Interagency Ecological Program 2006-2007 Work Plan to Evaluate the Decline of Pelagic Species in the Upper San Francisco Estuary

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Executive Summary

Abundance indices calculated by the Interagency Ecological Program (IEP) through 2005 suggest recent marked declines in numerous pelagic fishes in the upper San Francisco Estuary (the Delta and Suisun Bay). Although several species show evidence of long-term declines, the recent low levels were unexpected given the relatively moderate winter-spring flows of the past several years.

In response to these changes, the IEP formed a Pelagic Organism Decline ("POD") work team to evaluate the potential causes. The product of this effort was a 2005 study to provide insight into the best lines of inquiry for 2006-2007 studies. The major findings through 2005 were synthesized using two conceptual modeling approaches. First, we developed species matrix models. We used the matrix models to examine which stressors (entrainment, toxic effects on fish, toxic effects on fish food items, harmful algal blooms, clam *Corbula* effects on food availability, and disease and parasites) were most likely to be important. Here we use importance to mean either stressors supported by the available data or stressors which could not be ruled out based on the available data. Secondly, we constructed narrative explanations for the recent step decline in abundance of pelagic species in the context of their long term trends or previous patterns. To date, two narrative models have been developed: 1) the *Winter Entrainment* H*ypothesis*, which focuses on sources of mortality in the central and southern Delta; and 2) the *Bad Suisun Bay Hypothesis*, which focuses on food web effects in Suisun Bay and the west Delta.

The overall approach for 2006-7 is intended to evaluate and refine the evidence for the conceptual models. To address the matrix models, the study design is based on *temporal*, *spatial* and *species* contrasts for selected fish and zooplankton. For each contrast, the variables to be evaluated include: abundance, growth rate and fecundity; and feeding success, condition factor, parasite load and histopathology (fish only). To the extent possible, these data will be collected simultaneously to help evaluate the relative importance of different stressors. The narrative models, on the other hand, posit linkages among different stressors and their possible pathways to produce the observed declines of more than one species. The workplan elements that are based on the two narrative models, therefore, emphasize analyses of the proposed linkages among stressors.

The proposed studies represent an interdisciplinary, multi-agency effort including staff from DFG, DWR, USBR, USEPA, USGS, CBDA, SFSU and UCD. Project components were selected based on their ability to evaluate the conceptual models, and their feasibility in terms of methods, staffing, costs, timing and data availability. The proposed work falls into three general types: 1)

an expansion of existing monitoring (five expanded surveys); 2) ongoing studies (19 studies); and 3) new studies (15 studies). None of the work will affect the mandated monitoring currently under performed by IEP. The initial cost estimate for 2006-2007 is approximately $3.709 million annually.

The program will be run by the existing IEP Project Work Team (Pelagic Organisms Decline – "POD PWT" to develop, direct, review and analyze the results of the effort. The program will yield a range of products and deliverables including management briefs, publications and reports, web-based monitoring data, and presentations at conferences, workshops and meetings.

Introduction

In the last several years, the abundance indices calculated by the Interagency Ecological Program (IEP) Fall Midwater Trawl survey (FMWT) and Summer Townet Survey (TNS) showed marked declines in numerous pelagic fishes in the upper San Francisco Estuary (the Delta and Suisun Bay) (IEP 2005a,b). The abundance indices for 2002-2004 include record lows for delta smelt and age-0 striped bass and near-record lows for longfin smelt and threadfin shad. In contrast, the San Francisco Bay Study did not show significant declines in its catches of marine/lower estuary species. Based on these findings, the problem appears to be limited to fish dependent on the upper estuary.

While several of these declining species - including longfin smelt and juvenile striped bass have shown evidence of long-term declines - there appears to have been a precipitous "step-change" to very low abundance by at least 2002-2004 (IEP 2005a,b). Moreover, the record or near-record low abundance levels are remarkable in that winter-spring river flows into the San Francisco Estuary were moderate during this period. Many estuarine organisms including longfin smelt and striped bass typically produce poor year classes in dry years (Jassby et al. 1995); delta smelt abundance is generally lowest in very wet or very dry years (Moyle et al. 1992). Thus, we expected the moderate hydrology during the past three years to support modest production.

In response to these changes, the IEP formed a Pelagic Organism Decline ("POD") work team to evaluate the potential causes. The product of this effort was a 2005 work plan, which provided an overview of the problem, a conceptual model, and description of a "screening level" study to examine some of the suspected major causal factors (IEP 2005a). Note that the 2005 work was not designed to "prove" which stressor(s) was responsible for the observed trends. Instead, this effort was intended to provide insight into the best lines of inquiry for the 2006-2007 studies. Highlights of the 2005 results included the following initial results. More details are available in IEP (2005b).

Pelagic fishes. 1) In 2005, the highest spring outflow conditions since 2000 failed to improve fish abundance; 2) there was no evidence of a recent decrease in the amount of "physical habitat" for delta smelt or juvenile striped bass; 3) there was no evidence of a recent major decline in apparent growth rates for delta smelt, longfin smelt, or striped bass; 4) in 1999 and 2004, delta smelt in Cache Slough had higher residual growth/condition than other locations; 5) striped bass age-fecundity relationships in 2005 did not differ substantially from relationships developed in the 1970s and 1980s; and 6) otolith analyses indicated that in 1999 delta smelt spawned throughout the upper estuary recruited to the adult population, whereas in 2004, only fish spawned in the Delta recruited.

Food web/exotic species. 1) Reanalysis of the zooplankton data revealed that there was no recent step-change in calanoid copepods; however, we are still determining whether regional e.g. Suisun Bay, declines occurred; 2) there has been no recent major decline in chlorophyll *a* (an index of phytoplankton biomass); however, we are still determining whether regional e.g. Suisun Bay, declines occurred; 3)the toxic blue-green alga *Microcystis* was present throughout the Delta at substantially higher levels in summer 2005 than in summer 2004; 4) although there has been a recent expansion in the range of the clam *Corbula*, recent occurrence is comparable to the 1987-

1992 drought; and 5) changes in sediment composition and benthic assemblages occurred estuary-wide in 1999-2000.

Toxics. 1) Studies on contaminants found that there have been changes in the patterns of use for herbicides and pyrethroid pesticides. It is plausible, but unclear if these changes pose serious risks for aquatic species; 2) significant acute or chronic toxicity to the amphipod, *Hyalella azteca*, was detected at four out of ten sampling sites, however the cause(s) was not identified; 3) no significant toxicity to the cladoceran, *Ceriodaphnia dubia*, the delta smelt or the juvenile striped bass was observed during the study period; 4) delta smelt are more sensitive to copper than previously reported and are 10-12 times more sensitive than juvenile striped bass; and 5) delta smelt from 2003 and 2005 (limited) showed more liver lesions at two locations representing general regions in Suisun Marsh (near and in Nurse Slough) and the Sacramento River at Cache Slough and the Sacramento Deepwater Ship Channel.

Water Project Operations. 1) There have been changes in the input flows to the Delta in recent years, including a slight increase in average Sacramento River flow since 2001 and a substantial reduction in peak San Joaquin flows since 1999. 2) There was no evidence of a recent major change in residence time, consistent with the lack of change in chlorophyll *a*. 3) Increases in the pattern of wintertime salvage are consistent with hydrodynamic changes occurring each winter since 2001. 4) Nonconsumptive water use by Contra Costa and Pittsburg power plants may reach 3200 cfs (both facilities combined). The fish population impacts of these diversions have not been evaluated since the early 1980s, but given their location and the potentially large cooling water flux through them, the impacts could be substantial.

Conceptual Model

Initial Conceptual Model

Based on the initial hypothesis that fish abundance declined abruptly by 2002, we developed an initial conceptual model (IEP 2005a). Specifically, we proposed at least three general factors that may have been acting individually or in concert to lower pelagic productivity: 1) toxic effects; 2) exotic species effects; and 3) water project effects (Figure 1). The conceptual model used these categories to illustrate the potential pathways by which pelagic species in the Delta could be affected (Figure 1). For each group of "boxes" shown in the model, one or more examples are provided in italics. The arrows represent the potential mechanisms for changes. Note that not all of the organisms shown in each box are necessarily responsible for each of the mechanisms. Some of the rationale for these components is described below.

Toxins could affect fishes directly or indirectly by reducing lower trophic level quantity or quality. Herbicides could directly affect phytoplankton, zooplankton and fishes, while insecticides are most likely to affect zooplankton and fish. Toxic effects at lower trophic levels may reduce food supply for fishes and/or their invertebrate prey. Blooms of the blue-green alga (cyanobacteria) *Microcystis aeruginosa* have been observed in the Delta since 1999 (Lehman and Waller 2003, Lehman et al. 2005). This species complex often produces toxic metabolites collectively known as microcystins. Microcystins are cancer-causing to humans and wildlife,

including fish (Carmichael 1995), and reduce feeding success in zooplankton (Rohrlack et al. 2005). Microcystins have been found in Delta zooplankton and clam tissue and could impact organisms at higher trophic levels through bioaccumulation (Lehman et al. 2005). The switch from organophosphate to pyrethroid pesticides increased substantially through the 1990s (see Oros and Werner report in Attachment A of 2005 POD Synthesis Report). Pyrethroid pesticides have been shown to be less harmful to humans and terrestrial wildlife but more harmful to aquatic organisms. The rising use of organic herbicides and copper-based compounds to control nuisance aquatic weeds and algal blooms in the Delta may also pose a threat to desirable aquatic organisms.

The negative effects of invasive exotic species in the estuary have been well-established. Some notable examples were the substantial declines in lower trophic level productivity that followed the introduction of *Corbula amurensis* (Nichols et al. 1990; Kimmerer and Orsi 1996; Jassby et al. 2002, Kimmerer submitted) and the reduced abundance of native nearshore fishes associated with proliferation of *Egeria densa* and centrarchid fishes along Delta shorelines (Brown and Michniuk in review; Nobriga et al. 2005). At this time, we have limited information about quantitative aspects of the estuarine food web needed to estimate *Corbula* grazing rates or predict whether nearshore and pelagic food webs are coupled in ways relevant to the production of pelagic fishes.

Kimmerer (2002a) showed that water project operations have resulted in lower winter/spring inflow and higher summer inflow to the Delta. As noted previously, the actions by the CALFED implementing agencies have restored some spring inflow, but have also increased summer inflows to meet increasing summer export demands. Winter exports have also increased by about 50% in recent years. These shifts were implemented based on the assumption that it would be more protective to sensitive early life stages of key estuarine fishes and invertebrates. However, it is possible that high export during summer-winter months has unanticipated food web effects by exporting biomass that would otherwise support the estuarine food web. Other possible mechanisms include increased entrainment of fishes during the summer-winter months, or a reduction in habitat quality downstream (e.g. less area of the appropriate salinity). Total annual exports have continued to increase. It is also possible that the total volume diverted on an annual basis influences estuarine productivity (Livingston et al. 1997, Jassby et al. 2002).

Delta Pelagic Species Conceptual Model

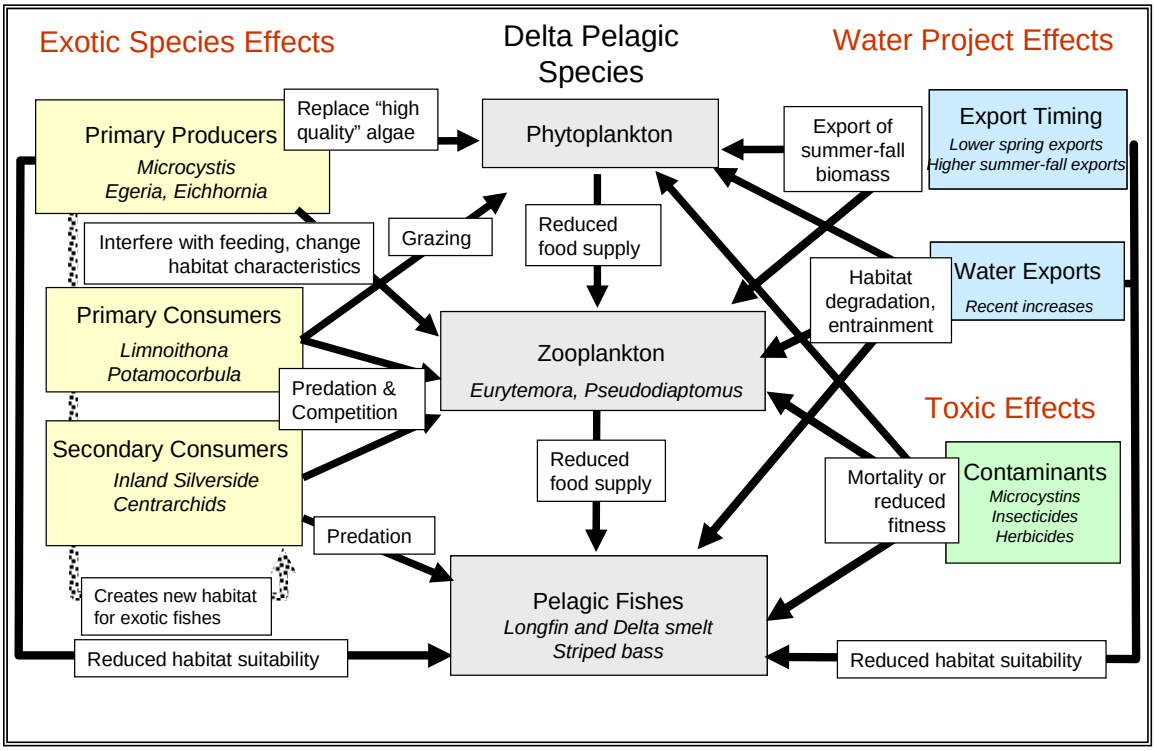


Figure 1. Delta pelagic species conceptual model

Revision of 2005 Conceptual Model

We had planned to use the initial conceptual model (Figure 1) as the basis of the synthesis. However, this conceptual model was based on earlier data showing a system-wide decline in calanoid copepods, which a re-examination of the data in 2005 did not support. Moreover, we found that the model did not adequately reflect spatial and temporal variation in the stressors on pelagic organisms. Initial results from 2005 also suggested that some stressors might act independently of the estuarine food-web that was central to our conceptual model. Though the model provided a useful basis to design the 2005 study program, we chose a somewhat different approach for the 2006-2007 effort.

The 2006-2007 models represent an improvement over the 2005 model, but it is important to recognize that there are still potentially numerous limitations (IEP 2005b). Much of the 2005 data is preliminary or unavailable at this writing and has not yet been peer-reviewed, so the new models should be considered equally preliminary. Moreover, we acknowledge that our models may have been influenced by potential biases in the sampling programs. Several changes in the size and distribution of the target species have the potential to change our perceptions of trends in abundances and distributions. This, in turn, has the potential to affect our conceptual models. Finally, it is important to recognize that the recent step decline in pelagic fish species is superimposed over long term declines for several of them and long term relationships of these fish with other environmental factors.

The major findings through 2005 were synthesized in two general ways (IEP 2005b). First, we developed species matrices to examine which stressors were most likely to be important based on the available data or which could not be ruled out because we had no data to base such a conclusion. Secondly, we constructed narrative explanations for the recent step decline in abundance of pelagic species in the context of their long term trends or previous patterns. Note that both types of models were specifically developed for the purposes of designing the work plan for 2006 and beyond—they were not intended to be the basis of setting resource management priorities.

Matrix Model for Species and Stressors: Matrix models were developed for the four target fish species (delta smelt, longfin smelt, threadfin shad and juvenile striped bass) to summarize the potential role of various stressors in the recent decline. The matrices depict our current consensus of whether or not each stressor impacted each species-life stage during 2002-2004, possibly influencing the decline. The level of information used to support our consensus is also ranked. Though we attempted to develop information on most of the stressors listed, there are numerous cases where data are unavailable or have not been analyzed. In such instances we indicate no information, but have an expectation that information will be available soon to refine the models. The stressors evaluated are listed below:

- Mismatch of larvae and food. This stressor focuses on the separation of larval fish and food items in time and geographical space. If young fish are not co-located with food, they will starve or have increased vulnerability to predation (Cushing 1990). For the purposes of the matrices, the stressor is considered to apply only to larvae—it is considered separate from fish that can swim strongly enough to search large areas to locate food.

- Reduced habitat space. Amount of open-water habitat as defined by physical and chemical parameters that limit the distribution of species.

- Adverse water movement/transport. Changes in Delta hydrodynamics that direct fish to unsuitable areas due to water project operations. Transport refers to movement of a life stage as influenced by Delta hydrodynamics which can be altered by water project operations (i.e. exports, gate operations, reservoir releases, barriers). Delta hydrodynamics affects transport through its effects on migratory cues, habitat quality or hydrologic resident times. This stressor specifically excludes entrainment, but may include thermal effects of power plant effluent.

- Entrainment. Mortality of pelagic fishes caused by loss to water diversions for exports, in-Delta uses, and power plant cooling.

- Toxic effects on fish. Acute and chronic effects sufficient to increase mortality and/or reduce fecundity of pelagic fishes.

- Toxic effects on fish food items. Acute and chronic effects sufficient to increase mortality and/or reduce fecundity of pelagic fish food items.

- Harmful *Microcystis* blooms. Acute and chronic effects of *Microcystis* sufficient to result in one or more of the following in pelagic fishes: increase mortality; reduce fecundity, reduced feeding; or habitat avoidance.

- *Corbula* effects on food availability. *Corbula* decreases phytoplankton and zooplankton, which is reflected in the production of larger zooplankton, invertebrates or fish especially in early lifestages.

- Disease and parasites. Disease or parasites that result in reduced survival or fecundity of pelagic fishes.

The species matrices are included as Figures 3-7. Annotations for the matrices are provided in Appendix A. Columns represent key times of the year, with reference to the corresponding life stages. The rows describe the relationships between life stages and the major stressors. Within each cell is an idealized "map" containing sub-cells to represent the major regions of the upper estuary (Figure 2). The various regions of the Delta have been described differently by different authors. For aquatic organisms, we believe the tidal nature of the estuary overrides many of the geographic features. Thus, in our discussion of the areas of the Delta, we intentionally use overlapping areas to better account for the fact that water frequently moves from area to area while still bearing in mind that the stressors and processes in different areas are different. This overlap is most pronounced in discussing "Suisun Bay" and the "Northern Delta" (i.e. the blue and green areas in Figure 2). Marine influences, including X2 position can have impacts up the axis of the estuary as far as Decker Island, while significant factors, such as sediment plumes from the Yolo Bypass are at times prominent downstream to at least Chipps Island. Similarly, the San Joaquin River is not representative of a single area's influences but rather the southern limit of Central Delta processes and the northern limit of South Delta processes. Therefore, we have included the San Joaquin River within both areas in our delimitation of the Delta. The actual areas of overlap may also be taken to represent the tidal excursions in each area, such that areas of overlap are much longer in the western regions than in the more upstream locales. Overall, we are concerned with identifying the areas where stressors and processes originate and less concerned with their exact locations of impact.

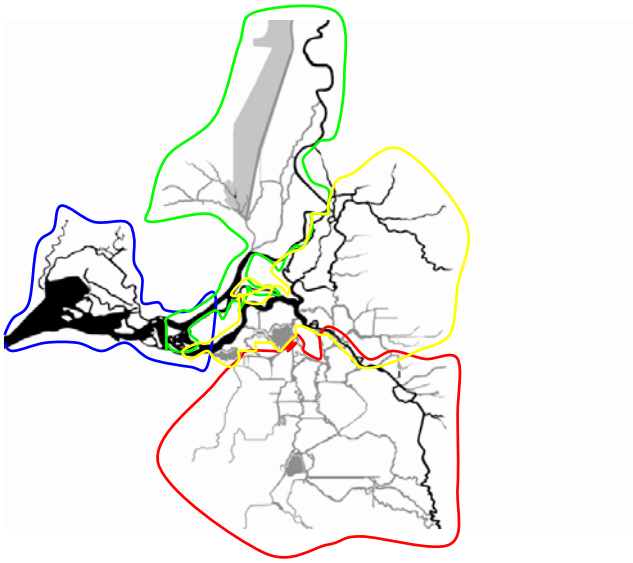


Figure 2. Map of the Delta to identify the regions specified in the matrix.

The geographic boundaries roughly correspond to: Suisun Bay (Suisun Bay, river confluence area downstream of Decker Island and Big Break); Central Delta (South of Rio Vista, North of Franks Tract): North Delta/Lower Sacramento River; South Delta/San Joaquin River (Franks Tract and south/east Delta). The symbols within the "map" are designed to reflect a binary potential for the impact of each stressor (described below) and the degree to which available data support our assertions. Additional details about the logic for each symbol are provided as annotations in Appendix B in 2005 POD Synthesis Report.

Impact

Plausible Impact = The factor (stressor) is likely to have a substantial influence on lifestage survival (*Large Symbol*).

No Likely Impact = The factor (stressor) is unlikely to have a substantial influence on lifestage survival (*Small Symbol*).

Information

Strong = Substantial information exists for directly addressing the stressor influence on the specific lifestage (*Dark Symbol*)

Limited = Either available information or current data analysis is too limited to support strong conclusions regarding stressor) influence on the specific lifestage (*Grey Symbol*).

None = Either information is not available, or no available data have been appropriately analyzed, to address stressor influence on the specific lifestage (*Clear Symbol*).

Figure 3. Legend for Matrix Models

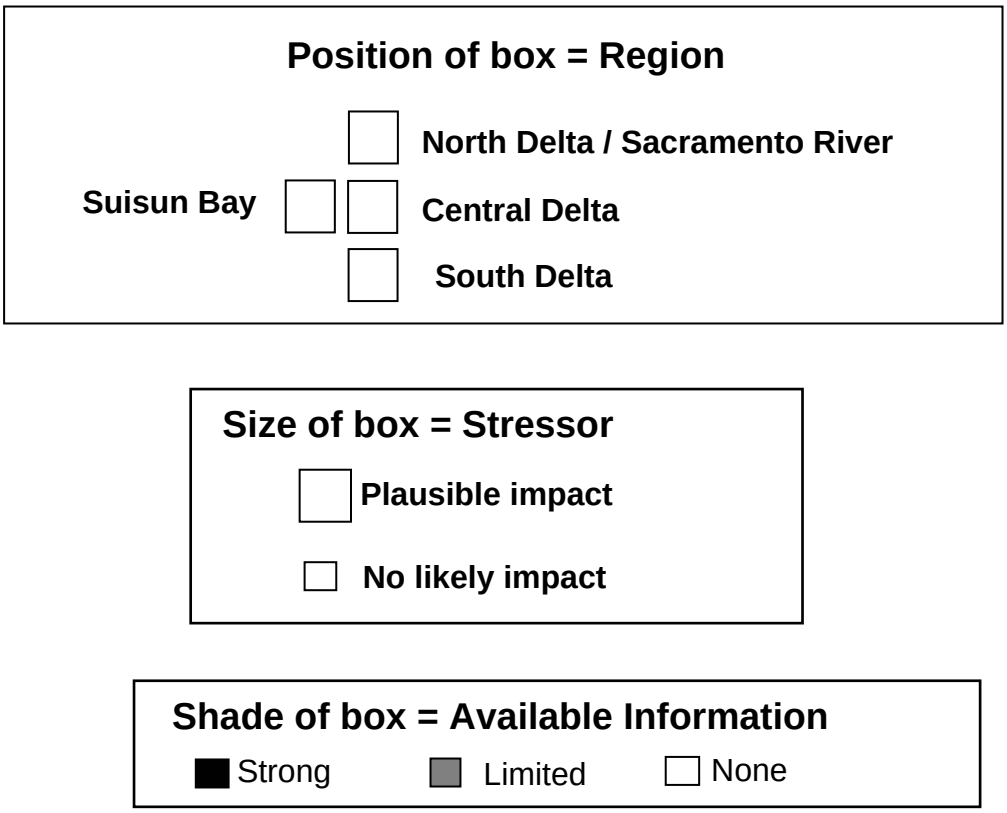


Figure 4. Longfin smelt matrix model

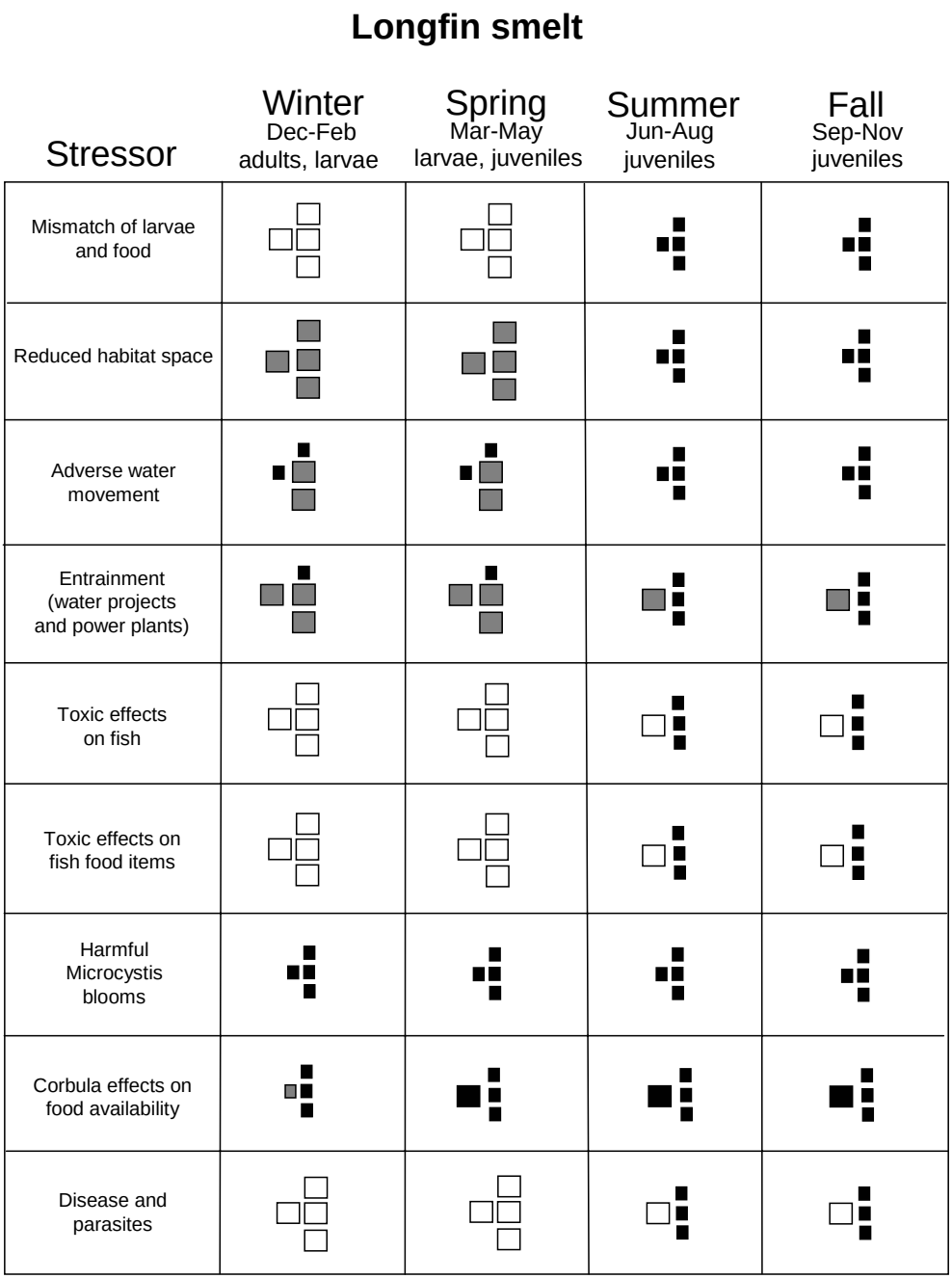


Figure 5. Threadfin Shad matrix model

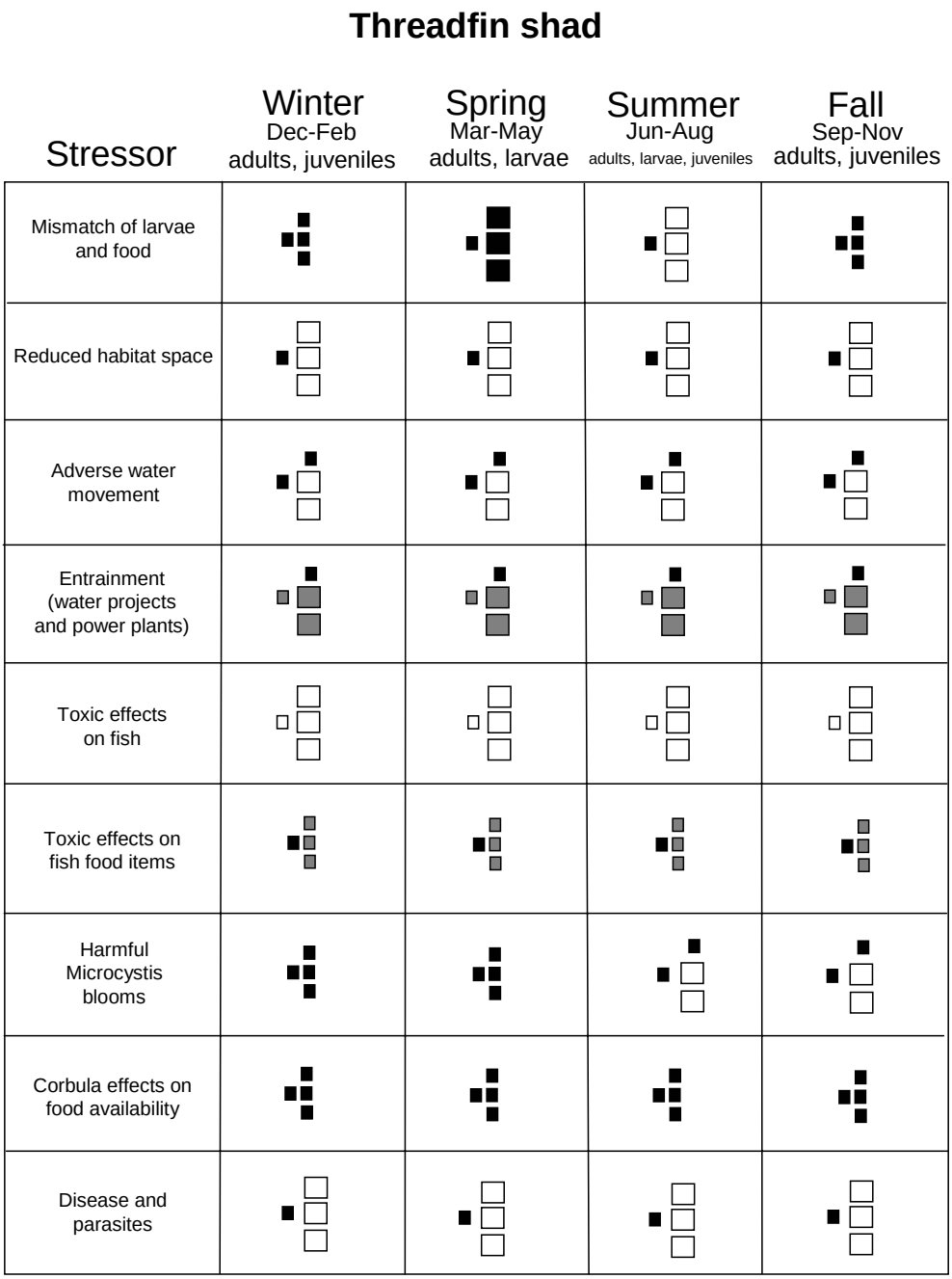


Figure 6. Striped Bass matrix model

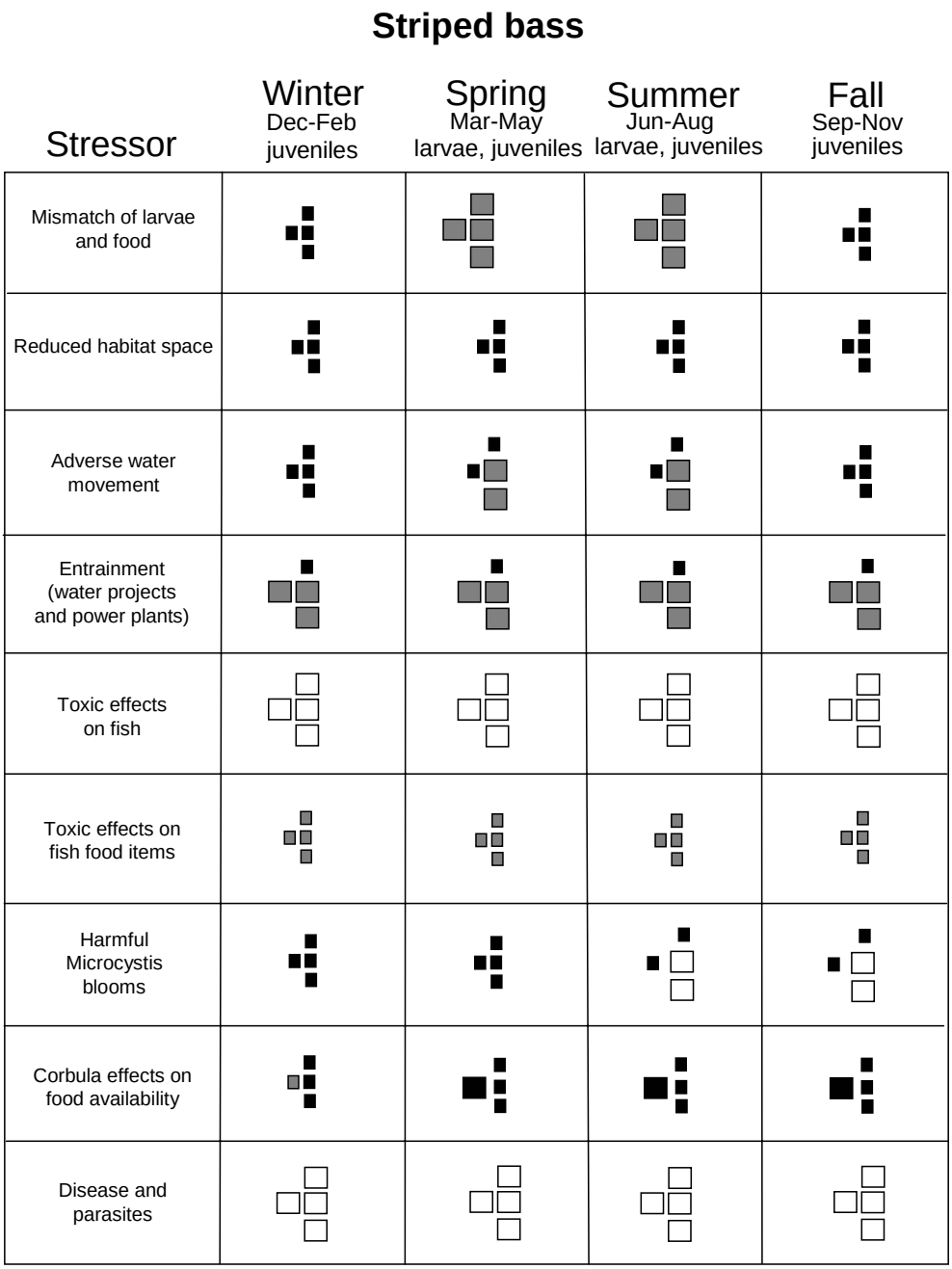
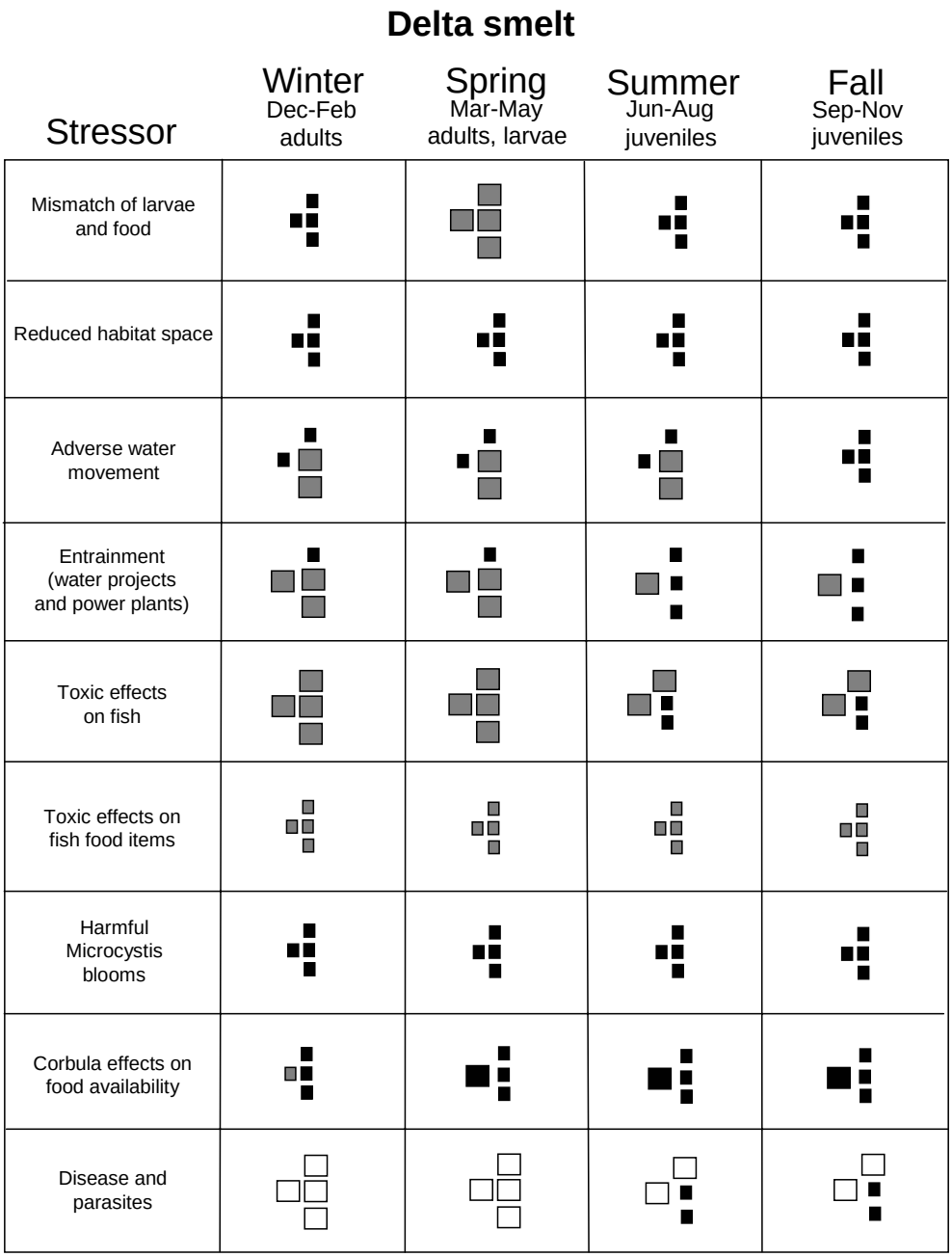


Figure 7. Delta Smelt matrix model



Example Narrative Models: Guided by available results, we developed two narratives to describe possible mechanisms by which recent changes in the ecosystem could produce the observed declines in catch of pelagic fish species. The first narrative describes changes in Suisun Bay that reduce its suitability as habitat for delta smelt, longfin smelt and young-of-year striped bass. Longer term trends suggest that the south Delta has previously become less suitable as habitat and therefore the loss of Suisun Bay habitat value produces a great reduction in the area of suitable rearing habitat. The second narrative describes sharply increased loss of adult delta smelt, longfin smelt and threadfin shad from the south Delta during the winter that negatively affects the stock size. These two narratives identify key elements that will be further analyzed in the 2006-2007 workplan.

Note that these narratives are not exclusive of other explanations for the observed changes in fish abundance, nor are they intended to suggest priorities for resource management. Instead, they were intended as examples of how the different stressors may be regionally linked. Note that neither of these narratives by itself explains the declines of all four species though both in tandem plausibly could. Additional narrative models will be developed as data become available. In the meantime, we believe that the two initial narrative models provide a useful basis for the development of more detailed hypotheses and studies for 2006-2007.

Suisun Bay/Marsh has historically been a major rearing habitat for striped bass, delta smelt and longfin smelt (Stevens and Miller 1983; Steven et al. 1985; Moyle et al. 1992; Matern et al. 2002). The marshes and other adjacent shallow habitats are also used by threadfin shad (Matern et al. 2002; Nobriga et al. 2005). Pelagic productivity was reduced and trophic linkages were altered in Suisun Bay coincident with the invasion of *Corbula amurensis* (Kimmerer and Orsi 1996; Feyrer et al. 2003; Kimmerer submitted manuscript). The ***Bad Suisun Hypothesis*** posits that particularly in drier years *Corbula* depresses zooplankton production in Suisun Bay, resulting in decreased availability of food for larval and juvenile striped bass, longfin smelt, and delta smelt. Evidence for the hypothesis includes the following. Additional details are provided in IEP (2005b).

1. *Corbula* abundance and distribution in 2001-2004 was higher than during the 1995-1999 wet period but similar to the 1987-1992 drought.
2. In 1999 and 2004, residual delta smelt growth was low from the Sacramento-San Joaquin confluence through Suisun Bay relative to other parts of the system.
3. In 2005, delta smelt collected from the Sacramento-San Joaquin confluence and Suisun Bay had high incidence of liver glycogen depletion.
4. In 2003 and 2004, striped bass condition factor decreased in a seaward direction from the delta to the bay.
5. Based on analysis of the summer townet survey and the fall midwater trawl, it does not appear that physical habitat suitability (based on available water quality data) has changed in recent years or has had a consistent long-term downward trend.
6. Suisun Bay ambient water bioassays in the summer of 2005 were not toxic to *Hyalella azteca*, *Ceriodaphnia*, juvenile striped bass, or delta smelt.
7. *Microcystis* biomass was low in the Suisun Bay region in the summer of 2004 and 2005.
8. Zooplankton abundance in the upper estuary has not changed substantially in recent years. However, we have not yet determined whether this conclusion applies to Suisun Bay.

These observations reveal that fishes in the Suisun Bay region show unusually poor growth rates, health and condition. Thus far, the weight of evidence suggests poor growth/condition is not attributable to the effects of toxic contaminants. Therefore, our working hypothesis is that the poor growth and condition are due to food limitation.

If fishes are food limited in Suisun Bay during larval and/or juvenile development, then we would expect greater cumulative predation mortality, higher disease incidence, and consequently poorer abundance indices at later times. Slower growth rates might also distort trawl abundance indices if large numbers of fish do not grow large enough to be sampled efficiently by annual surveys.

Dramatic increases in winter CVP and SWP salvage occurred contemporaneously with recent declines in several pelagic fish species. These unexpected increases in salvage density coincide with the step decline of pelagic fishes in 2002. The ***Winter Adult Entrainment Hypothesis*** posits that these events are causally linked. Evidence for the hypothesis includes the following. Additional details are available in IEP (2005b).

(1) There appears to have been a step increase in salvage density of adult delta smelt, threadfin shad and longfin smelt between 2001 and 2002. This increase is consistent with recent-year changes in winter water export operations.
(2) There appears to have been a step decrease in the Fall Midwater Trawl indices of adult delta smelt, threadfin shad, and longfin smelt between 2001 and 2002.
(3) Winter exports from the CVP and SWP have increased since the late 1990s.
(4) Winter export:inflow ratios have increased since 2000.

Increased winter entrainment of delta smelt, longfin smelt and threadfin shad represents a loss of the pre-spawning adults and all potential progeny. This means on a per capita basis loss of each adult fish may be equivalent to the loss of hundreds or even thousands of juveniles later in the year. Entrainment impact specifically affecting adult fishes has the potential to be strong, so we regard finding an explanation for this coincidence a high priority.

The main explanations for why winter salvage densities may have increased since 2002 include: (1) the source of exported water has been changed to an area where more of these fishes occur during the winter; (2) the affected fishes have moved to areas from which exports are drawn; and/or 3) winter exports have increased past a hydrodynamic threshold below which fish were better able to avoid entrainment.

We have only just begun to examine the data on wintertime salvage, but they reveal a consistent pattern across species that corresponds with the period of fish declines. Three main areas of explanation must all be considered. Are there operational changes that produce an apparent increase in salvage? Are there changes in the health of fish that make more of the population susceptible to entrainment? Are there changes in water movement or water quality that could produce higher densities of fish in the south Delta? Some of these factors can be rapidly assessed with data already in hand or that can be gathered in the coming months. Assessing the population impacts will be a difficult task since reliable numbers for the number of fish entrained

or in the source population are available. If it can be shown that a large part of the field sampled populations are within the range of entrainment that is probably the most compelling argument for a population level impact of entrainment.

Study Approach

The overall approach recommended by the POD PWT in 2005 was a "triage" model to better define the degree to which toxics, exotic species and water project operations may be responsible individually, in sequence, or in concert for the apparent long-term fish abundance declines and step-changes. Based on the work in 2005 and on previous information, the following represents the proposed approach for 2006-2007. A key difference is that the work is based on entirely different conceptual models (see previous section). In addition, we have developed a more integrated strategy to evaluate contaminant effects, an issue that has not been evaluated extensively by IEP or the 2005 POD effort.

Approach to Address Matrix Models

Many of the studies described in the next section are designed to address questions arising from the matrix models. Much of the rationale for the study design is based on *temporal*, *spatial* and *species* contrasts for selected fish and zooplankton. For each contrast, the variables to be evaluated include: abundance, growth rate and fecundity; and feeding success, condition factor, parasite load and histopathology (fish only).

Temporal Contrasts. Temporal contrasts will be made seasonally and interannually. Analyses of monitoring data and additional samples will identify if there are specific times of the year in which stressors are most pronounced. To the extent possible, these results will be contrasted with historical data or samples to determine if current observations are consistent with earlier years. For example, the hydrology in 2005 provided an excellent opportunity for a "natural experiment"—flow conditions were consistently high throughout the spring, which typically results in good abundance levels for many pelagic species (Jassby et al. 1995). Kimmerer (2002b) updated analyses that suggest these relationships have remained reasonably consistent through 2000, despite the invasion of the clam *Corbula*. As noted previously, pelagic fishes did not increase substantially in 2005, so we have more confidence that the apparent step change is real.

Working Hypotheses for 2006-2007:

- The response of pelagic species to flow will continue to deviate from relationships with abundance developed prior to the recent step change.
- Stressor effects have increased relative to historical data.

Spatial Contrasts: Monitoring data and new samples will be thoroughly evaluated to determine whether there is a specific region(s) of the estuary where stressor effects are strongest and to the extent possible, whether regional effects have changed in recent years. For example, one of the key spatial contrasts is whether fish and zooplankton show similar responses (e.g. growth, survival, fecundity, toxicological indicators) in the Delta and Napa River because some key

stressors (*Microcystis*, waterweed treatment compounds) appear to be largely absent from the latter.

Working Hypotheses for 2006-2007:

- Pelagic species will show the strongest responses to stressors in specific regions of the estuary.
- Stressor effects have increased in specific regions of the estuary relative to historical data.

Species Contrasts: Fish species (delta smelt, striped bass, longfin smelt, threadfin shad and inland silverside) will be the focus of the 2006-2007 effort. These species were selected because they form convenient contrasts: The first four are declining in abundance – striped bass and longfin smelt over the long-term, delta smelt and threadfin shad more recently, while the last is increasing. Our rationale is that contrasts among these species will help to clarify the relative importance of different stressors.

Working Hypotheses for 2006-2007:

- The more recent invaders (inland silverside) will show less response to stressors.
- Nearshore fishes (e.g. inland silverside) will show less response to stressors.

Approach to Address Narrative Models

The matrix models highlight the stressors in each season and each geographical area that might affect each species. Work based on the matrix models ask fundamentally qualitative questions; is the stressor likely to have an effect? The narrative models, on the other hand, posit linkages among different stressors and their possible pathways to produce the observed declines of more than one species. The workplan elements that are based on the narrative models, therefore, emphasize analyses of the proposed linkages among stressors. Questions addressed by the narrative models are much more quantitative; to what degree do these stressors affect the species of concern? Eventually, we intend to have models that link each species life history with the impacts of various stressors.

Bad Suisun Bay Hypothesis: Based on the narrative model, studies that would improve our understanding of the role of food availability in Suisun Bay include:

(1) continuing studies cited above that are underway but not yet completed;
(2) expanding fish gut content analyses to enable regional comparisons of diet, ration, and prey selectivity;
(3) expanding toxicity testing of standard and native species to enable comparisons that may reveal whether we have missed exposures of Suisun Bay fishes to toxins in other seasons or places (i.e., the exposure occurs in another region before the fish move into Suisun Bay); and
(4) repetition of histopathological analyses to expansion of the investigation to all POD target species.

Winter Entrainment Hypothesis: To further develop our understanding of the role of winter adult entrainment, the 2006-2007 workplan includes the following:

(1) a model-based investigation of Delta hydrodynamics that compares Delta-circulation patterns under conditions that existed before 2002 to conditions after 2001, to see whether any differences in circulation pattern support fish redistribution hypotheses.
(2) a model-based investigation of changes in the size and disposition of the entrainment zone under conditions that existed before 2002 to conditions after 2001 to see whether large differences exist or whether there is any reason to believe threshold effects exist in the extent or location of the zone of entrainment zone.
(3) a statistical investigation of larval and juvenile abundance to see whether there is a stock-recruit effect specifically attributable to high adult salvage. There are enough concerns about the strength of the larval and juvenile monitoring programs (for this purpose) that we do not believe the absence of a measurable effect would weaken this hypothesis. However, actually affirmative or contradictory evidence from the larval and juvenile monitoring would indeed strengthen or weaken this hypothesis.
(4) are there changes in the health of fish or water quality that make more of the population susceptible to entrainment?

Some of these factors can be rapidly assessed with data already in hand or that can be gathered in the coming months. Assessing the population impacts will be a difficult task since reliable numbers for the number of fish entrained or in the source population are available. If it can be shown that a large part of the field sampled population are within the range of entrainment, there would likely be a compelling argument for a population level impact.

Approach to Address Toxic Effects

The 2005 findings did not clearly support or eliminate contaminants as a possible significant cause or additive stressor in the POD. The toxicity work in 2005 was limited due to spatial and temporal restrictions on the sampling and analyses. The focus on pyrethroids and aquatic herbicides investigations was based on the overall hypothesis of a step decline coinciding with a major change in contaminant loading due to a change in land use coinciding with the decline. Research into these two areas was in the form of white papers, and did not include field level work. Though aquatic toxicity to *Hyalella* was observed in the Delta in 2005, there was little evidence from the review of aquatic herbicide application data indicating this is a source of toxicity.

Due to the relative lack of information about contaminant effects, we did not attempt to develop a narrative model specific to this issue. Nonetheless, we recognized the need to develop an integrated strategy to make the best use of the available resources for contaminant studies. To summarize briefly, the approach for 2006-2007 is to expand the toxicology testing to additional sites over a greater period of time. Toxicity tests will be run on *Hyalella*, since this organism has established TIE procedures. Delta smelt and striped bass will be tested with water samples from some of the sites: if toxicity is observed, analyses will advance to TIE procedures to try and isolate the compound. Fish exhibiting toxicity will be submitted for histopathology to be compared with hatchery fish to characterize organ effects. These results will provide a useful

comparison with field and archived fish samples that would be analyzed for histopathology. Additional information about potential toxic effects will be gleaned from histopathological analyses of recent and archived fish samples collected from the field. Biomarkers may also be used to help identify specific causes, although more work is needed to identify the most appropriate assays. Moreover, related studies on trends in contaminant use and *Microcystis* bloom location and toxicity will help to illuminate the mechanisms responsible for observed effects.

The components of the contaminant approach are discussed below, with additional detail in the Study Components section. The relationships among these components are shown below in Figure 8.

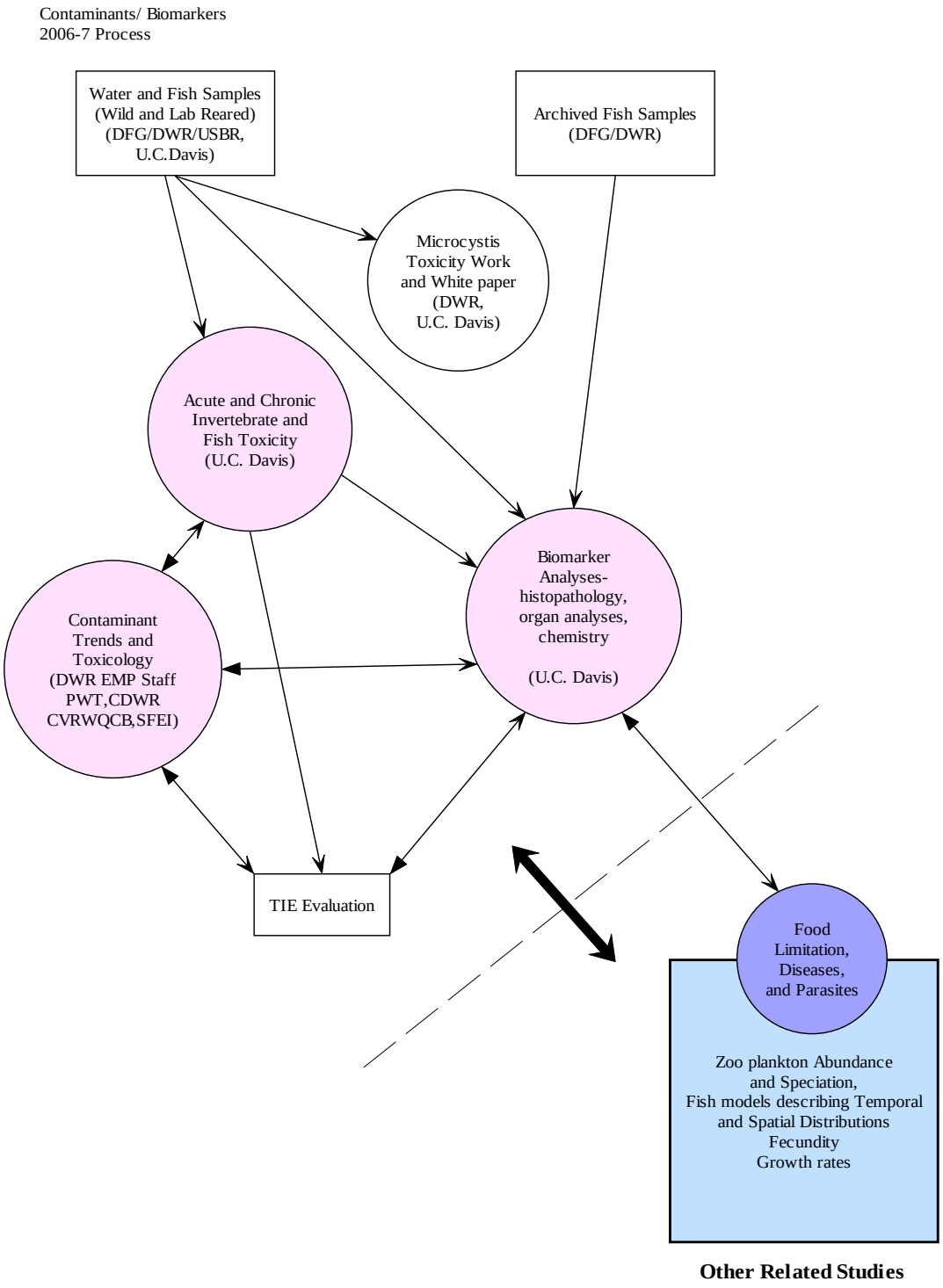


Figure 8. Relationship between components of the POD contaminant investigations.

Water and Fish Samples: Work in 2006-07 will consist of a spatially and temporally expanded sampling for toxicity testing program. Spatial distribution of Delta sampling sites will follow the 2005 pilot program, and additional sites will be sampled in accordance with the prevalent distribution patterns of fish species of concern. A subset of these samples will also be used for *Microcystis* studies. Additional analyses will be conducted using archived samples of fish held by DFG (delta smelt) and UCD (striped bass).

Acute and Chronic Invertebrate and Fish Toxicity Tests/TIE Process: As noted above, the 2006-2007 toxicity work includes a substantial expansion of the 2005 effort. The indigenous amphipod species, *Hyalella azteca*, will be used for routine toxicity testing throughout the year. This species is resident in the Delta, sensitive to contaminants, and routinely used in toxicity testing programs throughout the Nation. Moreover, it can be used to identify the causative agents of toxicity through Toxicity Identification Evaluation (TIE) procedures. If toxicity is observed at a site through initial screening, TIEs will be initiated immediately. Adequate quantities of water will be collected to proceed with TIEs in case toxicity is observed.

Two fish species of concern, delta smelt and striped bass, will be used to test water samples from selected Delta sites, from larval to juvenile stages during periods when the respective life stages are rearing in the Delta. Fish from these tests will be preserved for biomarker and histopathological analyses. These laboratory tests will identify sites that are acutely toxic to larval/juvenile stages of delta smelt and striped bass, and help differentiate the effects of toxic contaminants from the effects of food depletion (fish will be fed during the laboratory trials), and natural stressors such as water temperature and/or oxygen depletion (laboratory tests are performed at constant temperature and water is oxygenated).

Contaminant Trends and Toxicology: Information will be gathered on land use (e.g. PUR) to ascertain the potential class of toxicant(s) that could potentially be present at the sampling sites. The work will include temporal and spatial analyses of contaminant transport, fate, and toxicity. The information will be used in the toxicity and biomarker research to help aid identification of potential suspects as well as location and timing of possible toxicological effects.

Histopathology/ Biomarkers: Histopathological analysis of fish tissues can identify a variety of tissue lesions resulting from exposure to environmental stressors such as contaminants, disease and food limitation. Histopathological lesions often manifest themselves over longer periods of time, and therefore integrate the effects of multiple stressors. It is a useful tool to identify affected organs and can help identify certain groups of contaminants with known mechanism of action (e.g. carcinogens, endocrine disruptors) and target organs (e.g. liver, gonads). Histopathologic studies therefore play an important role in directing and focusing special studies.

Work in 2006-07 will focus on the examination of fish exposed to water samples or collected from sites where: 1) 2005 results indicated that fish were affected by environmental stressors; 2) where invertebrate toxicity tests indicate the presence of toxic compounds. Lesions in fish from laboratory studies should be compared to lesions observed in fish from field sites, but keeping in mind that actual exposure duration may differ between laboratory-exposed and field-collected

fish. Additionally, wild fish may be exposed to natural stressors (water temperature, oxygen levels, and food depletion).

Additional analyses may be conducted with biomarkers, the molecular, biochemical, physiological and histological changes inside an organism which are indicative of exposure to and/or the effects of environmental stressors. For the POD program, it is important to identify and apply biomarkers that can be applied to the fish species of concern, and help differentiate and quantify stressor groups. Not all biomarkers that are presently being explored in research labs fulfill these requirements, and careful consideration should be given to a workplan for future POD work involving biomarkers. A "Fish Biomarker Task Force" consisting of experts in this field could provide state-of-the-art information on biomarkers. This task force should examine and describe 1) available biomarkers according to a number of criteria including specificity and cost; 2) identify which biomarkers are applicable to Delta fish species of concern and what information they can provide; 3) identify research objectives and timelines for developing specific biomarker tools for Delta fish species of concern.

Microcystis aeruginosa Bloom Biomass and Toxicity: Field surveys will be conducted to measure *Microcystis aeruginosa* bloom biomass and toxicity. The 2006 surveys will build on the 2004-2005 survey and be closely coordinated with the fish surveys (Summer Townet Survey and Fall Midwater Trawl) and toxicity assays. Sample collection at fish survey stations will help elucidate the link between *Microcystis* biomass and toxicity and its direct effect on zooplankton and fish. Zooplankton, benthos, and fish toxicity will be evaluated based on microcystin content in whole animal (zooplankton and benthic) or liver and muscle tissue (fish). Animals for these analyses will be collected during fish surveys.

Study Components

Linkages among workplan elements: All workplan elements relate to the narrative and matrix models. Identifying these linkages ensures that all stressors are pursued; linkages among stressors and studies are identified and should help in future syntheses of the POD results. The following table allows easy identification of the justification for each workplan element

Table 1. Relationships among POD workplan elements and narratives.

1. Expanded Monitoring			Narrative model	Matrix model link	
IEP #	**POD #**	**Title**	connection	Main stressors	Minor stressors
2006-096	1a	Larval Fishes Survey	Suisun	1,3,4,5,9	
2006-007	1b	Summer Townet Survey	Suisun	1-9	
2006-003	1c	Fall Midwater Trawl	Both	1-9	
2006-072	1d	Environmental Monitoring program	Suisun	1,2	6,7,8
2006-089	1e	Other sample collection efforts	Both	5-7,9	

2. On-going work

IEP #	POD #	Title			
2006-084	2a	Analysis of historical population dynamics	Both	1-9	
2006-051	2b	Apparent growth rates of pelagic fishes	Suisun	1	2,4-9
2006-060	2c	Evaluation of delta smelt otoliths	Both	1	2,4-9
2006-061	2d	Pelagic fish liver histopathology	Both	5,9	1,4,6-8
2006-062	2e	Fish diet and condition	Both	1	2,4-9
2006-063	2f	Acute and chronic invertebrate and fish toxicity tests	Suisun	5,6,7	2,9
2006-079	2g	Field survey of Microcystis bloom biomass and toxicity		7	2,5,6,9
2006-010	2h	Trends in contaminants	Both	5,6	2
2006-042	2i	Striped bass health investigations	Suisun	5,6,9	
2006-045	2j	Phytoplankton primary production and biomass	Suisun	1,8	3,6,7
2006-066	2k	Evaluation of changes in pelagic fish habitat quality	Suisun	2	1,7,8
2006-031	2l	Delta and Suisun Bay particle tracking investigations	Both	3,4	1
2006-087	2m	Investigation of power plant impacts	Suisun	4	
2006-015,016,017	2n	South Delta fisheries and hydrodynamic studies	Salvage	3,4	
2006-065	2o	Trends in benthic macrofauna abundance and biomass	Suisun	8	1,2
2006-078	2p	Retrospective analysis of long-term benthic data	Suisun	8	1,2
2006-064	2q	Striped bass and delta smelt fecundity estimates	Suisun	1,4,5,8,9	
2006-068	2r	Delta water operations	Both	2,3,4	8

3. New work

IEP #	POD #	Title			
2006-080	3a	Winter salvage studies	Salvage	2,3,4	
2006-047	3b	Bad Suisun Bay studies	Suisun	1,2,8	9
2006-086	3c	Gear Efficiency Studies	Both	1-9	
2006-043	3d	Estimation of pelagic fish population sizes	Both	1-9	
2006-039	3e	Analysis of threadfin shad data - population dynamics	Salvage	1-5,7,9	
2006-076	3f	Corbula salinity tolerance	Suisun	8	1,2
2006-046	3g	Synthetic analysis	Both	1-9	
2006-041	3h	Modeling delta smelt populations in the S.F. Estuary	Both	1-9	
2006-038	3i	Development of striped bass and longfin smelt models	Both	1-9	
2006-018	3j	Striped bass disease and contaminant loads	Both	5,9	1,6,7,8
2006-037	3l	Update striped bass egg supply estimates	Both	1-9	
2006-044	3n	Zooplankton fecundity and population structure	Suisun	1,2,6	6,7,8
2006-082	3o	Food web support for delta smelt and other estuarine fishes	Suisun	1,8	2,4,5,6,7
2006-078	3q	CASCadE	Suisun	2	3,4,8

Stressor number and Stressor	
1	Food-fish mismatch
2	Habitat space
3	Adverse water movement
4	Entrainment
5	Toxic effects on fish
6	Toxic effects on fish food
7	Harmful algae
8	Corbula
9	Disease

Expanded Monitoring

Expanded monitoring in 2006-2007 emphasizes gathering life-stage specific information on the target fish species, but effort will also include expanded collection of introduced jellyfish and a newly introduce shrimp, *Exopalaemon modestus* and updated distribution and abundance analyses. Jellyfish in the San Francisco Estuary are know to feed on copepods and rarely larval fish, and anecdotal evidence suggest that introduced species have recently increased in abundance in the upper estuary (Rees and Kitting 2002). The distribution and seasonal abundance of jellyfish has been investigated (Rees and Kitting 2002, Moreno 2003), but until recently data for trend analyses has been absent. Starting in the early 2000s the San Francisco Bay Study and the Fall Midwater Trawl Survey began identifying and counting jellyfish (Honey et al. in prep). These data will be summarized and additional collections started (see Summer Townet Survey below) to investigate whether jellyfish might be a factor in the pelagic fish decline. The freshwater shrimp, *Exopalaemon modestus*, has dramatically increased in abundance since it was first documented in the estuary in 2000 (Brown and Hieb in prep). Based on the diet of a similar species (Sitts 1978, Siegfried 1982), this shrimp could affect abundance of mysids, amphipods and copepods within its range. We plan to update and expand abundance and distribution information summarized in Brown and Hieb (in prep). Additional revisions are summarized by elements below.

I. Expanded Monitoring

1a. Larval Fish Survey

IEP 2006-096
Lead Agency: DFG
What: This survey compares catches of delta smelt larvae and those of other species between surface-towed nets and nets retrieved in the traditional oblique manner (IEP 1987; Rockriver 2004, Dege and Brown 2004) to determine if surface catch is sufficient to effectively document species distribution. Two field seasons of data collection (2005-2006) were planned as the basis for evaluating the surface oriented nets. If surface-oriented larva tows prove sufficient (they may not, see Rockriver 2004), then concurrent larva and 20mm Survey sampling could take place to simultaneously target larva and post-larva to small juveniles. The alternatives of conducting two

oblique tows in succession or two separate surveys for larva and 20mm fish are not feasible with current staff and boats. In 2005, larva sampling took place at 19 of the 41 locations historically sampled by the 20mm Survey (all within the Delta proper) from February through early March using surface and oblique towed nets, and from late March through June for surface nets and the larger-mesh 20mm Survey nets towed obliquely. Catch of delta smelt in the larva nets was low (n = 209 fish) for the survey; 206 larvae came from surface tows after mid-March. Completion of data analysis is planned for fall 2006, after the upcoming field season. In 2006, sampling will begin in January to facilitate capture of larval longfin smelt, will include collection of zooplankton samples and will cover the 41 20mm Survey stations plus three additional locations in the main channel of central and eastern San Pablo Bay.
Questions: Can the distribution of larval delta smelt be effectively determined using surface-oriented plankton nets when compared to catches from traditional ichthyoplankton gear and methods? If current surface gear proves effective for larval delta smelt, what are the trends in relative abundance and distribution of smelt and other surface-orientated larva? How are their distribution, condition, and diets related to zooplankton abundance and environmental factors? Can these data be used to investigate growth and mortality?
When: Every other week from January through early July.
Cost: The 2005 pilot program was budgeted at $142,000. The expansion in 2006 will cost an additional $100,000 and will use existing and new staff and resources.
Comments: The 2005 survey replaced the North Bay Aqueduct monitoring as required by the USFWS 2005 OCAP Biological Opinion for delta smelt. The delta smelt workgroup designed this survey as a two year trial. Protocol and methods developed in 2005 will be used in 2006. If the surface tow method does not produce the desired result, it is likely the USFWS will ask the Delta Smelt Workgroup to modify the sampling design for 2007.
Feasibility: High. The gear was successfully deployed and caught larval delta smelt in 2005, and the methods didn't adversely extend the field work. It remains to be determined whether surface catches can approximate overall distribution.

1b. Summer Townet Survey
IEP 2006-007
Lead Agency: DFG
What: The Summer Townet Survey (TNS) has collected juvenile fishes in the range of 20 to 50mm since 1959 (Turner and Chadwick 1972). Samples are collected using a conical net with a 1.5 m^2 mouth and 12.7-mm (½ in.) stretched mesh nylon lashed to a hoop frame and mounted on skis. Three, 10-minute oblique tows are made against the current at each of 32 stations located from eastern San Pablo Bay to Rio Vista on the Sacramento River and Stockton on the San Joaquin River. This survey was expanded in 2005 to include simultaneous zooplankton sample from each station, and, at a subset of 10 stations, water collections for invertebrate toxicity tests (Werner, 2005 3e) at a subset of 10 stations, and a water quality profile at every station. The water quality profile will be conducted with an YSI 6600 Sonde that collects temperature, depth, dissolved oxygen, turbidity, chlorophyll *a*, conductivity, salinity, pH, date and time. Also, delta smelt and striped bass heads and bodies were preserved separately for otolith and histopathological analyses, respectively (Bennett 2005 3a and Teh 2005 3b) or were preserved for diet and condition analyses (Gartz and Slater 2005 3c). In 2006, sampling will continue as described above, except that water collections will employ a separate boat and crew; longfin

smelt and threadfin shad will be collected along with delta smelt and striped bass for diet and condition; and begin numeric and volumetric estimation of jellyfish abundance will begin.
Questions: What is the relative abundance (via abundance index) of striped bass and delta smelt? Can these data be used to estimate apparent mortality? How are juvenile striped bass and delta smelt distributed in relation to potential food items? Is the density of food items related to fish condition, growth rate or health indices?
When: Sampling is conducted every other week beginning the first or second week of June and continuing through the third or fourth week of August. Six surveys are completed every year, and each survey takes about one week to complete.
Cost: The existing IEP TNS budget is $225,000. The additional zooplankton samples add $65,000 ($50,000 for an additional ½ PY of senior laboratory assistant; $15,000 field costs).
Comments: The TNS collected delta smelt and striped bass for otolith and histopathology investigations, but did not collect sufficient numbers of either to support those projects in 2005, so additional field collections were necessary. A similar circumstance is expected for 2006 and 2007. TNS catch data are used to calculate the striped bass 38.1 mm index (Turner and Chadwick 1972) and an annual abundance index for juvenile delta smelt (Moyle et al. 1992). This survey is part of the long-term monitoring carried out by IEP and is mandated in the OCAP Biological Opinion for delta smelt.
Feasibility: High. The proposed sampling was successfully completed in 2005, and water collection has been removed.

1c. Fall Midwater Trawl (FMWT)
IEP 2006-003
Lead Agency: DFG
What: This survey targets age-0 striped bass and other pelagic species 30-150 mm in length using a midwater trawl towed through the water column for 12 minutes in a stepped oblique manner (Stevens and Miller 1983). There are 116 stations located from San Pablo Bay upstream through Suisun Marsh and Bay and into the Delta. In September 2005 only, tasks added to the survey included water profile measurements and a zooplankton tow at 32 selected sites, and for a subset of 10 sites water was collected for invertebrate toxicity tests (Werner, 2005 3e). Delta smelt and striped bass heads and bodies were preserved separately for otolith and histopathological analyses, respectively (Bennett 2005 3a and Teh 2005 3b) or fish were preserved intact for diet and condition analyses (Gartz and Slater 2005 3c). In 2006, sampling will continue as described above, except that zooplankton sampling will be discontinued, water collections will employ a separate boat and crew, and longfin smelt will be collected for diet and condition. Also trends in distribution and abundance of jellyfish will be examined for data collected since 2001.
Questions: What is the relative abundance (via abundance index) of striped bass, delta smelt and other pelagic fishes of the upper estuary? Can these data be used to estimate apparent mortality?
When: Collections are made monthly from September through December and take the first two weeks of each month to complete.
Cost: The existing IEP FMWT budget is $311,000 for staff and resources. With an additional $65,000 needed for additional field and laboratory work ($50,000 for an additional ½ PY of senior laboratory assistant; $15,000 equipment and fuel costs).
Comments: The FMWT Survey collected delta smelt and striped bass for otolith and histopathology investigation, but did not collected sufficient numbers of either to support the

projects in 2005, so additional field collections were necessary. A similar circumstance is expected for 2006 and 2007. This survey currently reports annual abundance indices for 6 fishes. The ratio of same-year Fall Midwater Trawl to Summer Townet Survey indices for age-0 striped bass is used as an index of summer survival (Stevens et al. 1985).
Feasibility: High. The proposed sampling was completed in 2005 with additional tasks.

1d. Environmental Monitoring Program
IEP 2006-072
Lead Agencies: DWR and DFG.
What: As part of this program, water quality, chlorophyll a, benthos and three types of zooplankton samples are taken monthly at up to 21 locations distributed from eastern San Pablo Bay upstream into the Sacramento and San Joaquin rivers. Since 1972, microzooplankton samples have been collected by lowering a 15 L/min pump from the surface to the bottom and back to the surface two times, capturing the discharged water in a large carboy and taking a 1.9 L subsample of this mixture preserved with formalin to examine completely for zooplankton. The accuracy and precision of resulting density estimates has been questioned, so a study commenced in fall 2005 to compare traditional methods and gear with 1) examination of a larger sample volume collected with the same pump and 2) examination of a much larger sample volume collected using a higher capacity pump. In the latter two cases, sub-sampling methods will be used, which were not necessary with the low volumes of traditional sampling. The 3-types of pump samples will be collected and examined from each sampling location monthly through at least June 2006. Initially, only a fall and spring subset of samples will be examined to identify the optimal gear and method and additional samples archived. If analyses indicate increased volume or the new pump substantially improves accuracy and precision, then the program will adopt the new method or pump and 2006 samples collected in the selected manner will be completely examined.
Questions: How well is abundance (density) estimated by each of the methods for common and uncommon taxa? What can be inferred about the effectiveness of historical methods and data from these results? Can microzooplankton data be used to estimate mortality rates and construct a vertical life table? What changes in protocol are recommended for the future long-term monitoring?
When: Sampling will be conducted monthly for about one year. It does not appear that the extra sampling will adversely extend what has been a week-long survey.
Cost: $50,000 for additional field, laboratory and analytical costs.
Comments: Some laboratory methods and whether samples need to be taken monthly for a year is still subject to change. Recommendations for changes in sampling derived from this investigation will likely be incorporated into Program protocol.
Feasibility: High. A couple months of field sampling has been successfully completed for all three sample types and initial organism densities suggest that larger sample volumes will provide necessary improvements in accuracy and precision.

1e. Other focused sample collections
IEP 2006-089
Lead Agencies: DFG and DWR
What: Focused, short-term field collections. In 2005 focused collections were used to increase the number of delta smelt and striped bass available for otolith analyses and histopathology, and

to collect inland silversides for diet and condition. Focused collections were also used to gather water for fish toxicity tests. In 2006, focused collections will be used to collect water for both invertebrate and fish toxicity tests (see 2006-063) and they may be used for some gear efficiency tests, if time permits. As staff and boat time permits, focused sampling will continue to be used to enhance collection of target fishes.
When: As needed and when staff and boats are available. For water collections, sampling will take a couple weeks per month.
Cost: $160,000 has been allocated to this effort. Included in this is $25,000 for the collection of water for invertebrate and fish toxicity testing.
Comments: One example may be the use of the boat-based beach seining employed during the IEP Shallow Water Habitat Predator-Prey Dynamics Study. This technique was an effective method for collecting large numbers of inland silverside and striped bass > 100 mm with low effort (Nobriga et al. submitted; consistently 10^2-10^3 fish per hour of sampling during summer months).
Feasibility: High for water collections because of priority and flexible vessel needs. Otherwise, feasibility depends largely on the methods used and the level of effort.

II. On-going Studies

2.a. Analysis of historical population dynamics

IEP 2006-084
Lead agency: USBR
What: These investigations were a component of the 2005 investigations. Based on results to date, we believe continuation is warranted to complete work already started, complete work that could not begin in 2005 due to unavailable data and to extend the investigation in ways intended to comport with reviewer recommendations.
Questions addressed in 2006-7: The examination will extend the 2005 analysis of FMWT and Bay Study data to include other fish datasets, including the FWS JFMP seine dataset. This will include the evaluation of, or search for, (i) long-term trends, (ii) discernable epochs in the data, (iii) notable point or short-duration events, and (iv) coordinated or contemporaneous changes in multiple species that suggest a common explanation. New methods developed in 2005 for the purpose will be employed, as well as other techniques. Second, we will examine relevant historical data to evaluate historical support for the two "narrative" hypotheses developed in 2005. Because 2005 analyses revealed that a particular focus on years since 2001 would be a mistake, this investigation will assume the fullest historical scope possible. In 2006 we will also submit at least two manuscripts for publication. One will be a methods paper dealing with the new regime change analysis developed by Bryan Manly; the other will be an account of the 2005 analysis of FMWT and Bay Study data, and what the findings imply.
When: Ongoing through 2007.
Cost: Approximately $60,000 per year. Some funds may be required for contracts with external parties in the future.
Comments: Statistician Bryan Manly has agreed to assist. San Luis Delta Mendota Water District has generously agreed to support Dr. Manly's work. Other outside assistance may be required in the future.
Feasibility: Very high.

2b. Apparent growth rates of pelagic fishes and relationship to abundance
IEP 2006-051
Lead Agency: DFG (Randy Baxter)
What: Fish growth rates can be an indicator of toxic exposure or food limitation (Bennett submitted). Sweetnam (1999) noted a step decline in mean length of delta smelt that started in about 1990. The FMWT length data had not been analyzed for other species or for recent-year effects, nor had any other long-term monitoring data sets. In 2005 as a complement to otolith based growth rates (see Bennett 2005 3a), we examined apparent growth rates for selected fishes collected in the 20mm Survey, Summer Townet Survey, Fall Midwater Trawl Survey, the Bay Study Survey and the Suisun Marsh Survey to determine whether rates changed abruptly during 2002-2004 as compared to previous years. We also compared year-end mean lengths from the FMWT following Sweetnam (1999) to see if the size attained had changed over time, particularly after 2001. We did not find any indication of a growth change after 2001, but we were not able to complete calculation of rates for all years of data, nor compare these rates with species abundance or environmental factors. We propose to complete and update these tasks in 2006 and add new data in 2007 as it becomes available.
Questions addressed: Have species' apparent growth rates or year-end mean lengths declined, particularly those of 2002-2004 versus previous years? Are environmental factors, such as X2 position or zooplankton abundance, predictive of apparent growth rates or year-end mean size?
What: Complete growth rate analyses based on existing length frequency data from the trawl surveys to determine if the apparent growth rates of target pelagic fishes have changed over the long-term and/or recently (2002-2004).
When: The analysis can be completed in 2006.
Cost: $75,000
Feasibility: Current results and those from Sweetnam (1999) indicate this approach may be insightful.

2c. Evaluate delta smelt otolith microstructure and microchemistry
IEP 2006-060 and 2006-040
Lead Agency: UC Davis (Dr. Bill Bennett)
What: Analysis of otoliths from delta smelt to determine daily growth rate and area of origin. Analysis of otoliths that includes microchemical work can provide detailed information on fish origin and growth that can be related to histopathology analyses and potentially to ambient water toxicity for 2005 and 2006. This work has been done successfully on delta smelt (Bennett submitted). Fish samples for this element will be collected by the Summer Townet and Fall Midwater Trawl surveys, with supplemental sampling based on availability of boats and crew. In addition IEP has archived delta smelt samples from 1995 through 2005 that might be added to these analyses.
Questions: Do growth rates of delta smelt vary seasonally or geographically? When and from where in the estuary are delta smelt produced?
When: Work should be started as soon as practical and continue for at least one year.
Cost: Estimate is for $350,000 to process approximately 500-600 samples per year. Funding to come from a CALFED ERP grant. $76,000 funding for J. Hobbs is from CALFED-Sea Grant.
Comments: This work will be an extension of the delta smelt work (Bennett submitted) and striped bass work carried out by Dr. Bill Bennett and colleagues (Bennett et al. 1995). This work

would be most effective if coupled with the histopathology work in item 3b and diet/condition work in 3c to provide a comprehensive timeline of the relative condition of the fish that we could compare to timing of potential stressors. Given the specific technology and expertise needed to do this work, it is recommended that this work continue along with that in item 3b supported by CALFED ecosystem restoration funding.
Feasibility: High. This work will be an extension of the delta smelt work (Bennett submitted) and striped bass work carried out by Dr. Bill Bennett and colleagues (Bennett et al. 1995). Existing samples of frozen delta smelt from 1995 through 2005 are already archived, but are not appropriate for histopathology or diet work.

2d. Delta smelt histopathology investigations
IEP 2006-061
Lead Agency: UC Davis and Dr. Swee Teh
What: Histopathological Examination of fish
Questions addressed: Does fish histopathology suggest recent increases in toxic exposures and/or food limitation? Does the histopathological condition vary in severity by life stage within or among species and/or geographic regions? What percentage of fish is affected by environmental stressors? What are the target organs of these stressors, and can the observed effects lead to population declines? What are the stressors affecting the fish?
When: 2006-2007
Cost: $350,000 from CALFED ERP grant
Comments: Histopathological analysis of fish tissues can identify a variety of tissue lesions resulting from exposure to environmental stressors such as contaminants, disease, and food limitation. Histopathological lesions often manifest themselves over longer periods of time, and therefore integrate the effects of multiple stressors. It is a useful tool to identify affected organs and can help identify certain groups of contaminants with known mechanism of action (e.g. carcinogens, endocrine disruptors) and target organs (e.g. liver, gonads). Histopathologic studies play an important role in directing and focusing special studies.

Work in 2006-07 will focus on the examination of fish exposed to water samples or collected from sites where 1) 2005 results indicated that fish were affected by environmental stressors; 2) where invertebrate toxicity tests indicate the presence of toxic compounds. Lesions in fish from laboratory studies should be compared to lesions observed in fish from field sites, but it is important to keep in mind that actual exposure duration may differ between laboratory-exposed and field-collected fish, and that wild fish may additionally be exposed to natural stressors (water temperature, oxygen levels, and food depletion).
Feasibility: High

2e. Quantitative analysis of stomach contents, body weight and parasite load for pelagic fishes
IEP 2006-062
Lead Agency: DFG
What: Food habit studies have been done on many of the fish and zooplankton found in the estuary (IEP 1987; Orsi 1995; Lott 1998; Nobriga 2002; Feyrer et al. 2003); however, many of these studies were done more than 10 years ago and the feeding habits of the local inland silverside and threadfin shad populations have only been studied in a limited geographical range (Grimaldo 2004). As evidence that feeding success may be an important issue for survival, initial

analyses by BJ Miller suggest that delta smelt survival in different parts of the estuary was linked to whether there was co-occurrence of prey. The only previous evaluation of parasite load was an evaluation of cestode infection in striped bass (Arnold and Yue 1997). However, information on gut parasites can be collected quickly during the processing for stomach contents analysis. Parasite load can influence susceptibility to other stressors (Moles 1980). In 2003, IEP started a study of fish length-weight relationships needed to estimate species biomass and to develop a program to monitor trends in relative weight. Preliminary information from 2005 indicated that delta smelt have expanded their diet to include a broader variety of copepods, that the introduce copepod *Limnoithona tetraspina* is eaten by estuarine fishes -- particularly inland silverside -- and that striped bass condition was lower in western Suisun Bay than in other regions of the estuary (Slater 2005 3c; Gartz 2005 3c). Work on diet and condition will be continued in 2006 and 2007, and be expanded to include longfin smelt among the target species and the periodic collection of all target fishes (delta smelt, striped bass, longfin smelt and threadfin shad) from Salvage. Disease and parasite information from 2005 indicated that methods developed were not refined enough to detect potentially important agents (see Gartz 2005 3c and Ostrach 2005), thus current methods will be discontinued; however, the disease and parasites tasks may be undertaken during special sampling by other researchers (see Ostrach proposal for 2006).
Questions addressed: Is there evidence of reduced feeding success during specific times of the year or in certain parts of the estuary? If so, are these changes associated with changes in growth rate, relative weight or liver condition? Do stomach contents, condition (weight at length) or histopathology vary between salvaged fish and fish collected elsewhere?
When: 2006.
Cost: This will require $75,000 for 2-3 scientific aides to process the samples and enter the data. Staff time to analyze the data and prepare a report can be done by redirecting existing staff.
Comments: DFG staff in the IEP can collect samples and process diet information; parasite examinations and identification may require some assistance from the DFG Pathology Laboratory.
Feasibility: Moderate. The IEP has extensive experience with these techniques, but lost staff leading part of this work.

2f. Acute and Chronic Invertebrate and Fish Toxicity Tests
IEP 2006-063
Lead agency: UC Davis
What: Toxicity testing with invertebrates and fish species of concern
Questions addressed: Is water in the Delta and the Napa River toxic to pelagic fish and fish food organisms? If yes, where and when? How does fish and zooplankton distribution and abundance compare to bioassay results? What is the spatial and temporal distribution of water column toxicity in relevant areas of the Delta? What are the primary toxicants?
When: 2006-2007
Cost: $644,000 for 2006
Comments: Work in 2006-07 will consist of a spatially and temporally expanded sampling and toxicity testing program. Spatial distribution of Delta sampling sites will follow the 2005 pilot program, and additional sites will be sampled in accordance with the prevalent distribution patterns of fish species of concern. The indigenous amphipod species, *Hyalella azteca*, will be used for routine toxicity testing throughout the year. This species is resident in the Delta, sensitive to contaminants, and is routinely used in toxicity testing programs throughout the

Nation. Moreover, it can be used to identify the causative agents of toxicity through Toxicity Identification Evaluation (TIE) procedures. If toxicity is observed at a site through initial screening, TIEs will be initiated immediately. Adequate quantities of water will be collected to proceed with TIEs in case toxicity is observed.

Two fish species of concern, delta smelt and striped bass will be used to test water samples from selected Delta sites, from larval to juvenile stages during periods when the respective life stages are rearing in the Delta. Fish from these tests will be preserved for biomarker and histopathologic analyses. These laboratory tests will identify sites that are acutely toxic to larval/juvenile stages of delta smelt and striped bass, and help differentiate the effects of toxic contaminants from the effects of food depletion (fish will be fed during the laboratory trials), and natural stressors such as water temperature and/or oxygen depletion (laboratory tests are performed at constant temperature and water is oxygenated).

In addition, information will be gathered on land use (e.g. PUR) to ascertain the potential class of toxicant(s) that could potentially be present at the sampling sites (see contaminant trends). This will aid in the TIE process, and also direct focused studies on timing and duration of potential toxic effects.

If TIE work identifies specific contaminants as toxicants of concern, focused laboratory studies should be designed and performed to expand our knowledge of the specific effects and biological effect levels of these toxicants. Specific biomarker responses can then be selected for identifying the effects of these toxicants in field studies.

If multiple stressor effects are suspected to play a role (e.g. food limitation plus contaminants), laboratory experiments could help quantify the combined effects. Fish could be reared in the laboratory under a normal and a food-limited regime, examined for resulting histopathological lesions, then exposed to water from different Delta sites, or to specific contaminants identified as toxicants present in the Delta.
Feasibility: High

2g. Field survey of Microcystis aeruginosa Bloom Biomass and Toxicity
IEP 2006-079
Lead agencies: DWR-DES, DFG
What: Field surveys to measure *Microcystis aeruginosa* bloom biomass and toxicity. The 2006 surveys will build on the 2004-2005 survey and be closely coordinated with the fish surveys (Summer Townet Survey and Fall Midwater Trawl) and toxicity assays. Sample collection at fish survey stations will help elucidate the link between *Microcystis* biomass and toxicity and its direct effect on zooplankton and fish. Water samples for *Microcystis* biomass and both algal tissue and dissolved microcystins toxicity will be collected monthly by DWR-DES staff at selected fish survey and zooplankton and fish toxicity assay stations, as well as stations with high *Microcystis* biomass identified in the 2004 survey. Zooplankton, benthos, and fish toxicity will be evaluated based on microcystin content in whole animal (zooplankton and benthic) or liver and muscle tissue (fish). Animals for these analyses will be collected during fish surveys. Epibenthic and benthic organisms will be collected by Ponar dredge or box sampler (C. Messer, personal communication) as a part of the bloom sampling effort or fish survey as appropriate.

Environmental conditions associated with the bloom biomass and toxicity will be measured at each station with an YSI 6600 Sonde and by water samples for a suite of discrete water quality measurements including nutrient concentration. Qualitative observations of *Microcystis* surface blooms will be recorded by fish survey staff during all fish survey dates and at all sites.
Major Findings from 2005: A single day study in 2003 and seasonal studies in 2004 and 2005 indicated that a toxic *Microcystis aeruginosa* bloom was wide spread throughout the Delta (Lehman et al. in press). In 2005, blooms of *Microcystis aeruginosa* appeared to expanded and intensified in the delta, especially at the San Joaquin River stations (Antioch, Frank's Tract, Old River and San Joaquin River Ship Channel). *Microcystis aeruginosa* was not found downstream of the low salinity zone and its bloom in the delta was apparently delayed by the cooler water temperatures in 2005 relative to earlier years. Furthermore, microcystins in tissue of zooplankton, amphipods, clams, and other benthic organisms collected in each year indicated that the base of the food web contained *Microcystis* toxins that could impact organisms at higher trophic levels through bioaccumulation (Lehman et al. in press).
Questions addressed: Is *Microcystis* biomass or toxicity increasing over time in the Delta? Does *Microcystis* bloom biomass or microcystins toxicity occur in areas important to pelagic fish species in the Delta? Is there a relationship between bloom biomass and toxicity with zooplankton and fish abundance? Is there a relationship between the bloom biomass, microcystins in algal tissue or microcystins dissolved in the water column, and microcystins toxicity in zooplankton, benthic, epibenthic and fish tissue? Do regions of high zooplankton and benthic tissue microcystins toxicity coincide with high microcystin tissue content, lower density and poor health of planktonic feeding fish? Are dissolved microcystins produced during the decomposition phase of the bloom sufficiently toxic to impact fish and zooplankton survival and health based on densities at sampling stations and toxicity bioassays? What are the origins of the *Microcystis* blooms?
When: Summer and fall 2006-2007.
Cost: Student at UCD – $20,000
CALFED grant: 2006-2007-$500,000
Comments: This work would be conducted by redirected and additional hired temporary DWR-DES staff including a boat operator; microcystins toxicity analyses by Dr. G. Boyer at State University of New York. Dr. Peggy Lehman also submitted a proposal to the CALFED Science program for additional funding for a *Microcystis* study starting in 2006.
Feasibility: DWR-DES staff under the direction of Dr. Lehman has successfully carried out *Microcystis* surveys in 2003-2005 and is experienced in field sampling and sample preparation methods (Lehman et al. in press). Toxicity analysis will be done by Dr. G. Boyer of the State University of New York, an expert on cyanobacterial toxicity. His group has extensive experience in determination of cyanobacterial toxins and routinely analyzes samples for NOAA, CDC, and departments of health and conservation for several states. They also participated in the previous surveys. Future analyses may be possible at DFG's Water Pollution Control Laboratory.

2h. Contaminant Trends and Toxicology
IEP 2006-010
Lead Agencies: DWR EMP Staff, SWRCB and CVRWQCB, SWRCB SWAMP, CDPR, SFEI
What: The evaluation of current contaminants and the trends in use and loading to the system. Temporal and spatial analyses of contaminant transport, fate, and toxicity. The information will

be used in the toxicity and biomarker research to help aid identification of potential suspects as well as location and timing of possible toxicological effects. SFEI will convert older Boating and Waterways data to electronic format to run simple black models on potential fates and effects.
Questions addressed: Are there to be enough of various contaminants present in the Delta to present a plausible problem individually or in combination?
When: Immediate 2006-2007
Cost: DWR will commit one staff half time to facilitate the linkage of data with POD efforts, $15,000 will be needed for SFEI's participation.
Feasibility: High, many programs already exist.

2i. Striped bass health investigations
IEP 2006-042
Lead Agency: UCD (Ostrach), support from DFG
What: Waters of the Bay/Delta carry a wide range of contaminants with the potential to induce pathological and physiological changes that may contribute to both the long term and recent declines in fish populations. Earlier work by Ostrach and others have strongly suggested that maternal burdens of contaminants may affect hatching success and health of larvae. The long life of striped bass greatly increases the possibility of maternal body burdens affecting young relative to shorter-lived species like the smelts and shad. Direct effects on larvae are also reasonable. This work will assess the health status of larval, juvenile, and adult female striped bass collected from selected locations in the Bay Delta using morphometric, histopathological, otolith (aging, growth and microgeochemical analyses) and biochemical metrics. Comparison with archived samples will allow for estimation of the contribution of this type of stressors to the long vs. short-term declines in abundance of young striped bass.
Questions: Does the condition of adult or larval striped bass suggest that contaminants and diseases could be depressing the populations of striped bass in the estuary? If present, have these effects increased in recent years? What life stages are most critical?
When: Analysis of archived samples can begin as soon as contracts are in place. Gravid females will start arriving on the spawning grounds in April and May, and be sampled by DFG as part of their normal operations. Reports on results of the adults and larvae should be available by October 2006. 2006 results may indicate a need for more detailed work on physiological and population processes in 2007 at an additional cost of about $240K. Proposals for such work are in hand. Ambiguous results in 2006 may simply call for a second year of such studies in 2007.
Cost: $415,865
Comments: The investigator has a great deal of experience and unpublished information on this topic. Transforming new and accumulated data and information into peer-reviewed literature must be an essential part of this element. The additional laboratory and modeling work proposed by the investigator would cost another $240,000 but may not be available separately in 2007.
Feasibility: High. The additional proposed work not funded in 2006 is more experimental and may not be as conclusive as the work proposed for funding.

2j. Phytoplankton primary production and biomass in the Delta
IEP 2006-045
Lead agencies: UCD, DWR-DES

What: This is an extension of an ongoing data analysis project with CALFED-ERP funding granted to Dr. Alan Jassby at UC Davis and collaborators at DWR-DES. The full title is "Primary Production in the Delta: Monitoring Design, Data Analysis and Forecasting." Phytoplankton production is at the base of the pelagic food web leading to the zooplankton and fish species currently experiencing rapid declines. One goal of this ongoing project is to analyze available historical data on chlorophyll *a* concentrations and other water quality variables in Delta subregions or at specific long-term monitoring stations in order to determine processes underlying changes in primary production and biomass. This is an extension of similar analyses conducted at the Delta-wide scale (Jassby and Cloern 2000; Jassby et al. 2002). Results from this study will help assess the potential for sub-regional and local bottom-up food web effects on pelagic zooplankton and fish, effects of changed export patterns on phytoplankton production in different Delta areas, etc.
Major Findings in 2005: While earlier studies by Jassby et al. (2002) showed that chlorophyll *a* levels declined substantially during the late 1980s, preliminary results indicate no obvious recent downward trend during 1996-2004. Of the 16 "good" monitoring sites that he analyzed, the 2005 effort showed that three stations in the San Joaquin River actually showed increases in chlorophyll *a*. The rather coarse species data provide no evidence that there has been a major decrease in diatoms ("good algae") or a corresponding increase in the amount of blue green algae ("bad algae"). However, the existing monitoring program does not adequately address patchy "blooms" such as *Microcystis*.
Questions addressed: What are long-term patterns and trends in phytoplankton production and biomass and other water quality variables in different Delta subregions and at specific locations? How do they compare to Delta-wide trends? What factors may be responsible for these patterns and trends? How may the Delta food web be affected by these patterns and trends? Have changes in water exports affected phytoplankton in different Delta areas? Do the previous questions differ when only "nutritious" algae are considered? Can monitoring data be used to evaluate benthic grazing rates?
When: Ongoing through 2007.
Costs: $50,000/year.
Comments: The key staff includes Dr. Alan Jassby, UC Davis, in collaboration with DWR-DES staff (Dr. Anke Mueller-Solger & Dr. Marc Vayssières)
Feasibility: High (on-going).

2k. Evaluation of changes in pelagic fish habitat quality using the IEP long-term monitoring data

IEP 2006-066
Lead agencies: DWR and DFG
What: Long-term monitoring data are being used to characterize physical habitat for delta smelt and striped bass and to test the hypothesis that there has been no long-term change in the amount of physical "habitat" for these pelagic fishes. The basic approach used in 2005 was similar to instream flow methods (IFIM) that have been applied to rivers and streams. First, we developed habitat criteria to define the physical and chemical conditions that were suitable for striped bass and delta smelt. Second, we divided the study region into smaller area units based on the location of sampling (TNS and MWT) stations. Third, we applied the habitat criteria (step 1) to long-term water quality monitoring data for each station to determine which stations provided suitable habitat. Finally, we summed the area units (step 2) representing suitable habitat to

provide an estimate of total suitable area. Note that a major difference between our approach and traditional IFIM methods is that we relied on actual water quality monitoring data at sampling stations to calculate suitable habitat, while IFIM typically uses model simulations to generate data for each station. In 2006-2007 we propose to: 1) Complete the initial analyses of habitat area for the TNS and MWT; 2) submit results to a peer-reviewed journal for publication; 3) evaluate the results based on trends in physical habitat for major geographical areas (e.g. delta vs. Suisun Bay); and 4) evaluate the feasibility of using zooplankton prey availability as an additional habitat suitability criterion.
Questions addressed: Has the surface area of suitable striped bass and/or delta smelt habitat changed? Does interannual variation in estuarine hydrology influence the spatial extent of striped bass and/or delta smelt habitat? Have export changes affected the spatial extent of striped bass and/or delta smelt habitat? What are the trends in physical habitat area in the Delta versus Suisun Bay? Do the previous findings differ when the availability of zooplankton prey are factored into the analysis?
Major Findings from 2005: Based on the data available to define "habitat" and analyses of the townet data:

- There is no evidence that delta smelt and striped bass, physical habitat quantity has decreased since 1970.
- There is no evidence that variation in physical habitat quantity significantly influences delta smelt population dynamics.
- There is a relationship between delta smelt physical habitat area and hydrodynamic conditions indexed by X2.

Cost: Two Environmental Scientists $55,000 (25% time). Additional assistance of redirected IEP staff may also be needed.
Feasibility: High. This study component is a continuation of the successful 2005 effort.

2l. Delta and Suisun Bay hydrodynamics investigations relying on particle tracking models
IEP 2006-031
Lead agencies: DWR and USBR
What: This is a three-pronged element. The first prong shares the goals of the South Delta Hydrodynamics and Fisheries studies: to understand the transport of fishes through the delta and to determine whether adjustments to water project operations may allow a useful reduction in entrainment of protected fish species. For the foreseeable future this work will be conducted using DSM2 and the DSM2 particle tracking model. While this part of the element is fish-oriented, we plan to adapt the investigation if possible to couple model outputs with distribution data and production models for lower trophic level organisms to assess the likelihood that water diversions could significantly influence regional productivity under certain circumstances. The second prong of the element is an investigation that will consist of particle tracking studies of Suisun Bay and surrounding waters to support the power plant operations element of the workplan. The intent will be to estimate entrainment risk and risk of exposure to high temperatures and/or chlorine produced by the Pittsburg and Contra Costa power plants. Initial work will rely on DSM2 and its PTM, but we plan to replace it with more sophisticated 3-D tools during the study period. The third prong is PTM support for development of population size estimation in the IEP field surveys. We plan to use reverse-PTM to help estimate the boundaries of sampling regions represented by fixed stations in the surveys. This work will rely on DSM2 and its PTM.

When: Follow-up 2005 PTM studies underway. Other applications will be ongoing through 2007.
Questions addressed: How does the spatial distribution of entrainment risk vary under different hydrologic (flows and exports) and operations (DCC, south delta barriers) scenarios? How does risk of (power plant) entrainment in Suisun Bay and environs vary with environmental conditions and power plant operations? How does risk of exposure to adverse physical or chemical conditions created by power plant operations vary with environmental conditions and power plant operations? What geographical areas do samples taken at IEP trawl stations actually represent?
Costs: Cost estimate has not been made, but if funding is needed funds allocated to the 2006-047 (Suisun Bay investigations) and 2006-080 (winter salvage investigations) can be used. Use of 3-D technologies will require contracting with an outside entity and the cost of this is unknown at present.
Comments: The key staff includes Mike Mierzwa, Ted Sommer and Bob Suits (DWR) and Mike Chotkowski (USBR). Additional study questions will be developed by the POD Flows and Operations PWT.
Feasibility: Very high (2005 work successfully completed, other work ongoing).

2m. Power Plant Operations
IEP 2006-0087
Lead agency: DWR and others
What: This study was previously a component of the 2005 work element, "Analysis/summary of recent changes in delta water operations". Based on the initial data review, we believed that the issue warranted a focused study. The purpose of this element is to closely examine power plant operations to identify whether there were effects strong enough to contribute to the long-term and recent apparent step change in pelagic fish abundances.
Major findings from 2005: Non-consumptive water use by the power plants may reach 3200 cfs, which may be enough to create a substantial entrainment risk for fishes residing in that region of the estuary. There may also be some risk to fishes created by thermal pollution or residual chlorine from antifouling activities. The magnitude of these risks is unknown.
Questions addressed: What are the characteristics of the cooling water diversions associated with the Contra Costa and Pittsburg power plants, and what effects might they have on pelagic fishes? Have there been recent increases in pelagic fish entrainment?
When: Ongoing through 2007.
Cost: $70,000 per year. The initial cost estimate is based on the assumption that the effort will require an environmental scientist working 50% time for two years.
Feasibility: Although we were unable to obtain detailed data on recent project operations and fish entrainment for the 2005 synthesis report, we have had new and promising contacts regarding power plant data.

2n. South Delta fisheries and hydrodynamic studies (larval fish behavior study)
IEP 2006-017
Lead agencies: USBR, USGS and DWR
What: This is part of the separately-funded South Delta Hydrodynamics and Fisheries investigation that was initiated in 2004. Its goal is to develop a behavioral model of larval fish

behavior to support estimation of entrainment risk in the south Delta under differing hydrologic and operations scenarios.
When: The second phase of field data collection was completed during spring 2005; a summary report should be available shortly. Further work will be ongoing through 2007.
Questions addressed: What are the behaviors of larval fishes in the south Delta and how is behavior likely to affect entrainment risk under different hydrologic conditions?
Costs: This element is funded by non-POD sources.
Feasibility: High (in progress).

2o. Trends in benthic macrofauna abundance and biomass
IEP 2006-065
Lead agency: DWR
What: Over the past three decades, the Interagency Ecological Program (IEP) Environmental Monitoring Program (EMP) has collected benthos community composition and abundance information at 22 sites, including four long-term monitoring stations. Trends at the four long-term stations are the subject of an ongoing investigation. Though it is presently recognized that biomass data are crucial in determining the role of benthic organisms in the ecosystem, (especially the feeding potential of various functional groups, potential availability and transmission of contaminants bioaccumulated in benthos, and trends in production as well as the ecological significance of changes in benthic community composition and abundance) measurements of benthic macrofauna biomass have, never been conducted by the EMP. Fortunately, the EMP has developed a comprehensive plan to analyze archived benthos samples dating back to 1975 which can be used for biomass estimation using a simple wet-weight method. The objective for 2006 is to measure and examine the biomass of benthic organisms collected quarterly from 1975 – 2004 at two long-term stations located in the central and northern Delta. Data analysis would be conducted as part of the next workplan element (see below).
Major Findings from 2005: The laboratory work for this project is still underway. No report was submitted.
Questions addressed: At central & northern Delta locations, what are the long-term trends in biomass, production, and grazing rates of benthic species? How are these changes related to physical-chemical gradients? How do changes in benthic functions such as production and grazing affect the pelagic food web?
When: 2006
Cost: Total: $66,000. Environmental Scientists: 365 hours = $31,400; 1 Scientific Aide : 550 hours = $21,110; Wayne Fields: 30 hours = $3000; Supplies: $10,000)
Comments: This work would be conducted by redirected and additional hired temporary DWR-DES staff including Dr. Dean Messer, Karen Gehrts, and a scientific aid. Wayne Fields of Hydrobiology would provide identification help and Dr. Janet Thompson, USGS, would provide additional expertise.
Feasibility: High. Investigation does not depend on the availability of new field data. Special analytical techniques that are required are well-known.

2p. Retrospective analysis of long-term benthic community data
2006-078
Lead agency: DWR & USGS

What: This is an ongoing data analysis project with IEP and CALFED-Science funding. The goal of this project is to investigate long-term trends and ecological processes involving benthic organisms from historical data collected by the IEP Environmental Monitoring Program (EMP) at its four long-term benthos monitoring stations. Specifically, this analysis seeks to uncover historical trends in community composition in relation to environmental variability, hydrology, and exotic species invasions.
Major Findings from 2005: Changes in sediment composition and benthic assemblages occurred estuary-wide in 1999-2000. The changes in community composition were much less pronounced than changes occurring in 1987-1989 following the *Corbula amurensis* invasion. In San Pablo Bay, the most significant increase of a grazer organism was of the amphipod *Ampelisca abdita*. Since 2001, *C. amurensis* has rebounded to former high abundance levels observed during the 1987-1992 drought. Brackish water organisms, including *C. amurensis*, have also increased in abundance at the Sacramento-San Joaquin River confluence to 1987-1992 levels. Based on previous studies, it is presumed this resurgence could depress lower trophic level productivity in Suisun Bay and the western Delta (Kimmerer and Orsi 1996; Kimmerer submitted). Total bivalve abundance was lower in recent years than during wetter conditions in the 1990s. However, this was mainly due to reduced abundance of the freshwater bivalve *Corbicula fluminea*. In Old River, *C. fluminea* numbers have dropped recently relative to the latter 1990s. Though *C. amurensis* has never been detected in Old River, lower chlorophyll *a* levels also became more prevalent in the Delta after 1988. This was despite an increase in water clarity that should have favored phytoplankton production. There are indications that phytoplankton production capacity might have been higher prior to the late 1980s. Thus, other phenomena in addition to bivalves might be contributing to depressed phytoplankton abundance (Jassby et al. 2002).
Questions addressed: At the four core sites, how do benthic community assembly and structure change over time? How are these changes related to physical-chemical gradients? Can spatial or physical thresholds be identified for benthic macrofauna, especially for species of concern such as invasive species, species with important trophic effects, (e.g. *Corbicula fluminea* and C*orbula amurensis* which act as a sink for suspended organic particles), and other benthic species that are important prey items for higher trophic levels such as bird, fish and mammals? What is the environmental significance of changes in species assemblage?
When: Ongoing through 2006.
Cost: Covered under Environmental Monitoring Program element (2006-072).
Comments: Key staff includes Heather Peterson (USGS), Dr. Marc Vayssieres (DWR), and Dr. Janet Thompson).
Feasibility: High (on-going).

2q. Striped bass and delta smelt fecundity estimates
IEP 2006-064
Lead Agencies: DFG and UC Davis
What: Develop contemporary age fecundity (or length-fecundity) relationships for striped bass and delta smelt and compare for significant historical change. Observed declines in fall juvenile fish abundance could result from poor survival of larval and early juvenile life stages, or could simply result from declining egg production. Declining egg production could result from a decline in the average size, age or total number of spawning females, or a reduction in individual female fecundity caused by degraded environmental conditions (e.g. exposure to contaminants or

poor food availability). Previous to 2005, fecundity relationships were most recently developed for San Francisco Estuary striped bass and delta smelt in the mid 1980s and late 1990s, respectively (Knudsen and Urquhart 1988). For striped bass, fecundity relationships will be used in combination with adult population estimates to calculate current estimates of overall egg production (see 3l (element 2006-037, Striped bass egg supply); Steven's et al. 1985; Kimmerer et al. 2000, 2001). In 2005, ovaries from the 30 adult bass were visually examined for general health and egg number estimated. The overall condition of the ovaries appeared to be excellent with only one fish having noticeable parasites. Size -fecundity relationships in 2005 did not appear to differ substantially from relationships developed in the 1970s and 1980s. Also in 2005, a delta smelt length fecundity estimate was developed by UC Davis researchers from 30-40 females collected in 2003 and additional historical delta smelt samples were uncovered that included fish from 1993, 1995, 1996 and 1997 year classes. Processing these historical delta smelt samples will provide means for inter-annual comparisons. Inter-annual comparisons completed for striped bass do not indicate a need to repeat collections in 2006 or 2007.
Questions addressed: Has there been a recent decrease in the fecundity of delta smelt? Has the relation between fecundity at length changed?
When: In 2006, DFG complete processing of delta smelt samples for 1993-1997 year classes for comparison with 2002 and 2004 year class samples processed by UC Davis.
Cost: DFG portion - $7,000 for additional laboratory processing and oversight. UC Davis portion – an internal grant will allow fecundity estimation for fish collected in 2005.
Comments: Age-fecundity information developed for striped bass in 2005 did not indicate a change from historical levels, so additional work will not be needed. This information will be integrated into the striped bass egg production model (see 3l (element 2006-037, Striped bass egg supply).
Feasibility: This work is highly feasible; a portion was successfully completed in 2005.

2r. Recent changes in water project operations
IEP 2006-068
Lead Agencies: USGS
What: The purpose of this element is to continue to examine recent changes in water project operations to identify effects potentially strong enough to account for the apparent step change in pelagic fish species abundances since at least 2001. Other historical changes in water project operations will also be studied to support the "Analysis of historical population dynamics" study element and advance our knowledge of the role of water project operations in the long-term decline of certain pelagic fish species. However, these analyses will be secondary to the investigation of recent changes.
Major Findings from 2005: There have been changes in the input flows to the Delta in recent years, including a slight increase in average Sacramento River flow since 2001 and a substantial reduction in peak San Joaquin flows since 2001. There are some methodological issues with the hydrology report that will have to be addressed in 2006-7.
Questions addressed: How have recent (1995 – 2004) water project operations changed delta hydrology? "Hydrology" is meant here to include the volume, timing, and pattern of input flows into the delta, delta outflow, exports, and operation of various water project gates and barriers. We also ask: which, if any, of the changes might plausibly have contributed to, or caused, a recent step change in pelagic fishes abundance?
When: 2006

Cost: $30,000
Comments: The results will be reviewed by the POD PWT and other biologists, who will evaluate the strength of evidence that might connect water operations changes to the recent decline of pelagic fish species. The committee will recommend follow-up investigations to explore leading hypotheses, if appropriate.
Feasibility: High. Most data should be readily available.

III. New studies

3a. Wintertime Salvage Investigations

IEP 2006-080
Lead Agency: DFG, DWR, USBR, EPA
What: A pattern of increasing wintertime salvage of pelagic species during recent years, while other measures of abundance indicate declining abundance, requires explanation. These investigations will include new studies, many of which are incorporated into other workplan elements, and analysis of existing data.
Questions addressed: Are salvage data comparable across recent years? Are there operational, data gathering or QA/QC issues that can explain greater salvage at times when field surveys indicate fewer fish? Are salvaged fish different in health, feeding success or other parameters than fish in the field surveys? Are hydrodynamic conditions resulting in greater accumulations of fish in salvage during recent years than before? Do salvage numbers indicate a high enough level of loss to suggest population level effects?
When: Analysis of existing data should proceed at a high level of effort immediately. Salvaged fish, particularly longfin smelt, delta smelt, threadfin shad and striped bass should be collected and archived for later analysis immediately. If analysis of existing data suggest that changes in salvage cannot be explained by operational changes at the salvage facilities or by data errors, fish should be examined as described under the food habits, contaminants and disease portions of this workplan, beginning in February. Hydrodynamic modeling should be pursued simultaneously to estimate the changes in particle fate and areas of effect under recent export patterns. Population estimation and modeling must be pursued in order to address the question of population impacts of salvage; this may best be done by a collaboration of local expertise with a high level statistician/modeler from the broader academic community. Searching for an appropriate person should begin immediately.
Cost: This work will involve both the new work which is yet undefined and the analysis of existing data is likely to require the work of diverse people totaling. Included in this is the archiving and processing fish from salvage and field operations, hydrodynamic and particle tracking modeling and analysis and an intensive population estimate/ impact scale assessment. It is anticipated that we will need the assistance of one or more statisticians for this work. We have budgeted $500,000 for this work with the expectation that as the specific activities are more closely defined in the upcoming months a better cost estimate will be produced.
Comments: These analyses are likely to be the most hotly discussed results of the POD work because of their direct implications water management. Extreme caution and review are required and we should anticipate the need to redo and review many of the analyses, both of data and of fish and modeling. Costs should reflect this need

Feasibility: High. The population implications are the only part that may resist completion due to difficulties in the underlying data.

3b. Suisun Bay Studies
IEP 2006-047
Lead agencies: DFG, DWR, RTC, other?
What: This is a synthetic analysis intended to support or refute the "Bad Suisun Bay" hypothesis developed by the POD Management Team in its 2005 synthesis report. The "Bad Suisun Bay" hypothesis posits that the fish production potential of Suisun Bay has been reduced since the invasion of *Corbula*, primarily due to its strong influence on the pelagic food web (Alpine and Cloern 1990; Kimmerer and Orsi 1996; Kimmerer 2002). In the last few years *Corbula* densities may have resurged to late 1980s/early 1990s levels, exacerbating the pelagic productivity problem. This study will compile and synthesize previously published data, previously known, but unpublished data, and new POD/CALFED commissioned work relevant to the "Bad Suisun Bay" hypothesis.
Questions addressed: What are the lines of evidence that support or do not support the "Bad Suisun Bay" hypothesis? Is pelagic production limitation in Suisun Bay primarily related to *Corbula* effects on the food web or do other factors such as contaminants or competitive interactions among invasive zooplankter play significant confounding roles? What levels of pelagic organism recovery are reasonable to expect in the post-clam estuary?
When: Ongoing through 2007
Cost: $500,000
Comments: The staffing for this element remains to be determined.
Feasibility: The feasibility of this study is probably high. Many *Corbula* influences have been reported already (e.g., Alpine and Cloern 1990; Kimmerer and Orsi 1996; Kimmerer 2002). Other unpublished signals that may be attributable to Corbula are known by IEP staff and the local scientific community. Lastly, many of the other POD studies (e.g., 2a, c, d, e, f, i, j, m, o, p, 3f, h, i, n, o) are expected to contribute to the synthetic analysis directly or through their spatial, temporal, species contrasts outlined above.

3c. Gear Efficiency Studies
IEP 2006-086
Lead Agencies: DFG and TBA
What: Trawl fishing gear is selective for fishes inhabiting open water or a relatively smooth bottom. In addition, trawl dimensions and mesh sizes affect the size of fishes enclosed and retained. We propose to review existing information, conduct data analyses and plan new experiments to show the effective retention size range(s) for fishes and estimated capture efficiencies of trawl nets currently used by DFG long-term fish monitoring. Review and planning will probably take most of 2006, and field experiments commence in 2007. One step was taken in September 2005 with the addition of a 1/8" mesh cover to the cod-end of the Fall Midwater Trawl (FMWT) net to document the sizes of fishes retained and of those that passed through the net during sampling. Concern about the additional cod-end material on the behavior of the net in the water (slower decent at deployment), lead to limited experimentation during 2005 FMWT sampling. We intend to develop field studies for 2007 (possibly 2006) to examine retention and capture efficiencies.

Questions addressed: What is the retention efficiency (fish in the net that remain held) of trawl nets and how does it vary by fish species and individual size? What is the capture efficiency of trawl nets for target species? With this information, can existing monitoring data be used to estimate fish population sizes?
When: As time becomes available during 2006.
Cost: $10,000 with $3,000 for gear purchase, $5,000 for temporary personnel and $2000 for boat operations costs.
Comments: Staff time to complete this task has not been identified.
Feasibility: Moderate for review of existing information. Low for additional field investigations in 2006, moderate for 2007 assuming improved staffing. Literature review can be accomplished with temporary personnel and some permanent time. Currently planned field efforts and projected staffing levels for 2006 leave little vessel and staff time to fit in sampling.

3d. Estimation of Pelagic Fish Population Sizes
IEP 2006-043
Lead agencies: DFG, DWR, USBR, consultants and contractors.
What: Except for adult striped bass, the status of pelagic fish populations has primarily been assessed using abundance indices. IEP has been reluctant to translate these data into population sizes because of sampling selectivity (i.e., non-random site selection), gear efficiencies are unknown for each of the sampling programs and fish tend be patchy, likely adding substantial variability. Other approaches for pelagic fish population estimation are unreasonable (e.g., direct counts, mark-recapture, and change in ratio). However, the POD effort would benefit greatly from at least crude population estimates, allowing calculation of mortality rates and population modeling. The development of mean-density expansion estimators based upon stratified random trawl sampling represents the most practicable alternative. As initial steps to estimate population size, Bennett (2005) has used the TNS and MWT data. This element will build on those earlier efforts to develop population estimates for as many of the target pelagic species as possible. Refinements of their efforts may include the use of known salinity and temperature effects on target species distributions, updated bathymetry and the particle tracking models to: 1) post-stratify survey data (i.e., set more efficient region boundaries); 2) improve habitat volume estimates represented by fixed stations and regions for each of the surveys; and 3) test the assumption of randomness in the data.
Questions addressed: What are the most efficient regions (strata) for each target species sampled by the TNS, MWT and Kodiak surveys? Do fixed sampling stations in a highly tidal system approximate random distributions? What are the population sizes for each of the target pelagic species? Should strata variance be calculated based upon a normal distribution or another type of distribution?
When: Ongoing through 2007.
Costs: $50,000 for contracts.
Feasibility: Moderate. Although there are substantial obstacles to measurement of population sizes, the recent efforts of Bennett (2005) provide a reasonable foundation for future work.
Comments: The staffing for this effort remains to be determined.

3e. Threadfin shad data analysis and population dynamics
IEP 2006-039
Lead agencies: DWR and DFG

What: In1959, threadfin shad were introduced into reservoirs in the Sacramento and San Joaquin drainages, and from these introductions the species expanded throughout the freshwater portions of the system. Little is known about their population dynamics within the delta and until about 2002 even their abundance trends were not regularly reported (e.g., their absence IEP Newsletter 2001 (2)). We propose to continue the examination of the distribution and abundance patterns of threadfin shad within the Delta and expand analyses to include investigation of fish entering from upstream.
Questions addressed: What are the seasonal and spatial trends in threadfin shad abundance? What factors affect their abundance and distribution? Do salvage estimates seasonally or cumulatively appear related to the longer term relative abundance of threadfin shad?
When: 2006.
Cost: $55,000 will be needed for this element.
Comments: Completion of this work will depend upon identifying an investigator.
Feasibility: Substantial catch, length and distribution data exists in state and federal survey databases that can be used to address the study questions.

3f. Corbula salinity tolerance, distribution and grazing rates
IEP 2006-076
Lead agency: DWR, USGS and SFSU
What: A central part of the "Bad Suisun Bay Hypothesis" is that *Corbula* distribution has changed, perhaps in response to recent salinity increases during autumn. To better evaluate this hypothesis, we need to develop salinity tolerance information for the clam. This will be performed in a controlled laboratory setting, likely at SFSU Romberg Tiburon Center. To provide additional insight into the "Bad Suisun Bay Hypothesis", we need better fine-scale regional data on the distribution and grazing rates of benthic organisms. Towards this end, field surveys will be performed by EMP staff in 2006 and 2007. Two spatially intensive (~250 samples/event) surveys will be performed each year to assess the distribution, abundance, size (and therefore grazing rate) of benthic bivalves.
Questions addressed: What is the salinity tolerance of C*orbula amurensis?* How well do salinity tolerances explain the distribution of *Corbula*? What are regional trends in benthos and grazing rates?
When: Mid-2006 through 2007.
Cost: $50,000 for laboratory studies of salinity tolerances. No additional costs for the field surveys and data analyses.
Comments: Key staff includes Dr. Marc Vayssieres (DWR), and Dr. Janet Thompson and Heather Peterson (USGS), and Karen Gehrts (DWR).
Feasibility: High.

3g. Synthetic analysis of POD data
IEP 2006-046
Lead agencies: DWR, DFG, USBR and consultants
What: Continuous analysis of POD data to examine overlap in space and time of pelagic species, food organisms, toxicants, toxic algae, and diversions. Effort will tie together and analyze field data, environmental data, operations information and information from otolith, histopathological and bioassays.
Cost: $240,000

Comments: Assumes two senior level researchers dedicated full time. If existing agency staff can't be redirected or new staff hired, then the use of post-doctoral researchers will be investigated.
Feasibility: Fairly high assuming acquisition of suitable PI(s).

3h. Modeling the delta smelt population in the San Francisco Estuary
IEP 2006-041
Lead agencies: USGS, SFSU-RTC, LSU and consultants
What: This element is a CALFED Science PSP grant that will use three different modeling approaches for looking at delta smelt population dynamics.
Questions addressed: What factors are the dominant drivers of delta smelt population dynamics? What are the best management strategies for this species?
When: 2006 - 2008
Cost: $332,000 for 2006, this is a three year study
Feasibility: High.

3i. Development of striped bass and longfin smelt life cycle models
IEP 2006-038
Lead agencies: UCD, SFSU-RTC, LSU, and consultants
What: Life cycle models are need for both striped bass and longfin smelt. Significant information exists and for striped bass some existing models may be able to be modified to meet these purposes. Synthetic modeling capabilities are a very powerful means of evaluating the interactive influences of multiple stressors on fish population dynamics (Rose 2000).
Questions addressed: What factors are the dominant drivers of striped bass and longfin smelt population dynamics? What are the best management strategies for each of these species?
When: 2006-2007
Cost: $200,000 for 2006
Comments: Principal investigators have not been identified at this point.
Feasibility: Fairly high assuming acquisition of suitable PI(s).

3j. Contaminant loads in pelagic fish eggs
IEP 2006-018
Lead agencies: UCD, DFG
What: Striped bass are long-lived predatory fish with the potential to accumulate toxic materials either through food or across the gill surface. Their high fat content make eggs likely physiological targets for toxic effects of fat-soluble contaminants. Unpublished work on egg and larval health of striped bass provides strong grounds for concern. This project will assess the contaminant load of striped bass eggs collected in 2005 and compare that to work done in 1999 and 2000 following the methods developed by David Ostrich. The shorter-lived smelt and shad are less likely to display "maternal gift" impacts, so this work focuses on striped bass. This work will complement and fit in with that described in element 2i.
Questions asked: Has there been a change in amount and/or type of contaminants contained in striped bass eggs since 1999.
When: Chemical analysis of archived samples will take place as soon as DFG water pollution laboratory can process the samples and analysis of the results will follow soon thereafter.
Co*st:* $10,000

Feasibility: High

3k. Preliminary investigations of disease as a factor in the POD
IEP 2006-036
Lead agencies: DFG, USFWS, and UCD
What: Diseases and parasites can generally be found at low frequency and severity in wild fish populations, but outbreaks most often result in fish populations weakened by other stressors. Two minor efforts in 2005 found evidence of parasites and disease. Gartz (2005-3c) examined formalin preserved delta smelt, striped bass, inland silverside and threadfin shad and found internal parasites in about 30 percent of the striped bass, but rarely (<10%) in other species; no external and only one incident of gill parasites were observed. As part of their pathobiological investigation, Ostrach et al. 2005- 3b found numerous pathobiologic indicators in young striped bass, including microscopic parasites not observable by Gartz (2005 3c). The general conclusion of the pathological reports was that findings were not out of the ordinary for wild fish populations. However, Ostrach speculated that incidence of disease and infection could interact with other stressors to depress population abundance. A broader application of appropriate pathobiological methods (including processing of fresh fish) is warranted to assess the need to continue or expand this line of investigation.
Questions asked: What are the incidences and severities of indicators of disease or parasites for each target fish species? What can be inferred from these data about the impacts of disease and parasites on POD fish populations?
When: In addition to the collection of striped bass and delta smelt for histopathology in 2006, sampling will be augmented to allow collection and as needed on-board processing of fresh specimens of all four target fishes for several time periods. Based upon 2006 results, sampling may be repeated in 2007 with enhanced effort for some or all target species.
Cost: $16,000 in direct costs for processing fishes and preparation of report; field collection effort costs are covered in 2006-089 (other sample collection efforts).
Feasibility: This work is moderately feasible and will depend upon our ability to supply field crews at the proper time, coordinate field assistance with diverse PI's and collect sufficient specimens in a limited number of field days.

3l. Update striped bass egg supply estimate
IEP 2006-037
Lead agencies: DFG
What: In 2005, we found no evidence of a recent major change in striped bass fecundity relative to historical data from the 1970s and 1980s (Gingras report). However, striped bass population fecundity is length-adjusted fecundity multiplied by the population estimate of each length group (Stevens et al. 1985; Kimmerer et al. 2000). This element will update the historical striped bass population fecundity estimates through 2005 using the latest length-fecundity relationship and the latest population fork length distribution and abundance estimate information.
Questions asked: Has there been a recent trend in the fecundity of the striped bass population?
When: 2006
Cost: $5,000
Feasibility: Feasibility is high – this is an update of a previously published methodology using existing data.

3m. Zooplankton fecundity and population structure
IEP 2006-044
Lead agencies: SFSU-RTC
What: This is an analysis of *Pseudodiaptomus forbesi* and *Eurytemora affinis* life stage structure and fecundity from archived zooplankton samples (1996-2005) and associated water temperature data. The goals are to determine whether the recent increase in *Corbula* abundance was associated with an increase in mortality of sub-adult (i.e., copepodite stage) *P. forbesi* and *E. affinis*, and/or a reduction in adult *P. forbesi* and *E. affinis* fecundity.
Questions asked: Has there been a downward shift in egg production and/or nauplius survival that resulted in lowered ratios of copepodites to adults? Has there been a change in copepodite survival?
When: 2006
Cost: $70,000
Feasibility: Feasibility is high because the samples have already been collected and pilot work indicates the methods are appropriate to answer the study questions.

3n. Foodweb support for the threatened Delta smelt and other estuarine fishes in Suisun Bay and the western Sacramento-San Joaquin Delta
IEP 2006-082
Lead agencies: SFSU-RTC
What: This is a CALFED Science Program-funded study focused on two related topics:
Topic 1: The threatened delta smelt (*Hypomesus transpacificus*) is now the principal species of concern for management of freshwater flow and diversions in the Sacramento-San Joaquin Delta, and the principal target for restoration in the upper San Francisco Estuary. The abundance of this federally-listed threatened species has been low since the early 1980s, and it has not recovered to the point where it can be considered for delisting; indeed, the 2004 abundance index was the lowest on record. Potential reasons for its low abundance are many, but evidence points to the direct and indirect effects of export pumping of freshwater in the south Delta, toxic substances, and low food supply as likely contributing factors. We believe that the feeding environment of delta smelt may be implicated in the continued low abundance of this species. Delta smelt feed for their entire lives on zooplankton, principally copepods, mainly in the brackish waters of the western Delta and Suisun Bay. As outlined in the submitted proposal, copepod abundance is depressed in this region.
Topic 2: Previous work on the responses of the estuarine ecosystem to interannual variation in freshwater flow has demonstrated a decoupling between the abundance of lower trophic levels and that of fish and shrimp (Kimmerer 2002a, b, 2004). This decoupling may imply that variability in foodweb support is unimportant to variability of higher trophic levels, but there are some important pieces missing from the puzzle. Chief among these is the fact that the supply of labile organic matter from freshwater to the LSZ varies with freshwater flow, and this flux has not been accounted for in analyses of the estuarine foodweb.
The funded proposal includes efforts aimed at understanding and possibly improving the foodweb supporting delta smelt and other estuarine species.
Questions addressed: Within the Low-Salinity Zone of the northern estuary:
1. How do benthic grazing, available solar irradiance, and the concentrations of and composition of nitrogenous nutrients interact to influence the species composition and production of phytoplankton?

2. How does bacterial production respond to changes in particulate and dissolved organic carbon (POC & DOC) delivered primarily through river flow?
3. What is the role of the microbial foodweb in supporting higher trophic levels?
4. To what extent is copepod production dependent on these alternative energetic pathways (phytoplankton and bacterial production)?
When: 2006-2008
Cost: $390,000 each year for three years
Feasibility: High.

3o. CASCaDE computational assessments of scenarios of change for the Delta ecosystem
IEP 2006-078
Lead agencies: USGS
What: This is a CALFED Science Program-funded study. The goals of this project are to develop and apply a model-based approach of ecological forecasting (Clark 2001) to project future states of the Delta ecosystem under prescribed scenarios of change, and to communicate the outcomes of those scenarios to resource managers. Specific objectives include: 1) Develop/refine/calibrate/ verify a set of mechanistic numerical models of climate, watershed hydrology, Bay-Delta hydrodynamics, sediments and geomorphology, and water quality; 2) Link these models to project system dynamics from prescribed forcings, beginning with the climate system (including sea level) and then cascading to the watershed (water, sediment, contaminant runoff), river system (flow, heat, sediment and contaminant transport), and Delta-Bay (hydrodynamics, water temperature, salinity, primary productivity, suspended sediments, geomorphology); 3) Compare projections under prescribed scenarios of within-Delta habitat change and catastrophic levee failures; 4) Apply model projections to assess changes in water and habitat quality, potential habitat expansion of key alien species (*Egeria, Corbicula, Potamocorbula*), incorporation of contaminants such as mercury and selenium into foodwebs, and qualitative population responses of native fishes, and; 5) Work in collaboration with CBDA agencies and interested stakeholders to develop flexible strategic plans based on a range of plausible, quantitative depictions of the Bay-Delta Rivers and Watershed system as it changes during the 21st century.
Questions addressed: This study will establish a model-based approach for placing quantitative bounds on water resource and ecosystem responses to a plausible range of future changes in the Bay-Delta Rivers and Watershed system – critical information that will allow resource agencies to anticipate changes and develop flexibility in their strategic planning to accommodate those changes before they occur. While this project has broad relevance to many goals of the CALFED Science Program, it is most directly relevant to the third priority research topic identified in the 2005 Science Program PSP, which solicits “analytical frameworks that will support assessments and refined predictions of how likely future changes such as population or climate-related hydrological shifts may affect water operations, ecosystem processes, and CALFED projects”.
When: 2006-2008
Cost: $554,000 each year for three years
Feasibility: High.

Feasibility:

The IEP consists of individuals in institutions, agencies and companies uniquely qualified for this study effort. Our program combines the experience and expertise of staff and researchers at multiple agencies including CDWR, CDFG, USFWS, U.S.GS, USBR and UC Davis.

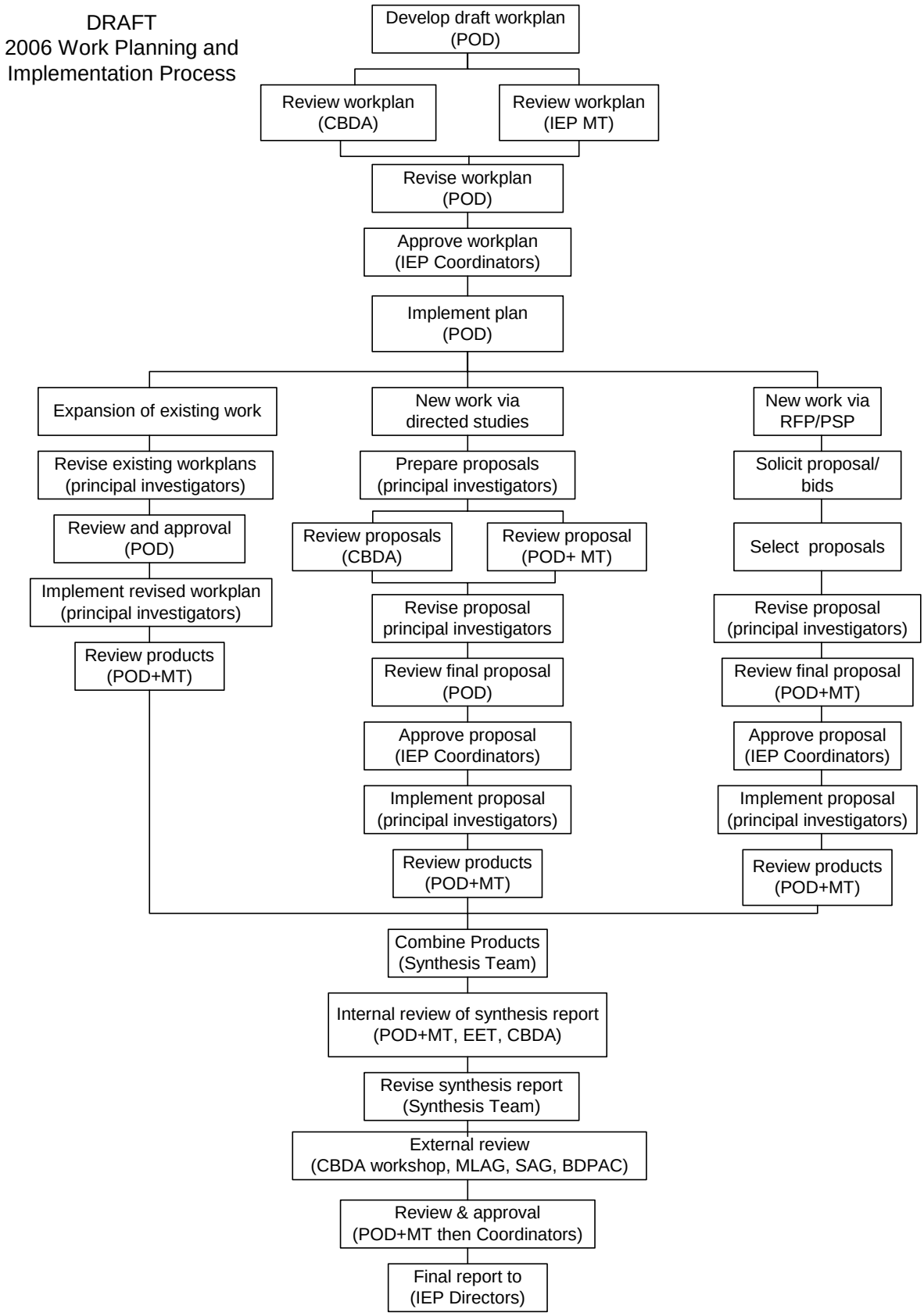
The 2006-2007 study components have been carefully selected based on their feasibility and potential to help differentiate among potential stressors. As demonstrated by the successful 2005 effort, the research team has extensive experience with all of the proposed methods and sampling locations. The proposed monitoring component is a slightly expanded version of sampling that has been conducted for many years, some of which comprises field work that has been performed for 30 to 45 years. Focused data analyses have been proposed as a study component because of the extent of the long-term data sets, and because of the relatively low cost and efficiency. The extensive studies conducted by other groups including Department of Waterways and the Regional Water Quality Control Board will be a major additional asset for the contaminant analyses. To perform the data analyses, only modest redirection of IEP staff will be required. Obviously, the ongoing studies represent a highly feasible study component as these efforts are already underway—they have already been peer-reviewed and have secured funding from IEP or CBDA. Finally, the proposed new studies are based largely on proven field and laboratory methods. Most of these studies are essentially an extension of pilot-scale or shorter-term efforts during the past five years. Examples include otolith studies and histopathology (Drs. Bennett, Hobbs and Teh for 1999 samples) and *Microcystis* surveys (Dr. Lehman for 2004).

The studies will be completed using the existing Endangered Species Act "take" levels authorized by U.S. Fish and Wildlife Service and NOAA Fisheries. The expansion of sampling is relatively modest and should result in minimal change in "take" because smelt population levels are relatively low (i.e. low catch in sampling) and the sampling methods are unlikely to collect substantial numbers of winter- or spring-run Chinook salmon.

Adaptive Management:

An annual and intra-annual adaptive work planning process will be used for the investigations into the observed decline of the pelagic guild (Figure 9). The work in 2006 was designed to look at the range of possible causative factors from a broad perspective in an effort to remove some from consideration and to focus future efforts in the most appropriate directions. The results of the 2006 work will be used to define and focus the efforts needed in subsequent years. For example, if the statistical analysis of historical trends suggests other species or time period should be considered, they will be added to the 2007 program. Actions considered for 2006 may also include changes in water project operations as an adaptive experiment to evaluate effects on entrainment or food web production. Similarly, there may also be recommendations for adaptive regional efforts to reduce contaminant load, reducing populations of exotic species, or increasing food web inputs (e.g. habitat restoration). This effort would likely be coupled with hydrologic and perhaps biological modeling to help screen the range of alternatives. Within any year as information is developed and evaluated, changes in emphasis and direction may be needed. The POD PWT will provide this oversight and evaluation function.

Figure 9.



Updated: May 25, 2005

Project Management, Coordination, and Oversight:

The study is exceptionally complex, including multiple agencies, research topics and principal investigators. Responsive management, close coordination among study participants, and some degree of oversight by independent experts will be critical to the successful completion of the study. We propose the components summarized below for project management, coordination, and oversight. Similar models have been used for IEP and CALFED projects in the past. We hope this level of coordination and oversight will assure the success of this study without overly burdening project staff.

Project Management Team: The project will be managed by a collection of State and Federal agencies: Chuck Armor (DFG), Randall Baxter (DFG), Rich Breuer (DWR), Mike Chotkowski (USBR), Pat Coulston (DFG), Steve Culberson (CBDA), Bruce Herbold (EPA), Anke Mueller-Solger (DWR), Matt Nobriga (DWR) and Ted Sommer (DWR). As in 2005, the group will typically meet weekly to evaluate the progress of the effort. This is the same group that prepared this study plan.

POD Project Work Team: Project design, coordination, and discussion of preliminary results will occur in the newly formed POD PWT. This is a proven model that has been used for a variety of different interdisciplinary IEP studies. This is intended as the primary forum for all principal investigators, and will also be open to other parties, including other regional experts, provided they are willing to actively contribute to the effort. The PWT would meet a minimum of every 2 months, with project management team members alternating as meeting chair. Satellite PWT's would also be formed to allow more intensive communication about technical areas (see below).

POD PWT Satellite Teams: We expect that the parent POD will be fairly large, making it difficult to have detailed discussions about each component. To provide an opportunity for more intensive communication and planning, at satellite project work teams have been formed: 1) food web (Wim Kimmerer); 2) Contaminants (Swee Teh); 3) water exports (Ted Sommer and Mike Chotkowski); 4) sampling (Bill Bennett); and 5) geographical variability (Rick Sitts). At least one additional satellite team is being considered to handle data management and analysis. The lead person(s) from each subject area will routinely be in contact with the appropriate principal investigators and will conduct subject area meetings with principal investigators as needed. Subject area e-mail reflectors may also be set up to further facilitate communications.

Email reflector: Much of the communication for the project would be conducted via a new POD PWT email reflector. The reflector would primarily be used for communication and coordination among the principal investigators; however, it may also be a useful outlet for other scientists who wish to contribute.

Oversight: Project oversight will be provided by the project management team, the POD PWT and an additional group of regional and national experts on the various aspects of this study. These scientists will be part of IEP Science Advisory Group (SAG), with additional support from CALFED and other agency science advisors. This "POD-Science" group will oversee the scientific soundness of this project and provide recommendations for improvement. This group is invited to attend any of the meetings mentioned above and receive e-mails via the newly

established list serves. Meetings with POD PWT members may be arranged as needed. In addition, the POD-Science group will meet in the end of each year to discuss project results, synthesis, and further studies with POD PWT members.

Outreach: Various products and deliverables (see below) will be completed as part of the project. Staff will give a presentation at the numerous conferences (see below) to describe the status of the fish decline and the efforts to identify causes. In addition, the POD PWT will organize an IEP workshop by late 2007 to present preliminary results. A substantial portion of the 2006 and 2007 IEP Annual Meetings will provide opportunities to update the results and present key information.

Analytical Plan:

[To be prepared later]

Budget:

The initial cost estimate for 2006 is approximately $3,709,000. CALFED grants that directly support various POD efforts or that will supply information useful to the POD effort are estimated at $2,379,000 for 2006. Cost estimates for individual program components are provided in Table 2 and in the previous section as part of the project summaries.

Table 2. 2006 POD Budget (amounts are in $1,000)

	ID #	Element POD Total	DWR POD	USBR POD	CALFED	Comments
I. Existing Monitoring						
EMP - Water Quality Monitoring	72	$50	$25	$25		
Fall midwater trawl	3	$65	$33	$32		
Summer townet survey	7	$65	$32	$33		
Larval fish survey - replaces NBA	96	$100	$50	$50		
Field support for additional work	89	$160	$80	$80		
I. TOTAL for EXISTING MONITORING		**$440**	**$220**	**$220**	**$0**	
II. Ongoing Work						
Otolith analysis of delta smelt fish	60	$350			$350	CALFED-ERP
Liver histopathology for pelagic fish	61	$350			$350	CALFED-ERP
Fish diet and condition	62	$75	$38	$37		
Striped bass and delta smelt fecundity estimates	64	$7	$3	$4		
Delta smelt otolith geochemistry and stock structure	40	$76			$76	CBDA Science
Striped bass health investigations	42	$416	$208	$208		
Apparent growth rates of pelagic fish	51	$75	$37	$38		

Delta and Suisun Bay particle tracking investigations	31	$0				
South Delta study: Fishes investigation	17	$0				
Field survey of Microcystis bloom biomass and toxicity	79	$250			$250	CBDA Science
Changes in pelagic fish habitat	66	$55	$28	$27		
Phytoplankton primary production and biomass in the Delta	45	$50	$25	$25		
Benthic macrofauna biomass trends	65	$66	$33	$33		
Analysis of historical population dynamics	84	$60	$30	$30		
Analysis of recent changes in delta water operations	68	$30	$15	$15		
Investigation of Antioch and Pittsburg power plant impacts	87	$70	$35	$35		
Contaminant trends	10	$15	$7	$8		
Acute and chronic invertebrate and fish toxicity	63	$644	$322	$322		
Retrospective analysis of long-term benthic community data	78	$0				
TOTAL for ON-GOING STUDIES		**$2,589**	**$781**	**$782**	**$1,026**	

III. New Special Studies

Contaminant loads in striped bass eggs	18	$10	$5	$5		
Technical review of POD contaminant issues	14	$77			$77	CBDA Science
Preliminary investigations of delta fish diseases	36	$16	$8	$8		
Striped bass and threadfin shad life cycle modeling	38	$200	$100	$100		
Analysis of threadfin shad data	39	$55	$28	$27		
Estimation of pelagic fish population sizes	43	$50	$25	$25		
Overlap analyses of fish, zooplankton, etc.	46	$240	$120	$120		
Undefined studies to support Bay Suisun Bay narrative	47	$500	$250	$250		
Undefined studies to support the winter salvage narrative	80	$500	$250	$250		
Update striped bass egg supply estimates	37	$5	$2	$3		
Modeling delta smelt population in the SF Estuary	41	$332			$332	
Zooplankton fecundity and population structure	44	$70	$35	$35		
CASCaDE computational assessments of scenarios	81	$554			$554	CBDA Science
Foodweb support for delta smelt and estuarine fishes	82	$390			$390	CBDA Science
Gear vulnerability studies	86	$10	$5	$5		
Corbula salinity tolerance, distribution and grazing rates	76	$50	$25	$25		
TOTAL for NEW STUDIES		**$3,059**	**$853**	**$853**	**$1,353**	

2006 POD TOTAL	**Overall POD 2006**	**DWR POD**	**USBR POD**	**CALFED**
	$3,709	**$1,854**	**$1,855**	**$2,379**

Products and Deliverables:

The monitoring and assessment program developed by this multi-institutional collaboration will yield a range of products and deliverables. The POD PWT oversight team above is responsible for the timely completion of all deliverables and serves as the principal contact for IEP staff and other stakeholder groups. The deliverables can be grouped into four general categories:

Monitoring Data. As in previous years, all data collected from the monitoring elements of this study program will be uploaded to the Bay Delta and Tributaries (BDAT) Project Site (http://bdat.ca.gov). BDAT contains environmental data concerning the San Francisco Bay-Delta and provides public access to that data. Over 50 organizations contribute data voluntarily to this project. The database includes biological, water quality, and meteorological data that are used to gauge the health of the estuary and to manage water and environmental resources. Also zooplankton, macroinvertebrate and fish monitoring data will be available directly via the web (http://www.delta.dfg.ca.gov).

Conferences and Workshops. The results of the study will be presented at a special session at the IEP Annual Workshop each year during 2006-2008. A special CDBA workshop will also be considered to discuss the project's final report. Several members of the program will also present their results at a special POD session at the spring 2006 American Fisheries Society meeting. Similar group presentations will be made at the CALFED Science conference (October 2006) and the State of the Estuary Conference (autumn 2007).

Publications and Reports. The researchers in this effort all place high value on the publication of peer-reviewed information. In 2005, the short timeline and management importance of the study effort limited our ability to produce journal articles. For 2006, we propose to submit a minimum of four articles to peer reviewed journals on: 1) analysis of trends in estuarine species (2 articles); 2) trends in physical habitat (1 article); 3) particle tracking results (1 article). By 2007, we propose to submit an additional 4-5 articles on diverse topics including regional analysis of factors affecting primary productivity (Jassby, UCD), toxic effects (e.g. Teh and Werner UCD), and food limitation (e.g. Bennett, Hobbs and Teh UCD). If appropriate, a feature article or collection of articles on the results of the overall effort will be submitted to the IEP Newsletter by winter 2007.

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Appendix A
Annotations for the Species Matrix Models (Figures 3-7)

Longfin Smelt

Mismatch of larvae with food
In winter-spring larvae are present throughout region (See POD 2005 Synthesis Report Appendix A: 2a, Baxter et al.), but no feeding data are available. In summer-fall young fish are beyond larval stage.

Reduced Habitat Space
The longfin smelt has a strong X2 relationship (Jassby et al. 1995) and the 20 mm survey shows its distribution is centered on X2 (Dege and Brown 2004). There is evidence that habitat space can vary with X2 for delta smelt; this may also apply to longfin smelt (See POD 2005 Synthesis Report Appendix A: 2g, Feyrer et al; 2g, Nobriga et al.). Beyond the winter and spring larval period, habitat extends to marine waters (See POD 2005 Synthesis Report Appendix A: 2a, Baxter et al.), so habitat limitation is less likely.

Adverse Water Movement
The increased amount of Sacramento River water pulled towards export facilities in winter (POD 2005 Synthesis Report Appendix A: 2h, Simi and Ruhl) could potentially increase false attraction to upstream migrating adults and the retention of their larvae. In north Delta and Suisun Bay, as well as summer and fall, fish are distributed away from major water project influence (POD 2005 Synthesis Report Appendix A: 2a, Baxter et al.).

Entrainment (Water Projects, Power Plants)
In winter-spring adults and larvae are present throughout region (See POD 2005 Synthesis Report Appendix A: 2a, Baxter et al), and increased salvage has been observed during winter in recent years (See POD 2005 Synthesis Report Appendix A: 2h, Herbold et al.) In summer-fall young fish are beyond export facility influence. In addition, salvage rates are lower in wetter years, when survival is also higher (Jassby et al. 1995; Sommer et al. 1997). In Suisun Bay, effects from power plant operations are possible year-round (See POD 2005 Synthesis Report Appendix A: 2h, Matica and Sommer).

Toxics Effects on Fish
In winter-spring adults and larvae are present throughout region (See POD 2005 Synthesis Report Appendix A: 2a, Baxter et al.). The juvenile and adult population is located downstream (Suisun and farther) in summer and fall. However, there is no current information on direct toxicity or histopathological evidence of toxicity.

Toxics Effects on Fish Food Items
Copepods and larger crustaceans are present throughout range of longfin (See POD 2005 Synthesis Report Appendix A: 2a, Baxter et al.). Results to date, for summer only, indicate that toxicity to standard organisms (*Ceriodaphnia dubia* and *Hyalella azteca*) was sporadic in space and time (see POD 2005 Synthesis Report Appendix A: 3e, Werner).

Harmful Microcystis Bloom
There is no likely impact from *Microcystis* due to mismatch of summer algal blooms in the south and central Delta and longfin smelt habitat, which extends from the north Delta through central San Francisco bay at that time (See POD 2005 Synthesis Report Appendix A: 2a, Baxter et al.; 3d, Lehman et al.).

***Corbula* Impacts on Food Availability**
Corbula reduces availability of zooplankton (Kimmerer and Orsi 1996), which may have declined in Suisun Bay and the west Delta with a recent rebound in clam abundance and distribution. Kimmerer (2002b) reported a step change in longfin smelt abundance following the introduction of *Corbula*. However, *Corbula* is still only abundant in Suisun Bay (See POD 2005 Synthesis Report Appendix A: 3g, Vayssieres and Peterson). Lower grazing rates are suspected to occur in winter.

Disease and Parasites
There is a plausible impact everywhere longfin smelt are present and throughout the year (POD 2005 Synthesis Report Appendix A: 2a, Baxter et al.), but no current information on disease or parasites.

Delta Smelt

Mismatch of larvae with food
In spring larvae are present throughout region (See POD 2005 Synthesis Report Appendix A: 2a, Baxter et al.) with some feeding data available (Nobriga 2002). In other months young fish are beyond larval stage.

Reduced Habitat Space
There is evidence that habitat space can vary with X2 for delta smelt, but it does not show a strong relationship with abundance or a time trend (See POD 2005 Synthesis Report Appendix A: 2g, Feyrer et al; 2g, Nobriga et al.). There is some evidence that south Delta habitat has degraded seasonally (DFG, unpublished data); however, this is a long-term pattern (e.g. 1940s).

Adverse Water Movement
The increased amount of Sacramento River water pulled towards export facilities in winter (POD 2005 Synthesis Report Appendix A: 2h, Simi and Ruhl) could potentially increase false attraction to upstream migrating adults and the retention of their larvae. In north Delta and Suisun Bay, as well as in mid summer through fall, fish are distributed away from major water project influence (POD 2005 Synthesis Report Appendix A: 2a, Baxter et al).

Entrainment (Water Projects, Power Plants)
In winter-spring adults and larvae are present throughout region (See POD 2005 Synthesis Report Appendix A: 2a, Baxter et al), and increased salvage has been observed during winter in recent years (See POD 2005 Synthesis Report Appendix A: 2h, Herbold et al.) In Suisun and north Delta, young fish are beyond export facility influence. In addition, salvage rates are lower in wetter years (Sommer et al. 1997). In Suisun Bay, effects from power plant operations are possible year-round (See POD 2005 Synthesis Report Appendix A; 2h, Matica and Sommer).

Toxics Effects on Fish
Adults and larvae are present throughout region during winter-spring but the juvenile population is distributed away from central and south Delta in summer and fall (See POD 2005 Synthesis Report Appendix A: 2a, Baxter et al.). A single ambient water toxicity test in 2005 failed to show an impact to juvenile delta smelt (See POD 2005 Synthesis Report Appendix A: 3e, Werner), but limited histopathology analysis showed liver lesions, potentially indicators of toxics exposure (See POD 2005 Synthesis Report Appendix A: 3b, Teh).

Toxics Effects on Fish Food Items
Copepods are present throughout range of delta smelt (See POD 2005 Synthesis Report Appendix A: 2a, Baxter et al.). Results to date for summer only indicate that toxicity to standard organisms (*Ceriodaphnia dubia* and *Hyalella azteca*) is sporadic in space and time (see POD 2005 Synthesis Report Appendix A: 3e, Werner).

Harmful Microcystis Bloom
There is no likely impact from *Microcystis* due to mismatch of dense summer algal blooms in the south and central Delta and delta smelt habitat, which extends from the north Delta through

Suisun Bay at that time (See POD 2005 Synthesis Report Appendix A: 2a, Baxter et al.; 3d, Lehman et al.).

Corbula Impacts on Food Availability

Sweetnam (1999), Bennett (2005) and Souza et al. (POD 2005 Synthesis Report Appendix A: 2b) report a decrease in size of delta smelt following the introduction of *Corbula*. Similarly, Teh (POD 2005 Synthesis Report Appendix A: 3b) reports a chronic depletion in liver glycogen levels, possibly a result of food limitation. *Corbula* reduces availability of zooplankton (Kimmerer and Orsi 1996), which may have declined in Suisun Bay and the west Delta with a recent rebound in clam abundance and distribution. However, *Corbula* is still only abundant in Suisun Bay (See POD 2005 Synthesis Report Appendix A: 3g, Vayssieres and Peterson). Lower grazing rates are suspected to occur in winter.

Diseases and Parasites

There is a plausible impact everywhere delta smelt are present and throughout the year (POD 2005 Synthesis Report Appendix A: 2a, Baxter et al.), but no information on disease. A very low incidence of macroscopic internal parasites was detected in the 50 delta smelt examined in 2005 (POD 2005 Synthesis Report Appendix A: 3c, Gartz).

Threadfin Shad

Mismatch of larvae with food
In summer larvae are present throughout region except Suisun Bay (See POD 2005 Synthesis Report Appendix A: 2a, Baxter et al.), but no feeding data are available. In other months young fish are beyond larval stage.

Reduced Habitat Space
Threadfin shad are present everywhere, but less abundant in Suisun Bay (see POD 2005 Synthesis Report Appendix A: 2a, Baxter et al.), but no information was developed on habitat trends or criteria.

Adverse Water Movement
Present everywhere (see POD 2005 Synthesis Report Appendix A: 2a, Baxter et al.). Mechanism unknown, but hydrodynamic effects likely regionally limited to central and south Delta

Entrainment (Water Projects, Power Plants)
Adults and larvae are present throughout region (See POD 2005 Synthesis Report Appendix A: 2a, Baxter et al.). Increased salvage has been observed during winter in recent years (See POD 2005 Synthesis Report Appendix A: 2h, Herbold et al.). However, north Delta is likely outside of entrainment influences. Threadfin shad are less abundant in Suisun, where effects from power plant operations possible year round (See POD 2005 Synthesis Report Appendix A; 2h, Matica and Sommer).

Toxics Effects on Fish
Adults and juveniles are throughout region, but less abundant in Suisun Bay (See POD 2005 Synthesis Report Appendix A: 2a, Baxter et al.). There is no current toxicology or histopathology information.

Toxics Effects on Fish Food Items
Copepods and cladocerans are present throughout range of threadfin shad (See POD 2005 Synthesis Report Appendix A: 2a, Baxter et al.). Results to date for summer only indicate that toxicity to standard organisms *Ceriodaphnia dubia* and *Hyalella azteca*) was sporadic in space and time (see POD 2005 Synthesis Report Appendix A: 3e, Werner).

Harmful Microcystis Bloom
Dense blooms are present in south and central delta during summer and fall, when threadfin larvae, juveniles and adults are also present, posing a plausible impact (See POD 2005 Synthesis Report Appendix A: 2a Baxter et al.; 3d, Lehman et al.).

***Corbula* Impacts on Food Availability**
There are no likely impacts at anytime. There is little distributional overlap between threadfin shad and *Corbula*. (POD 2005 Synthesis Report Appendix A: 2a, Baxter et al.; 3g, Vayssieres and Peterson).

Diseases and Parasites

There is a plausible impact everywhere longfin smelt are present and throughout the year (POD 2005 Synthesis Report Appendix A: 2a, Baxter et al.), but little current information on disease and parasites. A very low incidence of skin lesions was observed for threadfin shad in 2005 (POD 2005 Synthesis Report Appendix A: 3c, Gartz).

Striped Bass

Mismatch of larvae with food
In spring and summer larvae are present throughout region (See POD 2005 Synthesis Report Appendix A: 2a, Baxter et al.), with some feeding data available (Bennett et al. 1995; Bryant and Arnold, In press). In other months young fish are beyond larval stage.

Reduced Habitat Space
Striped bass survival has a strong X2 relationship (Jassby et al. 1995) and 20 mm survey shows its distribution is centered upstream of X2 (Dege and Brown 2004). However, X2 has no time trend (Kimmerer 2002a). There is evidence that habitat space can vary with X2 for young striped bass, but it does not show a strong relationship with abundance or a time trend during summer and fall (See POD 2005 Synthesis Report Appendix A: 2g, Feyrer et al; 2g, Nobriga et al.).

Adverse Water Movement
Increased amount of Sacramento River water pulled towards export facilities in spring and summer (POD 2005 Synthesis Report Appendix A: 2h, Simi and Ruhl) could potential increase the retention of eggs and larvae. Sacramento River flow can also affect transport of eggs and larvae. Flows in the Sacramento River were relatively low in winter and spring of 2001, but increased during subsequent years (POD 2005 Synthesis Report Appendix A: 2h, Simi and Ruhl). In Suisun Bay, fish are away from major water project influence (POD 2005 Synthesis Report Appendix A: 2a, Baxter et al.).

Entrainment (Water Projects, Power Plants)
Striped bass are present throughout region at all times (See POD 2005 Synthesis Report Appendix A: 2a, Baxter et al), and increased salvage ahs been observed during winter in recent years (See POD 2005 Synthesis Report Appendix A: 2h, Herbold et al.). Jassby et al. (1995) found that exports may help to explain variability in striped bass survival. In Suisun Bay, effects from power plant operations are possible year-round (See POD 2005 Synthesis Report Appendix A: 2h, Matica and Sommer).

Toxics Effects on Fish
Juveniles are present throughout region at all times and larvae in late spring-summer (See POD 2005 Synthesis Report Appendix A: 2a, Baxter et al.). Although earlier work showed some evidence of larval toxicity (Bennett et al. 1995), a pair of ambient water toxicity tests for striped bass in 2005 failed to show an impact to juveniles (See POD 2005 Synthesis Report Appendix A: 3e, Werner).

Toxics Effects on Fish Food Items
Copepods, larger crustaceans and small fishes are present throughout range of striped bass (See POD 2005 Synthesis Report Appendix A: 2a, Baxter et al.). Results to date for summer only indicate that toxicity to standard organisms *Ceriodaphnia dubia* and *Hyalella azteca*) was sporadic in space and time (see POD 2005 Synthesis Report Appendix A: 3e, Werner).

Harmful Microcystis Bloom

Dense blooms are present in south and central Delta during summer and fall, when juvenile striped bass also present, posing a plausible impact (See POD 2005 Synthesis Report Appendix A: 2a, Baxter et al.; 3d, Lehman et al.).

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***Corbula* Impacts on Food Availability**

Corbula reduces availability of zooplankton (Kimmerer and Orsi 1996), which may have declined in Suisun Bay and the west Delta with a recent rebound in abundance and distribution. A diet shift and decrease in abundance of striped bass occurred following the introduction of *Corbula* (Feyrer et al. 2003; Bryant and Arnold, in press; DFG unpublished data). However, *Corbula* is still only abundant in Suisun Bay (See POD 2005 Synthesis Report Appendix A: 3g, Vayssieres and Peterson). A lower grazing rate is suspected to occur in winter.

Diseases and Parasites

There is a plausible impact everywhere striped bass are present and throughout the year (POD 2005 Synthesis Report Appendix A: 2a, Baxter et al.). Recent evidence of disease and parasites has been found in young bass (POD 2005 Synthesis Report Appendix A: 3c, Gartz; 3h, Ostrach; Arnold and Yue 1997).