Delta Smelt and CALFED's Environmental Water Account

Summary of a Workshop held September 7, 2001
Putah Creek Lodge
University of California, Davis

By

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Contents

Introduction

The delta smelt (*Hypomesus transpacificus*) is a small euryhaline osmerid native to California's San Francisco Estuary—spending much of its life near the confluence of the Sacramento and San Joaquin rivers (Figure 1). This area provides a home or a migratory corridor for more than 45 species of native and introduced fish and their supporting ecosystem. After exhibiting population declines in the 1980s, in 1993 the US Fish and Wildlife Service and the California Fish and Game Commission listed the smelt as threatened pursuant to the federal and state endangered species acts. Four other native fishes, winter and spring chinook, steelhead rainbow trout, and Sacramento splittail, are also listed as endangered or threatened under either the federal or state endangered species acts.

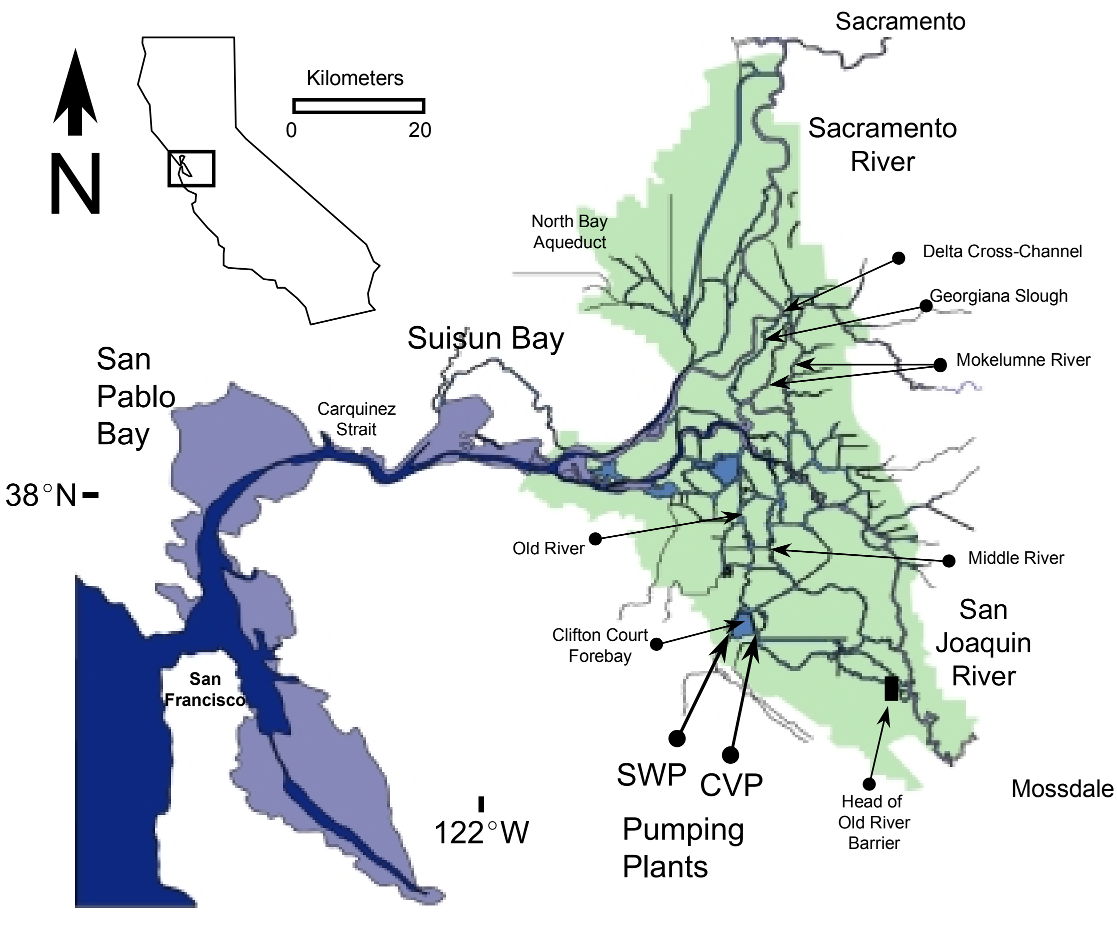

Figure 1 Map of the San Francisco Estuary showing discrete basins, the Sacramento–San Joaquin River Delta (shaded area), and other hydrologic features

The freshwater Sacramento-San Joaquin Delta (henceforth the Delta) is also a vital component of the California water management system. Diversions from above and within the Delta provide water to local irrigators and municipalities, cities in the San Francisco Bay area, irrigators in the San Joaquin Valley, and to cities on the Central Coast and in Southern California. More than 20 million Californians receive all or part of their water supply from the Delta.

The conflict between managing water for environmental protection and water supplies has intensified with the California's expanding population—over 33 million in 2000. In 1995, with support from environmental and water stakeholders several state and federal agencies joined forces to create the CALFED Bay–Delta Program (CALFED). Environmental restoration and stable water supplies are central tenets in CALFED's vision and goals statements, with balanced water management being a key program component. CALFED's Record of Decision (ROD), issued in 2000, included an Environmental Water Account (EWA) that, in concert with several other actions and activities, is intended to enhance environmental protection and water supply reliability. The EWA is built around acquiring water from willing participants and using this water (termed "assets") to repay the waters costs of reducing diversions or increasing flows to protect sensitive fish species.

The first year of the proposed four-year evaluation of the EWA occurred during the period October 1, 2000, through June 2001. On several occasions during this period CALFED member agencies used EWA assets to protect salmon, steelhead, and delta smelt. As part of the EWA review process, CALFED convened a salmonid workshop (Brown and Kimmerer 2001a, which is available on-line at www.calfed.water.ca.gov, click on "Science"), a delta smelt workshop, and an October 2001 panel of outside experts. The goals of the EWA review process are (1) to assess the benefits of using EWA assets to protect fish and their ecosystem; (2) to assess the procedures used to acquire and allocate assets; and (3) to find ways to improve the process in subsequent years. The goal is not to determine if the EWA worked as intended—that determination will occur at the end of the four-year evaluation period.

In keeping with the overall review goals, organizers of the delta smelt workshop assembled about 60 agency and stakeholder biologists and engineers (see Appendix A for the list of attendees) for the following purposes.

- To update the attendees and the CALFED community on our current understanding of the biology of delta smelt.

- To propose and discuss conceptual models of the delta smelt's life history, including possible bottlenecks and stressors.

- To describe the chronology and benefits of EWA actions taken to protect delta smelt, recognizing that actions may have been taken to benefit other species and ecosystem components.

- To determine how EWA actions relate to critical delta smelt life history stages.
- To make the workshop information available to the attendees and other interested individuals in a summary report available as hard copy and on-line.

The workshop agenda (Appendix B) was geared to the audience of scientists and engineers actively involved in management or research on delta smelt. In this summary, we target a broader audience and have arranged the material such that someone not intimately familiar with the system and the animal can better appreciate the complexity of issues involving water management and resources protection. This summary is drawn from presentations, the panel discussion and, where necessary for completeness, supplemented by published information. The presenters and others have reviewed the report and most of their comments incorporated. Final responsibility for the report's contents, especially the observations and recommendations, lies with the authors.

We have organized the report around the following topics: the environmental setting; institutional setting (EWA, CALFED, water projects, and related activities); methods used to learn about delta smelt; delta smelt biology; conceptual life history models and stressors; 2000–2001 EWA actions; a summary of a panel discussion; and our observations on the workshop and delta smelt science and recommendations. The generally brief descriptions include references containing additional information.

Environmental Setting—The San Francisco Estuary and Its Watershed

A more complete description of the estuary and the watershed can be found in Brown and Kimmerer (2001b; this document is available online at www.calfed.water.ca.gov, click on "Science"). The following are some excerpts from that description—excerpts that we modified somewhat to make the text more specific to delta smelt.

The Watershed

The Sacramento and San Joaquin rivers, and numerous major and minor tributaries drain the Sierra Nevada and coast range in the Central Valley catchment (Figure 2), comprising about 40% of the area of California. Major tributaries and streams, all with one or more dams, are the Feather River, American River, Mokelumne River, Stanislaus River, Tuolumne River, and the Merced River. Several smaller streams (Battle, Butte, Deer, and Mill creeks, and the Bear, Yuba, and Cosumnes rivers) are ecologically important and support salmonid runs.

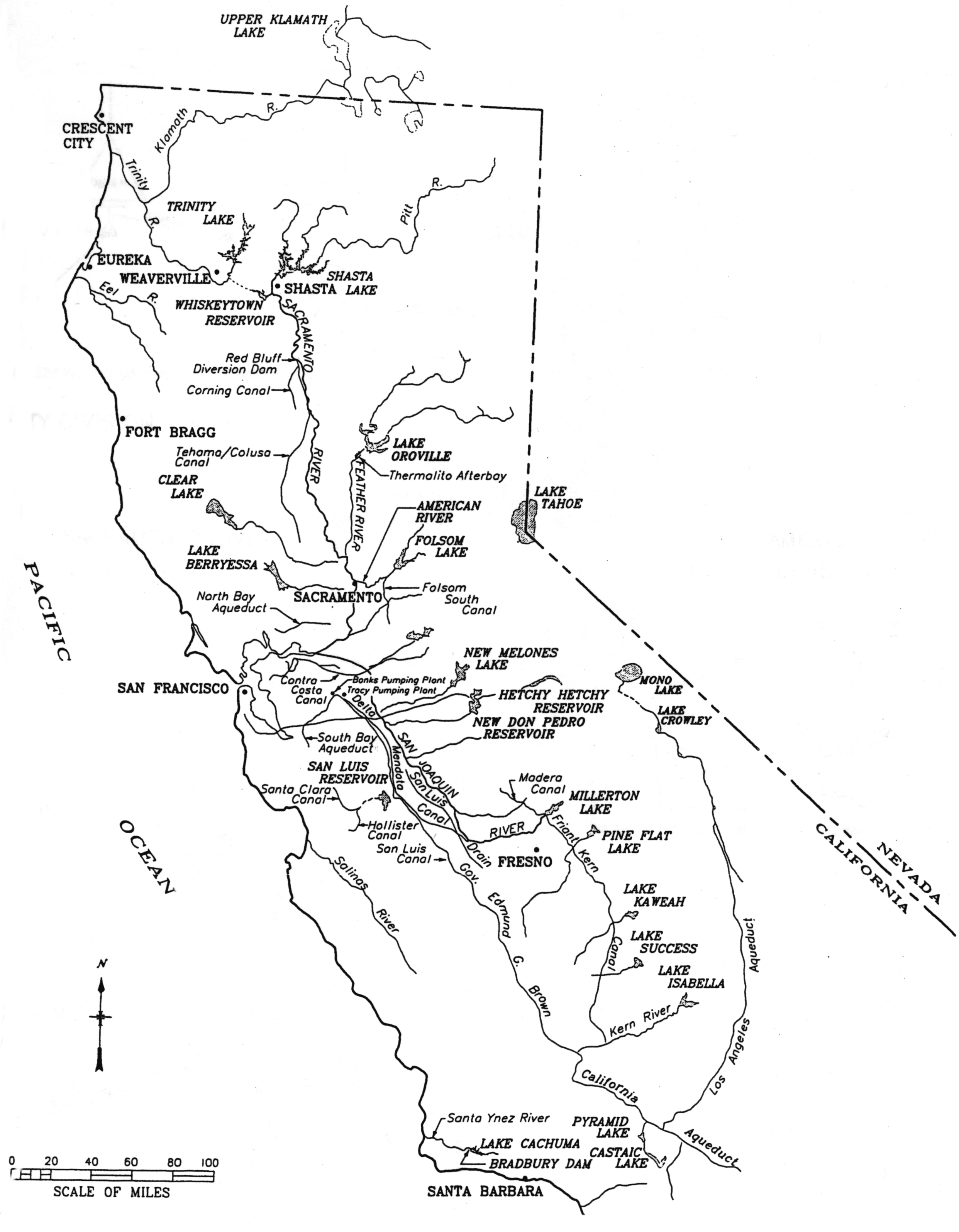

Figure 2 Major features of the Central Valley Project and the State Water Project

Hydrology

California's Mediterranean climate has distinct wet and dry seasons, with about 80% of annual precipitation occurring between November and March, and very little rain from June through September. This large seasonal variability, coupled with changing ocean conditions and water management, results in significant seasonal variation in the streamflows entering the Delta from the watershed (Figure 3). Water managers have reduced intra- and intra-annual variation to provide more constant water supplies (Figure 4). Flow is now greater in the streams entering the estuary during the summer and fall, and lower in winter and spring, than historically. Summer and fall flows, mainly from reservoir releases, are elevated to meet urban and agricultural demands during the dry season. In recent years, streamflows and Delta inflow have also been modified to provide environmental benefits. During water years 1956 through 2000, the annual average total amount of water reaching the Delta has been about 25 million acre-feet (maf) or 31 x 10^9 m^3.

The State Water Project (SWP) and the Central Valley Project (CVP) divert water from the south Delta-the CVP since the early 1940s and the SWP since the late 1960s. The amount diverted is controlled by water availability, requests by water contractors, and environmental requirements. The State Water Resources Control Board (SWRCB), through its water rights and water quality authorities, defines environmental conditions needed to protect beneficial uses-conditions which affect reservoir releases and diversions. For example, SWRCB Decision 1641 imposes a limit of 35% and 65%, depending on the time of the year on the ratio of exports to total inflow to the Delta, termed the Export:Inflow ratio. Figure 5 illustrates the historical water project diversions from the Delta.

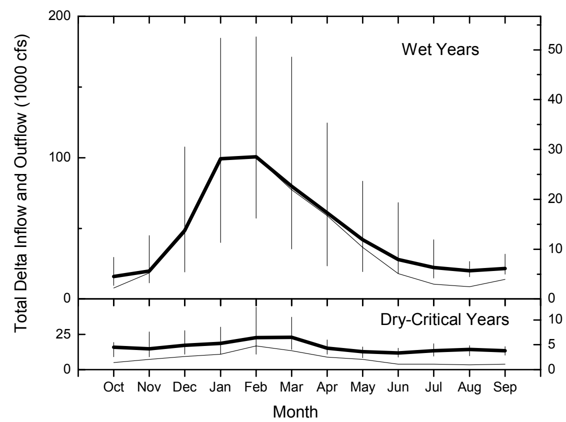

Figure 3 Seasonal patterns of flow into the Sacramento–San Joaquin Delta and outflow from the Delta. Source: DAYFLOW program (DWR) for water years 1956–2000. Inflow (heavy lines): medians with 10th and 90th percentiles for years designated as wet (above, 20 years) or dry or critically dry (below, 15 years). Outflow (thin lines): medians.

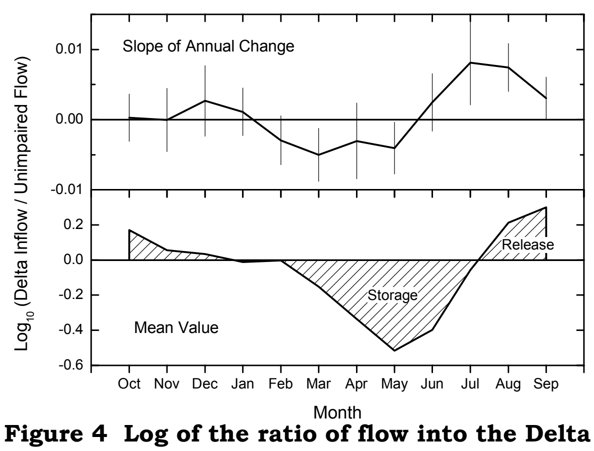

Figure 4 Log of the ratio of flow into the Delta to unimpaired flow for the same month. Top, slope of the log ratio vs. year with 95% confidence limits. A negative slope means that a progressively smaller proportion of the precipitation in the basin reaches the delta in the same month, that is, storage is increasing. Bottom, mean log ratio, where a positive value indicates more water is entering the delta than is available from precipitation, implying release from storage (natural or man-made). Source: DWR DAYFLOW and records.

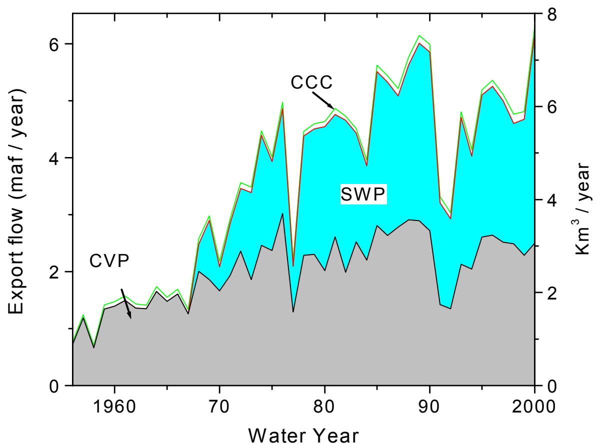

Figure 5 Export flow by water year, including the Central Valley Project, State Water Project, and Contra Costa Canal. Source: DWR DAYFLOW.

The San Francisco Estuary

The San Francisco Estuary forms a continuous system linking freshwater inflows with the coastal ocean, but it is convenient to divide the estuary into discrete basins (Figure 1). For all intents, in 2000–2001, allocation of EWA resources focused on processes and biological components of the estuary east of Carquinez Strait. We therefore limit our description to the Delta and the Suisun-Grizzly-Honker Bay complex.

The interaction among seasonally varying inflows, tidal flows, and bottom topography result in a complex and not completely understood estuarine ecosystem that is important economically, environmentally, and socially. It is beyond the scope of this report to completely describe this system and the reader is referred to several references for more complete descriptions (for example, Conomos 1979; Herbold and others 1992; Hollibaugh 1996).

The Sacramento-San Joaquin Delta

Historically the Delta consisted of sloughs, channels, and marshes at the confluence of the Sacramento and San Joaquin rivers and some smaller streams such as the Mokelumne, Cosumnes and Calaveras rivers. In the 1850s, the Delta began to change substantially as immigrants to California built levees to isolate land from water. With construction of dams in the watershed, water began to be diverted from the Delta late in the 19th century. Projects on the Tuolumne, Merced, Mokelumne and other streams stored water for use by farmers and local and Bay area urban water users. The Central Valley Project began directly diverting water from the Delta in 1940.

Today the Delta is a series of leveed islands separated by channels, some of which have been altered for shipping and to increase the flow of freshwater for agricultural use and export. About 92% of the Delta's 738,000 acres (1,624,000 hectares) is land and the remainder is open water. It is likely that less than 5% of the present Delta resembles the pre-1850 system. Much of the Delta land is devoted to agriculture, with the primary crops being corn and other grains, hay, alfalfa, sugarbeets, pasture, tomatoes, asparagus, safflower, and fruit. In 1990 the estimated annual value of these crops was over $500 million

(DWR 1993). In addition to the large CVP and SWP diversions and the smaller Contra Costa Water District diversion in the south Delta, more than 2200 mostly unscreened, small agricultural diversions withdraw water from the Delta for irrigation (Herren and Kawasaki 2001).

The Delta is permanent or temporary home for more than 45 species of fish and a supporting community of benthic and planktonic organisms, as well as marshes and macrophytes. Many of the dominant fish species (for example, striped bass, white catfish, largemouth bass) are introduced and may compete with or consume native fishes. Delta water is turbid and poor light penetration limits primary production. There is some indication that turbidity is decreasing, which if continued could result in increased algal growth. The Delta is affected dramatically by inter- and intra-annual changes in inflow with generally depressed abundance of native fishes in drier years, as seen during the 1987-1992 drought. Superimposed on all of this is management of reservoir storage and releases and diversions in the watershed to direct diversions from the Delta. All of these factors and others affect decisions on use of EWA assets.

Suisun-Grizzly-Honker Bay Complex

In this relatively shallow system, tidal currents and freshwater interact to form an ecologically rich mixing zone. For the early life stages of some fish, such as delta smelt and striped bass, successfully reaching and remaining in Suisun Bay may benefit subsequent year class strength. One of the estuary's more important water management standards, X2 (the bottom location in kilometers of the tidally averaged 2 practical salinity units isohaline), is based on the concept that when X2 is in Suisun Bay, many of the estuary's living resources benefit. Part of the rationale for this concept is that some fish and other organisms in Suisun Bay may be less vulnerable to being drawn into water project diversions than when they are in the Delta. Positioning X2 in Suisun Bay may also create more productive habitat for some fish.

As in the Delta, environmental conditions in Suisun Bay complex are affected by freshwater and tidal flows. The principal influence of freshwater flow on Suisun Bay is to alter salinity, which in turn can alter salinity stratification in deeper regions, and change residence time. The interaction between flow and X2 or salinity is well understood, but the mechanisms by which these affect various species have not been determined.

Conditions in the Suisun Bay complex have changed over the past 2 or 3 decades. There has been a decrease in spring and early summer algal standing crop, a reduction that has been attributed to climate change (Lehman 2000) and to grazing by an Asian clam, *Potamocorbula amurensis*, introduced around 1986 (Alpine and Cloern 1992; Kimmerer and others 1994). Declines in copepods, mysids, and some fish may be a result of the high rate of filter-feeding by this clam, which has eliminated the summer-long phytoplankton blooms once characteristic of Suisun Bay (Kimmerer and Orsi 1996; Kimmerer 1998).

Delta smelt early juveniles spend much of their time in the Delta itself and the relative importance of the Suisun Bay nursery area has not been clearly demonstrated.

Delta Hydrodynamics

Understanding water movement in the Delta is critical to understanding fish movement, although key aspects of fish behavior are as yet poorly understood. Flow in the Delta is an amalgam of river-derived net flow, exports, and tidal oscillation. The relative magnitudes of net and tidal flow depend on location and river flow, with greater tidal dominance toward the west and at lower river flow. For example, at various locations in the south Delta, tidal volume flow rates were about 3 to 10 times net flows during the spring 1997 in the Vernalis Adaptive Management Plan (VAMP) period of reduced exports (Oltmann 1998). At Chipps Island, however, tidal flows are about 50 to 100 times net outflow at low to moderate river flow.

Tidal flows oscillate but, because of the complex geometry of the Delta and Suisun Bay, they can produce net flows independent of the river, and can cause extensive mixing. Mixing by the tides requires a gradient; for example, salt is mixed upstream into the Delta mainly by the interaction of tidal flow with the salinity gradient. Similarly, differences in concentration of any substance in the Delta cause that substance to disperse in a direction to eliminate the differences.

For purposes of this discussion, the main interest in Delta hydrodynamics arises because of the influence of hydrodynamics on delta smelt. That influence is largely a matter of speculation. The influence of hydrodynamics on fish is unknown, but probably depends on the size of the fish, whether they are migrating through the Delta or residing there, and their habitat use. For example, early delta smelt larvae in the open water probably move mostly with the tides, whereas salmon fry in shallow areas are less subjected to tidal or net currents.

During high flow periods, water flows into the Delta from the Sacramento, San Joaquin, and other smaller rivers, and exits the Delta into Suisun Bay as net Delta outflow. During most summers, flow in the San Joaquin River is lower than export flows in the southern Delta, so water is released from reservoirs feeding the Sacramento River to provide flow for export and to meet salinity and flow standards in the Delta. Under these conditions, most of the freshwater in the Delta originates in the Sacramento River.

The proportion of freshwater entering the Delta that is subsequently exported during the June through September dry season has a median of 38% over the last 30 years, with 90th percentiles of 20% and 54%. Channel depletion, an estimate of in-Delta consumptive use, has a median value of 18% of total inflow in the same period, with 90th percentiles of 10% and 35%. Gross consumption, the actual amount removed from the estuary, has been estimated as about one-third higher than net consumption (DWR 1995).

The above comparison of export flow to inflow may be inappropriate, given the dispersive conditions during low flow periods. A more appropriate comparison may be between absolute diversion flows and total Delta volume, which would scale the risk of a particle being exported in a day if the Delta were well mixed. Daily export flows range up to 2.8% of Delta volume in summer, but most of the time in summer the fraction of Delta volume exported daily amounts to less than 2%. Channel depletion flows (that is, net intake by Delta farms) average about half this value in summer. These export and diversion flows may have a considerable cumulative effect on slowly growing resident biota but are unlikely to affect populations with high turnover rates such as phytoplankton (turnover rate about 10% to 50% per day) or zooplankton (turnover rate about 10% to 20% per day).

Several particle tracking models of the Delta have been developed. Until recently all of them used a simplified one-dimensional representation of Delta channels. Although the one-dimensional models may be inaccurate in their depiction of the details of particle or substance transport, the general patterns arising from these models have at least heuristic value, and their predictions may be accurate enough for many purposes. Enright and others (1996) showed results of simulations of movements of contaminants that matched the data quite well within the Delta.

The general trend of model results seems to be that a patch of particles released in the Delta will move generally in the direction of net flow, but with extensive spreading of the patch due to tidal dispersion. The export pumps in the south Delta and the agricultural diversions impose a risk that a particle will be removed from the system. This risk increases with diversion flow, initial proximity of the particle to the diversion, and duration of the model run. In a model run to examine the suitability of QWEST (a calculated net flow in the lower San Joaquin River) as an indicator of flow conditions for management, it was found that computed reverse flows (negative QWEST) had at most a minor effect on the entrainment of neutrally buoyant particles, which was better predicted by the absolute magnitude of project exports. Thus, the earlier concept under which fish were “sucked” up in this part of the Delta toward the pumps does not match the reality of flow in this region, which is dominated by tides under low flow conditions. Of course, we are unable to adequately determine the effects of net flow on the behavior of fish.

Particle tracking model runs in 1999 and 2000 did demonstrate that CVP and SWP entrained some particles released near the confluence (K. Fleming, personal communication), indicating that net flow may result in some movement of particles towards the pumps.

Institutional Setting

The Environmental Water Account operates in a complex institutional and regulatory environment and must be considered and evaluated in the context of this environment. The following summarizes some of its key components.

Water Projects

The federal Central Valley Project (CVP) and the State Water Project (SWP) store water in the watersheds and provide water directly to users in the basin and, by means of diversions from the southern Delta, to other in-basin and out-of-basin users. Water operations for both projects is coordinated in a joint operations center located in Sacramento. A summary of the water projects can be found in Brown and Kimmerer (2001b) with more complete descriptions in DWR and USBR (1994, 2000).

To understand the relation of the water projects to delta smelt, we are most interested in the following facilities and operations.

Delta Pumping Plants

The intakes to the state and federal pumping plants are located about 1 mile apart in the southern Delta (Figure 1). Although in close physical proximity they have some important differences.

Capacity

Peak capacity at the CVP intake is about 4,600 cubic feet per second (cfs) whereas the state can divert up to 10,600 cfs. (Regulatory constraints limit average daily diversion at the SWP intake to 6,400 cfs during most of the year.) Both plants have several pumps of different sizes to adjust total daily pumping.

Pumping Schedule

Water and other conditions permitting, the CVP pumps are operated at near maximum capacity around the clock. The SWP often operates its pumps more at night to minimize energy costs.

Intake Design

The CVP diverts directly from a Delta channel that has a fluctuating water level due to tidal and riverine conditions. The SWP periodically (around high tide) diverts water into a 2100-acre regulating reservoir, Clifton Court Forebay, and pumps from this Forebay. The state intake design does allow for more stable water levels at the pumps but, as discussed later, has environmental consequences.

Fish Protection Facilities

Both CVP and SWP Delta intakes have fish screening and holding systems to salvage many of the fish that have been entrained into the diversions. It should be noted that the fish screens are not 100 percent effective for most juvenile fish, and are particularly inefficient for fish less than about one-inch in total length. Subsampling is used to periodically estimate the numbers and species of fish salvaged and project operators use tanker trucks to return salvaged fish to the Delta, but away from the draft of the pumps. The CVP constructed its fish salvage facilities in the 1950s and the state used the same basic design in the 1960s. The state made extensive modifications to its fish screens and added a new holding tank in the 1980s. In addition, the presence of the forebay allows better velocity control (an important aspect of determining salvage efficiency for fish larger than about one inch) at the state as compared to the federal intake. Salvage efficiency has not been determined for delta smelt. The Clifton Court Forebay creates additional predator habitat and this can dramatically affect the numbers of fish salvaged.

Reservoirs

Although it is beyond the scope of this report to discuss operation of the numerous state and federal reservoirs above and below the Delta, a few points may help later discussion of the EWA asset allocation process.

Shasta and Keswick Dam and Reservoir Complex. These two CVP dams are located on the Sacramento River above Redding (see Figure 2 for location of these and other facilities described below), with the 4.5 million acre-feet (maf: af = 43,560 cubic feet or about 1,200 cubic meters) in Shasta Reservoir being the largest storage feature of the federal project. The USBR releases water from the reservoir to meet in-basin environmental needs, flood control, and project demands. These releases reach the Delta in about 5 days and help meet export and in-Delta needs and satisfy environmental requirements, such as the number of days X2 is at or seaward of a specified location.

Oroville Dam and Reservoir. Oroville Dam (Figure 2), located on the Feather River, impounds the 3.5 maf Oroville Reservoir and is the main SWP storage facility. DWR releases water from Oroville Reservoir for flood control, instream fish flows, to meet in-basin demands, to provide for water quality and other conditions in the Delta and to export. Water from Oroville Reservoir takes about 3 days to reach the Delta.

Folsom and Nimbus Dam Complex. This feature of the CVP is located on the American River, just above the Delta. Although the capacity of Folsom Reservoir is relatively small at about 1 maf, transit time of releases to the Delta is less than one day and these releases may be made to help ameliorate unexpected water and other problems in the Delta.

New Melones Dam and Reservoir. The USBR operates New Melones Reservoir, located on the Stanislaus River, for water quality and water supply benefits. During low flows periods in the San Joaquin River, releases from New Melones may be used to achieve target water quality conditions in the lower San Joaquin River.

San Luis Dam and Reservoir. This off-stream, joint CVP–SWP water project is located south of the Delta and is typically filled by pumping from the Delta during winter and spring. The approximate 2 maf storage space is shared about equally between the two projects and some of this capacity may be used to temporarily store EWA assets.

Delta Cross Channel. Early in the 1950s, the USBR constructed this short, gated canal near the town of Walnut Grove on the Sacramento River (Figure 1) to help move Sacramento River water into the Mokelumne River system and then to its Delta pumping plant. To maintain interior Delta water quality, the Bureau typically kept the gates open when Sacramento River flows were less than 25,000 -30,000 cfs. Studies conducted by the Interagency Ecological Program (IEP) indicated that survival of juvenile emigrating chinook salmon was adversely affected when the gates were open and subsequent biological opinions and water quality control plans mandate that the gates be closed from February 1 through May 20 of each year. Up to 45 additional days of gate closures can be requested by fish agencies during the October 1—January 31 period and up to 14 additional days from May 21 through June 15. Operation of the cross channel gates appears less critical to delta smelt survival than to that of juvenile chinook salmon.

South Delta Barriers. To alleviate low water level problems in the South Delta due to project operations, DWR and the USBR annually may install up to four temporary rock barriers in south Delta channels. DWR typically installs three barriers to protect agricultural diversions (on Grantline Canal, in Middle River and in Old River, see Figure 1) around April 15 and removes them each fall Each barrier has a low area in the middle to allow for overflow at high tides and culverts to permit flow at other tides. The USFWS may require that the gates to the culverts be tied open, or the barriers removed, when flow and pumping conditions are such that it appears that delta smelt may be harmed. The fourth barrier, at the upstream head of Old River, is to help keep emigrating juvenile chinook salmon in the mainstem San Joaquin River where survival to the ocean may be improved. (The hypothesis that having the barrier in place improves salmonid survival is being tested as part of the study plan called for in multi-year Vernalis Adaptive Management Plan.) Salmon biologists would like the HOR barrier in place from about April 15 to June 1. Concerns about its impacts on Delta smelt may result in it being removed earlier or the gates to several culverts through the barrier be tied open. The HOR barrier can only be installed when flows in the San Joaquin River are below about 5,000 to 7,000 cfs.

Incidental Take Limits

The 1995 biological opinion for CVP and SWP operations and the 2001 opinion for the South Delta Temporary Barriers contained provisions relating to the take of delta smelt at the project intakes. Although explained in more detail later in this report, project operations may be modified to reduce the take of a listed species such as delta smelt. Take calculations, in the context of CVP and SWP incidental take, are limited to numbers estimated to have been salvaged. In a broader sense, take includes harassment, harm, and other actions that adversely affect a listed species. A few terms may be useful in understanding how incidental take is used in the regulatory context.

Incidental Take. The biological opinion contains conditions regarding pumping rates, the proportion of the incoming water that can be diverted (export:inflow ratio) and X2 location. When operating under these conditions, the numbers of delta smelt estimated to have been salvaged by the diversions is termed "incidental take." With delta smelt, larvae and juveniles less than about one inch go through the screens and are not counted towards take limits.

Salvage

The CVP and SWP fish protection facilities result in fish being diverted to holding tanks where their numbers are periodically estimated and the fish hauled to remote sites for release. For delta smelt the estimated number salvaged is equivalent to take. (With salmonids, salvage is converted to take by incorporating losses to predators, losses through the screens and losses during hauling. These conversion factors are not available for delta smelt.)

Red Light. Based on historical salvage data, the water projects are expected to remain at a certain take level, the so-called "red light." The monthly allowable totals vary between wet and dry years (see page 37). Reaching or exceeding the red light level results in reconsultation—not automatic operational changes.

Yellow Light. The "yellow light" is a warning level (14-day running average of 400 or more) and is designed to warn water project operators that measures may be needed to avoid exceeding the red light.

Pre-yellow Light. When approaching the pre-yellow light level, the USFWS and DFG may request changes in barrier configuration or operation.

CALFED

In 1994 several federal and state agencies and stakeholders signed a "Delta Accord" resulting in interim Delta protection standards until more long-lasting ones could be developed through the federal-state process organized as the CALFED Bay-Delta Program. Participants envisioned an ambitious multi-decade, multi-billion dollar program with environmental restoration and water management as two of its cornerstone activities. Environmental documentation, including the Record of Decision (ROD), was filed in 2000. Agency managers and stakeholders are working with California government and Congress to obtain long- term funding. CALFED is described more completely at www.calfed.water.ca.gov.

The EWA

The ROD includes the Environmental Water Account (EWA) as an integral component of its environmental protection and water management plan. The concept of the EWA arose out of a series of modeling studies conducted to assess the possible benefits of having a significant amount of environmental water available in storage. Stored water could then be allocated to increase protection of key sensitive fish species (all chinook salmon races, steelhead rainbow trout, delta smelt, splittail and green sturgeon). Although modeling indicates that the EWA was feasible, CALFED recognized the uncertainty of the modeling results by limiting it to a 4-year trial period. As mentioned earlier, 2000-2001 was the first of the four years. CALFED authorized funding, about 95 million dollars in the first year, to cover water acquisition and costs of moving and storing the water and staff resources to develop needed environmental documentation and administrative functions.

The EWA includes three proposed tiers:

- **Tier 1—**No use of EWA water: existing regulatory and other mechanisms provide adequate resource protection. The "baseline" condition.

- **Tier 2—**Regular EWA assets (water) are used to protect fish as the need arises.

- **Tier 3—**Extraordinary circumstances dictate that EWA managers acquire and use additional water. Acquisition of Tier 3 assets may require paying a premium price. There was no Tier 3 water available in 2000–2001.

The Tier 1 baseline is an essential component of the EWA concept. The baseline consists of operation of the state and federal water projects as constrained by existing regulatory mechanisms. These mechanisms include, but are not limited to:

- Water rights permits (Decision 1641) and water quality control plans (the 1995 Water Quality Control Plan) issued by the State Water Resources Control Board to balance protection of water uses in the San Francisco Estuary. These documents include pumping and other restrictions and standards that can affect project operations. Important standards include the seasonally varying ratio of project pumping to Delta inflow (Export:Inflow ratio) and a salinity and flow standard based on the bottom location of the 2 practical salinity unit isohaline—the so-called X2 standard.

- Applicable federal biological opinions for listed species include conditions that are to help ensure project operations don't jeopardize the species. Many of these conditions are included in the water quality control plans and water rights permits.

- The 1992 Central Valley Project Improvement Act authorized use of up to 800,000 acre-feet (af) for environmental purposes (600,000 in dry years) and includes a component, the Anadromous Fish Restoration Plan (AFRP), with the goal of doubling the natural populations of chinook salmon, steelhead and sturgeon. Up to 450,000 af of this environmental water can be used in the Delta to help protect and restore fish populations.

- The Vernalis Adaptive Management Plan (VAMP) is a multi-year study to assess the interaction of project pumping, river flows, and operation of a fish mitigation barrier at the head of Old River (see Figure 1) on survival of juvenile chinook salmon emigrating from San Joaquin River tributaries (San Joaquin River Authority 2001). VAMP includes a matrix of pumping levels and San Joaquin River flows implemented during a 30-day period between April 1 and May 30 each year—a critical period in the delta smelt life history.

- CALFED's Ecosystem Restoration Program (ERP) has several components that may be important to delta smelt.

  <u>Environmental restoration</u>, including acquisition, restoration and maintenance of habitat in the Delta.

  <u>Funding research and monitoring</u> to learn more about the environmental requirements and stressors affecting the estuarine and watershed ecosystems. With the help of a Science Board, the ERP is considering the use of adaptive management principles to help define the effects of restoration and other actions on the ecosystem.

  <u>Commission of several "white papers</u>" describing what we know about some key species and their habitats. Four of these white papers—now in partial draft form—are of particular interest to delta smelt biologists.

  1. *Delta Smelt* by Bill Bennett of UCD. Information from this paper is used later in this report.

  2. *Open Water Processes* by Wim Kimmerer of San Francisco State University is a thorough compilation of our understanding of the physical and biological processes in such open area as Suisun Bay.

  3. *Intertidal and Shallow Water Habitat* by Larry Brown of USGS is a review of habitat that may be important to delta smelt during certain portions of its life cycle.

  4. *Diversion Effects on Fish* by Frank Ligon and others from Stillwater Science, Inc. will examine the effects of the CVP and SWP diversions on some key fish.

  The goal is complete the drafts, obtain peer review as needed and publish the white papers in an on-line technical report series being established by the Bay-Delta Science Consortium.

- CALFED's Environmental Water Program (EWP) is a component of its Ecosystem Restoration Program and will be seeking to acquire water from willing sellers and use for environmental purposes. No EWP water was available in 2000–2001.

The Workshop

The following material was developed mostly from material presented at the workshop.

The Delta Smelt Big Picture

The Delta Smelt Workshop began with an overview—The Big Picture—presented by Zach Hymanson. We follow Zach's division of the big picture into areas related to management, science and regulatory issues. Readers are referred to Appendix C for a comprehensive listing of reports and articles relating to delta smelt in the San Francisco Estuary.

Management

The CALFED agencies are responsible for maintaining and restoring delta smelt and its habitat, with the emphasis on system management. The traditional fishery management paradigm is not appropriate for an animal whose protection is based on the need to preserve the species rather than economic incentives associated with its harvest. Management occurs within a complex institutional framework (described previously) and a host of site-specific Bay-Delta standards as exemplified in Figure 6. Managers, generally at the division chief and deputy director level, require high quality and timely information to make informed decisions. This information comes from monitoring and research via agency technical staff. Managers attempt to reach consensus through effective inter and intra-agency communications. The management process is represented schematically in Figure 7.

Managers have several tools to achieve their restoration goals, including:

- Use EWA or the CVPIA's b(2) water.
- Defer exports to a later time (project reoperation).
- Comply with the X2 salinity standard by either meeting daily or average specific conductance values or by outflow.
- Move the point of diversion from the federal to the state plants when this would reduce fish entrainment. This is called the "joint point of diversion"—which now only allows CVP water to be moved through the SWP. Project operators are working with regulators and south Delta water interests to have the option of a reverse joint point—that is, move state water through the federal project. In both cases excess capacity must be available at the new diversion point to handle increased flows.
- With agreement of the fish agencies and approval by the SWRCB, modify the export:inflow ratio.
- Modify operation of the South Delta Temporary Barriers, including removal of one or more barriers.

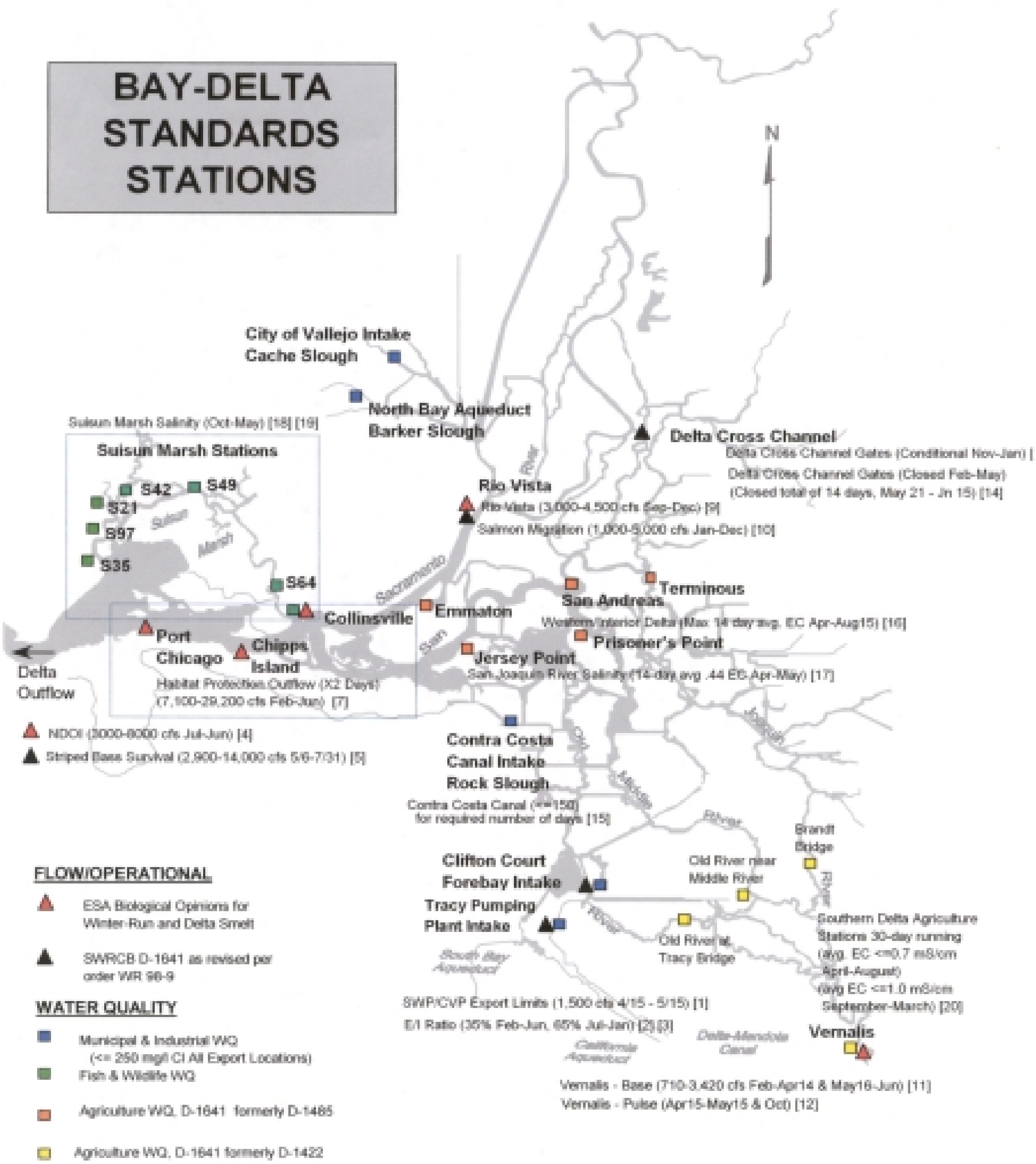

Figure 6 Bay–Delta standards stations

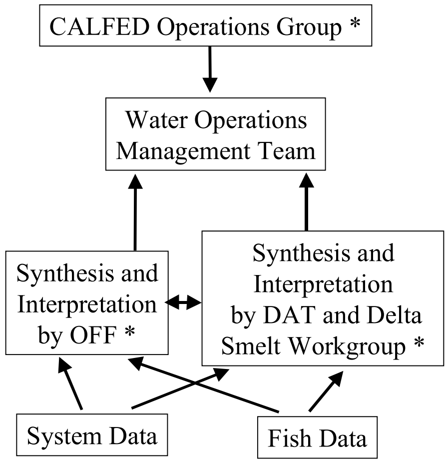

Figure 7 The CALFED Ecological Fish Management Process. Asterisk (*) indicates forums for stakeholder input.

Agency managers, technical staff and stakeholders work together in an iterative process, somewhat analogous to adaptive management (although not so rigorous). This process generates such questions as:

- Does VAMP affect delta smelt?
- Why do delta smelt salvage patterns differ between the state and federal intakes?
- What indicators do biologists use to initiate and evaluate the benefits of EWA actions?

Science

CALFED agencies, with the help of universities and support from stakeholders, collect and interpret data gathered through research and monitoring. Scientists have several monitoring tools—described in the next section—as well as laboratory, descriptive and modeling studies. The tools help scientists assess delta smelt distribution and abundance (monitoring) and to determine factors that may be influencing or controlling distribution and abundance (research).

Scientists must work with managers to obtain the necessary funding, staff resources and to determine the questions (and their priority) that need to be answered. They must also be an integral part of an environment that encourages collaboration, communication (including publications and participation in scientific conferences and workshop) and integration of science into the management and regulatory aspects of delta smelt protection and recovery.

Some scientific efforts are constrained by regulatory measures. Because delta smelt is listed and IEP's monitoring program captures delta smelt, the IEP prepared a biological assessment of the effects of its program on the animal. As part of its resulting biological opinion, USFWS issued an incidental take limit for all monitoring elements. In some years, high smelt abundance or high concentrations in areas with intensive sampling—for example near Chipps Island—may result in curtailments of field activities to remain below the take limit.

Regulatory Factors

Pursuant to the federal and state Endangered Species Acts, regulatory protection of delta smelt is delegated to the California Fish and Game Commission, the Department of Fish and Game, and the U.S. Fish and Wildlife Service. The 1993 listing, based on low abundance during the 1980s and continued threats, resulted in a formal and arduous consultation process. The consultation process in turn resulted in a biological opinion regarding the effects of CVP and SWP operation on delta smelt. The South Delta Temporary Barriers Project has a separate biological opinion.

Listing also resulted in the production of a native fishes recovery plan (USFWS 1996) listing recovery criteria for several native fish including delta smelt. The biological opinion and recovery plans were based on the best scientific information and professional judgement available when they were written. The opinion and recovery plan are intended, along with other actions in the system, to recover the species with eventual delisting. The fish agencies use tools such as X2, flows in the San Joaquin River, take limits, critical habitat designation and recovery criteria to achieve and measure restoration.

To perform their regulatory functions the state and federal agencies need information (science), adequate staffing to keep up with the flow of new information and resources to implement recovery plan actions.

Integration

It is clear from the descriptions of the three elements in the big picture, that data collection and analysis coupled with communications and adequate staff resources are essential to making it all work. For example, when the water projects approach the incidental take threshold, technical staff, managers, and regulators must have a good idea where the smelt are, whether they are moving, projected project operations, hydrology and other factors before making recommendations and decisions that affect water project operations. Staff must be able to collect and analyze the data, make the data and derived information available in near real-time and the managers and regulators must have time to consider the information before making decisions.

Research Methods

Our understanding of delta smelt biology has developed through the analysis of data collected in a variety of field and laboratory studies and monitoring programs. Additional information is contributed by mathematical modeling of particles treated as surrogate delta smelt. In turn, field data are used to initiate, calibrate, and help verify the model. Workshop presentations by Zach Hymanson, Andy Rockriver, Bradd Baskerville-Bridges, Steve Foss, Aaron Miller and Bill Bennett provided most of the information for this section, supplemented by references where necessary.

Field Monitoring Programs

The Interagency Ecological Program (IEP) has conducted a variety of monitoring programs for the past four decades. Although most of the early efforts focused on understanding the biology of striped bass, delta smelt were incidentally captured and counted and the resulting data provide valuable long-term indices of delta smelt abundance. In response to the petition to list delta smelt, the IEP initiated additional field monitoring programs in the early1990s that specifically target this species. As noted by Herbold (1996), the biology of delta smelt and field data do not lend themselves to calculating actual abundance, a limitation that is discussed later in this report.

Following are brief descriptions of the more important sampling programs, including some representative data. Sampling at the state and federal fish facilities is included in this summary.

The Townet Survey

DFG has conducted the Townet Survey (TNS) since 1959 (except 1967 and 1968) to index the abundance of young-of-the-year (YOY) striped bass when their average size was 38 mm. The survey includes about twenty sites from San Pablo Bay through the Delta. The survey generally begins in June, with sampling every two weeks until the average size of the striped bass is 38 mm, usually in late July or August. Abundance indices are based on catch and the estimated volume of water in the sampled areas. The zeros are dropped and the resulting striped bass indices have ranged from less than 5 to over 100.

The TNS also captures delta smelt and DFG biologists developed abundance indices for the period of record. The resulting indices are shown in Figure 8A. Miller (2000) examined the data and recommended that the delta smelt index be modified to include consideration of catch as well as timing of the striped bass indexing—the latter as a surrogate for annual habitat variablity. The recommendation has not been adopted by the IEP.

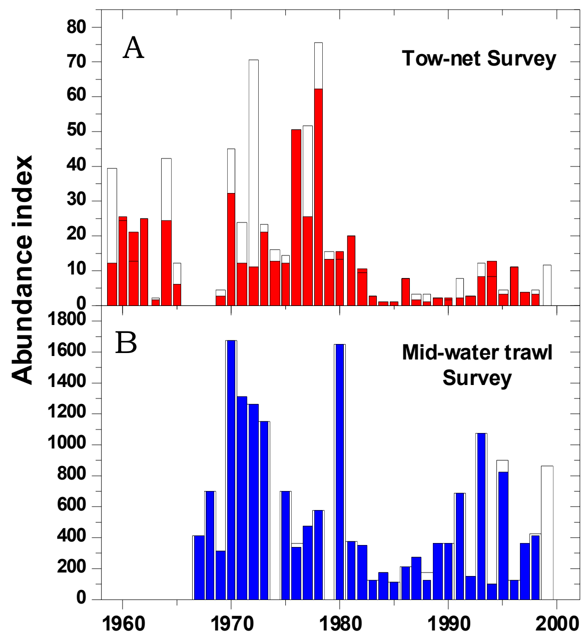

Figure 8 1980–2000 delta smelt abundance indices for the (A) townet survey and (B) fall midwater trawl survey

The Fall and Spring Midwater Trawl Surveys

Since 1967 (except 1974 and 1979 and missing months in 1969 and 1976) DFG has conducted a fall mid trawl survey to obtain a second index of the abundance of YOY striped bass. Sampling for the survey is conducted from September through December and includes more than 80 sites in 17 subareas from San Pablo Bay through the Delta. Although there are numerous problems with using midwater trawl data to index delta smelt abundance (gear efficiency, non-random station distribution) Sweetnam and Stevens (1993) concluded that the survey provides reasonable evidence for abundance trends and recovery criteria are based on this index. Fall midwater trawl abundance indices over time are shown in Figure 8B).

Beginning in the mid-1990s IEP extended the midwater trawl surveys through March to obtain a better understanding of the movement and distribution of prespawning adults. These data are used by agency technical staff and managers to assess the annual variation in spawning location and year class strength.

The 20-mm Survey

Recognizing that the townet survey was missing the smaller delta smelt, the IEP initiated the 20-mm survey in 1995. The data have proved so useful that it is now a separate IEP program element. The 20-mm surveys start around April 1 and field crews sample several stations every two weeks until the end of June. (When approaching the incidental take red light, for example, sampling frequency may be increased to weekly.) An essential feature of the 20-mm survey is the conversion of field data to "bubble plots" (Figure 9, data are available on-line at www.delta.dfg.ca.gov/data/20mm/), in near real time so biologists and operators can assess the distribution, abundance and movement of delta smelt. As long as most of the standing stock remains near project intakes, the risk of being entrained is high.

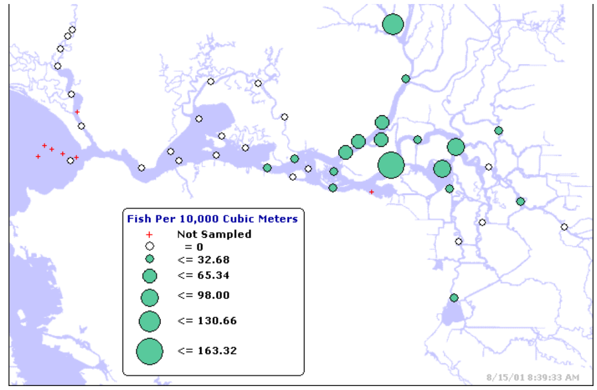

Figure 9 An example of data obtained from 20-mm surveys—Survey 6, May through June 2001

North Bay Aqueduct Sampling

The NBA diverts water from Barker Slough in the North Delta. Although the pumping plant capacity is relatively small (about 170 cfs) the intake is located near Cache Slough, an important delta smelt spawning area in many years. DWR is required to fund monitoring surveys in the vicinity of the intake and limit pumping if the numbers of captured smelt exceed the specified threshold level. This monitoring program conducted by DFG, which begins around February 1 and targets the early life stages, provides limited information contributing to understanding delta smelt distribution and abundance.

The Egg and Larvae Survey

The IEP conducted the egg and larvae survey in the 1980s with the original goal of providing information on the early life stages of striped bass. The study was temporarily suspended several years ago with the expectation that the data set would be analyzed and a recommendation made to either terminate the program permanently or continue in some form. The analysis has not been completed and the de facto result is termination of the element. We include reference to it here because the sampling program provided invaluable samples of not only striped bass, but other fish larvae as well. For example, much of the data on the early life stages of delta smelt, Sacramento splittail, Sacramento blackfish and Sacramento suckers used by Wang (1986) came from examining samples collected in the egg and larvae program.

Other Monitoring Efforts

The sampling programs described above yield much of the routine data needed to assess delta smelt movement and abundance. The programs below provide additional information, either about distribution and abundance or about factors that may be affecting abundance and distribution.

Beach Seines. As part of IEP's efforts to monitor the abundance of juvenile salmonids, the USFWS samples several nearshore habitats throughout the Delta with conventional 50-foot beach seines. Delta smelt are incidentally caught and reported.

Kodiak Trawls. Kodiak trawls are towed by two boats and typically sweep a larger area than midwater trawls. Side-by-side comparisons of kodiak and midwater trawls indicate that the kodiak trawls capture delta smelt in areas where none are captured by the midwater trawl and consistently capture more delta smelt (DWR and USBR 1994). Although kodiak trawls have been used sporadically since 1994 to collect delta smelt, they are not part of the present routine smelt monitoring program.

Suisun Marsh Fish Sampling. Under contract with DWR, UCD biologists sample several stations in Suisun Marsh each month. The gear used (an otter trawl) is not very efficient for delta smelt: however, some are captured and reported.

Zooplankton Surveys. Zooplankton serve as a major delta smelt food source throughout their life cycle, thus information on changes in the abundance of key zooplankton species can shed light on delta smelt abundance. The IEP conducts routine zooplankton sampling from late winter through fall in the areas where delta smelt are found. Results of these surveys have show that there has been a decline in the abundance of some important food items. The 20-mm Survey also collects zooplankton by use of a Clarke–Bumpus net attached to the 20-mm sampling frame.

Phytoplankton Surveys. IEP also conducts routine survey of the abundance (chlorophyll *a* concentration) and species composition of planktonic algae in the Delta and Suisun and San Pablo bays. The survey results have demonstrated lower than historical spring blooms in Suisun Bay—key habitat for rearing delta smelt. The phytoplankton decreases have been attributed to changing climatic conditions (Lehman 2000) or losses to an introduced filter-feeding clam, *Potamocorbula amurensis* (Kimmerer and Orsi 1996).

Benthic Organisms Survey. IEP's benthic surveys have been used to document changes in the distribution and abundance of *P. amurensis* and confirm that it has remained in

Suisun and San Pablo bays, even after several high flow years. The abundance data have also been used in conjunction with clam filtering rates to conclude that the clam biomass has the potential to remove a significant fraction of the particulates (including zooplankton and phytoplankton) in the overlying waters (Kimmerer 1998).

Monitoring Hydrology, Water Levels, Velocity, and Salinity. The IEP and others maintain an extensive system of water level and velocity monitoring stations in the Delta and Suisun Bay (see for example, Oltmann 1998). These stations provide data for calibrating and verifying mathematical models—models that in turn can help scientists and engineers better understand water and delta smelt movement.

Salvage at the State and Federal Delta Fish Protection Facilities. Steve Foss described the salvage procedures at water project facilities in the south Delta. He described the physical and operational differences between the two facilities—differences that may help explain observed differences in salvage pattern and total numbers of delta smelt salvaged. In the following description, we first discuss the purpose and general principles of the fish salvage process then to the two facilities themselves, including some salvage data.

The fish salvage (or fish protection) facilities are located at the intakes to canals leading to CVP and SWP pumps in the south Delta. The facilities consist of a screening system to separate some of the fish from the water being diverted and a holding and transport component to return the salvaged fish to the Delta. The plans for both facilities included the physical ability to periodically divert water to a "counting" tank. The fish in this tank would then be transferred to a small container for counting, identification, measuring and later, to obtain tissue samples for genetic analysis. Until about 1986, the counts were used mainly to estimate fish density in the main holding tanks and time fish transport runs to prevent too many fish from being hauled at one time. The counts also provided daily, monthly and annual estimates of the direct effects of project diversion on fish and indirect measures of fish abundance trends. As sampling devices, they operate almost every day each year and see large amounts of water and fish.

In 1986, the counts took on additional importance, especially at the SWP intake, when the DFG–DWR 4-Pumps Mitigation Agreement began using counts and estimates of losses of steelhead, chinook salmon and striped bass to define the mitigation obligation. The fish counted and reported are now used to determine compliance with incidental take limits as part of biological opinions. Take is calculated in two ways at the project intakes. For chinook salmon, take is based on the estimated numbers of fish salvaged as modified by losses of fish through the screens, taken by predators before fish encounter the screens, and the losses during handling and hauling the salvaged fish to release sites. This version of take is an estimate of the total numbers of fish lost through the salvage process and depends on having estimates for losses at each step.

For delta smelt, we do not have estimates of the intermediate losses and take is defined as the estimated numbers of delta smelt salvaged by the two projects. An additional caveat is that the salvage facilities are not very efficient for fish less than about 20-25 mm, thus larval and early juvenile delta smelt are not included in the estimated take.

Figure 10 illustrates the total delta smelt salvage for the two facilities for the period 1979 through 1999. Note the interannual variability. More information about difference in salvage is found on page 31.

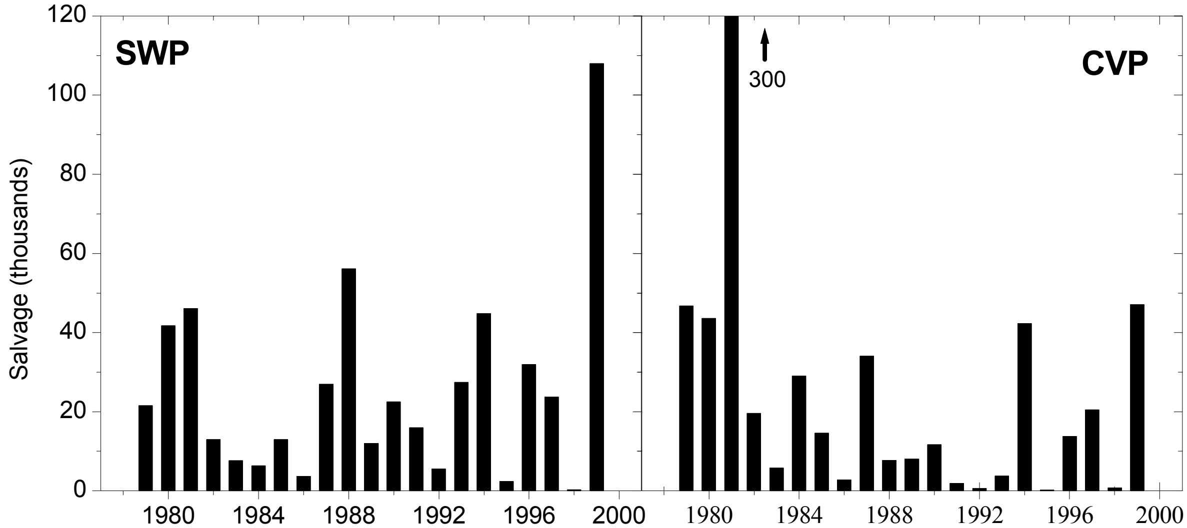

Figure 10 Total delta smelt salvage for the State Water Project and Central Valley Project from 1979 through 1999

Particle Tracking Model. One of the more important tools to come along recent years, the Particle Tracking Model (PTM) uses a DWR 1-dimensional mathematical model (DSM2 or Delta Simulation Model 2) and a particle tracking component with a pseudo 3-dimensional velocity field. The PTM makes use of 20-mm Survey distribution and abundance data and measured and projected water levels, inflows, in-Delta consumptive use and water project operations to predict particle movement up to four weeks in the future. The model assumes that delta smelt behave like particles but the model can be modified to include alternate behavior. Although this assumption is certainly not true for post-larval smelt, the model is an extremely useful tool to examine the effects of potential operational scenarios.

Figure 11 provides a schematic of the particle tracking process and Figure 12 the results of a typical model run, including the assumed hydrological conditions. In this case the model used the 20-mm survey data from June 1 and the projected operations and hydrology for the following 28 days to predict where the particles would wind up. For example, particles in the south Delta on June 1, were mostly lost to the Delta agricultural diversions and to the CVP intake. The model provides additional information that can be used to compare alternative operational scenarios. The model is not adequate to determine the fate of delta smelt.

Delta Smelt Biology

The monitoring and research efforts listed above have led to a reasonably good understanding of some key aspects of delta smelt biology. The following, drawn mostly from the presentations by Bradd Baskerville-Bridges, Andy Rockriver and Bill Bennett and from Bill Bennett's draft white paper, DWR and USBR 1994, and Moyle and others (1992) summarizes some of the biological characteristics.

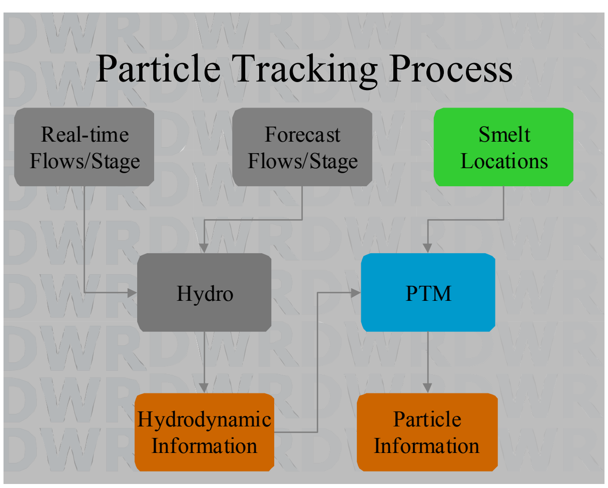

Figure 11 The particle tracking process

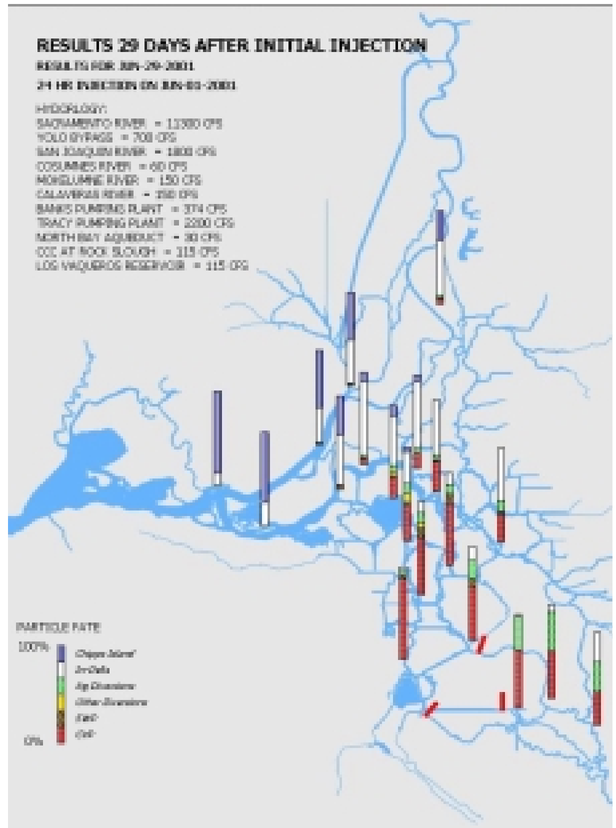

Figure 12 An example of typical results from a particle tracking model run.

Taxonomy

Until 1961, the delta smelt, *Hypomesus transpacificus*, was considered to be the same species as the widely distributed pond smelt, *H. olidus*. Pond smelt were brought into California in 1961 to stock in reservoirs as a forage fish for trout (Wales 1962). Subsequent analyses have confirmed that we have two species in California, *H. transpacificus* and *H. nipponensis*, the wakasagi. Wakasagi, planted in the Sacramento River watershed are now present in the Delta, often most prevalent in the eastern, more freshwater, portions of the delta. Wakasagi also appear to be more abundant in the Delta during high flow years.

There is some evidence of hybridization between the two species (Moyle 1995). Distinguishing delta smelt from wakasagi, especially during the early juvenile stages is difficult. IEP biologists are working with Johnson Wang and others to develop an early life-history taxonomic key to help identify the two species.

Geographic Distribution

The delta smelt is restricted to the San Francisco Estuary, with the Delta and the Suisun–Honker–Grizzly bay complex being their core geographic range Delta smelt also spawn in the Napa River during most years.

Length at Maturity

Maximum length is typically from 55 to 70 mm, but some may reach over 100 mm in length. The average size has decreased in recent years (Sweetnam 1999).

Age at Sexual Maturity

Mostly one year but a small and relatively unknown percentage (in the range of 3% to 8%) of the population lives two years. It isn't clear if two year olds spawn again.

Fecundity

Moyle and others (1992) found no relation between length and fecundity and, on average, females in the range of 59 to 70 mm had 1,907 eggs. Mager (1996), on the other hand did find a relationship between size and fecundity. In any event, delta smelt fecundity is relatively low compared to other osmerids; mostly due to their small size.

Feeding

Delta smelt are planktivorous, feeding almost exclusively on such copepods as *Eurytemora affinis* and *Pseudodiaptomous forbesi*.

Spawning

Delta smelt spawn from February to May at temperatures from 12 to 20 °C. Females may spawn more than once during this period, and spawning may be prolonged because individuals may mature at different rates. The eggs, about 1 mm in diameter before fertilization (Wang 1986), are demersal and attach to the substrate. Attempts to monitor spawning location by collecting eggs deposited on artificial substrates have not been successful. Spawning occurs in tidally-influenced rivers, deadend sloughs and shallow waters in the eastern Delta and the Sacramento River (Wang 1986).

Time to Hatching

In the wild hatching probably occurs from 12 to 14 days after egg deposition.

Size at Age

Baskerville-Bridges provided the following size-at-age values for delta smelt from laboratory data.

Day	*Size (mm)*
1	5
8	7
30	12
60	18
150	40
450	70

Generalized Life History Model

Figure 13 indicates the general timing of several key aspects of the delta smelt's life cycle. It is important to note that in most years the entire life cycle is completed in the almost constantly changing region of the estuary dominated by the effects of freshwater inflows and pumping from the south Delta by the state and federal water projects.

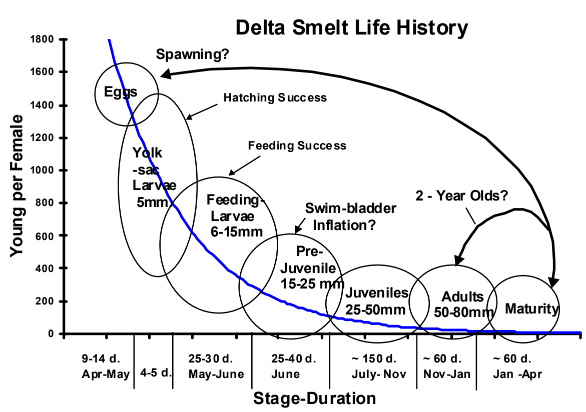

Figure 13 Delta smelt life history model. Source: Bennett, personal communication.

The Delta Smelt Culture Program

The following is based on a presentation by Bradd Baskerville-Bridges.

The culture program, began in 1992 as a cooperative IEP–UC Davis–Biosystems Analysis, Inc. effort with the initial goals of learning more about the biology of delta smelt and to produce juveniles for use by researchers. The culture studies are now being conducted at the site of the SWP's Skinner Fish Protection Facility and takes advantage of a laboratory and outside tanks formerly used in a striped bass growout program. The initial culture work was conducted at UC Davis laboratories.

Until this past season, production of juveniles was limited by a bottleneck at about day 40 post-hatch. This year the bottleneck was breached and about 10,000 juvenile smelt were provided for research ranging from the study of daily growth rings on the otoliths to studies of their swimming ability.

In addition to providing research animals, the other goal has also been realized. Below are some of the findings by Baskerville-Bridges and his colleagues.

- Spawning in the laboratory occurred at 12 to 19 °C. In looking at the spawning data Bennett (personal communication) concluded that the number of eggs spawned and the spring-neap tidal oscillations (as measured by the root-mean-square of the tidally filtered water level) were correlated.
- Spawning occurs mainly at night.
- Eggs are demersal and adhesive.

- Time from fertilization to hatching in the laboratory, 8 to 10 days at 17 °C, appears consistent with field data.

- Laboratory hatching success varied considerably—from 29% to 81%.

- Few early larvae feed in clear water but do feed well when particles are introduced (either organic or inorganic)—perhaps because the particles provide a contrast between the prey and their background.

- By the time the larvae reach 15 to 20 mm, they are less dependent on turbid conditions.

- Temperature affected survival and growth of larvae from hatch to 60 days post hatch. Percent survival at 14 and 17 °C was significantly higher (average of about 65%) than at 20 °C (about 25%). On the other hand, after 140 days post hatch juveniles maintained at 23 °C were significantly larger than those maintained at either 17 or 20 °C (Figure 14).

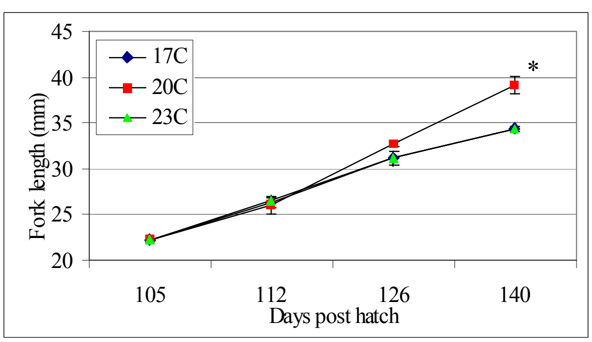

Figure 14 Effect of temperature on growth of juvenile delta smelt

Conceptual Model of Factors Controlling Delta Smelt Abundance and Distribution

In this section of the workshop the presenters were asked to describe their conceptual models of some of the major factors that may be affecting delta smelt. The following narrative conceptual model takes components from all the presentations but relies heavily on Bill Bennett's discussion of his draft CALFED white paper, *Delta Smelt Population Structure and Factors Influencing Population Dynamics*. Presentations by Zach Hymanson, Matt Nobriga, Lenny Grimaldo, Kevin Fleming, Steve Foss and Bradd Baskerville-Bridges also contributed to the model.

The general approach is to examine some of the key factors one at a time, including information supporting the role of a factor in delta smelt population dynamics. The order is arbitrary—that is, factors are not necessarily listed in order of their importance. We need to emphasize that much of the material remains speculative and needs more work to confirm or refute preliminary conclusions. It is presented in the spirit of all conceptual models—to stimulate discussion of alternate explanations and hypotheses for observed patterns in delta smelt related data.

Importance of Two-year Old Spawners

Although the percentage of two-year old spawners in the population now appears to be on the order of 3% to 8%, Bennett used autocorrelation analyses on the townet (TNS) and midwater trawl (MWT) data to show that there was significant autocorrelation lagged 1 and 2 years for the TNS and 1 year for the MWT. These analyses suggest that two-year-old spawners may be more important than would be indicated by their relative abundance.

These preliminary results require additional field and laboratory data to verify the importance of two-year olds. Since two-year olds are generally determined based on size frequency distribution, we may need more otolith analyses to confirm that they are not being undersampled. The otolith work is particularly important if the average size of the population is decreasing with time (Sweetnam 1999). Also the fecundity and gonad quality of two-year olds needs to be determined.

Water Temperature

Water temperature affects, among other things, the timing and duration of spawning, gamete, embryo and larval viability, growth and subsequent movement of young from the Delta to the Lower Salinity Zone (LSZ) in Suisun Bay. Temperatures are not consistent between years and not consistent between areas in any given year. Different years have different spawning patterns that may be tied to temperature differences. For example, in 1997 there was a short spawning season and in 1999 a relatively long spawning season. Length of spawning season is tied to both delta smelt abundance indices. Movement patterns may be tied to growth, which in turn is related to temperature.

As mentioned earlier, using delta smelt culture data, Bennett found evidence for a spring–neap pattern in laboratory spawning. Temperatures in the 15 to 20 °C coinciding with the appropriate spring–neap cycle could determine appropriate spawning times. He also indicated that, since 1992 spawning has generally occurred later in the year. Later spawning could result in the fish not growing to the size most vulnerable to the sampling gear used to determine individual indices. Slow growers could wait until the next year to spawn. This may explain the occurrence of 2-year olds in the population.

An important conclusion by many presenters was that there are not enough water temperature data being collected in the upper estuary. Given the increasing recognition of the importance of temperature effects on delta smelt distribution and abundance, more field efforts should be devoted to this environmental variable.

Outflow, X2, and Low Salinity Zone

These three terms are used here to denote the effects of flow patterns that affect the amount of habitat that may be important to delta smelt year class strength. In general terms, the amount of low salinity habitat in Suisun Bay is maximized by intermediate outflows. Although either outflow or X2 can be used to index the amount of habitat, the location of X2 is by convention the regulatory definition.

Intuitively one might expect that intermediate outflows would benefit delta smelt survival. At high flows, the young smelt would be carried down to the less productive lower bays and at low flows they would remain in the Delta longer and be vulnerable to agricultural and water project diversions. Initial analyses (Stevens and Miller 1983 and Jassby and others 1995) did not find a relationship between outflow and delta smelt abundance as indexed by the fall MWT survey. Subsequent analyses focusing on the spring months only (Herbold 1994) found a positive but weak relation between abundance and flow or position of X2. Bennett duplicated Herbold's analyses and also found a weak relationship suggesting delta smelt abundance benefited by positioning X2 in Suisun Bay in the spring (r^2 = 0.16). We have also included a recent analysis of the relation between X2 and summer townet smelt abundance, broken down into the 1959–1981 (filled boxes) and 1982–2000 (open boxes) periods (Figure 15, original data from Kimmerer). No explanation for the rather puzzling pattern is available.

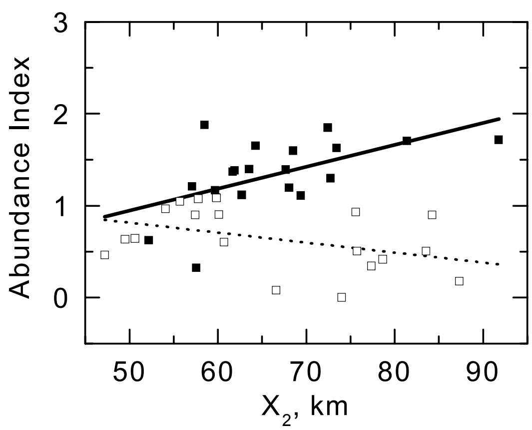

Figure 15 Relationship between X2 and summer townet delta smelt abundance during two periods: 1959–1981 (filled boxes) and 1982–2000 (open boxes)

Additional work is needed to determine the causative mechanisms that are potentially involved in the importance of Suisun Bay habitat to delta smelt and other fish. This is especially important now that the introduced clam, *Potamocorbula amurensis*, has changed the basic trophic structure in this critical area by sequestering pelagic food sources (zooplankton and phytoplankton) in the benthos.

From a delta smelt management standpoint, it is clear that concerns about the impacts of water project operations (and use of EWA water) decrease when the bulk of the population moves below the confluence of the Sacramento and San Joaquin rivers. The mechanisms causing the juvenile smelt to reach the confluence—either transport or active movement or a combination of—are not understood.

Food Limitation and Competition

The speakers presented little information about the effects of food limitation through competition or changes in prey abundance. It is clear that delta smelt are near obligate zooplanktivores throughout their life cycle. Other studies have demonstrated declines in the abundance of key zooplankton prey (Kimmerer and Orsi 1996, Kimmerer and others 1994). Invasion of the upper estuary by potential competitors, for example, inland silverside (*Menidia audens*) and the asian clam, *P. amurensis* also can reduce the food supply available to delta smelt. Finally the introduced wakasagi may compete with delta smelt for food in those areas and years when it becomes abundant in the Delta.

The circumstantial evidence indicates that food supply as affected by competition and other factors could be important to delta smelt year class success. Analysis of these data is complicated by the spatio-temporal distribution of the predators and their prey (see for example Bennett and Moyle 1996). Bennett did discuss the overall system carrying capacity, which includes food supply, and concluded that the population may be near the system's average long-term carrying capacity. (See correlation coefficients in Table 1.) If food is a problem, it has major implications for recovery.

Entrainment

Delta smelt larvae, juveniles and adults are entrained in a variety of water diversions ranging from small agricultural diversions to power plant intakes in the lower San Joaquin River to the large water project intakes in the southern Delta. Much work has been conducted to estimate salvage in the federal and state water project diversions, and a fair amount of work devoted to power plant losses. Although there are more than 2,200 small Delta agricultural diversions (Herren and Kawasaki 2001), little information is available on fish losses to agricultural diversions. This discussion is limited to the effects of the federal and state water projects.

Federal and State Water Projects. Bennett presented data indicating that losses of prespawning adults during the winter early spring were negatively correlated with survival rate (residuals from stock-recruit model) (Table 1). His analyses also suggested that high losses to the fish facilities in 1980 and 1981 contributed to the decline observed in the 1980s and early 1990s. He emphasized that these conclusions were tentative and more work is needed to verify them and suggest causative mechanisms.

Table 1 Population characteristics

	Abundance index		*Stock-recruit residual*			*Mortality index*		
External factors	*TNS*	*MWT*	*TNS-MWT (0)*	*MWT-TNS (1)*	*MWT-MWT (2)*	*Egg-Juv.*	*Juv.-Adult*	*Egg-Adult*
Inland silverside	**–0.595****	–0.258	0.248	**–0.477***	–0.108	**0.426***	–0.438	–0.027
	(0.003)	(0.246)	(0.266)	**(0.042)**	(0.660)	**(0.054)**	(0.047)	(0.911)
Suisun Bay, X2	0.191	**0.405***	**0.447***	0.158	0.034	0.079	–0.156	–0.192
	(0.350)	**(0.040)**	**(0.028)**	(0.458)	(0.872)	(0.715)	(0.467)	(0.380)
Exports, Mar-Jun	–0.300	–0.109	0.047	**–0.373***	–0.097	–0.034	–0.314	–0.097
	(0.107)	(0.567)	(0.812)	**(0.046)**	(0.631)	(0.865)	(0.104)	(0.629)
Exports, Jul-Oct	**–0.387***	–0.230	0.098	**–0.523****	–0.070	–0.249	–0.299	–0.229
	(0.035)	(0.222)	(0.621)	**(0.004)**	(0.730)	(0.201)	(0.122)	(0.250)
Exports, Nov-Feb	**–0.407***	–0.340	–0.169	–0.243	–0.306	–0.403	–0.196	–0.039
	(0.028)	(0.071)	(0.399)	(0.213)	(0.121)	(0.037)	(0.327)	(0.851)
Salvage, Mar-Jun	0.195	–0.168	–0.314	0.131	0.298	0.070	0.369	**0.517***
	(0.409)	(0.478)	(0.177)	(0.592)	(0.230)	(0.781)	(0.120)	**(0.028)**
Salvage, Jul-Oct	0.292	0.182	–0.005	–0.253	–0.111	–0.206	0.128	0.179
	(0.211)	(0.443)	(0.983)	(0.296)	(0.662)	(0.413)	(0.603)	(0.478)
Salvage, Nov-Feb	0.417	0.286	0.166	0.011	**–0.502***	0.050	0.143	0.278
	(0.076)	(0.235)	(0.497)	(0.965)	**(0.034)**	(0.843)	(0.559)	(0.265)

Steve Foss presented data demonstrating that seasonal and interannual delta smelt salvage patterns are quite variable and also vary between the two facilities. The differences between the two facilities are likely due to a combination of the effects of a forebay in front of the state intakes, differences in the ability to control screen approach velocities, the more variable pumping schedule at the SWP and the smelt population in water diverted. The differences are illustrated in Figure 16, CVP and SWP delta smelt salvage during May 2000. For the first two weeks, the CVP took more smelt but this changed dramatically during the last two weeks of the month when take at the SWP dominated. These differences offer the opportunity to reduce total take by changing the point of diversion, with the caveat that excess capacity must be available. Also most delta smelt are salvaged at night at the SWP.

Matt Nobriga, Lenny Grimaldo and Zach Hymanson hypothesized (in other words, presented a conceptual model) that Clifton Court Forebay may play an important role in the numbers of delta smelt salvaged by the SWP. In this scenario larval delta smelt use the forebay to rear young and are eventually salvaged. Lenny Grimaldo reported on a multiple regression analysis of delta smelt salvage versus exports, water temperature and turbidity. Based on 1999 and 2001 salvage data, he found that (1) Delta smelt salvage was significantly related to water temperature and turbidity in the forebay, but not export rate in 1999; and (2) in 2001, salvage was significantly related to water temperature but not turbidity or export.

These results suggest the physical properties of the forebay affect delta smelt salvage dynamics. They proposed an experiment to test this hypothesis—an experiment involving sampling in and just outside the forebay.

VAMPGrimaldo, Nobriga and Hymanson further hypothesized that the VAMP has changed water movement in the southern Delta during the early delta smelt life history. The assumptions and information leading to this hypothesis are as follows.

- Since the initiation of VAMP in 1996, modeling and field data demonstrate that April through May net flows in southern Delta channels are more positive than occurred pre-VAMP, with less water movement towards the pumps.
- Since VAMP started, the projects have exceeded the red light take level more often than they would have pre-VAMP.
- The VAMP flows and pumping restrictions provide better spawning and rearing conditions in the south Delta than was formerly possible.
- With better rearing conditions, the larvae in the south Delta that are not entrained grow to the size (greater than 20 mm) that is successfully salvaged and counted at the intakes.
- Taking this model to its logical conclusion, the projects are not removing more fish than they did historically, they are removing more older fish. In the past the larval fish did not reach the salvageable size and went down the aqueduct without being counted.
- On balance, VAMP effects on delta smelt are likely to be neutral or slightly positive since delaying higher levels of exports may allow more of the oldest fish to avoid entrainment.

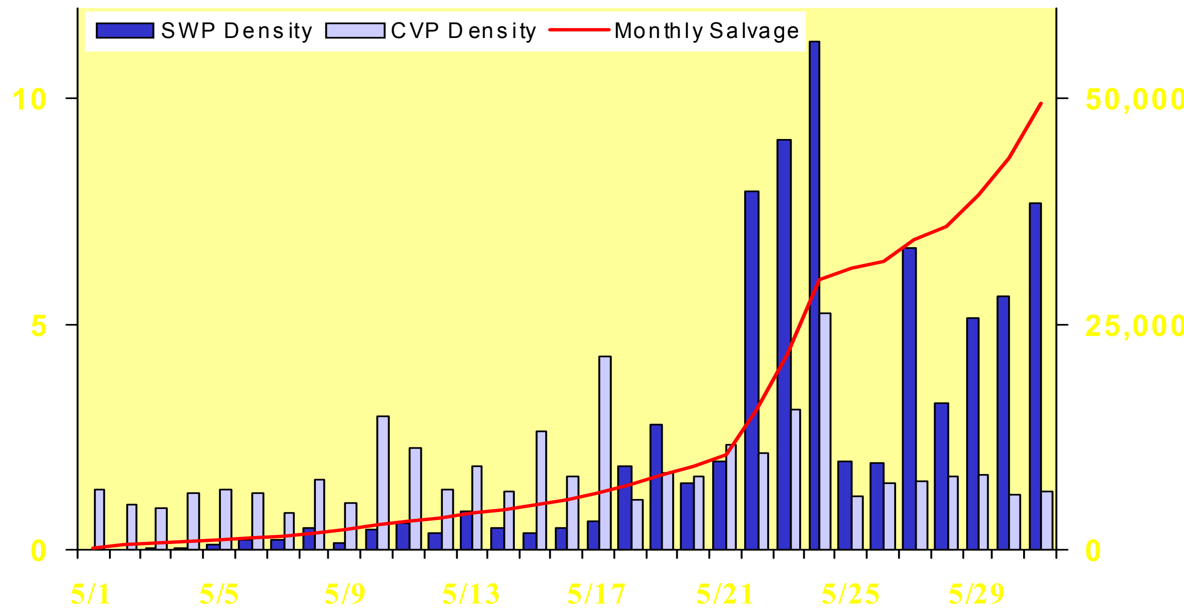

Figure 16 Differences in delta smelt densities and cumulative salvage at the state and federal facilities, May 2000

Shallow Water Habitat

No information was presented on the importance of shallow water habitat to delta smelt recovery. The role and need for more shallow water habitat remain largely unanswered but important management questions.

Predation

Although many species may prey on adult and juvenile delta smelt, much of the attention to date has focused on inland silversides. After their accidental introduction to the Delta in 1975, their population expanded quite rapidly through the 1990s (Figure 17). Estimates of abundance of delta smelt and silversides are negatively correlated (Figure 18). Bennett and Moyle (1996) give evidence to suggest that inland silversides may be an important predator on larval delta smelt, and further observed silversides preying on larval striped bass (Bennett 1993). Silversides often occur in dense schools near shorelines and their occurrence may detract from the value of shallow water habitat created to aid delta smelt restoration. Bennett, working with the IEP, is conducting studies to help determine if silversides constitute a serious threat to delta smelt.

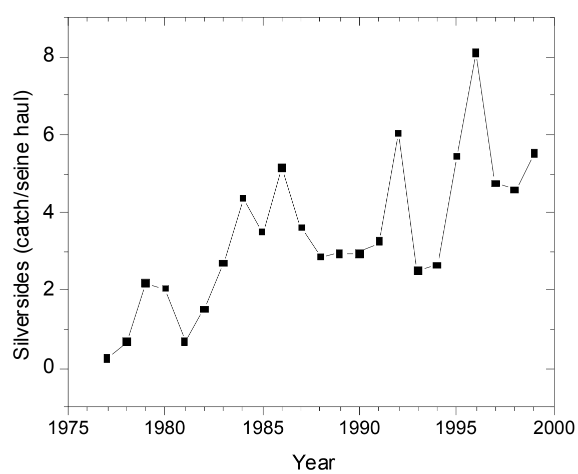

Figure 17 Inland silverside catch per seine haul, 1977–1999

Contaminants

Although there is no reliable time series to describe potential effects of contaminants on delta smelt, work to date doesn't indicate that toxic chemicals pose a serious impediment to the species' recovery. For example, Bennett indicated that less than 10% of the smelt examined in 1999 (which showed good year-class success) appeared to have been affected by contaminants.

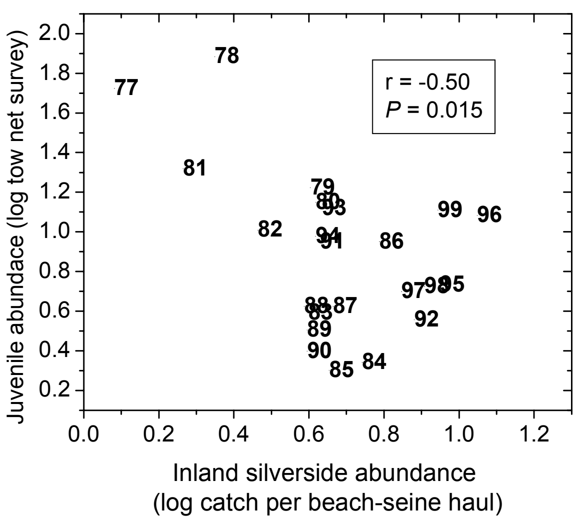

Figure 18 Inland silverside abundance vs. juvenile abundance of delta smelt, 1977–1999

Density Dependence

Density dependence can be broadly defined as the case where more of one life stage (larvae for example) does not necessarily result in more adults and implies that there is a finite carrying capacity. Bennett used traditional stock-recruitment analyses and calculations of mortality between life stages to conclude that density dependence has regulated delta smelt abundance over the period of record. For example, Figure 19, indicates that mortality increases significantly with abundance. If it exists, density dependence in delta smelt would have major implications for application of EWA assets.

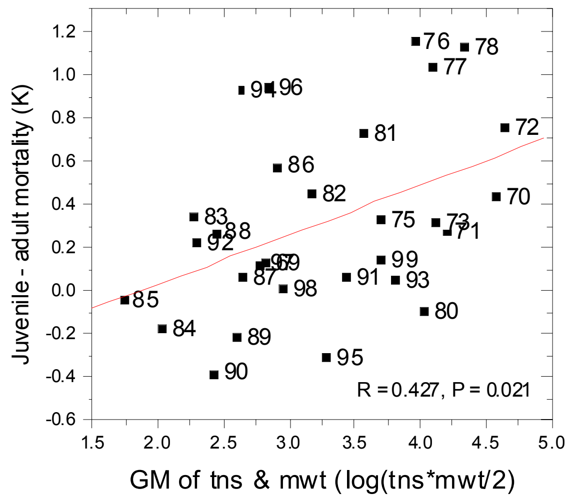

Figure 19 Mortality rate (K) between the juvenile and adult life stages ($\log_a - \log_{a1}$) and the geometric mean (GM) of juvenile and adult abundance [log (tns*mwt)/2]

Not everyone at the workshop agreed with the conclusion that the data demonstrated density dependence. As with all conceptual models, the idea is to put a concept or hypothesis before a group of peers and see how well it holds up against additional data and analyses. We now need the additional data and analyses to support or refute this important hypothesis.

2000–2001 EWA Actions

We first briefly describe the process of allocating EWA water to delta smelt and the chronology of EWA actions, including the amounts of water used. The descriptions are based respectively on workshop presentations by Jim White and Matt Vandenberg.

The EWA Water Allocation Process

Agency and stakeholder biologists and engineers and managers used an interlocking set of teams and groups to obtain and evaluate information, develop and act on recommendations to allocate water to protect delta smelt. The following is a brief summary of the teams and groups and a hypothetical example to illustrate how a recommendation could be developed and implemented.

Agency biologists posted abundance and distribution information from the 20-mm surveys on the web and distributed the data by email as needed. Project operators obtained and disseminated salvage at the federal and state pumping plants as well as pumping forecasts. DWR provided status reports on installation and operation of the temporary barriers.

The Data Assessment Team (DAT), consisting of agency and stakeholder representatives, held weekly conference calls to discuss survey results, salvage as compared to take limits, operational plans, X2 location, water temperature and other related data. After considering the information, the DAT might make a recommendation to change project pumping, to change operation of the temporary barriers, or in some instances recommend that one or more of the barriers be removed. The DAT was most active from October 2000 through March 2001 when chinook salmon and steelhead actions might have coincided with actions to protect delta smelt.

After April 1, the Delta Smelt Working Group (DSWG), biologists from USFWS, USBR, EPA, DWR, SWRCB and DFG (as specified in the delta smelt biological opinion on operation of the state and federal projects) assumed much of the DAT's responsibility for examining delta smelt biological and operational data and making recommendations for operational changes. The workgroup's purpose is to "resolve biological and technical issues raised by this opinion and to develop recommendations." The working group developed a decision tree (Appendix D) to make the analysis and recommendation process somewhat formal and to inform others of the decision process. The decision tree was divided into the three main components of the delta smelt life cycle: adults, larvae and juveniles. In all three cases the information collected and analyzed included distribution, abundance, salvage (including trends), hydrology, water quality and temperature.

The Water Operations Management Team (WOMT), consisting of management level representatives of the management and project agencies, also met weekly to discuss operations and consider recommendations for use of EWA water. For example, the DSWG might recommend that pumping be curtailed for 3 days to reduce delta smelt take. Project operators would estimate the water costs of this curtailment. If the water were available in the EWA account, WOMT would approve the curtailment as soon as practicable.

Two additional groups provided the opportunity for stakeholder interaction in the decision process. The Operations and Fisheries Forum could be convened when needed to quickly obtain stakeholder input and consider operational changes in more detail. The CALFED Operations Group met monthly in a public forum to share and discuss proposed and recent operations, including the use of EWA water and the amount of water remaining in the EWA account.

A final group, the b(2) Interagency Team, worked to integrate the use of the CVPIA's b(2) water with that of the EWA to help ensure maximum resource protection. Since the CVPIA is a federal act, the project operators must ensure that b(2) is used to meet the CVP's restoration responsibilities. Use of EWA assets must not cost either water or power.

The following <u>hypothetical</u> example below may help to clarify the complicated process.

1. DFG completes the 20-mm survey and posts the data on the web. The survey shows that the smelt are mostly in the southern Delta and the average size is approaching 30 mm. Delta smelt salvage at the state and federal intakes shows an upwards trend and appears that it will soon reach the red light level. The operators project that pumping will remain near a combined 6000 cfs. The agricultural barriers and the head of Old River barriers are all in and the flap gates closed.

2. The DSWG meets to consider these and other data and recommends that pumping be curtailed for 5 days to a combined 4000 cfs. They also recommend that water flow in the south Delta be improved by opening the flap gates in all barriers. To obtain additional data, the working group asks DWR to run its particle tracking model to compare delta smelt distribution with and without the proposed changes. The model runs indicate that the proposed operational changes will likely result in take reduction.

3. WOMT meets to consider the recommendation. The project agencies indicate that the reduced pumping will result in a water cost of 20,000 af, They also indicate that the EWA account has over a 100,000 af remaining. Finally, hydrodynamic model runs indicate that tying open the flapgates will not cause water level concerns to south Delta diverters. Based on these data, the project operators agree to begin the curtailment the following day with the SWP taking all of the cutback in pumping. The flapgates are tied open until further notice.

4. At the next regularly scheduled meeting of the CALFED Operations Group, agency staff explains to stakeholders the EWA action, its

justification, water and other cost and the amount of water remaining in the EWA account.

Monthly Chronology of EWA Actions

The following are some of the highlights of EWA expenditures for delta smelt protection. In many ways, 2000-2001 was not a very meaningful test of the use of EWA to protect smelt. Unlike winter chinook (see Brown and Kimmerer 2001a), delta smelt take was never a serious problem, consequently there was never a need for dramatic action. Recent history suggests this will not be the case every year.

Although delta smelt were taken at the project salvage beginning in August 2000, no EWA actions directly or indirectly occurred until February 2001.

February

- The water year was officially classified as dry on February 15. As shown in Table 2, this classification affects the allowable delta smelt take at the federal and state intakes.
- On February 12, daily expanded take increased from 12 to 207, indicating movement of adult smelt to the spawning grounds.
- On February 16 the management agencies requested that combined pumping be reduced to 7,000 cfs for 5 days. Although the action was primarily to protect winter chinook juveniles, a reduction in take indicated that it also benefited delta smelt.
- Total take for February was 3,768.
- EWA water use for February was 52,000 af.

Table 2 Monthly take limits for delta smelt

	Water year classification	
Month	*Above normal*	*Below normal*
Jan	5,397	13,354
Feb	7,188	10,910
Mar	6,979	5,368
Apr	2,378	12,345
May	9,769	55,277
Jun	10,709	47,245
Jul	9,617	35,550
Aug	4,818	25,889
Sep	1,329	1,978
Oct	11,990	6,440
Nov	3,330	2,001
Dec	733	8,052

March

- Except for a few days early in the month, combined take levels were generally less than 200. These low levels may have been in part due a pumping curtailment to protect winter chinook that extended through March 11. The take never approached the yellow light level of 400 based on a 14-day running average.
- On March 19, the results of the first 20-mm survey indicated that the delta smelt were centered around the confluence of the Sacramento and San Joaquin rivers, but their small size meant the distribution could change substantially in later surveys.
- Total delta smelt take for the month was 3,730. The 14-day running average remained below the

200 early warning value that could have triggered changes in the temporary barriers to improve conditions for delta smelt.

- Total EWA expenditures for the month of 65,000 af probably provided some unquantified benefit to delta smelt.

April

- The second and third 20-mm surveys indicated that delta smelt were concentrated in the southern Delta and by the end of the month the average size approached 11 mm.
- The management agencies requested export reductions from April 5 through April 9 to protect emigrating spring chinook juveniles.
- The Vernalis Adaptive Management Plan study began on April 20 and combined exports were reduced to1,500 cfs.
- By the end of the month the three agricultural barriers and the head of Old River mitigation barrier were installed. As required when the mitigation barrier was in place, the center section and flap gates in the Grantline barrier were open.
- Total delta smelt salvage for the month was a modest 519.
- Total EWA expenditures for the month were 29,000 af, 20,000 for spring run protection and 9,000 for VAMP.

May

- Because of VAMP, exports remained at 1,500 cfs through May 20.
- On May 14, the 14-day running average of delta smelt take exceeded 200, the pre-yellow light warning level that triggered protection actions as required in the 2001 biological opinion for the temporary barriers. The DSWG recommended opening the flap gates on the agricultural barriers and the culverts on the mitigation barrier. This action was completed on May 16.
- On May 21, the 14-day running average take exceeded the 400 yellow light level. The management agencies recommended that pumping be maintained at 1,500 cfs through the end of the May.
- On May 26, the USFWS recommended that the Grant Line barrier be breached. Subsequent particle tracking model results indicated that breaching the barrier would not benefit delta smelt and the barrier remained in place. At DFG's request, DWR removed one of the flashboards on the Grantline barrier to increase flow past the barrier. The head of Old River barrier was also breached on May 26.
- On May 28, DWR closed the Clifton Court Forebay gates.
- Total delta smelt salvage for May was 13,278.
- Total EWA expenditures for the month were 48,000 af, 34,000 for

VAMP and 14,000 to maintain export levels of 1,500 cfs from May 21 through the end of the month.

June

- DWR opened the gates to Clifton Court Forebay on June 1. Combined exports were forecast to range from 2,000 cfs to 3,300 cfs through June 5.
- The DSWG recommended no increased exports until the average size of delta smelt reached 30 mm, hopefully allowing them to move beyond the influence of the pumps.
- Since the delta smelt take level continued to exceed the 400 yellow light, the management agencies requested that the SWP reduce exports during the first five days of June.
- Due to a leak in the California Aqueduct, DWR stopped diversions and again closed the gates to Clifton Court Forebay.
- Delta smelt salvage continued to decline during the remainder of June.
- Total delta smelt salvage for the month was 2,454.
- Total EWA expenditures for the month—to cover export reduction in the first five days—were 9,000 af.

As stated earlier, the past season was rather uneventful. Delta smelt take was consistently below the authorized take level (see Table 2) and use of EWA water both for salmonids and delta smelt helped lower the take. No analyses have been conducted to determine the population level benefits of using these resources.

Panel Discussion

After the presentations a panel was convened, consisting of Matt Vandenberg (USFWS), Zach Hymanson (DWR), Bill Bennett (UCD), Kevin Fleming (DFG). They were asked to address the following questions.

1. What are the most critical scientific information needs necessary to substantially improve our understanding of delta smelt biology and ecology?
2. Three conceptual models for delta smelt were presented today. What specific similarities and differences did you note? What work is needed to refine and unify these models?
3. Given the Environmental Water Account Program is a four year experiment, what specific recommendations do you have for experiments that should be conducted in the next three years?

Individual panel members, as well as the workshop audience, responded to the questions posed above. Their responses are presented below.

Responses from Matt Vandenberg

Question 1. What are our critical information needs?

- Temperature and salinity information and its effects on delta smelt abundance and distribution.
- Relation between net flows and larval fish movement.
- We could use a delta wide experiment—collect lots of information during period of controlled flows.
- Information on effects of agricultural diversions and habitat loss.
- Habitat restoration—what are attributes of good habitat and how do we create it.

Question 2. What are your thoughts on the most appropriate conceptual model?

- No response to this question.

Question 3. What do we need in the next three years of the EWA evaluation?

- A water level response plan in the south Delta that minimizes the need to install and operate the temporary barriers, thus reduces their potential impacts on delta smelt.

Responses from Zach Hymanson

Question 1. What are our critical information needs?

- We need a delta smelt research plan including priorities for individual studies and programs.
- The USFWS needs a staff position devoted to delta smelt science and restoration.
- We need to implement the fish–X2 study to help understand the underlying mechanisms.
- We need additional water temperature monitoring stations.
- We need to understand and quantify the variability in abundance indices.
- We need to develop an abundance index for the 20-mm survey.

Question 2. What are your thoughts on the most appropriate conceptual model?

- I found consistency among the proposed models.
- We need to use some of the proposed experimental work as part of the process of updating and verifying the models.
- There is a significant gap in our knowledge of temperatures in the upper estuary.
- We need to explicitly build in more physical factors in the models.

- Contaminant related components in the models are weak or non-existent.

- Food supply and its effects also need to be formally incorporated in the models.

- Density dependence in the juvenile stage is an important concept in the Bennett model. More data and analyses are needed to determine if density dependence exists since it may change our management strategy.

Question 3. What do we need in the next three years of the EWA evaluation?

- We need a “VAMP” for delta smelt to examine the interlocking effects of San Joaquin River flows, water project diversions and barriers on delta smelt distribution and abundance.

- We need to determine if temperature information can be used to provide more definitive clues for timing of spawning and movement.

- Determine if there is a relation between the 20-mm survey results and those of the TNS. Such a relation could help evaluate the benefits of EWA expenditures applied during the spring and summer.

Responses from Kevin Fleming

Question 1. What are our critical information needs?

- We have only scratched the surface of the basic biology of delta smelt—we need much more work in this area.

- We need to know what moves smelt from point A to B—dispersion, active movement, combination of two (and more)?

- There seems to be a disconnect between food abundance and delta smelt abundance. Why?

- It appears that both density dependent and interdependent mortalities are occurring. What is their relative importance?

- The value of shallow water habitat. Much money is being spent, or being considered for spending, on shallow water habitat for delta smelt without knowing its benefit to the species.

Question 2. What are your thoughts on the most appropriate conceptual model?

- No comments in this area.

Question 3. What do we need in the next three years of the EWA evaluation?

- More experimental work to backup allocation and benefits of EWA actions.

Responses from Bill Bennett

Question 1. What are our critical information needs?

- Recognize that short term and long term needs are quite different

- Long term information needs are most important and we need a plan on how to get there.

- We need to get beyond simple correlation analyses.

- We need to maximize use of fish collected as part of routine monitoring programs by extracting all information possible from them—to begin, we need to look at the insides for parasites and condition of organs and tissues and examine otoliths.

- We need absolute abundance estimates, perhaps by indexing and collecting additional fish to get a better handle on abundance. This will be difficult.

- We need to consider using an Individual Based Model approach to assess the benefit of EWA and other protective and restorative actions.

- We should continue the culture studies since they are providing a close look at the animal's "personality."

Question 2. What are your thoughts on the most appropriate conceptual model?

- The models are used to help guide thinking.

- CALFED may need an explicit model when considering actions or funding proposed research.

- I don't see any major disagreements in the models presented.

- Scientific support for density dependence is about as solid as anything we have.

- Factors that drive fish abundance are variable and complex.

Question 3. What do we need in the next three years of the EWA evaluation?

- No comments in this area.

Comments from the Audience

- We need to clearly define the benefits of EWA actions.

- Bennett's data suggest that delta smelt may be at carrying capacity. Does this have implications for recovery?

- We have a wealth of information. Should this be used to develop a multi-variate model?

- If we are at carrying capacity, could this be modified by changes in water project operations to increase capacity?

- EWA does not have a large amount of water to allocate. EWA water must be used in concert with other actions and must be used where it has the maximum likelihood of benefiting delta smelt.

- There are data indicating that even juvenile smelt can control their location and movement to some extent. We need to know more about this.

- We need more quantitative estimates of delta smelt abundance. These estimates then could be used to assess the relative impacts of losses to the water projects to the population.

The Authors' Observations

The following are some observations based on the workshop and from following the delta smelt studies for the past several years.

The Workshop

We found the workshop to be a productive means of exchanging ideas and data among the various workers on the biology of delta smelt. It is apparent that DFG and the IEP have devoted considerable effort to collecting and reporting monitoring data in a time frame that assists the management and project agencies in guiding project operations to protect smelt. The use of the particle tracking model in developing recommendations was particularly appealing.

The workshop format did not lend itself to detailed discussion of the data and models. Additional, smaller and focused workshops are needed to facilitate this type of discussion.

Communications Among Biologists

It did not appear that there is adequate frequent contact among many of the biologists working on delta smelt.

Long-term Study Plan

There does not appear to be a long-term plan around which the studies can be developed and conducted. Although research, monitoring and analysis will continue with or without a plan, such a plan would be helpful for setting priorities and that funded research helps answer essential management questions. This plan should be based on a revised delta smelt white paper which will provide a comprehensive view of our understanding and uncertainties about this enigmatic fish.

Publication of Results

A rather cursory examination of the list of delta smelt references distributed by Fred Feyrer on behalf of the IEP (Appendix C) paints a bleak picture of results peer reviewed and published in the open literature on the biology and life history of delta smelt. The following is a rough breakdown of published articles devoted mostly to delta smelt.

- Published in the *IEP Newsletter*: 70
- Published in *California Fish and Game Quarterly*: 4
- Submitted to IEP agencies as final project report: 12
- Published as IEP technical reports: 2
- Published as dissertations or master's theses: 3
- Published in open literature by others (essentially UCD): 9. (Mostly related to work on the physiology

and swimming ability of delta smelt and its genetic characterization.)

- Published in open literature by authors in IEP agencies: 1. (This was a 1992 *Transactions of the American Fisheries Society* article co-authored by Don Stevens and Lee Miller, with Peter Moyle and Bruce Herbold as lead authors.)

This analysis leads us to conclude that the several million dollars IEP has spent on delta smelt science since the early 1990s are (1) not going to the sort of work that is publishable, or (2) that the scientists doing the work don't have the either the time, or inclination (or both) to publish. In either case, we believe that the publication in the open literature is essential to having the ideas and models critically reviewed. This process should result in a more confident approach to managing this somewhat enigmatic fish.

Integration of Qualitative and Quantitative Analytical Techniques

Perhaps partly because of communication problems, there is not adequate integration of such techniques as regression analyses, multi-variate analyses and modeling (for example, an individual based model) approaches to the data sets. The full array of analytical techniques is needed to help tease out the factors affecting delta smelt distribution and abundance.

Water Temperature

Water temperature was shown to be an important environmental variable. It was also clear that not enough water temperature data are being collected or made available in a timely manner.

Culture Studies

These studies are not only providing larvae and juveniles but also providing valuable insight into the biology of this animal.

Population Benefits of EWA and Other Actions

Almost no data were presented to help managers determine if EWA water had population benefits. While this is understandable with the limited knowledge on factors controlling delta smelt abundance and distribution, assessing population level impacts should be an integral feature of a delta smelt study plan.

Recommendations

- We recommend that IEP establish an IEP project work team devoted strictly to delta smelt science. The team should be chaired by someone whose only job is to better understand delta smelt science. The team's first assignment should be to develop a long-term study plan, including a process to get study results in the open literature. We strongly recommend that the authorship of technical articles include academic, agency and stakeholder representatives as appropriate.

- We also recommend that DFG complete the analysis of the egg and larvae data set and consider if it should be re-initiated, perhaps in a reduced form with a delta smelt focus. It appears that the early life history may provide useful insight into delta smelt biology.
- We recommend that the culture studies be continued.
- Finally, we recommend that IEP develop a more extensive temperature monitoring system in the Delta–Suisun Bay complex.

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Appendix A: List of Attendees

California Dept. of Fish and Game

Jim White
Steve Foss
Scott Cantrell
Andy Rockriver
Kevin Fleming
Pat Coulston

California Dept. of Water Resources

Ted Sommer
Lenny Grimaldo
Heidi Rooks
Barbara McDonnell
Fred Feyrer
Randy Mager
Matt Nobriga
Zachary Hymanson
Aaron Miller
Bill Harrell

U.S. Fish and Wildlife Service

Mike Thabault
Ryan Olah
Matt Vandenberg
Dan Buford
Roger Guinee
Marty Kjelson
Paul Cadrett
Doug Morrison
Mike Fris
Andy Hamilton
Derek Hilts

U.S. Bureau of Reclamation

Mike Chotkowski
Ken Lentz
Dave Robinson
Erwin Van Nieuwenhuyse
Johnson Wang
Brent Bridges
Tom Morstein-Marx
Lloyd Hess
Rene Reyes

University of California, Davis

Bill Bennett
Peter Moyle
Bradd Baskerville-Bridges
Jim Hobbs

U.S. Geological Survey

Larry Brown
Kathy Kuivila

CALFED

Sam Luoma
Kim Taylor
Wim Kimmerer
Dave Fullerton
Randy Brown

Stakeholders

Rick Sitts
Joan Lindberg
Tina Swanson
Chuck Hanson
Leo Winternitz

Appendix B: Delta Smelt EWA Workshop Agenda

Friday September 7, 2001
UCD, Putah Creek Lodge

8:00–8:50. Assemble for caffeine and calories

8:50–9:00. Welcome, agenda overview, and workshop ground rules. Wim Kimmerer, RTC

9:00–9:30. The big picture for delta smelt: integrating management, science, and regulation. Zach Hymanson, DWR

Delta smelt basic biology and tools for evaluating its distribution, abundance, and responses to changing conditions

9:30–10:00. The biology of delta smelt with observations from laboratory studies. Bradd Baskerville-Bridges, UCD

10:00–10:20. Break

10:2–10:50. Trends in delta smelt abundance and distribution. Andy Rockriver, DFG

10:50–11:20. Trends in delta smelt salvage at the SWP and CVP. Steve Foss, DFG

11:20–11:50. The particle tracking model: a tool for estimating delta smelt responses to changing conditions. Aaron Miller, DWR

11:50–12:50. Lunch

Conceptual models to explain patterns and dynamics in delta smelt

12:50–1:20. Conceptual modeling of factors influencing delta smelt population dynamics and restoration. Bill Bennett, UCD

1:20–1:50. A conceptual model of delta smelt population biology emphasizing the importance of physical factors. Kevin Fleming, DFG

1:50–2:20. Springtime events in the south delta and their possible influence on delta smelt spawning and salvage. Matt Nobriga and Lenny Grimaldo, DWR

2:20–2:40. Break

EWA indicators, actions, and response

2:40–2:55. EWA overview: the concept and the process. Jim White, DFG

2:55–3:25. The delta smelt decision tree and indicators for response to EWA actions. Kevin Fleming, DFG

3:25–3:55. Water year 2001 EWA actions for delta smelt: overview, rationale, and estimates of response. Matt Vandenberg, FWS

3:55–5:00. Panel discussion and Audience Q&A: Improving the situation for delta smelt: strengthening the linkages between science, management, and regulation.

Panel: Zach Hymanson, Bill Bennett, Kevin Fleming, and Matt Vandenberg.

Appendix C: Categorized Bibliography of the Delta Smelt (*Hypomesus transpacificus*), 2nd Edition

September 2001
Frederick Feyrer and Linda Rivard
California Department of Water Resources

The delta smelt bibliography contains 178 references (the first edition in 1998 contained 102). To increase comprehensiveness, non-primary literature (gray literature, newsletter articles, memos, etc.) has been included. References have been placed into eight applicable categories to help readers find information on specific subjects. Most of the references in the bibliography are readily available at major libraries. Gray literature associated with the IEP can be obtained from the California Department of Water Resources, Environmental Services Office, Sacramento, California, or the California Department of Fish and Game, Central Valley Bay-Delta Branch, Stockton, California. Delta smelt resources available on the Internet is given last. Please contact Fred Feyrer (ffeyrer@water.ca.gov) to make revisions or to add new references.

Categories

1. Life history, ecology, status and taxonomy. 1, 2, 14, 17, 30, 32, 37, 38, 48, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 67, 80, 81, 85, 86, 90, 91, 96, 98, 104, 105, 106, 108, 109, 112, 114, 118, 119, 120, 122, 123, 126, 127, 128, 129, 132, 133, 134, 135, 146, 147, 148, 149, 150, 152, 153, 154 155, 156, 157, 164, 165, 166, 167, 168, 169, 170, 171, 177

2. Physiology and swimming performance. 21, 39, 40, 43, 44, 73, 74, 97, 136, 137, 138, 139, 140, 141, 142, 143, 144, 145, 175, 176

3. Reproduction, culture and disease. 4, 5, 10, 11, 12, 13, 33, 34, 35, 75, 76, 77, 78, 79, 82, 83

4. Management. 16, 20, 22, 23, 24, 25, 26, 27, 28, 29, 66, 87, 92, 99, 111, 131, 135, 149, 150, 151, 159, 160, 161, 162, 163

5. Monitoring studies with limited delta smelt information. 6, 15, 69, 84, 93, 94, 103, 121

6. Salvage and screening. 3, 7, 8, 9, 18, 19, 24, 31, 41, 42, 110, 113, 115, 116, 130, 173, 174, 178

7. Broad investigations and summary reports that include delta smelt information. 36, 37, 45, 46, 47, 49, 50, 51, 62, 63, 64, 65, 68, 70, 71, 72, 89, 95, 107, 117, 124, 125, 158, 169, 172

8. Texts with information or chapters on delta smelt. 88, 100, 101, 102

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Internet Resources

U.S. Fish and Wildlife Service final rule on delta smelt:

http://www.fws.gov/r9endspp/r/fr93492.html

U.S. Fish and Wildlife Service, Endangered Species Division, Sacramento Filed Office species account (the Sacramento-San Joaquin Native Species Recovery Plan is also available here):

http://sacramento.fws.gov/es/animal_spp_acct/delta_smelt.htm

California Department of Fish and Game, Central Valley Bay-Delta Branch:

http://www.delta.dfg.ca.gov./data/dsstatus/dsstatus.html

Interagency Ecological Program:

http://www.iep.ca.gov

Salvage Report (updated):

http://wwwoco.water.ca.gov/cmplmon/reports/smelt.html

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Appendix D: Delta Smelt Decision Tree

The Delta Smelt Decision Tree

Life stage	Adults
Timing	Pre-VAMP (February 1 through April 15)
Concerns	1) High relative densities of adults in the south Delta are a concern due to the potential for increase entrainment at the SWP and CVP. 2) High relative densities of delta smelt in the south Delta also suggest spawning may occur in the south Delta, increasing the chances for exceeding the red light level[a] of incidental take in the late spring and early summer.
Data of interest	Before pre-VAMP, consider fall midwater trawl indices Spring midwater trawl Salvage Beach seine Chipps Island trawl Hydrology (wet or dry year; placement of X2) Water quality conditions and water temperature Condition of the fish
Assessment of conditions	Adult distribution in Delta and downstream of the Delta Salvage levels/densities, yellow light Potential high numbers in juvenile salvage if high numbers of adults are concentrated in the south Delta
Tools for change	Reduction in exports, either concurrently at both facilities or at the facility that is salvaging the most fish
Biological questions using the available data	1) Is the adult distribution broad or not? 2) Is salvage elevated or not? 3) Is previous FMWT index high or low? 4) Are water quality conditions (e.g. water temperatures) conducive to spawning? 5) Are fish ripe for spawning? (Both of above may help determine if there will be a protracted spawn.)
Questions concerning operations	1) Is there a need to reduce exports at either or both facilities based on either the distribution of adults and/or an increase in the salvage of adult delta smelt? 2) Is it likely to be a difficult spring or summer? That is, do we expect high levels of delta smelt salvage in the spring or summer?
Assessment of concern	I. If the stated recovery criteria index is lower than 239, then concern is high. II. If distribution information shows adults delta smelt are concentrated in the south and central Delta, then concern is high. III. If the observed or predicted salvage of adults increases sharply, then concern is high. IV. If fish at the salvage facilities are on the verge of spawning and temperatures are conducive to spawning, then concern is high.
Recommendations	A) If concern is high and salvage increases abruptly, then recommendations for action is likely. B) If the observed or predicted salvage is at or approaching the red light or at the yellow light, then a recommendation for action is likely. C) If assessments II and I are true, then we expect a difficult spring or summer (June and July).

a Yellow light and red light as defined in the 1995 OCAP opinion.
b If fortnightly 20-mm survey is occurring and red light occurs, then effort will increase to weekly sampling.
c Salvage levels at this time will likely not reflect the number of delta smelt in the south Delta, since smelt begin to be counted at the salvage facilities at about 25 mm.
d The barriers shall be operated as stated in the USFWS biological opinion (1-1-96-F-53), April 26, 1996.
e Changes considered under “a” and “b” would aim to increase net positive flows in Old and Middle rivers downstream of the export facilities.

The Delta Smelt Decision Tree (Continued)

Life stage	Larvae
Timing	VAMP (April 15 through May 15)
Concerns	High numbers of larvae in the south Delta will likely result in higher numbers of fish rearing to juvenile stages and higher levels of entrainment.
Data of interest	Light traps surveys 20-mm survey[b] Water temperatures Salvage[c] Hydrology (wet or dry year; placement of X2)
Assessment of conditions	Spawning distribution Percent distribution Timing: start and duration of spawning Implement model to predict future salvage (end of VAMP) Water quality conditions, water temperature
Tools for change	Change in San Joaquin River flows Change in export reductions (1–3 = net flow) Change in barrier operations
Biological questions using the available data	1) Is distribution of spawning broad or restricted? 2) Is larval distribution broad or restricted? 3) When does spawning start? 4) Do we expect punctuated or protracted spawning? 5) Do we expect SWP and CVP to reach red light salvage levels?
Questions concerning operations	Do we consider changing net flows in Old and Middle rivers?
Assessment of concern	I. If light trap results demonstrates that spawning has occurred in the south Delta, then concern is high II. If the 20-mm survey shows 50% of the delta smelt are in the zone of influence (e.g,. east of the confluence), then concern is high. III. If abundance in the 20-mm survey is low relative to other years, then concern is high. IV. If substantial larval recruitment is expected to occur in the south and central Delta post-VAMP, then concern is high
Recommendation	If concern is high and salvage is at or approaching red light or at yellow light, then recommendations to improve net flow in Old and Middle Rivers are likely. (This recommendation applies during VAMP and post-VAMP, although the tool used will vary.)
Life stage	**Juveniles**
Timing	Post-VAMP (May 15 through July 1)
Concerns	High numbers of delta smelt juveniles in the south and central Delta will likely result in increased entrainment when export levels increase at the end of VAMP
Data of interest	20-mm survey[b] Salvage Summer townet Hydrology (wet or dry year; placement of X2) Export rates

a Yellow light and red light as defined in the 1995 OCAP opinion.
b If fortnightly 20-mm survey is occurring and red light occurs, then effort will increase to weekly sampling.
c Salvage levels at this time will likely not reflect the number of delta smelt in the south Delta, since smelt begin to be counted at the salvage facilities at about 25 mm.
d The barriers shall be operated as stated in the USFWS biological opinion (1-1-96-F-53), April 26, 1996.
e Changes considered under “a” and “b” would aim to increase net positive flows in Old and Middle rivers downstream of the export facilities.

The Delta Smelt Decision Tree (Continued)

Assessment of conditions	Percent of the distribution outside the zone of influence (e.g., east and west of the confluence) Salvage level (number) Salvage density
Tools for change	Change in exports Change in agricultural barrier operations[d] Removal of HORB[d] Position of cross-channel gates Flow changes in San Joaquin, Old, and Middle rivers
Biological questions using the available data	1) What is the relative distribution in and outside the zone of influence (e.g. upstream and downstream of the confluence)? 2) Is abundance high? 3) Is salvage at or approaching red light or at yellow light? 4) Are fish migrating west from the Delta?
Questions concerning operations	1) Do we consider changing exports?[e] 2) Do we consider changing agricultural barrier/HORB operations?[e] 3) Do we consider changing the position of the cross channel gates after May 20?
Assessment of concern	I. If the 20-mm survey shows 50% of the delta smelt are in the zone of influence (e.g. east of the confluence), then concern is high. II. If abundance in the 20-mm survey is low, relative to other years, then concern is high.
Recommendation	If concern is high and salvage is at or near red light, then recommendation for action is likely.

a Yellow light and red light as defined in the 1995 OCAP opinion.
b If fortnightly 20-mm survey is occurring and red light occurs, then effort will increase to weekly sampling.
c Salvage levels at this time will likely not reflect the number of delta smelt in the south Delta, since smelt begin to be counted at the salvage facilities at about 25 mm.
d The barriers shall be operated as stated in the USFWS biological opinion (1-1-96-F-53), April 26, 1996.
e Changes considered under “a” and “b” would aim to increase net positive flows in Old and Middle rivers downstream of the export facilities.