Progress Report to the Collaborative Science Policy Group

Prepared by:

The Collaborative Adaptive Management Team (CAMT)

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Table of Contents

1.0 Introduction 1
2.0 Process Framework 5
3.0 CAMT Priority Workplans 10
4.0 Problem Statements, Key Questions, and Conceptual Models 32
4.1 Fall Outflow Management for Delta Smelt 32
4.2 OMR and Delta Smelt Entrainment 39
4.3 South Delta Salmonid Survival 58
5.0 Other Related Activities 68
5.1 The Fall Outflow Adaptive Management Plan (FOAMP) 68
5.2 FLaSH Studies in the IEP Workplan 69
5.3 Delta Smelt Lifecycle Modeling Studies 69
5.4 Trawl Gear Efficiency Evaluation 78
5.5 Smelt Survey Review Study 78
5.6 Central Valley Chinook Life Cycle Model 79
5.7 Enhanced PTM 80
5.8 Other Studies Pertaining to Juvenile Survival in the South Delta 80
5.9 IEP Studies Relevant to OMR and Delta Smelt Entrainment 80
Attachment A: Progress Report South Delta Salmonid Research Collaborative
(provided under separate cover)

List of Tables

Table 1-1 Considerations for CAMT Near-term Priorities ... 3
Table 1-2 Final List of CAMT 2013 Priority Topic Areas ... 4
Table 2-1 CSAMP Phases ... 8
Table 3-1 CAMT Fall Outflow Workplan ... 13
Table 3-2 CAMT OMR/Entrainment Workplan ... 19
Table 3-3 CAMT South Delta Salmonid Survival Workplan ... 24
Table 4-1 Understanding How Habitat Attributes in the Fall Affect Growth and Recruitment ... 33
Table 4-2 Identifying Risks and Management Strategies ... 34
Table 4-3 Measurements of Entrainment, Abundance, and Distribution ... 41
Table 4-4 Factors Affecting Entrainment ... 42
Table 4-5 Population Level Effects ... 43
Table 4-6 Implications for Management ... 44
Table 4-7 SDSRC Study Proposals ... 61
Table 5-1 FLaSH Studies Being Conducted by IEP ... 71
Table 5-2 Ongoing or Completed Studies Related to South Delta Salmonid Survival ... 81
Table 5-3 Planned IEP Studies to Support CAMT Entrainment Effort ... 84
Table 5-4 Potential Additional 2014 IEP Studies to Support CAMT Entrainment Effort ... 88
Table 5-5 Potential Additional 2015 IEP Studies to Support CAMT Entrainment Effort ... 88

List of Figures

Figure 2-1 Delta Plan's Adaptive Management Framework ... 6
Figure 4-1 Revised Conceptual Model for Delta Smelt ... 36
Figure 4-2 Conceptual Model for Transition from Delta Smelt Subadults to Adults ... 36
Figure 4-3 Mechanistic Entrainment Model for Adult Delta Smelt ... 52
Figure 4-4 Mechanistic Entrainment Model for Larval Delta Smelt ... 53
Figure 4-5 Hypothesis-Driven Entrainment Model for Adult Delta Smelt ... 55
Figure 4-6 Hypothesis-Driven Entrainment Model for Larval and Post-larval Delta Smelt ... 56
Figure 4-7 Management Action Entrainment Model for Adult Delta Smelt ... 57
Figure 4-8 Conceptual Model for South Delta Smolt Survival ... 60

1.0 Introduction

Purpose

This document provides a nine-month progress report on the establishment of a new Collaborative Science and Adaptive Management Program (CSAMP) being undertaken in the Sacramento—San Joaquin Delta.

Content

The report documents the organization, activities, and initial outcomes of a series of meetings and workshops held by the program's Collaborative Adaptive Management Team ("CAMT") operating under the leadership and guidance of the Collaborative Science Policy Group ("Policy Group"). Further, the report includes initial workplans for three broad topic areas that emerged as sources of significant disagreement among participants. Lastly, the report includes relevant background information, a discussion of the framework and process needed to successfully implement collaborative science and adaptive management, a summary of the current and future activities planned as part of the CSAMP, and highlights of the collaboration efforts currently underway.

General Background

The CSAMP was launched following a decision by the United States District Court for the Eastern District of California on April 9, 2013 entitled "Memorandum Decision and Order regarding Motion to Extend Remand Schedule" ("Court Order"), issued in response to a motion to extend the court-ordered remand schedule for completing revisions to salmon (NMFS 2009) and Delta Smelt (FWS 2008) Biological Opinions ("BiOps").

The Court Order allowed the parties making the motion (i.e., U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and the California Department of Water Resources) additional time for the development of a proposed "robust science and adaptive management program, with collaboration of the scientists and experts from the Public Water Agencies ('PWAs') and the NGO community" intended to "inform the development and implementation of the BiOps" (Lohoefener 2012 and included in O'Neill 2013).

Organization

Following the issuance of the Court Order, a two-tiered organizational structure was established to implement CSAMP comprised of: (1) a Policy Group made up of agency directors and top-level executives from the entities involved in the litigation, and (2) the CAMT including designated managers and scientists to serve as a working group functioning under the direction of the Policy Group.

Mission Statement

The CAMT arrived at the following mission statement at its July 23, 2013 meeting:

> The Collaborative Adaptive Management Team (CAMT) will work, with a sense of urgency, to develop a robust science and adaptive management program that will inform both the implementation of the current Biological Opinions, including interim* operations; and the development of revised Biological Opinions.
>
> *The term "interim" refers to the period during which revised Biological Opinions are being developed.

CAMT Behavioral Norms

At its first meeting on June 11, 2013, the CAMT expressed a willingness to work together according to behavioral norms proposed by Jim Beck, General Manager of the Kern County Water Agency and a member of the Policy Group. Beck suggested that throughout its deliberations, CAMT members should strive to be:

- **Transparent:** Significant communication regularly occurring with all participating parties present.
- **Accessible:** Ability for everyone to be heard and participate in the dialogue.
- **Solution-Oriented:** Looking for how to get things done.
- **Honest:** Direct without being disrespectful.
- **Timely:** Issues raised are addressed in a rapid manner, and schedules are met.
- **Creative:** Willingness to think outside the box.
- **Open Minded:** Willingness to truly consider all points of view—even when "I know I am right."

Disagreements and Collaborative Science

At the outset, it should be stated that strong disagreements persist among CAMT members regarding the state of knowledge in certain areas of importance to water project operations. Nonetheless, all CAMT members strongly support collaborative science; and in spite of unresolved differences regarding the premises, formulation, and management implications of certain workplan elements, CAMT has chosen to be as inclusive as possible in the content of topic area workplans.

CAMT members agreed that a collaborative approach to science offered a means of improving decision-making and reducing disagreements resulting from factual uncertainties, provided that the collaborative approach relies on accepted standards for scientific analysis and review. Consequently, CSAMP studies will need to be pursued with as much scientific rigor as is possible, and without bias.

The CAMT hopes that the results will help refine the understanding of biological processes, the role of water project operations, and other forces in determining biological outcomes. The CAMT believes the development of reliable information through collaborative, inclusive scientific studies will help reduce disagreements over time.

Identification of Priority Topics for 2013

Addressing the need to focus on specific topic areas of urgency and relevance to CAMT members, a preliminary list of potential topics was developed at the June 25, 2013 CAMT meeting, together with a list of screening considerations to assist in arriving at a short-list of priorities. Those considerations identified by CAMT members are included in Table 1-3 below.

It is important to note that this list is a compilation of diverse factors offered by individual CAMT members during a brainstorming exercise. Consequently, the relative importance of each item varies considerably among individuals, with some CAMT members assigning no importance to certain of the considerations listed.

Table 1-1

Considerations for CAMT Near-term Priorities
SCOPE
Are the activities within the Delta?
Does it address the issues defined as part of the remand process?
EFFECTIVENESS
Is there the potential for significant, meaningful results that can inform management actions?
Is there a potential for significant near-term benefits to fish species?
Is there the potential to significantly reduce uncertainty and increase understanding?
EFFICIENCY
Is there a potential for using water supply to provide fish protection more efficiently?
Is this an opportunity to show fish protection and water supply can be managed together?
Can results be achieved in a timely manner?
RESOURCE AVAILABILTY
Does it reinforce and capitalize on successful existing efforts?
Is there capacity (staffing) and capability (funding) available in the time remaining?
TEAM BUILDING
Could is this be an opportunity to demonstrate successful adaptive management?
Is this an opportunity to strengthen the trust and relationships among the participants?

Source: CAMT Meeting #2 Minutes (June 25, 2013)

Following group discussions of both topic areas and relevant screening questions, the CAMT agreed upon four general topic areas for further development. They included:

- Old and Middle River (OMR) Flow Management and Entrainment of Delta Smelt, Longfin Smelt, and Salmonids,
- Fall Outflow Management for Delta Smelt,
- South Delta Salmonid Survival, and the
- Effectiveness of Habitat Restoration.

At a July 25, 2013 progress update meeting of the CAMT Co-Chairs and the Policy Group, several Policy Group members questioned whether or not the CAMT had the time and resources needed to complete all four of the topic areas selected. The Co-Chairs agreed to take the issue up with the full CAMT and render a final decision. At its August 27, 2013 meeting the CAMT agreed to table further investigation of the Effectiveness of Habitat Restoration until March 2014. At that point, the final list of initial topic areas was confirmed (see Table 1-2).

Table 1-2: Final List of CAMT 2013 Priority Topic Areas

Topic Area	Regulatory Framework
Fall Outflow Management for Delta Smelt	FWS, CDFW
OMR Management and Entrainment of Delta Smelt	FWS, CDFW
South Delta Salmonid Survival	NMFS, CDFW

Relationships to other Adaptive Management Programs and Research

Finally, it should be noted that there are several research programs and adaptive management efforts currently underway outside of the CSAMP. The CSAMP does not replace these efforts or reduce their importance. Instead, the CSAMP will supplement and inform them.

The CSAMP will provide a new approach to integrating stakeholder points of view into these processes, or to create new groups if necessary to collaboratively address remand-related questions. The CAMT's intent is to ensure that disagreement about the basis for and effectiveness of the RPAs be addressed by a science-based process that is legitimate, credible, and relevant to stakeholder concerns.

2.0 Process Framework

Introduction

In addition to focusing on the development of individual workplans for the priority topic areas presented in Table 1-2, CAMT members participated in regular discussions regarding the framework and process for both the design and implementation of recommendations contained in this report, as well as an ongoing process for collaborative science and adaptive management during the current revision of the BiOps and over the longer term.

At the foundation of the CAMT process is its mission "to develop a robust science and adaptive management program" with increased collaboration among state and federal agencies, PWAs, and NGOs that are parties to the remand process. In the court exhibit entitled, Federal and State Proposal for Modification to the Remand Schedule and an Alternative Process for Development of Operational Strategies and a Collaborative Science and Adaptive Management Program, dated November 29, 2012, the proposed purposes for the CAMT process were presented as follows:

> The adaptive management process will include the active evaluation of current hypotheses associated with key operating parameters that are associated with the Bay Delta oriented measures of the BiOps, synthesizing current scientific information, developing new modeling or predictive tools, and testing and evaluating alternative operational strategies and other management actions to improve performance from both biological and water supply perspectives. (DN 1080-1, 2)

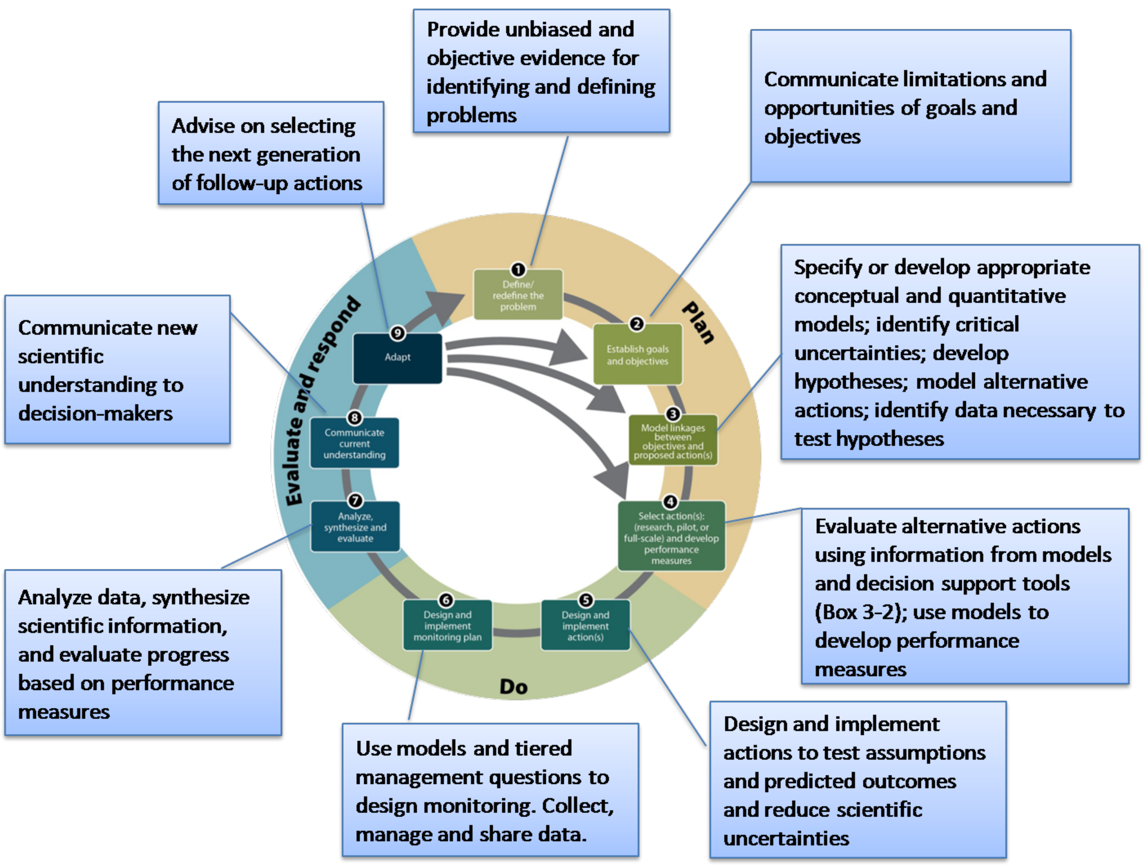
More specifically the Court Order, quoting from the declaration of Lohoefner, stated:

> With respect to the disputed BiOps, CSAMP's specific goals are to: (a) Identify and evaluate management actions, including but not limited to actions set forth in the [BiOps' Reasonable and Prudent Alternatives ("RPAs")], to protect one or more of the listed species; (b) Develop a monitoring program to allow for the evaluation of costs and benefits and of alternative management actions; and (c) Support the development and adoption of an annual operational plan by no later than December 15 of each year.

The CAMT science process will be broadly consistent with the adaptive management process described in the DOI Adaptive Management Technical Guide and the Delta Science Plan. The first steps in that process consist of identifying problems, translating those problems into goals and objectives, and formulating and evaluating alternative actions to achieve the goals and meet the objectives, thereby dealing with the problems (see Figure 2-1).

These initial, general steps involve development of conceptual models, identifying uncertainties and disagreements, formulating hypotheses or questions that address the uncertainties and disagreements, and testing those hypotheses or answering questions using various scientific techniques, including collection or generation of new data, and analysis and modeling of existing data, with appropriate attention to sources and reliability of data.

This progress report represents a preliminary version of these initial steps. Problem statements have been developed for each topic, as have questions and hypotheses. Preliminary versions of conceptual models are included in this report. More detailed specification of questions, hypotheses, and conceptual models, potentially incorporating review by science experts (including independent scientists), will be an important next step. So will specification of who will carry out the work, and what approaches and methods are feasible and appropriate.



(Source: Delta Science Plan 12/30/2013, 23)

Figure 2-1: Delta Plan's Adaptive Management Framework with the role of science identified in call-out boxes for each step.

In the CAMT process, the results of these initial steps have identified some disagreements and better defined the uncertainties. As shown in Figure 2-1, a key initial step of the science effort is the development of CSAMP conceptual models for the priority topics listed in Table 1-2. Preliminary versions of these models are included in this report. As the CSAMP process proceeds, the conceptual models will be continually improved and serve as a useful tool to clearly identify uncertainties and disagreements, keeping the CSAMP effort focused on feasible and appropriate means of addressing them.

Where existing adaptive management or other research programs have developed and adopted conceptual models upon which ongoing studies are based, those models are not expected to be replaced by the CSAMP conceptual models, although the collaborative process may result in changes to the existing models as it moves forward.

Discussions regarding the precise point of entry to the adaptive management cycle for each of the priority topic areas revealed the complexity of intervening during ongoing adaptive management activities, as well as the differences among the ongoing science programs within each topic area. CAMT members expressed divergent views about the extent to which the CAMT should create new groups to address specified tasks versus relying on existing efforts, while not wanting to impede or duplicate current programs. A challenge for the CAMT moving forward will be efficient coordination with the existing programs in completing the package of investigations the CAMT concludes are needed to inform the remand process.

Formulation of CSAMP Problem Statements and Scientific Questions

The CAMT recognized the need to develop its own problem statements (Step 1 in Figure 2-1) for each of the topic areas and spend time articulating disagreements regarding conceptual models and hypotheses underlying the associated RPA actions.

To carry out its activities consistent with the adaptive management framework, CAMT members also saw the need to engage qualified scientists and experts who could contribute to developing new scientific information for the CSAMP. Recognizing that the CSAMP is an overlay on other programs, this expertise would be applied to:

- Develop problem statements
- Review current conceptual models and science activities
- Identify relevant key questions
- Articulate alternative conceptual models and hypotheses to facilitate assessment of disagreements
- Propose data collection and/or analysis capable addressing areas of uncertainty

Schedule and Phasing

As presented in Table 2-1, the CSAMP process can be viewed in four distinct phases: (1) the initial nine-month period between the issuance of the Court Order and February 15, 2014, when the parties will submit a joint status report to the Court; (2) the period from February 15, 2014 to the end of court approved extensions; (3) completion of the new BiOps; and (4) the long-term future following the completion of the revised BiOps. The final schedule will be determined by court decisions from the district and appellate courts.

The focus of this section is on the second phase of the process, and it assumes that the CAMT will continue its efforts.

Table 2-1: CSAMP Phases

Phase	Duration	Milestones/Dates	
		Start	Finish
1. Initial Extension	9 Months	Court Order (4/9/13)	Joint Status Report Submittal (2/15/2014)
2. Subsequent Extension(s)	2 years	Court decision(s) on further extensions	Court order[1]
3. Completion of Revised BiOps		When extensions end	Court order
4. Operations according to revised BiOps	Long-Term	Acceptance of Revised BiOps	Ongoing, with collaborative science and adaptive management milestones

[1] The current court order requires the USFWS to issue its final biological opinion by December 1, 2014, and NMFS to issue its final biological opinion by February 1, 2017.

There was broad agreement within the CAMT that a successful long-term program of collaborative science and adaptive management requires a credible and legitimate framework and process that ensures broad-based acceptance and support for the science and decisions resulting from the process.

At the same time, for the CSAMP process to be considered successful in the immediate near term, the completion and implementation of detailed workplans, building on the progress achieved during Phase 1, is essential to maintaining trust in the legitimacy of the program for many CAMT members.

CAMT members agreed that credible workplans required input from qualified scientific professionals with expertise and experience in the issues being addressed; and that there must continue to be urgency, perseverance, and resources applied to the completion of the resulting science activities in keeping with the commitment made by the federal and state agencies to evaluate and, if appropriate, refine the RPAs.

Integration with other Science Activities

CAMT members are hopeful that that the CSAMP process can complement and add value to existing science initiatives by strengthening stakeholder engagement and offering a new bridge between and among stakeholders, scientists, management agencies, and policy-makers.

Completion and Implementation of Topic Area Workplans

Two initial CAMT subgroups prepared draft problem statements and identified key questions and hypotheses related to: (1) OMR Flow Management and Entrainment of Delta Smelt, Longfin Smelt, and Salmonids; and (2) Fall Outflow Management for Delta Smelt. CAMT members deferred consideration of a third subgroup and built on the final report prepared by the SDSRC. Some items in the workplans could add to, but will not replace, existing ongoing studies planned for 2014, such as FLaSH or other IEP studies.

Plans include questions and hypotheses that can be addressed using existing data sets (as opposed to requiring the collection of new data). The specific tasks may vary depending on the nature of the specific question(s) being addressed. The process may rely on (1) existing investigations by others (e.g. Fall Outflow AMP or South Delta Salmonid Research Collaborative); (2) new work by agency staff, stakeholder staff, and other experts; or (3) a combination of the two. Such investigations may be incorporated into existing efforts such as the Fall Outflow AMP or IEP Project Work Teams, or they may be done outside of these efforts.

Expanding the Public Communications and Engagement

From the outset, the Policy Group and CAMT members recognized that for the CSAMP to have lasting value beyond the court-ordered remand process, it would need to reach out to and engage wider circles of stakeholders and interests than those organizations that are parties to the remand. A detailed proposal for communications and outreach will be a critical element of the Phase 2 process.

3.0 CAMT Workplan

Tables 3.1 through 3.3 outline proposed near-term priority work elements for each of the three high priority topic areas identified by CAMT (see Table 1.2). The tables below focus primarily on work to be conducted in 2014, recognizing that some work elements will require more than one year to complete and thus will extend into 2015. The process for identifying priorities, managing investigations, and facilitating credible science in further developing and executing the work plans is described below.

Identifying Priorities

CAMT members and their designees determined priority work elements based on a review of the key questions and other materials prepared by technical subgroups (see Section 4). Criteria for determining priority work elements included their timeliness (i.e. they could be completed within the next two years), relevance to interim operations and the Biological Opinions (i.e. results would inform the development of revised biological opinions), and potential to directly address specific disagreements between CAMT participants regarding the design or interpretation of existing analyses.

Scoping, Conducting and Reviewing Science Investigations

CAMT members view a clear, transparent process for scoping, conducting and reviewing new science investigations as critical to ensuring the relevance and legitimacy of the collaborative science and adaptive management process and outcomes. CAMT proposes to organize its work according to the following three functions:

1. ***Scoping*** – This function will be conducted by new CAMT designated Scoping Teams with guidance from the Delta Science Program to ensure consistency with the Delta Science Plan. The purpose of these teams would be to scope workplan investigations, interact with others doing related work, develop workplans for conducting investigations, report progress back to the full CAMT, and assist the CAMT in revising work plans as needed. "Scoping" means establishing the relevance and legitimacy of work plan elements and putting boundaries on the breadth of what would be investigated as part of the CAMT work plan so as to assure relevance to the Biological Opinions and the CAMT mission; it does not mean prescribing exactly how and by whom studies will be conducted. Scoping Teams may also assist with guiding, coordinating, and tracking implementation of work elements, as requested by CAMT.
2. ***Conducting Investigations*** – Actual science investigations would be performed by qualified technical experts, identified and recommended by the DSP, with input from the Scoping Teams, and approved by CAMT. Investigations may be performed by individuals or teams of individuals. CAMT would rely on existing groups and programs when appropriate, and would engage new groups as needed.
3. ***Reviews*** – Structured reviews would be organized and managed by the Delta Science Program for both study plans and work products resulting from investigations.

The following provides additional details on the formation and responsibilities of the Scoping Teams:

- Scoping teams will be comprised of CAMT members or their designees, a representative from the Delta Science Program; a facilitator; and additional people nominated by CAMT co-chairs, and approved by CAMT, who provide additional skills, subject area knowledge and experience. The CAMT co-chairs will designate scoping team chairs with the approval of the full CAMT.
- Scoping teams will refine the key questions and hypotheses and identify more detailed workplans, for each workplan element, in conjunction with the technical experts.
- Scoping teams will submit workplans (including budgets and schedules) and reports to CAMT for approval.
- The Delta Science Program shall oversee independent review of workplans and any reports produced as a result of the investigations.
- Scoping teams will report directly to CAMT.

Delta Science Program Assistance

The CAMT proposes to draw upon the resources of the Delta Science Program (DSP) and mechanisms outlined in the Delta Science Plan to facilitate implementation of the work plans. The CAMT views this as critical to ensuring the credibility and integrity of the scientific process and the outcomes. CAMT proposes that under the direction of the Delta Lead Scientist, the DSP would:

- Provide guidance on scientific methods and best practices to be used in developing, refining and implementing workplans and ensure consistency with the Delta Science Plan.
- Help identify technical experts that would design and carry out the scientific investigations called for in the CAMT work plan and synthesize results. These experts would be provided the freedom and flexibility to design and conduct specific investigations within the boundaries of the scope established by the CAMT scoping teams described above.
- Help the CAMT identify any additional subject-related expertise that would assist with scoping and coordination tasks.
- Manage and implement all independent reviews of CAMT science proposals, study plans, and results. This would occur under the leadership and decision-making authority of the Delta Lead Scientist. Additional review may come from the Delta Independent Science Board (DISB), if deemed appropriate by the CAMT.

The DSP would also continue to assist the CAMT in general by identifying specific mechanisms for facilitating credible science processes as outlined in Sections 4.5 and 4.6 of the DSP plan.

Coordinating with Ongoing Studies

One goal of the CAMT workplan is to leverage existing studies and monitoring to avoid duplication of effort. Tables provided in Section 5 illustrate IEP studies that may address CAMT data needs, hypotheses, and questions. Multiple surveys, data sets, and studies will be necessary to address the questions and hypotheses. The CAMT Scoping Teams would be responsible for coordinating and integrating CAMT activities with these existing efforts.

Principles for Designing and Implementing Science Studies

To assure relevance and credibility, all CAMT studies will be designed and implemented according to scientific principles in the Delta Science Plan and include

- Well-stated goals and objectives
- A statement of relevance to the CAMT priority work elements
- Clear conceptual and/or mathematical model(s)
- Questions and hypotheses that are clearly linked to the conceptual or mathematical model(s)
- A study design capable of addressing the questions with sufficient precision and accuracy and with standardized, well-documented methods for data collection
- Analytical rigor and sound logic for analysis and interpretation
- Clear documentation of methods, results, and conclusions
- Publication of results in peer-reviewed scientific journals or reports

Independent review of proposals, study plans, and results managed and implemented by the DSP (see above) will assure that all analyses will be carried out with scientifically credible and rigorous investigative methods and accepted analytical techniques.

Specific analyses and experiments designed to address key questions and hypotheses listed in Tables 3-1, 3-2, and 3-3 will be developed in Phase 2 of the CAMT process (see Table 2-1). Because of time constraints, initial efforts will focus on the analysis of existing data sets. These investigations will not involve experimental designs in the traditional sense of lab or field data collection, but will be designed and implemented according to the same rigorous scientific principles.

New field and lab experiments identified following the initial data analyses will include explicit experimental designs focused on addressing specific hypotheses or predictions. This may include large-scale adaptive management experiments (i.e. active adaptive management) and associated field data collections, monitoring and studies associated with non-experimental (passive) adaptive management, and smaller-scale field and laboratory studies.

To the extent feasible, CAMT will work with existing ongoing science efforts to leverage opportunities for collection and use of any new data. The CAMT may also review and consider ongoing data collection and monitoring programs to assess the need for possible refinements that could improve the applicability of the data for evaluating the key questions and hypotheses articulated by CAMT

Finally, this workplan reflects a good-faith effort on the part of the CAMT to respond to the urgency of its mission, recognizing that resources constraints, changing circumstances, or unexpected events could impact proposed schedules. For example, the timely availability of third-party investigators has not been confirmed; and uncontrollable circumstances, such as the drought, may impose new priorities that may impact schedules.

Table 3-1 CAMT Fall Outflow Workplan

Work Element	Key Question(s)	Example Draft Hypotheses	Relevance/Rationale	Possible Investigative Approach	Schedule
High Priority Items					
1. Review monitoring methods for delta smelt	Are there biases in the IEP survey data? How should the survey data be utilized if biases do exist?	NA	Investigate and clarify characteristics of existing monitoring data sets, including potential weaknesses in spatial coverage and other details of study design. Clarification of weaknesses will help ensure that analyses based on these datasets are appropriately qualified. Could allow for corrections (or adjustments) to more accurately represent underlying variables. Findings may suggest that results of previous studies should be reviewed. Findings may also allow for improvements in future data collection.	Convene a workshop to discuss possible survey problems and identify opportunities to address in 2014 with existing data. Consider ongoing work and approaches of Emilio Laca. Many of these issues have been proposed by FWS to be addressed through a package of gear efficiency and smelt distribution studies (see Section 5); however, that package includes extensive field work, and some elements have timelines extending beyond the remand period.	Discuss at IEP Resident fishes PWT meeting on Feb 20, 2014 Workshop (discuss E. Laca study plan) April 2014 Finalize study plan – May 2014 Gear efficiency study discussions June 2014 Draft report Sept 2014 IEP Presentation Feb 2015

Work Element	Key Question(s)	Example Draft Hypotheses	Relevance/Rationale	Possible Investigative Approach	Schedule
High Priority Items					
2. Investigate importance of fall period for delta smelt.	Under what circumstances does survival in the fall affect subsequent winter abundance?	Survival of delta smelt during the fall varies significantly from year to year and is important in explaining the annual changes in abundance.	Needed to establish whether survivorship through the fall is important in influencing year-to-year changes in delta smelt abundance. Survivorship through the fall is one vital rate that may be important.	Quantitatively determine the contribution of delta smelt survivorship in the fall to inter-annual population variability. Review available lifecycle models for applicability.	Scoping group to evaluate available life cycle models July 2014 Study plan Dec 2014. Draft report April 2015
3. Investigate effects of fall outflow on delta smelt.	Under what circumstances do environmental conditions in the fall season contribute to determining the subsequent abundance of delta smelt?	A significant correlation exists between the survival of delta smelt from summer to winter in a year and habitat conditions in the fall.	This element re-examines analyses presented in the 2008 BiOp. New work would include review of new information as it applies to the original analyses, and complement or challenge existing analyses to evaluate the relationship between outflow through the Delta and demographic response in delta smelt.	Investigate the relationship between fall outflow and the relative change in delta smelt abundance using univariate and multivariate and available historic data. Related to work undertaken in the MAST report, which examined pairs of dry and wet years in 2005/6 and 2010/11. Also explore effects occurring through other avenues (e.g. growth or fecundity).	Study plan development June 2014 Draft report Nov 2014

Work Element	Key Question(s)	Example Draft Hypotheses	Relevance/Rationale	Possible Investigative Approach	Schedule
Secondary Priorities					
4. Examine project impacts on fall outflow.	How much variability in tidal, daily, weekly, and monthly fluctuations in fall X2 is attributable to water project operations?	Changes over time in the distribution and extent of habitat, as represented by the distribution and extent of the low-salinity zone (or the position of the X2 isohaline) during the fall is attributable to water export project operations.	The intent is to refine our understanding of how project operations are influencing outflow volumes.	Hydrological modeling tools to determine the prospective locations of X2 in the fall under circumstances with and without project operations. An analysis of historical data will also be carried out to examine outflow during periods when the projects were required to meet specific outflow requirements, to evaluate the degree of control that has been possible at various time scales. See work addressing this issue by: Grossinger, Hutton, and a paper by Cloern & Jassby 2012	Relevant IEP presentation by Paul Hutton, MWD – Feb 26, 2014

Work Element	Key Question(s)	Example Draft Hypotheses	Relevance/Rationale	Possible Investigative Approach	Schedule
Secondary Priorities					
5. Investigate importance of summer period for Delta Smelt	Under what circumstances is survival of Delta Smelt through the fall related to survival or growth rates in previous life stages?	Survival of Delta Smelt through the fall is related to survival or growth rates in previous life stages.	This topic complements some of the investigations in the FOAMP. By establishing whether survival or growth rates through any life stage (or season) are dependent on the status or condition of Delta Smelt entering that life stage, the potential exists to identify environmental factors in preceding seasons that influence survival during the fall.	Compare Delta Smelt survival during the fall to both survival in prior seasons and to fork length at the end of the summer/start of the fall. New data is being collected as part of FOAMP. Consider IBM modeling.	Draft study plan – Oct 2014 Analysis of existing data – mid 2015

Work Element	Key Question(s)	Example Draft Hypotheses	Relevance/Rationale	Possible Investigative Approach	Schedule
Secondary Priorities					
6. Investigate the relationship between fall outflow and habitat attributes.	Does outflow during the fall have significant effects on habitat attributes that may limit the survival and growth of Delta Smelt during the fall?	A significant relationship exists between the survival of Delta Smelt from summer to winter within a year and habitat conditions experienced by Delta Smelt during the intervening fall.	This element re-examines analyses presented in the 2008 BiOp. New work would include review of new information as it applies to the original analyses, and complement or challenge the existing work by developing new analyses to evaluate the strength of evidence for mechanisms under which outflow may influence Delta Smelt survivorship growth rates during the fall.	There may be competing approaches that will be simultaneously pursued. One is to develop graphs and conduct univariate and multivariate analyses involving survival ratios and growth rates. Test whether month-to-month declines in abundance or growth during the fall is greater when X2 is located further east. See also the analytical approach in MAST report, work by Kimmerer, Burnham & Manly.	Work may begin in 2014 as resources allow

Work Element	Key Question(s)	Example Draft Hypotheses	Relevance/Rationale	Possible Investigative Approach	Schedule
Secondary Priorities					
7. Develop a new habitat index for Delta Smelt	Can an index based on multiple habitat attributes provide a better surrogate for Delta Smelt habitat than one based only on salinity and turbidity?	The distribution and areal extent of the low-salinity zone (or the position of the X2 isohaline) in the estuary in the autumn is significantly correlated with the distribution and extent of habitat available to support Delta Smelt.	An updated habitat index may provide a useful tool to mangers to identify areas for restoration and improved management actions. Earlier analyses used only abiotic factors to define habitat. Additional information since 2008, could allow for development of a better habitat index based on additional potentially important habitat variables.	Review approaches in existing literature. There may be competing approaches that will be simultaneously pursued, depending on expert advice. One possible approach is to develop suitability index curves and combine geometrically to create a habitat quality index. Utilize data from areas where Delta Smelt are frequently observed to assess habitat quality. See work by Burnham Manly, and Guay.	Work may begin in 2014 as resources allow
8. Identify impacts of fall project operations on Delta Smelt	Under what conditions (e.g., distribution of the population, prey density, contaminants) do fall operations have significant effects on survival?		Complements and/or challenges previous studies. Important for identifying the impact of project operations on the success of Delta Smelt during the fall.	Utilizing relationships identified in the above studies, simulate how changes in project operations may influence survival of Delta Smelt during the fall.	Work may begin in 2014 as resources allow

Table 3-2 CAMT OMR/Entrainment Workplan

Work Element	Key Question(s)	Draft Example Hypotheses	Investigative Approaches	Schedule
		High Priority[1]		
1. Assess factors affecting adult Delta Smelt entrainment	What factors affect adult Delta Smelt entrainment during and after winter movements to spawning areas? (4) a. How should winter "first flush" be defined for the purposes of identifying entrainment risk and managing take of Delta Smelt at the south Delta facilities? b. What habitat conditions (e.g. first flush, turbidity, water source, food, time of year) lead to adult Delta Smelt entering and occupying the central and south Delta?	The probability of observing adult Delta Smelt in the central and south Delta is significantly higher following the first major increase in Delta inflow (e.g. >25,000 cfs), which contributes to rising turbidity levels in the central and south Delta.	Summarization of environmental and fish distribution/abundance data (e.g. FMWT, SKT). Multivariate analyses and modeling (e.g. 3D particle tracking) to examine whether fall conditions affect winter distribution. Completion of First Flush Study analyses. The Delta Conditions Team (DCT) is currently developing a scope of work to use turbidity modeling to examine various "first flush" conditions, expected entrainment risks, and potential preventative actions that could be taken to reduce entrainment, consistent with key question (a). The DCT could also conduct analyses to address key question (b).	Detailed workplan for key question (b) April 2014 Initial report on (a) for OCAP review panel Sept 2014 Independent review for key question (a) Nov 2014

[1] Work element #1 from the Fall Outflow Workplan is also considered a high priority work element for the OMR/Entrainment topic area.

Work Element	Key Question(s)	Draft Example Hypotheses	Investigative Approaches	Schedule
High Priority				
2. Assess population effects	What are the effects of entrainment on the population? (6) a. What is the magnitude (e.g. % of population) of adult and larval entrainment across different years and environmental conditions? b. How do different levels of entrainment for adults and larvae affect population dynamics, abundance, and viability?	Delta Smelt are entrained at Project facilities at levels that are likely to affect the long-term abundance of the Delta Smelt population.	2.a. Application of different models (e.g. IBM, life history) to estimate proportional entrainment. A direct approach to addressing 6a has been proposed by Kimmerer 2008 as modified in 2011. This or a derivative approach should be explored as a means to directly estimate the proportional entrainment that has occurred in recent years. Apply to as much of historical record as possible. 2.b. Application of different models (e.g. IBM, life history, PVA) to simulate effects on population dynamics, abundance, and variability.	Detailed workplan for direct approach April 2014 Product (based on direct approach) for submission to Long-term Ops Opinion panel Sept 2014 Independent review (Long-term Ops Opinion panel) Nov 2014 Final peer reviewed product for Life Cycle Model approach June 2015

Work Element	Key Question(s)	Draft Example Hypotheses	Investigative Approaches	Schedule
Secondary Priorities				
3. Develop a better estimate of adult Delta Smelt entrainment	How many adult Delta Smelt are entrained by the water projects? (1d)	NA	Workshop or expert panel review. Testing of new field methodologies such as SmeltCAM. Gear efficiency and expanded trawling experiments. Evaluation of alternative models to estimate abundance, distribution and entrainment.	Work may begin in 2014 as resources allow
4. Develop a better estimate of post-larval Delta Smelt entrainment	How many larval and post-larval Delta Smelt are entrained by the water projects? (2d)	NA	Expert panel or workshop review. Testing of new field methodologies such as SmeltCAM. Gear efficiency and expanded trawling experiments (e.g. 20 mm). Evaluation of alternative models to estimate abundance, distribution and entrainment.	Work may begin in 2014 as resources allow

Work Element	Key Question(s)	Draft Example Hypotheses	Investigative Approaches	Schedule
Secondary Priorities				
5. Evaluate conditions that affect adult movement prior to spawning	What conditions prior to movement to spawning areas affect adult Delta Smelt entrainment? (3) Is there a relationship between Delta Smelt distribution and habitat conditions (e.g. turbidity, X2, temperature, food) during fall and subsequent distribution (and associated entrainment risk) in winter?	Adult Delta Smelt distribution and abundance in winter is influenced by Delta Smelt distribution and abundance in the fall, as well as habitat conditions (e.g. turbidity, salinity, temperature, food availability), and hydraulics (e.g. velocity, tidal flow splits) during winter.	Summarization of environmental and fish distribution/abundance data (e.g. FMWT, SKT). Multivariate analyses and modeling (e.g. 3D particle tracking) to examine whether fall conditions affect winter distribution. Completion of First Flush Study analyses.	Work may begin in 2014 as resources allow
6. Assess factors affecting larval and post-larval Delta Smelt entrainment	What factors affect larval and post-larval Delta Smelt entrainment? (5) a. How does adult spawning distribution affect larval and post-larval entrainment? b. What conditions (e.g. first flush, spawning distribution, turbidity, water source, food, time of year) lead to larvae and post-larvae occupying the central and south Delta?	Larval Delta Smelt distribution and abundance in spring is influenced by adult Delta Smelt distribution and abundance, habitat conditions (e.g. turbidity, salinity, temperature, food availability), and hydraulics (e.g. velocity, tidal flow splits).	Summarization of environmental and fish distribution/abundance data. Statistical analysis and modeling (e.g. 3D PTM) of effects adult distribution (e.g. SKT) on larval (e.g. 20 mm) distributions. Summarization of environmental and fish distribution/abundance data (e.g. 20 mm). Multivariate analyses/modeling to identify conditions promoting occupancy of central and south Delta.	Work may begin in 2014 as resources allow

Work Element	Key Question(s)	Draft Example Hypotheses	Investigative Approaches	Schedule
Secondary Priorities				
7. Explore alternative management actions	What new information would inform future consideration of management actions to optimize water project operations while ensuring adequate entrainment protection for Delta Smelt? (8) a. Can habitat conditions be managed during fall or early winter to prevent or mitigate significant entrainment events? b. Should habitat conditions (including OMR) be more aggressively managed in some circumstances as a preventative measure during the upstream movement period (e.g. following first flush) to reduce subsequent entrainment?	NA	Synthesis of available information and study results by CAMT Entrainment Team, designated expert panel, or both. Consultation with regulatory agencies and operators about the feasibility of different actions.	Work may begin in 2014 as resources allow

Table 3-3 CAMT South Delta Salmonid Survival Workplan

Work Element	Key Question(s)	Relevance/Rationale	Possible Investigative Approach	Schedule
High Priority: Expected for implementation in 2014				
1. Synthesize published reports and empirical data on water export effects and link to the current SDSRC conceptual model; identify/document scientific agreements and disagreements regarding the effects of south Delta water operations on juvenile salmonid survival in the Delta.	What are key uncertainties, agreements, and disagreements in the understanding of direct and indirect effects of south Delta water operations on salmonid survival as linked to the SDSRC conceptual model? What are the areas/issues of scientific agreements and disagreements that contribute to the controversy over the effects of project operations on salmonid survival? Can the population level effects of a single management action be evaluated? If so, what tools are available?	Unfinished business of the SDSRC in 2013; identified as a priority for 2014 in the 2013 Progress Report. Potential opportunity to consider the PWA and other interests' questions, tasks, and hypotheses yet to be considered by CAMT.	Convene a series of working sessions to review and potentially refine the current SDSRC conceptual model; identify, screen and document published reports and empirical data, as linked to the conceptual model. Identify key information gaps. Identify key scientific agreements and disagreements. Review PWA questions and hypotheses in this context, and develop a collaboratively produced report.	- Status updates in April, June, and August of 2014 - Draft report September 2014 - Final report November 2014

Work Element	Key Question(s)	Relevance/Rationale	Possible Investigative Approach	Schedule
High Priority: Expected for implementation in 2014				
2. Briefing about SWFSC winter-run salmonid life cycle model LCM).	What is the general structure of the model and what are key assumptions, key uncertainties, and evaluation metrics used to assess biological responses to alternative export operations, changes in river flows, DCC gate operations, habitat capacity, and other actions on salmon survival and abundance? How will the model be validated? Will the model be available for independent peer review and simulations?	In order to ensure development of a widely accepted LCM, its development should be transparent and shared with interested parties.	A briefing needs to be held on the status of the SWFSC salmonid LCM and its specific components with interested and knowledgeable parties.	Briefing to CAMT and interested parties by April 2014
3. Data synthesis and meta-analysis	Can synthesis of data from previous Delta salmonid tagging studies be combined and analyzed to address key questions/ uncertainties about the direct and indirect ecological effects of exports on salmonid	There are numerous salmonid tagging studies conducted in the Delta over the past several decades that, when considered together, can potentially address key uncertainties about factors affecting migrational behavior and survival of juvenile	Pending review and agreement on a proposal: 1) establish a working group to plan and oversee the strategy for identifi-cation and meta-analysis of existing data; 2) identify initial questions to address and relevant	- SDSRC will revise and agree on a written proposal by April 2014; - Progress report March 2015; anticipated to continue in 2015; draft report by November 2015; manuscript for publication completed

Work Element	Key Question(s)	Relevance/Rationale	Possible Investigative Approach	Schedule
High Priority: Expected for implementation in 2014				
	survival?	salmonids	data sets; and 3) conduct preliminary analyses.	by June 2016
4. Pending results of the gap analysis and initial data synthesis efforts (Elements 1 and 3); investigate alternative metric(s) for management of south Delta water operations.	Are there alternative or additional metrics (e.g., OMR flows, export volumes, monthly export limits, etc.) that can be used to manage south Delta water operations, and improve survival of migrating salmonids in the south Delta?	SDSRC participants discussed metrics in addition to, or other than, inflow:export ratio that may be relevant to manage south Delta water operations to improve salmonid survival.	Convene a working group to synthesize and evaluate existing data to identify potential metrics and evaluate their benefits and limitations.	- Status check in June 2014 - Progress report November 2014
5. Re-charter the SDSRC	Should the SDSRC be re-chartered to report to the CAMT?		Modify the charter to require the SDSRC to periodically report progress to the CAMT. SDSRC will continue to use existing facilitator.	

Work Element	Key Question(s)	Relevance/Rationale	Possible Investigative Approach	Schedule
Secondary Priority: May be implemented in 2014, contingent on progress of high priority workplan elements				
6. Pending outcomes of Elements 1, 3, and 4, investigate tools to evaluate the efficacy of export management actions.	To what extent and under what conditions do the export management actions reduce mortality of migrating salmonids?		Summarize tools available or in development that can be used to evaluate the efficacy of export management actions.	Pending outcomes of other workplan elements, status check in November 2014
7. After briefing on SWFSC LCM, assessment of other potential modeling needs. Pending outcomes of Elements 1-4 identify and evaluate indirect ecological effects of project operations that affect the survival of listed salmonids.	Are there questions important to CAMT that cannot be answered using the SWFSC LCM? Are there elements of other salmon models that would be beneficial to incorporate or link to the winter-run model (e.g., IOS, DPM, OBAN, SALMOD, Bureau egg mortality model, CALSIM, DSM2, etc.)? Are there alternative management actions that can address water project effects on listed salmonids?	CAMT is continuing to discuss the scope of management actions that should be evaluated within the CAMT scope. Future discussions should include: What management actions have the greatest influence on survival of salmonids migrating in the south Delta? What water management actions might be taken to improve salmon survival? What is the relative effectiveness of current and potential alternative management actions in improving salmon survival?	Pending acquisition of new resources, convene a working group to evaluate the potential for existing models or new tools to inform the consultation on project operations including: 1) Review available information (including literature, data, and models) to identify controllable factors, linked to project operations, with greatest influence on survival; 2) Identify actions which might be taken to improve survival; 3) Evaluate actions and report relative	Status Update in September 2014 Pending outcomes of Elements 1-4, complete preliminary analysis and write-up by November 2014.

Work Element	Key Question(s)	Relevance/Rationale	Possible Investigative Approach	Schedule
Secondary Priority: May be implemented in 2014, contingent on progress of high priority workplan elements				
			contribution to survival.	
8. Define an expanded scope for the SDSRC to include indirect ecological effects of south Delta water operations	What are the indirect ecological effects of water export; and are there management actions to minimize indirect project effects that influence salmonid survival?	The SDSRC worked within a narrow scope focusing on direct export effects on hydrodynamics and direct behavioral and survival effects of altered hydrodynamics. Broadening the scope to including indirect effects (e.g., predation effects) could potentially inform approaches to minimize south Delta project operation effects on salmonid survival.	Conduct a working session of the SDSRC to agree on a detailed description of an expanded scope; link to the current SDSRC conceptual model.	Revised scope by March 2014
9. Enhanced learning from 6-year steelhead study (OCAP BiOp RPA VI.2.2)	Are there experimental modifications of the 6-year steelhead study that will enhance the understanding of the effect of inflow/export conditions on south Delta survival of steelhead?	The 6-year steelhead study is intended to estimate steelhead survival over a range of ambient inflow:export conditions. Recent analysis of conditions tested during the first three years identified several conditions that have not been tested or are underrepresented among the conditions tested to date. A greater range of conditions will also enhance learning in	Identify opportunities and develop plans to enhance learning from the 6-year steelhead survival study (RPA IV.2.2) by testing untested or underrepresented I:Es, testing combinations of very high and very low San Joaquin inflows and very high and very low export levels; and testing similar I:Es at different discharge volumes (e.g.,	Given evolving drought, it may be challenging to manipulate operations in April and May of 2014. - Identify options, develop implementation plans, and prepare request for prescribed conditions no later than June 2014; implementation in 2015 or later depending on environmental

Work Element	Key Question(s)	Relevance/Rationale	Possible Investigative Approach	Schedule
Secondary Priority: May be implemented in 2014, contingent on progress of high priority workplan elements				
		ongoing USFWS fall-run Chinook survival studies.	1:1 at 1,500cfs/1,500cfs; 6,000cfs/6,000cfs. Any new experimental components will include a clear statement of objective, approach, and statistical analysis plan.	conditions; study plan, including proposed operations, would be developed for review no later than March 15.

Work Element	Key Question(s)	Relevance/Rationale	Possible Investigative Approach	Schedule
Third Priority: important to CAMT but not likely to be implemented in 2014 pending results of ongoing research and development of necessary technology				
10. Salmonid near-field movement under selected export and tidal conditions.	Does tidal forcing in combination with export volumes affect migrational behavior and survival of migrating south Delta salmonids?	The 2012 IRP recommended investigating the combined influence of export and tidal forcing on salmonid migrational behavior and survival. Based on a concept proposal developed in the SDSRC in 2013, this study was identified for further development.	Convene a working group to develop a detailed proposal suitable for peer review; including objectives, experimental approach, and a detailed statistical analysis plan. Arrange for and submit to external peer review. Review results of Enhanced PTM tool in development by SWFSC. A prerequisite for this	- Proposal and peer review by November 2014; - Review of Enhanced PTM tool when available; - Implementation of Near-Field Movement study dependent on availability of a predation-sensitive acoustic tag (probably 2015)

Work Element	Key Question(s)	Relevance/Rationale	Possible Investigative Approach	Schedule
Third Priority: important to CAMT but not likely to be implemented in 2014 pending results of ongoing research and development of necessary technology				
			element is completing the testing and validation of the technology to distinguish a free swimming tagged salmonid from one that has been preyed upon.	
11. Pending gap analysis, investigate hatchery- and natural-origin salmonid surrogacy.	Are results of tests using hatchery-reared salmonids representative of results of natural-origin salmonids? Are the results of tests using one run of Chinook salmon representative of results of other runs? Are the results of tests using Chinook salmon representative of steelhead? If not, in each case can a correction factor be developed to allow for application of such test results?	The question of whether results of tests conducted using hatchery-reared salmonids are representative of results relevant to natural-origin salmons is a key uncertainty routinely identified in most survival studies.	Convene a working group to review and synthesize existing information on hatchery- and natural-origin surrogacy; if warranted, develop a concept proposal to investigate surrogacy.	SWFSC study planned for spring 2014 may provide information relevant to wild vs. hatchery surrogacy.

Development of Experimental Designs

Specific experiments designed to address key questions and hypotheses listed in Tables 3-1, 3-2, and 3-3 above will be developed in Phase 2 of the CAMT process (see Table 2-1). Initial efforts will focus on the analysis of existing data sets. These investigations will not involve experimental designs in the traditional sense of lab or field data collection, but will include clearly defined methods and accepted analytical techniques, and will include review and examination of the existing data sets and how those data were obtained. Any new field experiments identified following the data analyses will include explicit experimental designs focused on addressing specific hypotheses or predictions. These designs will be consistent with the scientific process including the following elements:

- Well-stated objectives
- A clear conceptual or mathematical model
- A good experimental design with standardized methods for data collection
- Statistical rigor and sound logic for analysis and interpretation
- Clear documentation of methods, results, and conclusions.

To the extent feasible, CAMT will work with existing ongoing science efforts to leverage opportunities for collection and use of any new data. The CAMT may also review and consider ongoing data collection and monitoring programs to assess the need for possible refinements that could improve the applicability of the data for evaluating the key questions and hypotheses articulated by CAMT.

The SDSRC has already initiated discussions regarding conceptual designs for the research proposals it has suggested. This work included a power analysis to assess sample sizes and other factors that would be necessary to detect statistically significant differences in juvenile survival under various environmental conditions. The SDSRC has also examined the ongoing 6-year Steelhead study (now entering its fourth year) to assess possible adjustments in the experimental design that could enhance the value of the study.

Similarly, the ongoing FLaSH studies being administered by IEP and the Fall Outflow AMP involve specific experiments designed to assess environmental conditions and ecological responses to those conditions, including the testing of specific predictions articulated in the AMP.

4.0 Background on CAMT Priority Topic Areas

The following provides background information on each of the three priority topic areas, including problem statements, key questions, and relevant conceptual models identified through the CAMT process to date. Information provided in the tables below represents draft concepts developed by each respective technical subgroup (Fall Outflow, OMR/Entrainment, and South Delta Salmonid Survival). The information in the tables below is not a plan of work. Rather, it is meant to be used as a resource to inform development of the CAMT workplan.

4.1 Fall Outflow

The 2008 Biological Opinion for Delta Smelt contains a Reasonable and Prudent Alternative (RPA, Action 4) intended to improve fall habitat for Delta Smelt. The action specifically seeks to maintain the position of X2 in the fall at 74 km east of the Golden Gate Bridge in wet years, and at 81 km east in above normal years.

Fall Outflow Problem Statement

Questions have been raised by some about the biological effectiveness of the RPA that stem from disagreements about the scientific basis for the fall outflow action. These disagreements concern the factors that may limit the extent and quality of habitat for Delta Smelt in the fall, the extent to which fall habitat is a limiting factor on the survival and reproduction of the population, the use of X2 as a surrogate indicator for Delta Smelt habitat, and the costs and benefits of different approaches to restore Delta Smelt habitat. Questions have also been raised in CAMT discussions regarding the sampling methods used to collect the data that are used to calculate abundance indices (i.e. do they accurately reflect the size and distribution of the population). An updated and more complete understanding of the habitat requirements of Delta Smelt might help clarify under what circumstances project operations may adversely impact habitat in the fall, and subsequently, what habitat modifications would benefit Delta Smelt annual year class success. This improved understanding may also allow more effective use of project water supplies to protect Delta Smelt.

A Fall Outflow Adaptive Management Plan (FOAMP, Reclamation 2011, 2012) was developed to resolve some of the uncertainties and questions regarding the RPA, but not all CAMT parties have been engaged to date in the FOAMP. The FOAMP developed a set of conceptual models and a suite of studies about the importance of “fall low salinity habitat” (FLaSH) for Delta Smelt. As an ongoing adaptive management project, the FOAMP will be informed by the results of the FLaSH studies, the CAMT efforts, and other input. Additional information on the FOAMP and ongoing investigations is provided in Section 5 of this report.

Fall Outflow Key Questions and Hypotheses

Tables 4-1 and 4-2 below list key questions and draft hypotheses developed by a technical subgroup for use as a resource in framing specific science investigations for the CAMT workplan. Table 4-1 lists questions related to Delta Smelt habitat and recruitment, while Table 4-2 lists key questions related to identifying and managing risks to Delta Smelt. The key questions presented in Tables 4-1 and 4-2 reflect the recommendations of the technical subgroup and have not been modified by CAMT. CAMT may refine these questions for the purposes of developing its workplan (see Section 3), and expects that further refinements to the questions and draft hypotheses will be made in the process of developing detailed study plans for specific work elements. Ultimately, it is expected that pursuing answers to key questions will lead to the resolution of disagreements about the relative importance of drivers and mechanisms and result in more efficient use of resources and greater protection for the species.

Addressing the questions presented in Tables 4-1 and 4-2 will require evaluation of available data and some combination of ongoing and new studies. Several of the hypotheses presented in these tables are addressed at least in part in the existing Fall Outflow Adaptive Management Plan (AMP) and/or in the IEP Management, Analysis, and Synthesis Team (MAST) report.

Table 4-1

Understanding How Habitat Attributes in the Fall Affect Growth and Recruitment
Questions
1. Under what circumstances do the habitat attributes listed in the conceptual model limit growth and survival of Delta Smelt in the fall? a. How, and under what circumstances do habitat attributes such as food availability, toxicity, harmful algal blooms, predation, water temperature, turbidity, and size and location of the low salinity zone in the fall, collectively or individually, affect growth and/or survival of Delta Smelt during the fall? b. What are the mechanistic (ecological) relationships underling each factor? Under what conditions does each factor act? Do the existing descriptions of interconnections between environmental drivers acting on Delta Smelt in the available conceptual models and their expected effects on ecosystem responses within and among seasons need to be revised? c. How can existing data sets be further analyzed to better explain how outflow affect Delta Smelt growth, health, and condition variability during fall, winter and spring? d. Is there a need to include additional habitat attributes or environmental drivers from previous seasons and/or fall in the fall conceptual model? Is the timing and intensity of hydrology (separate from outflow) ecologically important? e. Under what set of circumstances do environmental conditions in the fall season contribute to determining the subsequent abundance of Delta Smelt? f. Which habitat attributes limit the abundance or growth of Delta Smelt in the summer and/or fall? What actions could be implemented to address those limiting attributes? g. Can a better habitat index be developed?
Draft Hypotheses
(H1): The habitat attributes of: food availability, toxicity, harmful algal blooms, predation, water temperature, turbidity and size and location of the low salinity zone in the fall, collectively or individually, have a significant effect on the growth and/or survival of Delta Smelt during the fall. *(H1a): There is a statistically significant relationship between abundance and two factors, abundance in the previous fall and previous fall X2.*

(H2): There is a significant correlation between growth during the fall and subsequent recruitment. *(H3): The variability in growth of Delta Smelt during the fall that is explained by abiotic variables is less than that explained by biotic variables.* *(H4): Survival of Delta Smelt during the fall varies significantly from year to year and is important in explaining the annual changes in abundance.* *(H5): Survival of Delta Smelt through the fall is related to survival in previous or subsequent life stages.* *(H6a): A significant correlation exists between the survival of Delta Smelt from summer to winter in a year and Delta outflow in the fall.* *(H6b): A significant correlation exists between the survival of Delta Smelt from summer to winter in a year and habitat conditions in the fall.* *(H7): Delta outflow in the fall has significant effects on habitat attributes found to be limiting.* *(H8): Years with low survival during the fall can be associated with limiting levels of habitat attributes found to be significant in analyses associated with H1.* *(H9): The timing and intensity of hydrology (separate from outflow) during the fall is ecologically important to Delta Smelt (i.e. affects the survival and/or growth).* *(H10): Entrainment risk to adult Delta Smelt during the subsequent winter and spring are lower when average X2 is below 81km in the fall.*

Table 4-2

Identifying Risks and Management Strategies
Questions
1. Under what circumstances (e.g., distribution of the population, prey density, concentrations of contaminants) do project operations in the fall have significant effects on survival, population viability, and recovery of Delta Smelt? 2. When circumstances occur in the fall that place Delta Smelt at high risk of mortality, what actions can be implemented to reduce the impacts of project operations on the fish? 3. How can those actions (under 2. above) be implemented and be consistent with the objectives of the water projects? How can strategic increases in fall outflow be achieved with minimal water supply impacts? 4. How much variability in tidal, daily, weekly, and monthly fluctuations in fall X2 is attributable to water project operations?
Draft Hypotheses
(H11): In the Fall, the extent of the area occupied by Delta Smelt is significantly correlated with the areal extent of the low-salinity zone (or the position of the X2 isohaline). *(H12): The distribution and extent of habitat for Delta Smelt, as represented by the distribution and extent of the low-salinity zone (or the position of the X2 isohaline) during the fall has diminished over the available historic record.* *(H13): Changes over time in the distribution and extent of habitat, as represented by the distribution and extent of the low-salinity zone (or the position of the X2 isohaline) during the fall is attributable to water export project operations.*

(H14): There is a significant positive correlation between the survival rate of Delta Smelt during the fall and the percentage of the Delta Smelt population in the confluence, or west of it, during the fall.

Delta Smelt Conceptual Models

Figures 4-1 and 4-2 below depict recent conceptual models for Delta Smelt proposed by the Interagency Ecological Program (IEP), Management, Analysis, and Synthesis Team (MAST) draft July 2013 report. While uncertainty exists regarding some mechanisms and the relative importance of the various habitat attributes and drivers, these models generally incorporate and reflect the research that has been done on Delta Smelt to date (see reports describing the POD, FLaSH, and MAST, and reviews by the NRC and Delta Science Program). Continued work is needed by universities, agencies, and stakeholders to reduce these uncertainties and improve our understanding.

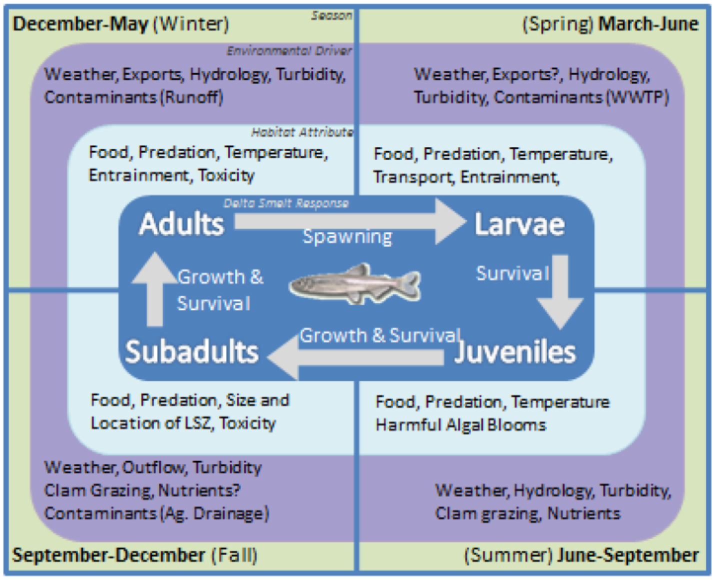


Figure 4-1 Revised Conceptual Model for Delta Smelt

A revised conceptual model for Delta Smelt (MAST 2013) showing responses (dark blue box) to habitat attributes (light blue box), which are influenced by environmental drivers (purple box) in four “life stage seasons” (green box).

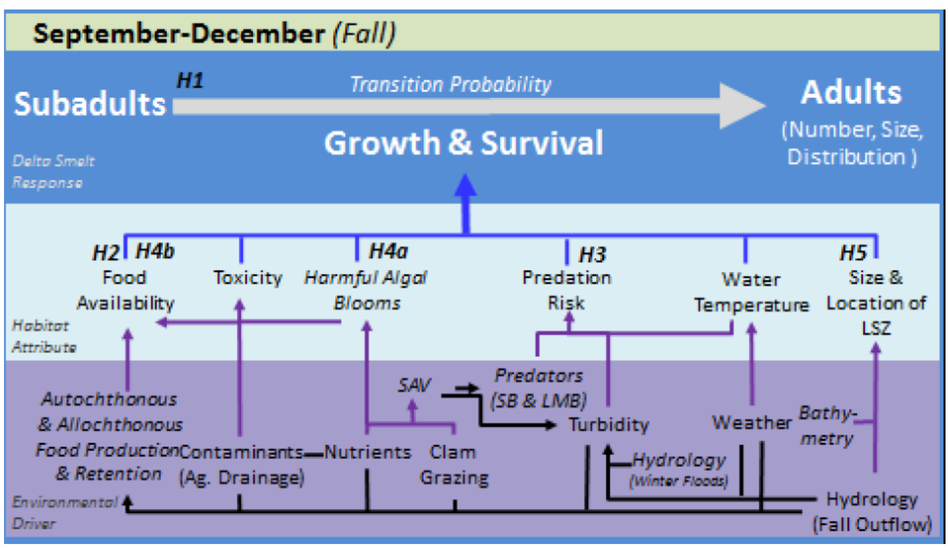


Figure 4-2 Conceptual Model for Transition from Delta Smelt Subadults to Adults - Source: (MAST 2013)

Fall Habitat and Delta Smelt Distribution

The Fall Outflow Subgroup discussed how Delta Smelt habitat has been defined in the fall and what relationships exist between fall outflow and Delta Smelt distribution in the fall. The Subgroup agreed that these relationships should be updated with the most recent data (e.g., Cache Slough data, data post 2011), and that new analytical approaches could provide more information regarding the relative importance of various covariates yet to be considered. The existing conceptual models suggest the quality of habitat is determined by a complex combination of factors, and is unlikely to be characterized adequately using only salinity and turbidity. As an example, the group agreed that food may limit Delta Smelt abundance or habitat and those biotic factors require further investigation, including understanding the relationships between biotic and abiotic factors. The group also acknowledged that more work could be done to explore the relationship between habitat attributes and the distribution of Delta Smelt.

The Subgroup also recognized that in some years a portion of the Delta Smelt population may reside in Cache Slough and was interested to see if higher fall outflows might benefit the Delta Smelt population in the Cache Slough area during wet and above normal water year types, and how water project operations affect the Delta Smelt population when fall outflow is at lower levels.

The Subgroup acknowledged that data sets and habitat attributes that have not been previously considered could be incorporated into the habitat index modeling, but recognized that data limitations exist for some key variables of interest. Nonetheless, the Subgroup agreed that it would be worthwhile to explore other long-term data sets and analyses might benefit from exploratory modeling to determine if relationships could be extrapolated to the full record of the FMWT data.

Finally, the Subgroup noted that there are inherent shortcomings (including biases) in the existing monitoring data and that those shortcomings may affect inferences regarding the distribution, occurrence, and abundance of Delta Smelt. The group agreed that more work is needed to identify these uncertainties and suggested that some re-analysis of relationships in the conceptual model is necessary. Specifically, an argument was made that the habitat-index analysis did not incorporate recently added FMWT data points from Cache Slough and that the historical FMWT survey does not adequately sample the entire Delta Smelt range. In addition, concerns were raised regarding the methods used to determine the habitat index, including that it should be re-calculated with additional variables such as abundance, geography and food.

Delta Smelt Abundance and Stock-recruit Relationships

The Subgroup discussed existing stock-recruit and stage-recruit relationships for all Delta Smelt life stages and the approaches used to explore how fall habitat variables and especially X2 may improve the ”explained variance” in survival and recruitment from fall to the next year. The group acknowledged that the stock-recruit (SR) model used in the FWS Biological Opinion should be updated with the most recent data and that other variables should be tested in the model. However, as noted above, a challenge is finding suitable long-term data sets for key variables of interest. Most importantly, the group acknowledged that the mechanisms underlying SR relationships should be explored in more detail and noted that the growth rate studies supported by the FLaSH investigation should be completed. The group also noted that additional investigations of diet (including prey selection) should be conducted for all life stages of Delta Smelt in all year types.

The Subgroup acknowledged that there is substantial variability in the relationship between the FMWT index and the fall habitat index in the same year, but noted that the effects of fall habitat improvements may not be realized immediately and/or that the antecedent population abundance and conditions during the preceding summer should be taken into account as well.

4.2 OMR and Delta Smelt Entrainment

The 2008 Biological Opinion for Delta Smelt contains a Reasonable and Prudent Alternative (RPA) – that includes three actions intended to protect pre-spawning adult Delta Smelt (Actions 1 and 2) and larval and juvenile smelt (Action 3) from excessive entrainment. Specifically, the actions set limits on flows in Old and Middle River (OMR) during December-June.

OMR/Entrainment Problem Statement

A 2010 National Research Council (NRC 2010) review concluded: *"[T]here is substantial uncertainty regarding the amount of flow that should trigger a reduction in exports. In other words, the specific choice of the negative flow threshold for initiating the RPA is less clearly supported by scientific analyses. The biological benefits and the water requirements of this action are likely to be sensitive to the precise values of trigger and threshold values. There clearly is a relationship between negative OMR flows and mortality of smelt at the pumps, but the data do not permit a confident identification of the threshold values to use in the action, and they do not permit a confident assessment of the benefits to the population of the action. As a result, the implementation of this action needs to be accompanied by careful monitoring, adaptive management, and additional analyses that permit regular review and adjustment of strategies as knowledge improves*."

Water users and the Department of Water Resources have raised questions regarding the design and implementation of the RPA and its overall effectiveness in protecting Delta Smelt. The specific disagreements include: (1) whether and, if so, under what circumstances entrainment has an effect on the overall viability of the Delta Smelt population; and (2) the efficacy of managing OMR flows as a means of reducing entrainment (including the establishment of specific triggers and thresholds). The proposed mechanisms by which entrainment could affect the population are described in more detail in this report's conceptual models (see below), and have been tested to varying degrees by modeling studies such as Kimmerer (2008; 2011), Miller (2011), Miller et al. (2012), Maunder and Deriso (2011), Rose et al. (2013 a, b), and BDCP (2013). There is disagreement about the interpretation of the model results and the degree to which they indicate population effects. These issues reflect a broader disagreement between water users and other CAMT Entrainment Subgroup members regarding whether, and if so, to what extent, entrainment affects Delta Smelt population dynamics. There may be opportunities to better understand and predict the conditions that influence entrainment levels.

Concerns and disagreements have also been raised regarding the data and methods currently being used to estimate entrainment and to set take limits. Further, as noted by the NRC (2010) and Kimmerer (2011), the historical distribution of Delta Smelt has shifted, and the recent addition of new monitoring stations and techniques has revealed the existence of greater variation in Delta Smelt life history strategies and geographic distribution than was previously recognized. Both changing distributions and different life history strategies may affect the interpretation of current proportional entrainment estimates and their likely response to hydraulic alterations (Miller 2011).

OMR/Entrainment Background

The CAMT Entrainment Subgroup organized its efforts to address three primary areas of disagreement:

1. How to assess distribution, abundance, and entrainment of Delta Smelt.
2. Circumstances when entrainment affects the viability of the Delta Smelt population.
3. The efficacy of current and alternative actions to manage entrainment or mitigate its effects.

In this document, the term "entrainment" is used to specifically refer to the incidental removal (mortality) of Delta Smelt in water diverted from the estuary by CVP and SWP export pumping in the south Delta. It is distinct from "salvage" which refers to fish captured and counted in the state Skinner Fish Protective Facility (SFPF) and the federal Tracy Fish Collection Facility (TFCF) before they reach the pumps. The fish collected in these facilities are trucked to release sites in the western Delta. Salvage does not account for entrainment-related mortality that occurs before the fish reach the fish facilities ("pre-screen losses") or during the capture, handling, trucking and release process (Baxter et al. 2013, Castillo et al. 2012), nor does it account for fish size or operations-based changes in louver efficiency at the facilities that affect the ability to detect and separate fish from exported water.

Salvage of Delta Smelt at the fish facility screens has been assumed to be an index of entrainment of fish more than about 20 mm in length; at smaller sizes, there is less likelihood that salvage indexes entrainment (Kimmerer 2008, 2011; Miller 2011). The degree to which salvage parallels entrainment under different environmental conditions and pumping rates has only begun to be tested for Delta Smelt, but recent evidence suggests that salvage may not be a reliable measure of the magnitude of Delta Smelt entrainment (Castillo et al. 2012). The results support the hypothesis that under some conditions, pre-screen losses are high, suggesting that salvage measurements will sometimes require a relatively high level of expansion to estimate entrainment. The most recent independent scientific panel review was particularly concerned that "*direct and indirect losses due to entrainment into the pumping facilities and the variance estimates associated with those losses may be substantially underestimated, and are not well-connected to population size estimates*." The panel also stated that *"(n)ew information about potential losses associated with entrainment at the pumping facilities (e.g., Castillo et al. 2012) suggest that the determination of allowable incidental take even from extended salvage estimates may underestimate actual facility impacts on this species*" (Delta Science Program. 2013. Report of the 2013 Independent Review Panel (IRP) on the Long-term Operations Biological Opinions (LOBO) Annual Review

This document does not specifically address other hypothesized ecological impacts that have been attributed to water exports from the operation of the Delta water projects such as the loss of food web production to the pumps. There is substantial disagreement in the group about whether these "indirect effects" should be part of the current scope. The environmental NGOs have specifically raised concerns that the CAMT's consideration of hypotheses and actions relating to improved management of entrainment's direct mortality effects must take into account both these indirect effects and the extent to which access to habitat in the south Delta affects the long-term viability of Delta Smelt.

OMR/Entrainment Key Questions and Hypotheses

Conceptual models described in subsequent sections were used to develop a generalized list of key questions and potential hypotheses that could be used to frame specific science investigations. The questions are organized into five broad categories:

1. *Measurement of Entrainment, Abundance, and Distribution.* This section focuses on the data that are needed to address subsequent categories. There are separate questions for Adults, and Larvae/Post-Larvae.
2. *Factors Affecting Entrainment.* This category deals with the mechanisms described in the Mechanistic Conceptual Model and in the preceding narrative. The Hypotheses were generated in part from the Hypothesis-Driven Conceptual Model. There are separate questions for Adults, and Larvae/Post-Larvae.
3. *Population Level Effects.* This category deals with the population level effects described in the Mechanistic Conceptual Model and its preceding narrative.
4. *Implications for Management.* This category focuses on how addressing the previous questions could help to guide management. The questions here were generated based in part on the Entrainment Management Conceptual Model.
5. *Models.* This category focuses on how new information would be used to refine, update, or replace existing draft conceptual models. This could also be extended to the further development and refinement of quantitative models.

Hypotheses have not been included for all categories, partly because not all questions lend themselves to hypothesis testing (e.g. method development questions), but also because the subgroup did not have sufficient time. Additional revisions are likely, particularly after input from a broader audience of experts and the development of specific priorities.

Table 4-3

Measurement of Entrainment, Abundance, and Distribution
Questions
1. How many adult Delta Smelt are entrained by the water projects? a. What is the best feasible method for estimating the number of adults entrained by the water projects? b. What is the relationship between salvage and entrainment, how variable is the relationship, and what factors influence that variability? c. What methods should be utilized to assess the distribution and abundance of adult Delta Smelt prior to entrainment? d. What new tools would provide a better understanding of adult entrainment levels, abundance, and distribution? 2. How many larval and post-larval Delta Smelt are entrained by the water projects? a. What is the best feasible method for estimating the number of larvae and post-larvae entrained by the water projects? b. What is the relationship between salvage and entrainment, what is the variability in

Measurement of Entrainment, Abundance, and Distribution
the relationship, and what factors influence that variability? c. What methods should be utilized to assess the abundance and distribution of larval and post-larval Delta Smelt prior to entrainment? d. What new tools would provide a better understanding of larval and post-larval entrainment levels, abundance, and distribution?

Table 4-4

Factors Affecting Entrainment
Questions
3. What conditions prior to movement to spawning areas affect adult Delta Smelt entrainment? a. Is there a relationship between Delta Smelt distribution and habitat conditions (e.g. turbidity, X2, temperature, food) during fall and subsequent distribution (and associated entrainment risk) in winter? 4. What factors affect adult Delta Smelt entrainment during and after winter movements to spawning areas? a. How should winter "first flush" be defined for the purposes of identifying entrainment risk and managing take of Delta Smelt at the south Delta facilities? b. What habitat conditions (e.g. first flush, turbidity, water source, food, time of year) lead to adult Delta Smelt entering and occupying the central and south Delta? c. What conditions (e.g. flow, turbidity, water source, time of year) cause fish to move towards the export facilities? d. How should the region where entrainment risks are elevated be defined or delineated for the purposes of managing take of Delta Smelt at the export facilities? e. What new methods or tools can be developed to provide a better understanding of factors affecting adult entrainment? 5. What factors affect larval and post-larval Delta Smelt entrainment? a. How does adult spawning distribution affect larval and post-larval entrainment? b. What conditions (e.g. first flush, spawning distribution, turbidity, water source, food, time of year) lead to larvae and post-larvae occupying the central and south Delta? c. What conditions (e.g. flow, turbidity, water source, time of year) cause fish to move towards the export facilities? d. What new tools or methods can be used to provide a better understanding of factors affecting larval and post-larval entrainment?
Hypotheses
(H1): Adult Delta Smelt distribution and abundance in winter is influenced by Delta Smelt distribution and abundance in the fall, as well as habitat conditions (e.g. turbidity, salinity,

Factors Affecting Entrainment
temperature, food availability), and hydraulics (e.g. velocity, tidal flow splits) during winter. *(H2): The probability of observing adult Delta Smelt in the central and south Delta is significantly higher following the first major increase in Delta inflow (e.g. >25,000 cfs), which contributes to rising turbidity levels in the central and south Delta.* *(H3): Entrainment levels of adult Delta Smelt are higher when more fish are distributed in the central and south Delta (a consequence of suitable habitat conditions such as high turbidity,) and when there are negative OMR flows. Example sub-hypothesis include:* *a. Once adult Delta Smelt are observed in the central and south Delta, they will stay there throughout the spawning period unless water conditions become unfavorable, even if OMR flows become positive.* *b. Once adult Delta Smelt have moved into the south and Central Delta, entrainment levels of adults will be correlated in a non-linear way with negative OMR flows and fish abundance.* *(H4): Larval Delta Smelt distribution and abundance in spring is influenced by adult Delta Smelt distribution and abundance, habitat conditions (e.g. turbidity, salinity, temperature, food availability), and hydraulics (e.g. velocity, tidal flow splits).* *(H5): Entrainment levels of larval Delta Smelt are higher when more fish are distributed in the central and south Delta (a consequence of suitable habitat conditions such as high turbidity, and temperatures <25 C) and when there are negative OMR flows.*

Table 4-5

Population Level Effects
Questions
6. What are the effects of entrainment on the population? a. What is the magnitude (e.g. % of population) of adult and larval entrainment across different years and environmental conditions? b. How do different levels of entrainment for adults and larvae affect population dynamics, abundance, and viability? c. How does entrainment affect life history diversity of adults and larvae over time? d. What are "natural" (i.e. background levels) mortality rates in the south Delta and how do they compare to rates estimated for entrainment? 7. Which new tools (e.g. Population Viability Analysis, 2- or 3-D particle tracking, Individual based Modeling, life history modeling), etc. provide opportunities to more accurately and precisely quantify the population level effects of adult and larval entrainment? a. What are the strengths and weaknesses of the different approaches? b. How do they complement each other? c. How can these models be used individually or in combination to establish seasonal or real-time measurements of population effects?

Population Level Effects
Hypotheses
(H6): Individual young of the year Delta Smelt found in the south Delta exhibit similar likelihood of survival compared to young of the year found elsewhere in the estuary. *(H7): Delta Smelt are entrained at Project facilities at levels that are likely to affect the long-term abundance of the Delta Smelt population.* *(H8a): There are circumstances under which the losses of Delta Smelt to entrainment are sufficient to cause a demonstrable impact on population viability..* *(H8b): The losses of Delta Smelt to entrainment are sufficient to affect N(e) and result in reductions in allelic diversity in the population.*

Table 4-6

Implications for Management
Questions
8. What new information would inform future consideration of management actions to optimize water project operations while ensuring adequate entrainment protection for Delta Smelt? a. Can habitat conditions be managed during fall or early winter to prevent or mitigate significant entrainment events? b. Should habitat conditions (including OMR) be more aggressively managed in some circumstances as a preventative measure during the upstream movement period (e.g. following first flush) to reduce subsequent entrainment? c. If Delta Smelt move into the region where entrainment risks are elevated, how can OMR or other habitat conditions be managed to prevent or mitigate significant entrainment of adults and larvae? d. If preventive actions are undertaken to reduce entrainment risk, could there be unintended consequences that adversely affect Delta Smelt population viability or demographics? e. How can the operation and design of the export facilities be modified to reduce entrainment mortality? f. Can low risk circumstances be identified that would not result in significant levels of entrainment but that might allow pumping levels to be increased? g. Are there other actions, which may or may not involve water project operations that could be taken to achieve the same purposes of entrainment RPAs or that could offset or mitigate effects of entrainment? What would these actions be, under what circumstances would they be effective, and what would the effect of each action be? h. What other approaches to data collection and analyses beyond the ones currently in use, could be used to help manage entrainment levels and associated population effects?

Implications for Management
9. How should conceptual models be updated based on study results designed to answer the preceding questions? 10. How should quantitative models be further developed based on study results designed to answer the preceding questions?

Delta Smelt Entrainment Conceptual Models

A key first step in adaptive management is to develop one or more conceptual models to guide the process. Below we describe recent conceptual models that helped frame the development of the study questions and hypotheses. While uncertainty exists regarding some mechanisms and the relative importance of the various habitat attributes and drivers, these models generally incorporate and reflect the existing analyses and spectrum of hypotheses created to date on Delta Smelt. The models will benefit from, and be improved by, a rigorous and comprehensive review and further testing. There is still substantial uncertainty about the relative importance of different habitat attributes and drivers on entrainment, so continued research is needed to improve our understanding and protection of this species.

As presented in Section 4.1 above, the draft MAST Delta Smelt Conceptual Model (Baxter et al. 2013) is intended to be a generalized overview of factors affecting Delta Smelt at various life stages. It illustrates the role of entrainment across different life stages, with respect to other habitat attributes and environmental drivers. To provide further insight into short- and long-term changes in distribution, entrainment, and related management issues, the CAMT Entrainment Subgroup has developed complementary models that focus on more specific aspects of entrainment and provide more details about the interactions of management actions and drivers. These models, and the associated review of background information presented below, is expected to be revised as a result of the CAMT science investigations, and should not be taken as a sign of agreement of all group members to all details of the material presented. At this stage, the conceptual models are tools to identify uncertainties and disagreements and formulate questions and hypotheses intended to help address the uncertainties and resolve disagreements. The models are intended as a starting point that will be refined substantially based on additional input and studies.

Although it may be simpler to have fewer models for species management, we provide several formulations because none have been vetted and reviewed by the scientific community; they were developed by the subgroup for the CAMT. Each of the models helps address a specific scientific or management issue that may not be easily portrayed in a single overly-complex model. The specific models and their purposes are as follows:

1. Mechanistic Entrainment Model. This model is designed to illustrate how several different mechanisms may interact to cause entrainment, and associated effects on the Delta Smelt populations.

2. Hypothesis-Driven Entrainment Model. This model incorporates several of the key mechanisms from the previous model to illustrate how specific hypotheses can be formulated to test the different alternatives.

3. Management Action Entrainment Model. This model is designed to show how management actions could be considered to reduce entrainment and associated effects.

Background Information for Entrainment Models

Background information about entrainment is provided below to aid in understanding the conceptual models. The basic entrainment conceptual models cover two general life stages: adult and larval Delta Smelt. The seasonal timing of each life stages varies from year to year and usually overlaps, as depicted in the MAST conceptual model for the life cycle of Delta Smelt (Baxter et al. 2013): December-May (winter) for adults; and March-June for larvae (and post-larvae[2]). Note that these periods are somewhat different than the specific periods of management actions described in the Delta Smelt Biological Opinion (USFWS 2008). As discussed in USFWS (2008), the primary period of concern for entrainment in a given year is roughly bounded by "first flush" (see below) in winter through March for adults and between the onset of suitable spawning temperatures and unsuitably warm water temperatures for larvae and post-larvae in spring or early summer. Entrainment during these periods may have population effects, with pertinence to relevant management issues.

Delta Smelt are endemic to the San Francisco Estuary; their nearest known relative is the marine surf smelt (Stanley et al. 1995). There is no evidence that Delta Smelt have differentiated into persistent sub-populations, and a recent genetic study concluded that the species is a single population (Fisch et al. 2011). However, this does not mean that all individual Delta Smelt behave the same way or use habitat the same way. Some Delta Smelt live year-round in fresh water, and some are found in mesohaline waters; others spend the summer and fall in the low-salinity zone of the estuary. Currently, all usable summer-fall rearing habitats are at a relatively safe distance from the South Delta SWP and CVP pumps. The abundance, distribution, and movement of adult Delta Smelt affect entrainment risk of this life stage (Sweetnam 1999; Sommer et al. 2011). Entrainment is also an issue for larval Delta Smelt that hatch during the spring. Dispersal from hatching areas to favorable nursery areas with sufficient food to enable rapid growth through the vulnerable larval stage is generally considered one of the most important factors affecting the mortality of fish larvae (Houde 1987). Many factors are thought to affect larval Delta Smelt entrainment risk including adult spawning site selection, hydrodynamics, turbidity, temperature, and proximity to the south Delta export pumps (Kimmerer and Nobriga 2008; Baxter et al. 2013).

Adults

To help provide an understanding of the entrainment process, the following discussion divides the issue into three basic phases: 1) the antecedent fall period; 2) the spawning movement period; and 3) the period when entrainment occurs. The first two periods represent the conditions that determine the winter distribution of adult smelt, a primary factor that influences

[2] Defined here as fish large enough to be observed in salvage during late spring and early summer

entrainment risk. In reality, these periods overlap. However, they are described separately to help provide a conceptual context for how different conditions during each phase may influence (or help avoid) subsequent entrainment.

Antecedent Fall Period: The distribution of Delta Smelt during fall has been covered in detail by several studies including Merz et al. (2011), Sommer et al. (2011), and Murphy and Hamilton (2013). Based on the data available from existing surveys, the distribution covers a broad range of salinities from about 0 to 10 psu (Sommer et al. 2011; Sommer and Mejia 2013; Murphy and Hamilton 2013). The FMWT suggests that the apparent distribution is affected by salinity, but the survey has not fully represented habitat use in areas on the periphery of the species' geographic range such as Cache Slough Complex or Napa River (Merz et al. 2011; Sommer and MeJia 2013; Murphy and Hamilton 2013). Distribution also likely depends on several other habitat conditions such as turbidity, temperature, food availability, and predator abundance.

One hypothesis is that distribution and habitat conditions during this period could have an effect on subsequent entrainment risk. For example, it is possible that a more eastward distribution in the fall may increase the risk that fish will later disperse into the lower San Joaquin River and central Delta, where entrainment risk is higher (Grimaldo et al. 2009; BOR 2012). However, Delta Smelt that remain in more distant regions such as Cache Slough Complex or the Suisun region will not be entrained.

Spawning Movement Period: Winter is associated with substantial environmental changes that trigger upstream movements toward freshwater spawning areas in a portion of the Delta Smelt population (Moyle 2002; Grimaldo et al. 2009; Sommer et al. 2011; Murphy and Hamilton 2013). There is disagreement over how large a portion moves upstream versus to channel margins or downstream (Murphy and Hamilton 2013). As noted in recent studies, not all adult Delta Smelt move at the same time or in the same direction. For example, a portion of the Delta Smelt population rears in the freshwater Cache Slough region during fall and likely remains there to spawn (Sommer et al. 2011; Sommer and Mejia 2013). Furthermore, multiple peaks of fish salvaged at the fish facilities suggest that movements during the spawning season are not completely synchronous (Grimaldo et al. 2009).

The factors that trigger Delta Smelt movement to spawning areas are not well understood, but fish may shift their distribution in response to "first flush" (Grimaldo et al. 2009; Sommer et al. 2011). The specific features of a first flush cue for pre-spawning movements of Delta Smelt require an understanding of key characteristics and thresholds. From a physical perspective, first flush refers to the first large storm-induced increases in river flows into the Delta – usually during winter; it is often associated with elevated sediment inputs and sediment-bound pesticides (Bergamaschi et al. 2001). The environmental factors that may trigger and support movements during first flush still need to be investigated. Candidate habitat variables that could be associated with first flush include one or more of the following: increased turbidity, decreased salinity, decreased temperature, increased food availability. It also appears that time of year is important because flow increases in late fall (e.g. November) do not result in major increases in salvage, the primary indicator of entrainment (Grimaldo et al. 2009). Note that the Report of the 2013 Independent Review Panel (IRP) on the Long-term Operations and Biological Opinions (LOBO) Annual Review questioned whether first flush was a critical event based on their comment that "it seems counter-intuitive that an annual species such as the Delta Smelt would have evolved to depend for its survival on temporally unreliable environmental cues to trigger migrations associated with crucial life cycle events such as spawning or selection of nursery locations."

As noted above, it appears that not all Delta Smelt respond, or respond immediately, to these changes – movements do not appear to be entirely synchronous. It is unclear whether there is a particular cue during first flush events that trigger Delta Smelt movements or whether first flush events merely increase the area of higher quality habitat for Delta Smelt to spread into (Murphy and Hamilton 2013). However, the movements of at least a portion of the Delta Smelt population are consistent with migratory behaviors exhibited by a suite of other native fishes during the same period (Sommer et al. 2011; 2013).

The major factors affecting subsequent entrainment risk during winter first flush periods are the direction and magnitude of Delta Smelt movement. Specifically, South Delta entrainment does not occur unless adult fish swim into the lower San Joaquin River and its central Delta distributaries during winter. As noted above, a hypothesis is that one or more individual covariates of increasing winter inflow (turbidity, salinity, temperature, food availability) could individually, or in combination, affect whether Delta Smelt move into the San Joaquin River channels. Several of these factors can be affected by water operations or management actions (e.g. net flow direction and the dispersion of turbidity).

Adult Entrainment Period

As noted in the previous two periods, environmental conditions during winter and fall likely influence the distribution of adult Delta Smelt. Fish that move into the lower San Joaquin River system face elevated entrainment risk for themselves and/or their progeny. The risks include a continued movement towards the south Delta pumps, where the adults are more vulnerable to entrainment, perhaps adult mortality due to unfavorable habitat conditions in the vicinity of the pumps, and spawning in areas where their offspring are vulnerable to entrainment. This section focuses only on adult entrainment. Whether Delta Smelt continue towards the south Delta pumps depends on a number of factors including hydraulics and habitat conditions.

Hydraulics: One focus of management actions is the area near the pumps where net flows are often reversed. Inflow, tributary contribution (e.g. San Joaquin River versus Sacramento River), export and diversion levels, and tidal effects all play a major role in whether and the degree to which flows in the south Delta are reversed. At present, Old and Middle River (OMR) flows are used as a key indicator of the flow reversals that are most relevant to the movement of Delta Smelt towards the south Delta pumps, and therefore the risk of fish entrainment (Kimmerer 2008; Grimaldo et al. 2009). Actions to manage OMR levels include changing reservoir releases, export rates, and Delta Cross Channel gate operations.

Habitat Conditions: In addition to hydraulics, habitat characteristics including turbidity, temperature, predation risk, and food availability could affect the movement of fish into the San Joaquin River and their subsequent risk of entrainment. For example, salvage data suggest that adult Delta Smelt entrainment is low when south Delta water clarity is high (Grimaldo et al. 2009). A hypothesized mechanism is that Delta Smelt actively avoid moving into the south Delta and its channel connections to the SWP and CVP facilities unless there is a "bridge" of higher turbidities and perhaps other water quality conditions. An alternative hypothesis is that Delta Smelt do not avoid clearer water; rather, apparent entrainment (salvage) does not occur because Delta Smelt are eaten by visual predators before they reach the fish screens. Some of these factors may interact, and could be influenced by management actions such as changing reservoir releases, export levels, and Clifton Court Forebay or Delta Cross Channel gate operations.

Larval Entrainment

Even if adult Delta Smelt that move into the central and south Delta are not entrained, their offspring may be vulnerable to entrainment. The primary period of concern for larval entrainment in the south Delta lasts through spring until temperatures rise to lethal levels, presumably resulting in mortality of any remaining individuals (USFWS 2008). There is uncertainty as to how well current models are able to mimic movement of Delta Smelt; however, studies using a particle tracking model have suggested that entrainment risk increases strongly with proximity to the export facilities (Kimmerer and Nobriga 2008). Thus, a hypothesis is that the adult spawning distribution is of primary importance to the entrainment risk of their offspring during late winter and spring – particularly if outflow does not increase during the period that adults spawn and eggs hatch, thereby helping to move the larvae seaward.

In addition, entrainment risk for Delta Smelt larvae may be influenced by river flow direction and velocity, and by other environmental conditions such as turbidity, temperature, and food. However, the way these environmental conditions affect larvae is likely different than for adults because the younger fish are weaker swimmers, are seeking rearing habitat, and initially are not as strongly associated with turbidity as metamorphosed individuals (e.g. Miller 2011). For example, if adults encounter unsuitable water quality conditions (e.g. low turbidity) in channels adjacent to the pumps, they may have some ability to avoid being entrained by moving toward habitat with better conditons (e.g. higher turbidity). By contrast, unsuitable water quality conditions may not be enough to redirect larval fish movements, especially closer to the export facilities where the ebb tide can be absent.

Salvage numbers are currently used to determine incidental take limits and index entrainment for post-larvae. Fish greater than 20 mm FL are counted at the screens (Grimaldo et al. 2009, Morinaka 2013), but because salvage data suggest that the fish screens do not effectively catch fish smaller than 30 mm FL (e.g. Figure 6 in Kimmerer 2008), there is a high degree of uncertainty about the number of larvae entrained.

Population Effects

Ultimately, a major question for Delta fisheries managers is the effect of entrainment on the Delta Smelt population. For the purposes of the conceptual models, three types of population effects are considered: 1) the proportion of the population entrained at each life stage; 2) the resultant effects on population viability; and 3) demographic effects.

Proportional Entrainment of Delta Smelt: The proportional entrainment of Delta Smelt is a major management issue for the establishment of take limits in the Delta Smelt Biological Opinion (FWS 2008). Given the complexity of the issue, proportional entrainment is exceptionally difficult to estimate. Below are two example approaches based on: (1) population estimates and (2) relative measures.

The first approach requires estimates of both entrainment losses and the population size of Delta Smelt. Unfortunately, the relationship between salvage and entrainment is poorly understood and likely variable, making it difficult to get accurate estimates of entrainment (Kimmerer 2011; Miller 2011; Castillo et al. 2012). Second, key information is lacking to develop reliable population estimates for Delta Smelt (Newman 2008). One approach to deal with these issues is to model fish survey and salvage data in combination with multiple (and mostly untested) assumptions (Newman 2008; Kimmerer 2008, 2011; Miller 2011; Mount et al. 2013; Rose et al. 2013a,b). These efforts have provided estimates of both adult and larval losses for selected recent years. However, a major challenge is that Delta Smelt catch in fish surveys has been very low since the onset of the Pelagic Organism Decline in 2002 (Sommer et al. 2007). The present low detection probability means that uncertainty is high about both entrainment and relative population levels.

A second approach to estimate entrainment levels does not require actual population estimates. For example, densities of fish collected at the export facilities can be compared with densities at multiple locations across the distribution of the species (e.g. Kimmerer 2008; Mount et al. 2013). This approach has been used in at least a conceptual way to establish take levels (i.e. winter entrainment) of adults by examining data from the previous season (Fall Midwater Trawl, FMWT) to index relative population levels (USFWS 2008). The FMWT has been used in this relative approach because it has a wider range of sampling stations and a longer historical record than is available in winter (the Spring Kodiak Trawl, and allows the development of take levels in advance of first flush events that often coincide with increased entrainment.

Effects on Population Viability & Dynamics: Understanding the proportion of fish lost to entrainment is a key issue in the determination of incidental take levels, but a broader question is the degree to which entrainment affects Delta Smelt population dynamics and viability. This insight is needed to better describe when Delta Smelt entrainment levels are at a low or high risk to the population.

Several modeling studies have examined Delta Smelt population dynamics and included an entrainment component. As noted in Mount et al. (2013), these efforts, which are based on numerous assumptions, have relied on estimates of population parameters that have not been validated, so caution is needed in the interpretation of the results. One example is a transport-based approach (Mount et al. 2013), which, although moderately uncertain, suggested that changes in flow and export patterns modeled under some BDCP scenarios would reduce entrainment and substantially change long-term survival of Delta Smelt. Another example is a state–space multistage life cycle model to examine the effects of different environmental variables including entrainment on different life stages (Maunder and Deriso 2011). There is disagreement in the CAMT Entrainment Subgroup about whether the Maunder and Deriso (2011) results support the hypothesis that adult entrainment affect population trends. More recently, Rose et al. (2013a,b) developed an individual based life cycle model that included estimates of both larval and adult entrainment. They propose that there is a higher degree of support for entrainment effects, though this claim is based on assumptions about which there is disagreement including the assumptions that particle tracking model results are a reliable proxy for Delta Smelt movement and that Delta Smelt engage in a large-scale eastward migration annually. In addition, Miller et al. (2012) found evidence of entrainment effects on adult-to-juvenile survival but not over the fish's life cycle. Others have examined the effects of covariates on Delta Smelt population trends, but relied on seasonally averaged export levels rather than specific estimates of entrainment (MacNally et al. 2010; Thomson et al. 2010).

Genetic effects are considered as a key tool to understand the effects of harvest mortality on populations. Such effects may include loss of genetic variation, and selective genetic changes (Allendorf et al. 2008). One approach to examine patterns in population viability is to examine effective population size (N_e) based on genetics, as well as overall population size (N) though this is not the only approach and it may yield results inconsistent with other approaches (e.g., measurement of allelic richness). Low N_e/N ratios can indicate the population has low genetic variability, potentially resulting in reduced adaptability, persistence, and productivity (Hauser et al. 2002). Efforts are currently underway to measure both N_e and N for Delta Smelt. Population viability can also be examined using alternative, non-genetic approaches. For example, Bennett (2005) presented a population viability analysis (PVA) using historical Delta Smelt FMWT indices to assess the long-term trajectory of the population. To our knowledge, there have been no attempts to incorporate different stressors such as entrainment into a PVA model.

Demographic Effects: There is an increasing recognition in fisheries biology that there can be substantial diversity in the life history strategies of individuals and sub-groups of populations (e.g. Secor 1999). It is hypothesized that these different strategies provide “bet hedging” against variable environmental conditions. Recent studies on otolith microchemistry (Hobbs et al. 2007; Hobbs 2010) reveal that Delta Smelt have substantial variability in their use of different salinities across the estuary. Examples of life history types observed include: freshwater residents; brackish residents; and fish that move to and from brackish and freshwater. This type of diversity may not be confined to salinity - other variation such as temporal or geographic could be considered. Given these issues, it is important to understand whether and how entrainment affects the range of life history strategies that can be exhibited by Delta Smelt.

Mechanistic Entrainment Model. This model illustrates how several different mechanisms may interact to cause entrainment, and associated effects on the Delta Smelt population. The individual models for adults and larvae are provided below in Figures 4-3 and 4-4, respectively.

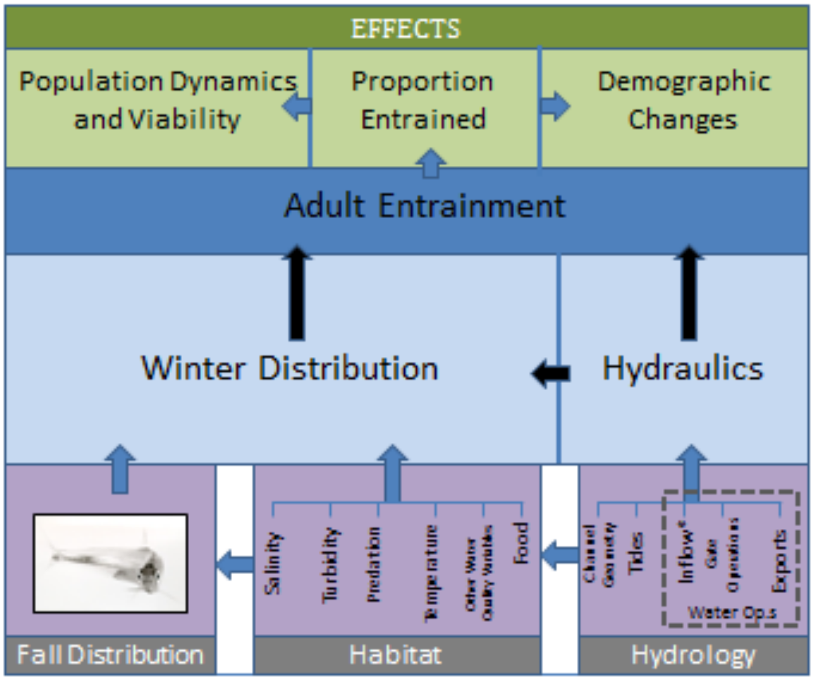


Figure 4-3 Mechanistic Entrainment Model for Adult Delta Smelt

Inflow is shown with an asterisk (*) in the "Water Ops" box (lower right) because it is driven by both operations and external weather conditions.

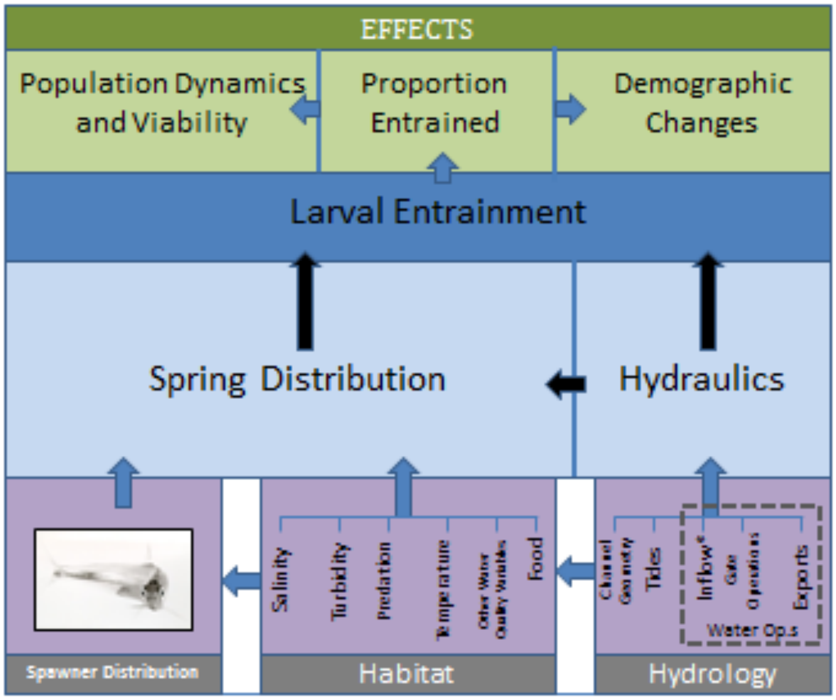


Figure 4-4 Mechanistic Entrainment Model for Larval Delta Smelt

Inflow is shown with an asterisk (*) in the "Water Ops" box (lower right) because it is driven by both operations and external weather conditions.

The background information supporting the adult and larval Mechanistic Entrainment Models were provided in the previous section. The following is a brief explanation of how different model components interact for the adult model.

The focus of this model is entrainment, shown as a dark blue row. The model illustrates how entrainment can have three types of population level effects (green rows in upper part of figure). These effects can include proportional entrainment, population dynamics, and demographic effects.

A hypothesis is that the two main factors influencing entrainment (dark blue row) are Winter Distribution of Delta Smelt, and Hydraulics (light blue row). Of primary interest for Winter Distribution is the proportion of the Delta Smelt spawning population that is distributed in the region of the lower San Joaquin River (south Delta), where entrainment risks are elevated. Hydraulics includes factors such as Old and Middle River flow direction and velocity that may influence movement of the fish towards the south Delta export facilities.

Moreover, the model posits that Winter Distribution (left light blue box) can be influenced by winter Hydraulics (Right light blue box), as well as two additional factors (purple row): Habitat conditions during winter and Fall Distribution of pre-spawning Delta Smelt. Specifically, the model predicts that Delta Smelt will not shift their Winter Distribution into the south Delta unless habitat conditions are suitable. Example Habitat conditions in this model include: Salinity, Temperature, Turbidity, Food, Predation, and Other Water Quality Variables. Fall Distribution of pre-spawning fish is included because fish may be at more or less risk depending on where they are located prior to moving to spawning areas. For example, pre-spawning fish distributed in the Cache Slough Complex are highly unlikely to be entrained by the South Delta export facilities. The model also recognizes that Habitat conditions (middle purple box) can affect the Fall Distribution (left purple box) of pre-spawning Delta Smelt.

Finally, the model proposes that Hydrology (right purple box) affects Habitat Conditions (middle purple box) and Hydraulics (right light blue box). Note that Hydrology is divided into two general categories: (1) non-operational (channel geometry and tides); and (2) operational (exports, gate operations). Inflow is considered a component of both categories. Hence, the latter grouping helps to illustrate the potential role of operations in the management of entrainment.

The Mechanistic Entrainment Model for larvae (Figure 4) is very similar to what was described for adults (Figure 3). The only difference in the organization is that the Spring Distribution of larvae (left light blue box) is determined by Spawner Distribution (lower left purple box in Figure 4) rather than Fall Distribution as described for the adult model (lower left purple box in Figure 3).

Hypothesis-Driven Entrainment Model. This model incorporates several of the key mechanisms from the previous model and background information to illustrate how specific alternative hypotheses can be constructed about the movement of Delta Smelt. We propose that the entrainment of Delta Smelt in the south Delta is a spatially explicit process that depends on the movement of Delta Smelt as depicted in the following conceptual models for adults (Figure 4-5) and larvae and post-larvae (Figure 4-6).

Figure 4-5 for adult Delta Smelt illustrates that there are three general possibilities for winter spawning movements: (1) adults can move seaward; (2) adults can already be rearing in the Sacramento River system and stay there; or (3) adults can be near (or approaching) the confluence of the Sacramento and San Joaquin rivers. Only (3) has any meaningful probability of entrainment in the south Delta (depicted as P(E) > 0).

This conceptual model framework allows multiple alternative hypotheses to be depicted as quasi-mathematical statements. Each numbered alternative in each box represents a different draft conceptual model/hypothesis for why Delta Smelt move in a particular direction during the winter based on habitat conditions and hydraulics (see Figures 4-3 and 4-4 for Mechanistic Entrainment Model).

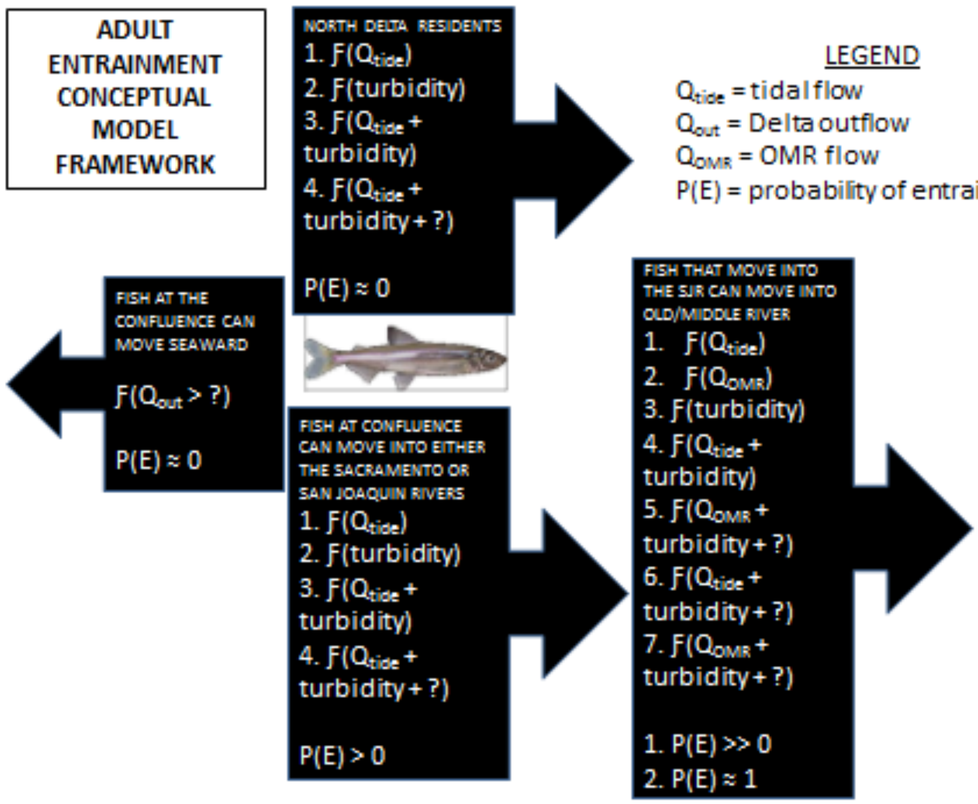


Figure 4-5 Hypothesis-Driven Entrainment Model for Adult Delta Smelt

The larval/post-larval entrainment framework is very similar except that it has some different elements; for instance, the location that eggs were spawned and hatched into larvae is included in the hypotheses, and tidal flows are de-emphasized because the larvae (1) rear for extended periods in freshwater (Dege and Brown 2004), and (2) are not attempting to move to freshwater spawning areas like the adults. For a small fish in a tidal environment like Delta Smelt, energetically effective upstream movement requires tidal surfing (use of the flood tide to propel fish upstream and ebb tide to propel fish downstream, and avoidance of full velocity parts of the water column to maintain position (Sommer et al. 2011; Feyrer et al. 2013). Very little directional swimming is required for position maintenance in a strongly tidal environment (Kimmerer et al. 1998; 2002; Bennett et al. 2002). Particle tracking models have been used to predict larval Delta Smelt distributions (Kimmerer 2008); however, models that are able to incorporate tidal surfing and other behaviors may provide more confident predictions.

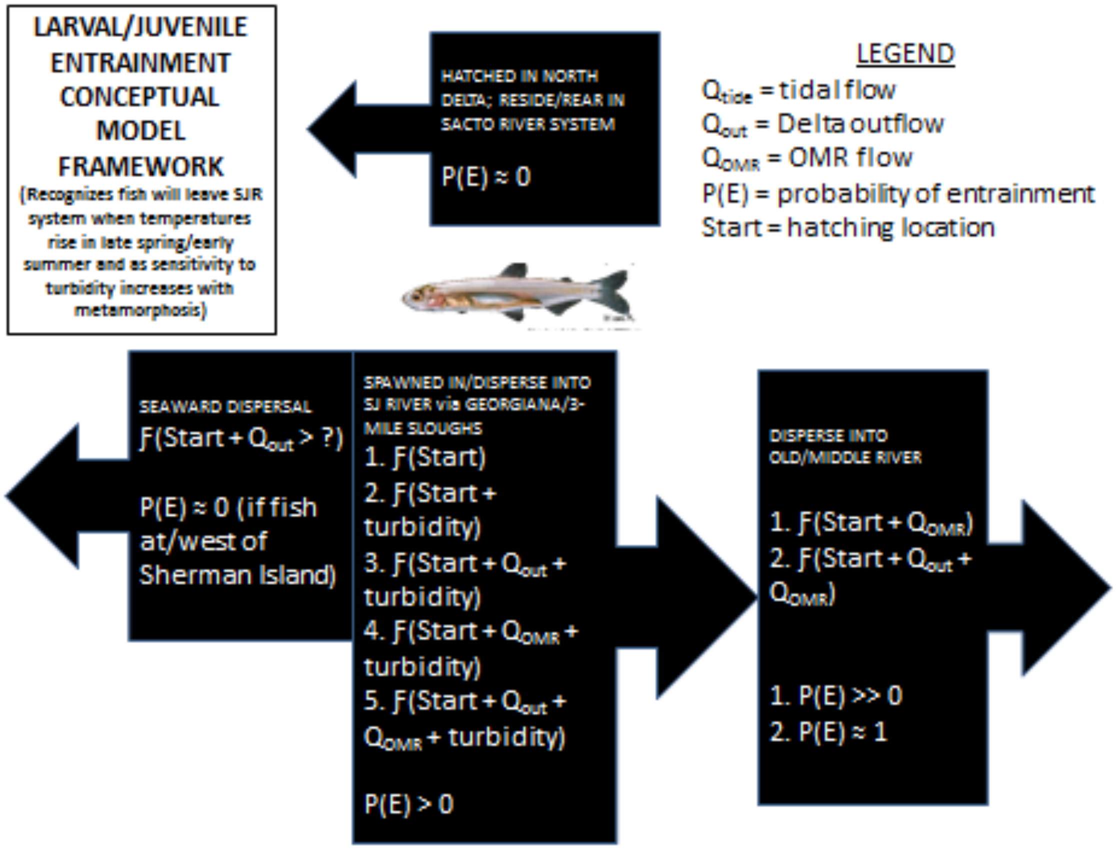


Figure 4-6 Hypothesis-Driven Entrainment Model for Larval and Post-Larval Delta Smelt

Management Action Entrainment Model. The third conceptual model (Figure 4-7) is structured to show how management actions (salmon-colored boxes) interact with ecosystem drivers (blue boxes) to produce physical responses in multiple ecosystem attributes (green boxes), which in turn lead to ecological responses of management concern (orange boxes). The example provided is for adult Delta Smelt, but a similar model could be developed for larvae. The primary ecological response of management concern is the proportion of the Delta Smelt population in the vicinity of the water project pumps in the south Delta. Water project operations in the south Delta may then potentially influence the movement of fish toward project intake facilities, leading to entrainment. The model acknowledges environmental cues that trigger movement to spawning areas in the winter. A working hypothesis is that pre-spawning adults disperse to suitable spawning habitats in response to individual life history circumstance (the relevance of their area of origin) and cues (e.g. that might lead them to fresher water), but the biotic and abiotic conditions, particularly turbidity, must be suitable for the fish to initiate and sustain that movement. For Delta Smelt located near the river's confluence, the choice of whether to move into the San Joaquin River system or remain in the west or northern portion of the estuary may be determined in part by flows, tides, and habitat conditions such as water quality. Hence, the relative conditions in the San Joaquin River versus the Sacramento River may be a key factor guiding the fish towards one tributary versus another.

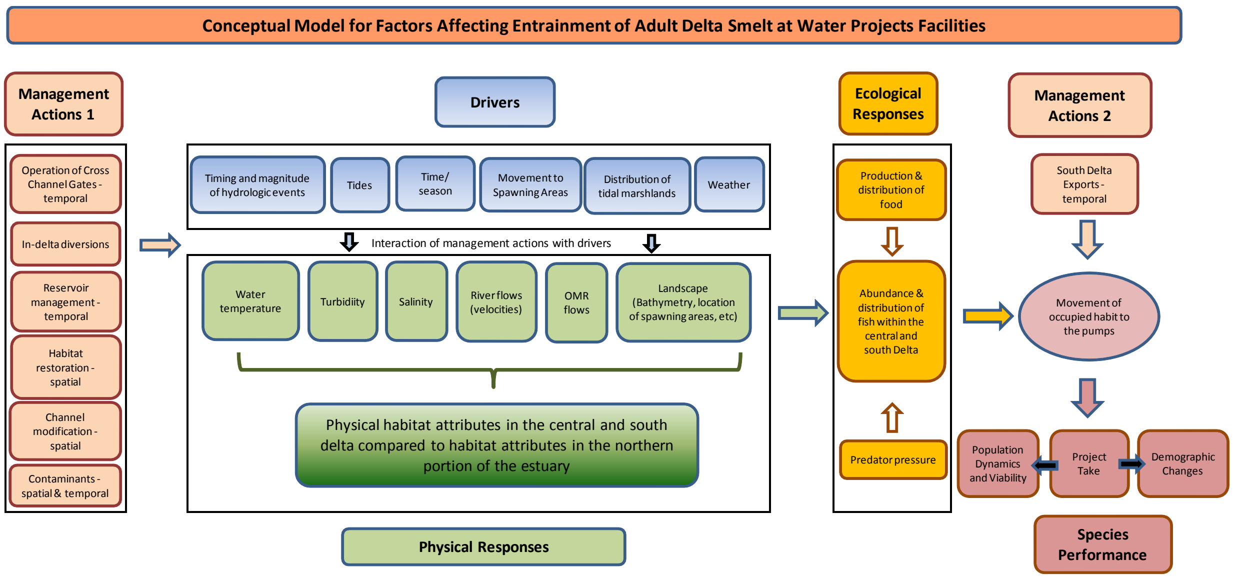


Figure 4-7 Management Action Entrainment Model for Adult Delta Smelt

4.3 South Delta Salmonid Survival

The NMFS 2009 Biological Opinion on long-term operations of the CVP and SWP includes two RPA actions that focus on Delta project operations (and associated hydrodynamic conditions) and through-Delta outmigration success of salmonids:

> Action IV.2.3 – Requires OMR flows to be no more negative than -5,000 cfs; less negative levels are required when salmonid salvage at the export facilities exceeds specified triggers
>
> Action IV.2.1 – Requires the projects to operate to a particular San Joaquin inflow to Delta export (I:E) ratio based on the San Joaquin water year classification.

South Delta Salmonid Survival Problem Statement

There is general agreement that survival of emigrating salmonids from the San Joaquin River system through the south Delta has declined in recent years and is now very low. There is a range of views regarding the effects of south Delta hydrodynamics, as affected by San Joaquin inflow or delta exports, on the survival of salmonids emigrating from the San Joaquin River (and for that matter from the Sacramento River) through the south Delta.

Whether I:E ratio or OMR flows are appropriate metrics for linking to salmonid survival is subject to different views. Some feel that both metrics are useful, some feel that one metric may be more useful than the other, and some question the use of either metric as a factor influencing salmonid survival.

The understanding of causal mechanisms for the decline in survival could be improved through targeted studies, additional in-depth analyses of existing data, and development of new modeling tools. This will require consideration of linkages between various physical and hydrodynamic factors and biological behavioral cues and responses (including those of both salmonids and predators). The influence of San Joaquin River inflows and project exports on these factors is of particular importance to CSAMP due to the scope of the Section 7 consultation. Reducing uncertainties in how management of water operations affect patterns of survival and mortality of outmigrating salmonids is a key goal of the CSAMP effort.

South Delta Salmonid Research Collaborative (SDSRC)

In an effort to improve understanding and reduce uncertainties concerning the role of water project operations, NMFS and DWR jointly initiated the South Delta Salmonid Research Collaborative (SDSRC) in early 2013 (prior to the formation of CSAMP and CAMT) with input and participation of Reclamation, U.S. Fish and Wildlife Service (USFWS), California Department of Fish and Wildlife (DFW), State Water Contractors, Westlands Water District, and Delta Stewardship Council. The SDSRC was convened as an open technical forum bringing together researchers and managers to focus on improving the understanding of juvenile salmonid survival in the south Sacramento-San Joaquin Delta.

While the SDSRC was not formed, or directed by CAMT, CAMT has looked to the work of the SDSRC to inform the development of its workplan (see Section 3). The sections below provide highlights from the SDSRC work to date. A more complete description of the SDSRC and its activities can be found in Attachment A.

Beginning with its initial meeting in January 2013, the SDSRC adopted a stepwise strategy and aggressive timeline to design, peer review, and implement new research focused on increasing the understanding of the role of water project operations on juvenile salmonid survival. The SDSRC developed a series of technical products, including:

- A conceptual model of south Delta salmonid migrational survival (see Figure 4-8);
- An analysis of statistical power for a 1-year through-Delta survival study of steelhead and fall Chinook (Appendix M in Attachment A);
- Identification of potential effect size differences that may be important biologically for the purposes of experimental design development and scientific inquiry;
- Fourteen hypothesis-based concept proposals for research improving the understanding of south Delta salmonid survival (Appendix G in Attachment A);
- Guidelines for concept proposal evaluation (Appendix H in Attachment A);
- A review of the ongoing 6-year steelhead survival study (RPA Action IV.2.2), to include identification of inflow-export conditions that have not yet been tested (Appendix L in Attachment A);
- Identification of opportunities and constraints to enhance learning from the 6-year steelhead study in 2014 (Section 4.4 in Attachment A);
- Identification of a new “Desktop Survival Study” (still in review) for implementation in as early as 2014 that includes additional analysis or meta-analysis of data from previously conducted studies of the survival and movement of tagged salmonids (Appendix J in Attachment A)

The SDSRC has proven to be a productive forum for exchanging views and exploring different approaches to new scientific efforts targeting management-relevant questions. In addition to developing a conceptual model and associated research proposals focusing on key research pathways, the group has had technical discussions about a wide range of topics, including what levels of effect are biologically relevant, the statistical power and experimental conditions needed to detect a particular effect, the potential ambiguities in interpreting results from acoustic tag data, the kinds of covariates that would ideally be measured during any experiment, and the various specific hydrodynamic cues that fish may be responding to.

South Delta Salmonid Survival Conceptual Model and SDSRC Study Proposals

Figure 4-8 below shows the current conceptual model being used by the SDSRC as a framework for development of hypotheses and concept proposals relating to south Delta salmonid smolt survival. Because this model includes extra-regional drivers affecting mechanistic relationships in the model, such as tidal forcing, and incorporates endpoints related to the fuller life cycle, such as juvenile condition and timing of ocean entry, it accommodates a wide range of hypotheses regarding the major factors influencing South Delta migration survival and population outcomes. Figure 4-8 also highlights (in white text) how the fourteen research proposals developed by the SDSRC relate to specific elements of the conceptual model. The numbers shown below each element refer to specific research proposals, as listed in Table 4-7.

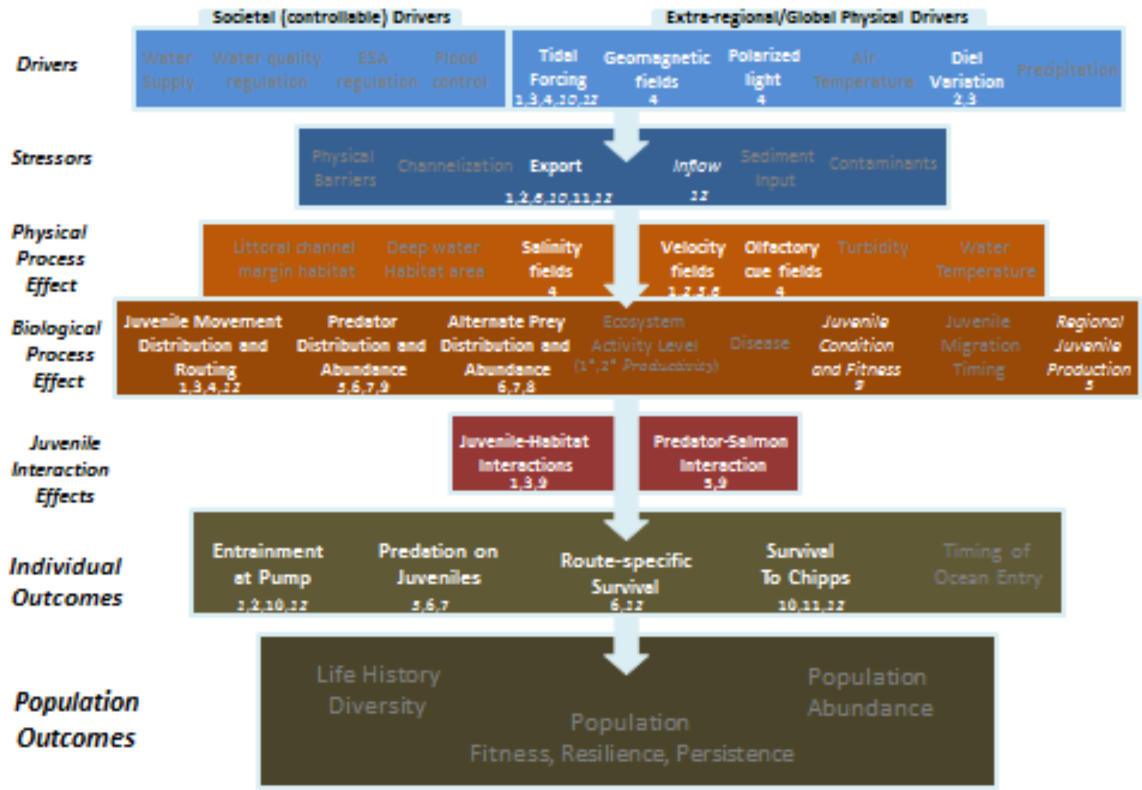


Figure 4-8 Conceptual Model for South Delta Smolt Survival (reflecting scope of SDSRC proposed studies)

Table 4-7 SDSRC Study Proposals

	Title	Conceptual Model Links		Study Questions
	Physical Drivers and Processes			
1	**Influence of tides and exports on movement of smolts in Old River**	*Drivers:* *Stressors:* *Physical Process:* *Biological Process:* *Interaction Effect:* *Individual Outcome:*	**Tidal Forcing** **Export** **Velocity Fields** **Juvenile Movement** **Juvenile-Habitat Interactions** Entrainment at Pumps	*How does OMR in combination with spring/neap tidal phase affect net movement of smolts along Old River?* *What is general movement behavior of smolts in relation to tidal stage?*
2	**Shifting Clifton Court fill rate and fill time to minimize smolt entrainment**	*Drivers:* *Stressor:* *Physical Process:* *Individual Outcome:*	**Diel Variation** **Export** Velocity Field **Entrainment at Pump**	*Does a reduced fill rate or a shift to nighttime filling reduce juvenile salmonid entrainment into Clifton Court Forebay?*
3	**Diel and tidal effects on fine-scale movement and habitat use in freshwater tidal environment**	*Drivers:* *Physical Process:* *Biological Process:* *Interaction Effects:*	**Tidal Forcing** **Diel Variation** Velocity Fields **Juvenile Movement/Dist/Routing** **Juvenile-Habitat Interactions**	*Does juvenile salmonid holding versus active migration behavior differ according to tidal stage or time of day in freshwater tidal environment?* *What habitat type do juveniles prefer during holding and during migration, or during day and night?*
4	**Juvenile salmonid navigation cues in a freshwater tidal environment**	*Drivers:* *Physical Process:* *Biological Process:*	**Tidal Forcing** **Geomagnetic Fields** **Polarized Light** **Salinity Fields** **Olfactory Cue Fields** **Juvenile Movement/Dist/Routing**	*How do juvenile salmonids determine migration direction in a tidal environment?* *Are changes in water quality parameters over the tidal cycle associated with active migration versus holding behavior?* *Are juveniles predisposed to migrate in a fixed compass direction, and does this direction differ between northern and southern stocks from the Central Valley?*

	Title	Conceptual Model Links		Study Questions
	Biological Process: Predation			
5	**Predator-prey dynamics in a tidal environment: a modeling study**	*Biological Process:* *Interaction Effects:* *Individual Outcome:*	Predator Dist/Abund Regional Smolt Production **Predator-Salmon Interaction** Predation on Juveniles	*Can the activity patterns of predators and prey be understood as the outcome of coupled games played in the physical setting of the estuary?*
6	**Reach-specific influence of hydrodynamics on predation and factors affecting predation on steelhead**	*Stressor:* *Physical Process:* *Biological Process:* *Individual Outcome:*	Export Velocity Fields **Predator Dist/Abund** **Alternate Prey Dist/Abund** **Predation on Juveniles** **Route-specific Survival**	*Is survival related to predator density?* *Is predator density related to alternative prey density or net flow?* *Is survival, or predator and prey densities, related to proximity to CVP/SWP pumping facilities?*
7	**Prey base of dominant predators on juvenile salmonids**	*Biological Process:* *Individual Outcome:*	**Predator Dist/Abund** **Alternate Prey Dist/Abund** **Predation on Juveniles**	*What are the dominant predators on juvenile salmonids in the South Delta?* *What are the primary prey species that support these predators throughout the year?*
8	**SAV indirect support of dominant predators by support of alternative prey**	*Biological Process:*	**Alternate Prey Dist/Abund**	*Does submerged aquatic vegetation (SAV) support high densities of small centrarchids that potentially serve as alternative prey to predators on juvenile salmonids?*
9	**Habitat-associated predation risk and food availability**	*Biological Process:* *Interaction Effects:*	**Predator Dist/Abund** Juvenile Condition **Juvenile-Habitat Interactions** **Predator-salmon Interactions**	*Does predation risk or food availability for juvenile salmonids differ between freshwater tidal habitat types?*

	Title	Conceptual Model Links		Study Questions
	Individual Outcomes			
10	**Survival change detectability under extreme high-low export treatments**	*Drivers:* *Stressors:* *Individual Outcome:*	Tidal Forcing **Export** **Entrainment at Pumps** **Survival to Chipps**	*Can a clear export effect on survival be detected using extreme and sustained high and low export treatments?* *Is detectability different during spring versus neap tide conditions?*
11	**CVP/SWP pumping ratio on survival of entrained salmonids**	*Stressor:* *Individual Outcome:*	Export **Survival to Chipps**	*Can shifting SWP pumping to CVP increase survival of entrained juvenile salmonids?*
	Other (focus to be determined)			
12	**Reanalysis of existing acoustic tag study data**	*Drivers:* *Stressors:* *Biological Process:* *Individual Outcome:*	*Tidal Forcing* *Export and Inflow* *Juvenile Movement/Dist/Routing* *Route-specific Survival* *Entrainment at Pump* *Survival to Chipps*	*Can data from previous acoustic tag studies be reanalyzed to address important questions regarding juvenile salmonid route selection, migration rate, and survival not addressed in original reports?*

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5.0 Other Relevant Science Activities

The following sections briefly describe ongoing science activities that are not being directed by CAMT (most of the activities pre-date the formation of CAMT), but are relevant to the CAMT priority topic areas and the development of revised Delta Smelt and Salmonid Biological Opinions. Many of these activities have had little or no involvement by water agency or NGO representatives; however, the CAMT is exploring opportunities to improve collaboration on some of these in the future and the agencies are committed to greater stakeholder involvement.

5.1 The Fall Outflow Adaptive Management Plan (FOAMP)

The Biological Opinion required that Reclamation establish and conduct an adaptive management program to address uncertainties about the efficiency of the Fall X2 Action. The Biological Opinion requires that the adaptive management plan include "a clearly stated conceptual model, predictions of outcomes, a study design to determine the results of actions, a formal process for assessment and action adjustment, and a program of peer review…." (BiOp p. 369.) Reclamation worked with other federal and state agencies to develop and implement the Fall Outflow Adaptive Management Plan (FOAMP). The FOAMP is intended to effect adaptive management of the 2008 fall outflow RPA element, as well as inform development of future Biological Opinions.

As part of the FOAMP, a set of conceptual models was developed by an interagency team with the assistance of a few academic scientists. The team subsequently identified specific studies and and a written monitoring plan. The plan was informed by advice from a National Research Council panel that independently evaluated the biological opinions in a report published in 2010 (http://www.nap.edu/catalog.php?record_id=12881).

After over a year of development under Reclamation's supervision, the FOAMP investigations began in August of 2011 in cooperation with the Interagency Ecological Program (IEP), which is a research consortium of state and federal agencies, including California Department of Fish and Wildlife, California Department of Water Resources, U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, U.S. Geological Survey, and NOAA Fisheries Service. Individual studies were designed to answer questions about the ecology and dynamics of low-salinity habitat (LSH) in the San Francisco Estuary (SFE) and, specifically, the role of LSH in the biology and ecology of Delta Smelt. Because of the broad range of questions being explored by these studies, Reclamation, in cooperation with the IEP, perceived the need for a broad synthesis of the fall habitat studies, ongoing IEP monitoring and research, ongoing research funded by other entities, and previous studies in the San Francisco Estuary. The Fall Low Salinity Habitat, or "FLaSH" Report (Brown et al. 2013), is the first such synthesis, and regular updates are expected in the future as part of the annual AMP cycle. The FOAMP studies are summarized in the *Overview of Study Efforts* section below.

Subsequent to the release of the FlaSH Report, an IEP Modeling and Synthesis Team (MAST) conducted additional integrative analysis of fall habitat study results and has been preparing its findings in a document known as the MAST Report. In addition to synthesizing information on the effects of flow and other environmental drivers on Delta Smelt, the MAST has taken additional steps in refining the conceptual models underlying the FOAMP. The MAST conceptual models are now being used as a point of departure for both the FOAMP and the new CAMT studies.

The FOAMP was designed from the start to be subjected to independent scientific review on an ongoing basis. A standing independent expert science panel was created by the Delta Science Program in 2011. The panel reviewed an initial draft FOAMP in 2011, and then reviewed a more complete FOAMP and initial study results in 2012. Both reviews are available from the Delta Science Program website (http://deltacouncil.ca.gov/science-program/long-term-operations-biological-opinions-annual-science-review). The FOAMP expects to conduct another review with the panel in 2014 or 2015. The timing will depend on progress integrating stakeholder science priorities into the development process that will result in an updated FOAMP workplan in 2014.

5.2 FLaSH Studies in the IEP Workplan

The FLaSH studies fall broadly into several categories: 1) population estimation and support for interpretation of ongoing Delta Smelt monitoring programs; 2) environmental and hydrodynamic covariate sampling and interpretation; 3) nutrient source, fate, dynamics, and role in food web support; 4) phytoplankton dynamics, zooplankton dynamics, and Delta Smelt prey sampling; 5) Delta Smelt growth rate estimates and otolith micro chemistry interpretation; 6) histopathological characterization of Delta fishes and indicators of individual health; 7) smelt culture and genetics characterization, 8) bivalve biology and behavior, and; 9) contaminants and harmful algal bloom detection and effects characterization. Table 5-1 below provides a summary listing of the ongoing FLaSH studies.

5.3 Delta Smelt Lifecycle Modeling Studies (Newman et al., USFWS)

A Delta Smelt life cycle model to be used as a management decision support tool is under development. The initial modeling objective is to use the model to assess and to predict the effects on the Delta Smelt population of water manipulations in the central and south Delta during the winter and spring months. In particular the focus is on the effects of various levels of reverse Old and Middle River (OMR) flows, which are primarily a function of water inflows, water export levels, and the tides, on fish survival and reproductive success while accounting for water turbidity and the spatial distribution of the fish population. Effects of fall outflow strategies will be examined in future applications of the model and supporting data sets.

The underlying statistical framework is a state space model (SSM). A SSM is a technique for modeling two parallel time series, one describing the underlying population dynamics (the "state" process) and another describing the available fish survey and environmental data (the "observation" model). The current state process formulation has a monthly time step and splits the Bay-Delta into four regions. The population dynamics include explicit definition of survival, reproduction, and movement processes. The effects of OMR flows enters into the model via the adult fish survival probabilities, particularly for fish present in the south and central Delta, and via hydrological partical tracking model predictions (DSM-2 PTM) of the entrainment of larvae and post-larvae. The model is being fit to data from several fish monitoring programs (e.g., 20mm, Summer Townet, Fall Midwater Trawl, Bay Study Midwater Trawl, and Spring Kodiak Trawl surveys) and incorporates other bioitic data, e.g., Environmental Monitoring Program's zooplankton survey, and abiotic data, (e.g., water conditions such as tidal velocity, turbidity, etc.).

Table 5-1 FLaSH Studies Being Conducted by IEP

Investigation	Relevance	Investigative Approach	Responsibility	Schedule
Population Estimation and support for interpretation of ongoing Delta Smelt Monitoring programs				
1. #89 Directed Field Collections - Supplements to long-term population abundance surveys. Collection support analyses including smelt health, otolith, gut content, food web investigation	Raw data to address hypotheses	Field collection associated with FLaSH	DFW-POD (Existing effort) (Baxter)	TBA
2. #208 Smelt life cycle model - State-space model construction and estimate Delta Smelt population abundance	Model construction	2 phased effort to develop life history model of Delta Smelt and multiple single species life history models/or single integrated multispecies life history model	USFWS (Existing effort) (Newman)	Manuscripts in progress. Data needed for model fitting are nearly complete
3. #130 Towed imaging System Testing of video-based towed abundance sampling for application to Delta Smelt and longfin	Raw data to address hypotheses		USBR (Existing effort) (Portz)	Complete. Publication Feyrer et al. 2013
4. #131 Acoustics to estimate trawl openings- Supports gear efficiency	Tool Development- support gear		DFW (existing effort) (Baxter)	

	evaluation and interpretation of catch effort	efficiency			
5.	#182 Develop Acoustic transmitter suitable for use in Delta Smelt	Tool for population estimate of Delta Smelt	Tool Development	UCD (Existing effort) (Loge)	Complete. Final report available
Environmental and Hydrodynamic covariate sampling and interpretation					
6.	#205 Delta Sediment measurements and #206 boundary condition monitoring - Measurement and calibration of particle-size binned sediment dynamics at the Delta Boundaries	Raw data to address hypotheses	Collect field monitoring data Data used to support development, calibration and validation of numerical models of sediment transport and turbidity	USGS (Wright)	3^{rd} year of 4 year agreement
7.	#230 Suspended sediment and X2 in Suisun Bay and the confluence during fall, 1994-2011-Sediment dynamics time series	Data collection and analysis to address hypotheses	Analysis of historical Data	USGS (Existing effort) (Schoellhammer)	4^{th} year of 5 year agreement
8.	#180 Hydrodynamics and Particle Tracking modeling of Delta Smelt Habitat and Prey - Support for the individual-Based model published by Rose et al.	Individual-Based Model Support and understand variability of physical fish habitat with Fall X2 and population dynamics of	Modeling and analysis of lab data	SFSU (Existing effort) (Kimmerer)	Contract ended 12/31/13- 3 manuscripts in prep

	Calanoid copopods			
9. #232 Suisun Bay Hydrodynamics: Flows, salt fluxes and X2 dynamics during the IEP fall X2 study	Modeling to address hypotheses	Hydrodynamic modeling and mapping	Stanford (Existing effort) (Monismith)	Ongoing
10. #207 3D simulation of Delta Smelt hatchling distribution and mortality	Modeling to address hypotheses	Mechanistic modeling	RMA Associates (Gross)	Ongoing. Draft expected spring 2014
11. #236 Sample Processing for nutrients, suspended solids, and chlorophyll concentrations for fall X2 work.			UC Davis (Existing effort) (Dahlgren)	2nd year of 5 year agreement
Nutrient source, fate, dynamics, and role in food web support				
12. #175 Effects of Seasonal variation in flow on the spatial and temporal variations of nutrients, organic matter, and phytoplankton	Raw data to address hypotheses	Analysis of existing data and new modeling work	USGS (Kendall)	Ongoing
13. #179 Causes of Seasonal and spatial seasonal variation in variation in NH4 sources, sinks, and contribution to algal productivity using a multi-isotopic approach	Raw data to address hypotheses	New multiple stable isotope approach to analyze existing and new data	USGS (Kendall)	Ongoing
14. #234 Residence time as an aid to interpret nutrient	Raw data to address		USGS (Kendall)	4th year of 5 year agreement

dynamics and other habitat characteristics in Suisun, SJR confluence and Cache Slough complex	hypotheses			
15. #235 Enhanced fall habitat characterization using a multi-fingerprinting approach	Raw data to address hypotheses	Extend and enhance ongoing IEP Investigations Analysis of previously collected samples	USGS (Kendall)	4th year of 5 year agreement
16. #173 Distribution, concentrations, and fate of ammonium in the Sacramento River and the low salinity zone (phytoplankton uptake and bacterial nitrification rates)	Raw data to address hypotheses	Lab experiment	SFSU (Dugdale)	Extended to 12/31/13
17. #174 Influence of elevated ammonium on phytoplankton physiology in the SFE during Fall	Raw data to address hypotheses	Lab assessment of primary productivity and ammonium uptake	Cal Maritime (Parker)	Extended to 12/31/13
18. #229 Supplemental Nutrient and phytoplankton monitoring in Suisun Bay			Cal Maritime (Parker)	Ends 12/31/13
Phytoplankton dynamics, zooplankton dynamics, and Delta Smelt prey sampling				
19. #169 Delta Smelt feeding and food web interactions. Ongoing studies of smelt feeding	Data need to define habitat of Smelt	Field and experimental work	SFSU (Existing effort) (Kimmerer)	Extended to 12/31/13 Sample processing to

behavior under varying conditions of prey density and predators				continue through 2014 2 manuscripts submitted 6 manuscripts in prep
20. #62 Fish Diet and condition, See FLaSH report (2013)			FLaSH report (Existing effort)	
Delta Smelt growth rate estimates and otolith micro chemistry interpretation				
21. Interdisciplinary studies on Delta Smelt and longfin smelt. Otolith microchemistry analyses and life-history reconstructions of Delta Smelt			UCD (Hobbs)	Completed. Publication status unknown
Histopathological characterization of Delta fishes and indicators of individual health				
22. #228 Estimation of survival, growth, and reproductive fitness of Delta Smelt	Raw data to address hypotheses		UCD (Teh)	Completed
Smelt culture and genetics characterization				
23. #108 Delta Smelt culture facility	Source of Fish for Lab and Field Experiments	Lab culture of fish	UCD (Existing Effort) (Lindberg)	Continuous
24. #135 Delta Smelt genetics	Development of new lab techniques	Development of 69 SNP markers to replace microsatellite markers	UCD (May)	

Bivalve biology and behavior				
25. #231 Bivalve effects on the food web supporting Delta Smelt and recruitment patterns of bivalves with varying freshwater flow	Raw data to address hypotheses		USGS (Thompson)	4th year of 5 year agreement Manuscript expected Summer 2014
Contaminants and harmful algal bloom detection and effects characterization				
26. #177 Medabolic responses to variable sensitivity environments in field acclimatized *Corbula amurensis*	Raw data to address hypotheses	Lab experiment	UCD (Stillman)	Extended to 12/31/13 I publication in MEPS 2 manuscripts in prep
27. Regarding environmental stresses associated with pollutants and changing turbidities	Raw data to address hypotheses	Lab experiment	UCD (Connon)	
28. #171 Remote sensing mapping and monitoring of Microcystis and turbidity in the upper SFE.- low resolution study (30 meter pixel) as proof-of-concepts for monitoring Microsystis			UCD (Ustin)	Complete
Other Studies				
29. Delta Smelt Lifecycle Modeling Study	Life cycle model to be used as a management		USFWS (Newman)	

	decision support tool. Particular focus on the effect of various levels of reverse OMR flows on fish survival and reproductive success.	
30. Trawl Gear Efficiency evaluation	Estimates of gear efficiencies for Delta Smelt survey data for calculating absolute Delta Smelt abundance over particular interval	DFW and USFWS (Baxter)
31. Smelt Survey Review Study	Evaluation of existing sampling programs and interpretation efforts, describing explicit management driven information need and anticipated data gaps	UCD (Emilio Laca)

5.4 Trawl Gear Efficiency Evaluation

This study will provide estimates of gear efficiencies for Delta Smelt survey data for calculating absolute Delta Smelt abundances over particular intervals, and to support models of smelt population dynamics using integrated data (including gear efficiency estimates) from several of the existing IEP surveys. The objective is to more completely understand how current and historical surveys reflect actual Delta Smelt populations, locations, and densities. Current estimates do not include estimates of error, and therefore are unsatisfactory to assess real smelt abundance, or to measure smelt response to management inputs. This project is expected to generate more accurate data in the future that will be used to inform Delta Smelt population models under construction by members of the IEP and others (see, for example, Newman et al.). The study is being led by the California Department of Fish and Wildlife.

Below is a brief list of work plan elements included in the evaluation:

- *Understand logistical requirements and develop coordinated IEP scheduling*
  - Assemble California Department of Fish and Wildlife (DFW) and IEP employees to discuss and characterize logistical items for coordination and planning purposes, specifying constraints, safety issues, vessel coordination, gear redundancy needs, equipment, and deployment choreography and responsibilities.
- *Conduct pilot scheduling and testing*
  - Execute whatever trial sampling and deployment rehearsals necessary to de-bug and fail-safe data collection procedures. Establish vessel responsibilities, generate crew requirements and identify temporary staff hiring needs. Determine crew and sampling safety requirements.
- *Execute targeted gear deployments and repeated surveys*
  - Collect controlled and targeted information on the volume sampled at various depths by various gear types. Determine the depth and lateral distributions of Delta Smelt by life stage and/or gear type.
- *Evaluate gear performance, prepare reports*
  - Calculate the relative gear efficiencies for different IEP fish surveys, emphasizing those focused on Delta Smelt (e.g., Spring Kodiak Trawl survey, 20mm survey, Summer Townet, Fall Midwater Trawl survey), and adding important additional surveys if possible (e.g., Chipps Island Survey, Bay Study Midwater Trawl). Prepare analysis and interpretation as reports on gear performance to the IEP and to the various modeling teams using survey data as input information to understand Delta Smelt life cycle and population variability over time and space.

5.5 Smelt Survey Review Study

This study is critically evaluating existing sampling programs and interpretation efforts, describing explicit management-driven information needs and anticipated data gaps, and will propose updated or alternative protocols to match needs, sampling/collection schemes, and interpretation constraints. The study is being conducted by Professor Emilio Laca at the University of California, Davis with funding provided by the FWS.

Below is a brief list of work plan elements included in the Smelt Survey Review Study:

- *Conduct Scoping Workshop*
  - Assemble Agency (IEP) representatives for the purpose of identifying available programmatic materials for review, identifying available support personnel, finalizing project timelines and specifying deliverables under general contract terms. Ongoing Juvenile Fish Monitoring Program and Juvenile Salmon Survivorship Study review planning shall be used as a guide for finalizing work priorities and deliverables.
- *Understand and characterize current aims and protocols*
  - Collect background on purpose and requirements for surveys. Understand current field protocols and equipment limitations. Become familiar with past and current needs for data and information, management questions, and water operations recommendations. Provide context for IEP regulatory requirements, special studies demands, and Workplan formulation.
- *Evaluate statistical validity of collection and interpretation protocols and procedures; propose alternative methods if necessary*
  - Examine temporal and spatial aspects of sampling routines in light of long-term collection aims and newer, near-term data interpretation needs. Incorporate updated collection and interpretation methods where warranted. Provide contrast between past, present, and proposed protocols for illustration. Describe shortcoming and strengths of existing sampling schemes given existing infrastructural and programmatic limitations.
- *Devise implementation plan/change scheme and provide oversight for modification efforts (as needed)*
  - Using current IEP sampling programs as a basis for recommendation, provide updated or modified sampling plan, if needed. Oversee data conversion where necessary. Provide archive/conversion services as needed to avoid “orphan” data sets. Provide guidance regarding change-over to newer or modified data collection and interpretation schemes.

5.6 Central Valley Chinook Life Cycle Model

The NMFS Southwest Fisheries Science Center is leading a team developing a Central Valley Chinook Life Cycle Model (CVC-LCM) that tracks the production, movement, survival, and development of monthly cohorts of winter-run Chinook salmon through five distinct habitats: River, Delta, Floodplain, Bay, and Ocean. Hydrodynamics and water quality in the River and Delta play a key role in determining the probability that salmon will survive through the different stages of their life cycle. For example, water flow and velocity drives the movement of salmon through their ecosystem, which influences their ultimate survival and ability to reproduce. In addition, salmon survival is affected by the availability of highly-productive floodplain habitat that is generated by flows of sufficient magnitude to overtop weirs in the Central Valley.

A variety of water management decisions, such as reservoir releases, water diversions, pumping schedules, etc., influence the hydrodynamics of the River and Delta habitats. Initial modeling will use existing models (CALSIM II, HEC-RAS and DSM2) to describe the physical environment under various hydrological and operational scenarios. Later versions of the model will use a modified DWR Particle Tracking Model (PTM) to include fish-like behaviors, to predict salmon survival under different conditions in the Delta.

5.7 Enhanced PTM

As described in the summary of the CVC-LCM above, the LCM development team expects to incorporate a modification of the DWR's PTM module in later versions of the CVC-LCM that will model how particles with fish-like behaviors respond to hydrodynamic conditions in the Delta. Development of this tool will allow evaluation of RPA actions that affect within-delta hydrodynamic conditions.

5.8 Other Studies Pertaining to Juvenile Survival in the South Delta

Juvenile salmonid migrational behavior and survival in the south Delta has been the subject of considerable research. Table 5-2 provides a summary listing of proposed, ongoing, and recently completed studies pertaining to salmon survival in the south Delta.

5.9 IEP Studies Relevant to OMR and Delta Smelt Entrainment

Tables 5-3, 5-4, and 5-5 provide summary of some of the 2014 and 2105 IEP studies that help to address specific questions and hypotheses regarding OMR and Delta Smelt entrainment. These tables illustrate how many IEP studies directly address data needs, hypotheses, and questions. The tables summarize: studies planned for 2014 (Table 5-3); likely studies to be added in 2014 (Table 5-4); and additional relevant work that is being considered for 2015 (Table 5-5). It should be clear from the tables that multiple surveys, data sets, and studies will likely be necessary to address the questions and hypotheses outlined in Section 4.2.

Table 5-2 Ongoing or Completed Studies Related to South Delta Salmonid Survival

	Title	Conceptual Model Links		Study Questions	Study Lead	Status
	Biological Process: Smolt Routing					
1	**2012 Steelhead Stipulation Study**	*Stressors:* *Biological Process:* *Individual Outcome:*	Inflow and Exports **Juvenile Movement/Distribution** Survival to Chipps	*What are the effects of April/May OMR flows on steelhead survival and migration?* *How do tidal conditions and OMR flows affect route entrainment?*	Kevin Clark, DWR	Final Report pending
2	**Barrier Studies at Georgiana Slough**	*Stressors:* *Physical Process:* *Biological Process:* *Individual Outcome:*	**Barriers (*physical & non-physical)*** Inflow and Exports **Velocity Fields** **Juvenile Movement/Routing** Entrainment at Pump Predation on Juveniles Route Specific Survival **Survival to Chipps**	*How does fish distribution at junctions and hydrodynamics affect route selection?* *How do non-physical barriers affect route selection?* *What are route specific survival rates to Chipps Island?*	Jacob McQuirk, DWR	Completed; Additional work proposed for 2014
3	**Six-Year Acoustic Tagging Study**	*Stressors:* *Biological Process:* *Individual Outcome:*	Inflow and Exports **Juvenile Movement/Distribution** **Entrainment at Pumps** **Route Specific Survival** **Survival to Chipps**	*What is the survival of steelhead from tributaries to the SJR, through SJR, and the Delta?* *How does survival vary among individual reaches and salvage?* *What is the influence of flow and exports on steelhead distribution and survival?*	Joshua Israel, USBR	Ongoing
4	**Smart-particle modeling of juvenile route selection, travel time, and survival**	*Stressors:* *Physical Process:* *Biological Process:* *Individual Outcome:*	**Physical Barriers** Salinity **Velocity Fields** Turbidity Water Temperature **Juvenile Movement/Dist/Routing** **Predation on Juveniles**	*Can hydrodynamic fields, non-physical barrier operation and water quality factors explain route choice, travel time, and survival of juvenile salmonids?*	Xiaochun Wang, DWR	Ongoing

	Title	Conceptual Model Links		Study Questions	Study Lead	Status
	Biological Process: Predation					
5	**Head of Old River Fish Studies**	*Drivers:* *Stressors:* *Physical Process:* *Biological Process:* *Individual Outcome:*	Diel Variation **Barriers (*physical & non-physical*)** Inflow Water Temperature **Velocity Fields** **Juvenile Movement/Routing** **Predator Distrib/Abund** Alternate Prey Distrib/Abund Predation on Juveniles Route Specific Survival Survival to Chipps	*How does smolt distribution at junctions and hydrodynamics affect route selection?* *How do non-physical barriers affect route selection?* *How do barriers affect predation on salmon and steelhead?* *How do environmental variables affect predator density, habitat use, residence time and predation on juvenile salmonids in vicinity of barrier?*	Jacob McQuirk, DWR	Synthesis report thru 2013 pending; 2013 data yet to be analyzed
6	**Clifton Court Forebay Predation Studies**	*Biological Process:* *Individual Outcome:*	**Predator Distribution/Abundance** **Predation on Juveniles**	*What is the predator behavior in CCF, before and after installation of proposed fishing facility?* *What is the survival of salmonids in CCF, before and after installation of proposed fishing facility?*	Kevin Clark, DWR	Ongoing
7	**2013 – 2015 Predator Manipulation Study**	*Physical Process:* *Biological Process:* *Interaction:* *Individual Outcome:*	Velocity Fields **Predator Distribution/Abundance** Predator-Salmon Interaction **Predation on Juveniles**	*How does predator density affect predation rate?* *Is transit time or transit distance a better predictor of predation risk and survival?*	Sean Hayes, NOAA Fisheries	Ongoing
	Outcomes					
8	**San Joaquin Fall-run Salmon Outmigration**	*Stressors:* *Biological Process:* *Individual Outcome:*	**Inflow** and Exports Juvenile Routing **Entrainment at Pumps** Route-specific Survival **Survival to Chipps**	*How does fall-run survival vary across managed inflow (i.e., VAMP) and export conditions?* *How does survival vary between natural outmigration and salvage at the pumping plants?*	Patricia Brandes, UWFS	Ongoing

	Title	Conceptual Model Links	Study Questions	Study Lead	Status
9	**NMFS Winter-run Life Cycle Model**	*Stressors:* Export and Inflow *Physical Process:* Littoral Channel Margin Habitat Deep Water Habitat Area Velocity and Salinity Fields Water Temperature *Biological Process:* Juvenile Movement/Distrib/Routing Predator Distribution/Abundance Regional Juvenile Production Migration Timing *Interaction Effects:* Juvenile-Habitat Interactions Predator-Salmon Interaction *Individual Outcome:* Entrainment at Pump Predation on Juveniles Route-specific Survival Survival to Chipps Timing Ocean Entry *Pop Outcome:* **Life History Diversity** **Population Abundance** Population Fitness/Resilience	*Given relationships based on best available science between environmental variables and juvenile salmon migration behavior, predation risk, and ocean survival: how do water supply management decisions and proposed habitat restoration actions affect year-to-year survival, long-term population growth, and life-history diversity of winter-run Chinook Salmon?*	Steve Lindley, NOAA Fisheries	Ongoing

Table 5-3 Planned IEP Studies to support CAMT Entrainment Effort

Investigation	Key Question(s)	Relevance	Investigative Approach	Responsibility	Schedule
1. Environmental Monitoring Program (IEP)	3a, 4a-c, 5b-c H1-H5	Raw data to address hypotheses	Field monitoring data	DWR (Existing effort)	Monthly
2. Delta Flow Measurement and Database Management	4a-c, 5b-c H1-H5	Raw data to address hypotheses	Field monitoring data	USBR, DWR (Existing effort)	Monthly
3. Smelt Culture Facility	Many potential applications	Source of fish for possible lab and field experiments	Lab culture of fish	UCD (Existing effort)	Continuous
4. Physical Processes Influencing Smelt Migration	1c, 3a, 4a-c	Migration is key component of entrainment conceptual model	Analyses of field data collected in Sacramento and San Joaquin Rivers	UCD & BOR (Existing effort)	Ongoing through 2014
5. Data Management and Utilization	1a-b, 2a-b, 3a, 4a-c, 5a-c H1-H5	Data management system for effort	Data storage and management	DWR (Existing effort)	Continuous
6. 20 mm Delta Smelt Survey	2a-b, 5a-c H4-7	Raw data to address hypotheses	Field monitoring data	DFW (Existing effort)	Monthly
7. Gear efficiency in Support of Delta Smelt Modeling	1a-b, 2a-b, 3a, 4a-c, 5a-c H1-H5	Raw data to address hypotheses	Field monitoring data	DFW, FWS (Existing effort)	Variable
8. Delta Sediment Measurements	3a, 4a-c, 5b-c H1-H5	Raw data to address hypotheses	Field monitoring data	USGS, DWR (Existing effort)	Monthly

9. Fall Midwater Trawl Survey	3a H1, H6-8	Raw data to address hypotheses	Field monitoring data	DFW (Existing effort)	Monthly (fall)
10. Spring Kodiak Trawl	1a, 4a-c H1-3, H6-8	Raw data to address hypotheses	Field monitoring data	DFW (Existing effort)	Winter-Spring
11. Summer Townet Survey	2a-b, 5a-c H4-8	Raw data to address hypotheses	Field monitoring data	DFW (Existing effort)	Summer
12. Upper Estuary Zooplankton Monitoring	3a, 4a-c, 5b-c H1-H5	Raw data to address hypotheses	Field monitoring data	DFW (Existing effort)	Monthly
13. Delta Smelt Sampling Protocols and Ecological Interpretation	1a, 2a,3a,4a-c,5a-c H1-8	Evaluation of survey methods and data quality	Analysis of existing data	FYS (Existing effort)	Variable
14. Delta Smelt Life Cycle Model	H6-8	Need to evaluate population effects.	Modeling	FWS (Existing effort)	Continuous
15. Physiological Mechanisms of Environmental Tolerance in Delta Smelt	3a, 4a-c, 5b-c H1-H5	Study on habitat needs of Delta Smelt	Lab Experiment	UCD (Existing effort)	Seasonal
16. Suspended Sediment and X2 in Suisun Bay and the Confluence	3a, 4a-c, 5b-c H1-H5	Study on pre-movement conditions and possible triggers to movement.	Data analysis	USGS (Existing effort)	Variable

17. Evaluation of Natural Marking in Delta Smelt	1a-d, 2 a-d	Tool for field studies on entrainment	Tool development	FWS? (Existing effort)	Variable
18. Operation of Thermograph Stations	3a, 4a-c, 5b-c H1-H5	Raw data to address hypotheses	Field monitoring data	USBR, DWR (Existing effort)	Monthly
19. Bay-Delta Integrated Database	1a-b, 2a-b, 3a, 4a-c, 5a-c H1-H5	Data management system for effort	Data storage and management	Multiple agencies (Existing effort)	Continuous
20. Otolith Analyses of Pelagic Fish	4b, 6c H8	Data on movement patterns of smelt	Analysis of historical otoliths	UCD (Earlier Effort)	Report due in 2014
21. Estimation of Pelagic Fish Population Sizes	1a, 2a, 6a-b, d H6-H8	Needed to evaluate population effects	Analysis of historical data	FWS (Earlier Effort)	Report due in 2014
22. Feeding and Growth of Delta Smelt	3a, 4a-c, 5a-c H1-8	Data needed to define habitat of smelt.	Analysis of laboratory data	RTC (Earlier Effort)	Report due in 2014
23. Patterns of Predation on Delta Smelt	2-b, 5b-c, 6a-b,d H4-8	Information needed to evaluate mortality of larval smelt.	Analysis of laboratory and field data.	DWR, UCD (Earlier Effort)	Report due in 2014
24. Monitoring Inter-Annual Variability of Delta Smelt Contingents and Growth	1a-d, 2a-d, 3a, 4c, 5c, 6c H5-8	Needed to evaluate effects on life history diversity.	Analysis of historical field samples	UCD (Earlier Effort)	Report due in 2014
25. Delta Smelt Feeding and Food Web Interactions	3a, 4a-c, 5a-c H1-8	Needed to define habitat of Delta Smelt.	Analysis of field and lab data	RTC (Earlier Effort)	Report due in 2014

26. Longfin and Delta Smelt Bioenergetics	3a, 4a-c, 5a-c H1-8	Needed to define habitat of Delta Smelt.	Analysis of lab data	UCD (Earlier Effort)	Report due in 2014
27. TFCF Efficiency Evaluation for Delta Smelt	1a-d, 2 a-d	Needed for entrainment estimates	Analysis of experimental data	USBR (Earlier Effort)	Report due in 2014
28. Juvenile Salmon and Adult Delta Smelt Salvage Efficiency During VAMP at TFCF	1a-d, 2 a-d	Needed for entrainment estimates	Analysis of experimental data	USBR (Earlier Effort)	Report due in 2014

Table 5-4 Potential Additional 2014 IEP Studies to Support CAMT Entrainment Effort

Investigation	Key Question(s)	Relevance	Investigative Approach	Responsibility	Schedule
29. SmeltCAM	1d, 4e, 5d	Raw data to address hypotheses	IEP	USBR, DWR, DFW, Others (New effort)	TBA
30. Increased Survey Effort	1d, 4e, 5d	Raw data to address hypotheses	IEP	DFW, FWS (New effort)	TBA
31. Increased Spatial Coverage	1d, 4e, 5d	Raw data to address hypotheses	IEP	DFW, FWS (New effort)	TBA

Table 5-5 Potential Additional 2015 IEP Studies to Support CAMT Entrainment Effort

Investigation	Key Question(s)	Relevance	Investigative Approach	Responsibility	Schedule
32. Shadow Trawling	1d, 4e, 5d	Raw data to address hypotheses	IEP	DFW, FWS (New effort)	TBA
33. Random Sampling	1d, 4e, 5d	Raw data to address hypotheses	IEP	DFW, FWS (New effort)	TBA
34. Mark-Recapture Efficiency, Recapture, and Loss Experiments	1d, 4e, 5d	Raw data to address hypotheses	IEP	DFW, FWS? (New effort)	TBA

Attachment A: Progress Report South Delta Salmonid Research Collaborative (provided under separate cover)