitation

1) Summer-fall stock-recruit relationship for delta smelt apparent when co-occurrence of fish and food organisms is considered;
2) High incidence of liver glycogen depletion during summer;
3) Fall fork lengths chronically lower than long-term average (note: this has hypothesized explanations other than food limitation);
4) *Pseudodiaptomus* abundance in western Delta/Suisun Bay may be mediated by advection from the Delta and thus, partly under hydrodynamic influence.
5) Primary productivity in the Yolo Bypass is high, but net flow in Cache Slough is upstream once floodwaters drain.

Scientific Uncertainty: Very High – The hydrodynamics of the Cache Slough complex are very uncertain. It is unclear if/how objective could be met, so research is needed before actions could be recommended. This action is likely to involve structural modifications and not operations changes.