CVCWA
Central Valley Clean Water Association
Representing Over Fifty Wastewater Agencies

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February 2, 2012

Via email

Phil Isenberg, Chairman and Council Members
Delta Stewardship Council
980 Ninth Street, Suite 1500
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eircomments@deltacouncil.ca.gov

Attn: Terry Macaulay

SUBJECT: Comments on the Delta Plan Draft Environmental Impact Report

Dear Mr. Isenberg:

The Central Valley Clean Water Association (CVCWA) appreciates the opportunity to provide comments on the Delta Stewardship Council's Draft Environmental Impact Report (DEIR). CVCWA is a nonprofit association of Publicly Owned Treatment Works (POTWs) throughout the Central Valley whose primary mission is to represent wastewater agencies in regulatory matters while balancing environmental and economic interests. CVCWA members have a deep commitment to the protection of beneficial uses in the waters of the Central Valley, and have a special interest in the recovery of the Delta ecosystem. Many of CVCWA's members will be directly impacted by the Delta Plan and have a considerable interest in its development and implementation. In general, CVCWA is concerned with the adequacy of the DEIR for the Fifth Staff Draft of the Delta Plan.

I. The Project Description in the DEIR Is Inadequate and Fails to Articulate the True Environmental Impacts of the Proposed Project

As a preliminary matter, CVCWA finds the project description in the DEIR to be incomplete and insufficient to comply with the mandates of the California Environmental Quality Act (CEQA). Specifically, the DEIR fails to provide CVCWA, our members, and others with an adequate understanding of what the Delta Plan is intended to do, and what the public can expect as a

result of Delta Plan adoption. Without an accurate and complete project description, stakeholders and those affected by the Proposed Project are unable to adequately evaluate the actual impact of the policies and recommendations in the Delta Plan on the environment. On the one hand, the DEIR asserts that the Delta Plan is a legally enforceable, comprehensive management plan for the Delta. (DEIR, p. 2A-1.) However, the DEIR also characterizes the Delta Plan as being comprised of "regulatory policies" and "non-binding recommendations," which are merely policy directions to other agencies that "*could* lead to other types of specific physical action." (DEIR, p. ES-2, emphasis added.) Further, the DEIR states that the "Delta Plan does not direct the construction of specific projects, nor would projects be implemented under the direct authority of the Delta Stewardship Council." (DEIR, p. 3-85.) Accordingly, the DEIR appears to indicate that the Delta Plan, in and of itself, will not mandate any physical changes in the environment. If that is true, then it is uncertain how the Delta Plan will actually achieve its goals. This lack of information regarding how the Delta Plan will affirmatively achieve the project objectives prevents CVCWA and others from being able to fully analyze the environmental impacts of the Proposed Project. In addition, if the policies and recommendations in the Delta Plan are merely speculative and will not necessarily result in any physical actions, it is unclear how the Proposed Project will achieve any more quantifiable benefits than the No Project Alternative.

The Project's general concept that stressor "reduction," at any level, will produce net positive outcomes is also problematic, as projects required on the basis of "stressor reduction" may, in fact, provide little benefit to beneficial uses. The DEIR states that, "the Delta Plan involves an environmental tradeoff between short-term construction impacts and long-term impact reductions related to water reliability, water quality, flood risk and ecosystem health." (DEIR, p. ES-7.) This statement presupposes that all of the projects proposed in the Delta Plan will, with certainty, accomplish the long-term impact reductions, that such reductions have been clearly defined, and that the improvement is measurable. At least with regard to water quality and ecosystem health, such certainty does not exist. The DEIR's failure to include an adequate project description prevents any analysis with respect to environmental impacts of the Project, which is implementation of the Delta Plan.

In addition, the production of a DEIR prior to the establishment of performance measures for implementation of the Delta Plan makes the actual environmental impacts of the Proposed Project extremely difficult to ascertain, and thus nearly impossible to comment on. Specifically, the Delta Plan is required to include quantified or otherwise measurable targets associated with achieving the objectives of the Delta Plan. (Wat. Code, § 85308(b).) However, the Plan still contains no such quantifiable or otherwise measurable targets. This makes it incredibly difficult for those who will be affected by the Delta Plan to ascertain how the Council intends to accomplish this mandate, what types of performance measures are being considered, when these targets will be adopted, and as it relates to the DEIR, how the Council intends to comply with CEQA in adopting the required targets. The project description in the DEIR fails to discuss these required targets and the DEIR fails to evaluate the potential impacts associated with these targets, rendering it impossible for the affected community to know what the true impacts of the Delta Plan will be.

II. The DEIR Fails to Establish the Environmental Benefits of Increased Wastewater Treatment, and Fails to Account for Potential Adverse Environmental Impacts of Such Actions

The DEIR presumes that the Proposed Project (Delta Plan implementation) will create long-term ecosystem benefits, as a matter of course. One stated component of the Project is to encourage and influence more restrictive requirements on various source categories, including wastewater treatment facilities. Specifically, the DEIR states that "[t]he Delta Plan . . . seeks to influence, either through limited policy regulation or through recommendations, other agencies to take certain actions that will lead to achieving the dual goals of Delta ecosystem protection and water supply reliability. Project may include . . . wastewater treatment plants . . . ." (DEIR, p. 4-1.) However, the DEIR fails to quantify or establish the asserted benefits of increased wastewater treatment beyond the currently permitted levels or how those actions would contribute to the achievement of the dual goals, and fails to provide a complete analysis of the operational impacts of those projects. The benefits of "stressor reduction," as a general concept, are implied, but not articulated or specifically defended. These issues need to be addressed in the DEIR.

As one example, the DEIR infers that installation of state-of-the-art reverse osmosis (membrane) treatment at wastewater treatment facilities is a plausible/desired outcome of the Delta Plan. (DEIR, pp. 2A-44, 4-74.) However, the DEIR fails to address the well-understood and significant adverse environmental impacts of membrane treatment, which include dramatically increased energy use and greenhouse gas impacts, as well as the long-term commitment of community resources required by such treatment. The DEIR also states that recycled wastewater projects encouraged by the Delta Plan may include modification of existing wastewater treatment plants to add filtration, membrane filtration, reverse osmosis, and/or disinfection. (DEIR, pp. 2A-22, 2A-44.) Membrane treatment and reverse osmosis are not commonly applied in recycled water projects because of the exorbitant capital and energy costs associated with such levels of treatment. Thus, the DEIR is incomplete in its assessment of the net environmental impact (i.e., intended benefits versus certain adverse environmental impacts) of specific actions, such as membrane treatment. The Delta Plan must identify the significant environmental impacts and energy requirements of such extreme levels of treatment to avoid reckless encouragement of these wastewater treatment options. Without performing such an analysis, the DEIR fails to accurately characterize the true environmental tradeoffs between the benefits that are asserted to be achieved by the Proposed Project and the impacts of the individual projects that are presumed to create those benefits.

Moreover, the DEIR improperly implies that inadequate wastewater treatment is causing contamination of surface water and/or ground water in many areas of the Central Valley. (DEIR, p. 2A-44.) As a general statement, this implication is both unsupported and inaccurate. The DEIR also states that wastewater treatment "could improve drinking water and environmental quality," though this generalized statement is not supported by findings of fact in the DEIR. In fact, reports prepared for the Drinking Water Policy Work Group and posted on the Central Valley Regional Water Quality Control Board's website contain information that contradicts this statement. A technical report prepared for the Drinking Water Policy Work Group (West Yost, 2011) provides a current assessment of loadings from existing and planned wastewater treatment plants in the Central Valley, and shows that future wastewater treatment plant loadings of organic carbon and nitrogen compounds will be *less* than current loadings, despite population growth. This report is highly relevant, contradicts the statements highlighted above, and should be reviewed and cited in the DEIR. In addition, a report prepared for the Drinking Water Policy

Work Group by Malcolm Pirnie in 2011 indicates that Delta drinking water uses are not adversely impacted by current ambient organic carbon or pathogen levels in the Delta.

III. The No Project Alternative in the DEIR Is Internally Inconsistent and Not Supported by Substantial Evidence

The DEIR's discussion of the No Project Alternative is internally inconsistent and contradicted by evidence in the DEIR itself. For example, the DEIR states that under the No Project Alternative, "drinking water quality would continue to be impaired in communities in the Delta and areas outside the Delta" and that the "[i]mplementation of additional local and regional water treatment facilities may not be reasonably expected to occur in the foreseeable future under the No Project Alternative based on current plans and available infrastructure." (DEIR, p. 2A-88.) However, there is no evidence or analysis cited in support of these conclusions. In fact, these statements are directly contradicted by information in the DEIR itself. Specifically, other provisions of the DEIR cite the ongoing efforts of the State and Regional Water Boards to develop more stringent and comprehensive water quality objectives. (DEIR, pp. 2A-40 - 2A-43.) These ongoing efforts are recognized in the numerous sections of the DEIR and the Delta Plan, and many wastewater treatment facilities that discharge into the Delta are already in the process of planning for or constructing upgraded treatment facilities. Thus to assert, as the No Project Alternative does, that drinking water will "continue to be impaired" and water treatment facility upgrades and construction would not be expected to occur in the absence of the Proposed Project is contrary to the weight of evidence before the Council.

IV. The DEIR Fails to Adequately Discuss the Alternatives

The DEIR provides an overview of Alternatives 1A and 1B in the executive summary, but unfortunately, Alternatives 1A and 1B do not achieve the co-equal goals of ecosystem protection since they would result in an increase in Delta exports from the system. As noted in the August 2010 SWRCB Delta flow criteria report, the Delta ecosystem will be better sustained by an increase in flow through the Delta through actions that include a reduction in current and recent past Delta export volumes. Alternatives such as 1A and 1B, which increase exports from the system, should be considered to be fundamentally invalid in that they fail to achieve one of the co-equal goals. Moreover, there are sub-alternatives to Alternative 2 that may be more feasible/reasonable than the other described alternatives. For instance, the specific means to address habitat or flood control measures can be disconnected from measures to decrease Delta exports, as each measure can be undertaken separately. (See DEIR, p. ES-6.) The DEIR analysis of this alternative should de-couple these elements in order to reflect this reality.

In addition, many of the statements regarding Alternative 2 are incorrect and not supported by substantial evidence. Specifically, the DEIR executive summary states that Alternative 2 is "environmentally inferior" to the Proposed Project because it would result in the greatest amount of water supply uncertainty and agricultural land losses due to restrictions on the total amount of water to be exported from the Delta. (DEIR, p. ES-8.) However, water supply uncertainty and potential agricultural land losses, in and of themselves, are not "environmental impacts" and should not be treated as such in the DEIR. First, it is premature and speculative to state that Alternative 2 would result in the greatest amount of "water supply uncertainty." This statement is not necessarily true, since any certainty or uncertainty in water supply will depend on the clarity of Delta flow objectives and their implementation. Second, the DEIR alleges that Alternative 2 would result in the "loss of agricultural land," and that agricultural land is an environmental

resource under CEQA. (DEIR, p. ES-9.) A reduction of Delta exports and reduced water supply to an area does not impact the existence or future use of the land that *might* have received that supply. The use of land for agricultural production may change based on a wide variety of factors, including cropping patterns or economic viability of specific parcels of the land. Third, it is alleged that Alternative 2 would result in fewer redundancies in the water supply system and thus water users could be without sufficient water during droughts. (DEIR, p. ES-9.) This conclusion improperly presumes that Delta supplies are the only source of redundancy, which is not the case. While Delta supplies may currently be the most economical source of such redundancy, this circumstance may have limited the exploration of other sources, which could serve as viable sources of supply during drought periods. The DEIR should recognize that Alternative 2 may not result in fewer redundancies in the system, and thus may have less of an impact on backup water supplies. Finally, Table ES-1 (DEIR, pp. ES-10 - ES-56.), the Summary of Impacts and Mitigation Measures for Proposed Project, only addresses short-term water quality impacts associated with construction. The table mentions that the Proposed Project could "require or result in" the construction and operation of new or expanded water, wastewater, and storm water treatment systems, but fails to analyze or include mitigation measures for the impacts of such requirements.

V. The DEIR Contains Numerous Misstatements With Respect to Other State Policies and Guidelines

In addition to its failings to comply with the principles of CEQA, the DEIR also makes incorrect reference to other state policies and guidelines. For example, the DEIR states that "[t]he types of projects to reduce stressors can best be seen by looking at the recommendations in the Conservation Strategy for Restoration of the Sacramento-San Joaquin Delta Ecological Management Zone and the Sacramento-San Joaquin Valley Regions." (DEIR, p. 2A-36.) The word "draft" was left off this statement, and the DEIR fails to properly identify that this is still a draft document. The Department of Fish & Game (DFG) is still in the process of reviewing comments and making changes to the final document; as such, the Delta Plan should not rely on its content.

In another example, the DEIR incorrectly states that current Central Valley Regional Water Quality Control Board (Central Valley Water Board) policies and plans "do not include strategies to effectively protect drinking water." (DEIR, p. 2A-41.) In fact, the results of the technical investigations by the Drinking Water Policy Work Group indicate that drinking water uses are being effectively protected in the Delta based on an assessment of current and future ambient levels of organic carbon and pathogens. The DEIR also incorrectly identifies the date of initiation of the Drinking Water Policy Work Group process as 2008. In fact, the process began in 2002. Finally, the 2010 Regional Water Board resolution referenced in the DEIR was not describing a new process; it referred to actions and deadlines to develop a Drinking Water Policy that were associated with the Work Group process initiated in 2002.

In addition, the DEIR erroneously asserts that, under the No Project Alternative, conditions related to a variety of factors, including water quality, would "continue to degrade." (DEIR, p. 2A-67.) The DEIR does not contain any support for this assessment that water quality is deteriorating, and should provide citations to the ambient data analysis that was used as the basis for this statement. This should also include references to specific water quality parameters. Without such additional information, the DEIR's conclusory assertion that water quality will "continue to degrade" is inappropriate and should be modified or eliminated.

VI. The DEIR Fails to Adequately Discuss the Impact of Diversions on the Delta Ecosystem and Fails to Acknowledge the Impact of Known Stressors on the Effectiveness of Proposed Actions

The section of the DEIR addressing biological resources (Chapter 4) contains several accurate statements regarding impacts to the Delta ecosystem from invasive species and diversions, though there is insufficient analysis of a number of the issues raised, and in some instances failure to acknowledge how existing impacts affect the viability of proposed actions. For instance, the DEIR correctly states that two clam species from Asia currently dominate the benthos of Suisun Marsh and the Delta and alter habitat suitability, consume vast volumes of primary and secondary producers, and alter species composition and the food web structure. (DEIR, p. 4-7, citing Lund et al., 2007, p. 71).) However, the DEIR does not properly articulate or address the consequences of that situation. The DEIR should acknowledge that these observed significant impacts in Suisun Bay create a limit on the effect that ammonium, nutrients, or other stressors may have in Suisun Bay, and the viability/necessity of several proposed actions should be adjusted accordingly.

As another example, the DEIR states that, "net flows in the southern Delta have strong north-to-south directionality (toward the CVP and [SWP] South Delta export pumps) . . . ." (DEIR, p. 4-7), and also that "current flow conditions favor resident freshwater invasive organism such as largemouth bass and Brazilian waterweed." (DEIR, p. 4-7, citing Moyle et al., 2010b, p. 14.) However, the DEIR does not indicate whether and how the Delta Plan will address these impacts. The DEIR should acknowledge whether the future Delta Plan will remedy these effects, which may significantly impact the realization of the co-equal goals of ecosystem protection.

The DEIR also acknowledges that significant entrainment and export of vital biological materials will continue to occur as a result of the Delta Plan, but does not contain an analysis or evaluation of the significance of these impacts. Specifically, the DEIR states that ". . . large numbers of fish are lost to the CVP and SWP water export facilities located in the South Delta . . ." as a result of the ". . . entrainment effects caused by the Banks and Jones pumping plants." (DEIR, p. 4-8.) The DEIR also notes that the 110 million fish that were salvaged over a 15-year period ". . . greatly underestimates the actual number of fish entrained" and that "diversions may also create conditions that increase the risk of predation by trapping fish in diversion forebays." (DEIR, p. 4-8.) However, the DEIR should also reference the findings of studies by Castillo (2009) and Kimmerer (2011) (both attached hereto) which confirm that pre-screen predation greatly outweighs the fish lost at the screening facilities and in the salvage operations. The DEIR states that the CVP and SWP water export facilities and other diversions export phytoplankton, zooplankton, nutrients, and organic material that would otherwise contribute to supporting the base of the food web in the Delta. (DEIR, p. 4-8, citing Jassby and Cloern, 2000, p. 348.) However, the DEIR does not sufficiently evaluate the impact of these diversions. The DEIR must attempt to evaluate the significance of these effects, since these indirect effects on the Delta ecosystem that result from continued CVP and SWP diversions will persist under the Delta Plan.

The DEIR makes the generalized statement that contaminants have been identified as "an important driver of declines in ecosystem function in the current Delta and Suisun Marsh." (DEIR, p. 4-9.) However, there is no citation to the reference for this statement, and no acknowledgement that contaminants are but one potential driver of declines in ecosystem function. This statement should be modified to indicate that contaminants have been identified

as but one of a number of stressors that may be impacting the Delta ecosystem, but that the importance to ecosystem function has not been established. In addition, in the listing of "primary" threats to delta smelt, the DEIR includes stressors with known impacts (habitat loss, entrainment in South Delta export facilities) in combination with stressors with potential impacts (toxic chemicals). (DEIR, p. 4-16.) However, the DEIR does not distinguish between observed and potential impacts. This is an important distinction that should be clarified in the DEIR.

The DEIR also describes numerous actions and projects that "could improve water quality," which may include "implementation of plans/programs that lead to reduced constituents from agricultural runoff and wastewater treatment plants." (DEIR, p. 4-72.) However, the reduction in constituent loadings over and above current permitted loadings will not, in and of itself, necessarily result in (a) significant changes in ambient water quality, (b) improved protection of ecosystem health, (c) improved protection of beneficial uses, or (d) net environmental benefit, when the environmental impact of new or increased treatment is considered in comparison to the benefit of a reduction in loadings. The DEIR fails to acknowledge these facts in its analysis of the environmental impacts of the various actions and projects that the Delta Plan seeks to encourage. The DEIR does acknowledge that the projects encouraged by the Proposed Project (e.g., construction of new wastewater treatment plants) could result in substantial adverse effects that are considered to be significant. (DEIR, p. 4-73.) However, the DEIR fails to describe mitigation to be performed by the proponents of the Proposed Project to offset these significant impacts. Such mitigation must be described in the DEIR. Finally, the DEIR states that operation of facilities intended to improve water quality such as discharges from wastewater treatment plants or the discharge of brine waste are not expected to produce significant impacts, since such discharges will be regulated by the State and Regional Water Boards. (DEIR, p. 4-74.) However, the DEIR fails to address the significant operational impacts associated with greenhouse gas emissions, power use, and chemical use associated with the use of membrane treatment in Central Valley wastewater treatment plants. These impacts must be addressed in the DEIR in order to provide an accurate and complete picture of how the operation of such facilities will ultimately impact the environment.

The DEIR specifies that any covered action that would have one or more of the significant environmental impacts listed in section 4 of the DEIR "shall incorporate" mitigation measures as described in section 4.4.3.6. (DEIR, p. 4-82.) This statement appears to seek to transfer responsibility for any projects encouraged by the Proposed Project to local communities, including the burden of demonstrating that such projects are reasonable, cost-effective, or otherwise create a net environmental benefit. This apparent transfer of the responsibility for mitigation of the adverse environmental impacts of membrane treatment and other projects to local communities, rather than the Council taking responsibility for such mitigation as the Project proponent, is inappropriate.

VII. The DEIR Fails To Identify Appropriate Mitigation Measures For Continued Use of South Delta Export Pumps

According to the DEIR, in order to meet the goals, continued use of the South Delta pumps into the future will need to occur. However, the DEIR fails to identify mitigation measures for the continued use of the South Delta. Such continued use will occur under any of the alternatives considered, and is recognized to have caused significant long-term impacts (losses far exceeding the 110 million fish that were "salvaged" in the Delta pump fish screening facilities in a 15-year period). Significant losses above the "salvage" number occurred due to entrainment, pre-screen

predation, and salvage operations during past operation of the state and federal water projects. Implementation of a north Delta intake under the Bay Delta Conservation Plan (BDCP) is not sufficient mitigation for the significant loss of fish that will continue to occur in the South Delta, since exports from the South Delta are projected to continue, representing the vast majority of water exported by the state and federal projects. Moreover, mitigation in the DEIR for the continued operation of the South Delta pumps must also address the indirect effects of South Delta exports, including food web effects, altered flow regime, modified salinity regime, increased residence time that increase the suitability of the Delta to invasive species, other water quality impacts, and adversely impact the Delta food web.

VIII. The DEIR Contains an Insufficient Discussion of How the BDCP Will Impact Implementation of the Delta Plan

There is an important interplay between the implementation of Delta Plan and requirements of the BDCP, if ultimately adopted and incorporated into the Delta Plan. Unfortunately, the DEIR does not clearly articulate how the incorporation of the BDCP into the Delta Plan will change its scope and regulatory effect, and contains no discussion of the resultant environmental impacts. The absence of any significant discussion of the BDCP makes it unclear to CVCWA and other affected entities how the regulatory effect of the BDCP will change if it is incorporated into the Delta Plan, and more specifically whether provisions of the BDCP would be considered "policies" of the Delta Plan and thus subject to consistency determinations. The DEIR indicates that this would be the case, noting that "[i]f BDCP is incorporated into the Delta Plan, it will become part of the Delta Plan and, therefore, part of the basis for future consistency determinations." (DEIR, p. 2A-24.) However if this occurs, then the BDCP's incorporation into the Delta Plan would dramatically expand the scope of both Plans. The DEIR's brief discussion of the BDCP in section 23 fails to discuss how the BDCP will be used for future consistency determinations, and what the environmental impacts associated with that circumstance will be.

CEQA requires that an EIR evaluate the whole of the action that will be approved, including the reasonably foreseeable indirect physical changes to the environment that will occur from the project. The BDCP, to the extent that is must be incorporated into the Delta Plan, should be treated as a reasonably foreseeable future element of the Project. The DEIR does not treat it as such. The DEIR should provide a full and complete discussion of the BDCP in the project description, and should evaluate the impacts of the BDCP as part of the Project and all alternatives. Without such a description, the DEIR fails to adequately describe the actual scope of the Proposed Project and cannot provide an adequate discussion of its environmental impacts. The lack of information in the DEIR regarding the regulatory and environmental consequences of incorporating the BDCP into the Delta Plan makes it impossible for the public to evaluate and understand the environmental consequences of adoption of the Delta Plan. The DEIR must be revised so that the project description and impacts analysis clearly and thoroughly explain the scope of the Plan with respect to the BDCP and evaluate the resulting environmental impacts, and must be revised to fully explain the BDCP's role in the Delta Plan and the type and significance of environmental effects that will occur if all covered actions are required to comply with the BDCP. In addition, the DEIR needs to clarify, through direct statements, that the certification of the Delta Plan EIR will in no way override, negate, or otherwise influence the process for review and approval for the BDCP or the BDCP EIR.

IX. The DEIR Fails to Include Delta Plan Policies in the Body of the Document, Impacting the Ability of Affected Entities to Understand the Impacts of Those Policies

The DEIR states that the primary effects of the Plan will result from agencies implementing the 12 Plan policies that will have regulatory effect. (DEIR, pp. ES-1, 2A-1.) However, the DEIR does not list these policies in the body of the DEIR. Rather, they are effectively buried in an appendix to the DEIR, Appendix C. The California Supreme Court has stated that essential elements of CEQA analyses cannot be buried within the appendices. (*Vineyard Area Citizens for Responsible Growth, Inc. v. City of Rancho Cordova* (2007) 40 Cal.4th 412.) CEQA requires that the information in an EIR be presented in a manner calculated to adequately inform the public and decision makers, who may not be previously familiar with the details of the project. Thus, the failure to include the 12 Delta Plan policies in the project description or other relevant sections of the DEIR makes it difficult for affected entities to understand the nature of the Project and its potential environmental impacts. The DEIR should be revised to include the 12 Delta Plan policies in the body of the document itself.

X. The DEIR Indicates Projects Undertaken to Implement Regulatory Actions of Other State Agencies May Not be Exempt From Consistency Determinations

The DEIR contains statements indicating that the Proposed Plan will involve dual regulation of certain actions taken as a result of regulatory actions of other state agencies, a situation that will result in unnecessary delay in the implementation of projects that would have a positive impact on the environment. While the Delta Plan excludes certain activities from the definition of a covered action, including regulatory actions by other state agencies, it also states that the underlying actions regulated by those agencies would not be exempt. (DEIR, pp. 2A-2 - 2A-4.) Thus, the exemption is seemingly ineffective. This apparent failure to exempt projects undertaken to implement regulatory requirements, such as wastewater treatment plant upgrades necessitated by a NPDES permit issued by the Regional Water Quality Control Board, may have significant adverse consequences for these projects. Entities implementing regulatory requirements of other state agencies will be required to prepare detailed findings of consistency with the Delta Plan, and environmentally beneficial projects will inevitably be delayed. Such delays are unreasonable, counterproductive, and will have adverse environmental impacts that are not discussed in the DEIR. Instead of subjecting such actions to consistency determinations that will result in additional cost and unreasonable delay, the Delta Plan should do everything possible to facilitate and encourage projects that implement regulatory requirements. The Delta Plan should be revised to clearly exempt projects that implement NPDES permits and similar regulatory requirements adopted for the protection of the environment, and at a minimum acknowledge and discuss the adverse environmental impacts that would result from not granting such an exemption.

XI. Information About the Financing of Delta Plan Projects Is Necessary to Understand the Feasibility of the Proposed Project in Relation to DEIR Alternatives

The DEIR fails to address the Finance Plan within the Delta Plan, noting only that "[t]he Finance Plan Framework relies upon other agencies to authorize or to establish mechanisms for the development of funding and/or collection of funds, steps which would not result in changes in physical conditions in the environment in addition to those that are already discussed and analyzed in this EIR." (DEIR, p. 2-56.) While the Finance Plan itself may not directly impact the

physical environment, information regarding the Finance Plan is critical to understanding the feasibility of the Proposed Plan, particularly as it relates to the alternatives in the DEIR. The assumption built into the Finance Plan and only superficially referenced in the DEIR is that entities identified as "stressors" will be successful in procuring funding for Plan projects. Given the realities of Proposition 218 and the existing scarcity of funds for such projects, such an assumption is highly questionable. The DEIR should disclose the important elements of the Finance Plan, discuss the likelihood that funding will be available for such projects, and address the timing of any such funding. Without this information, the public cannot understand the relative feasibility, and thus merits, of the Project and the alternatives.

XII. There Are No Adopted Water Quality Objectives for Methylmercury

Footnote f in Table D-1 of Appendix D implies that 0.06 ng/l MeHg has been adopted as an enforceable water quality objective in the Delta Mercury TMDL Basin Plan amendment. This statement is inaccurate and the table should be modified to clarify that this value has no regulatory effect and clearly is not an adopted water quality objective.

XIII. Conclusions

CVCWA appreciates the work of the Delta Stewardship Council and staff in assembling this DEIR in support of the Delta Plan. CVCWA members are communities with a strong track record of environmental protection in the Central Valley and in the Delta. We are supportive of a Delta Plan that is strategic and effective in resolving the major problems that are impairing the Delta ecosystem. However, we remain concerned that the DEIR contains deficiencies that prevent members of the public from adequately understanding the true environmental impacts of the Proposed Project, and believe that a number of the statements contained in the DEIR are not supported by substantial evidence. The DEIR contains an incomplete project description, an inaccurately characterized no project alternative, and an inadequate discussion of the remaining alternatives. Moreover, the DEIR fails to account for major changes in scope that may be brought about by incorporation of the BDCP into the Delta Plan, and fails to acknowledge or analyze the environmental tradeoffs between the perceived benefits to be achieved by the Proposed Project and the adverse environmental impacts of individual projects (e.g., state-of-the-art wastewater treatment facilities) that are intended to create those benefits. These issues need to be thoroughly addressed before the DEIR can be considered adequate under CEQA.

We look forward to working with the Council and staff in the future to assist in the resolution of issues raised in this comment letter. Please feel free to contact me if you have additional questions or concerns.

Sincerely,

Debbie Webster

Debbie Webster,
Executive Officer

Attachments
cc: Pamela Creedon, CVRWQB (*via email*)

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Manuscript in Review: San Francisco Estuary & Watershed Science

Pre-Screen Loss and Fish Facility Efficiency for Delta Smelt at the South Delta's State Water Project, California

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The findings and conclusions in this article are those of the author(s) and do not necessarily represent the views of the U.S. Fish and Wildlife Service.

ABSTRACT

Water exports have been implicated in the decline of fish populations in the upper San Francisco Estuary, California. We evaluated the relation between delta smelt salvage at the Skinner Fish Facility (SFF) and underlying entrainment losses at the State Water Project (SWP, south Delta). We used cultured delta smelt in mark-recapture experiments in February and March 2009 (adults) and June 2009 (juveniles) to estimate: 1) the percent of fish recaptured at SFF of the total released at the entrance of SFF (fish facility efficiency), 2) the percent of fish recaptured at SFF of the total released at the entry point of Clifton Court Forebay (CCF), a reservoir for SWP exports (percent recovery), and 3) the fish losses in CCF (pre-screen loss). Mean fish facility efficiency declined in successive releases: February (53.2%), March (44.0%) and June (24%). The mean percent recovery of fish released in CCF also declined over time: February (3.01%); March (0.41%) and June (0.03%). 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 and residence time in CCF, and decreased exports, resulted in lower percent of recovered fish at the SFF. Further evaluations are recommended to validate relations between salvage and the magnitude and variability of unaccounted entrainment losses for delta smelt.

KEY WORDS: fish entrainment, *Hypomesus transpacificus*, mark-recapture, salvage, calcein, photonic, water diversion, reservoir, predation, temperature.

INTRODUCTION

Although water diversions for urban and agricultural uses have long been a common feature of aquatic ecosystems, the long-term implications of reduced fresh water inflow and increased entrainment losses on aquatic organisms present challenging management trade-offs for ecosystem sustainability and water use reliability (e.g. Lund and others 2010; Vörösmarty and others 2010). Due to record low fish population abundance indices for several pelagic species since the early 2000s' (Sommer and others 2007; Feyrer and others 2007; Messineo and others 2010), this challenge has become increasingly critical for the Delta of the upper San Francisco Estuary (hereafter Delta), one of the most intensively water-managed estuarine systems in the world. The water diversions by the State Water Project (SWP) and Central Valley Project (CVP), including water export from the south Delta for agricultural, industrial and urban use have long been considered factors contributing to the decline of fishes in the upper San Francisco Estuary (Erkkila and others 1950; Stevens and Miller 1983; Moyle and others 1992; Arthur and others 1996; Bennett and Moyle 1996; Sommer and others 2007; Grimaldo and others 2009).

Limiting entrainment losses has been a major fisheries management goal in the Delta, particularly for listed species such as the delta smelt (*Hypomesus transpacificus*), an endemic osmerid and predominantly annual species. Delta smelt was listed as threatened (federal and state) in 1993. The state of California uplisted the delta smelt to endangered in 2009. Delta smelt was also deemed to warrant federal endangered

status in 2010 but was precluded from a status change due to other workload priorities (Federal Register 2010). The SWP and CVP use fish facilities to collect a fraction of the fish that are drawn to the export pumps. Salvage is the estimated number of fish that are recovered at either the state of federal fish facilities. Salvage data from the SWP's Skinner Fish Protective Facility (SFF) has been commonly used as an index of direct entrainment of some fish, including delta smelt, into Clifton Court Forebay (CCF), a SWP reservoir located in the south Delta (37.8298^{o} N - 121.5574^{o} W, Figure 1). A percentage of the fish entrained into CCF is lost and unable to reach the screens of the SFF. Such loss has been termed pre-screen mortality or pre-screen loss (Tillman 1993; Brown and others 1996). Fish are also lost within the SFF and may not be unaccounted for in the salvage estimates. Results of 11 studies conducted for juvenile fishes between 1976 and 2007 in CCF (Chinook salmon, striped bass and steelhead) revealed consistently high pre-screen losses ranging from 63% to 99% (Gingras 1997; Clark and others 2009).

Salvage comprises one of the largest historical databases on Delta fish species. It has been used to evaluate the effects of new facilities and programs and proposed water project operations and as index of fish entrainment by the SWP and CVP in the south Delta (e.g. Moyle and others 1992; Brown and others 1996; Sommer and others 1997; Bennett 2005; Grimaldo and others 2009). In the case of delta smelt, efforts aimed at interpreting salvage data in terms of their effectiveness at screening fish (Brown and others 1996) or in terms of population level losses (Kimmerer 2008) have been challenged by the significant uncertainty due to the lack of empirically derived pre-

screen loss estimates. The extent and variability of entrainment-related losses, including pre-screen losses, remain long-standing unknowns for delta smelt (e.g. Hymanson and Brown 2006; Kimmerer 2008) Thus, the critical need for empirical estimates on the magnitude of the direct export losses resulting from pre-screen loss and fish facility efficiency. Complementary information derived from hydrodynamic particle entrainment models, fish surveys and water quality data have also been used to infer fish entrainment by SWP and CVP (Kimmerer 2008; USFWS 2008a). Yet, process-oriented methods are still needed to validate the hypothesized relations between reported delta smelt salvage and underlying entrainment losses inferred through field surveys and particle tracking based methods.

As part of a three year study, we conducted the first mark-recapture experiments to assess entrainment losses of delta smelt at the SWP. We investigated 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 CCF, as defined earlier. In addition to fish facility efficiency and pre-screen loss in CCF, other factors can affect salvaged delta smelt at the SFF, including injury and mortality due to collection, handling, trucking and release (CHTR), (e.g. Miranda and others 2010; Morinaka, in press). Other water project impacts include near- and far-field losses in the south Delta and the entire Delta system, as revealed by long-term declines in the quality of physical habitat for several fishes (e.g. Feyrer and others 2007; Nobriga and others 2008); and shifts in fish assemblage composition away from native and desirable species (Moyle and others 2010).

The objectives of this study were to obtain mark-recapture estimates for the: 1) salvage efficiency of juvenile and adult delta smelt at the SFF, 2) percent of marked juvenile and adult delta smelt released in CCF and recovered at the SFF and 3) pre-screen loss for juvenile and adult delta smelt in CCF.

Study area

The SWP in the south Delta comprises CCF, SFF, the Harvey O. Banks Pumping Plant and seasonally, temporary barriers in several Delta channels. Our study was confined to the SFF and CCF, located close to the CVP Tracy Fish Collection Facility (TFF, Figure 1). The CCF is a 38.24 million m^3 reservoir (31,000 acre feet) primarily used for off peak pumping storage (i.e., it stores diverted water so that most export pumping can occur at night when electricity is less costly).

The original SWP operations in the South Delta began in late 1968 and did not utilize the CCF. Fish were initially entrained into the SWP from the Delta through the Italian Slough and arrived directly to the SFF, formerly known as the Delta Plant (Heubach ca. 1973; Kano 1990). When CCF became operational in November of 1969, the end of the Italian Slough intake channel was closed, and the remainder of the channel was connected to the CCF. The CCF diverts water from the Delta through an intake structure which connects CCF to West Canal. West Canal in turn is connected to Old River. Inflow into CCF is regulated by five radial gates positioned side by side at the southeast corner of the reservoir, with a combined operational limit of 339.8 m^3/s (12,000 cfs).

Water circulation patterns in CCF are largely driven by the interaction of wind and the operation of the radial gates which allow inflow to CFF and the operation of the Banks Pumping Plant exports water from CCF (Kano 1990; M. MacWilliams and E. Gross, River Modeling, unpublished data).

For a fish entrained into the SWP to be salvaged, it must first pass through CCF, avoid predation and other potential mortality sources and then be directed into holding facilities at the SFF. The minimum distance from the radial gates to the primary louvers of the SFF is 4.0 km (Figure 1).The SFF is a system of primary louvers, secondary louvers, perforated plates and connecting pipes that can direct some of the entrained fish into holding tanks where they are counted and subsequently transported by trucks to two locations in the west Delta where these salvaged fish are released for the purpose of reducing entrainment losses. The TFF and the SFF share some design elements and were originally designed to salvage juvenile Chinook salmon (*Oncorhynchus tshawytscha*) and striped bass (*Morone saxatilis*), (Brown and others 1996). Delta smelt were not the focus of the design criteria. The smaller juvenile delta smelt (< 30 mm FL) are particularly undersampled in the salvage process at these fish facilities (Kimmerer 2008; Morinaka, in press).

METHODS

I. Culture and Marking

All delta smelt used for this study were produced at the U.C. Davis Fish Conservation and Culture Lab (FCCL), located adjacent to the SFF and a short distance

to release locations used throughout this study (Figure 1). We used cultured delta smelt because the number of delta smelt needed to conduct mark-recapture experiments far exceeded the number of wild fish we would have been able to obtain due to their limited abundance and take restrictions. Delta smelt were spawned during 2008 to provide ca. 4,000 juveniles for the June 2008 experiments (size range: 20-44 mm FL), and 11,200 adults for the February-March 2009 experiments (size range: 47-90 mm FL). Additional delta smelt were spawned in 2009 to provide ca. 16,200 juveniles for the June 2009 experiments (size range: 20-41 mm FL). Production of delta smelt was based on rearing methods developed at the FCCL (Lindberg and others1999; Baskerville-Bridges and others 2004). Fish marking was conducted at the FCCL[1] and involved two types of marks: 1) calcein (Sutphin and Morinaka 2010; G. Castillo, U.S. Fish and Wildlife Service, unpublished data). SE-MARK™ Calcein was the primary mark used for all juvenile and adult delta smelt, 2) photonic marks, used in all adult delta smelt to differentiate days and/or location of fish releases (Sutphin 2008).

An SE MARK™ detector (Western Chemical) was used to distinguish calcein marked fish from unmarked fish. Calcein marking protocols during the 2009 mass mark-recapture experiments (USFWS 2008b) consisted of: 1) a three minute bath (full immersion) in a 1% salt solution and 40 mg/l ms-222 (pre-treatment) and 2) a five

[1] Trans-generational marking was further required for all adult delta smelt to resolve the California Department of Water Resources (CDWR) concerns that the offspring of released adult delta smelt into CCF would count against their ESA-mandated take limits.

minute bath in calcein - 5.0 g/l (adults) and 2.5 g/l (juveniles) - (treatment). Previous marking trials revealed 100% mark retention for at least three months (G. Castillo, U.S. Fish and Wildlife Service, unpublished data).

Photonic marking was conducted using pressurized CO_2 guns (model BMX2000 POW'R-Ject System, New West Technologies) and BMX2000 Photonic Marking Solutions (Cobalt Green, Cobalt Blue and Titanium White). Photonic marking was only used for marking adult delta smelt as preliminary tests showed increased mortality for juveniles. Most photonic marks were readily visible by direct observation of fish in a petri dish. We also used the SE MARK™ detector or a stereomicroscope when photonic marking required further verification. We observed 100% retention of photonic marks in all recovered calcein-marked adults released in February and March 2009.
All recaptured delta smelt were independently examined for calcein and photonic marks by at least two persons. All unmarked delta smelt were considered wild fish[2].

II. Fish Releases

We released juvenile and adult fish during actual export conditions to assess fish facility efficiency and pre-screen loss. Marked fish were released between the trash rack and the primary louvers to assess fish facility efficiency at the SFF (location 1 in Figure 1), (Figure 2).

[2] No trans-generationally marked juvenile delta smelt were detected in salvage operations at the SFF during the 2009 juvenile salvage season (J. Hobbs, University of California, Davis, unpublished data).

In response to seasonal temperature increases, juvenile fish were acclimated to ambient temperatures one week prior to their release at the SFF and CCF in June 2008 and 2009.

Five-gallon black buckets secured with a rope in the handle and another rope attached to the bottom of the bucket were used to lower the bucket from the elevated walkway and empty the bucket just above the water surface.

Juvenile delta smelt were released midday at two CCF locations in June 2008 to obtain initial estimates of loss in CCF: near intake channel (location 2) and near the center of CCF (location 3), (Figure 1). A total of 500 marked juveniles were transported by boat in two, 20-gallon carboys to the west side of Clifton Court Forebay and released on June 12, 2008. A total of 2,647 marked juveniles were transported by boat in five, 20-gallon carboys to the middle of CCF and released on June 26, 2008 (Figure 1). In 2009, adult and juvenile fish were released in CCF from the boat ramp adjacent to the radial gates to assess percent recovery at the SFF and to estimate pre-screen losses (location 4, Figure 1). Fish were released in CCF in early afternoon hours in February, March and June, concurrent with normal water export operations.

III. Release Controls

Control groups of marked fish were held in tanks at ambient water temperature to evaluate post release survival of marked fish. Water was pumped to the control tanks from the export channel immediately downstream of the primary louvers of the SFF. Control fish were fed daily and held in 235-gallon circular tanks (122 cm diameter x 76

cm height) at the FCCL. Tanks were covered with shade cloth to protect fish from avian predators. Controls were terminated after no fish were recaptured at the SFF for at least a week.

IV. Fish Recapture

Fish were recaptured from routine CDWR fish counts conducted at the SFF (Figure 2). Whenever possible we also counted all the salvaged fish collected in the fish holding tanks and from the routine CDWR fish counts (total census). The total census of the holding tanks was completed just prior to loading of transport truck and release in the Delta. Due to constraints on the authorized take of other listed species, only routine CDWR counts were used to estimate the number of marked fish recovered from the March 2009 experiment. In March 2009, the number of marked fish recovered was calculated by multiplying the number of marked fish observed in each routine count by the time period of fish collection divided by actual duration of the counts (usually a fraction of the collection time). This is the same procedure normally used to estimate fish salvage. A few marked fish were also obtained alive from the SFF's secondary louver channel - as part of CDWR's routine weekly predator removal operations in the secondary channel - and were included as part of the recapture. No attempt was made to examine stomach contents of potential delta smelt predators.

V. Data Analyses

Percent fish facility efficiency (*FFE*) was computed as:

$$FFE = \frac{TRrec}{TRrel}100;$$

where *TRrec* is the total number of marked fish that were recaptured in the regular counts, total census and in the weekly predator removal operations and which were released at the trash rack. *TRrel* is the number of marked fish released at the trash rack.

Percent recovery (*PR*) was computed as:

$$PR = \frac{CCrec}{CCrel}100;$$

where *CCrec* is the number of marked fish recaptured at the SFF that were released at a particular location in CCF and *CCrel* is the number of marked fish released at the corresponding location in CCF. In the case of fish released at the radial gates, we further define percent of entrainment loss as 100% – *PR* (e.g. total entrainment losses of non-salvaged fish).

Percent pre-screen loss in CCF (*PSL*) was computed as:

$$PSL = \left[1 - \left\{\left(\frac{RGrec}{RGrel}\right)\left(\frac{1}{0.01FFE}\right)\right\}\right]100;$$

where *RGrec* is the number of marked fish recaptured at the SFF that were released in the radial gate area and *RGrel* is number of marked fish released at the radial gate area and *FFE* is as defined earlier.

Bypass velocity ratio (*BR*) for primary or secondary louvers at SFF is defined as:

$$BR = \frac{Vb}{Vc};$$

where *Vb* is the water velocity entering the primary or secondary bypass openings and *Vc* is the average channel velocity upstream of the louvers (Bates and others 1960). Bypass velocity ratios above 1.0 provide a “capture velocity” for fish near the bypass entrance (Bowen and others 2004), (see appendix for detailed formulas used to compute *BR* and water velocities).

The daily residence time for entrained water in CCF over each recapture period (T) was computed as:

$$T = \frac{V}{Q};$$

where *V* is the estimated volume of CCF at 12:00 a.m. and *Q* is the daily average outflow (export). Because changes in outflow and residence time of CCF often exceeded 100% over the course of a mark-recapture experiment, average T was computed over different periods to evaluate hydrodynamic patterns during mark-recapture experiments. Daily exports were obtained from the dayflow database (CDWR 2010). Daily water volume of CCF was provided by T. Hinojosa (California Department of Water Resources). Hourly volumes used to estimate volume of CCF at 12:00 a.m. were provided by M. MacWilliams (River Modeling).

Regression analysis was used to evaluate potential linear relations between: 1) the percent of recaptured fish and the minimum distance from the release sites and 2) the percent of recovery and residence time (or exports). To evaluate the short-term

influence of residence time and export flow on the percent recapture, three and 10 d averages were considered for these parameters as such periods corresponded with the peak in recovery and the time when all, but one fish, had been recovered. Only the 3 d averages of residence time (and export flow) are subsequently reported as they produced improved fit than the 10-d averages. Differences in size composition between released and recaptured fish were analyzed with the Mann-Whitney U test.

RESULTS

I. Fish Facility Efficiency, Percent Recovery and Pre-Screen Loss

Juvenile Experiments (June 2008-2009)

Only 24% to 30% of the juvenile fish released downstream of the trash rack (upstream of the primary louvers) at the SFF in June 2008-2009 were recaptured at the SFF, indicating low fish facility efficiency (mean = 27.0%, SE= 3.0, Table 1). The recovery of all juvenile delta smelt released in CCF -west side (intake channel area), center and east side (radial gate area) - took place within seven days in 2008 and four days in 2009. Increasing distance between the release location and SFF did not result in consistent increase of recovery time (Table 2). Juvenile experiments in June 2008 and 2009 occurred during a period of lower water exports and higher residence time in CCF when compared to adult experiments (Table 2). Moreover the daily peak in percent recovery of juveniles occurred just one day after the releases, both in the west side and center of CCF (Figure 3A) and in the east side of CCF (Figure 3B). The juvenile delta

smelt group released in June 2009 showed extremely low percent recovery (0.03%) and extremely high pre-screen loss (99.9%).

Daily survival of juvenile delta smelt controls remained consistently high at ambient temperatures below 27 ^{O}C for five days following the last fish recovery. In contrast, survival declined strongly when maximum water temperatures reached a threshold (27.5-28.0 ^{O}C). Subsequent decrease in water temperatures below that threshold did not prevent further decline in juvenile survival (Figures 4A, 4B).

Adult Experiments (February-March 2009)

Photonically-marked fish groups released at the SFF in February and March 2009 had recapture rates ranging from 36% to 89% (Table 1). The average fish facility efficiency was slightly higher in February (53.2%, SE= 12.2) than in March (44.0%, SE= 1.0). Hence, overall fish facility efficiency was only about 50% for adult delta smelt.

The percent recovery for adult delta smelt released at the radial gate area over four consecutive days from February 24 to 27, 2009 was very low (mean= 3.01%, SE=0.78). The peak recovery per group occurred two or three days after the release and except for one fish, all fish were recovered within 10 days (Table 2, Figure 5A). The pre-screen loss for the February 2009 release group was very high (mean= 94.3%, SE=1.5). On the other hand, the survival rate (S) of control marked fish held at the lab remained very high until the control was terminated on March 16, 2009 (S = 99.3%, n = 400). Thus, the

very low recovery cannot be attributed to experimentally induced post-release mortality (i.e., the handling and marking).

Compared to February experiments, the recaptures from radial gate area releases conducted on March 26 and 27, 2009 occurred over a shorter period and only within five days from the releases. March experiments coincided with a period of lower exports and higher residence time in CCF (Figure 5B). Although take restrictions on winter-run Chinook salmon prevented total censusing during the March 2009 experiments, regular fish counts sub-sampled approximately 25% of the fish salvaged at the SFF. Despite expanding the number of mark-recaptured fish in CDWR counts, the percent recovery for both fish groups released in March was extremely low (mean= 0.41%, SE=0.41, Table 2). Hence, the estimated pre-screen loss for the March 2009 release group was extremely high (mean= 99.1%, SE=0.9). Similar to the February 2009 experiment, the survival rate of the control fish held in the lab in March 2009 was still very high on March 31 (S=100%, n=100); the last day marked fish were recovered, Survival was still 98% when the control experiment was terminated on April 20, 2009.

II. Size Composition of Delta Smelt

The size composition of recaptured delta smelt overlapped with that of unmarked wild delta smelt when the later were also reported at the SFF (Figure 6). No obvious differences were observed between the size of fish released and those recaptured for adult delta smelt released either in February or March 2009 (Figure 6). However, recovered juvenile delta smelt that were released in the center of CCF in June 2008 and

in the radial gate area in June 2009 were larger relative to the size composition of released fish ($P < 0.001$ Mann-Whitney U test); (Figure 6).

III. Factors Influencing Percent Recovery

The percent of recovered delta smelt at the SFF declined significantly with increasing distance from the release site, both for juvenile releases (Figure 7A) and combined adult and juvenile releases (Figure 7B). Despite the higher fish facility efficiency for adults, the percent recovery for the six groups of adults released at the radial gates between February and March 2009 was consistent with the very low percent recovery of juveniles released in the center of CCF and in the radial gate area.

The percent recovery of delta smelt declined exponentially with increasing residence time in CCF for the groups of fish released at the radial gate area between February and June 2009 (Figure 8A). Increased exports were associated with higher percent recovery (Figure 8B). Relative to the number of fish released at the radial gate area, the number of adult delta smelt recovered showed nearly a ten-fold decrease from February to March 2009. A similar ten-fold decrease was observed for juvenile recoveries in June relative to adults in March 2009 (Figures 8A and 8B).

DISCUSSION

I. Summary and Conclusions

Our results revealed significant spatio-temporal variability in fish recapture. Residence time in CCF and exports seem to control the entrainment losses of delta smelt at the SWP. Although only a negligible number of juvenile and adult delta smelt released into CCF were subsequently recovered at the SFF, similar levels of fish recoveries in the salvage at the SWP could potentially represent substantially different levels of underlying entrainment losses. We found that the number of entrained fish per salvaged fish in different periods varied c.a.10-100 fold. The substantially lower recoveries for fish released in CCF relative to SFF are ascribed to extremely high pre-screen losses in CCF. The percent recovery of delta smelt showed a consistent decline from February (adults) to March (adults) and then to June (juveniles). Such decreased recovery is primarily attributed to increased residence time in CCF which increases exposure time to predators and other potential mortality sources to be discussed further. Mean daily water exports from CCF decreased moderately from February to March 2009. However, water exports and CCF storage volume in June were significantly lower. The extremely high loss of juvenile delta smelt in June 2009 was likely due to predation in CCF, which may have been enhanced by unusually low water levels in CCF (coinciding with low exports and high residence time), extensive aquatic vegetation coverage and increasing temperature in CCF relative to previous adult mark-recapture experiments in 2009. The lower percent recovery of juvenile delta smelt in the June

2009 experiment is to a lesser extent attributed to decreased SFF efficiencies through time, as expected, as the size of the test fish decreased.

II. Previous Studies

All past studies to estimate pre-screen loss at the SWP were for other species and made use of cultured fishes and a combination of fluorescent dye; coded-wire tags; fin clips (Gingras 1997) and PIT tags (Clark and others 2009) to derive pre-screen loss estimates. Despite methodological differences among studies such as marking methods, release and recapture locations, our reported pre-screen losses in CCF are consistent with the high pre-screen losses reported in all previous studies. Juvenile fish used in previous studies generally had larger mean sizes and experienced lower average pre-screen losses (*PSL*) than those reported in our study: 86.7% *PSL* for 88.1 mm FL Chinook salmon; 82% *PSL* for 53.5 mm FL striped bass (Gingras 1997) and 80% *PSL* for 217 mm FL steelhead (average *PSL* of two estimates by Clark and others 2009).

Relative to SFF efficiencies for juvenile Chinook salmon (Brown and others 1996), estimated efficiencies in our study were generally low for adult delta smelt and substantially lower for juvenile delta smelt. On the other hand, our SFF efficiency estimates for adult delta smelt was nearly two times higher than the estimated fish facility efficiency for adult delta smelt at the TFF (22.5 % *FFE*, Bowen and Svoboda, in review). Yet, in the absence of removal of debris and aquatic vegetation at the TFF, decreased efficiency could be expected due to the attendant headloss at the TFF

trashrack (SDFFF 2003a). To some extent, this could explain the generally similar long-term median salvage densities between CVP and SWP reported for delta smelt (Kimmerer 2008). Our average adult delta smelt entrainment estimates at the SWP ranged from values similar to those assumed for SWP-CVP by Kimmerer's (2008) for our February 2009 experiments to losses nearly tenfold higher in our March 2009 experiments.

Reservoirs can delay fish migration, increase the role of predation and fish disease and favor exotic fishes to the detriment of native fishes (Gray and Rondorf 1986; Li and others 1987). Our finding of decreased percent recovery of delta smelt with increasing residence time of CCF or decreased exports (Figures 8A and 8B) is consistent with the inverse relations between survival of outmigrating salmonids in impoundments and their residence time (e.g.Trefethen 1968; Mullan 1980) and with the overall pattern of lower water exports from CCF resulting in higher prescreen losses (Gingras 1997). Thus, residence time and exports act as key forcing factors on pre-screen loss.

III. Potential Mortality Sources and Study Biases

Several potential mortality sources and experimental biases could individually or in combination account for the pre-screen losses and facility efficiencies reported in our study: 1) predation; 2) starvation; 3) unfavorable physical-hydrodynamic conditions; 4) emigration through CCF intakes; 5) post-mark release induced mortality; 6) use of cultured fish; and 7) calculation biases. These factors are discussed below:

1) Predation mortality: Pre-screen loss has been largely explained in terms of predation in CCF (e.g. Kano 1990; Brown and others 1996; Clark and others 2009). The highest population estimates of predators reported by Kano (1990) were white catfish (*Ictalurus catus*, range: 67,000 - 246,000) and striped bass (*Morone saxatilis*, range: 35,000 - 118,000). However, predation by striped bass may account for much of the pre-screen loss (Kano 1990; Brown and others 1996) while white catfish may have a lower predation rate on fish species because they feed opportunistically on a broad food base, including invertebrates (Turner 1966). Yet, the number of predator-sized striped bass in CCF may have been greatly higher than Kano's estimate (M. Gingras, California Department of Fish and Game, pers. comm.). Five other species of potential piscivores reported in Kano's (1990) study were: channel catfish (*Ictalurus. punctatus*), black crappie (*Pomoxis nigromaculatus*), largemouth bass (*Micropterus salmoides*), brown bullhead (*I. nebulosus*), and Sacramento pikeminnow (*Ptychocheilus grandis*). In addition, the potential for avian predation in CCF has also been recognized (Clark and others 2009).The extremely low recovery of juvenile delta smelt released at the radial gate area in June 2009 occurred within four days from the release. Despite the extended residence time and reduced exports, such short recovery time seems surprising for a release of nearly 14,000 fish. Examination of fish present in the regular CDWR secondary channel flushing to remove predators in June 2009 revealed over 2,000 juvenile striped bass, virtually all of them were less than 50 mm FL. The mean size of striped bass in CDWR counts was 33.3 mm FL (SE= 1.37) over the juvenile delta smelt mark-recapture period (June 22-26, 2009). Age-0 striped bass may rely on invertebrates and fish as prey (Stevens 1966).Yet, no larval fish were reported among

the prey items of age-0 striped bass during the summer (Bryant and Arnold 2007). Striped bass may not become piscivore until 70-100 mm FL (R. Fujimura, California Department of Fish and Game, unpublished data). Over an annual period, Kano (1990) reported that the smallest sizes of striped bass in CCF occurred in July (Mean= 341 mm FL, SE= 3). Thus, the possibility that striped bass may have preyed upon marked juvenile delta smelt in the SFF is far less likely when compared to predation in CCF.

2) Starvation: Based on the regular influx of water containing plankton and pelagic organisms from the Delta into CCF and the high export/outflow ratio for phytoplankton carbon in the Delta (Jassby and others 2002), and the very short period of fish recapture following the releases in CCF, evidence on starvation induced mortality to account for the observed high pre-screen losses is lacking for delta smelt. Although no data on survival of food deprived delta smelt is available, for the smallest corresponding size of delta smelt released in CCF (20 mm FL), cod juveniles (*Gadus morhua*) are able to survive at least a week of food deprivation (Folkvord 1991).On the other hand, cultured larva and juvenile delta smelt up to 120 days post hatch are able to switch prey within two hours of exposure to zooplankton (L. Sullivan, Romberg Tiburon Center, San Francisco State University, unpublished data). Thus, marked delta smelt in CCF are not likely to have experienced starvation mortality within days from their release.

3) Unfavorable physical-hydrodynamic conditions within CCF: Although CCF cannot be considered a physically favorable area for delta smelt, the very high pre-screen loss experienced by adult delta smelt in March 2009 (Figure 5B, Table 2) a period of low

water temperatures, rule out temperature as the cause of high pre-screen loss. For juvenile delta smelt acclimated at 17 ^{o}C, Swanson and others (1998) reported 25.4 ^{o}C as the critical thermal maxima (loss of equilibrium endpoint). Based on our temperature controls for juvenile delta smelt initially acclimated to temperatures in the range of 20-22 ^{o}C (Figures 4A and 4B), cumulative exposure to peak daily ambient water temperatures above 27 ^{o}C could have significantly reduced juvenile survival. However, all recaptured juvenile fish released at the radial gate area in 2009 were recovered between June 23 and 25, in spite of the fact that most control juvenile fish were still alive by June 30 (Figures 3B, 4B). Temperature gradients in different areas of CFF, if large enough, could have potentially resulted in survival differences for delta smelt, irrespective of their origin (wild or cultured). It is conceivable that increased temperatures in CCF could have interacted synergistically with predation (e.g. by increasing prey vulnerability and/or predator activity). Whether the salvage of wild juvenile delta smelt observed at the SFF after our last recaptures of marked juveniles in 2008 and 2009 was due to newly, or previously, entrained fish is unknown.

The hydrodynamic characteristics of CCF can also reduce the likelihood that entrained delta smelt will be salvaged, particularly during low export conditions when residence times are longer. Based on simulated 3D water circulation patterns for CCF during June 2007 (M. MacWilliams and E. Gross, River Modeling, unpublished data), and drifter trajectory during our June 2008 experiments (C. Ruhl, U.S. Geological Survey, unpublished data) a basin wide counter-clockwise circulation in CCF seemed a persistent hydrodynamic feature. Conceivably, such a wind-driven circulation pattern in

combination with low exports could enhance dispersion and residence time of entrained fish within CCF, increasing the likelihood of pre-screen loss. On the other hand, during high export and low wind conditions, residence times in CCF are much shorter. Under such conditions most particles are transported roughly in a straight line trajectory from the radial gates to the Banks Pumping Plant (M. MacWilliams and E. Gross, River Modeling, unpublished data).

The observed low reservoir level and excessive aquatic vegetation in June 2009 could have contributed to increased mortality through lack of pelagic habitat and by reducing access to the salvage facility. Other potentially lethal conditions such as contaminants or reduced dissolved oxygen, if present, should have been also reflected in lower than observed juvenile control survival, making such mechanisms unlikely.

4) Emigration through CCF intakes: Emigration from CCF has been documented for radio-tagged striped bass (mean size: 431 mm FL, Gingras and McGee 1997) and steelhead (mean size: 217 mm FL, Clark and others 2009), two strong swimming species. Water velocity through the radial gates often exceeds 300 cm/s (Kano 1990) and approaches 400 cm/s at maximum CCF/Old River stage differential (Gingras 1997). In contrast, the critical swimming speed juvenile-adult delta smelt (40-60 mm SL) has been estimated to be 25-29 cm/s (Swanson and others 1998; 2000). Hence, potential emigration of delta smelt through the CCF intakes seems unlikely, except toward the end of the water intake period when water velocities become significantly reduced. In the case of steelhead, the effect of fish emigration through the radial gates was

estimated to result in a *PSL*= 78%, relative to *PSL*= 82% without accounting for emigration (Clark and others 2009).

5) Potential marking induced mortality: Based on the extremely high survival of control adult fish and the very high survival of juvenile marked fish at temperatures below 27°C, this scenario seems unlikely. Further, laboratory tests designed to evaluate striped bass predation on marked and unmarked delta smelt revealed no significant differences between marked (calcein and photonic marking) and unmarked delta smelt (G. Castillo, U.S. Fish & Wildlife Service, unpublished data). Moreover, those tests suggested no significant differences on predation among the photonic mark colors used in our field experiments.

6) Use of cultured fish: The extent to which potential differences between cultured and wild delta smelt may have affected our results is unknown. Predator avoidance in other species seems more developed in fish habituated to predators (e.g. Patten 1977; Healey and Reinhardt 1995; Alvarez and Nicieza 2003). Nevertheless, a mark-recapture test of field-collected juvenile Chinook salmon released in CCF in May 1996 resulted in only 0.32% of the fish being recovered at the SFF (J. Morinaka, California Department of Fish and Game, Stockton, unpublished data). Thus, results from other species and environments may not be safely extrapolated to our study, particularly if the habituated fish have not been recently exposed to predators in the wild.

Comparison of secondary louver efficiency at three different speeds between cultured and wild delta smelt revealed no significant differences (M. Bowen, U.S. Bureau of Reclamation, unpublished data). These results lend support to use of cultured delta smelt to approximate the behavior of wild fish to louver systems. On the other hand, the CHTR experiments revealed that wild delta smelt experienced higher levels of cortisol response and took longer to recover than cultured delta smelt (V. Afentoulis and A. Rockriver, California Department of Fish and Game, unpublished data). Therefore, cultured and wild delta smelt may differ in their physiological responses to human-induced stress.

7) Calculation Biases: Pre-screen losses were inferred from the number of recovered fish released at the radial gate area and from facility efficiencies. Facility efficiencies were estimated a few days before fish released in CCF were recovered at the SFF. Therefore, short-term changes in fish facility efficiency could have affected actual pre-screen loss. Yet, such estimation biases seem negligible when considering the relatively smaller contribution of facility losses relative to the pre-screen losses in CCF (Tables 1 and 2). Our estimated fish facility efficiencies also accounted for potential predation losses. Nevertheless, our results should reflect the prevailing facility efficiencies under normal operation conditions. Over the course of our experiments, CDWR operators continued conducting routine weekly removal of predators from the secondary channel. CDWR operators also continued searching for marked delta smelt in regular counts through the end of the salvage season.

Because we only considered fish recovered from the regular counts, total census and weekly secondary channel flush, subsequent salvage related losses due to the hauling, transport, and release fish in the Delta are not accounted for in our fish facility efficiency estimates. Additional losses could be inferred from the DFG CHTR Acute Mortality and Injury Study (Morinaka, In Press).

IV. Management Implications

Salvage of delta smelt at the SFF and the TFF is a practical tool for monitoring incidental take at the CVP and SWP (USFWS 2008a). The high variability and magnitude of pre-screen losses estimated from our mark-recapture suggest that improved quantification of delta smelt entrainment losses is justified and should be explored through additional field experiments, salvage data and other entrainment covariates. Such assessments could lead to improved entrainment models. Once the relations between pre-screen and facility losses and observed salvage have been better defined, then the estimation of overall survival estimates ranging from pre-screen losses to post-release survival of salvaged fish in the Delta could be attempted (e.g. NOAA Fisheries 2009).

Given the major declines of pre-adult delta smelt abundance indices in the Fall Midwater Trawl surveys (Messineo and others 2010), and in delta smelt salvage since the mid 2000’s (Aasen 2010), enhanced detection of entrained delta smelt could also

facilitate active adaptive management through improved evaluations on the effectiveness of flow management in the south Delta to control fish entrainment.

The decreased recovery of delta smelt as a function of increased residence time in CCF or distance from the SFF provides further rationale to suggested on-site options for reducing or eliminating prescreen losses in CCF. Namely: 1) removing predators from CCF (Tillman 1995); 2) export operational criteria to minimize exposure of entrained fish to predators within CCF (Gingras 1997) and 3) alternative configuration of the fish facility and intake channel (SDFFF 2003b). We consider the last option the most promising to greatly reduce or eliminate pre-screen loss in CCF while potentially providing greatly enhanced monitoring of entrained fish. Our results support Kano's (1990) conclusion that a reservoir preceding a fish screen system - such as CCF and SFF - increases the opportunity for fish predation and should be avoided. A number of preliminary designs to the SWP have been proposed to significantly reduce pre-screen losses in CCF (SDFFF 2003b, 2003c, Gingras and Mc Gee 1997) and to limit entrainment (Dorratcague and others 2009).

V. Future Entrainment Monitoring and Evaluations

Our results support the need for additional entrainment monitoring and evaluation of experimental methods to better interpret and validate relations between salvage statistics and the magnitude and variability of direct delta smelt losses in CCF. We recommend further studies to evaluate month-to-month pre-screen losses and fish facility efficiencies over the seasonal salvage periods for juvenile and adult delta smelt

under a variety of conditions in CCF (e.g. exports residence time, turbidity, temperature, wind speed) . Comparison of pre-screen loss estimates between cultured and wild delta smelt - or between cultured delta smelt habituated and not habituated to predators - could be further considered. Such studies would be useful to further quantify the extent to which additional entrained fish into CCF could be salvaged by manipulating CCF residence time, exports and SFF operations. However, initial analyses could be readily performed by integrating our results and those of MacWilliams and Gross (River Modeling, unpublished data) with previous studies (Gingras 1997; Clark and others 2009).

We further recommend modeling population-level effects of entrainment based on separate empirically derived entrainment estimates for the SWP and CVP, coupled with further estimates of population size and near-field and far-field water project related losses. Additional studies are critically needed to enhance the larval fish sampling at the SWP and CVP to quantify the loss of delta smelt larvae. Moreover, the long-term survival of salvaged delta smelt following their release in the Delta remains an important question.

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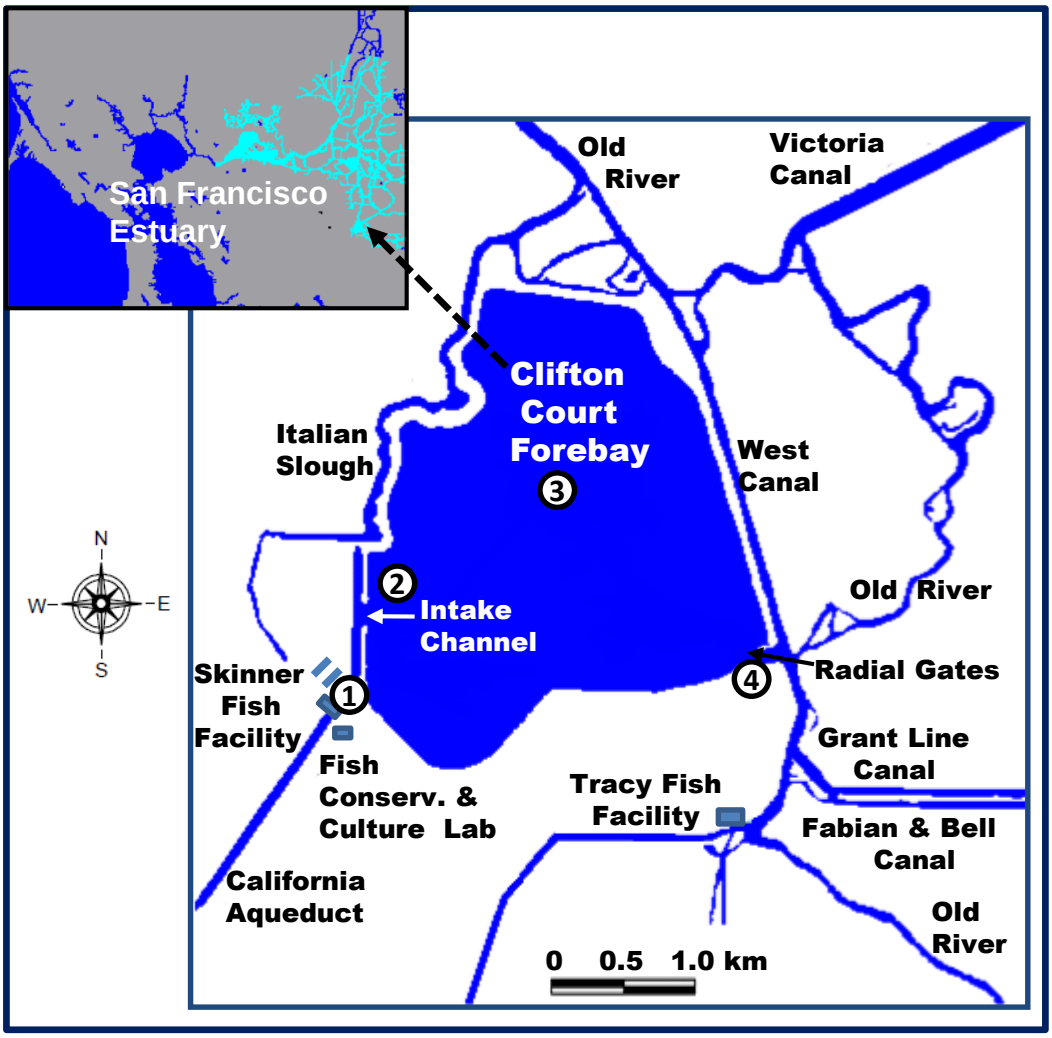

Figure 1. Location of Clifton Court Forebay, the John E. Skinner Delta Fish Protective Facility (SFF) in the south Delta of the upper San Francisco Estuary. Locations denoted by numbers are release sites: 1) trash rack upstream of primary louvers; 2) west side of Clifton Court Forebay; 3) center of Clifton Court Forebay and 4) radial gate area. Light color in the upper San Francisco Estuary denotes the general distribution of delta smelt (adapted from DFG-IEP).

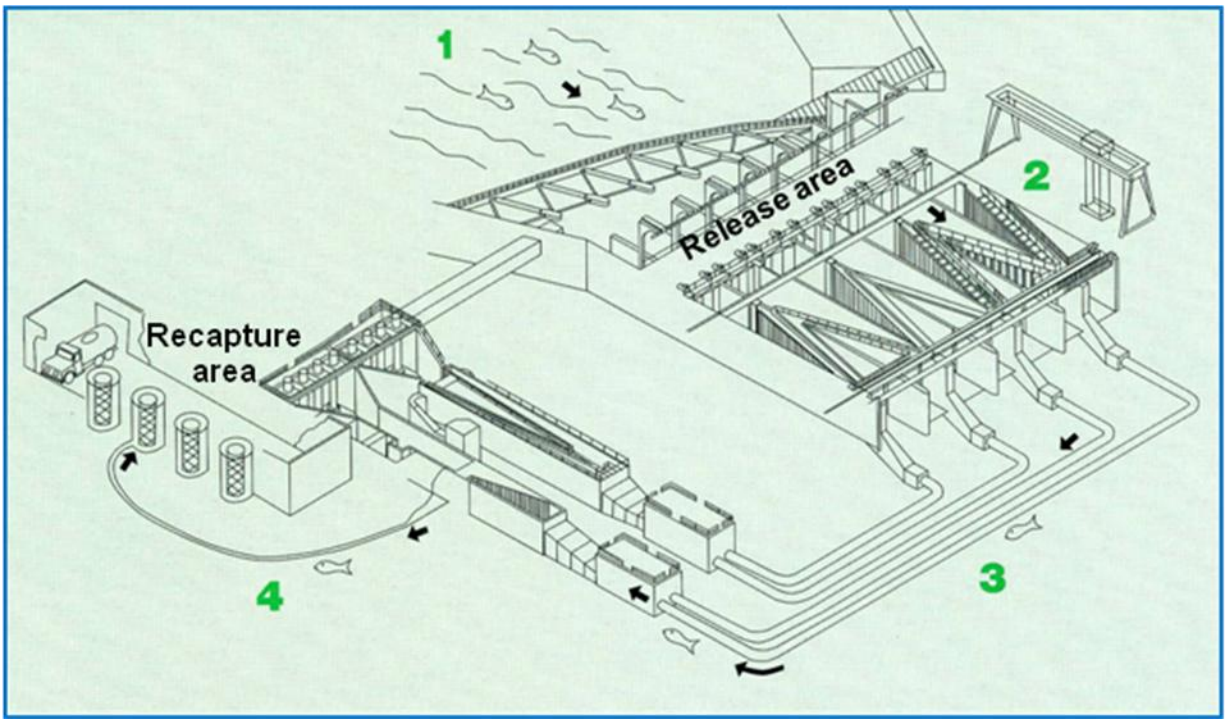

Figure 2. Schematic of the Skinner Fish Protective Facility (SFF) and passageway for salvaged fish showing release and recapture areas for marked delta smelt: 1) intake channel from Clifton Court Forebay ; 2) primary louvers; 3) bypass pipes toward the secondary louvers/screens; 4) holding tanks where fish are collected. Recapture area only shows holding tanks for the old building (Adapted from CDWR).

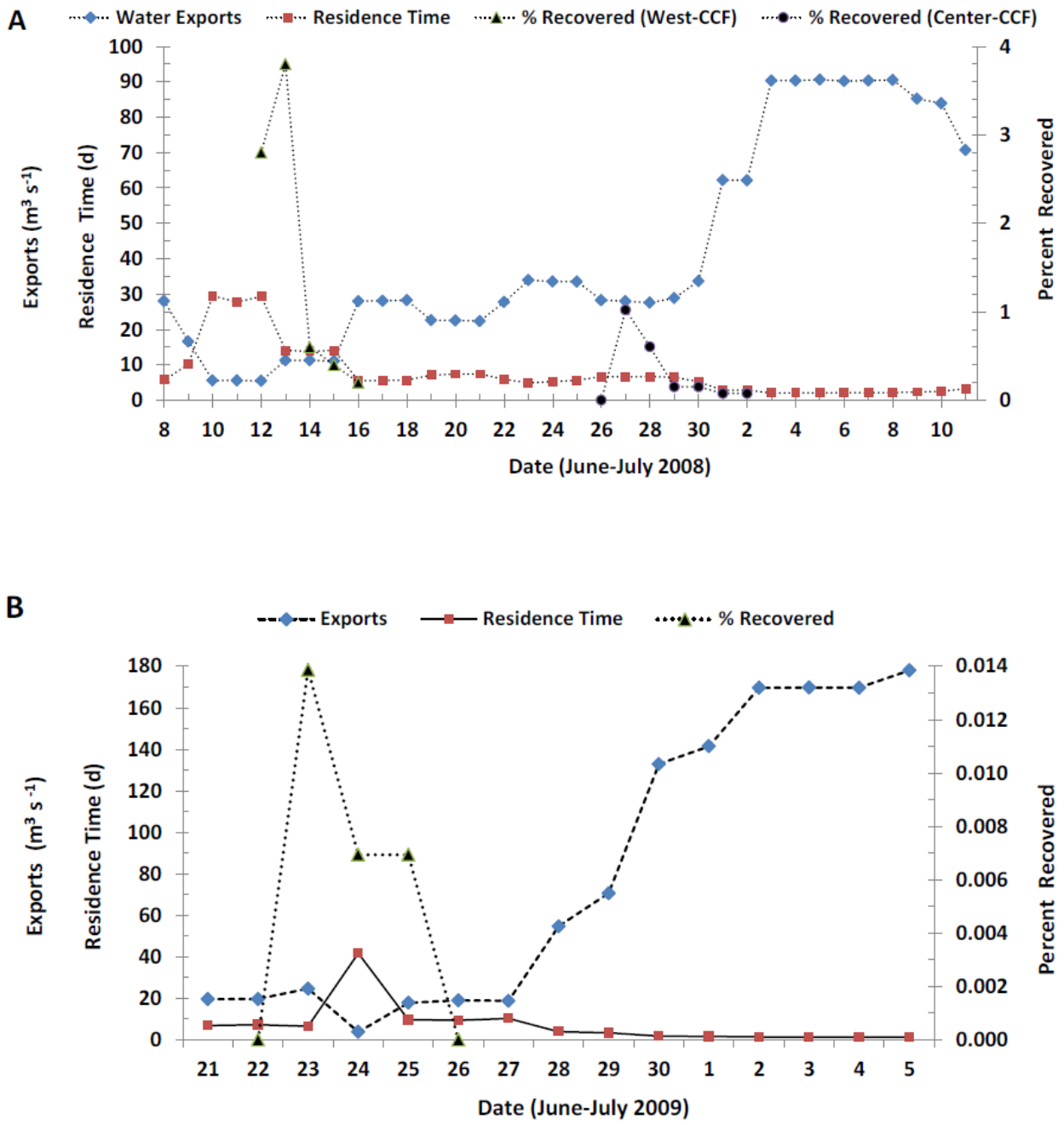

Figure 3. Daily water exports and residence time in Clifton Court Forebay in relation to the percent of calcein-marked juvenile delta smelt recovered at the Skinner Fish Facility: (**A**) Two groups of fish released in the west (n = 500 fish, June 12, 2008) and the center of Clifton Court Forebay (n = 2,647 fish, June 26, 2008). (**B**) One group of fish released in the radial gate area of Clifton Court Forebay (n= 14,413, June 22, 2009).

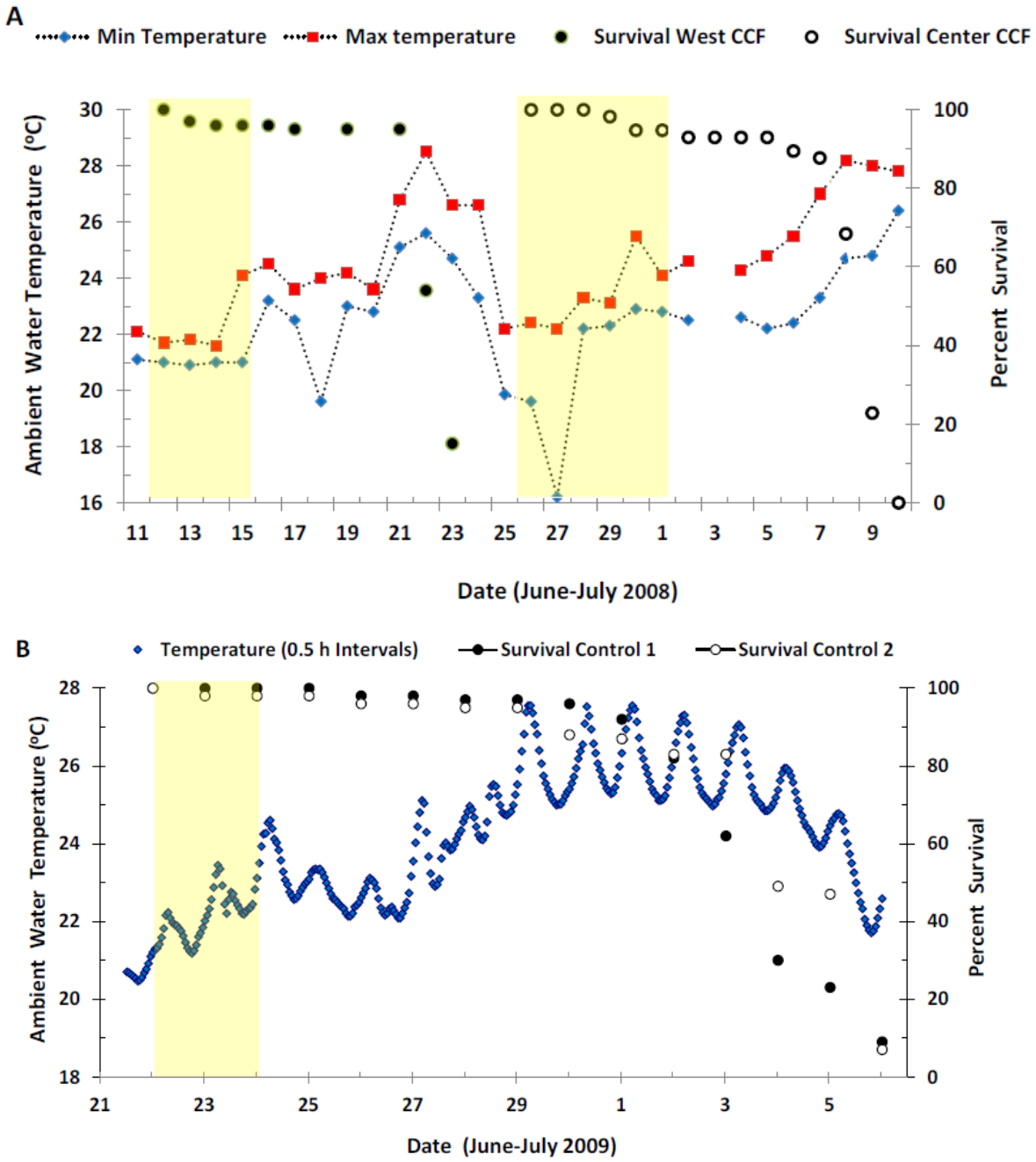

Figure 4. Daily survival of calcein marked juvenile delta smelt controls exposed to ambient water temperature: (**A**) Controls for releases conducted in the west and center of Clifton Court Forebay on June12 and 26, 2008. (**B**) Controls for the releases conducted in the east side of Clifton Court Forebay (radial gate area) on June 22, 2009. Bars denote the period between each field release and the last recapture. Initial number of fish per control was 100 at the time of releases in CCF.

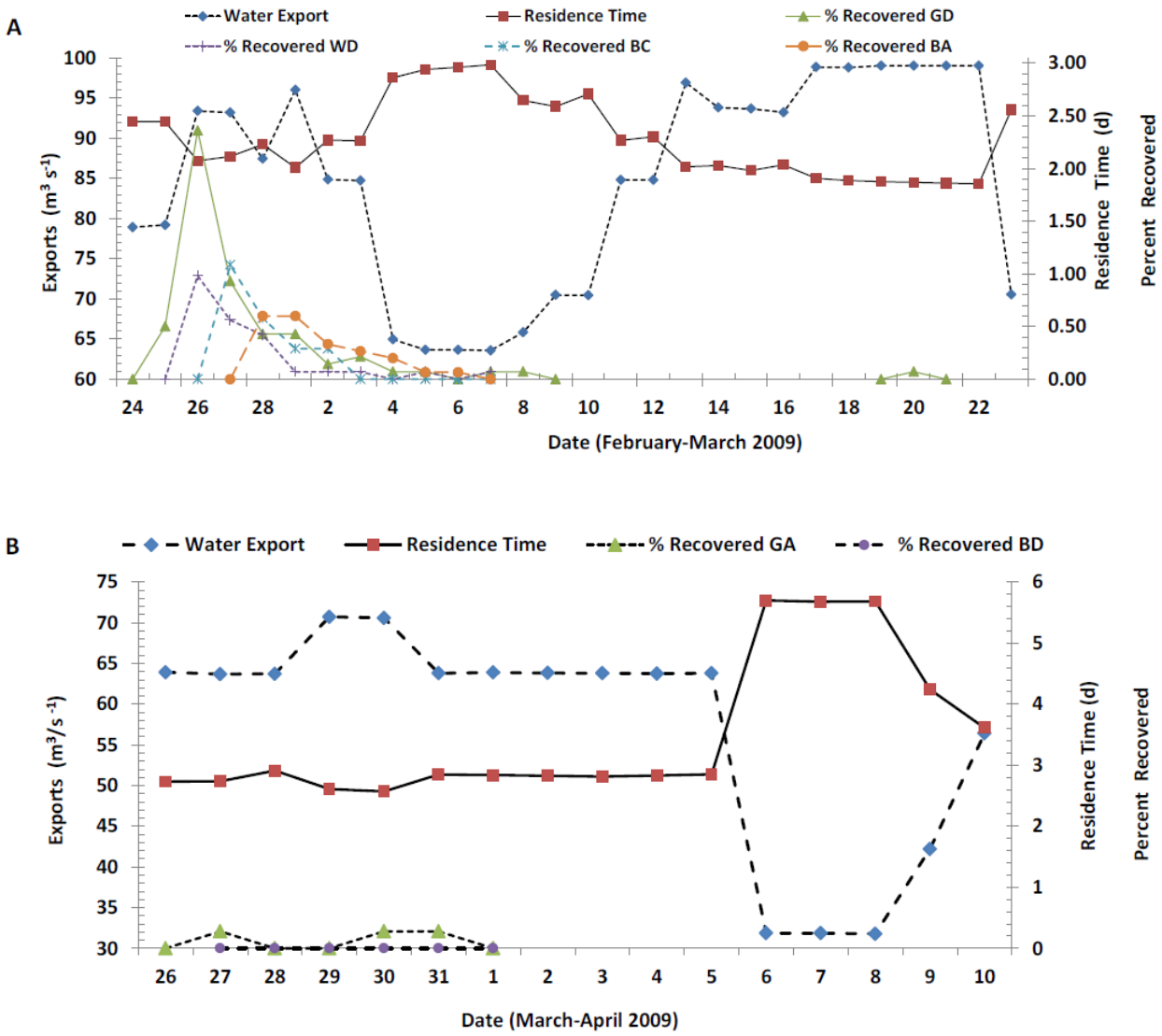

Figure 5. Daily water exports and residence time in Clifton Court Forebay in relation to the percent of recovered calcein- and photonically-marked adult delta smelt released in the radial gate area of Clifton Court Forebay: (**A**) Four fish groups released on February 24-27, 2009. (**B**) Two fish groups released on March, 26-27, 2009. Photonic mark codes are shown in Table 2.

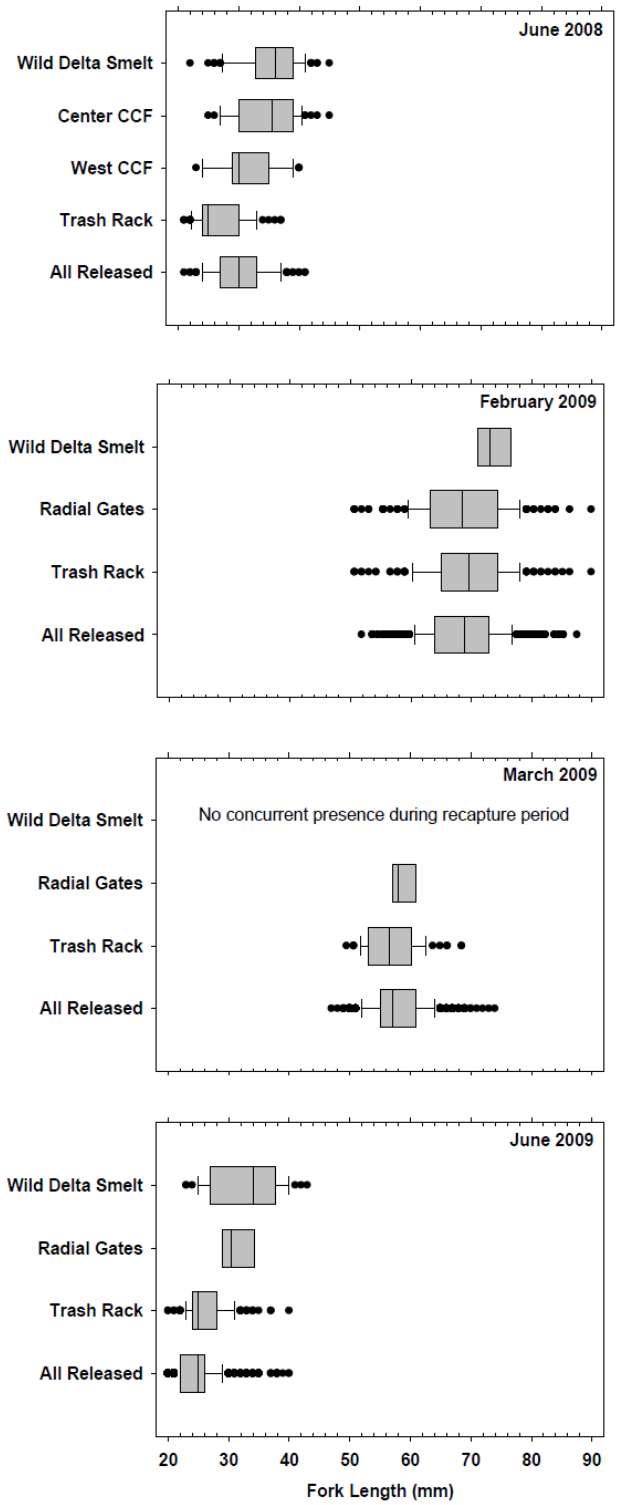

Figure 6. Size composition of marked (cultured) and unmarked (wild) delta smelt concurrently collected at the Skinner Fish Facility during mark-recapture experiments in June 2008 and 2009 (juveniles) and in February and March 2009 (adults). Size composition prior to releases is denoted as all released.

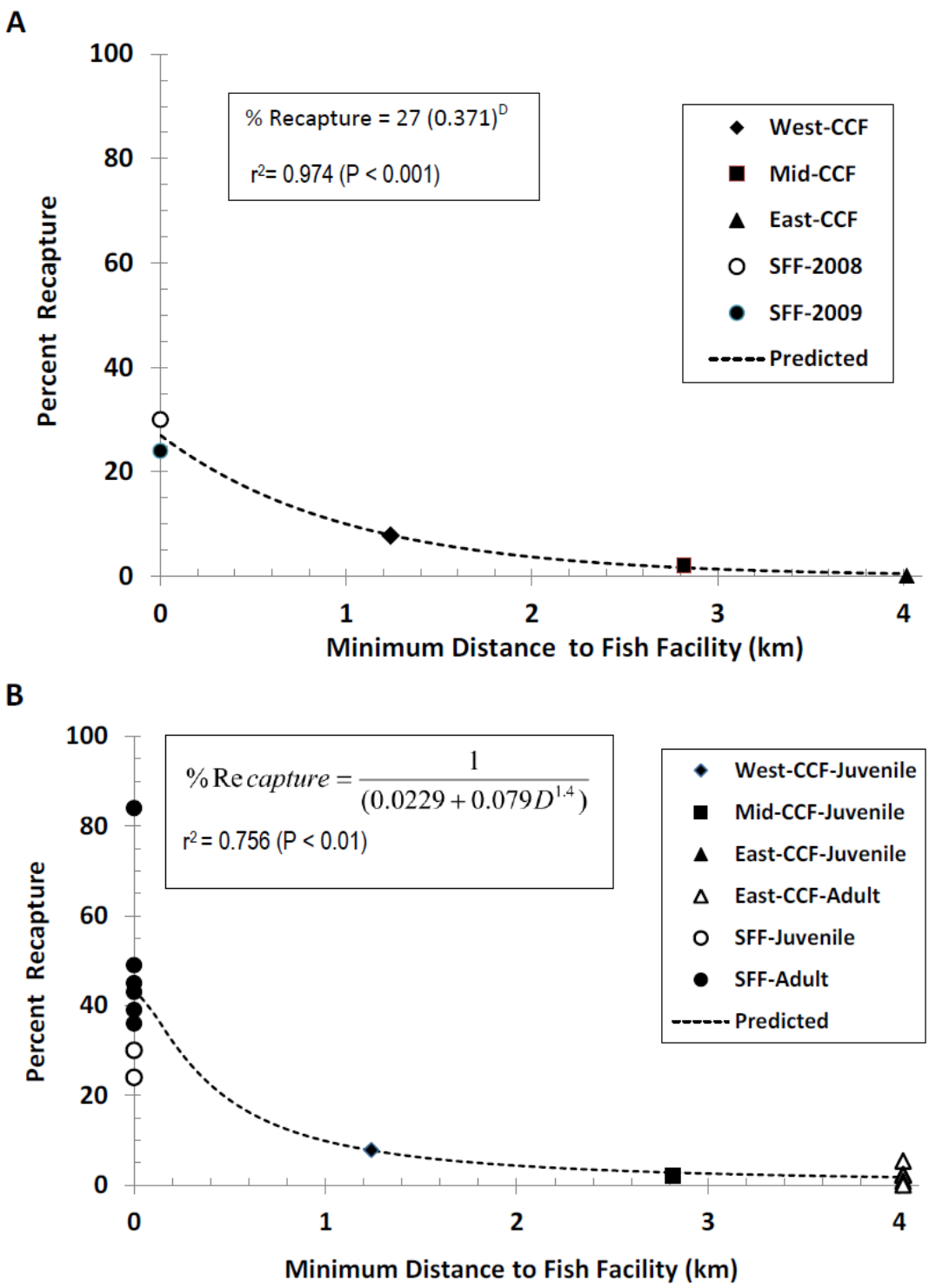

Figure 7. Percent of recaptured delta smelt at the Skinner Fish Facility as a function of the minimum distance (D) from each release site to the Skinner Fish Facility: (**A)** Juvenile delta smelt. (**B)** Combined juvenile and adult delta smelt.

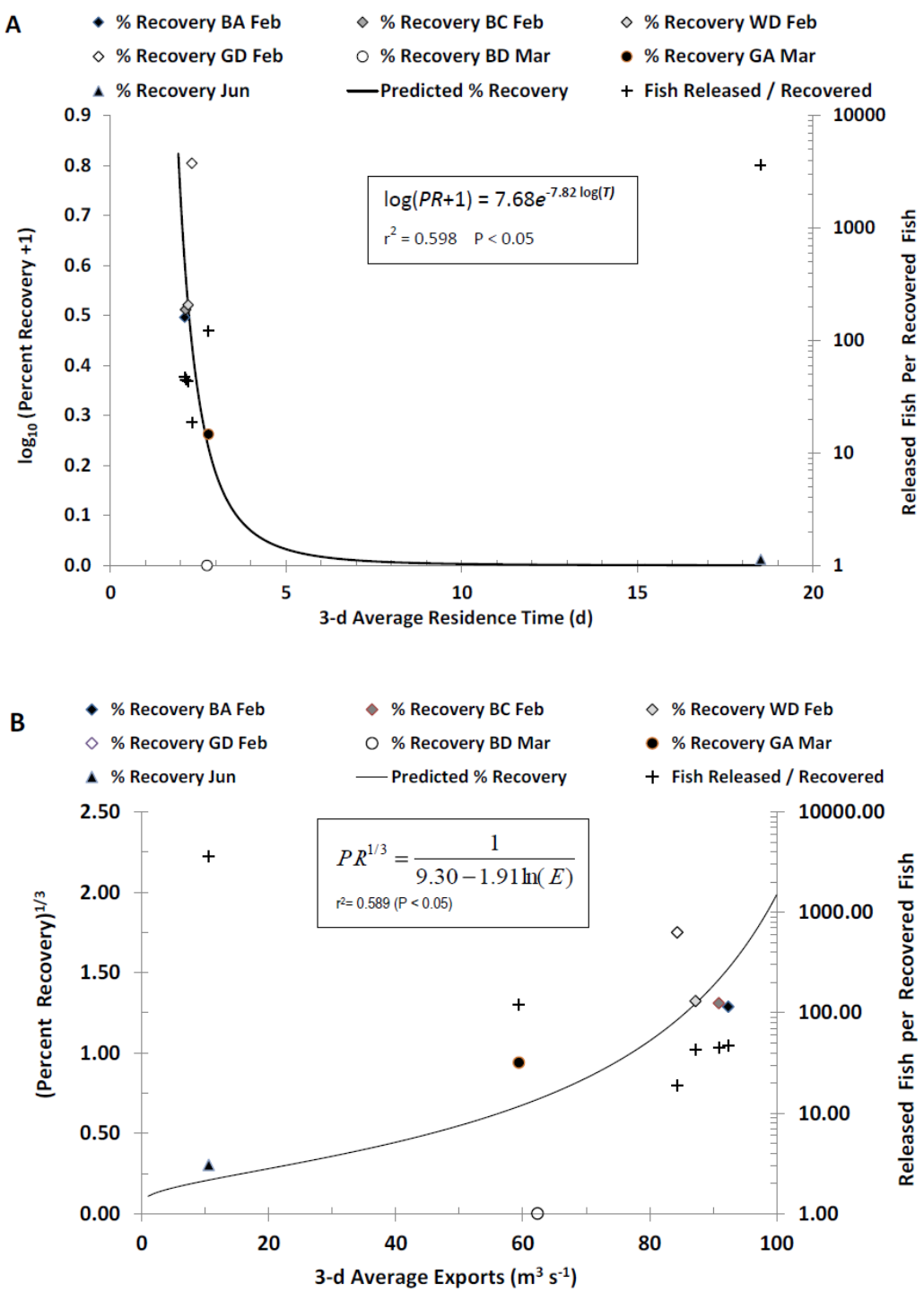

Figure 8. Observed and predicted percent recovery of delta smelt ($\log_{10}$ or cube-root transformed) as a function of: (**A**) residence time and (**B**) exports for releases conducted from February to June 2009. The total number of released fish per recaptured fish is indicated in the right axis (excluding the BD group released in March in which no fish were recovered).

Table 1. Delta smelt released and recaptured at the Skinner Fish Facility, south Delta, in February (adults), March (adults) and June 2008-2009 (juveniles) and concurrent mark-recapture results and hydrodynamic conditions.

Experiment	Mark [a]	Release Date	Mean Daily Export ($m\ s^{-1}$)	Channel Velocity [b] ($m\ s^{-1}$)	Primary Bypass Ratio	Secondary Bypass Ratio Old Bldg	Secondary Bypass Ratio New Bldg	Fish Released (n)	Fish Recaptured [c] (n)	Facility Efficiency
SFF1	G-A/D	2/23/09	82.0	1.00	1.22	1.24	0.61	100	39	39
SFF1	W-A/D	2/23/09	82.0	1.00	1.22	1.24	0.61	100	36	36
SFF1	B-C/D	2/23/09	82.0	1.00	1.22	1.24	0.61	100	89	89
SFF1	B-A/D	2/23/09	82.0	1.00	1.22	1.24	0.61	100	49	49
SFF2	G-A	3/23/09	70.7	0.94	1.19	1.21	N/A	100	43	43
SFF2	B-D	3/23/09	70.7	0.91	1.22	1.21	N/A	100	45	45
SFF0	Calcein	6/04/08	64.0	0.52	1.19	1.21	N/A	200	60	30
SFF3	Calcein	6/19/09	16.1	0.40	1.22	N/A	1.18	800	193	24

[a] Photonic marks: first letter denotes mark colors: B, G, W (blue, green, white). Second and third letters denote marked fins per fish: A, C, D (anal, caudal, dorsal). All juvenile and adults were calcein marked.

[b] Average channel velocities upstream of louvers at the time of fish releases.

[c] Total time from release to the last recaptured fish < 24 hr.

Table 2. Delta smelt released in Clifton Court Forebay and recovered at the Skinner Fish Facility, south Delta in February (adults), March (adults) and June 2008-2009 (juveniles) and concurrent recapture results and hydrodynamic conditions.

Experiment	Mark [a]	Date of Release	Recapture Period [b] (d)	Mean Daily Export [c] (m s^{-1})	Residence Time [c] (d)	Fish Released (n)	Fish Recaptured (n)	Percent Recovery	Pre-Screen Loss
RG1	G-D	2/24/09	24	83.4	2.36	1398	75	5.36	89.9
RG1	W-D	2/25/09	10	81.6	2.42	1426	33	2.31	95.6
RG1	B-C	2/26/09	4	79.9	2.47	1382	31	2.24	95.8
RG1	B-A	2/27/09	7	78.7	2.53	1501	32	2.13	96.0
RG2	G-A	3/26/09	5	63.2	2.77	1447	12	0.83	98.1
RG2	B-D	3/27/09	-	63.0	2.78	1402	0	0.00	100
West-CCF	Calcein	6/12/08	5	19.1	8.63	500	39	7.80	-
Mid-CCF	Calcein	6/26/08	7	54.2	3.89	2647	55	2.08	-
RG3	Calcein	6/22/09	3	27.1	9.54	14413	4	0.03	99.9

[a] Photonic marks: first letter denotes mark colors: B, G, W (blue, green, white). Second letter denotes marked fins per fish: A, C, D (anal, caudal, dorsal). All juvenile and adults were calcein marked.

[b] Days from release to last recapture.

[c] Daily mean over 10 days post-release.

APPENDIX

Computation of Primary and Secondary Bypass Ratios:

Primary Bypass Ratio Calculations

$$\textbf{Primary flow per bay} = \frac{\text{Primary channel flow}}{\text{No. of bays in use}}$$

$$\textbf{Primary channel approach velocity} = \frac{\text{(Secondary channel flow)}}{\text{(Primary channel depth x Width of 2 primary bypass openings)}}$$

$$\textbf{Water velocity at primary bypass opening} = \frac{\text{(Primary flow per bay x No. bays in use)}}{\text{(Total width of primary bays in use x Primary channel depth)}}$$

$$\textbf{Primary bypass ratio} = \frac{\text{(Water velocity at primary bypass opening)}}{\text{(Primary channel approach velocity)}}$$

Secondary Bypass Ratio Calculations

$$\textbf{Secondary channel approach velocity} = \frac{\text{(Secondary channel flow)}}{\text{(Width of secondary channel x Secondary channel depth)}}$$

$$\textbf{Water velocity at secondary bypass opening} = \frac{\text{(Flow into the holding tank building)}}{\text{(Secondary channel depth x Width of secondary bypass opening(s))}}$$

$$\textbf{Secondary bypass ratio} = \frac{\text{(Water velocity at secondary bypass opening)}}{\text{(Secondary channel approach velocity)}}$$

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Modeling Delta Smelt Losses at the South Delta Export Facilities

Wim J. Kimmerer[1]

ABSTRACT

I previously estimated proportional losses of delta smelt to the water export facilities in the south Delta (Kimmerer 2008). This note is in response to Miller (2010), who disputes these estimated losses on several grounds. A re-analysis using a better analytical approach suggests a slight downward revision of the previous estimates for adult smelt. The distribution of smelt seems to have shifted northward in the last few years; if so, the smelt may now be less vulnerable to export losses than they previously were, although the reasons for such a shift are a concern. I argue, however, that it is legitimate to attempt such estimates in the absence of perfect information, and that mechanistic analyses are a valid way of estimating population-level impacts even in the absence of statistically significant correlations of estimated impact with subsequent population size.

KEYWORDS

delta smelt, *Hypomesus transpacificus*, management, water diversions, population ecology

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INTRODUCTION

I previously calculated proportional losses of delta smelt (*Hypomesus transpacificus*) to the water export facilities in the south Delta (Kimmerer 2008). Here I respond to Miller (2010), who presents analyses to show that my estimates of proportional losses were overstated. Miller raises some valid points but misinterprets some of my original analyses, and offers comments that cannot be addressed with available information. His critique also raises, albeit indirectly, two important general issues for quantitatively estimating the impacts of human activities: (1) how such estimates can and should be made in the absence of complete information; and (2) the nature of evidence useful in quantifying these impacts. I first discuss Miller's more specific comments, and then return to these broader issues.

Kimmerer (2008) calculated proportional losses during times when delta smelt are captured in substantial numbers at the fish salvage facilities, i.e., roughly January to March for adults and March to June for larvae and juveniles. The proportional losses for each life stage were estimated using a rather complex procedure to determine inputs to a survival model (modified from Equation 12 in Kimmerer 2008):

$$P_L = 1 - \prod_{d=1}^{D}\left(1 - \frac{\Phi_d}{N_d}\right) \quad (1)$$

where P_L is the proportional loss during the season of vulnerability, that is, the decrement in the population by the end of the season attributable to export pumping. D is the number of days in that season, N_d is the population size on each day, and Φ_d is the daily loss to the fish facilities, including pre-screen mortality and assuming no successful salvage. Note that this formulation ignores mortality not attributable to export pumping, which was taken into account in the original analysis (see below).

To clarify Miller's arguments and my responses, I consider the following components of these calculations: (1) efficacy of the sampling programs used to estimate model inputs; (2) estimating the number of fish lost to entrainment per day Φ_d; (3) estimating the population size N_d; and (4) accumulating daily loss over the season of vulnerability.

EFFICACY OF SAMPLING

Sampling for fish involves numerous assumptions about their distribution and about the efficiency of the sampling gear used in relation to the particular species and size of fish collected (Rozas and Minello 1997). Generally, in any sampling process, the confidence limits around the estimate being made decrease as the number collected increases. Thus, very small catches do not invalidate a sampling effort, but the results are more uncertain than with large samples.

Three sets of sampling data were used in the original analysis. The Kodiak trawl survey of adults is considered to be an effective method that is roughly 100% efficient for fish in the channels. The 20–mm survey of larval and juvenile fish is most efficient for fish larger than 20mm, but less so for smaller fish. Kimmerer (2008, Equation 20) used a logistic model to correct catches for low gear efficiency for smaller fish. This model is based on the fact that surviving fish must grow through all size classes, and that therefore the abundance of the poorly sampled smaller sizes is constrained by the abundance of larger sizes. The principal assumption of the logistic model was that parameters of the model were constant *within* years but could vary *among* years. Statistical error in fitting the model contributed to rather large uncertainties in proportional losses, as much as a three-fold uncertainty in the relative abundance of the smallest (5 mm) size class. This error was propagated through subsequent analyses of proportional losses.

Miller argues that low catches of smaller fish in the 20–mm survey should not be scaled up using catch-efficiency curves. This is equivalent to saying that gear efficiency cannot be determined for small fish, and implies that the numbers in each size class must be determined independently of those in other size classes. However, he offers no argument why the logistic function cannot be used to estimate abundance of all size classes, how the larger fish might have arisen except by growth of the smaller ones, or what is wrong with providing estimates based on small catches if confidence limits are included. Furthermore, he labels as "unreliable" data from some 20–mm stations with zero catch, without an adequate explanation of why such data should be considered unreliable; 73% of the 20–mm tows from 1995 through 2005 had no delta smelt, but these contribute to the calculations of means and other population parameters.

The south Delta fish facilities sample far more volume and capture larger numbers of fish than the field surveys, but capture efficiency—the ratio of salvage to entrainment—is low and variable. Delta smelt are unlikely to be guided by the louvers, which were designed for and are most efficient for salmon (Bowen and others 2004). Mark–recapture studies with adult delta smelt gave an average 24% recovery of fish at the federal fish facility that had been released in front of the primary louvers. Castillo and others (2009) conducted a mark–recapture study of delta smelt in Clifton Court Forebay and concluded that pre-screen mortality presumably from predation was the largest source of mortality for fish entrained in the forebay, and likely much larger than for other studied fish such as salmon. These studies provide limited support, though not quantitative information, for the low capture efficiency of the salvage facilities.

Kimmerer (2008) found that catch per volume of water sampled differed between the two salvage

facilities on a daily basis, but that the overall mean differences were very small. This was the basis for using the same salvage efficiencies for both facilities. The salvage values are useful for indicating the timing and relative magnitude of entrainment events, but underestimate entrainment and mortality of delta smelt many-fold as discussed above. Without calibration to field data, salvage is not a useful proxy for mortality.

Miller reports a lack of correlation between salvage of young delta smelt and estimated flux to the pumps, concluding from this lack of relationship that the calculated flux is biased upward. The reason for this putative bias is not really explained. Three factors interfere with such a correlation: (1) the low and variable efficiency of the salvage facilities, (2) the high variability and small number of samples per survey (six) used in calculating the flux (see below), and (3) the distance from the sampling stations to the export facilities. None of these should introduce bias. I previously showed that the south Delta catches and salvage during springs of 4 years matched reasonably well in timing and magnitude but with a lot of error, and a low but non-zero correlation (Figure 7 in Kimmerer 2008). Thus, there is evidence for substantial statistical error but not for bias.

ESTIMATES OF FISH FLUX

The flux or entrainment of fish toward the salvage facilities Φ_d comprises three factors: pre-screen mortality, losses through the louvers, and salvage. Because salvage is likely a small fraction of entrainment (see above), it gives a poor estimate of Φ_d, which must therefore be determined using other information, such as the density and rate of movement of fish in the waterways leading to the fish facilities.

The basis for such calculations (not spelled out by Kimmerer 2008) is a simple hydrodynamic flux calculation for a channel:

$$\Phi_C = A\left[(U + U_s)C - (K_h + K_s)\frac{dC}{dx}\right] \qquad (2)$$

where Φ_C is the flux of a substance or particles with concentration C, A is cross-sectional area of a channel, U is water velocity, U_s is additional velocity of C (e.g., due to swimming in the positive x direction), K_h is a horizontal dispersion coefficient, K_s is an additional dispersion coefficient due to randomly directed swimming, and the last term is the longitudinal gradient in C. If the gradient is small and the particles are passive, the flux is simply $AU_C = Q_C$, where Q is the volume flow rate. Kimmerer (2008) used this to calculate the flux of young smelt with Q represented by the southward net flow in Old and Middle rivers and C by the catch per unit volume at six 20–mm stations in the south Delta. This calculation was not possible for adults because of low (often zero) catches, so the catches were used to calibrate salvage density (fish per unit volume of water) to catch per volume in the Kodiak trawl, and this calibration factor was applied to all salvage data to estimate flux.

Miller argues that since fish are not passive particles this calculation is invalid, but offers no alternative way to compute the fish flux. Larval fish have very limited swimming abilities and are essentially passive particles before they obtain a swim bladder, after which they can affect their position only through vertical migration. Tidal vertical migrations were found in pelagic fish larvae in the low-salinity zone but the sample size for delta smelt was small, and migration was not detected (Bennett and others 2002). Even the fish and copepods that demonstrably migrate tidally can overcome net seaward flow only in water that is stratified in salinity (Kimmerer and others 1998), which is not the case in the south Delta. The smelt that leave freshwater in early summer are post-larvae over 20mm long with developed swim bladders and initial distribution near the surface (also in the low-salinity zone, Bennett and others 2002). If this behavior applied in freshwater it would move most of the population westward to their brackish rearing habitat except those in the south Delta, which would move toward the pumps. Thus, during spring they can be treated as passive particles at the scale of the south Delta, and Equation 2 applies to these fish. Miller's argument implies that the fish are somehow escaping the

southward flow of Old and Middle rivers, but there is no evidence that they are capable of doing that, nor do environmental cues exist that would persuade them to orient away from the export facilities.

Adult smelt move up-estuary during their spawning migration and are, therefore, demonstrably capable of moving against the net downstream flow in the Delta. However, high salvage numbers indicate the existence of a large southward flux of adults. I calculated an efficiency Θ (Equations 16 and 17 in Kimmerer 2008) relating salvage to the estimated fish flux based on the Kodiak trawl samples in the south Delta, and applied that to salvage to get the fish flux for all days of the season.

Miller argues on several grounds that Θ was overestimated. The most cogent argument is that there were too many zeros in the data to use a Poisson model to fit the data. I therefore re-fit the model in Equation 17 (Kimmerer 2008) with a zero-inflated Poisson model (Lambert 1992) which has two parameters; the Poisson mean and the proportion of excess zeros. This model was fit using a Bayesian approach in WinBUGS (Lunn and others 2004) using fitting and model checking procedures in Kimmerer and Gould (2010). The resulting estimate of Θ was 22 with a 95% credible interval of 13 to 33. This estimate is about 76% of the previous estimate but with better resolution. Estimates of mean adult loss in Kimmerer (2008) should, therefore, be reduced by 24%. Miller also argues that the data are contaminated by a single high catch of 17 fish. This might be true if the model were improperly cast as a linear regression, but for a properly formulated model it poses no problem. In any case, the analysis should be based on the data at hand.

Miller also argues that the adults are not passive particles, implying that they can overcome the effects of net flow in the south Delta. That is, the term U_s in Equation 2 may be negative, reducing the actual fish flux Φ_C. In that case salvage would be lower than expected if U_s were zero, and the effect of a negative U_s would be accounted for in the calculation of Θ.

According to Miller, Old and Middle river flows are unrelated to salvage of either adult or young delta smelt and therefore are insufficient for calculation of fish flux. The relationship between these flows and salvage is actually quite obvious, if nonlinear and noisy (Figure 4 in Kimmerer 2008): when these rivers flow southward, salvage is often high, and when they flow northward, salvage is either mostly zero (juveniles, adults in the state facility) or sometimes non-zero (adults for the federal facility only). The latter case is likely due to U_s in Equation 2 being positive for some fish, i.e., toward the export facilities. Thus, while the fish are not entirely behaving as passive particles, their behavior is not necessarily oriented to take them away from the facilities.

The calculations of proportional losses of young smelt were remarkably consonant with predictions made using the DSM2 particle tracking model (Figure 16 in Kimmerer 2008). This supports the use of Old and Middle River flows for the calculations, and the assumption of passive transport for this life stage. Furthermore, the estimate of Θ above is, if anything, low—considering the estimates to date of pre-screen losses and losses through the louvers.

Delta smelt are more abundant where the water is turbid (Feyrer and others 2007) and, therefore, salvage and salvage-related losses should be more predictable using information about turbidity than without this information. This issue arose after I had finished the final draft of the 2008 paper, but, in any case, turbidity data for the south Delta were not available for the time–period of this study. Ignoring it introduces error in the calculations but there is no reason to expect bias, since all the calculations were based either on salvage (adults) or fish collected in the south Delta (juveniles).

SIZE OF THE POPULATION

The denominator in Equation 1 is essentially the mean catch in all samples times the volume over which those samples were taken. An alternative is to calculate mean catch per trawl by region of the estuary, multiply by area or volume of each region, and sum the result to get an index of abundance. The assumptions underlying these two approaches are somewhat different, but there are no data to suggest one is superior to the other. The annual abundance indices in several monitoring programs are calcu-

lated by region, but simple mean catch per trawl over all stations is closely correlated to these indices (Kimmerer and Nobriga 2005). Thus Miller's calculations of population size using a region–by–region approach are unlikely to be much different from the simpler calculation in Kimmerer (2008).

The fish fluxes Φ were calculated so that efficiency of the sampling gears was factored out of Equation 1. Therefore, the remaining issue for this part of the calculation is whether the samples in the south Delta represented the population there to the same degree that sampling throughout the Delta represented the overall population. Catchability is unlikely to differ between the south Delta and elsewhere (and we have no data either way on this), so the degree of representation boils down to whether the spatial coverage of sampling is adequate to represent the population.

Miller argues the contrary on the basis that high catches of adults in the Sacramento River Deep Water Ship Channel (sampled beginning in February 2005) indicate that most of the fish are in that region and are, therefore, under-sampled. Most of my analyses were for earlier years; furthermore, most of the salvage occurred between mid-December and the end of February (Figure 11 in Kimmerer 2008), when relatively few fish are yet in the north Delta (Figure 1). It does appear that more adults are in the north Delta during more recent years, mainly in the later surveys.

Miller makes a similar argument for young fish, although the argument is muddied by a claim that the 20–mm survey collects too few fish to provide a reliable index of total population size, based on projections of abundance of young fish from calculated abundance and assumed reproductive success of adults. If this were true it would call into question the results of all sampling programs. The stronger part of Miller's argument is the same as for adults: i.e., that a greater proportion of the population is in the north Delta and that it has been under-sampled. The data show an increasing proportion of the total catch in the north Delta stations (Figure 2) as the total catch has decreased. However, that proportion was never more than 8% during the period of this study.

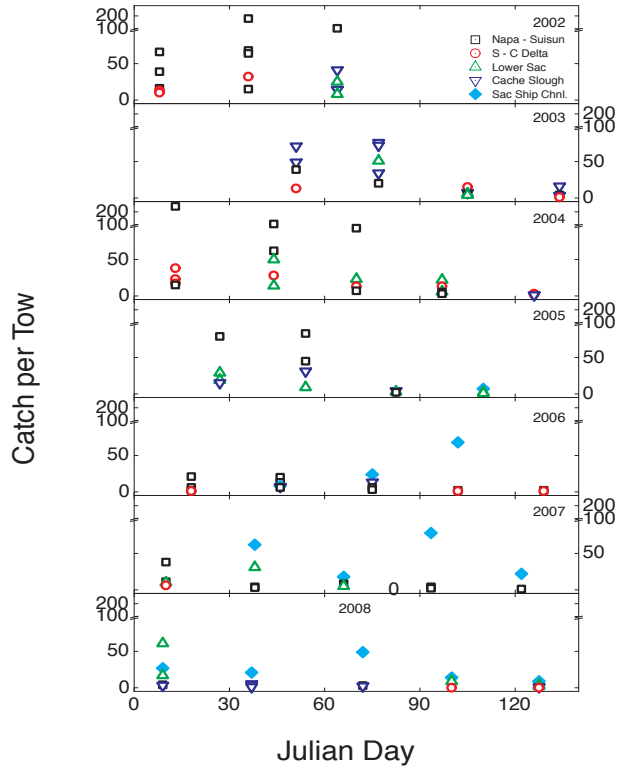

Figure 1 Delta smelt catch per tow in the Spring Kodiak trawl survey for the five stations with the highest catches during each month's sampling, by year. These stations made up at least 62% of the total catch of the respective surveys. Symbols indicate sampling regions, with stations included as follows: Napa–Suisun: stations <699 plus 801; South–Central Delta: 802 to 999; Lower Sacramento River: 704 to 707; Cache Slough area: 711 to 716; and Sacramento Ship Channel: 719, sampled beginning February 2005.

The apparent northward shift in distribution of adult and young smelt means that the exposure of the delta smelt population to export pumping is less in recent years than it was during the time period of my study. Although this might be considered a benefit, conceivable mechanisms for this shift are not promising for the long–term maintenance of the species. One possible such mechanism is that the south Delta is occupied less by delta smelt because of a degradation of the habitat (e.g., by increasing water clarity). The implications of that for proportional losses to exports would depend on the mechanism keeping abundance low in the south Delta, which are not yet known.

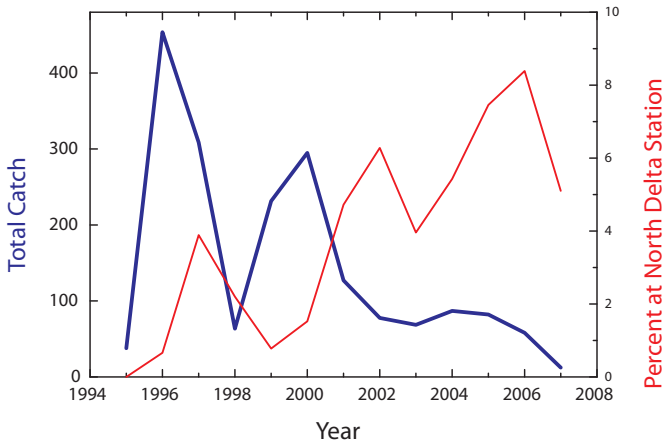

Figure 2 Delta smelt catch in the 20–mm survey. Heavy blue line, left axis: total catch in all samples; thin red line, right axis: percent of catch from Station 716 in Cache Slough in the north Delta. Note that catches at Station 719 in the Sacramento River Deep Water Ship Channel have been high since sampling at this station began in 2008, but there is no information on whether this is a sampling artifact or a result of smelt movement.

ACCUMULATING LOSSES OVER THE SEASON

Accumulating losses means calculating the proportional difference between the population that would have existed at the end of the exposure season with and without export losses. This requires that the relative size of the vulnerable population and other mortality be taken into account. For example, a high daily fractional loss early in spring when few young fish had hatched will have a smaller effect on ultimate population size than a high loss after all the fish had hatched.

Equation 1 could be parsed in a number of different ways, but the end result would not be very different using the same values of the fractional loss terms. The calculations are made a bit more difficult by the need to account for natural mortality of juveniles, as explained by Kimmerer (2008). Leaving mortality out of the calculations results in a modest increase in the calculated seasonal losses (Figure 15 in Kimmerer 2008). Although Miller argues that mortality is unlikely to be constant in space or time, the effects of such undeniable but unmeasured variability cannot, therefore, be very large. Since losses of larvae and juveniles were based on catches in the south Delta rather than salvage, an excess of mortality in the south Delta relative to the entire habitat would bias the loss estimates low, not high as Miller claims.

ALTERNATIVE APPROACHES TO ESTIMATING EXPORT EFFECTS

To date, nobody has reported a relationship between any measure of flow toward the export pumps or losses of delta smelt, and either subsequent population abundance indices or ratios of successive indices. Miller argues that this lack of statistical link to population estimates is evidence that losses calculated mechanistically are unimportant compared to other effects such as food limitation.

This is part of a broader issue: the nature of evidence to be used in estimating the magnitude of human impacts on a biological population. Fundamentally, such impacts can be estimated through correlative measures, or they can be determined mechanistically. I do not believe that Miller is arguing against the use of mechanistic approaches (as some have done), since far more of our current scientific understanding in most fields of science rests on mechanistic than on correlative analyses.

Mechanistic approaches are based on known or inferred processes that influence the population in some way. In the specific case of estimated mortality to a fish population, the key issue is whether subsequent density dependence compensates for that mortality. If not, it is tautological that mortality will proportionally reduce subsequent population size.

Density dependence is a controversial topic mainly because of statistical difficulties, although conceptual problems also contribute. Compensatory density dependence can arise through a wide variety of causes, most involving food supply or predation (Rose and others 2001). Density dependence in striped bass in the San Francisco Estuary apparently compensated for very high losses to the export facilities, at least during a period of relatively high abundance (Kimmerer and others 2000).

Density dependence in stock–recruit relationships for delta smelt were driven largely by high values in the 1970s, although some evidence for density dependence remained in the data after 1981 (Bennett 2005); however, these relationships and the influence of environmental factors on them have likely changed over the intervening decades. The key question for interpretation of export losses of delta smelt is whether density dependence is strong in the post-decline population. This seems unlikely: since 2002 abundance of delta smelt has been too low for most potential mechanisms for compensatory density dependence to exert much influence. If so, the delta smelt population does not compensate for reductions in abundance by, e.g., increased fecundity or reduced mortality. Therefore, losses at any life stage permanently and proportionally reduce the population from the trajectory it would have otherwise have followed.

Correlative measures can be useful to the extent that they offer statistical support for a relationship. However, they cannot establish cause. More importantly, there is a clear difference between a finding that a result does not meet statistical standards of significance, and concluding it is not important. Thus, in making such an argument it seems important to determine what level of impact could be detected by correlative methods.

I determined this level through simulations, assuming density-independent population processes by the arguments above. I used the observed ratio of the fall midwater trawl index to the previous year's index as a stock–recruit index that should be sensitive to losses in the spring. The percentage loss in a given year was set as:

$$P_L = P_{max} \left(\begin{array}{c} 0 \text{ if } OMR \geq 0 \\ \dfrac{OMR}{OMR_{min}} \text{ if } OMR < 0 \end{array} \right) \qquad (3)$$

where P_{max} is the maximum percentage loss in any year (a free parameter in this simulation), OMR is the mean flow in Old and Middle rivers in spring (negative is southward), and OMR_{min} is the minimum OMR flow (i.e., the maximum southward flow). OMR flows were determined for each spring as described in Kimmerer (2008). In this equation, P_L is zero for positive OMR, and scales linearly with negative OMR to a maximum at P_{max} when OMR = OMR_{min}. Alternative scaling would affect the quantitative results but not the qualitative conclusion.

For each year, the simulation ran using flow data from 1981 through 2006, with each year's fall population reduced by the simulated proportional loss during the previous spring. The choice of years to simulate was made to get a representative range of OMR flows, not to simulate an actual population trajectory, and the simulation was intended only to investigate the effects of export losses at low population size where density dependence would have a minimal effect. The flows were randomized among years to eliminate potential confounding factors from actual annual flow patterns. Then, for each integer value of P_{max} from 0 to 100% a regression was calculated between southward Old and Middle river flow (the quantity in parentheses in Equation 3) and the log of the stock–recruit index. The intent was to determine how large P_{max} had to be before losses become detectable in regression analyses.

The results (Figure 3) show that the losses were not generally detectable in the regression until P_{max} 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 biologically relevant (Stephens and others 2007).

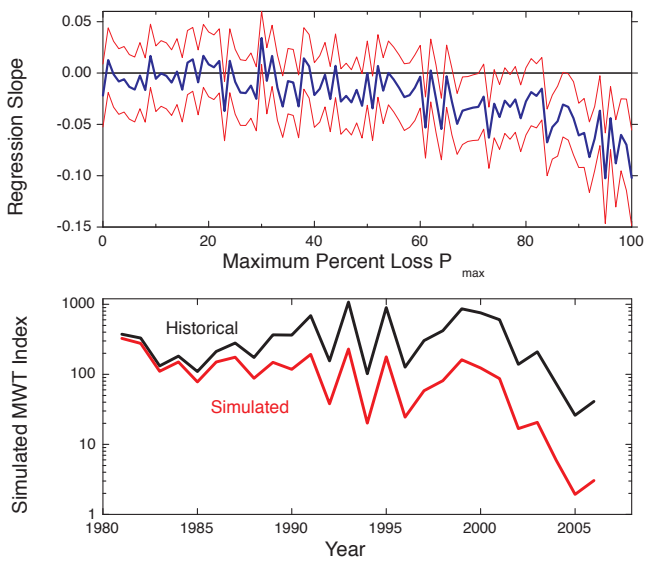

Figure 3 Results of simulation of ability to detect export loss through regression analysis. Upper panel: individual simulation results giving the slope (thick blue line) and 95% confidence limits (thin red lines) for regressions of the stock-recruit index on southward OMR flow. Lower panel: trajectory of the fall midwater trawl index (upper line) and the same index with a 20% P_{max} value imposed for the entire time series (mean P_L ~10%). This is for illustration only (see text), and does not imply anything about the cause of the decline in delta smelt.

CONCLUSIONS

Miller 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.

I previously reported that export effects had little effect on the striped bass population because of density dependence at levels of population abundance that existed up to 1995 (Kimmerer and others 2001). I also previously determined that export losses of mysids (*Neomysis mercedis*) were unlikely to be important to that population (reported by Orsi and Mecum 1996). During my work on the Environmental Water Account, I continually but unsuccessfully challenged my colleagues in the resource agencies to determine the effect of export pumping on fish populations, and therefore the magnitude of the benefit that the Account was having on fish (see Brown and others 2008). Therefore, 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.

All of that said, neither my paper nor this exchange is the final word on this subject. More sophisticated statistical tools and models could and should be brought to bear on what controls delta smelt abundance, and these should be updated as new data become available. Information from new studies (e.g., Castillo and others 2009; Grimaldo and others 2009) and based on more recent distributional data should also be considered, both in refining understanding of influences on the smelt population and in assessing changes in the population itself.

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