Additional Scientific Information Related to Pelagic Fish Species, Recommended Changes to the Bay-Delta Water Quality Control Plan, and Recommendations to Address Scientific Uncertainty and Changing Circumstances

Workshop 2: Bay-Delta Fishery Resources

Prepared by:
Jonathan Rosenfield, Ph.D.
The Bay Institute

Submitted to the State Water Resources Control Board on behalf of:
The Bay Institute
Natural Resources Defense Council

September 14, 2012

I. Response to Question 1: Additional Scientific Information and Recommended Changes to the Bay-Delta Water Quality Control Plan Regarding Pelagic Fish Species

In order to protect pelagic fishery resources,[1] the State Board's 2010 Delta Flow Report identified more flow, of a more natural flow pattern, including increased winter/spring Delta inflows and outflow, limitations on reverse Old & Middle River (OMR) flows and exports, and increased fall Delta outflows. New scientific information developed since 2010 largely confirm these recommendations and the Board's conclusion that "*the best available science suggests that current flows are insufficient to protect public trust resources*" (SWRCB 2010:2). For longfin smelt and other estuarine species, spring outflow continues to be the driver of abundance, and, as demonstrated by the high entrainment rates seen in 2012, additional restrictions to reduce and limit entrainment of adult, larval, and juvenile longfin smelt in the winter and spring months are necessary. For Delta smelt, substantial scientific information shows the necessity of limiting entrainment through OMR restrictions and the necessity and benefits of providing increased fall outflows. Additional evidence suggests that Sacramento splittail and other fishes benefit from increased flow rates on inundated floodplains, but that limitations on entrainment are also important (2011 was a record year for entrainment of Sacramento splittail (~9,000,000 individuals were salvaged at the SWP/CVP facility). And new scientific information since 2010 continues to show strong relationships between Delta outflow and the abundance of zooplankton and copepods that comprise much of the prey base for these species (diversions and barriers also play a role in altering and reducing available food supply).

Freshwater flow continues to be the "master variable" driving the health and productivity of the San Francisco Bay-Delta estuary, other estuarine systems, and pelagic fisheries. In our submission for Workshop 1 (cited here as TBI et al 2012), and in our prior submissions to the Board's 2010 proceedings (TBI et al. 2010), we:

- Identified the population status of pelagic fish species in the Delta;
- Documented the substantial declines in seasonal outflow due to increased diversions, particularly in recent decades by the State and Federal water projects;
- Documented the scientific basis demonstrating that improved outflow during the winter/spring, and fall (and possibly late summer) months is necessary to protect and restore pelagic fisheries;
- Discussed new science relating to other stressors on pelagic fisheries and the health of the estuary, including scientific information demonstrating that flow and physical habitat interact but are not interchangeable; and,
- Provided detailed information to guide the Board's development of adaptive management in the program of implementation.

[1] Pelagic fishes are those that spend all or most of their lives in open, flat water. For our purposes here, "pelagic" fishes include native smelt species (longfin and Delta), starry flounder, and striped bass as well as zooplankton and the foodwebs for these species. For simplicity (to avoid creating another category) we also include in this group Sacramento splittail, which are much more associated with shallow water habitats on the margin of larger water bodies.

In this submission we briefly summarize those prior findings and focus on issues relating to entrainment and in-Delta flows (including OMR flows), which were not previously addressed in Workshop 1. Based on the available scientific information, we conclude that these new studies and publications support the Board's findings in the 2010 Delta Flow Report, including:

(1) Existing flows are inadequate to protect Public Trust resources;
(2) Winter/Spring outflows should be substantially increased to levels that are sufficient to achieving restored population viability and ecosystem function, and should be implemented as a percentage of unimpaired flows occurring in a narrow averaging period;
(3) Fall (and possibly late summer) outflows should be increased to provide sufficient habitat, especially following wetter year types;
(4) Restrictions are needed to limit entrainment and poor survival in the Delta, beyond those described in the federal biological opinions and the State Incidental Take Permit for longfin smelt, including OMR flows and restrictions on exports; and
(5) Non-flow measures (such as physical habitat) interact with flow, but are not interchangeable and cannot substitute for flow.

A. FRESHWATER FLOW IS A "MASTER VARIABLE"[2] DRIVING THE HEALTH AND PRODUCTIVITY OF THE SAN FRANCISCO BAY-DELTA AND OTHER ESTUARINE ECOSYSTEMS.

In the hearing process that culminated in the Delta Flow Report (SWRCB 2010), and again in Workshop 1, the Board heard overwhelming scientific evidence that declines in freshwater flow into, through, and out of the Delta, resulting from increasingly intrusive human water management activities (diversions and storage), play a central role in the both the long-term and shorter-term declines in our once-abundant fisheries.[3] After reviewing this wealth of evidence, the State Board found:

> *The best available science suggests that current flows are insufficient to protect public trust resources.* [SWRCB 2010:2].

In its closing comments in the 2010 proceeding, the U.S. Department of Interior concluded that:[4]

---

[2] I interpret this term, coined by Poff et al. 1997, to mean that freshwater flow drives or strongly interacts with a wide variety of ecosystem variables and processes of importance to the physical characteristics and biota of river and estuarine systems. I interpret testimony during workshop #1 of this proceeding, from Dr. Cliff Dahm and Dr. Ted Sommer (DWR) to be completely consistent with this meaning of the term.

[3] These findings do not diminish the imperative to address other long-standing or emerging stressors to the Bay-Delta ecosystem, including water quality issues, sediment toxins such as selenium, and habitat loss; however, the evidence and testimony provided to the State Board demonstrates unequivocally that improved freshwater flow conditions (increased volumes of freshwater flow during key periods that match the needs imposed by the life histories and ecology of key species) must be part of any real solution to the Bay-Delta's ecological collapse – flow improvements are essential, even if flows alone are insufficient to address all the Bay-Delta's environmental challenges.

[4] United States Department of Interior. July 29, 2010. Comments regarding the California State Water Resources Control Board Draft Report: Development of flow criteria for the Sacramento-San Joaquin Delta Ecosystem. Available at:

> *Native fish populations dependent on the Delta have declined across the board, with some species on the brink of extinction. Food web dynamics have undergone significant changes in both abundance and composition. While we do not discount the importance of other stressors on the Delta ecosystem, such as urban runoff, other pollutants, and invasive species, flow in the Delta is one of the primary determinants of habitat availability and one of the most important components of ecosystem function. Timing, magnitude and variability of flow are the primary drivers of physical habitat conditions including: turbidity, temperature, particle residence time, nutrient loading, etc. The Draft report's recommendations to mimic the natural hydrograph under different hydrological conditions (both Delta inflows and Delta outflow) is consistent with the information provided to the State Board by most of the scientific experts involved in this process.* [p. 1]

Subsequent scientific information discussed in our Workshop 1 submission and below reinforces these conclusions.

[California Department of Fish and Game. 2010. Quantifiable biological objectives and flow criteria for aquatic and terrestrial species of concern dependent on the Delta. Available at: https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=25987]

DFG's final report on flow criteria for the Delta was released in December 2010. The Department concluded that,

> *Fish population declines coupled with these hydrologic and physical changes suggest that current Delta water flows for environmental resources are not adequate to maintain, recover, or restore the functions and processes that support native Delta fish.* [p. 1]

They also concluded that flow is the critical factor for native fisheries in the Delta:

> *Flow is the critical factor in maintaining suitable habitat conditions that support all or some of the life stages (spawning, rearing, and adult) of native fish species that depend on the Delta and its tributaries. Flow is the key factor in determining or maintaining water quality factors which determine the extent and suitability of habitat, temperature, turbidity, salinity, and dissolved oxygen.* [p. 96]

DFG summarized its findings as follows:

> *Water flow is a major determinant of species abundance and fish production. In general, the data and information available indicates:*
>
> 1. *Recent Delta flows are insufficient to support native Delta fishes in habitats that now exist in the Delta.*

---

http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/deltaflow/docs/closing_comments/doi_closing.pdf

2. *Water flow stabilization harms native species and encourages non-native species.*
3. *For many species, abundance is related to water flow timing and quantity …*
4. *For many species, more water flow translates into greater species production or abundance.*
5. *Species are adapted to use the water resources of the Delta during all seasons of the year, yet for many, important life history stages or processes consistently coincide with the winter-spring seasons and associated increased flows because this is the reproductive season for most native fishes and the timing of outmigration of most salmonid fishes. Examples:*
    a. *Propagation of splittail depends on the annual winter-spring flooding of the floodplains.*
    b. *Salmon life stages in the Sacramento River depend on certain base and pulse flows.*
    c. *Salmon life stages in the San Joaquin River need spring outflow to transport smolts through the Delta.*
    d. *Spring pulse flows in the Mokelumne River and other eastside streams are needed to support localized in-Delta water quality, salmon migration, and floodplain inundation.*
    e. *Winter Delta outflow has a positive effect on delta smelt.*
    f. *Fish species are dependent on adequate water temperature in spawning and rearing areas upstream of the Delta and sufficient dissolved oxygen for egg incubation, juvenile development, rearing, smolting, and migration.*
6. *The source, quantity, quality, and timing of Central Valley tributary outflow affects the same characteristics of mainstem river flow to the Delta and interior Delta water flows. Flows in all three of these areas influence production and survival of Chinook salmon in both the San Joaquin River and Sacramento River basins.*
7. *Some invasive species negatively influence native species abundance. The best evidence is the negative effects of overbite clam and several species of aquatic plants. Certain flows in and through the Delta may influence these undesirable species, both positively and negatively.*
8. *More research is needed on the effects of nutrients on the Delta ecosystem and its food web.…* [pp. 94-95]

The Department explicitly acknowledged the Delta ecosystem has been fundamentally altered, but concluded that implementing a combination of adequate flows and other measures can restore and maintain fisheries in good condition. [p. 96]

1. AQUATIC SPECIES POPULATIONS DISPLAY STRONG, PERSISTENT, HIGH ORDER CORRELATIONS BETWEEN RELEVANT INDICATORS OF FRESHWATER FLOW CONDITIONS

In our Workshop 1 submission, we reviewed data, scientific information and publications that have come to light since publication of the Delta Flow Report with respect to the effect of freshwater flow on the Low Salinity Zone and the species that reside or spawn in that environment, including Thomson et al 2010, Mac Nally et al 2010, Rosenfield 2010, FWS 2012, and NRC 2012. These new studies, life cycle models, and reviews all found strong relationships between outflow and longfin smelt abundance and viability, as well as persistent relationships between outflow and copepods that comprise the prey base for delta smelt and longfin smelt (TBI et al 2012: 7-16)

Pelagics – winter-spring outflow -- As we emphasized in our 2010 submission to the State Board (TBI et al 2010, Exhibits #1 and #2) and in our submission for Workshop 1 of the current proceeding, populations of numerous pelagic species (fish and invertebrates) have displayed statistically significant, high power (over orders of magnitude), correlations with Delta outflow over several decades of fish community sampling. Although "correlation is not causation", statistically significant correlations are rarely accidental (that is the entire meaning behind statistical significance) and the existence of such strong relationships across a wide diversity of species is incredibly powerful evidence that Delta freshwater flows drive (or interact strongly with the drivers of) population dynamics of aquatic species in the Delta. In fact, we know of no other single factor that better explains population dynamics of more Bay-Delta species over the past 5 decades (the temporal extent of data from many of our aquatic community sampling programs). Although the specific mechanism (or, more likely, *mechanisms*) behind these flow relationships remain somewhat uncertain, the State Board correctly declared in its 2010 Delta Flow Report:

> *There is sufficient scientific information to support the need for increased flows to protect public trust resources; while there is uncertainty regarding specific numeric criteria, scientific certainty is not the standard for agency decision making* [SWRCB 2010:4]

Mechanisms

Different flow-related mechanisms are believed to produce the similar responses to Delta outflow displayed by numerous species in the bay-Delta ecosystem (Kimmerer 2002 *and including species not explicitly studied by Kimmerer*). The four species whose population dynamics are depicted in Figure 1 represent three very different families of fishes and one invertebrate, and wide variety of life history patterns and ecological tolerances. Yet, these, species, and others not depicted here, have shown very similar relationships between abundance and winter-spring freshwater outflow for several decades (e.g., Stevens and Miller 1983, Jassby et al. 1995; Kimmerer 2002a; Sommer et al. 2007; Kimmerer et al. 2009; Mac Nally 2010).

It is almost certain that these species are responding to different flow-related mechanisms. For example, as described below, Sacramento splittail probably benefit from the effect of flow on

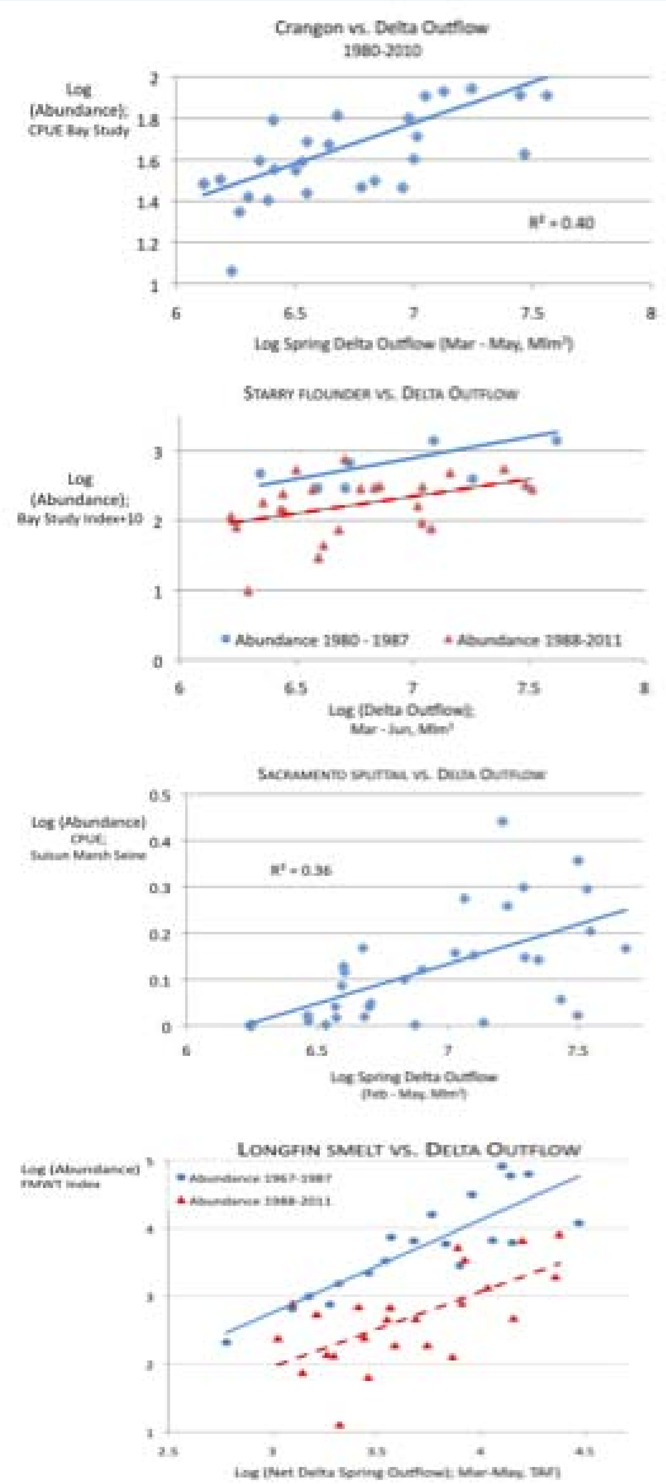

Figure 1: Long -term relationship of abundance indices with Delta freshwater outflow for four species of fishes native to the estuary. All relationships, except for the 1980-1987 starry flounder v. abundance relationship (p=0.075) are statistically significant.

creation and quality of spawning habitat as well as on transport to splittail rearing habitat in the Delta-proper and beyond; longfin smelt larvae and starry flounder juveniles rarely, if ever, occur on floodplains and are much more likely to benefit from kinetic energy mechanisms (low-salinity zone habitat area and position and retention from gravitational circulation in the estuary). The abundance of starry flounder and the bay shrimp, *Crangon franciscorum*, almost certainly respond to the strength of gravitational circulation (Kimmerer 2002a, b) and, probably also to the volume of available brackish habitat.

Just as the particular mechanisms driving the flow-abundance relationship for some species are unknown, those species/life stages for which a flow-related mechanism has been described may also be affected by additional, complimentary mechanisms that have not yet been studied. For example, the relationship between Sacramento splittail (a minnow species, found nowhere else in the world) and fresh water flow rates arises in part from this species' reliance on inundated floodplains for spawning and rearing (e.g. Sommer et al. 2001); clearly, floodplain inundation is very important to this species. Floodplain inundation is an interaction of floodplain elevation (or levee elevation) and the volume of freshwater flow. The relationship between floodplain inundation flows and splittail abundance is not binary (flood or no flood) – season, frequency, and duration of inundation are all extremely important (e.g., Moyle et al 2002, Sommer et al. 2001). Furthermore, even after a floodplain has been inundated, the magnitude of flow across the floodplain is an important indicator of the benefits it provides to native fishes (Figures 2 and 3).

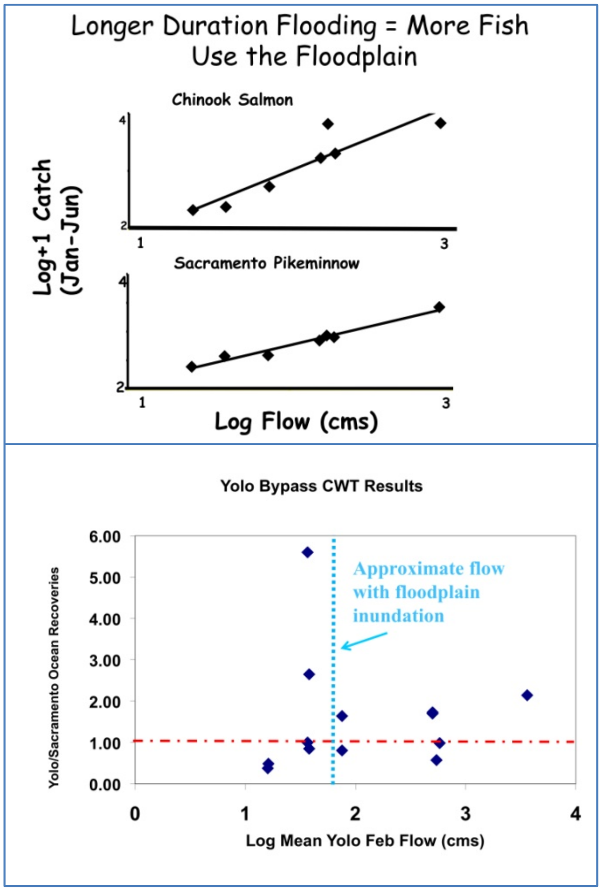

Figure 2: Chinook salmon survival (tag recoveries) as a function of flow rate on the Yolo Bypass. Figure from T. Sommer, CDWR, *personal communication*

The well-documented relationship between floodplain inundation and abundance of splittail (or other species) does not preclude or "disprove" additional mechanisms driving relationships between splittail abundance (or abundance of other fish) and flows elsewhere in their range, including Delta outflow. Given that juvenile and post-spawning splittail adults (and rearing Sacramento blackfish[5] and juvenile Chinook salmon that also use floodplains) move quickly from the floodplain habitats into the lower estuary, it is very likely that a mechanistic relationship between survival and Delta flow rates exists, although it is difficult to tease apart the effect of Delta inflow and Delta outflow in this case. Indeed, the Suisun Marsh Study (O'Rear and Moyle 2010) describes a likely mechanism by which Delta outflow affect Sacramento splittail (and other fish) populations in the Marsh:

> *… the timing, variability, and magnitude of Delta outflow continue to be important factors affecting the abundance of fishes recruiting into the marsh from upstream or downstream areas ... Additionally, Delta outflow, through its influence on marsh salinities, has also affected fishes produced in the marsh* [p 3].

For this reason, Figure 1 portrays the relationship between Sacramento splittail abundance in Suisun Marsh and Delta outflow; for simplicity's sake, we have not presented an analogous graph of Delta inflow and splittail abundance because we take that relationship as a given.

2. FLOW AND ANTECEDENT POPULATION (STOCK) EXPLAIN THE VAST MAJORITY OF VARIATION IN LONGFIN SMELT POPULATION SIZE AND REDUCED DELTA OUTFLOWS LIMIT LFS RESILIENCE AND PRODUCTIVITY

Longfin smelt and starry flounder both exhibit a "step decline" in the relationship between abundance and freshwater flow after 1987 that is commonly associated with the introduction and invasion of the Amur clam (*Corbula amurensis*; Figure 1). Much has been made of this significant change in the number of fish that correspond to any given flow for these two species, including assertions that this change indicated that flow was no longer a driving force for

5 *Orthodon microlepidotus*, is a Central Valley native fish species. A cyprinid (minnow), it is the only member of its genus. This fish is caught and sold commercially, particularly in Asian markets.

abundance of these two species; such conclusions reflect a fundamental lack of statistical understanding. For both species, the statistically significant, high power, and persistent relationship between winter-spring Delta outflow and subsequent abundance remains; even the slope of the relationship has not changed (Kimmerer 2002; Rosenfield and Baxter 2007; Kimmerer et al. 2009; TBI et al. 2010, exhibit #2), meaning that for each incremental increase or decrease in annual flow, we see the same proportional increase in abundance today as we saw in the pre-clam period. This bears repeating: *for both longfin smelt and starry flounder, abundance has historically been and still is strongly and significantly correlated with winter-spring freshwater outflow from the Delta*. Additionally, the significant positive relationships between winter-spring Delta outflow (and its close correlate, X_2) and (a) bay shrimp abundance, (b) striped bass survival, (c) Sacramento splittail abundance, and (d) Pacific herring survival remained unchanged following the introduction of the amur clam and the abundance of American shad *increased* at any given flow following the introduction of the amur clam,[6] (Kimmerer 2002a).

In our 2010 testimony to the Board (TBI et al. 2010 Exhibit 2), we demonstrated that, *even following the introduction of the Amur clam*, inter-generation population growth was strongly and positively associated with winter-spring Delta outflows. This analysis demonstrated that the population size in any one year was related both to environmental conditions that prevailed during the winter-spring larval-juvenile rearing period and to the antecedent population size of the generation that produced the current stock of longfin smelt. By accounting explicitly for the size of the spawning stock, this analysis removed the effect of environmental variables that display a time-trend (e.g. ammonium concentration, phytoplankton concentration, etc.) -- impacts of these variables are already reflected by the stock variable. Only conditions that occur within the two-year generation length of longfin smelt can affect the *change* in abundance between sequential generations. This "stock-recruit" or (more accurately) "stock-stock" effect is well known in fisheries biology and, in particular, among the longfin smelt population in this estuary (Rosenfield and Baxter 2007; Mac Nally et al. 2010).

3. Ecological Implications of Reduced Delta Inflow

As described in our previous testimony (TBI et al. 2010, exhibits 1-4) and our Workshop 1 submission (TBI et al 2012), severe alteration of the historical Delta inflow hydrograph (including the magnitude, timing, frequency, and duration of flows) reduces the viability of numerous species that contribute to the Public Trust. We list a small sample of these effects below (and note that there are likely to be similarly significant effects for species/attributes of viability that have not been well-studied at this time):

- Reduced access of native fishes (including splittail, Chinook salmon, Sacramento blackfish, etc.) to inundated floodplains and side channel rearing areas during the appropriate season and for the necessary duration to facilitate their spawning, rearing, and migration (*impact*: reduced abundance and productivity)

[6] Little attention has been paid to populations of American shad, which displayed a step-increase in population for any given flow after the clam invasion (Kimmerer 2002); shad live mainly in the freshwater Delta; their abundance relationship with flow is contrary to what might be expected from suppression of the food web in the freshwater Delta.

- Inadequate transport flows from upstream spawning and rearing areas to and through the Delta (*impact*: reduced abundance and productivity, reduced nutrient and sediment transport affects ecosystem productivity in the Delta)
- Diminished and or undetectable migration cues for both downstream migrants (e.g. salmon smolts) and upstream migrants (e.g. spawning salmon) (*impact*: reduced abundance, productivity, spatial distribution, and life history diversity)
- Migration pathways that are blocked by physical barriers (e.g. weirs) or physio-chemical barriers (e.g. temperature and low dissolved oxygen) (*impact*: reduced spatial distribution and life history diversity)

4. Considerations for Implementing Flow Standards Based on a Percentage of Unimpaired Flow

As detailed in our Workshop 1 submission, the National Research Council has endorsed the Board developing flow objectives as a fixed percentage of unimpaired flows:

> *… it appears that if the goal is to sustain an ecosystem that resembles the one that appeared to be functional up to the 1986-93 drought, exports of all types will necessarily need to be limited in dry years, to some fraction of unimpaired flows that remains to be determined. Setting this level, as well as flow constraints for wetter years, is well beyond the charge of this committee and accordingly we suggest that this is best done by the SWRCB, which is charged with protecting both water rights holders and the public trust.* [NRC 2012: 105]

We strongly agree that the Board should develop new objectives for Sacramento River (and San Joaquin River) inflow and Delta outflow in the winter and spring months based on a percentage of unimpaired flows. Such standards (with a narrow time-period for averaging and measuring the percentage of unimpaired flows that is feasible, such as 14 days) should form the basis[7] of new flow standards in a revision to the WQCP.

Constructing flow recommendations as a percentage of unimpaired flows will also result in great improvements in the timing, duration, and frequency of actual flows into, through, and out of the Delta because the percentage of unimpaired flows approach results in flows that mimic the pattern of natural hydrological conditions (the conditions that native species evolved with) in the ecosystem. We note that, as the percentage of unimpaired flows increases, the timing, duration, and frequency of critical flows will more closely match unimpaired flows – thus, with a standard based on a percentage of unimpaired flow, the magnitude of flows that the Board allocates to protection of the Public Trust is directly connected to other beneficial attributes of flow, including timing, duration, and frequency of beneficial flows.

[7] We recommend the use of the percentage of flow (POF) approach with respect to winter-spring inflows and outflows, while also recognizing that the Board may need to deviate from this basic template in specific cases, such as human health and safety benefits (e.g., flood control and human drinking water needs), as well as to provide flows in other seasons to provide other benefits (for instance, to mitigate impacts to salmon species that rely on upstream operations to provide habitats that were cut-off by construction of impassable dams).

The percentage of unimpaired flow approach is strongly supported in the literature, however, the Board's 75% criteria is actually low compared to other systems in which a "percentage of flow" (POF) approach has been implemented. The State Board's (2010) findings regarding the freshwater flow needs of this ecosystem represent a dramatic improvement over current flow conditions, and we firmly believe that such significant improvements are essential to restore the Bay-Delta's Public Trust resources (especially in the absence of credible plans to address other stressors in this ecosystem).

[Richter, B.D. M.M. Davis, C. Apse, and C. Konrad. 2011. A presumptive standard for environmental flow protection. River and Research Applications. River research and applications. DOI: 10.1002/rra.1511]

Richter et al. (2011) conducted a review of ecologically protective river flow standards developed by experts for other river systems to determine whether a presumptive standard could be developed for use when more exhaustive and detailed review and analysis of a particular system's needs had not or could not be performed. Although we believe that the State Board is appropriately engaged in a detailed analysis of Central Valley flow needs that supersedes application of a default, presumptive flow standard, Richter et al.'s findings are still informative as they set a context for protective standards in this system. Richter et al.'s review (and their significant professional expertise in the area of river hydrology and conservation) led them to conclude that:

> *"… a large body of scientific literature supports the 'natural flow paradigm' as an important ecological objective to guide river management (Richter et al., 1997; Poff et al., 1997; Bunn and Arthington, 2002; Postel and Richter, 2003; Arthington et al., 2006). Stated simply, the key premises of the natural flow paradigm are that maintaining some semblance of natural flow regimes is essential to sustaining the health of river ecosystems and that health is placed at increasing risk with increasing alteration of natural flows (Richter et al., 2003; Richter, 2009).*
>
> and
>
> *The POF* [percentage of natural flow] *approach has several strong advantages over other approaches. For instance, the POF approach is considerably more protective of flow variability than the minimum threshold standards. Minimum‐threshold‐based standards can allow flow variability to become 'flat‐lined' as water allocation pressure increases and reservoir operations are designed only to meet minimum release requirements. Statistically based standards, although usually more protective of flow regimes than minimum thresholds, can be confusing to non‐technical stakeholders, and complex statistical targets have proven difficult for water managers to implement (Richter, 2009). By comparison, POF approaches are conceptually simple, can provide a very high degree of protection for natural flow variability and can also be relatively simple to implement (i.e. a dam operator simply releases the prescribed*

> *percentage of inflow, or cumulative water withdrawals must not reduce flow by more than the prescribed percentage).*
>
> and
>
> *We found the recommendations for flow protection emerging from … expert groups to be quite consistent, typically resulting in a range of allowable cumulative depletion of 6% to 20% of normal to low flows, but with occasional allowance for greater depletion in seasons or flow levels during which aquatic species are thought to be less sensitive (Table II). These results suggest a consensus that modest alteration of water flows can be allowed with minimal to no harm to aquatic ecosystems and species.*

Table 1: Summary table of environmental flow standards case studies. Copied from Richter et al (2011).

Table II. Summary of per cent-of-flow environmental flow standards from case studies

Location	Ecological goal	Cumulative allowable depletion	Considerations	Decision process
Florida (SWFWMD)	Avoid significant ecological harm (max. 15% habitat loss)	8–19% of daily flow	Seasonally variable extraction limit; 'hands-off' flow	Scientific peer review of site-specific studies
Michigan	Maintain baseline or existing condition	6–15% of August median flow	Single extraction limit for all flow levels	Stakeholders with scientific support
Maine	Protect class AA: 'outstanding natural resources'	10% of daily flow	Single extraction limit for all flow levels above a 'hands-off' flow level	Expert derived
European Union	Maintain good ecological condition	7.5–20% of daily flow	Lower flow; warmer months; 'hands-off' flow	Expert derived
		20–35% of daily flow	Higher flow; cooler months	

> and
>
> *We suggest that a <u>high level of ecological protection will be provided when daily flow alterations are no greater than 10%</u>; a high level of protection means that the natural structure and function of the riverine ecosystem will be maintained with minimal changes. A <u>moderate level of protection is provided when flows are altered by 11–20%</u>; a moderate level of protection means that there may be measurable changes in structure and minimal changes in ecosystem functions. <u>Alterations greater than 20% will likely result in moderate to major changes in natural structure and ecosystem functions, with greater risk associated with greater levels of alteration in daily flows</u>. These thresholds are well supported by our case study review, as well as from our experiences in conducting environmental flow assessments for individual rivers (e.g. Richter et al., 2003, 2006; Esselman and Opperman, 2010).* [Richter et al. 2011, emphasis added]

As the State Board prepares to implement flow standards needed to protect and restore the Bay-Delta's critically imperiled Public Trust resources, water managers will undoubtedly raise concerns that such standards cannot be implemented because of operational constraints or water supply implications. It is instructive that Richter and his colleagues have encountered some of these same concerns in other river systems, writing that:

> *In our experiences in working with water and dam managers, we have found that a remarkable degree of creativity and innovation emerges when engineers and planners are challenged to meet targeted or forecasted water demands with the least disruption to natural flow patterns. Solving the water equation will require new thinking about how and where to store water, conjunctive use of surface water and groundwater, sizing diversion structures or pumps to enable extraction of more water when more is available during high flows, sizing hydropower turbines such that maximum power can be generated across a fuller range of flows, and other innovations. When such creativity is applied as widespread common practice, human impacts on freshwater ecosystems will most certainly be reduced substantially.* [Richter et al. 2011]

Finally, we agree with Richter et al.'s (2011) recommendation about how to proceed *if* the State Board opts not to provide the level of flow protection that it has already determined will be necessary to protect fisheries resources and other aspects of the Bay-Delta's Public Trust values (SWRCB 2010):

> *Some water managers will feel excessively constrained by having to operate within the constraints of the presumptive sustainability boundaries suggested here. However, managing water sustainably necessarily implies living within limits (Richter et al., 2003; Postel and Richter, 2003; Richter, 2009). We suggest that a strong social imperative has emerged that calls for setting those limits at a level that avoids damaging natural systems and the benefits they provide, at least as a default presumption. Where other socio*‐*economic priorities suggest the need for relaxation of the presumptive sustainability boundaries we suggest here, we strongly encourage governments and local communities to invest in thorough assessments of flow–ecology relationships (Richter et al., 2006; Poff et al., 2010), so that decision making can be informed with scientific assessment of the ecological values that would likely be compromised when lesser degrees of flow protection are adopted.* [Richter et al. 2011]

B. REDUCED DELTA FRESHWATER INFLOWS AND INCREASING SOUTH DELTA WATER EXPORTS RESULT IN ENTRAINMENT MORTALITY AND GENERATE IN-DELTA FLOW PATTERNS (HYDRODYNAMICS) THAT INCREASE THE ECOLOGICAL FRAGMENTATION WITHIN THE DELTA AND BETWEEN THE LOWER BAYS AND RIVER CORRIDORS.

As increasing amounts of water are removed from the southern Delta by the State and Federal water Projects and Delta inflows decrease, flow patterns in Delta channels are increasingly disrupted. These disruptions lead to a variety of ecological effects, including increased retention time, net reverse flows, inaccurate migratory cues (e.g. physico-chemical gradients that fish use to cue their migration pathway and timing), export of nutrients and food items, and entrainment of fishes. The last of these effects receives the bulk of public attention, probably because the notion of millions of fish every year being drawn into the export facilities is so compelling and the harm this causes is readily understood.

1. Recent Studies and Life Cycle Models Demonstrate Substantial Adverse Effects of Altered Flows and Entrainment on Delta Smelt

[Kimmerer, W.J. 2011. Modeling Delta Smelt Losses at the South Delta Export Facilities. San Francisco Estuary and Watershed Science, 9(1). Available at: http://escholarship.org/uc/item/0rd2n5vb]

[Miller, W.J. 2011. Revisiting assumptions that underlie estimates of proportional entrainment of delta smelt by state and federal water diversions from the Sacramento-San Joaquin Delta. San Francisco Estuary and Watershed Science 9(1). Available at: http://escholarship.org/uc/item/5941x1h8.pdf]

In response to a critique of his earlier paper (Kimmerer 2008[8]) that attempted to estimate the population level impact of entrainment mortality on populations of salmon and Delta smelt, Kimmerer (2011) modified and expanded his earlier analysis. This re-analysis of entrainment-related impacts to Delta smelt concluded that:

> *Miller* [2011, to which Kimmerer 2011 responds] *raises some valuable points about the data and methods used in calculating proportional losses. He also introduces new developments in understanding (e.g., turbidity effects) and in the delta smelt population (e.g., spatial distribution) that occurred recently. I do not believe these points cast doubt on the overall conclusion of my paper, which is that export–related losses to the delta smelt population during some of the years analyzed were substantial.* [Kimmerer 2011:8, emphasis added].

Kimmerer further addresses Miller's (2011) chief complaint, which was that entrainment-related population impacts to Delta smelt are not detectable on a continuous basis throughout the Delta smelt population abundance index record. Kimmerer's analysis demonstrates that:

> *… the* [entrainment-related] *losses were not generally detectable in the regression until P_{max}* [the maximum decrement in the population by the end of the season attributable to export pumping] *reached about 60% to 80%. The levels of loss reported by Kimmerer (2008) were obscured by interannual variability in nearly all simulations, and maximum losses less than 20% were undetectable. Yet a P_{max} of 20% (mean annual loss of ~10%) results in a 10-fold reduction in population size by the end of the 26–year simulation (Figure 3). Repeating the above simulation 10,000 times with P_{max} = 20%, the upper 95% and 90% confidence limits of the regression slope excluded zero (i.e., was statistically detectable) in 5% and 9% of the cases, respectively. Thus, a loss to export pumping on the order reported by Kimmerer (2008) can be simultaneously nearly undetectable in regression analysis, and devastating to the population. This also illustrates how inappropriate statistical significance is in deciding whether an effect is*

[8] Kimmerer, W.J. 2008. Losses of Sacramento River Chinook salmon and delta smelt to entrainment in water diversions in the Sacramento-San Joaquin Delta. San Francisco Estuary Watershed Science 6(2). Available at: http://escholarship.org/uc/item/7v92h6fs

> *biologically relevant (Stephens and others 2007).* [Kimmerer 2011:7, emphasis added].

Kimmerer, who has previously published papers showing that entrainment did not appear to have population level effects on striped bass or mysids, acknowledged that *"my labors on export losses of delta smelt began with a strong skepticism about the importance of these losses, and ended with considerable surprise at their magnitude."* [Kimmerer 2011:8]

[Thomson, J.R., W.J. Kimmerer, L.R. Brown, K.B. Newman, R. Mac Nally, W.A. Bennett, F. Feyrer, and E. Fleishman. Bayesian change point analysis of abundance trends for pelagic fishes in the Upper San Francisco Estuary. Ecological Applications 20:1431-1448. Available at: http://online.sfsu.edu/~modelds/Files/References/ThomsonEtal2010EcoApps.pdf]

[Mac Nally, R., J.R. Thomson, W.J. Kimmerer, F. Feyrer, K.B. Newman, A. Sih, W.A. Bennett, L. Brown, E. Fleishman, S.D. Culberson, and G. Castillo. 2010. Analysis of pelagic species decline in the upper San Francisco Estuary using multivariate autoregressive modeling (MAR). Ecological Applications 20:1417-1430. Available at: http://online.sfsu.edu/~modelds/Files/References/MacNallyetal2010EcoApps.pdf]

These two intensive analyses of pelagic species population dynamics in the estuary (co-authored by many of the leading researchers in the Bay-Delta) found that entrainment/salvage appeared to have a population level impact on Delta smelt and other pelagic species.

> *Increases in water exports in both winter and spring were negatively associated with abundance of delta smelt and increases in spring exports with abundance of threadfin shad. Losses of delta smelt previously have been related to exports through entrainment and mortality at pumping facilities and may be important to population dynamics under some circumstances, particularly during dry years (Kimmerer 2008). Effects of spring exports on threadfin shad have not been measured but possibly are important given that this is the only species of the four to occupy freshwater throughout its life cycle and whose main distribution is near the export facilities (Feyrer et al. 2009).* [Thomson 2010:1426]

Mac Nally et al. (2010) found that high summer water temperatures, spring water exports, abundance of largemouth bass, abundance of summer calanoid copepods, and winter water exports were negatively associated with Delta smelt abundance to some degree. The modeled covariates explained 51% of the variability in abundance, and the authors concluded that water exports and X_2 are associated with the declines and can be managed.

[Maunder, M.N. and R.B. Deriso. 2011. A state–space multistage life cycle model to evaluate population impacts in the presence of density dependence: illustrated with application to delta smelt (*Hyposmesus transpacificus*). Can. J. Fish. Aquat. Sci. 68: 1285–1306. Available at: http://www.nrcresearchpress.com/doi/pdf/10.1139/f2011-071].

This paper described a life cycle modeling framework, which it illustrated with application to Delta smelt. Maunder and Deriso (20111) reached very different conclusions regarding the factors affecting Delta smelt than Mac Nally et al. (2010), Thomson et al. (2010), or Kimmerer (2011). The paper's principle finding is that parameters of, and variables identified as important by, its multi-stage population modeling framework were heavily influenced by a finding of density-dependent population dynamics among Delta smelt – a finding that the authors admit "*… was probably heavily influenced by three consecutive years of data*" from early in the data record (Maunder and Deriso 2012:1296). The authors concede that: "*At the recent levels of abundance, density dependence is probably not having a substantial impact on the population, and survival is impacted mainly by density-independent factors*" [Maunder and Deriso 2012:1303].

When populations experience density-dependent mortality, losses at a given stage may be somewhat mitigated by improved survival in later stages because the initial loss reduced impacts related to density (e.g. competition) in the later life stage. However, when population dynamics are density independent, losses at any given life stage are expected to translate proportionately to the final population size (they are not compensated for by increased survival later, because survival/mortality rates are not a function of density); for example, a loss of 10% of a populations eggs or larvae would be expected to result in a 10% decrement to the final adult population size. Thus, it is surprising that Maunder and Deriso (2012) conclude that entrainment of adult Delta smelt at the south Delta export facilities is probably unimportant to overall status of this species, despite the fact that: (a) Kimmerer (2009) concluded that Delta smelt salvage appeared to represent a substantial portion of the population periodically; (b) the authors acknowledge that Delta smelt survival is probably density-independent at current levels of abundance; and (c) the modeling framework they present <u>identified adult entrainment as a significant factor</u>. The authors wrote:

> *"The coefficients are similar magnitudes for most covariates except those for water clarity (Secchi) and, particularly, adult entrainment (Aent), which had much larger effects. These both occurred before the stock–recruitment relationship from adults to larvae, which had a very strong density dependence effect. Pred2 had a small effect. The confidence intervals on the coefficients support inclusion of the covariates in the lowest AICc* [=best] *models .... The effects for* [water clarity] *and* [adult Delta smelt entrainment] *appear to be unrealistically large, and their coefficients have a moderately high negative correlation. This appears to be a consequence of the unrealistically strong density dependence estimated in the stock–recruitment relationship from adults to larvae for those models …"* [Maunder and Deriso 2012: 1295].

The authors do not explain why they felt the effect of adult entrainment on population dynamics was too "large" to be retained in the model nor what it says about their modeling framework that they believed it mischaracterized the importance of two variables (Secchi depth and Adult Entrainment) and that its estimate of density dependence (the major finding of the manuscript) was "*unrealistically strong*." In summary, Maunder and Deriso's (2012) modeling framework found that entrainment of Delta smelt adults had a large effect on the population modeling, before the authors inexplicably removed that term from the model.

A. Scientific Critiques of Maunder and Deriso 2012

[BDCP "Red Flag" Documents [California Department of Fish and Game; US Fish and Wildlife Service; and National Marine Fisheries Service. April 2012 BDCP EA (Ch. 5) Staff "Red Flag" Review Comprehensive List. Available at: http://baydeltaconservationplan.com/Libraries/Dynamic_Document_Library/Effects_Analysis_-_Fish_Agency_Red_Flag_Comments_and_Responses_4-25-12.sflb.ashx]

[U.S. Fish and Wildlife Service 2012. First Draft 2011 Formal Endangered Species Act Consultation on the Proposed Coordinated Operations of the Central Valley Project and State Water Project. Available online at: http://www.usbr.gov/mp/BayDeltaOffice/docs/Signed_FINAL%202011-F-0043_%20SWP-CVP%20BO%20Dec%2014%20FIRST%20DRAFT.pdf]

[National Research Council. 2012. Sustainable water and environmental management in the California Bay-Delta. National Research Council. The National Academies Press, Washington, DC. Available at: https://download.nap.edu/catalog.php?record_id=13394]

As discussed below, the state and federal fishery agencies and the National Research Council have raised substantial criticisms regarding the accuracy of Maunder and Deriso (2012), including its conclusions regarding density dependence and effects of entrainment. For instance, in the Red Flag comments on BDCP, the Fish and Wildlife Service notes that:

> *… the Maunder-Deriso model is a new application that needs additional collaborative work before it reaches maturity. We are concerned that the present model may have identifiability problems, as we discussed in our technical comments last fall. Until that concern is resolved, we are unsure whether the parameter estimates developed in that model represent what they are described to represent.*
>
> ….
>
> *The model also assumes a specific form of density dependence between generations. We have questioned the appropriateness of this choice, because on very thin ground it limits the universe of plausible explanations for delta smelt reproductive success that can be derived from the model. The intent of this new model was to explain a specific historical dataset, and other than some broad assumptions it does not contain much of the mechanism presented in current delta smelt conceptual models (like DRERIP, or POD conceptual model, or the Fall Outflow Adaptive Management Plan conceptual model). <u>The published version of the model used data through 2006. The model was updated for the Effects Analysis to include data through 2010. When this was done, the model fit deteriorated dramatically relative to what was reported in the paper</u>.* [BDCP Red Flags 2012:18] (emphasis added)

Likewise, in its 2011 draft Delta smelt biological opinion, FWS raised similar questions about the Maunder and Deriso (2011) model, particularly its assumption of density dependent mortality. (FWS 2011) The Service explained that there is strong evidence of density dependence during the summer and fall months, but that since the early 1980s recruitment between generations has been density independent:[9]

> *Since the decline, recruitment has been positively and essentially linearly related to prior adult abundance, suggesting that reproduction has been basically density-independent for about the past 30 years. This means that since the early 1980s, more adults translates into more juveniles and fewer adults translates into fewer juveniles without being 'compensated for' by density- dependence.* [FWS 2011: 154; *see also* p. 193].

The Service reviewed the three life cycle models in the draft biological opinion and showed that they reached different conclusions regarding the role of winter and spring exports. (FWS 2011:206-213, 243-244) FWS concluded that adult entrainment can have significant effects on Delta smelt abundance because of the lack of compensatory density dependence and that the effects of entrainment would probably not be discernable using correlation statistics (citing Kimmerer 2011, *see above*). (FWS 2011) In the biological opinion, FWS reached similar conclusions with respect to juvenile entrainment, and recommended that proactive OMR restrictions in the spring are necessary. (FWS 2011:244-250)

The National Academy of Sciences also raised questions about the Maunder and Deriso (2011) model, stating that, *"Maunder and Deriso (2011) recently published a life cycle model of delta smelt. This model includes some assumptions that need further additional evaluation (e.g., role of density-dependent survival)."* (NAS 2012: 84)

Finally, it is important to note that, although Maunder and Deriso (2012) is presented, appropriately, as an illustration of a modeling framework, the outputs of that illustration are unreliable not only because of its assumption of density dependence, but also because of substantial concerns with the covariates used in the model. Many of these covariates underwent substantial mathematical manipulation that is not adequately explained, other covariates are not described with sufficient detail to be reproduced by other researchers, and many covariates appear irrelevant and/or not what their labels purport to be. As the authors acknowledge,

> *Several factors were chosen for inclusion in the model (Table 3). <u>These factors are used for illustrative purposes only, and they may differ in a more rigorous investigation of the factors influencing delta smelt</u>. The environmental factors are taken as those proposed by Manly (2010b).* [Maunder and Deriso 2012:1290] (emphasis added)

Thus, while the modeling *approach* developed by Maunder and Deriso (2012) may become useful in the future, it is unlikely to produce a valid *model* of Delta smelt population dynamics until the inputs to that framework include all of the variables that ecologists believe may be relevant to the Delta smelt population.

---

[9] Maunder and Deriso themselves acknowledged that the density-dependent term in their population model was related to three data points from the early 1980's and that at current abundances, survival was likely density-independent.

B. Estimates of Salvage Dramatically Underestimate Delta Smelt Mortality

[Castillo, G. J. Morinaka, J. Lindberg, Robert Fujimura, B. Baskerville-Bridges, J. Hobbs, G. Tigan, L. Ellison. (*in review*). Pre-Screen Loss and Fish Facility Efficiency for Delta Smelt at the South Delta's State Water Project, California. Submitted to San Francisco Estuary and Watershed Science. Available at: http://www.fws.gov/stockton/jfmp/docs/DRAFT-Delta-Smelt-Pre-Screen-Losses-SWP.pdf]

One of the major problems with estimating the overall effect of entrainment on any particular fish species is that we are only able to directly measure "salvage", which is related to the number of fish species enumerated at the fish screening facilities of the State and Federal Water Projects. These facilities do not enumerate losses of fish eggs or larvae that are too small to respond to the behavioral screening system. In addition, predation just outside the fish screens is known to be extraordinarily high because predators aggregate in this area and have been trained to respond to the daily operations of the export facility (e.g. opening of intake gates). Historically, these pre-screen (but, post-entrainment into the diversion canals) losses have been estimated by multiplying salvage by a factor <10. Castillo et al (*in review*) reports on experimental releases of fish into Clifton Court Forebay. The study investigates "*two key sources of entrainment losses of delta smelt at the SWP: fish facility losses (i.e. fish lost within the fish facility due to partial louver efficiency and predation) and pre-screen losses in [Clifton Court Forebay]*. Their findings include:

> *Mean pre-screen losses increased over time: February (94.3%); March (99.1%) and June (99.9%). We concluded that: 1) entrainment losses of delta smelt could be higher at times compared to other species previously studied at the SWP; 2) pre-screen loss was the largest source of mortality for delta smelt; 3) increased distance from the SFF* [Skinner Fish Facility] *and residence time in CCF* [Clifton Court Forebay], *and decreased exports, resulted in lower percent of recovered fish at the SFF.* [Castillo et al. *in review*]

In other words, the number of Delta smelt entrained into waterways directly adjacent to the State Water Project may be ~16 to 1000 times greater than that enumerated during salvage. More work is needed to understand the relationship between pre-screen mortality for Delta smelt and other fishes (to say nothing of the larger impact to fishes before they are drawn into the water bodies directly adjacent to the fish salvage facilities), but it is critical that the Board recognize that salvage estimates are an extremely small fraction of the actual (but unestimated) mortality that is directly attributable to South Delta exports.

C. Forthcoming Scientific Studies and Life Cycle Models Also Conclude that Entrainment Has Population Level Effects on Delta Smelt

[Rose, K.A., W. J. Kimmerer, K.P. Edwards, and W.A. Bennett. *in prep.*, Individual-based population dynamics model of delta smelt: comparing the effects of food versus entrainment. Abstract Available at: http://www.water.ca.gov/iep/docs/041812agenda_abstracts.pdf]

Rose et al are developing an individual-based population dynamics model that they intend to use to assess potential causes of the Delta smelt population decline. While this work is ongoing, Dr. Rose presented the results to-date at the 2012 Interagency Ecological Program conference and reported that:

> *We simulated the population decline using 1995 to 2005 conditions, and explored the relative influence of historical changes in food and entrainment on delta smelt population dynamics. … Simulations indicated that the effect of entrainment on simulated delta smelt population growth rate was between 50% and equal to the effects of food; thus, both were important to the population decline. Increased understanding of how changes in food and entrainment affect delta smelt population dynamics will inform the protection and restoration of delta smelt.*

Several papers are being prepared for publication from this study, which should be available during this State Board proceeding.

[Bennett, W.J. 2012. Statistical Modeling of Unnatural Selection, and the Dialectics of Causation in the Decline of Delta Smelt. Presentation to the 2012 Interagency Ecological Program Conference]

In this presentation, one of the world's leading experts in Delta smelt ecology and population biology, Dr. Bill Bennett asks, "*Did water exports "Cause" the decline of delta smelt?*" and answers with an emphatic "*Yes*" [Slide 2]. The presentation identifies that detrimental entrainment-related impacts to Delta smelt include negative impacts to population abundance, productivity, spatial distribution, and life history. Thus, in addition to simple (though episodic) population-level impacts to Delta smelt, ongoing entrainment impacts have destroyed Delta smelt habitat and eroded the population's natural ability to recover and avoid temporally or geographically-restricted, catastrophic impacts. The author is preparing one or more publications based on the materials summarized in this presentation, which we hope will be published during this proceeding.

2. ENTRAINMENT OF LONGFIN SMELT MAY HAVE SIGNIFICANT POPULATION LEVEL EFFECTS IN SOME YEARS

[Rosenfield, J.A. 2010. Conceptual life-history model for longfin smelt (*Spirinchus thaleichthys*) in the San Francisco Estuary. California Department of Fish and Game, Sacramento, CA. http://www.dfg.ca.gov/ERP/conceptual_models.asp]

The California Department of Fish and Game's Ecosystem Restoration Program (formerly the CALFED ERP) has produced life history conceptual models for key native species. These models describe the magnitude and likelihood of impact of various stressors to particular life history stages of organisms that may contribute to the Public Trust. Regarding the impact of diversions on longfin smelt in this estuary, the CDFG life history conceptual model for longfin smelt (Rosenfield 2010) states that:

> *Mortality of sexually mature adult LFS at water diversions may represent a significant impact on the LFS population in some years (Tables 2, 3). .... Although overall entrainment (which largely reflects entrainment of Age 0+ fish) is significantly and negatively correlated with outflow …, entrainment of sexually mature Age 1+ LFS is significantly and positively correlated with fresh water export rates at the south Delta pumping facilities (ln(SWP+CVP exports):ln(age 1+ salvage)):* $R^2 = 0.418$; $p < 0.01$*; Fig 11). This result is consistent with that of Grimaldo et al. (2009) who studied the relationship between Old and Middle River flows (that are heavily impacted by export rates) and longfin smelt entrainment. This relationship is not an artifact of a correlation between entrainment and Age 1+ population size (Sommer et al. 2007). Age 1+ LFS entrainment is significantly negatively correlated with the Age 1+ LFS population size as measured by the FMWT index (Fig. 12). Entrainment has increased in recent years as the population declined.*
>
> *Spawning (Age 1+) LFS migrate eastwards, towards the Delta (Fig. 7). Their migration patterns expose these spawning fish (and their subsequent offspring) to entrainment at the CVP/SWP pumps. Significant Age 1+ LFS entrainment at CVP/SWP facilities has occurred in months between December and June. Between 1993 and 2007, longfin smelt entrainment was recorded in 12 years; in 7 of those years, the annual maximum entrainment occurred in January whereas December produced the maximum entrainment in three years.* [p. 21].

In addition, the conceptual model notes that entrainment/salvage mortality likely affects the spatial distribution of longfin smelt in addition to the negative impact to viability caused by negative effects of mortality on abundance:

> *Water export operations in the southern Delta may be responsible for the near-absence of spawning LFS in the lower San Joaquin River. The CVP/SWP pumps are located near where one would expect LFS to spawn in the lower San Joaquin River. If LFS spawned historically in areas of the San Joaquin River that were similar to those currently used in the lower Sacramento River, it is likely that CVP/SWP export operations entrained large numbers of spawning adults and recently- hatched larvae in this area. Deterioration of water quality in the lower San Joaquin River (a product of water exports and agricultural operations supported by those exports) could also be responsible for the absence of LFS spawning in this area if San Joaquin flows were toxic to developing eggs or prohibit spawning in this area. Furthermore, the low freshwater outflow rates from the San Joaquin River that result from operation of the larger hydrosystem may make this area unsuitable for spawning and/or incubation.*

[U.S. Fish and Wildlife Service. 2012. Endangered and Threatened Wildlife and Plants; 12-month Finding on a Petition to List the San Francisco Bay-Delta Population of the Longfin Smelt as Endangered or Threatened. 50 CFR Part 17. [Docket No. FWS-R8-ES-2008-0045]. Available at:

http://www.fws.gov/cno/es/speciesinformation/Longfin%20Smelt%2012%20month%20finding.pdf]

In its notice announcing that longfin smelt warranted protection under the Endangered Species Act, FWS acknowledged that entrainment can have significant effects:

> *Conversely, during low outflow periods, negative effects of reduced transport and dispersal, reduced turbidity, and potentially increased loss of larvae to predation and increased loss at the export facilities result in lower young-of-the-year recruitment.* [p. 38].

FWS analyzed the potential for significant entrainment effects, and found that entrainment levels in 2002 threatened the population.

[Salvage Data for Longfin smelt, 2012. Data available for download at: http://www.dfg.ca.gov/delta/apps/salvage/SalvageExportCalendar.aspx]

Salvage of longfin smelt during 2012 was among the highest recorded since 1993; through April, the number of Age 0 longfin enumerated at the salvage facility was second only to entrainment in 2002 (the year in which FWS suggested entrainment threatened the population). This occurred despite provisions in DFG's Incidental Take Permit (ITP) for the SWP. The ITP sets OMR flow targets based on detection of longfin smelt at a variety of sampling stations -- each of these OMR targets represents a net average negative ("reverse") flow. The ITP has no provision to increase Delta outflow, despite the wealth of documentation (e.g. Dege and Brown 2004; Grimaldo et al. 2009; Rosenfield 2010) that longfin smelt become susceptible to entrainment by the South Delta pumps only when X_2 is located relatively far to the east (i.e. during below normal and drier winter-springs). Nor does the ITP impose limits on how many longfin smelt may be entrained.

Based on the very high entrainment of longfin smelt in 2012, the low longfin smelt population currently, and the results of previous studies on entrainment of longfin smelt and other species (e.g. Grimaldo et al. 2009), I conclude that there is no scientific justification that would permit net negative OMR flows during larval and early juvenile period (April-May) of longfin smelt during years with hydrology that is classified as Critically Dry or Dry. Net negative flows represent a significant threat to several pelagic species under such conditions.[10]

3. Entrainment of Other Pelagic Species

[Cloern J.E. and A.D. Jassby *in press*. Drivers of Change in Estuarine-Coastal Ecosystems: Discoveries from Four Decades of Study in San Francisco Bay. Submitted to the SWRCB in Workshop 1]

[10] In preparing this testimony, I reviewed TBI's previous submission to the Board on in-Delta hydrodynamics (TBI et al. 2010, exhibit #4). In so doing, I became aware that a recommendation we made regarding protective OMR flows for longfin smelt (which I helped to develop) was misreported as a result of a typographical error. The recommendation reported in TBI et al. (2010, exhibit #4) on p. 8 and also Table 1, p. 30 should have read that net OMR flows be positive (>0 cfs) during April and May during Critically Dry years, Dry years *or* whenever the preceding longfin smelt FMWT index is below 500. That was and remains my recommendation.

Although most attention is focused on entrainment of commercially valuable and/or listed species, CVP and SWP operations in the Delta also export a significant proportion of phytoplankton from the system. Jassby and Cloern conclude that:

> *Water export from the Sacramento-San Joaquin Delta is a direct source of mortality to fish, including imperiled species such as delta smelt and longfin smelt (Grimaldo et al., 2009; NRC, 2010), and export plus within-Delta depletion alters system energetics of an already low-productivity ecosystem by removing phytoplankton biomass equivalent to 30% of Delta primary production (Jassby et al., 2002).*

In addition to removal from the system, barriers, exports, flows and other operations affect residence time in the estuary, which affects the production and geographic distribution of phytoplankton biomass. For a system in which, many researchers believe, fish productivity is food limited, export and removal of Delta primary production (not to mention tens to hundreds of millions of fish, fish larvae, and fish eggs – which are all food for other fish and avian predators) represents a major impact.

[The Bay Institute. 2012. Collateral Damage: A citizen's guide to fish kills and habitat degradation at the state and federal water project pumps in the Delta. Novato, CA. Available at: http://www.bay.org/publications/collateral-damage]

Earlier this year, The Bay Institute produced a white paper describing a range of impacts caused by excessive south Delta exports, including specifically entrainment/salvage of huge numbers of a wide variety of species at the SWP and CVP export facilities. The report describes that:

> *•Every day, between 870 and 61,000 fish – including from 200 to 42,000 native and endangered fishes – are "salvaged" at the pumps. Most die in the process.*
>
> *•On average, over 9 million fish – representing the twenty fish species considered in this report – are "salvaged" each year at the pumps. As many as 15 million fish of all species encountered are "salvaged" each year.*
>
> *•Up to 40% of the total population of the endangered delta smelt and 15% of the endangered winter-run population of Chinook salmon are killed at the pumps in some years. In the first half of 2011, over 8.6 million splittail were salvaged.*
>
> *•Salvage estimates drastically underestimate the problem. The numbers do not factor in the results of "indirect" mortality, as high levels of export pumping disrupt fish migration, shrink the amount of non- lethal habitat available to fish species, and remove vast amounts of biomass, including fish eggs and larvae too small to be screened at the pumps.*
>
> *•Export pumping causes the lower San Joaquin River to flow backwards most of the year and <u>removes the equivalent of 170 railroad boxcars of water – and the</u>*

> *accompanying fish, other organisms, and nutrients – from the Delta ecosystem every minute*.
>
> •*Large numbers of fish being entrained is a problem even for species that are not currently listed as "endangered." Killing large numbers of fish year after year cuts off population growth in response to favorable conditions and can start the species on a downward path to extinction. As the species declines, the population impacts of entrainment become proportionately larger*.
>
> •*Entrainment is a real problem. But the same interests in the Delta export community who claim that it isn't also back constructing expensive new conveyance facilities such as a peripheral canal or tunnel to solve the problem that they say doesn't exist.* [TBI 2012:4]

Collateral Damage also documented a record salvage[11] of almost 9 million Sacramento splittail in 2011 (Table 2); as the report describes, the salvage total almost certainly vastly underestimates (by perhaps two orders of magnitude) the total mortality to this and every other fish species captured in the export facilities' salvage mechanism. Salvage of Sacramento sucker in 2011 (27,362 fish) was also a record for this species and the 203 white sturgeon juveniles captured at the south Delta export facilities represented the highest salvage total for that species since 1998.

Although it is true that abundances of many fish species increased in 2011 (which may account in part for increased salvage of splittail), it is extremely unlikely that 2011 (following on years of record or near-record low populations) was a year of record high abundance for native fishes (although it did produce the highest level of water export from the south Delta ever recorded). Also, the loss of tens to hundreds of millions of fish, fish larvae, and fish eggs represents a severe impact to the food web of an ecosystem whose productivity is said to be declining. This type of impact demonstrates how Bay-Delta water management reduces species' productivity – even when conditions become suitable for population growth, native fish populations are held down artificially by high direct and indirect mortality at the south Delta export facilities; thus, these populations cannot capitalize on good years to recover from years of artificially prolonged and severe drought.

[11] Most salvaged fish are believed to die either from handling, transport stress, or predation at release sites.

Table 2: Summary of salvage of selected species through time at the South Delta export facilities. Numbers do not reflect pre-screening mortality (believed to be up to 100 times greater than actual salvage), larval fish or eggs, or other negative impacts. Table copied from *Collateral Damage* (TBI 2012).

STATUS KEY:

- Endangered - Federal
- Endangered - California
- Threatened - Federal
- Threatened - California

LEGEND:

- Native to CA
- Recent decline
- Important Fishery
- Commercial/Sport Fisheries Destroyed
- Protection Removed (for political reasons; species has not recovered)

Selected Fish Species	1993-2011 Annual Salvage Average	Maximum	Status
American shad	1,022,700	2,510,184	
Bluegill	127,133	394,952	
Channel catfish	45,799	131,484	
Chinook salmon (winter run)	51,955	183,890	
Chinook salmon (spring run)			
Chinook salmon (fall run)			
Chinook salmon (late-fall run)			
Delta smelt	29,918	154,820	
Green sturgeon	58	363	
Inland silverside	62,838	142,652	
Largemouth bass	54,180	234,198	
Longfin	6,228	97,686	
Prickly sculpin	76,403	274,691	
Steelhead (Rainbow trout)	5,278	18,580	
Redear sunfish	1,609	5,611	
Riffle sculpin	155	798	
Sacramento sucker	3,443	27,362	
Sacramento splittail	1,201,585	8,989,639	
Striped bass	1,773,079	13,451,203	
Threadfin shad	3,823,099	9,046,050	
White catfish	296,543	941,972	
White sturgeon	151	873	
Yellowfin goby	193,399	1,189,962	

Average yearly salvage total: 9,237,444

[1] Fish were selected to encompass the wide range of species and life history types that are affected by water pumps.

[2] "Average annual salvage" is mean yearly salvage from 1/1993 through 12/2011; "Maximum salvage" is the value for the calendar year with the highest salvage numbers (years differ among species).

These numbers underestimate the actual fish kills by not counting the fish that slipped through the bypass system and were killed by the pumps, and by not including indirect mortality. "Yearly Total" refers only to the 20 species listed.

RECOMMENDATIONS

With respect to pelagic species, we recommend that the Board consider the following measures in its update of the water quality control plan, consistent with the potential objectives identified in the 2009 staff report:

1. Delta Outflow Objectives: Increase winter/spring Delta outflow objectives, using a percentage of unimpaired flows approach, to achieve quantifiable targets for increased abundance of longfin smelt and zooplankton species (see our Workshop 1 submission for guidance on setting targets to define desired outcomes). Increase fall (and possibly summer) outflow objectives to achieve quantifiable targets for increased abundance of delta smelt.

2. Floodplain Habitat Flow Objectives: Establish Sacramento River inflow (and possibly structural modifications objectives) such that flows from the Sacramento River inundate floodplains for 15-120 days between December and May every year or twice in every three years.

3. Reverse Flow Objectives / Export: Inflow Objectives: Establish objectives limiting reverse flows in Old and Middle River (OMR) and/or other restrictions on hydrodynamics and exports (e.g., I:E ratios) that reduce entrainment and improve survival of pelagic species in the winter and spring months, including net positive OMR flows during Dry and Critically Dry year-types to help transport pelagic fishes away from the south Delta export facilities.

In our Workshop 1 submission (TBI et al 2012) we provided detailed recommendations regarding the use of adaptive management; we briefly expand on those recommendations here. In an Appendix to our Workshop 1 submission, we described the construction and application of a planning architecture we call "the Logic Chain." The Logic Chain sets conservation actions (such as those contained in the Water Quality Control Plan) in the context of overall and regionally specific goals (desired outcomes) and S.M.A.R.T. targets that articulate the goals (i.e. define what success looks like). Description of stressors that are believed to prevent attainment of the goal, stressor reduction targets (which are also S.M.A.R.T.) and the expected outcomes (positive and potential negative) of conservation actions force planners to identify the level of certainty and key assumptions behind different courses of action.

These assumptions and declarations regarding relative certainty of the response to specified actions become the fuel for an adaptive management implementation strategy. To the extent possible, adaptive management should actively seek to increase certainty and test assumptions that underlie the actions that are implemented. In theory, as different assumptions are tested and progress (or lack thereof) becomes clearer, the most effective and efficient pathways to the desired outcomes will come into focus.

However, this vision of adaptive management can only become reality if the implementation plan identifies specific outcomes/targets and specific and robust decision pathways that make clear how and under what circumstances management will "adapt" to new information and/or changing circumstances. Also, the decision pathways must identify what entities will make the decision to adapt, who has the final authority to make the decision to alter course, when (what time frame and under what circumstances) will those decisions be made, and what are the likely alternative actions. Decision pathways will thus identify adaptive management ranges, within which key variables will be managed to determine their effect, and adaptive management triggers, thresholds that when crossed lead to definitive adjustments in the implementation strategy.

The exact nature and structure of and adaptive management decision pathway depends in large part on information gleaned from the Logic Chain architecture (for example, what is the time bound (the "t" in SMART) for attainment of a particular conservation target?). Thus, we cannot develop a specific example of a decision pathway here. However, we strongly believe that, wherever an action plan will rely on adaptive management going forward, a clear and specific decision pathway should be defined in advance of implementing the relevant action. Developing the decision pathway "as we go along" is reactive management occurring under the guise of adaptive management. We stand ready to provide advice and expertise to the Board and Board staff on the development of these essential adaptive management decision-pathways as you move towards specific revisions of the Bay-Delta Water Quality Control Plan.

Literature Cited

BDCP "Red Flag" Documents [California Department of Fish and Game; US Fish and Wildlife Service; and National Marine Fisheries Service. April 2012 BDCP EA (Ch. 5) Staff "Red Flag" Review Comprehensive List. Available at: http://baydeltaconservationplan.com/Libraries/Dynamic_Document_Library/Effects_Analysis_-_Fish_Agency_Red_Flag_Comments_and_Responses_4-25-12.sflb.ashx.

Bennett, W.J. 2012. Statistical Modeling of Unnatural Selection, and the Dialectics of Causation in the Decline of Delta Smelt. Presentation to the 2012 Interagency Ecological Program Conference.

California Department of Fish and Game (CDFG). 2010. Quantifiable Biological Objectives and Flow Criteria for Aquatic and Terrestrial Species of Concern Dependent on the Delta: Prepared pursuant to the Sacramento-San Joaquin Delta Reform Act of 2009. Available at: https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=25987.

California Department of Fish and Game (CDFG). 2010. Studies and Surveys. 20mm Survey, Smelt Larva Survey, Spring Kodiac Survey, San Francisco Bay Study, Fall Midwater Trawl, Striped Bass Survey, Fish Salvage Monitoring, Sturgeon Survey, and Zooplankton Study. Available at: http://www.dfg.ca.gov/delta/data/.

Castillo, G. J. Morinaka, J. Lindberg, Robert Fujimura, B. Baskerville-Bridges, J. Hobbs, G. Tigan, L. Ellison. (*in review*). Pre-Screen Loss and Fish Facility Efficiency for Delta Smelt at the South Delta's State Water Project, California. Submitted to San Francisco Estuary and Watershed Science. Available at: http://www.fws.gov/stockton/jfmp/docs/DRAFT-Delta-Smelt-Pre-Screen-Losses-SWP.pdf.

Cloern J.E. and A.D. Jassby *in press*. Drivers of Change in Estuarine-Coastal Ecosystems: Discoveries from Four Decades of Study in San Francisco Bay. Submitted to the SWRCB in Workshop 1.

Dege, M. and L. R. Brown. 2004. Effect of outflow on spring and summertime distribution of larval and juvenile fishes in the upper San Francisco Estuary. Pages 49-65 *in* F. Feyrer, L. R. Brown, R. L. Brown, and J. J. Orsi, editors. Early life history of fishes in the San Francisco estuary and Watershed. American Fisheries Society, Symposium 39, Bethesda, Maryland.

Feyrer, F., K. Newman, M. Nobriga, and T. Sommer. 2011. Modeling the Effects of Future Outflow on the Abiotic Habitat of an Imperiled Estuarine Fish. Estuaries and Coasts **34**:120-128.

Fleenor, W.E., W.A. Bennett, P.B. Moyle, and J.R. Lund. 2010. On developing prescription for freshwater flows to sustain desirable fishes in the Sacramento-San Joaquin Delta. Report submitted to the State Water Resources Control Board. 43 pp. http://www.swrcb.ca.gov/waterrights/water_issues/programs/bay_delta/deltaflow/docs/exhibits/svwu/svwu_exh60.pdf.

Grimaldo, L. F., T. Sommer, N. Van Ark, G. Jones, E. Holland, P. B. Moyle, B. Herbold, and P. Smith. 2009. Factors Affecting Fish Entrainment into Massive Water Diversions in a Tidal Freshwater Estuary: Can Fish Losses be Managed? North American Journal of Fisheries Management **29**:1253-1270.

Jassby, A. D., W. J. Kimmerer, S. G. Monismith, C. Armor, J. E. Cloern, T. M. Powell, J. R. Schubel, and T. J. Vendlinski. 1995. Isohaline Position as a Habitat Indicator for Estuarine Populations. Ecological Applications **5**:272-289.

Kimmerer, W. J. 2002a. Effects of freshwater flow on abundance of estuarine organisms: Physical effects or trophic linkages? Marine Ecology Progress Series **243**:39-55.

Kimmerer, W. J. 2002b. Physical, Biological, and Management Responses to Variable Freshwater Flow into the San Francisco Estuary. Estuaries **25**:1275-1290.

Kimmerer, W. J. 2004. Open water processes of the San Francisco Estuary: from physical forcing to biological responses. San Francisco Estuary and Watershed Science 2(1). Available at: http://escholarship.org/uc/item/9bp499mv.

Kimmerer, W.J. 2008. Losses of Sacramento River Chinook salmon and delta smelt to entrainment in water diversions in the Sacramento-San Joaquin Delta. San Francisco Estuary Watershed Science 6(2). Available at: http://escholarship.org/uc/item/7v92h6fs.

Kimmerer, W. J., E. S. Gross, and M. L. MacWilliams. 2009. Is the Response of Estuarine Nekton to Freshwater Flow in the San Francisco Estuary Explained by Variation in Habitat Volume? Estuaries and Coasts 32:375-389.

Kimmerer, W.J. 2011. Modeling Delta Smelt Losses at the South Delta Export Facilities. San Francisco Estuary and Watershed Science, 9(1). Available at: http://escholarship.org/uc/item/0rd2n5vb.

Mac Nally, R., J. R. Thomson, W. J. Kimmerer, F. Feyrer, K. B. Newman, A. Sih, W. A. Bennett, L. Brown, E. Fleishman, S. D. Culberson, and G. Castillo. 2010. Analysis of pelagic species decline in the upper San Francisco Estuary using multivariate autoregressive modeling (MAR). Ecological Applications 20:1417-1430. Available at: http://online.sfsu.edu/~modelds/Files/References/MacNallyetal2010EcoApps.pdf.

Maunder, M.N. and R.B. Deriso. 2011. A state–space multistage life cycle model to evaluate population impacts in the presence of density dependence: illustrated with application to delta smelt (*Hyposmesus transpacificus*). Can. J. Fish. Aquat. Sci. 68: 1285–1306. Available at: http://www.nrcresearchpress.com/doi/pdf/10.1139/f2011-071.

Miller, W.J. 2011. Revisiting assumptions that underlie estimates of proportional entrainment of delta smelt by state and federal water diversions from the Sacramento-San Joaquin Delta. San Francisco Estuary and Watershed Science 9(1). Available at: http://escholarship.org/uc/item/5941x1h8.pdf.

Moyle, P. B. 2002. Inland Fishes of California Revised and Expanded. University of California Press, Berkeley, CA.

National Research Council. 2012. Sustainable water and environmental management in the California Bay-Delta. National Research Council. The National Academies Press, Washington, DC. Available at: https://download.nap.edu/catalog.php?record_id=13394

O'Rear T.J. and P.B. Moyle. 2010. Suisun Marsh Fish Study: Trends in Fish and Invertebrate Populations of Suisun Marsh January 2010-December 2010. Annual Report for the California Department of Water Resources Sacramento, California.

Poff N.L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestegaard, B.D. Richter, R.E. Sparks, and J.C. Stromberg. 1997. The natural flow regime: a paradigm for river conservation and restoration. Bioscience 47: 769–784.

Richter, B.D. M.M. Davis, C. Apse, and C. Konrad. 2011. A presumptive standard for environmental flow protection. River and Research Applications. River research and applications. DOI: 10.1002/rra.1511

Rose, K.A., W. J. Kimmerer, K.P. Edwards, and W.A. Bennett. *in prep.*, Individual-based population dynamics model of delta smelt: comparing the effects of food versus entrainment. Abstract Available at: http://www.water.ca.gov/iep/docs/041812agenda_abstracts.pdf

Rosenfield, J. A. and R. D. Baxter. 2007. Population dynamics and distribution patterns of longfin smelt in the San Francisco estuary. Transactions of the American Fisheries Society **136**:1577-1592.

Rosenfield, J.A. 2010. Conceptual life-history model for longfin smelt (*Spirinchus thaleichthys*) in the San Francisco Estuary. California Department of Fish and Game, Sacramento, CA. http://www.dfg.ca.gov/ERP/conceptual_models.asp

Sommer, T., C. Armor, R. Baxter, R. Breuer, L. Brown, M. Chotkowski, S. Culberson, F. Feyrer, M. Gingras, B. Herbold, W. Kimmerer, A. Mueller-Solger, M. Nobriga, and K. Souza. 2007. The collapse of pelagic fishes in the Upper San Francisco Estuary. Fisheries (Bethesda) **32**:270-277.

Sommer, T. R., L. Conrad, G. O'Leary, F. Feyrer, and W. C. Harrell. 2002. Spawning and rearing of splittail in a model floodplain wetland. Transactions of the American Fisheries Society **131**:966-974.

Sommer, T.R., M.L. Nobriga, W.C. Harrell, W. Batham, and W.J. Kimmerer. 2001. Floodplain rearing of juvenile chinook salmon: evidence of enhanced growth and survival. Can. J. Fish. Aquat. Sci. 58: 325–333. Available at: http://swrcb2.swrcb.ca.gov/waterrights/water_issues/programs/bay_delta/deltaflow/docs/exhibits/usdoi/spprt_docs/doi_sommer_2001.pdf

Stevens, D. E. and L. W. Miller. 1893. Effects of river flow on abundance of young Chinook salmon, American shad, longfin smelt, and delta smelt in the Sacramento-San Joaquin River system. North American Journal of Fisheries Management **3**:425-437.

State Water Resources Control Board (SWRCB). 2010. Development of Flow Criteria for the Sacramento-San Joaquin Delta Ecosystem. August 3, 2010. California EPA. Sacramento, CA. Available at: http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/deltaflow/docs/final_rpt080310.pdf (Delta Flow Report or SWRCB 2010).

The Bay Institute. 2012. Collateral Damage: A citizen's guide to fish kills and habitat degradation at the state and federal water project pumps in the Delta. Novato, CA. Available at: http://www.bay.org/publications/collateral-damage.

The Bay Institute, Natural Resources Defense Council, American Rivers, Natural Heritage Institute. [TBI et al. 2010 exhibits 1-4]. 2010. Written Testimony of Jonathan Rosenfield, Christina Swanson, John Cain, et al. Before the State Water Resources Control Board, Exhibits 1-4, summary, and closing comments. Available at: http://www.bay.org/publications/flow-criteria-for-the-delta-ecosystem.

The Bay Institute, Natural Resources Defense Council, American Rivers, and Pacific Coast Federation of Fishermen's Associations. 2012. Written Testimony of Jonathan Rosenfield. Before the State Water Resources Control Board, Workshop 1: Ecosystem Changes and the Low Salinity Zone. Available at: http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/docs/cmnt081712/jonathan_rosenfield.pdf (TBI et al. 2012).

Thomson, J. R., W. J. Kimmerer, L. R. Brown, K. B. Newman, R. Mac Nally, W. A. Bennett, F. Feyrer, and E. Fleishman. 2010. Bayesian change point analysis of abundance trends for pelagic fishes in the upper San Francisco Estuary. Ecological Applications 20:1431-1448. Available at: http://online.sfsu.edu/~modelds/Files/References/ThomsonEtal2010EcoApps.pdf.

U.S. Fish and Wildlife Service. 2012. Endangered and Threatened Wildlife and Plants; 12-month Finding on a Petition to List the San Francisco Bay-Delta Population of the Longfin Smelt as Endangered or Threatened. 50 CFR Part 17. [Docket No. FWS-R8-ES-2008-0045]. Available at: http://www.fws.gov/cno/es/speciesinformation/Longfin%20Smelt%2012%20month%20finding.pdf.

U.S. Fish and Wildlife Service 2012. First Draft 2011 Formal Endangered Species Act Consultation on the Proposed Coordinated Operations of the Central Valley Project and State Water Project. Available online at: http://www.usbr.gov/mp/BayDeltaOffice/docs/Signed_FINAL%202011-F-0043_%20SWP-CVP%20BO%20Dec%2014%20FIRST%20DRAFT.pdf.