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

January 12, 2007

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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. Narratives have been developed for the major components: 1) *previous abundance levels*, which describes how continued low abundance of adults leads to juvenile production; 2) *habitat*, which describes how water quality variables (including contaminants and toxic algal blooms) affect estuarine species; 3) *top-down effects*, which posits that predation and water project entrainment affect mortality rates; and 4) *bottom-up effects*, which focuses on food web interactions 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 model, on the other hand, posits linkages among different stressors and their possible pathways to produce the observed declines of more than one species. The work plan elements that are based on the narrative model, 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 (17 studies); and 3) new studies (25 studies). None of the work will affect the mandated monitoring currently under performed by IEP. The initial cost estimate for 2007 is approximately $3,260,000 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 2000 (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

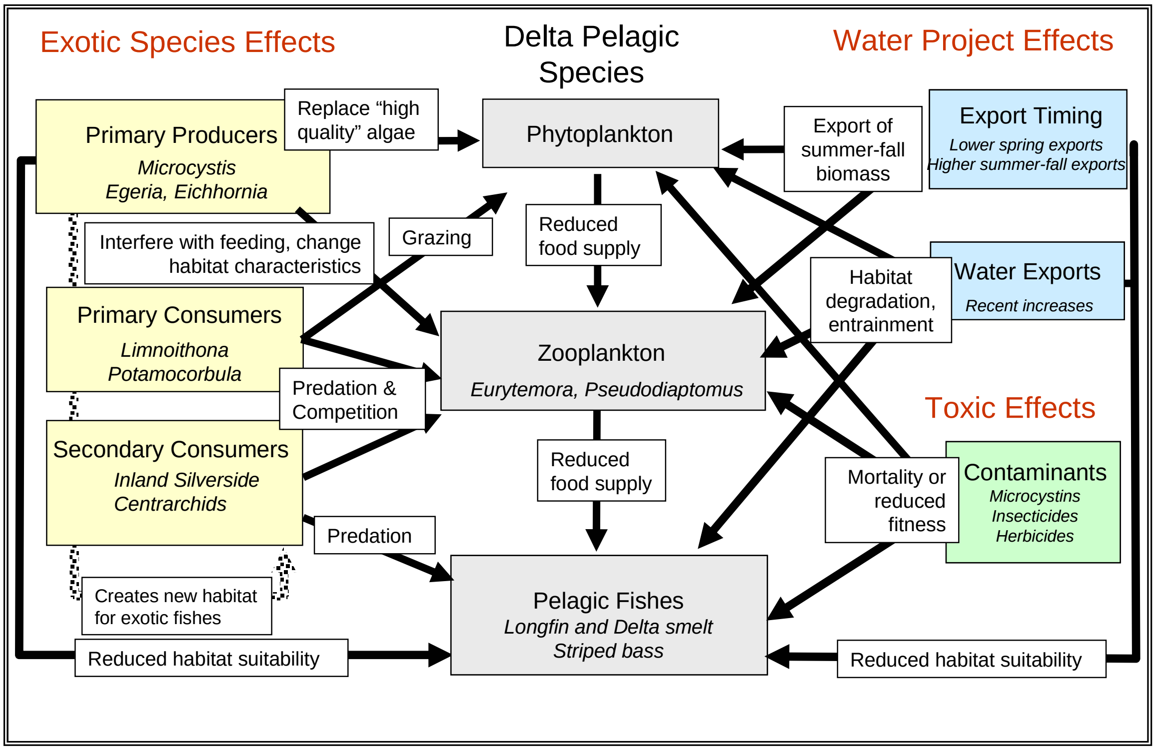


Figure 1. Delta pelagic species conceptual model

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 <u>not</u> 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.

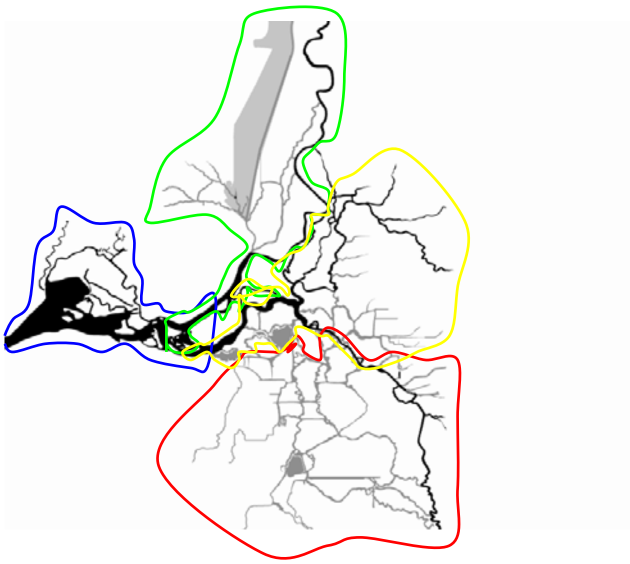


Figure 2. Map of the Delta to identify the regions specified in the matrix.

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

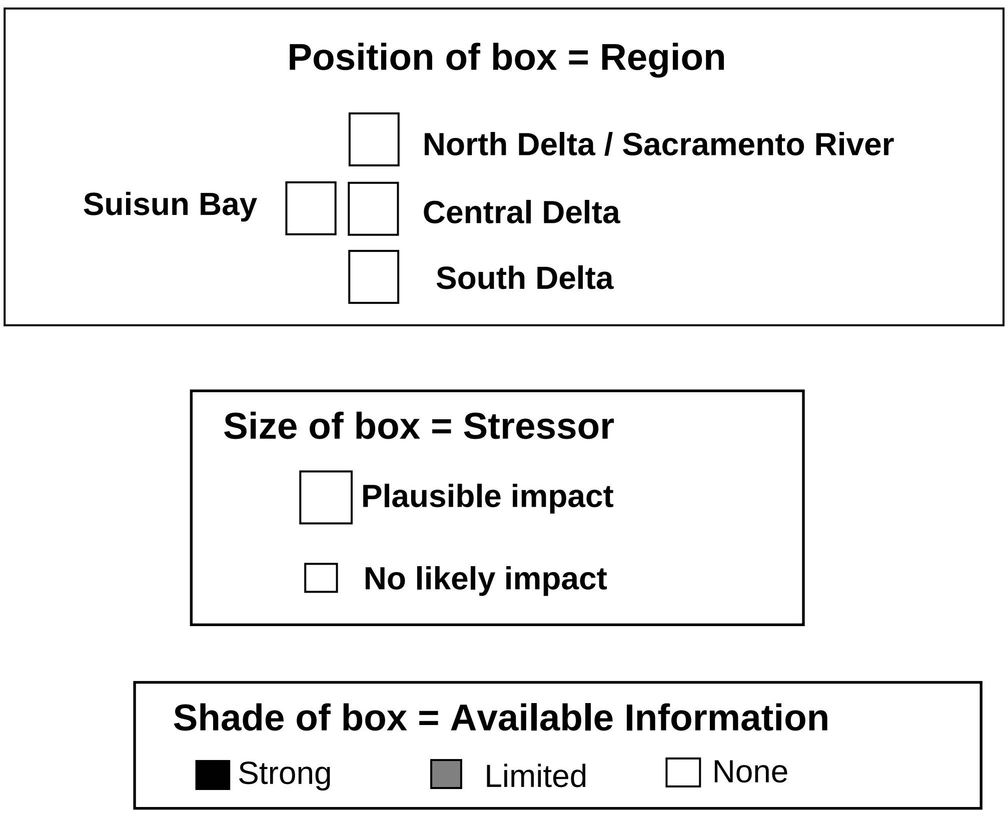


Figure 4. Longfin smelt matrix model

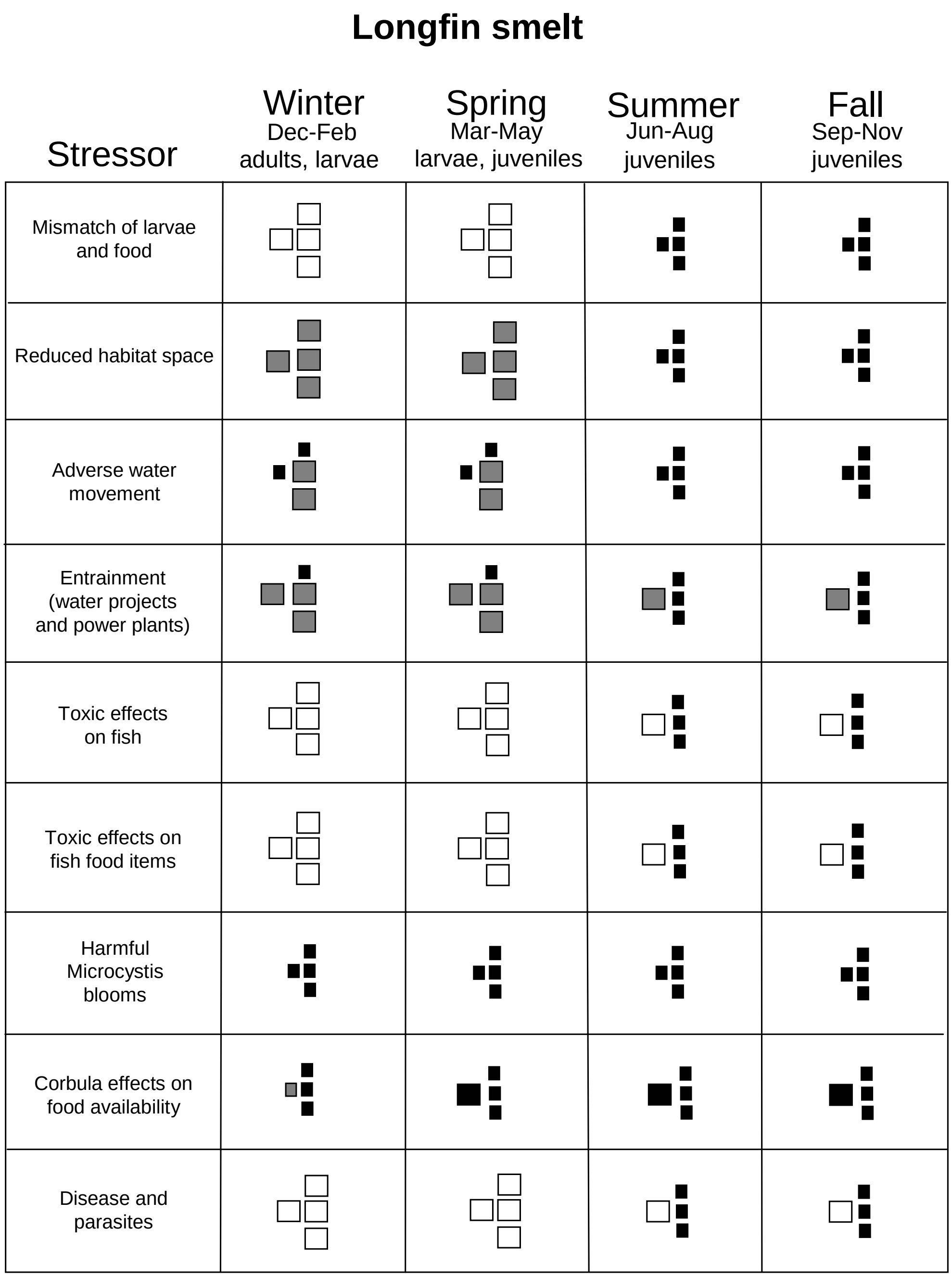


Figure 5. Threadfin Shad matrix model

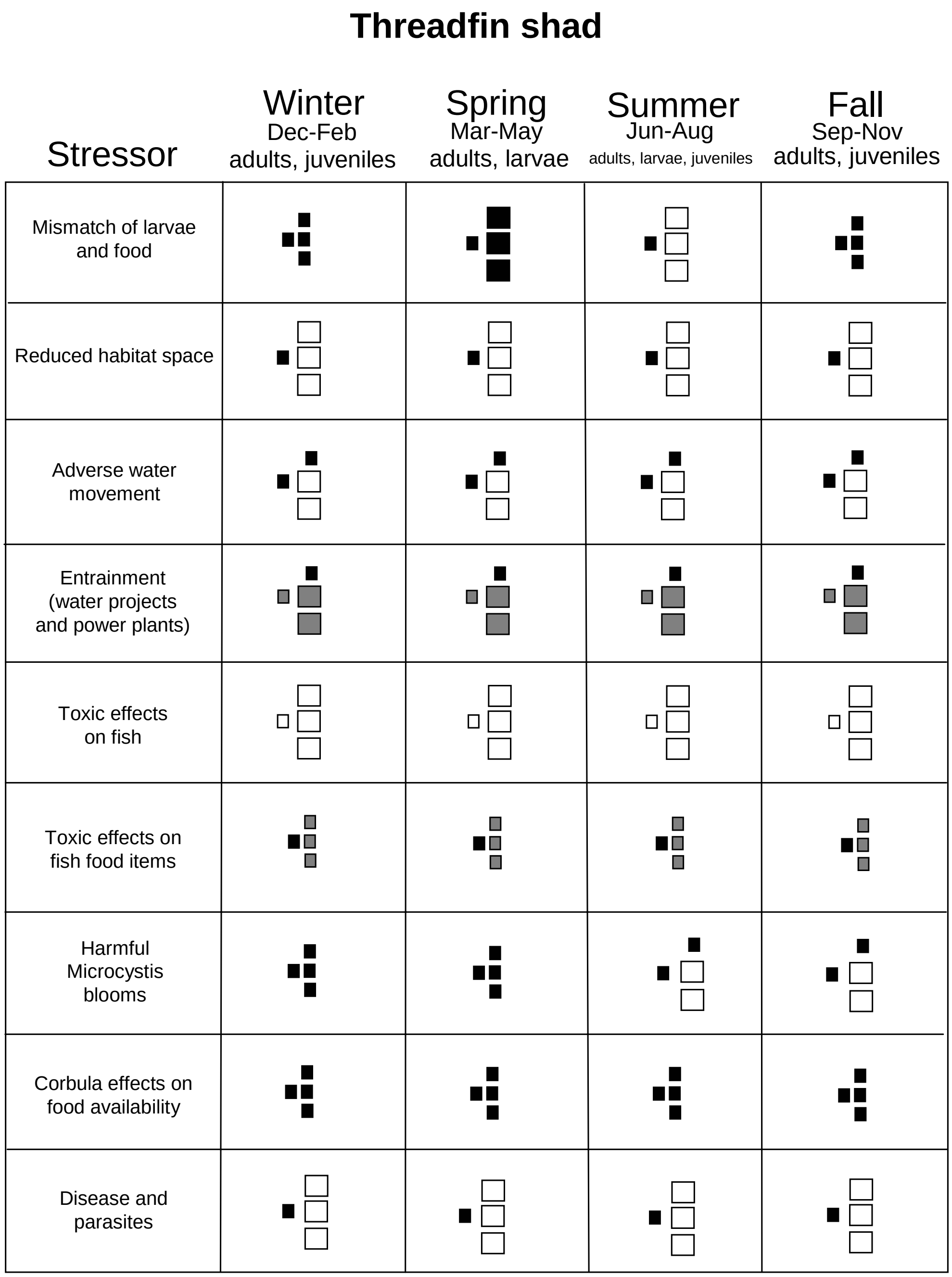


Figure 6. Striped Bass matrix model

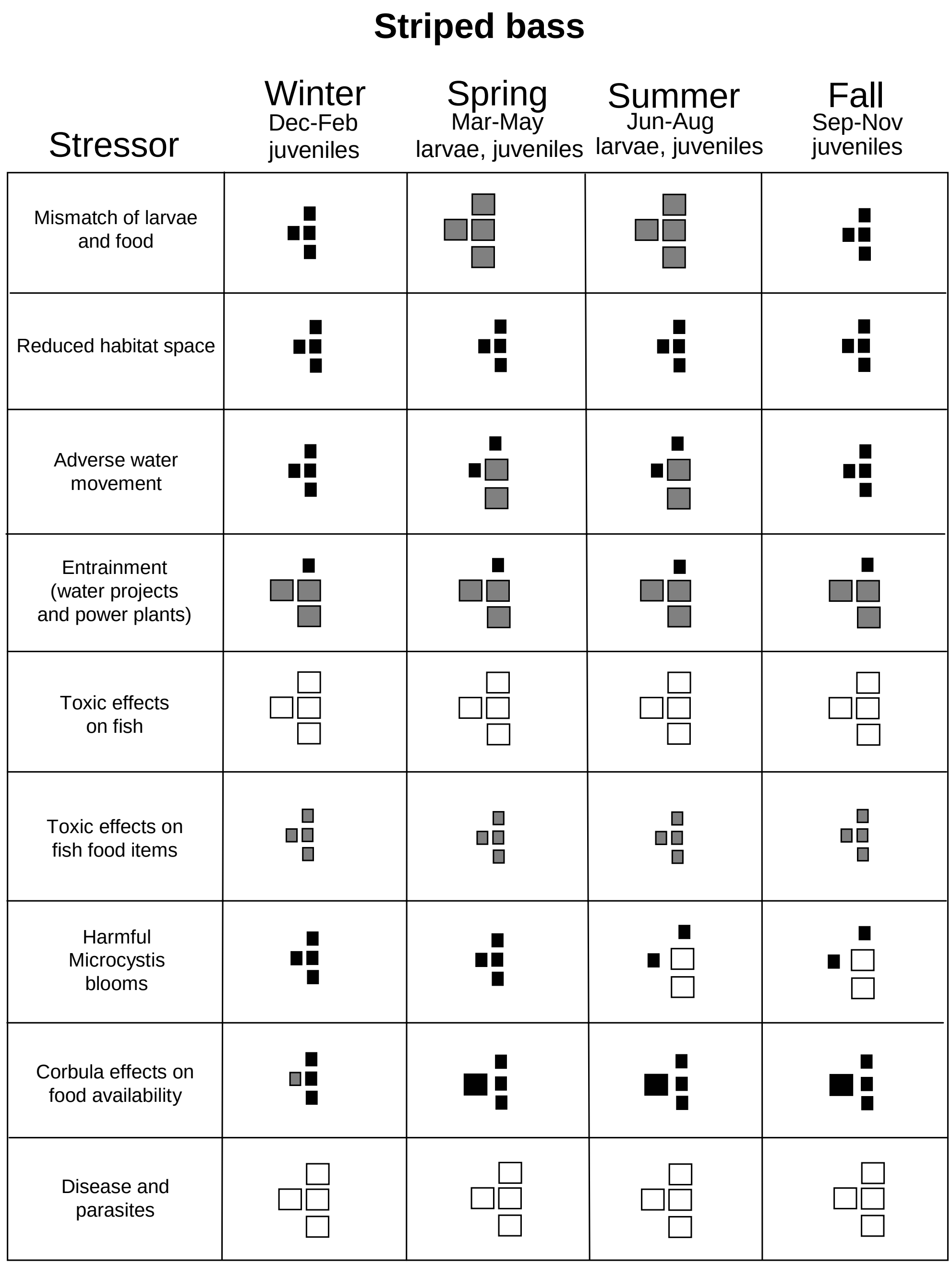
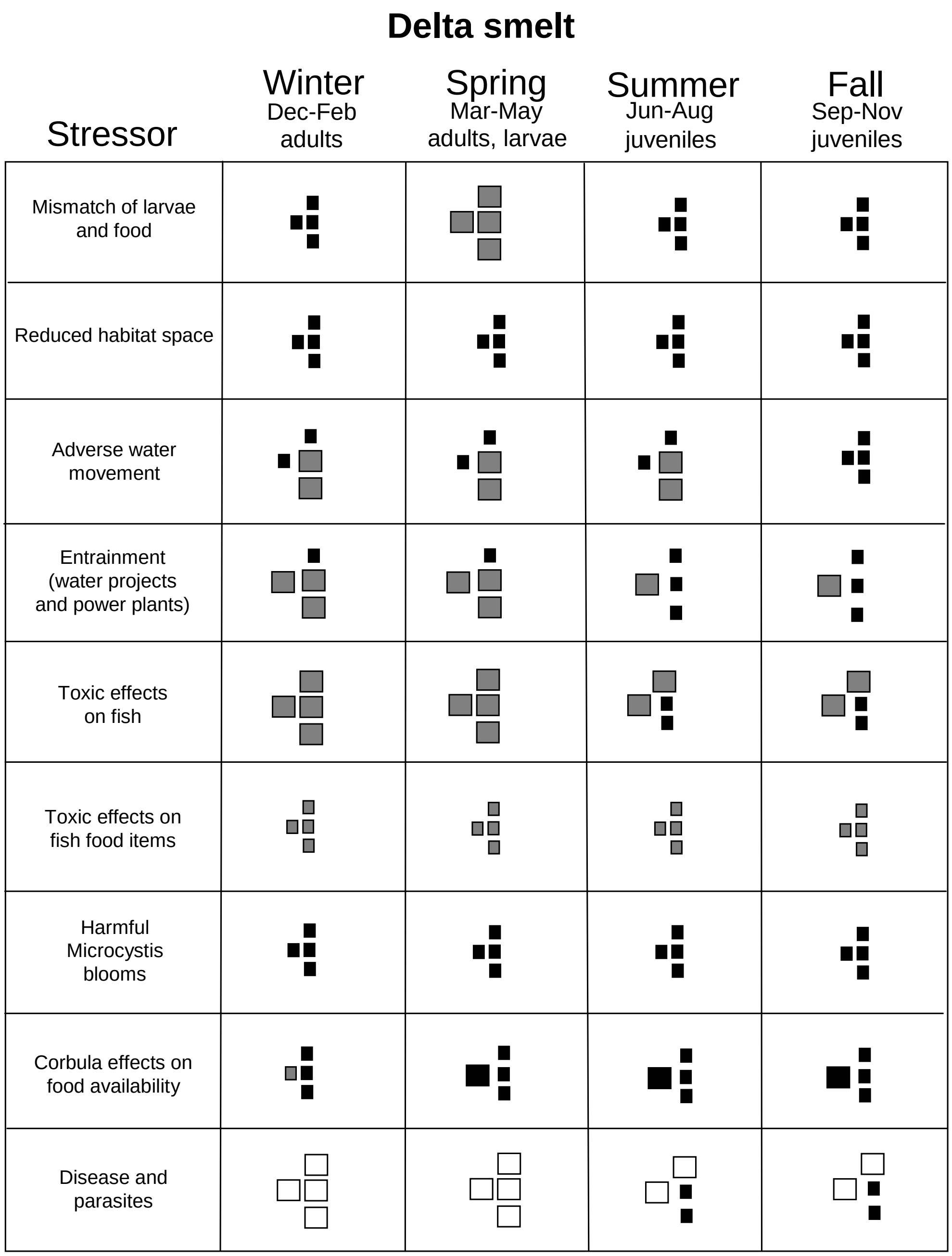


Figure 7. Delta Smelt matrix model



Narrative Model

Guided by available results, we developed a narrative model to describe possible mechanisms by which a combination of long-term and recent changes in the ecosystem could produce the observed declines in catch of pelagic fish species. The model is based on the simple schematic shown in Figure 8. The major components contained in the narrative model are as follows: 1) *prior fish abundance*, which describes how continued low abundance of adults leads to juvenile production; 2) *habitat*, which describes how water quality variables (including contaminants, disease and toxic algal blooms) affect estuarine species; 3) *top-down effects*, which posits that predation and water project entrainment affect mortality rates; and 4) *bottom-up effects*, which focuses on food web interactions in Suisun Bay and the west Delta. These narrative model components are described in detail in the following sections.

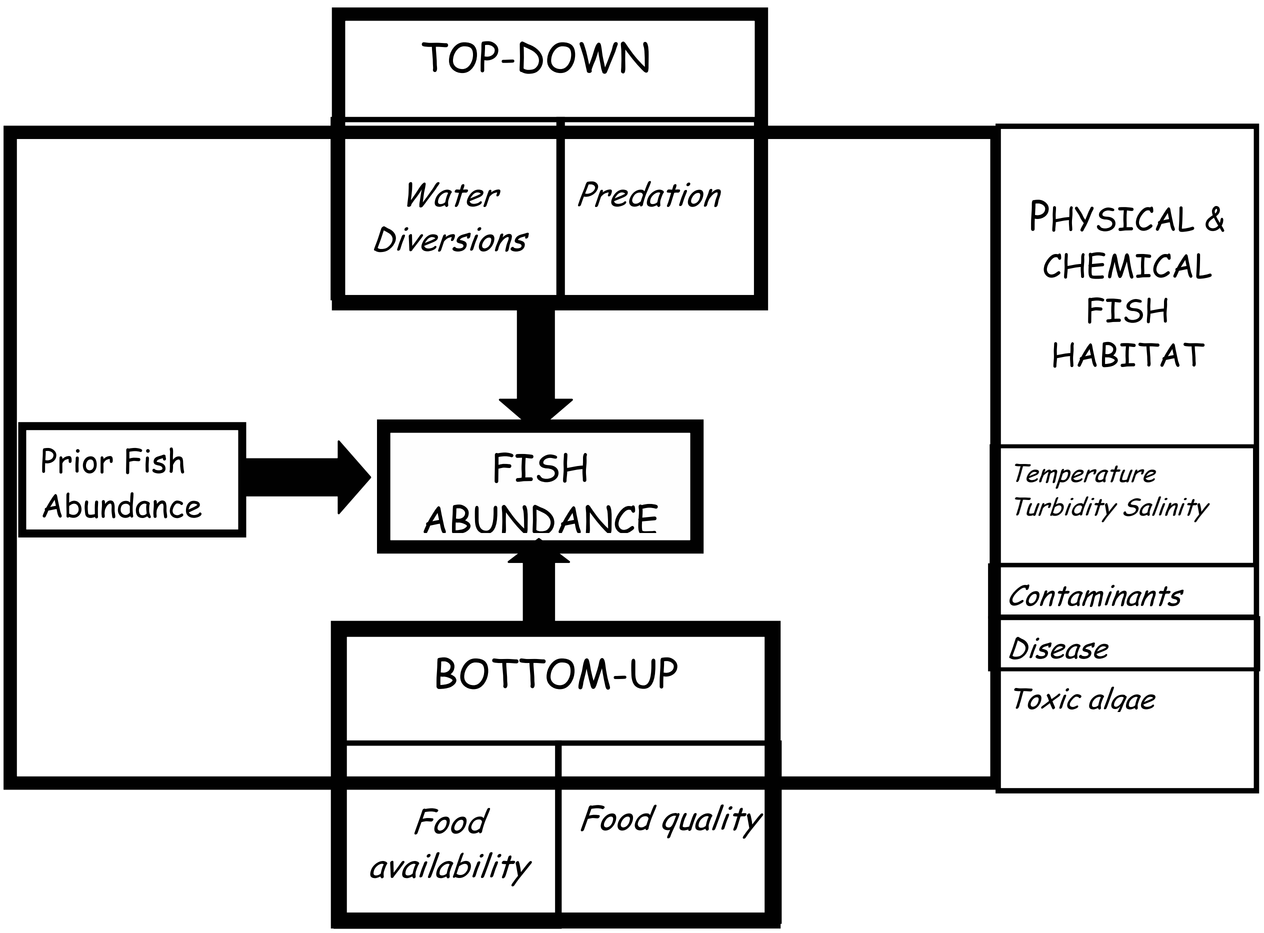


Figure 8: Components of the narrative model for the pelagic fish decline in the upper San Francisco estuary.

Note that these narrative model components 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. Moreover, no single narrative component can explain the declines of all four species though both in tandem plausibly could. The narrative models will be developed and refined 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.

Previous Abundance Narrative

The relationship between numbers of spawning fish and the numbers of young subsequently produced are known as stock-recruit relationships. Stock-recruit relationships have been described for many species and are a central part of the management of commercially and recreationally fished stocks. Different forms of stock-recruit relationships are possible, including density-independent, density-dependent, and density-vague types. The latter refers to situations where there is not a statistically demonstrable stock-recruit relationship observable in available data. Of particular importance for the POD is that adults are needed to make young, so in any form of a stock-recruit model, there is likely a point at which low adult stock will result in low juvenile stocks even under favorable environmental conditions while the stock 'rebuilds' itself. Currently, the adult striped bass stock is not very low, so the previous abundance narrative does not apply to striped bass. However, it may apply to the other three species. It is not currently known what level of abundance index would represent a "point of no return", or a point of slow return. This is partly due to the density-vague nature of delta smelt stock-recruit relationships (see Bennett 2005).

Habitat Narrative

Aquatic habitats are the suites of physical, chemical, and biological factors that species live in (Hayes et al. 1996). The maintenance of appropriate habitat quality is essential to the long-term health of aquatic resources (Rose 2000; Peterson 2003). In our narrative model, a key point is that <u>habitat effects occur on all other components of the model</u> (Figure 8). Hence, changes in habitat can not only affect pelagic fishes, but also their predators and prey. Moreover, we expect that this habitat is especially vulnerable to future climate change.

Pelagic Fish Habitat: Habitat for pelagic fishes is water. More specifically, it is water with suitable concentrations of natural physical-chemical properties such as salinity, turbidity, and temperature; suitably low levels of contaminants, and suitably high levels of prey production to support growth. The four POD fishes use a variety of tidally-assisted swimming behaviors to maintain themselves within open-water areas where water quality and food resources are favorable (Bennett et al. 2002). The four POD fishes also distribute themselves differentially along the estuarine salinity gradient (Dege and Brown 2004), so at any point in time, salinity is a major factor affecting these fishes' geographic distributions. Water clarity is also an important factor influencing the distribution of young-of-year striped bass and delta smelt (Nobriga et al. 2005; Feyrer et al. accepted manuscript). Water temperatures are important to spawning windows for the POD fishes, but do not appear to exert strong influence on population distributions during summer-fall.

The San Francisco Estuary is a tidal river estuary (also known as a river-dominated estuary). In tidal river estuaries, habitat quality varies rapidly because the sizes, shapes, and general suitability of nursery areas change as river flow changes (Stoner et al. 2001; Manderson et al. 2002). In the SFE, pelagic habitat quality is thought to be indexed by changes in the location of the 2 psu isohaline because the abundance of numerous taxa increases when flows into the estuary are high and the 2 psu isohaline is pushed seaward (X2; Jassby et al. 1995). Recent research has shown that X2 is a close surrogate for fall habitat quality for the POD fishes, but only a weak surrogate for summer habitat quality. Recent research has also shown that the *Corbula amurensis* invasion in the late 1980s changed the X2-abundance relationships, at least for longfin smelt (Kimmerer 2002) and young-of-year striped bass (IEP unpublished data). This is strong evidence that the present-day food web responds differently to flow than the pre-Corbula food web did. Food web changes also may have affected delta smelt (Bennett 2005). All of these analyses strongly suggest that a biologic aspect of pelagic fish habitat (food availability) has been degraded. Recent results of POD investigations also show that fall habitat suitability has declined due to increased salinity and water clarity in Suisun Bay and the Delta, respectively.

The IEP monitoring data show a trend toward increasing water clarity in the Delta (Jassby et al. 2002). The most likely reasons for this trend are decreasing sediment supply from the Sacramento River basin (Wright and Schoellhamer 2004) and proliferation of *Egeria densa* (Brazilian waterweed; Brown and Michniuk in press). We do not know whether *Egeria* continues to spread into new areas or whether it has filled all suitable shallow water habitats. In lakes, high densities of *Egeria* and similar plants can mechanically filter suspended sediments from the water column (Scheffer 1999). Increased water clarity may be detrimental to at least two of the POD species, young-of-year striped bass and delta smelt because these species/life stages appear to avoid water that is not very turbid.

In addition to habitat changes from salinity, turbidity and invasive species, contaminants can change ecosystem function and productivity through numerous pathways. The trends in contaminant loadings and their ecosystem effects are not as well understood as the natural water quality and zooplankton trend effects on pelagic fish habitat quality. We are currently evaluating general toxicity and Microcystis toxicity looking both for direct toxic effects on the POD fishes and evaluating indirect contaminant effects such as inhibition of prey zooplankton production.

Habitat for Other Aquatic Organisms: Much of the previous discussion about how physical conditions and water quality affects pelagic fishes is also relevant to other aquatic organisms including plankton and the benthos. Particularly for planktonic species, the residence time of water must also be considered. Lower residence time generally results in lower plankton biomass, but also may reduce cumulative entrainment effects. In contrast, higher residence time may result in higher plankton biomass build-up and increased food availability for planktivorous fishes; however, it may also promote high temperatures, invasion by *Egeria*, and nonnative fishes, *Microcystis* blooms, etc., and subject small fishes to increased cumulative entrainment. Recent particle tracking modeling results for the Delta show that San Joaquin River residence times are much lower than residence times in the Sacramento River, indicating differences in habitat conditions along a north-south gradient.

Climate Change Effects on Habitat: Climate change may have substantial influences on pelagic habitat in the long-term. There are several mechanisms by which climate change could degrade habitat quality for one or more POD fishes. First, there has been a trend toward more Sierra precipitation falling as rain. This increases the likelihood of floods and may further change Central Valley hydrographs. Altered hydrographs interfere with pelagic fish reproduction, which is usually tied to historical runoff patterns (Moyle 2002). Second, there is the potential for sea level rise. Sea level rise will increase salinity intrusion unless sufficient freshwater resources are available to repel the seawater. This will shift fish distributions upstream and possibly reduce habitat area for some species. Third, climate change is projected to result in warmer temperatures in Central California. As stated above, water temperatures do not currently have a strong influence on POD fish distributions. However, summer water temperatures throughout the upper estuary are fairly high for delta smelt. The lethal temperature limit for delta smelt is 25°C (Swanson et al. 2000). Median July water temperatures in the upper estuary are typically 20-23°C (IEP unpublished data). If climate change resulted in median temperatures in the upper estuary reaching 25°C, delta smelt would have little chance of maintaining viable populations.

Top-Down Narrative

This narrative component proposes that the most recent fish declines can be envisioned as the result of the interactive, top-down influence of two kinds of "predators"; piscivorous fishes, and water diversions. The 'top-down' narrative is predicated on the hypothesis that consumption or removal of fish biomass by piscivores (principally striped bass) and water diversions (SWP/CVP exports; power plant diversions) mattered more after the late 1990s because several bottom-up mechanisms interactively reduced the potential of the low-salinity zone and Delta to produce pelagic fish biomass.

Predation Effects: We hypothesize that striped bass predation on pelagic fish biomass had increased in all water year types by the latter 1990s due to an increase in the age-1 and older striped bass population during the 1990s. In the San Francisco estuary, adult striped bass have been at very high population levels in recent years (DFG, unpublished data), potentially exerting an unusually high predation pressure on smaller pelagic fishes.

A change in predation pressure may, in part, be an effect of interactions between biotic and abiotic conditions. Natural, co-evolved piscivore-prey systems typically have an abiotic production phase and a biotic reduction phase each year (e.g., Rodriguez and Lewis 1990). Changing the magnitudes and durations of these cycles greatly alters their outcomes (e.g., Meffe 1984). Generally, the relative stability of the physical environment affects the length of time each phase dominates and thus, the importance of each. Biotic interactions like predation will have stronger community-structuring influence in physically stable systems (e.g., lakes). Historically in the estuary, winter-spring flow variation was the abiotic production phase and the biotic reduction phase probably increased in importance during low-flow periods in summer-fall. Multi-year wet cycles probably increased (and still do) the overall 'abiotic-ness' of the estuary; drought cycles likely increased the estuary's 'biotic-ness' (e.g., Livingston et al. 1997). Our managed system has reduced flow variation much of the time and in some locations more than others. This has probably affected the magnitudes and durations of abiotic and biotic phases (e.g., Nobriga et al. 2005). In other words, reduced flow variability in the estuary may have exacerbated predation effects.

High river flow generally increases fish carrying capacity in the upper estuary (Jassby et al. 1995; Kimmerer 2002). This 'fundamental' relationship has been affected by overbite clams for most of the POD species, but not for all fishes responding to flow (e.g., American shad, splittail; Kimmerer 2002). Thus, because there are more prey fish available in wet years, we hypothesize that flow still increases carrying capacity for piscivorous (age-1 and older) striped bass even though it no longer improves age-0 striped bass carrying capacity. If this is true, the string of wet years between 1993 and 2000 likely allowed the adult striped bass population to rebound even though age-0 production declined. Note that juvenile striped bass also were stocked during this period. We hypothesize that this upsurge of piscivorous striped bass may have interacted with increased entrainment (see below) to reduce POD species abundance. This is analogous to long-term dynamics in cannibalistic fish populations where periods of high adult abundance result in low juvenile production until adult mortality reduces predation pressure on younger cohorts (e.g., Henderson and Corps 1997).

Entrainment: Major water diversions in the delta include the SWP and CVP export facilities, power plants, and agricultural diversions. Of the three, the patterns of agricultural diversions are the least likely to have changed during the pelagic fish decline. As a consequence, our narrative focuses on power plant and export effects.

The two power plants of concern are located in the western delta at Antioch and Pittsburgh. Nonconsumptive 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. Studies in the late 1970s indicate that losses of pelagic fishes can be very high. The recent effects of the diversions are unknown; however, the distribution of some pelagic fishes including delta smelt is centered near the diversions. 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.

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 by at least 2000. The changes in export timing following the Bay-Delta Accord also have the potential to increase entrainment of longfin and delta smelt larvae during late winter and early spring and threadfin shad larvae during summer. 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) Since at least 2001, there appears to have been a step increase in salvage density of most pelagic fishes.
(2) During the same time period, similar increases in salvage have also been observed for many non-pelagic fishes including centrarchids and inland silverside.
(3) 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.
(4) Winter exports from the CVP and SWP have increased since the late 1990s.
(5) Since 2000, San Joaquin River inflow has decreased, while Sacramento River has increased.

Increased winter entrainment of delta smelt, longfin smelt and threadfin shad represents a loss of the pre-spawning adults and all potential progeny. The altered fall-winter hydrodynamics (salinity intrusion, export to inflow ratios, Old and Middle river flows) also may result in more fish spawning in regions where their larvae are vulnerable to entrainment before protective measures begin in April. 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 2001 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. Three main questions need to be considered. Are the recent salvage trends reliable, or the result of data error? Assuming data are correct, why did salvage levels increase? Finally, do increases in salvage result in population-level effects? 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.

Bottom-Up Narrative

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 the clam *Corbula amurensis* (Kimmerer and Orsi 1996; Jassby et al 2002, Feyrer et al. 2003; Kimmerer submitted manuscript). The ***bottom-up hypothesis*** posits that, particularly in drier years, *Corbula* depresses phytoplankton and zooplankton production in Suisun Bay, resulting in decreased availability of food for larval and juvenile striped bass, longfin smelt, and delta smelt. In addition to changes in food availability, changes in food quality due to shifts in phytoplankton and zooplankton species composition may also impact pelagic fish species. Evidence for the hypothesis includes the following.

1. Pelagic productivity in the upper San Francisco estuary is poor relative to other estuaries.
2. Phytoplankton densities and productivity are especially low in the Suisun region.
    - There has been a significant long-term decline in phytoplankton (chlorophyll a) to very low levels in the Suisun region and the lower Delta, with no significant recovery (but also no further declines) over the most recent decade (Jassby et al 2002, Jassby et al in prep.).

- In contrast, phytoplankton did not decline significantly at the upstream Delta monitoring stations and actually significantly increased at the southern-most Delta monitoring stations over the last decade.

3. Phytoplankton species composition has changed more in the Suisun region than elsewhere.
    - Coincident with changes in phytoplankton abundance in the upper estuary, there were also shifts in phytoplankton species composition from more diatom to more flagellate dominated communities (Lehman 1996).
    - This shift was more pronounced in the Suisun region than elsewhere (Jassby et al. in prep).
4. The Suisun region experienced dramatic changes in zooplankton densities and composition.
    - The Suisun region experienced more pervasive long-term declines in the densities of three calanoid copepod species (*Eurytemora affinis, Sinocalanus doerri,* and *Pseudodiaptomus forbesi*) than the Delta (Mueller-Solger et al in prep.). These zooplankton species are important food organisms for pelagic fishes.
    - *P. forbesi* continued to decline in the Suisun and confluence regions over the last decade, while its numbers increased in the southern Delta. These trends may be related to increasing recruitment failure and mortality in the Suisun region due to inadequate food supplies, *Corbula* predation on copepod nauplii, and insufficient replenishment from more productive upstream regions (Durand et al in prep, Kimmerer et al in prep, Mueller-Solger et al in prep).
    - Coincident with the decline in *P. forbesi* abundance in the Suisun region, densities of a more recent invader, the cyclopoid copepod *Limnoithona tetraspina* significantly increased in the Suisun region. It is now the most abundant copepod species in the Suisun and confluence region, but does not occur in the freshwater upper Delta. (Kimmerer et al in prep, Mueller-Solger et al in prep.) This zooplankton species is thought to be inferior food for pelagic fishes including delta smelt.
    - *Acartiella sinensis*, a calanoid copepod species that invaded at the same time as *L. tetraspina,* also reached considerable densities in the Suisun region over the last decade, but not in the upper Delta. Its suitability as food for pelagic fish species remains unclear.
5. Benthic grazing may be a major mechanism for both the long-term and recent changes in the Suisun food web.
    - *Corbula* abundance and distribution in the Suisun region during 2001-2004 was higher than during the 1995-1999 wet period but similar to the 1987-1992 drought (IEP 2005, Vayssieres et al in prep.).
    - There is evidence that benthic changes have major effects on the pelagic food web and fishes (Kimmerer 2002).

5\. Indicators of growth and condition support the hypothesis that there is food limitation in pelagic fishes in the Suisun region (IEP 2005).

- 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.
- In 2005, delta smelt collected from the Sacramento-San Joaquin confluence and Suisun Bay had high incidence of liver glycogen depletion.
- In 2003 and 2004, striped bass condition factor decreased in a seaward direction from the delta to the bay.

6\. There is less evidence for other types of habitat changes in Suisun Bay (IEP 2005).

- Suisun Bay ambient water bioassays in the summer of 2005 were not toxic to *Hyalella azteca, Ceriodaphnia*, juvenile striped bass, or delta smelt.
- *Microcystis* biomass was low in the Suisun Bay region in the summer of 2004 and 2005.

Thus far, there is little evidence that the unusually poor growth rates, health, and condition of fishes in the Suisun Bay region is due to the effects of toxic contaminants or other adverse chemical or physical habitat conditions. Therefore, our working hypothesis is that the poor fish growth and condition in this region 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.

Note that there are some inconsistencies that make this hypothesis unlikely as a single mechanism for the recent pelagic organism decline. Specifically, it is unclear why there has been a substantial recent decline in some Suisun Bay calanoid copepod species, but not in phytoplankton chlorophyll *a* concentration. Second, recent *Corbula* levels are not unprecedented; they are similar to those found during the 1987-92 drought years, so it is unclear if and why benthic grazing would have a greater effect on the Suisun Bay food web during the POD years than during the earlier drought years. It is possible that shifts in phytoplankton and zooplankton community composition and perhaps related changes in the microbial food web in the Suisun region could provide a more consistent mechanism

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 the Narrative Model

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 model posits linkages among different stressors and their possible pathways to produce the observed declines of more than one species.

The work plan elements that are based on the narrative model, therefore, emphasize analyses of the proposed linkages among stressors. Questions addressed by the narrative model are much more quantitative; to what degree do these stressors affect the species of concern? The basic narratives comprising the model are shown in Figure 8. The approach to address each narrative component is described below. Table 1 provides a coded list of studies that will be used to address each of the narratives. Finally, we include a synthesis section to summarize the studies that will be used to integrate the effects of each of the model components, thereby addressing the ultimate question in the POD studies--what is the population level effect of each of the stressors?

An important point regarding the narrative model approach is that each of the component narratives should be considered as an integrated program, not as "stand-alone" programs. As one example, much of the data on abundance and other population measures (e.g. growth, origin) collected in the first narrative model element, "Previous Abundance and Current Abundance", will be used as part of the evaluations in all of the other narrative model elements. Similarly, the "Habitat" narrative element will collect data on hydrology, water quality, and other habitat measures that will be used as the basis for analysis by all of the other narrative elements.

Previous Abundance and Current Abundance

This narrative element will collect a variety of monitoring data that can be used by all of the other narrative elements, and the synthesis efforts. However, the data will also be used specifically to evaluate the role of previous abundance (i.e. adult stock) play in long-term population dynamics of the POD fishes. The major tasks are as follows: Two major types of data will be collected: 1) trends in fish abundance and population size; and 2) trends in other measures of population status.

Trends in fish abundance and population size will be evaluated using the following study elements:

- Summer Townet Survey (2007-007; DFG). This component provides a juvenile abundance index for striped bass and delta smelt.
- Fall Midwater Trawl Survey (2007-003; DFG). This component provides a juvenile abundance index for striped bass and longfin smelt, and adult abundance estimates for delta smelt and threadfin shad.
- Gear Efficiency Studies (2007-086; DFG). This element will explore potential limitations to interpretation of fisheries monitoring datasets that may limit their ability to be used for population abundance estimates.
- Estimation of Pelagic Fish Population Sizes (2007-043; DFG/USFWS-Ken Newman). This component will explore the ability of current IEP data to develop population abundance estimates for POD fishes.
- Threadfin Shad Data Analysis and Population Dynamics (2007-039; DWR). This component will take the first comprehensive look at long-term datasets for threadfin shad.
- Trends in fish biomass (2007-119; DWR). Building on previous estimates by Wim Kimmerer (SFSU), this component will use population data to develop regional estimates of trends in fish biomass.

- Historical population dynamics (2007-084; USBR). Consultant Bryan Manly will continue work with USGS staff on historical population dynamics to assess temporal and special trends in different fish species and communities.

A variety of other studies will collect fish for the evaluation of other useful measures of population health and status:

- Directed Field Collections (2007-089; DFG). This component provides additional fish samples for the elements listed below on an as-needed basis.
- Evaluation of Apparent Growth Rates (2007-051; DFG). This component provides a long-term time series of plausible growth trajectories for POD fishes.
- Delta Smelt Otolith Microchemistry (2007-060 and 2007-040; UCD). This component provides an empirical check of delta smelt growth rates in recent years.
- Delta Smelt Histopathology Investigations (2007-061; UCD). This component provides a basic health assessment for delta smelt to evaluate mechanisms for growth rate changes.
- Striped Bass Health Investigations (2007-042; UCD). This component provides a basic health assessment for young-of-year striped bass to evaluate mechanisms for growth rate changes.
- Disease as a Factor in the POD (2007-036; FWS). FWS will conduct surveys of disease occurrence in delta fishes.

Habitat Effects

This narrative element will collect a variety of physical, chemical and biological data that can be used by all of the other narrative elements, and the synthesis efforts. The data will also be used specifically to evaluate several habitat-specific questions: 1) what are the trends in basic habitat variables? 2) what changes in habitat quantity and quality affect pelagic fishes? 3) what changes in habitat quantity and quality affect other organisms in the estuary? 4) how do toxics, disease and toxic algal blooms affect the previous two groups of organisms? Although the last question is essentially a subset of the second and third, we have chose to include it separately because we have relatively little baseline information on this issue as compared to other water quality measurements.

Trends in basic habitat variables: General patterns in estuarine habitat will be assessed with water quality and hydrological data.

- Environmental Monitoring Program (2007-072; DWR). This component provides simultaneous water quality and relevant non-fish data (e.g., zooplankton, Corbula) throughout the year.
- Changes in Water Project Operations (2007-097; USGS). One result of this “data mining” effort will be to describe trends in the hydrology of the delta and its tributaries.
- CASCADE (2007-081; USGS) The potential effects of climate change on estuarine habitat will be addressed through a computational assessment of scenarios.

Effects of changes in habitat quantity and quality on pelagic fishes: The goal of this series of studies is to characterize trends in pelagic fish habitat suitability. We will pursue the following questions: Has the surface area of suitable habitat changed for one or more of the POD species? Does interannual variation in estuarine hydrology influence the spatial extent of pelagic fish habitat? What factors have affected the spatial extent of pelagic fish 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? How do flow changes alter the size and/or shape of pelagic fish habitat zones? Two main study elements are proposed:

- Evaluation of Changes in Pelagic Fish Habitat Quality using the IEP Long-Term Monitoring Data (2007-066; DWR). This element is a continuation of earlier work by DWR based on analyses of Fall Midwater Trawl and Summer Townet Survey data.
- Spatial Analysis of Habitat and Fish Co-occurrence (2007-120; TBD). The goal of this study element is to use GIS methods to evaluate short time-scale changes in habitat shape in relation to fish distribution and life history needs.

Effects of habitat quantity and quality on other organisms: The approach to evaluating the effects of habitat on other organisms involves several elements intended to improve our understanding of large-scale ecosystem changes.

- Evaluation of Changes in Pelagic Fish Habitat Quality using the IEP Long-Term Monitoring Data (2007-066; DWR). While this study focuses on fish effects (see above), the investigation will also include similar analyses for key zooplankton species, and to the extent possible, for Corbula.
- Corbula Salinity Tolerance and Grazing Rates (2007-076; SFSU). In a new study element, SFSU will use laboratory methods to analyze Corbula salinity tolerances, and the effect of salinity on clam grazing rates.
- Submerged Aquatic Vegetation (SAV) abundance and distribution (2007-102; UCD/USGS). The negative effect of SAV on native fishes in the Delta is now well-established in the literature (Grimaldo et al. 2004; Nobriga et al. 2005; Brown and Michniuk in press). Thus, our primary SAV study question is: Is the distribution of SAV continuing to expand through the Delta? The importance of turbidity as a necessary component of young striped bass and delta smelt habitat also is now recognized, so a second study question is: How much does SAV contribute to increased water clarity in the Delta?
- Delta and Suisun Bay Particle Tracking Investigations (2007-031; DWR). Residence time represents a key variable affecting planktonic organisms. This component will use the DWR DSM-2 model and its particle tracking model to evaluate trends in modeled particle transit times through the Delta. We expect this element to provide data pertinent to larval transport and entrainment of prey resources originating in the San Joaquin River.

Effects of contaminants, disease, and toxic algal blooms: 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.

Although there is a relative lack of information about contaminant effects, 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 9.

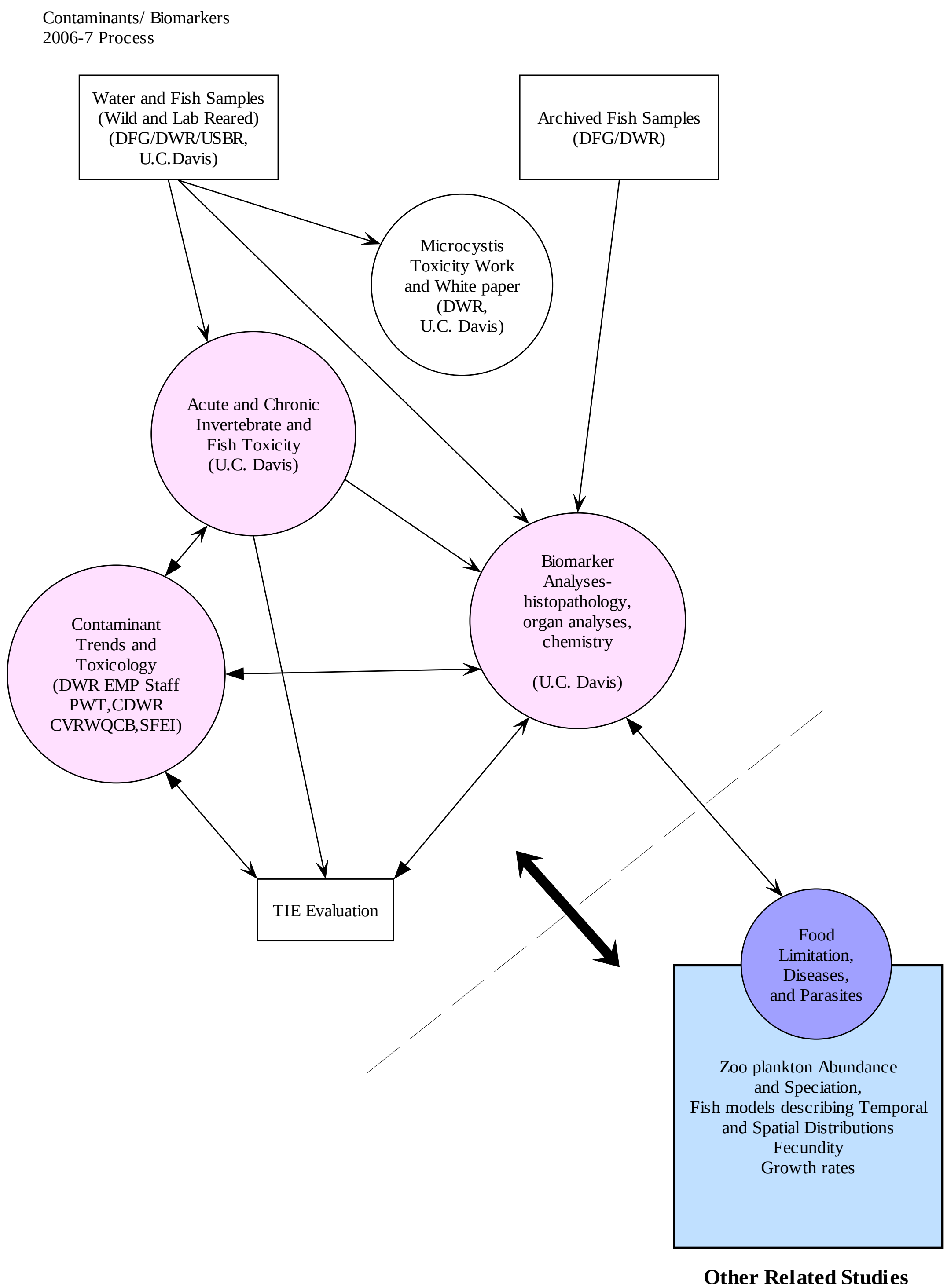


Figure 9. Relationship between components of the POD contaminant investigations.

Water and Fish Samples: Work in 2006-07 will consist of a spatially and temporally expanded sampling for toxicity testing program. As part of this effort, Directed Field Collections (2007-089; DFG) 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 (2007-063; UCD). 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).

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.

The main study elements include POD studies 2007-042 and 2007-061 (UCD), and 2007-036 (FWS). 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). IEP staff also will collaborate with EPA staff on a pilot endocrine disruptor study (2007-112).

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 (2007-121; DWR). 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 work plan 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 (2007-079; DWR). 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.

Top-Down Effects

Predation: The predation portion of the top-down study approach will focus on two major questions: 1) what are the status and trends of the major predators? and 2) what are the effects of changing predation pressure? The first question will be examined using the following suite of studies:

- Status and Trends of Predators in the Delta (2007-118; DFG). Several IEP fish surveys will be analyzed to evaluate the trends in predators, particularly adult striped bass, and largemouth bass. Because most surveys do not effectively sample littoral communities or subadult stages of striped bass, the effort will include exploratory analyses of SWP/CVP salvage, FWS beach seine, and delta bass fishery CPUE data.
- Data from standard Peterson methods will be used to update adult striped bass population estimates for the estuary (2007-116, DFG).

Evaluation of the effects of predation of fish communities is expected to be a more complicated effort, involving some methods that have not traditionally been used for IEP studies.

- Modeling Striped Bass Predation in the Delta (2007-115; DWR). Population estimates developed from the first question will be used as the basis for a bioenergetic model (Fish Bioenergetics 3.0) that will evaluate trends in predation pressure in the delta. The general approach will be to combine age-specific data on growth and abundance of striped bass with bioenergetics modeling to estimate the consumption demand of the striped bass population through time. We will try similar analyses for largemouth bass if sufficient population age structure and growth data are available.

- Modeling of Predator Population Dynamics (2007-116; DFG). Population estimates from the previous study element will be used to model compensatory population mechanisms in the striped bass population. Specifically, the model will examine the likelihood that the present high abundance of adult bass may suppress earlier life stages.

Entrainment and other Facility Impacts: Our overall approach to address the entrainment hypothesis is to focus on the following three the major questions: 1) are the salvage trends valid, or are they an artifact of data error or changes in fish facility operations? 2) assuming that the data are valid, what is the mechanism for the increase in winter salvage?   3) what are the effects of power plant diversions on pelagic fishes.

The study approach includes two studies to address the first question, salvage data quality. Some of these factors can be rapidly assessed with data already in hand or that can be gathered in the coming months.

- Fish Facility History (2007-107; USBR and DFG). One component of this study element will evaluate whether changes that have occurred at the state and federal fish facilities since 1956 have substantially impacted the reported number of salvaged fish
- South Delta Studies (2007-015, -016, and -17; DWR and USGS): The South Delta studies will include a component to examine whether the salvage data are consistent between the SWP and CVP facilities, and whether the salvage changes occurred in winter rather than other months. The logic is that if both observations are true, then it is unlikely that the observed increases in winter salvage are invalid.

To evaluate the second question (Why Did Salvage Increase?), we have identified three primary mechanisms (1) the source of exported water has been changed to an area (e.g. west Delta) 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. With regard to the second mechanism, a shift in distribution may have occurred because south Delta habitat conditions were attractive (e.g. food), or because habitat conditions deteriorated in some regions of the Delta (e.g. contaminants, toxic algae). By analyzing these potential mechanisms at local and region scales, we hope to differentiate the major pathway(s).

- South Delta Hydrodynamic Effects (2007-015, 2007-016, and 2007-017; DWR and USGS). A major focus of the south Delta studies is to determine the effect of hydrodynamics and physio-chemical variables near the SWP on fish behavior and entrainment during relatively short time scale (i.e., hours and days) events.
- Particle Tracking Modeling (2007-031; DWR, USGS and SFSU). Particle tracking using the model DSM2 will be used to evaluate the entrainment risk for different export/inflow scenarios and historical conditions. An additional task will be to model adult delta smelt migratory “behaviors” to evaluate potential entrainment risk during late fall and early winter.

- Changes in Water Project Operations (2007-068; USGS). One result of this "data mining" effort will be to describe any recent changes in water project operations that may have influenced entrainment rates.
- Statistical Effects of Environmental Conditions on Salvage (2007-084; USBR). Consultant Bryan Manly's work USGS staff on historical population dynamics will include statistical analyses of factors affecting entrainment rates.
- Regional indicators of habitat quality, described in detail in earlier sections on Prior Abundance and Habitat. Examples include:
  -Regional comparisons of fish health, growth and origin (2007-060, -061, -062, -018, -036, -121; UCD, DFG, FWS). These studies are designed to evaluate the origin of fish in the south Delta, and whether they show different health, growth or condition than other regions. This should allow us to determine whether there is evidence that environmental factors made fish more vulnerable to entrainment.
  -Regional comparisons of toxicity (2007-063; UCD). Regional toxicity testing will allow us to determine whether water toxicity was different in the south Delta than other areas.
  -Microcystis studies (2007-079; DWR, UCD). Regional sampling will evaluate whether toxic algal blooms were more prevalent in the south Delta than in other regions.

Our study approach to address the third question, the extent of power plant impacts, will be at a much more fundamental level than for the SWP and CVP. Because there have not been detailed studies on power plant entrainment since 1979, much of the focus of this study element will be to collect basic information about species loss, abundance and time. These issues will be addressed in a single study element, "Investigation of power plant impacts" (2007-087; DWR).

Bottom-Up Effects

The approach for to address the bottom-up narrative will focus on factors that may be disrupting the food web for pelagic fishes. Much of the emphasis will be on the greater Suisun Bay region, where it appears that pelagic productivity was reduced following the invasion of the clam *Corbula amurensis.* The major study questions to be addressed are: 1) What are the trends in plankton? 2) What factors influence food availability for pelagic fishes? 3) Are there regional or temporal differences in food quality for pelagic fishes?

Studies in support of the first question will be a continuation of work initiated in 2005. These include the following:

- Trends in Delta Phytoplankton. (2007-045; UCD). This UCD-study will evaluate long-term patterns and trends in phytoplankton production and biomass and other water quality variables in different Delta subregions.
- Zooplankton Trends (2007-072; DWR). As part of analyses for the IEP Environmental Monitoring Program, DWR staff will continue analyses of the zooplankton database to evaluate long-term and regional trends in zooplankton community structure.
- Zooplankton Fecundity and Population Structure (2007-044; SFSU). This new POD element will evaluate whether there are changes in zooplankton fecundity and population structure that may have influenced the pelagic food web.

The second question, food availability, will be addressed by evaluating food web linkages, particularly benthic effects. Several new studies are included.

- Food Web Disruption (2007-082; SFSU). In this CALFED-funded POD element, SFSU will lead an effort to evaluate how the food web has changed in recent years.
- Benthic Biomass and Abundance (2007-065; DWR). This POD element will continue to develop estimates of benthic abundance and biomass.
- Fish Diet and Condition (2007-062; DFG). To help develop an understanding of pelagic fish feeding ecology, DFG will continue with diet analyses of the primary pelagic fishes.
- Food Match/Mismatch (2007-122; DFG). This POD study element will use larval fish and zooplankton data from the 20 mm trawl survey to evaluate whether there is a mismatch between the locations of young pelagic fish and their zooplankton prey.

In addition to food quantity, there is substantial evidence in the literature that food quality can also play an important role in growth and survival of pelagic fishes. Because IEP has little experience with this issue, we are proposing an exploratory effort to identify whether food quality is likely to be an issue in the San Francisco estuary. As a first step, we intend to identify biomarkers that have been found to indicate the nutritional quality of fish diets. This will be combined with identification of biomarkers for contaminant exposure.

- Biomarkers of Contaminant Exposure and Food quality (2007-112; DWR). A new POD study will organize an expert panel to develop a suite of biomarkers that could be used as indicators of contaminant exposure or food quality.

Synthesis for the Narrative Model

The ultimate question for each of the stressors in the narrative model is the degree to which each has population-level effects. This question will be difficult to determine since population estimates are currently unknown. The gap will be addressed, in part, by one of the POD study elements to develop population estimates (see below); however, we acknowledge that the estimates may not be available until late in the study. To avoid delaying synthesis activities, synthetic study elements will emphasize modeling approaches that do not necessarily require absolute population estimates.

- Population modeling of delta smelt and striped bass (2007-041 and 2007-038; UCD, SFSU, LSU). These projects will include both age-structured matrix models and individual-based models that will help to evaluate the effects of each of the stressors on pelagic fishes. The striped bass effort will include a dose-response model to evaluate contaminant effects.
- Statistical analyses of pelagic fish abundance data (2007-084; USBR, consultants). Statistician Bryan Manly will continue his efforts to analyze the environmental factors that affect variation in pelagic fish abundance.
- Population estimates for pelagic fishes (2007-043; USFWS, USBR). Statistician Ken Newman will be working with IEP staff to determine whether existing trawl data could

be used for population estimates. As noted above, this issue is an important first-step in the evaluation of the population effects of different stressors.

- Analyses of historical abundance trends (2007-084; USBR). Consultant Bryan Manly's work with USGS staff on historical population dynamics will include statistical analyses of environmental factors affecting abundance trends.
- Comprehensive synthesis (2007-046; USFWS, USGS, DWR, DFG). Much of the synthesis effort for the POD program will be led by National Center for Environmental Analyses and Synthesis (NCEAS), who will organize a series of work teams of IEP and outside experts.

Study Components

Linkages among work plan elements: All work plan 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 work plan element

Table 1. Relationships among POD work plan elements and narratives.

1. Expanded Monitoring		Narrative model connection	Matrix model link	
PEN[1] #	**Title**		Main stressors	Minor stressors
2007-003	Fall Midwater Trawl	Both	1-9	
2007-007	Summer Townet Survey	Suisun	1-9	
2007-072	Environmental Monitoring program	Suisun	1,2	6,7,8
2006-089	Directed field collections	Both	5-7,9	
2007-096	Larval Fishes Survey	Suisun	1,3,4,5,9	

2. On-going work

PEN #	**Title**			
2007-015, 2007-016, 2007-017	South Delta fisheries and hydrodynamic studies	Salvage	3,4	
2007-031	Delta and Suisun Bay particle tracking investigations	Both	3,4	1
2007-042	Striped bass health investigations	Suisun	5,6,9	
2007-045	Phytoplankton primary production and biomass	Suisun	1,8	3,6,7
2007-051	Apparent growth rates of pelagic fishes	Suisun	1	2,4-9
2007-060	Evaluation of delta smelt otoliths	Both	1	2,4-9
2007-061	Pelagic fish liver histopathology	Both	5,9	1,4,6-8
2007-062	Fish diet and condition	Both	1	2,4-9
2007-063	Acute and chronic invertebrate and fish toxicity tests	Suisun	5,6,7	2,9
2007-065	Trends in benthic macrofauna abundance and biomass	Suisun	8	1,2
2007-066	Evaluation of changes in pelagic fish habitat quality	Both	2	1,7,8
2007-068	Analysis of recent changes in water operations	Both	2,3,4	8
2007-078	Retrospective analysis of long-term benthic data	Suisun	8	1,2
2007-079	Field survey of Microcystis bloom biomass and toxicity	Both	7	2
2007-084	Analysis of historical population dynamics	Both	1-9	
2007-087	Investigation of power plant impacts	Suisun	4	

3. New work

PEN #	**Title**	Conceptual model connection	Main stressors	Minor stressors
2007-018	Striped bass disease and contaminant loads	2D	5,9	1,6,7,8
2007-036	Disease as a factor in the POD	2D	5,9	1,6,7,8
2007-038	Development of striped bass and longfin smelt models	5	1-9	

2007-039	Analysis of threadfin shad data - population dynamics	1A	1-5,7,9	
2007-041	Modeling delta smelt populations in the S.F. Estuary	5	1-9	
2007-043	Estimation of pelagic fish population sizes	1A	1-9	
2007-044	Zooplankton fecundity and population structure	4A	1,2,6	6,7,8
2007-046	Overlap/Synthetic analyses of fish and zooplankton	5	1-9	
2007-076	Corbula salinity tolerance	2C	8	1,2
2007-081	CASCadE	2A	2	3,4,8
2007-082	Food web support for delta smelt and other estuarine fishes	4B	1,8	2,4,5,6,7
2007-086	Gear Efficiency Studies	1A	1-9	
2007-097	Hydrologic changes and Suisun Bay increased salinity	2A, 3A	3	2
2007-102	SAV abundance and distribution	2C	2	
2007-107	Fish facility history	3A	4	
2007-108	Delta smelt culture facility	2D, 3	3,4,5	
2007-112	Biomarkers Workshop	2D,4B	5,6	
2007-115	Striped bass bioenergetics	3B	1,2	
2007-116	Striped bass adult population dynamics	1A, 1B	1,2	
2007-118	Data mining for status and trends of predators	3A	1,2	
2007-119	Delta fish biomass estimation	1A	1-9	
2007-120	Relationship between habitat and distribution	2B	1,2	1,7,8
2007-121	Endocrine disruptor study	2D	5,6	1,7,8
2007-122	Food match-mismatch study	4B	1,2, 3	6, 8
[1] Program Element Number				

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

Conceptual Model Components	
1	Prior and current fish abundance
1A	Abundance trends
1B	Trends in other population indicators
2	Habitat effects

2A	Habitat changes
2B	Habitat effects on pelagic fishes
2C	Habitat changes for other organisms
2D	Disease and contaminants
3	Top down effects
3A	Water Diversions
3B	Predation
4	Bottom up effects
4A	Food availability
4B	Food quality
5	Synthesis

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 introduced shrimp, *Exopalaemon modestus* and updated distribution and abundance analyses. Jellyfish in the San Francisco Estuary are known to feed on copepods and rarely larval fish, and anecdotal evidence suggests 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

Fall Midwater Trawl (FMWT)

IEP 2007-003

Point person: Randy Baxter (DFG)

Lead Agency: DFG

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?

Description: 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 a zooplankton tow at 32 selected sites was conducted, 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 continued as described above, except that water collections for toxicity testing (2007-063) will employ a separate boat and crew, longfin smelt, threadfin shad, and inland silversides will be collected for diet and condition, zooplankton sampling will take place only in September and October.

Time period: Sampling is conducted monthly from September through December and takes 2 weeks to complete.

Resources required

Cost: The IEP FMWT budget is $328,000. An additional $3,000 required to do this work was already obtained in 2006 from POD sources.

PI(s): Randy Baxter (DFG) and Dave Contreras (DFG)

Contract needed / in place: N/A

Contract manager: N/A

Term of contract: N/A

Personnel: The field component of this project requires 1 boat operator, 1 biologist, and 1 scientific aide. The laboratory component requires numerous personnel for preseason preparation, fish identification, data validation, diet and condition procedures, and stomach content analysis.

Equipment: A boat with davits and hydraulics appropriate to pull a midwater trawl net, (such as the *R/V Scrutiny)*, laboratory facilities, warehouse space, formalin, ethanol, and suitable containers for sample collection and preservation.

Deliverables and dates: Survey by survey indices will be calculated and checked by the end of each month and annual indices for POD fishes will be complete by the first of the new year. An article is completed each spring for the Status and Trends edition of the IEP Newsletter. Also trends in distribution and abundance of jellyfish will be examined for data collected since 2001. Zooplankton identification and CPUE calculation will be completed at the end of the year, and will contribute to the fish and food-item match –mismatch analysis (2007-122).

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 all 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 and has collected count data on jellyfish since 2001. The ratio of same-year FMWT to TNS indices for age-0 striped bass is used as an index of summer survival (Stevens et al. 1985). This survey is mandated in the 2004 OCAP Biological Opinion for delta smelt.

Summer Townet Survey

IEP 2007-007

Point person: Randy Baxter (DFG)

Lead Agency: DFG

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?

Description: 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, 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 measurement was be conducted with a 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 continued as described above, except that: water collections employed a separate boat and crew; due to time and equipment limitations, only bottom and surface water quality measures were taken; longfin smelt, inland silverside and threadfin shad were collected along with delta smelt and striped bass for diet and condition; and numeric and volumetric estimation of jellyfish abundance did not begin.

Time period: Every other week from June through August.

Resources required

Cost: The IEP TNS budget is $273,000. The POD TNS budget is $23,000. An additional $60,000 required to complete this work was already obtained in 2006.

PI(s): Randy Baxter and Jason Dubois (DFG)

Contract needed / in place: N/A

Contract manager: N/A

Term of contract: N/A

Personnel: The field component of this project requires 1 boat operator, 1 biologist, and 1 scientific aide. The laboratory component requires numerous personnel for preseason preparation, larval fish identification, zooplankton identification, data validation, length weight procedures, and stomach content analysis.

Equipment: A boat with an A-frame and hydraulics appropriate to pull a sled-mounted townet (such as the *R/V Scrutiny or Munson)*, laboratory facilities, warehouse space, formalin, ethanol, and suitable containers for sample collection and preservation.

Deliverables and dates: Survey indices for striped bass (38-mm Index) and delta smelt will be produced by September 1 of each sampling year and reported to all Agencies through the POD Management Team. These indices will be part of any conference abundance-trend updates for CALFED Science or IEP, and will be published the following spring in the Status and Trends edition of the IEP Newsletter. Also trends in distribution and abundance of jellyfish will be examined for data collected since 2001. Zooplankton identification and CPUE calculations will be completed at the end of the year and will contribute to the fish and food-item match – mismatch analysis (2007-122).

Comments: The TNS collected delta smelt and striped bass for otolith and histopathology investigations, but did not collect sufficient numbers of either to completely support those projects in 2005, so additional field collections were necessary and were added in 2006. A similar circumstance is expected for 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 2004 OCAP Biological Opinion for delta smelt.

Environmental Monitoring Program
IEP 2007-072
Point person: Randall Baxter (DFG)
Lead Agency: DWR and DFG
Questions: How well is abundance (density) of microzooplankton estimated by the historical and alternative 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?
Description: As part of the environmental monitoring program (EMP), 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 including: 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 2 cases, sub-sampling methods will be used, which were not necessary with the low volume 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.
Time period: Sampling has been concluded in 2006. Sample and data analysis will continue in 2007.
Resources required
Cost: The POD EMP budget is $122,000. The IEP EMP budget is $3,034,000.
PI(s): Dean Messer, Anke Mueller-Solger (DWR)
Contract needed / in place: N/A
Contract manager: N/A
Term of contract: N/A
Personnel: A single supervising laboratory assistant identifies organisms from all samples. EMP staff at DWR is responsible for data analysis.
Equipment: Lab equipment available at the DFG lab in Stockton.
Deliverables and dates:
Comments: Recommendations for changes in sampling derived from this investigation will likely be incorporated into Program protocol. This program is mandated by Water Rights Decision 1641.

Directed field collections
IEP 2007-089
Point person: Randy Baxter (DFG)

Lead Agency: DFG and DWR
Questions: There are no questions related to the Directed Fish Collections effort. Questions are listed under the project description that the fish are being collected for (2007-040, 2007-042, 2007-060, 2007-061, 2007-062, and 2007-063).
Description: Directed, short-term field collections. In 2005 and 2006 directed 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. Directed collections were also used to collect water for fish toxicity tests. In 2007, directed collections will be used to collect water for both invertebrate and fish toxicity tests (see 2007-063) and they may be used for some gear efficiency tests, if time permits. Regular once or twice monthly sampling efforts were made to enhance POD fish collection and to allow time for field examination of larval and young juvenile fishes. As staff and boat time permits, directed sampling will continue to be used to enhance collection of target fishes.
Time period: As needed and when staff and boats are available. For water collections, sampling will take two weeks per month.
Resources required
Cost: The 2007 IEP budget for Directed Field Collections is $75,000 from POD sources. $143,000 required for this work was already obtained in 2006.
PI(s): Inge Werner (UCD), Swee The (UCD), Bill Bennett (UCD), David Ostrach (UCD), Steven Slater and Randy Baxter (DFG).
Contract needed / in place: N/A
Contract manager: N/A
Term of contract: N/A
Personnel: Water sampling - one boat operator and one crew member from participating research group; Fish sampling - one boat operator, one scientific aid or biologist and 1-3 researchers from participating research group. In addition, the point person contributes substantial time coordinating logistics for PIs and field crews.
Equipment: Water sampling – 20-32 ft. vessel with sufficient deck space for 8-10 large coolers. Fish sampling – 25-42 ft. vessel capable of deploying trawl gear targeting late stage larvae through juveniles; vessel and gear will change as life stage of fishes progress.
Deliverables and dates: See specific project descriptions listed above for this information.
Comments:

Larval Fish Survey
IEP 2007-096
Point person: Randy Baxter
Lead Agency: DFG
Questions: In 2006, we addressed the question – "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?" – and found the answer to be no. For 2007
Description: Using 2005-2006 sampling data, this survey compared 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 2006, sampling will begin in January to facilitate capture of larval longfin smelt, will include collection of zooplankton samples and will cover the 41 20-mm Survey stations plus 3 additional locations in the main channel of central and eastern San Pablo Bay.
Time period: Every other week from January through early July.
Resources required
Cost: The POD DSLS budget is $97,000. The IEP DSLS budget is $177,000. An additional $80,000 required to do this work was already obtained in 2006.
PI(s): Kevin Fleming (DFG) and Julio Adib-Samii (DFG)
Contract needed / in place: N/A
Contract manager: N/A
Term of contract: N/A
Personnel: The field component of this project requires 1 boat operator and 2 scientific aides. Numerous lab personnel are associated with preseason preparation, lab processing of samples, zooplankton and larval fish identification.
Equipment: This project requires the use of the *RV Munson* since it is the only boat equipped with fore-mounted larval nets. It also requires wet lab space to process approximately 400 quart jar samples that are collected throughout the field season.
Deliverables and dates: Completion of data analysis is planned for fall 2006.
Comments: The 2005 and 2006 surveys replaced the North Bay Aqueduct monitoring on a pilot basis 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 were used in 2006. Surface tows proved ineffective for larval delta smelt (Mayfield in prep.) so the USFWS asked the Delta Smelt Workgroup to modify the sampling design for 2007. The timing and locations of delta smelt larva sampling in 2007 will be guided by catches of ripe and spent adult delta smelt caught in the Spring Kodiak Trawl Survey (Kevin Fleming, DFG, pers. comm.).

II. On-going Studies

Larval fish behavior study
IEP 2007-017
Point person: Ted Sommer
Lead Agency: USBR, USGS and DWR
Questions: What are the behaviors of larval fishes in the south Delta and how is behavior likely to affect entrainment risk under different hydrologic conditions?
Description: 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.
Time period: 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.
Resources required

Cost: This element is funded by non-POD sources.
PI(s): Lenny Grimaldo (DWR)
Contract needed / in place: N/A
Contract manager: N/A
Term of contract: N/A
Personnel:
Equipment:
Deliverables and dates: 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.
Comments:

Delta and Suisun Bay hydrodynamics investigations relying on particle tracking models
IEP 2007-031
Point person: Ted Sommer (DWR)
Lead Agency: DWR and USBR
Questions: 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?
Description: 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 work plan. 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.
Time period: Follow-up 2005 PTM studies underway. Other applications will be ongoing through 2007.
Resources required
Cost: $49,000 from POD sources. Use of 3-D technologies will require contracting with an outside entity and the cost of this is unknown at present.
PI(s): The key staff includes Mike Mierzwa, Ted Sommer and Bob Suits (DWR) and Mike Chotkowski (USBR).
Contract needed / in place: N/A
Contract manager: N/A

Term of contract: N/A

Personnel:

Equipment:

Deliverables and dates:

Comments: Additional study questions will be developed by the POD Flows and Operations PWT.

Striped bass health investigations

IEP 2007-042

Point person: Marty Gingras (DFG)

Lead Agency: UCD, support from DFG

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?

Description: 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.

Time period: 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.

Resources required

Cost: $416,000 from POD sources.

PI(s): David Ostrach (UCD)

Contract needed / in place: In place.

Contract manager: Ted Sommer (DWR)

Term of contract: Through September 14, 2007.

Personnel:

Equipment:

Deliverables and dates: Reports on results of the adults and larvae are due by March 30, 2007 and September 14, 2007.

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 but may not be available separately in 2007.
The additional proposed work not funded in 2006 is more experimental and may not be as conclusive as the work proposed for funding.

Phytoplankton primary production and biomass in the Delta

IEP 2007-045

Point person: Anke Mueller-Solger

Lead Agency: UCD, DWR-DES

Questions: 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?

Description: 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 sub regions 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.

Time period: Ongoing through 2007.

Resources required

Cost: $50,000 per year from POD sources.

PI(s): Dr. Alan Jassby (UCD), in collaboration with DWR-DES staff (Anke Mueller-Solger & Marc Vayssières)

Contract needed / in place: In place

Contract manager: Ted Sommer (DWR)

Term of contract: Through June 30, 2008.

Personnel:

Equipment:

Deliverables and dates: An IEP newsletter article, progress report, and a presentation (CALFED or IEP) are due by June 30, 2007. By June 30, 2008, the deliverables will be an IEP newsletter article, a final report (an IEP technical report is intended), and at least one peer-reviewed journal article.

Comments:

Apparent growth rates of pelagic fishes and relationship to abundance

IEP 2007-051

Point person: Randy Baxter (DFG)

Lead Agency: DFG

Questions: Have species' apparent growth rates or year-end mean lengths declined, particularly those of 2001-2004 versus previous years? Are environmental factors, such as X2 position or zooplankton abundance, predictive of apparent growth rates or year-end mean size?

Description: 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).

Time period: We are examining various data sets for these analyses and propose to complete analyses by March 2007.

Resources required

Cost: The 2007 POD budget for this element is $38,000 from POD sources. $39,000 required to complete this work was already obtained in 2006.
PI(s): Randy Baxter, Kathy Hieb, Kevin Fleming, (DFG)
Contract needed / in place: N/A
Contract manager: N/A
Term of contract: N/A
Personnel: Existing IEP staff and funds can be redirected to this analysis.
Equipment: There are no field or laboratory requirements for this project.
Deliverables and dates: Two progress reports; March and August 2007.
Comments:

Evaluate delta smelt otolith microstructure and microchemistry
IEP 2007-060 and 2007-040
Point person: Randy Baxter (DFG)
Lead Agency: UCD
Questions: Do growth rates of delta smelt vary seasonally or geographically? When and where in the estuary are delta smelt produced?
Description: 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 TNS and FMWT 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.
Time period: Work should be started as soon as practical and continue for at least one year.
Resources required
Cost: Estimate is $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.
PI(s): Dr. Bill Bennett (UCD) and James Hobbs (UCD)
Contract needed / in place: In place
Contract manager: Steven Rodriguez (DFG)
Term of contract:
Personnel: Field personnel are supplied by DFG Townet, Fall Midwater Trawl and 20-mm surveys, and targeted sampling.
Equipment:
Deliverables and dates:
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 (2007-061) and diet/condition work (2007-062) to provide a comprehensive timeline of the relative condition of the fish that we could compare to timing of potential stressors.

Delta smelt histopathology investigations
IEP 2007-061
Point person: Randy Baxter (DFG)
Lead Agency: UCD

Questions: 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?
Description: Histopathological examination of fish. 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 indicate the presence of toxic compounds. Lesions in fish from important studies should be compared to lesions observed in fish from filed 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.)
Time period: 2006-2007.
Resources required
Cost: $350,000 from CALFED ERP grant
PI(s): Dr. Swee Teh (UCD)
Contract needed / in place: In place
Contract manager: Steven Rodriquez (DFG)
Term of contract:
Personnel: Field personnel are supplied by DFG Townet, Fall Midwater Trawl and 20-mm surveys, and targeted sampling.
Equipment: Field sampling vessels and nets, as well as laboratory supplies needed for storage and preservation of specimens are supplied by DFG. Laboratory analysis is conducted at UCD.
Deliverables and dates:
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). Histopathological studies play an important role in directing and focusing special studies.

Quantitative analysis of stomach contents and body weight for pelagic fishes
IEP 2007-062
Point person: Randy Baxter (DFG)
Lead Agency: DFG
Questions: 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 content, condition (weight at length) or histopathology vary between salvaged fish and fish collected elsewhere?
Description: 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 studies 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. 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. In 2006, examination of parasite load was transferred to researchers conducting histopathological investigations (2006-061, 2006-042).

Time period: 2006 and 2007

Resources required

Cost: The 2007 POD budget is $11,000. $66,000 required to do this work was already obtained from POD sources in 2006.

PI(s): Randy Baxter and Steve Slater (DFG)

Contract needed / in place: N/A

Contract manager: N/A

Term of contract: N/A

Personnel: Field collection is conducted by all long-term fish monitoring surveys. Fish are retained after reaching quotas for otolith and histopathology samples; all POD fishes are retained by Bay Study for condition and diet analyses. Laboratory personnel (3 scientific aids and part time Sr. Lab Assistant) are directed in sample processing by a Biologist.

Equipment: Current long-term monitoring vessels and gear will be employed; some gear modification may occur for directed sampling. Laboratory equipment is currently available at DFG Stockton.

Deliverables and dates: Posters for CALFED Science Conference, October 2006. Oral progress report, December 2006. Poster and oral presentation for IEP Asilomar Workshop, February 2007. Fish length-weight and diet databases will be added to until the start of 20mm Survey redirects lab staff in March of each year. Additional specimens will be archived for future investigation or increased sample size when staff time permits.

Comments: DFG staff will collect samples and process diet information. The IEP has extensive experience with these techniques, but lost staff leading part of this work. Lab work was delayed substantially in 2006 by the loss of a biologist and long delays in hiring Scientific Aides and Senior Lab Assistants.

Acute and Chronic Invertebrate and Fish Toxicity Tests

IEP 2007-063

Point person: Randy Baxter (DFG)

Lead Agency: UCD

Questions: 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?

Description: 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 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).

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.

Time period: 2006-2007

Resources required

Cost: $644,000 from POD sources.

PI(s): Inge Werner (UCD)

Contract needed / in place: Yes

Contract manager: Ted Sommer (DWR)

Term of contract: Through December 2007.

Personnel: Field water collection will be facilitated by a DFG boat operator; otherwise, UC Davis personnel will conduct all preparation and processing.

Equipment: Field collection via a 20-32 foot research vessel supplied by DFG. Bioassay and TIE equipment currently available at UC Davis Aquatic Toxicology Lab.

Deliverables and dates: Quarterly progress reports to Contract Manager; oral progress reports to IEP project work teams by September 2006 and September 2007; oral progress report at the IEP Annual Workshop in February 2006; peer-reviewed professional journal article and/or report in the summer 2007 IEP Newsletter.

Comments: 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

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Trends in benthic macrofauna biomass

IEP 2007-065

Point person: Anke Mueller-Solger (DWR)

Lead Agency: DWR

Questions: 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?

Description: 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 was 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 is conducted as part of work plan element IEP 2007-078 and other ongoing EMP data analyses. This work will continue in 2007.

Time period: 2006-2007

Resources required

Cost: Redirected staff from the EMP (2007-072) will be used to accomplish this work. Additional funding for an expansion of this project has recently been granted by the CALFED Science Program. This funding will likely become available by the end of 2007 or early in 2008.

PI(s): Dean Messer (DWR), Karen Gehrts (DWR), Wayne Fields of Hydrobiology would provide identification help and Dr. Janet Thompson, USGS, would provide additional expertise.

Contract needed / in place:

Contract manager:

Term of contract:

Personnel: Scientists: 365 hours = $31,400; 1 Scientific Aide: 550 hours = $21,110; Wayne Fields: 30 hours = $3000.

Equipment: Supplies: $10,000

Deliverables and dates:

Comments: Investigation does not depend on the availability of new field data. Special analytical techniques that are required are well-known.

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

IEP 2007-066

Point person: Ted Sommer (DWR)

Lead Agency: DWR and DFG

Questions: 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?

Description: 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.

Time period: 2006-2007

Resources required

- Cost: $184,000 from POD sources
- PI(s): Matt Nobriga, Fred Feyrer, and Ted Sommer (DWR)
  - Contract needed / in place: N/A
  - Contract manager: N/A
  - Term of contract: N/A
- Personnel: Two Environmental Scientists at 25% time. Additional assistance of redirected IEP staff may also be needed.
- Equipment: There is no field or lab component to this study.

Deliverables and dates: Two peer-reviewed journal articles will be prepared by June 30, 2007.

Comments: This study component is a continuation of the successful 2005 effort.

Recent changes in water project operations

IEP 2007-068

Point person: Rich Breuer (DWR)

Lead Agency: DWR

Questions: This element will address two major questions: 1) how have water project operations changes in recent years; and 2) what is the cause of fall salinity increases in the delta?

Description: This project will use hydrologic data from the delta and upstream areas to identify changes that have occurred in water project operation during the pelagic fish decline.

Time period:

Resources required

Cost: There are no additional funds required to accomplish this work.
PI(s): Lenny Grimaldo (DWR)
Contract needed / in place: N/A
Contract manager: N/A
Term of contract: N/A
Personnel: Existing staff members will be redirected to accomplish this task.
Equipment:
Deliverables and dates:
Comments:

Retrospective analysis of long-term benthic community data
IEP 2007-078
Point person: Anke Mueller-Solger (DWR)
Lead Agency: DWR & USGS
Questions: At the 4 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?
Description: 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.
Time period: ongoing through 2007
Resources required
Cost: Existing staff will be redirected to accomplish this task.
PI(s): Key staff includes Heather Peterson (USGS), Marc Vayssieres (DWR), and Dr. Janet Thompson (USGS).
Contract needed / in place: N/A
Contract manager: N/A
Term of contract: N/A
Personnel:
Equipment: No equipment is required.
Deliverables and dates:
Comments:

Field survey of Microcystis aeruginosa Bloom Biomass and Toxicity
IEP 2007-079
Point person: Rich Breuer (DWR)
Lead Agency: DWR-DES, DFG
Questions: 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?

Description: 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 (TNS, FMWT) 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.

Time period: Summer and fall 2006-2007.

Resources required

Cost: 250,000 from CBDA Prop 50 Science Program PSP.

PI(s): Peggy Lehman (DWR) and Dan Riordan (DWR).

Contract needed / in place: In place.

Contract manager:

Term of contract:

Personnel: 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.

Equipment:

Deliverables and dates:

Comments: 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.

Analysis of historical population dynamics

IEP 2007-084

Point person: Mike Chotkowski (USBR)

Lead Agency: USBR
Questions: 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 and search of, (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. We will also examine relevant historical data to evaluate historical support for the two "narrative" hypotheses developed in 2005.
Description: 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.
Time period: Ongoing through 2007.
Resources required
Cost: The 2007 budget is $62,000 from POD sources. Some funds may be required for contracts with external parties in the future.
PI(s): Mike Chotkowski (USBR) and Dr. Bryan Manly
Contract needed / in place: N/A
Contract manager: N/A
Term of contract: N/A
Personnel: Personnel other than the CO-PI's are not required.
Equipment: There is no field or lab equipment associated with this project.
Deliverables and dates: In 2006 we will 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.
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.

Power Plant Operations
IEP 2007-087
Point person: Ted Sommer (DFG)
Lead Agency: DWR and others
Questions: 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?
Description: 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.
Time period: Ongoing through 2007.
Resources required
Cost: Any additional costs for agency work will be absorbed by existing DWR personnel.
PI(s): Randall Mager and Stephanie Sparr (DWR)
Contract needed / in place: N/A

Contract manager: N/A
Term of contract: N/A
Personnel:
Equipment:
Deliverables and dates:
Comments: 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.

III. New studies

Contaminant loads in pelagic fish eggs
IEP 2007-018
Point person: Randy Baxter
Lead Agency: DFG, UCD
Questions: Has there been a change in amount and/or type of contaminants contained in striped bass eggs since 1999.
Description: 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 makes 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 Ostrach. 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 2007-042.
Time period: Chemical analyses of archived samples will take place as soon as DFG water pollution lab can process the samples and analysis of the results will follow soon thereafter.
Resources required
Cost: $10,000 required to conduct this work was obtained in 2006.
PI(s): David Ostrach (UCD)
Contract needed / in place:
Contract manager: Ted Sommer (DWR)
Term of contract: See Element 2007-042.
Personnel:
Equipment:
Deliverables and dates: See Element 2007-042.
Comments:

Preliminary investigations of disease as a factor in the POD
IEP 2007-036
Point person: Randy Baxter (DFG)
Lead Agency: DFG, USFWS, and UCD
Questions: 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?

Description:

Time period: 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. Sampling will be repeated in 2007 with enhanced effort for some or all target species.

Resources required

Cost: $24,000 from POD sources.

PI(s): Scott Foot (USFWS)

Contract needed / in place: In place

Contract manager: Ken Lentz (USBR)

Term of contract:

Personnel:

Equipment:

Deliverables and dates:

Comments: 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.

Development of striped bass life cycle models

IEP 2007-038

Point person: Ted Sommer

Lead Agency: UCD, SFSU-RTC, LSU, and consultants

Questions: What factors are the dominant drivers of striped bass population dynamics? What are the best management strategies for each of these species?

Description: Life cycle models are need for both striped bass and longfin smelt, but we will pursue a model for striped bass first. 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).

Time period: 2006-2007

Resources required

Cost: $224,000 required to conduct this work was obtained in 2006 from POD sources.

PI(s): Frank Loge (UCD) and Kenny Rose (LSU)

Contract needed / in place: In progress

Contract manager: Ted Sommer (DWR)

Term of contract: TBA

Personnel:

Equipment:

Deliverables and dates:

October 2006 - 1st progress report and CALFED Science Conference presentation.

April 2007- 2nd progress report, IEP Newsletter article, and IEP Workshop presentation.

October 2007 - 3rd progress report and CALFED Science Conference presentation.

April 2007- 4th progress report, IEP Newsletter article, and IEP Workshop presentation.

June 2008 - Submission of 3 peer-reviewed manuscripts addressing description, calibration, hypothesis testing, and comparison of a) dose-structured population dynamics, b) IBM, and c)

matrix models. Additionally, computer codes for each model and supporting documentation explaining use, inputs, and outputs.
Comments:

Threadfin shad data analysis and population dynamics
IEP 2007-039
Point person: Ted Sommer (DWR)
Lead Agency: DWR
Questions: 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?
Description: In 1959, 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.
Time period: 2006-2007
Resources required
- Cost: $57,000 from POD sources.
- PI(s): Fred Feyrer (DWR)
  - Contract needed / in place: N/A
  - Contract manager: N/A
  - Term of contract: N/A
- Personnel: 2 Scientific, 1 Environmental Scientist, and 1 boat operator are needed.
- Equipment: Equipment: $1,000, Toxicity analysis: $20,000.

Deliverables and dates: Poster presentation at CALFED, October 2006; Oral presentation at IEP Annual Workshop, February 2007.
Comments: Substantial catch, length and distribution data exists in state and federal survey databases that can be used to address the study questions.

Modeling the delta smelt population in the San Francisco Estuary
IEP 2007-041
Point person: Randy Baxter (DFG)
Lead Agency: USGS, SFSU-RTC, LSU and consultants
Questions: What are the best management strategies for this species?
Description: This element is a CALFED Science PSP grant that will use three different modeling approaches for looking at delta smelt population dynamics.
Time period: 2006-2008
Resources required
- Cost: $332,000 per year for 3 years. Total is $997,000.
- PI(s):
  - Contract needed / in place:
  - Contract manager:
  - Term of contract: 3 years, beginning in 2006

Personnel:
Equipment:
Deliverables and dates:
Comments:

Estimation of Pelagic Fish Population Sizes
IEP 2007-043
Point person: Mike Chotkowski (USBR)
Lead Agency: DFG, DWR, USBR, consultants and contractors.
Questions: 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? 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?
her type of distribution?
Description: Except for adult striped bass, the status of pelagic fish populations has primarily been assessed using relative 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, and Miller (2005) has analyzed the Kodiak trawl 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.
Time period: Ongoing through 2007.
Resources required
Cost: $42,000 required to conduct this work was obtained in 2006 from POD sources.
PI(s): Ken Newman (USFWS)
Contract needed / in place: N/A
Contract manager: N/A
Term of contract: N/A
Personnel: Ken Newman (USFWS)
Equipment:
Deliverables and dates:

Comments: Although there are substantial obstacles to measurement of population sizes, the recent efforts of Bennett (2005) and Miller (2005) provide a reasonable foundation for future work.

Zooplankton fecundity and population structure
IEP 2007-044
Point person: Anke Mueller-Solger (DWR)
Lead Agency: SFSU-RTC
Questions: 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?
Description: 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.
Time period: 2006-2007
Resources required
Cost: $80,000 from POD sources.
PI(s): Wim Kimmerer
Contract needed / in place: In progress
Contract manager: Ted Sommer
Term of contract: Through December 30, 2008.
Personnel:
Equipment:
Deliverables and dates: See Element 2007-076.
Comments: Feasibility is high because the samples have already been collected and pilot work indicates the methods are appropriate to answer the study questions.

Overlap/Synthetic analysis of POD data
IEP 2007-046
Point person: Randy Baxter (DFG)
Lead Agency: USGS, DFG, DWR
Questions: Specific questions and working groups have not been determined at this time. More discussions with NCEAS members need to occur before determining the most valuable questions to pursue.
Description: The overall goal for the proposed NCEAS working groups is to conduct and/or guide the integration, analysis, and synthesis of POD and other relevant data and information in a more efficient, sophisticated, unbiased, and synergistic manner than would be possible with local resources alone. The focus of the NCEAS working group should be identification of and testing of hypotheses about individual and interacting stressor(s) associated with the observed POD trends, the linkages among these stressors, and the mechanistic pathways leading to the observed trends._Continuous analysis of POD data will help 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.

Time period:
Resources required
Cost: The 2007 POD budget for this element is $656,000; an additional $290,000 was already obtained in 2006 from POD sources.
PI(s): Larry Brown (USGS), and Gonzalo Castillo (USFWS)
Contract needed / in place: In process.
Contract manager: Kim Webb will manage the NCEAS contract.
Term of contract: Scientifically sophisticated approaches and defensible conclusions require substantial time. We envision the IEP/POD-NCEAS interaction to continue beyond the term of this contract and at this time would like to establish a working relationship through the end of 2008, with the possibility of an extension.
Personnel: Other key staff members include Fred Feyrer (DWR) and Randy Baxter (DFG).
Equipment:
Deliverables and dates: Fall 2007: Draft synthesis report authored by NCEAS POD working team members, perhaps with the help of an NCEAS postdoc. A comprehensive synthesis report would follow one year later. Additionally, scientific presentations and presentations geared at lay audiences would be authored by individual POD or NCEAS working group members.
Comments: Existing staff members from the above agencies are being redirected to work closely with NCEAS to participate in the synthesis of IEP data as it relates to the POD.

Corbula salinity tolerance, distribution and grazing rates
IEP 2007-076
Point person: Ted Sommer (DWR)
Lead Agency: DWR, USGS and SFSU
Questions: 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?
Description: 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.
Time period: Mid-2006 through 2008.
Resources required
Cost: The 2007 POD budget is $65,000, however $117,000 is the total amount for laboratory studies of salinity tolerances through the contract period. No additional costs for the field surveys and data analyses.
PI(s): Jonathan Stillman and Wim Kimmerer (SFSU)
Contract needed / in place: In place
Contract manager: Ted Sommer
Term of contract: July 2006 through December 2008

Personnel: Key staff includes Marc Vayssieres and Karen Gehrts (DWR), Dr. Janet Thompson and Heather Peterson (USGS).

Equipment:

Deliverables and dates:

October 2007: Submit Year 1 progress report to IEP. This will be provided as one or more IEP Newsletter articles or manuscripts, depending on the results to date.

February 2008: Present preliminary results at Asilomar.

December 2008: Final reports, which will comprise draft manuscripts for submission to journals or the IEP Newsletter, as appropriate.

Comments:

CASCaDE computational assessment of scenarios

IEP 2007-081

Point person: Steve Culberson (CALFED)

Lead Agency: USGS

Questions: 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".

Description: 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 food webs, 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.

Time period: 2006-2008

Resources required

Cost: $554,000 per year. This is a CALFED Science PSP-funded study through contract with the USGS.

PI(s): Jim Cloern

Contract needed / in place: In place
Contract manager: Michelle Shouse
Term of contract: 3 years
Personnel:
Equipment:
Deliverables and dates:
Comments:

Food-web support for delta smelt and estuarine fishes in Suisun Bay and upper Estuary
IEP 2007-082
Point person: Steve Culberson (CALFED)
Lead Agency: SFSU-RTC
Questions: 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 food-web in supporting higher trophic levels?
4. To what extent is copepod production dependent on these alternative energetic pathways (phytoplankton and bacterial production)?
Description: 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 food-web 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 food-web.
The funded proposal includes efforts aimed at understanding and possibly improving the food-web supporting delta smelt and other estuarine species.
Time period: 2006-2008
Resources required
Cost: $390,000 per year. This is a CALFED Science PSP-funded grant.

PI(s): Wim Kimmerer
Contract needed / in place: This is a CALFED Science grant
Contract manager: Ladd Lougee
Term of contract: 3 years
Personnel:
Equipment:
Deliverables and dates:
Comments:

Gear Efficiency Studies
IEP 2007-086
Point person: Randy Baxter (DFG)
Lead Agency: DFG
Questions: 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?
Description: 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 to examine retention and capture efficiencies.
Time period: As time becomes available during 2007.
Resources required
Cost: $10,000 required to do this work was obtained in 2006.
PI(s): Staff time to complete this task has not been identified.
Contract needed / in place: N/A
Contract manager: N/A
Term of contract: N/A
Personnel: Staff time to complete this task has not been identified.
Equipment:
Deliverables and dates:
Comments: The feasibility for this element is moderate for 2007 assuming improved staffing. Literature review can be accomplished with temporary personnel and some permanent time.

Hydrologic changes and Suisun Bay Salinity
IEP 2007-97
Point person: Ted Sommer (DWR)
Lead Agency: USGS

Questions: This work will investigate what hydrologic or climatic changes have resulted in increased fall salinity in the western Delta. Watershed events such as reservoir operations, rice field flooding, and sea level rise will be used to help answer this question.
Description:
Time period:
Resources required
  Cost: The $62,000 required to conduct this work was obtained in 2006.
  PI(s): Cathy Ruhl (USGS)
    Contract needed / in place: In place
    Contract manager: Erwin Van Nieuwenhuyse
    Term of contract: N/A
  Personnel:
  Equipment: No equipment is required.
Deliverables and dates: A summary report has already been produced and a finalized report will be delivered in the second quarter of 2007.
Comments:

SAV abundance and distribution
IEP 2007-102
Point person: Bruce Herbold (EPA)
Lead Agency: USGS and UCD
Questions: Has Submerged Aquatic Vegetation (SAV) increased in the Delta? Has SAV altered the habitat to effect fish populations? Has SAV increased retention of suspended solids to create a less turbid environment, which is less hospitable to Delta Smelt?
Description: Using hyperspectral imagery, this project will provide annual acreage calculations of submerged aquatic vegetation (SAV) and quantify SAV regional distribution trends in the Delta for the past four years (2003-2006).
Time period: 2006-2008
Resources required
  Cost: $204,000 required to conduct this work has already been obtained 2006.
  PI(s): Susan Ustin (UCD) and Dave Schoellhamer (USGS)
    Contract needed / in place: Yes
    Contract manager: Ken Lentz (USBR) and Fred Feyrer (DWR)
    Term of contract:
  Personnel:
  Equipment:
Deliverables and dates: Fall 2007-progress report as part of Fall 2007 Synthesis. Write up by February 2008.
Comments:

Fish Facility History
IEP 2007-107
Point person: Marty Gingras (DFG)
Lead Agency: DFG, USBR
Questions: What changes have occurred at the state and federal fish facilities that would change the reported number of salvaged fish?

Description: This project will identify changes that have occurred at the state and federal fish facilities from 1956 to 2006 that may have impacted the reported number of salvaged fish. However, this investigation will not report potential items that may have impacted the retention of fish in the holding tanks (holding tank screen size changes) or survival of fish once counted (debris loads in holding tanks and impacts on released fish).
Time period: 2006 and 2007
Resources required
Cost: The 2007 POD budget for this element is $26,000; an additional $26,000 required to complete this work was obtained already obtained in 2006 from POD sources.
PI(s): Jerry Morinaka (DFG) and Brent Baskerville-Bridges (USBR)
Contract needed / in place: N/A
Contract manager: N/A
Term of contract: N/A
Personnel: 3 months of each PI's time, spread out over 6 – 9 months.
Equipment: No equipment is required for this analysis.
Deliverables and dates:
Comments:

Delta smelt culture facility
IEP 2007-108
Point person: Rich Breuer (DWR)
Lead Agency: UCD
Questions: Reliable supplies of all life stages of delta smelt are valuable to management and scientific communities for a number of reasons. Cultured delta smelt provide specimens with known rearing history, required for toxicological experiments; aids research and design of fish screen efficiency, and pre-screen losses; allows investigations into basic biology with application to wild populations; and enables the development of a formal delta smelt refugia population.
Description: This program will collect sub-adult broodfish via purse seine from the wild each year, and spawn and rear all life stages of delta smelt in the following year in accordance to the Delta Smelt Culture Manual (Baskerville-Bridges et al. 2005). Delta smelt would be housed and reared at the newly expanded Fish Conservation and Culture Laboratory (FCCL) located on Department of Water Resources (DWR) property near DWR's Skinner Fish Facility in Byron, CA.
Time period: This money will be used to produce F1 generation delta smelt from broodstock collected in December 2006.
Resources required
Cost: $165,000 from USBR Tracy operations, and $165,000 from POD sources.
PI(s): Drs. Raul Piedrahita, Joan Lindberg and Bradd Baskerville-Bridges
Contract needed / in place: Needed
Contract manager: Rich Breuer
Term of contract: TBD – Needs to be in place by July 1, 2007.
Personnel:
Equipment:
Deliverables and dates: 5,000 adults (>50mm) and 10,000 juvenile (20-50 mm) delta smelt specimens for 2007, and a Production Report.
Comments: A scope of work was submitted to IEP.

Biomarkers Workshop
IEP 2007-112
Point person: Rich Breuer (DWR)
Lead Agency: CALFED
Questions: Do biomarkers currently being evaluated for the pelagic organisms indicate a population level effect from stressors? Are current biomarker analyses techniques being used for POD adequate to discern the stressor source? C
Description: 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 work plan for future POD work involving biomarkers. A "Fish Biomarker Task Force" consisting of experts in this field would provide state-of-the-art information on biomarkers. This task force would 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.
Time period: Summer 2007
Resources required: POD PI's conducting Biomarker work and solicited experts in biomarkers. CALFED would solicited experts and organize a workshop where currently applied Biomarker analyses for POD would be discussed, as well as emerging biomarker analyses and their applicability to Delta fish.
Cost: $13,000 (USBR → CALFED) required to conduct this work was already obtained in 2006.
PI(s): Steve Culberson (CALFED)
Contract needed / in place: In place.
Contract manager: Steve Culberson
Term of contract:
Personnel:
Equipment:
Deliverables and dates: Fall, 2007: Findings from task force on biomarker applicability to discern population level effect stressors in the Delta.
Comments:

Striped bass bioenergetics evaluation
IEP 2007-115
Point person: Ted Sommer (DWR)
Lead Agency: DWR and DFG
Questions: What are the trends in estimated population consumption demand of age-1 and older striped bass? Has age-1 and older striped bass consumption demand decreased more slowly than prey relative abundance/relative biomass?
Description: This element will couple bioenergetics analyses to data provided by element 2007-116 (Adult striped bass population dynamics) to estimate the long and short-term (i.e., POD years) trends in consumption demand of piscivorous striped bass.

Time period: Calendar year 2007; assuming the population demographic data are available in early 2007.
Resources required:
Cost: $23,000 for an Environmental Scientist 25% time.
PI(s): Marty Gingras (DFG)
Contract needed / in place: N/A
Contract manager: N/A
Term of contract: N/A
Personnel: Matt Nobriga and DFG staff to be determined.
Equipment: None required – this is a data mining/data analyses effort.
Deliverables and dates: Draft manuscript for publication by December 2007.
Comments:

Adult striped bass population dynamics
IEP 2007-116
Point person: Marty Gingras (DFG)
Lead Agency: DFG
Questions: What are the age-specific estimates of annual abundance, harvest rate, survival rate, and growth rate among striped bass aged >= 3 years?
Description: Estimate the age-specific annual abundance (including confidence intervals), harvest rate, survival rate, and growth rate among striped bass aged 3 years and older. Abundance will be estimated using a modified Peterson calculation, data from fish tagged during spring, and data from fish observed during a year-long creel survey. Ages will be determined primarily from interpretation of marks on scales known to be made annually but will be estimated using an age-length table as needed. Harvest rate will be determined using returns from a high-value reward tagging program. Survival rate will be determined from changes in the return-rate of tags from each of the two years following application of tags to a cohort and by analysis of the catch-curve of fish captured during tagging. Growth rate will be determined from mark-recapture data and from analysis of length-frequency distributions.
Time period: Through December 2007.
Resources required:
Cost: No increase over base budget.
PI(s): Kyle Murphy (DFG)
Contract needed / in place: N/A
Contract manager: N/A
Term of contract: N/A
Personnel: Kyle Murphy; Nina Kogut; Mike Harris; Mike Donnellan (DFG).
Equipment:
Deliverables and dates: An IEP Technical Report, an IEP Status and Trends article, and an IEP Quarterly Highlights submission.
Comments:

Data mining for status and trends of predators
IEP 2007-118
Point person: Larry Brown (USGS)
Lead Agency: USGS

Questions: Have populations of predators that prey upon pelagic fishes increased in recent years in either a relative (in relation to populations of other fishes) or an absolute (total number) sense?
Description: The questions about population sizes will mainly be address through summarization and integration of recent analyses of IEP data sets and possible some data analysis of other pertinent existing data. These data will be used by a companion study for the construction of an individual based bioenergetics model for striped bass and then applying the model to the striped bass population.
Time period: To be determined.
Resources required:
Cost: Remaining funding in a CALFED contract to L. Brown. Other analyses will be conducted with redirected staff effort.
PI(s): Larry Brown (USGS) and Fred Feyrer (DWR)
Contract needed / in place: N/A
Contract manager: N/A
Term of contract: N/A
Personnel: Brown and Feyrer
Equipment: N/A – this is a data mining effort.
Deliverables and dates: Progress report by November 2007
Comments:

Delta Fish Biomass estimation
IEP 2007-119
Point person: Ted Sommer (DWR)
Lead Agency: DWR and DFG
Questions: What are the trends in fish biomass in the San Francisco estuary? Are there specific changes in biomass that coincided with the POD years?
Description: The questions about biomass will mainly be address through summarization and integration of recent analyses of IEP data sets and possible some data analysis of other pertinent existing data. The work will largely be based on initial biomass estimates by Wim Kimmerer. The present study will update Wim's work through 2006.
Time period: Calendar year 2007.
Resources required:
Cost: This work will be conducted with redirected staff.
PI(s): Fred Feyrer (DWR) and Randy Baxter (DFG)
Contract needed / in place: N/A
Contract manager: N/A
Term of contract: N/A
Personnel: Feyrer, Baxter, and Kimmerer
Equipment: N/A
Deliverables and dates: Progress report by November 2007.
Comments:

Relationship between habitat and distribution
IEP 2007-120
Point person: Bruce Herbold (USEPA)
Lead Agency: TBD

Questions: Have temporal-spatial shifts in the habitats required by pelagic fish reduced their likelihood of finding adequate amounts of different habitats? Have changes in the temporal-spatial distributions of habitats exposed them to new or more severe stressors?
Description: Habitat, as defined by studies of Feyrer and Nobriga of DWR, will be combined with physical data gathered throughout the estuary to allow GIS projections of suitable summer and fall habitats for delta smelt, threadfin shad and young of year striped bass. These habitats will be examined for several biologically important parameters: location, size, proximity to other habitat patches of the same sort, proximity to other sorts of habitat needed sequentially, and proximity to known or suspected sources of mortality or stress.
Time period: January through September 2007
Resources required:
    Cost: $100,000 (very approximate) from POD sources.
    PI(s): TBD
        Contract needed / in place: Needed, unless this can be covered under existing contracts or redirected IEP staff.
        Contract manager: TBD
        Term of contract: TBD
    Personnel: TBD
    Equipment: None.
Deliverables and dates: Draft report by September 15, 2007. Final report by October 15, 2007.
Comments: This work can probably best be done by USGS personnel or by consultants working in concert with DWR personnel.

In Situ Biomarker Study
IEP 2007-121
Point person: Rich Breuer (DWR)
Lead Agency: *DWR/ EPA Office of Research and Development, Cincinnati Ohio*
Questions: Do fathead minnows exposed to the Sacramento and San Joaquin Rivers show evidence of endocrine disrupters?
Description: 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 work plan for future POD work involving biomarkers. EPA-ORD and the DWR EMP program will conduct two one-month studies in November 2006 and February 2007. Batches of Fat Head Minnows will be exposed in a flow through system to Sacramento and San Joaquin River water. The minnows will be processed and sent to ORD where they will be analyzed for endocrine disruptors. The tissue will be preserved and future biomarker work for Organo-phosphates and Pyrethroids.
Time period: Fall 2006 -Winter 2007
Resources required
    Cost: Funding required for this element will be absorbed from existing program costs.
    PI(s): Dan Riordan (DWR)
        Contract needed / in place: Not needed
        Contract manager: N/A
        Term of contract: N/A
    Personnel:

Equipment:
Deliverables and dates: Fall 2007, findings from analyses.
Comments: CALFED would solicited experts and organize a workshop where currently applied Biomarker analyses for POD would be discussed, as well as emerging biomarker analyses and its applicability for Delta fish.

Food match mis-match
IEP 2007-122
Point person: Randy Baxter (DFG)
Lead Agency: DFG
Questions: Are spring mesozooplankton densities and proximity to/overlap with larval delta smelt and striped bass related to feeding success, fish body condition and eventual recruitment? Do environmental factors – temperature, turbidity, and salinity – have an apparent role in feeding success?
Description: Larval growth-rate variability can influence recruitment by affecting the duration of early life stages -- those most vulnerable to predation (Houde 1996). Growth-rate in turn is influenced by feeding success (Margulies 1988), which may be mediated by the overlap of larva preferred temperature and salinity zones with areas of highest prey concentration (North and Houde 2001). Here we examine the relationships between the geographical distributions of food-sized zooplankton and larval delta smelt and larval striped bass in conjunction with water temperature, turbidity, salinity, and relate those to fish feeding success, body condition (relative weight at length) and recruitment (fall abundance indices). We use historical paired zooplankton and fish samples from tandem-fished Clark-Bumpus (CB; zooplankton) and 20 mm Survey (or Townet) nets to obtain organism densities and select fish for condition and stomach content measures.
Time period: 2007 - 2008
Resources required
Cost: No additional cost, redirected DFG staff will be used to accomplish this analysis.
PI(s): Steve Slater and John Budrick (DFG)
Contract needed / in place: N/A
Contract manager: N/A
Term of contract: N/A
Personnel: 3 laboratory staff for fish measurements and diet examination.
Equipment: Laboratory space, a balance and microscopes for length-weight measurements and diet examination.
Deliverables and dates: Tri-annual progress reports (April, August, December 2007); presentation Asilomar 2008, manuscript for submission to regional peer-reviewed journal summer 2008.
Comments: Personnel for this element have only recently (late fall 2006) become available. Sampling design and analyses have yet to be completely developed.

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, USGS, USBR, USEPA and UC Davis.

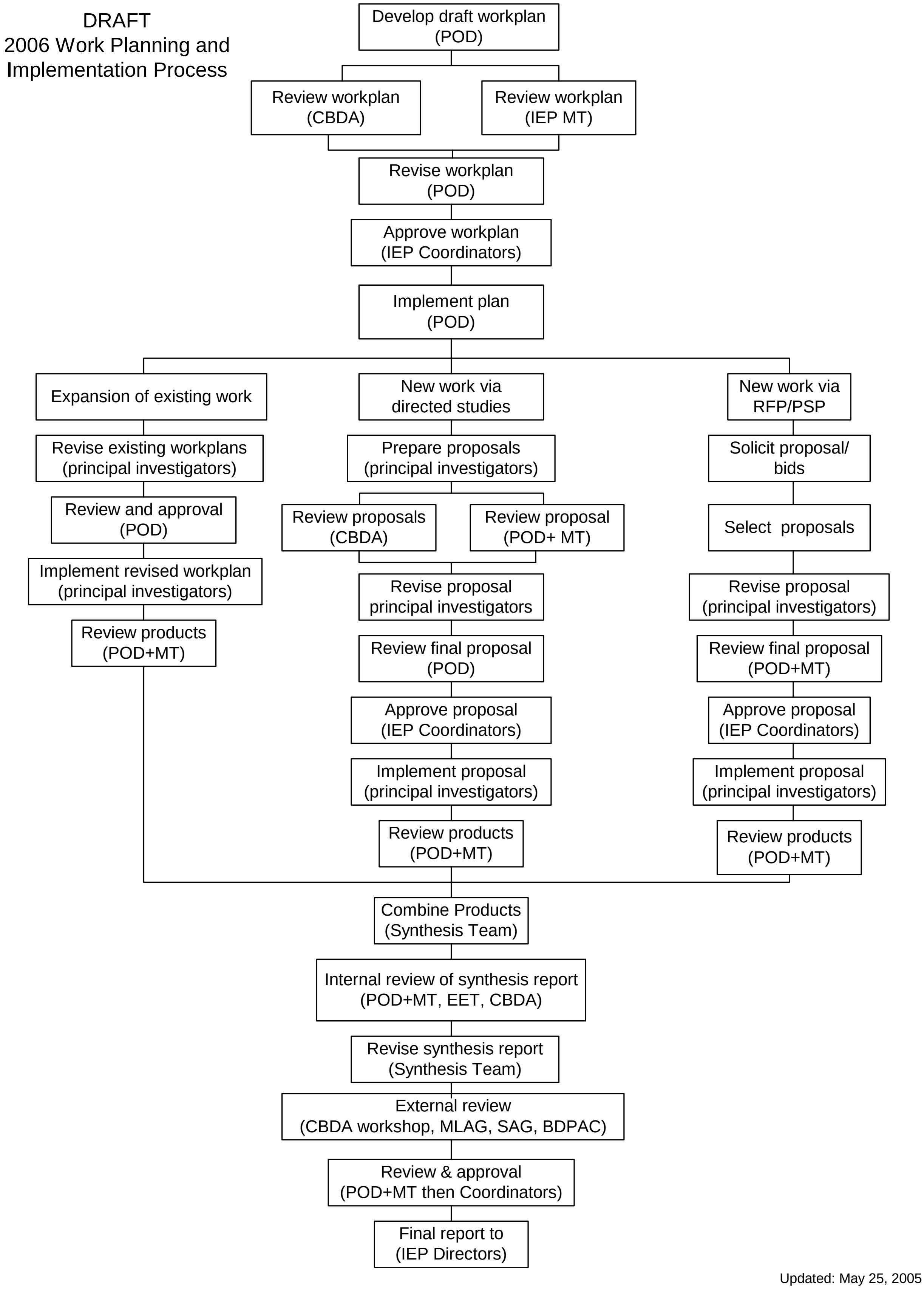
The 2006-2007 study components have been carefully selected based on their feasibility and potential to help differentiate among potential stressors. As demonstrated by the successful 2005 effort, the research team has extensive experience with all of the proposed methods and sampling locations. The 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.


DRAFT
2006 Work Planning and Implementation Process
Develop draft workplan (POD)
Review workplan (CBDA)
Review workplan (IEP MT)
Revise workplan (POD)
Approve workplan (IEP Coordinators)
Implement plan (POD)
Expansion of existing work
Revise existing workplans (principal investigators)
Review and approval (POD)
Implement revised workplan (principal investigators)
Review products (POD+MT)
New work via directed studies
Prepare proposals (principal investigators)
Review proposals (CBDA)
Review proposal (POD+ MT)
Revise proposal principal investigators
Review final proposal (POD)
Approve proposal (IEP Coordinators)
Implement proposal (principal investigators)
Review products (POD+MT)
New work via RFP/PSP
Solicit proposal/ bids
Select proposals
Revise proposal (principal investigators)
Review final proposal (POD+MT)
Approve proposal (IEP Coordinators)
Implement proposal (principal investigators)
Review products (POD+MT)
Combine Products (Synthesis Team)
Internal review of synthesis report (POD+MT, EET, CBDA)
Revise synthesis report (Synthesis Team)
External review (CBDA workshop, MLAG, SAG, BDPAC)
Review & approval (POD+MT then Coordinators)
Final report to (IEP Directors)
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 and 2006, 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.

Budget:

The initial cost estimate for 2007 is approximately $3,260,000. CALFED grants that directly support various POD efforts or that will supply information useful to the POD effort are estimated at $2,302,000 for 2007. Cost estimates for individual program components are provided in Table 2 and in the previous section as part of the project summaries. In some instances, money for 2007 work was obtained in 2006, therefore not reflected in the table below.

Table 2. 2007 POD Budget (amounts are in $1,000)

	PEN[1]	POD Total	DWR POD	USBR POD	CALFED	Comments
I. Existing Monitoring						
Summer Townet Survey	7	$23	$23	$0		
EMP - Water Quality Monitoring	72	$122	$96	$26		
Field support for additional work	89	$75	$75	$0		
Larval fish survey	96	$97	$97	$0		
I. TOTAL for EXISTING MONITORING		**$317**	**$291**	**$26**	**$0**	
II. Ongoing Work						
Delta and Suisun Bay particle tracking investigations	31	$49	$49	$0		
Delta smelt otolith geochemistry and stock structure	40	$76	$0	$0	$76	CBDA Science
Striped bass health investigations	42	$416	$416	$0		
Phytoplankton primary production and biomass in the Delta	45	$50	$50	$0		
Apparent growth rates of pelagic fish	51	$38	$38	$0		
Otolith analysis of delta smelt fish	60	$512	$39	$123	$350	CALFED-ERP
Liver histopathology for pelagic fish	61	$350	$0	$0	$350	CALFED-ERP
Fish diet and condition	62	$11	$11	$0		
Acute and chronic invertebrate and fish toxicity	63	$644	$0	$644		
Changes in pelagic fish habitat	66	$184	$184	$0		
Field survey of Microcystis bloom biomass and toxicity	79	$250	$0	$0	$250	CBDA Science
Analysis of historical population dynamics	84	$62	$0	$62		

TOTAL for ON-GOING STUDIES		**$2,480**	**$787**	**$829**	**$1,026**	
III. New Special Studies						
Preliminary investigations of delta fish diseases	36	$24	$16	$8		
Analysis of threadfin shad data	39	$57	$57	$0		
Modeling delta smelt population in the SF Estuary	41	$332	$0	$0	$332	
Estimation of pelagic fish population sizes	43	$0	$0	$0		
Zooplankton fecundity and population structure	44	$80	$80	$0		
Overlap analyses of fish, zooplankton, etc. and NCEAS	46	$656	$96	$560		
Corbula salinity tolerance, distribution and grazing rates	76	$65	$65	$0		
CASCaDE computational assessments of scenarios	81	$554	$0	$0	$554	CBDA Science
Foodweb support for delta smelt and estuarine fishes	82	$390	$0	$0	$390	CBDA Science
Gear efficiency studies	86	$0	$0	$0		
Fish facility history	107	$26	$0	$26		
Delta smelt culture facility	108	$165	$165	$0		
Biomarkers workshop and ORD study	112	$0	$0	$0		
Striped bass bioenergetics	115	$23	$23	$0		
Relationship between habitat and distribution	120	$100	$50	$50		
Statistical support	123	$0	$0	$131		
TOTAL for NEW STUDIES		**$2,472**	**$552**	**$644**	**$1,276**	

	Overall POD	**DWR POD**	**USBR POD**	**CALFED**
2007 POD TOTAL	**$5,562**	**$1,630**	**$1,630**	**$2,302**

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).