Interagency Ecological Program 2005 Workplan to Evaluate the Decline of Pelagic Species in the Upper San Francisco Estuary

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Executive Summary

Abundance indices calculated by the Interagency Ecological Program (IEP) suggest recent marked declines in numerous pelagic fishes and zooplankton in the upper San Francisco Estuary (the Delta and Suisun Bay). These low levels are unexpected given the relatively moderate hydrology over the past three years. IEP proposes to augment existing monitoring, perform new data analyses, and conduct special studies to investigate whether there is a new threat to pelagic fish and their prey, and if so, what has caused it.

Our conceptual model includes at least three general factors that may be acting individually or in concert to lower pelagic productivity: 1) toxins; 2) invasive species; and 3) water project operations (Figure 1). The overall approach for 2005 is a screening-level study to better define the degree to which each of these factors may be responsible individually, in sequence, or in concert for the apparent step-changes. The workplan is based on a "triage" model to identify the most likely causes, and to assign priorities to projects on the basis of where funds and resources can be best used. Results also may shed additional light on causes of long-term declines in several of the affected species. Several of the lines of inquiry will be managed on an adaptive basis in that information will be examined as it is made available and depending on the results, increasingly focused studies will be conducted in 2006 and later years.

The proposed studies represent an interdisciplinary, multi-agency effort including staff from DFG, DWR, USBR, USEPA, USGS, and UC Davis. Project components were selected based on their ability to differentiate the three major groups of stressors, and their feasibility in terms of methods, staffing, costs, timing and data availability. The proposed work falls into four general types: 1) an expansion of existing monitoring (four expanded surveys); 2) analyses of existing data (nine studies); 3) new studies (six studies); and 4) ongoing studies (four studies). 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). None of the work will affected of the mandated monitoring currently under performed by IEP. The initial cost estimate for 2005 is approximately $1.67 million.

The program will be run by a new 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. The major written products for 2005 will be a summary report, and a proposal for work in 2006 and beyond.

Problem Statement

In the last few years, the abundance indices calculated by the Interagency Ecological Program (IEP) Fall Midwater Trawl survey (MWT) show marked declines in numerous pelagic fishes in the upper San Francisco Estuary (the Delta and Suisun Bay). 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 (Bryant and Souza 2004; Hieb et al. 2005). Data from another IEP monitoring survey, the Summer Townet Survey (TNS), support the MWT findings: TNS abundance indices for striped bass and delta smelt were among the lowest indices in the 45-yr record. In contrast, the San Francisco Bay Study did not show significant declines in its catches of marine/lower estuary species (Hieb et al. 2004; Hieb et al. 2005). Based on these findings, the problem appears to be limited to fish dependent on the upper estuary.

In addition to the declines in fish species, IEP monitoring also found declining abundance trends for zooplankton with a substantial drop in calanoid copepod abundance in 2004. Calanoid copepods such as *Eurytemora affinis* and *Pseudodiaptomus forbesi* are the primary food for larval pelagic fishes in the upper estuary (IEP 1987; Meng and Orsi 1991; Nobriga 2002) as well as older life stages of planktivorous species such as delta smelt (Lott 1998). Conversely, the invasive cyclopoid copepod *Limnoithona tetraspina*, which may be a poor food source for fish and an intraguild predator of calanoid copepods, is increasing in abundance and continues to be the most abundant copepod in the estuary (Mecum 2005).

While several of these declining species - including longfin smelt, juvenile striped bass and calanoid copepods have shown evidence of a long-term decline - there appears to have been a precipitous "step-change" to very low abundance during 2002-2004. This observation is supported by initial statistical analyses of the MWT data (Manly in prep.). Moreover, the record or near-record low abundance levels are remarkable in that the hydrological regime in the San Francisco Estuary was 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, the moderate hydrology during the past three years should have supported at least modest production.

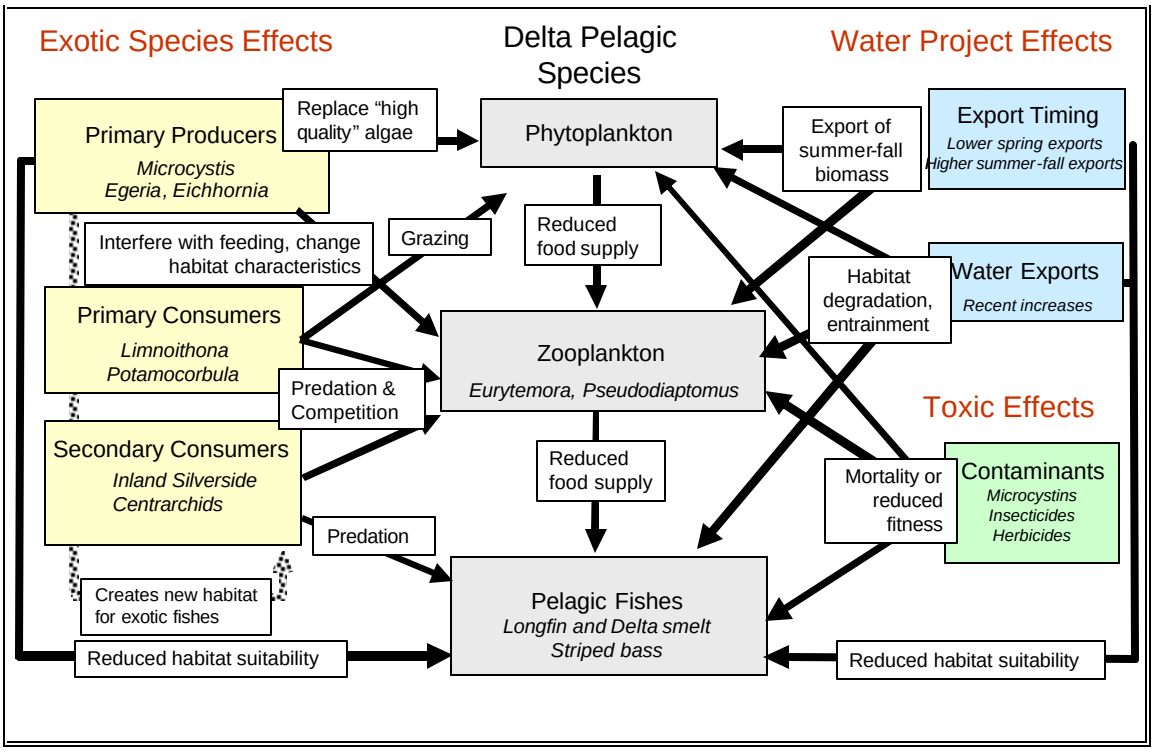
The fact that multiple pelagic species at more than one trophic level seem to show the 2002-2004 step decline is of particular concern. Regardless of whether the observations over the past three years are remarkable, the fact that the efforts of the California Bay-Delta Authority (CDBA) have apparently not arrested long-term declines in some pelagic species indicates that additional efforts are needed to identify what limits pelagic fisheries production in the upper estuary. Over the past decade, CBDA activities have resulted in a major shift in the timing of water exports, the development of an innovative Environmental Water Account, and construction of habitat restoration projects. Additional information about the factors affecting pelagic organisms is needed to optimize these CDBA efforts, and provide guidance for future activities in the upper estuary.

Conceptual Model

Based on the observations and analyses described above, we hypothesize that fish abundance declined unexpectedly during 2002-2004. Because numerous species were affected, we do not think these declines were due to population stochasticities, but rather to a change or changes in the estuary that impacted fish directly and/or indirectly via their zooplankton prey. Therefore, the IEP is proposing to augment monitoring, data analyses and special studies to investigate the cause of the low abundance indices of pelagic fish and their prey.

There are at least three general factors that may be 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 in Figure 1 uses these categories to illustrate the potential pathways by which pelagic species in the Delta could be affected. For each group of "boxes" shown in the model, one or more examples are provided in italics. The arrows show the potential mechanisms by which changes could occur. Note that not all of the organisms shown in each box are necessarily responsible for each of the mechanisms.

Delta Pelagic Species Conceptual Model



Toxins: 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 (e.g. pyrethroids) 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. in press). This species 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. in press). .The switch from organophosphate to pyrethroid pesticides increased substantially through the 1990s (Kuivila presentation to EET Feb 2005). 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.

Exotic Species: 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 *Potamocorbula 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 press; Nobriga et al. submitted). At this time, we have limited information about quantitative aspects of the estuarine food web needed to estimate *Potamocorbula* grazing rates or predict whether nearshore and pelagic food webs are coupled in ways relevant to the production of pelagic fishes.

Water Project Operations: 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 CBDA actions have restored some spring inflow, but have also increased summer inflows to meet increasing summer export demands. This shift was 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 under the CBDA. It is also possible that the total volume diverted on an annual basis influences estuarine productivity (Livingston et al. 1997, Jassby et al 2002).

Study Approach

Initial Efforts: After reviewing the fish and zooplankton abundance indices, the IEP Management Team asked the Estuarine Ecology Project Work Team (EET PWT) to meet to discuss the Management Team's observations. Following the EET meeting, a new IEP working group was organized, the Pelagic Organisms Decline Project Work Team (POD PWT). The POD PWT (the authors of this proposal) was formed to develop a study plan to explore the causes of the recent declines in abundance and to provide policy makers recommendations on what actions could be taken to improve abundance levels.

Based on concerns expressed during the EET meeting, the POD PWT began a series of statistical evaluations of the probabilities that both long-term abundance declines and the 2002-2004 step changes were statistically significant. Three independent approaches were taken. Two relied on

resampling the data that underlie the indices to develop estimates of within year variation. The results of the more comprehensive resampling effort are forthcoming (Kimmerer and Nobriga 2005). The third method used quartic regression techniques and principal components analyses to summarize changes, then calculated probabilities that fish abundances declined in 2002 (Manly in prep.). The early results suggest the step change observed in 2002-2004 is statistically significant for the pelagic fish guild, individual species reported on previously, and may extend to other species as well. We expect to have further results from this effort by the end of June.

The species declines fall into three groups, species exhibiting a long term decline, species with a long term decline and a significant decline (step change) in the past three years and species with no previous long-term trend, but a significant decline in the past three years. The efforts of the proposed research and analyses are focused primarily on understanding the cause(s) of the step decline in the past three years.

Next, the POD PWT established a conceptual model (Figure 1) to help guide subsequent work. Given the potential policy implications of the abundance declines and the need to provide some information in a timely manner, the POD strongly recommends parallel studies to examine causative factors rather than taking a more traditional sequential approach.

Proposed 2005 Study Approach: The overall approach recommended by the POD PWT for 2005 is 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 abundance declines and step-changes. While triage is closely associated with hospital operations (e.g. emergency rooms), the model has been used for many applications including habitat restoration, information technology and peer review processes (Vener et al 1993; Samways 2000). Essentially, the triage model involves an initial screening level effort to try and identify the most likely problems and to assign resources for follow-up efforts. The major benefit of triage is that it allows a rapid response and helps optimize the use of resources, which are typically limited. Resource optimization is a major issue as each species may have a different group of stressors implicated in its decline, making it difficult to comprehensively evaluate each stressor. We think our study plan is sufficiently flexible to address multiple factors and/or different factors affecting species in different ways. Stressors that show a major change in the past few years will receive closer scrutiny than those showing earlier changes or more gradual trends. Note that the triage approach is not intended as a substitute for a traditional detailed scientific study; rather it is an initial step that will help guide us toward more focused research studies will be needed in 2006 and beyond. We anticipate that fewer factors will need scrutiny each year – assuming additional major ecosystem perturbations do not continue to occur.

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 collected will identify whether there are

specific times of the year in which stressors are most pronounced. Much of the emphasis will be on the summer growth season, which is extremely important to fishery production dynamics in temperate zone ecosystems. To the extent possible, these results will be contrasted with historical data or samples to determine if current observations are consistent with earlier years. The hydrology in 2005 provides an excellent opportunity for a "natural experiment"—flow conditions have been consistently wet throughout the winter and spring, which typically results in good abundance levels for many pelagic species (Jassby et al. 1995). Kimmerer (2002b) has performed updated analyses that suggest that these relationships have remained reasonably consistent through 2000, despite the invasion of the clam *Potamocorbula*. If abundance levels for pelagic fishes do not increase substantially, we will have more confidence that the apparent step change in abundance in 2005 is not spurious.

Working Hypotheses for 2005:

- Stressor effects on pelagic populations are highest during the summer period.
- "Ideal" hydrology in 2005 will not result in substantial increases in the abundance of pelagic fish and calanoid copepods.
- Stressor effects have increased during the summer period relative to historical data.

Spatial Contrasts: Monitoring data and new samples will be 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 2005:

- 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: Three fish species (delta smelt, striped bass, inland silverside) and three zooplankton species (*Eurytemora affinis, Pseudodiaptomus forbesi, and Limnoithona tetraspina*) will form the focus of much of the 2005 effort. These species were selected because they form convenient contrasts: for each list, the first two are declining in abundance, while the third is increasing. Our rationale is that contrasts among these species will help to clarify the relative importance of different stressors.

Working Hypotheses for 2005:

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

Study Components

The proposed work falls into four general types: 1) an expansion of existing monitoring; 2) analyses of existing data; 3) new studies; and 4) ongoing studies that we anticipate will produce results relevant to this investigation. A matrix showing which of our proposed study elements address each of the three major stressors is provided in Table 1. None of the proposed work will displace or in any way decrease any of the mandated monitoring currently under way.

Several issues are not addressed in the 2005 study plan, most notably climate and oceanic conditions. Ocean conditions were excluded because they are unlikely to be responsible for upstream effects in the delta, the focus of the present study. The only possible exception is striped bass, but not at the early larval and juvenile stages that will be examined in the proposed effort. We also do not directly address all aspects of climate change. The most important component of climate change in this system is hydrology, which will be addressed as part of analyses of existing data (e.g. components 2g and 2h) and ongoing studies (e.g. components 4a and 4b). However, we will not examine temperature as we doubted that there had been a major recent change in that variable.

1. Expanded Monitoring

The IEP currently has an extensive monitoring program. IEP fish, zooplankton and water quality monitoring programs will be the source of most of the data and samples used for the present effort. However, we need to augment certain sampling programs to ensure adequate collection of all life stages of pelagic fish. We also need additional zooplankton sampling that is more closely coordinated with fish sampling to ensure we can detect significant regional and/or temporal changes in abundance that could affect fishery production. These changes are described where appropriate below. These monitoring augmentations will increase the likelihood that we can detect potentially detrimental events for each target species. Appendix A provides an overview of the months when sampling will be conducted, and time periods when additional effort is proposed. DFG will be the lead agency for these expanded surveys and provide the necessary personnel.

For 2005, we propose to conduct the IEP's Spring Kodiak Trawl Survey, 20mm Survey, adult striped bass survey, and the water quality, zooplankton, phytoplankton, and benthos surveys without modifications or additional funding needs. Note, however, that we anticipate that data collected by these surveys will be incorporated into analyses and decision-making.

Table 1: Proposed Activities for 2005

	Exotic species	Water Operations	Contaminants
1. Augmented Monitoring			
a. Delta Smelt Larval Survey		•	
b. Summer Townet Survey	•		•
c. Fall Midwater Trawl Survey	•	•	•
d. Focused collections	•		•
2. Analyses of Existing Data			
a. Fish & Invertebrate Descriptions	•	•	
b. Apparent Growth Rates	•		•
c. Zooplankton Fecundity	•		•
d. *Microcystis* Literature Review	•		•
e. Pyrethroid Literature Review			•
f. Herbicide Literature Review			•
g. Pelagic Fish Habitat Quality		•	
h. Water Operations Changes		•	
i. Historical Population Trends	•	•	
3. New Studies			
a. Fish Otolith Study	•	•	•
b. Fish Histopathology Study	•		•
c. Fish Diet and Condition	•		•
d. *Microcystis* Field Survey	•		•
e. Bioassays of Water Samples			•
f. Fish Fecundity Estimates	•	•	•
d. Benthic Biomass Trends	•	•	•
4. Ongoing Studies			
a. DSM-2 Particle Tracking		•	
b. South Delta Studies		•	
c. Phytoplankton Production	•	•	
d. Benthic Trends Review	•	•	•

a. Delta Smelt Larvae Survey
Lead Agency: DFG
What: This survey was designed to compare catch of delta smelt larvae in surface-oriented nets and nets retrieved in the traditional oblique manner. The original study plan for this work was scaled to fit within a budget of $142,000 which substantially limits the number of samples that can be taken. Currently, only the legal Delta, is being sampled (19 stations). IEP management recommends expanding this survey in 2006 to cover the full range of sampling detailed in the original study plan (up to 41 stations).
Questions: Can the distribution of larval delta smelt be more effectively determined from sampling with surface-oriented, bow-mounted plankton nets than by the historically used ichthyoplankton gear and methods (IEP 1987; Dege and Brown 2004)? If current surface gear proves effective for larval delta smelt, what are the trends in abundance and distribution of smelt and other surface-orientated larvae.
When: February through June with the work in February and March 2005 dedicated to refining sampling techniques.
Cost: The basic pilot program is an existing program budgeted at $142,000 for 2005. It uses existing staff and resources. The proposed expansion will require an additional $100,000.
Comments: This survey started in 2005 and replaces the North Bay Aqueduct monitoring as required by the USFWS 2005 OCAP Biological Opinion for delta smelt. The delta smelt workgroup designed this survey. If the surface tow method does not produce the desired result, it is likely the USFWS will ask the Delta Smelt Workgroup to modify the sampling design for 2006.
Feasibility: Although this is a pilot study, feasibility is high because similar methods were used successfully in the past.

b. Summer Townet Survey
Lead Agency: DFG
What: The Summer Townet Survey (TNS) has collected juvenile fishes in the range of 20 to 50mm since 1959 (Turner and Chadwick 1972). Samples are collected using a conical net with a 1.5 m^2 mouth and 12.7-mm (½ inch) 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. We recommend this survey be expanded to include a water quality profile and a simultaneous zooplankton sample from each station.
Questions: What is the relative abundance (via abundance index) of striped bass and other pelagic fishes? How are juvenile striped bass and delta smelt distributed within the upper estuary during summer?
When: Sampling is conducted every other week beginning the first or second week of June and continues until the third or fourth week of August. Six surveys are completed every year, with a survey defined as one week of sampling (the time it takes to complete all 32 stations).
Cost: The existing IEP TNS budget is $225,000. The additional zooplankton samples will add $75,000 ($50,000 for an additional ½ PY of senior laboratory assistant; $12,500 equipment; $12,500 field costs).
Comments: These data are used to calculate the striped bass 38.1 mm index (Turner and Chadwick 1972) and an annual abundance index for juvenile delta smelt (Moyle et al. 1992).

This survey is part of the long-term monitoring carried out by IEP and is mandated in the OCAP Biological Opinion for delta smelt.
Feasibility: High. The proposed sampling augmentation is considered minor.

c. Fall Midwater Trawl
Lead Agency: DFG
What: This survey targets age-0 striped bass and other pelagic species 30-150 mm in length using a midwater trawl towed through the water column for 12 minutes in a stepped manner (Stevens and Miller 1983). Fishes are collected from each of 116 stations located from San Pablo Bay upstream through Suisun Marsh and Bay and into the Delta. Additional work will include taking a water quality profile of the water column at each site and a zooplankton tow at selected sites during the September survey.
Questions: What is the relative abundance (via abundance index) of striped bass, delta smelt and other pelagic fishes of the upper estuary?
When: Collections are made monthly from September through December and take the first two weeks of each month to complete.
Cost: The existing IEP MWT budget is $311,000 for staff and resources. The additional zooplankton and water quality collections will add about 1.5 days to the total field time. The additional zooplankton samples will add $75,000 ($50,000 for an additional ½ PY of senior laboratory assistant; $12,500 equipment; $12,500 fuel costs).
Comments: The MWT survey currently reports annual abundance indices for 6 fishes. The ratio of same-year Fall Midwater Trawl to Townet indices for age-0 striped bass is used as an index of summer survival (Stevens et al. 1985).
Feasibility: High. The proposed sampling augmentation is considered minor.

d. Other focused sample collections
Lead Agencies: TBA.
What: Focused, short-term field collections. Where gaps appear in the sampling grid or when specific specimens are needed for laboratory analysis that can't be captured using the existing monitoring work, special focused field collections will be needed.
When: As needed. It is not anticipated these efforts will take more than a few days per month.
Cost: Cost should be about $3000 as the IEP has staff and resources available.
Comments: One example may be the use of the boat-based beach seining employed during the IEP Shallow Water Habitat Predator-Prey Dynamics Study. This technique was an effective method for collecting large numbers of inland silverside and striped bass > 100 mm with low effort (Nobriga et al. submitted; consistently 10^2-10^3 fish per hour of sampling during summer months).
Feasibility: The feasibility depends largely on the methods used and the level of effort; however, methods such as boat-based seining are highly feasible because they have been successfully used for other studies (Nobriga et al. submitted).

2. Analyses of Existing Data

The IEP monitoring dataset represents one of the most comprehensive long-term estuarine datasets in the world. However, the IEP budget and staff limitations affect how much and how thoroughly the data can be analyzed. The present component represents a focused effort to identify relevant spatial, temporal and species trends using existing data.

a. Summarize the spatial and seasonal presence of early life-stages of pelagic fishes and zooplankton
Lead agency: DFG (Randy Baxter)
What: A general qualitative description of the occurrence of the early life-stages of the principal pelagic fishes and zooplankton collected in the Delta Smelt Larvae Survey, Fall Midwater Trawl, the 20 mm Survey, and the Neomysis/zooplankton component of the Environmental Monitoring Program.
Questions Addressed: n/a. This is a basic summary of when different life stages of fish and pelagic fishes are present. It will be used as a resource for other program components.
When: First draft: June 15, 2005.
Cost: $2,000 of reallocated IEP funding and staff.
Comments: This is mostly a compilation of existing information to be used as a screening tool: co-occurrence matches and mismatches between species, life stages and potential causative stressors will inform us of the more probable mechanisms to investigate.
Feasibility: High. Already initiated and near completion.

b. Apparent growth rates of pelagic fishes and relationship to abundance
Lead Agency: DFG (Randy Baxter)
What: Fish growth rates can be an indicator of toxic exposure or food limitation (Bennett submitted). We want to examine length data for fishes collected in the MWT to determine whether mean lengths during fall (apparent growth rates) changed abruptly during 2002-2004. Sweetnam (1999) noted a step decline in mean length of delta smelt that started in about 1990. The MWT length data have not been analyzed for other species or for recent-year effects. This analysis may be particularly useful for striped bass because the approximate date that the population reached an average length of 38 mm is known from the TNS (Turner and Chadwick 1972). Thus, fall striped bass length distributions may be corrected for spawn timing or other factors that influence early larval growth and/or length at a particular time (Miller 2000). We will also compare length at date data with abundance to evaluate whether apparent growth rate influences abundance and we will make use of recently collected length-weight data and compare it to similar historical information derived from sampling in the upper estuary (e.g., Kimmerer et al. 2005).
Questions addressed: Have species' mean lengths, particularly those of 2002-2004 versus previous years, declined? What: Analyze existing length frequency data from the MWT to determine if the apparent growth rates of delta smelt and striped bass have changed over the long-term and/or recently (2002-2004).
When: The analysis can be completed in the next six months.
Cost: Existing IEP staff and funds can be redirected to this analysis.
Feasibility: Results from Sweetnam (1999) indicate this approach may be insightful.

c. Zooplankton fecundity and population structure
Lead agencies: DFG and USBR
What: This is an analysis of existing data to evaluate changes in the number and frequency of nauplii present per adult calanoid copepod, and eggs and embryos present per female mysid shrimp. These analyses will be conducted as part of Bryan Manly's ongoing fish and zooplankton data analyses in collaboration with DFG zooplankton survey staff. These population parameters may indicate the presence of environmental stressors for zooplankton including toxins, exotic species invasions, and habitat degradation. Decreased reproductive fitness can lead to population declines. Currently, egg/embryo numbers are determined only for mysids, but can be derived for copepods from new samples with a substantial increase in processing time. Based on the analyses from this study, decisions will be made regarding the utility of counting copepod eggs from preserved, archived samples.
Questions addressed: What are the monthly and spatial patterns & annual trends in calanoid copepod population structure and mysid shrimp fecundity? Do these patterns & trends coincide with any known environmental events or the presence of specific stressors? Did fecundity decrease over time or in certain regions, indicating worsening environmental conditions? Was there a step change in the last few years?
When: 2005
Cost: Redirection of IEP staff time, and a contract with B. Manly (via Delta Mendota Water Authority)
Comments: This work will be conducted by Bryan Manly (as part of his ongoing analyses) and redirected DFG Zooplankton staff.
Feasibility: Analyses are already in progress. Previous unpublished analyses of *Neomysis mercedis* fecundity by DFG zooplankton staff also exist.

d. Toxic and other harmful effects of Microcystis aeruginosa blooms
Lead agency: DWR-DES
What: This is a literature review on *Microcystis aeruginosa*. *Microcystis aeruginosa* blooms may be an important new stressor for pelagic species in the Delta. Many basic questions about ecological effects of *Microcystis aeruginosa* blooms can likely be answered from existing literature. Answers to these questions will provide important background information for *Microcystis* studies (see element 3d below) and data analysis and interpretation.
Questions addressed: What are the main *Microcystis* toxins? How do they act on fish and zooplankton? What concentrations are known to have lethal or sublethal effects on fish and zooplankton? What are other harmful effects of *Microcystis* blooms on pelagic species? How do blooms form? How variable is the production and toxicity of microcystins among blooms of *M. aeruginosa*?
When: 2005
Cost: Redirection of existing IEP staff time and funds.
Comments: This work would be conducted by redirected DWR-DES staff (Dr. Peggy Lehman)
Feasibility: Ongoing - Much of this literature review has already been completed by DWR's Dr. Lehman (Lehman in press). Dr. Lehman also submitted a proposal to the CALFED Science program for additional funding for a *Microcystis* study starting in 2006.

e. Use and toxicity of pyrethroid pesticides
Lead agencies: DFG, USGS (SFEI)
What: This is a literature review and data analysis of pyrethroid pesticide use and toxicity. Pyrethroid pesticides are used in increasing amounts by agriculture and vector control as other pesticides are withdrawn from use. Pyrethroid pesticides are known to be more toxic to aquatic organisms than some other classes of pesticides. A review of the available literature and data on pyrethroid use in the Delta area and pyrethroid toxicity to estuarine organisms will provide important information regarding the need for, and scope of, future studies of pyrethroid toxicity.
Questions addressed: What are the basic chemical and toxicological characteristics of pyrethroid pesticides? For which purposes and how much are pyrethroid pesticides used in the Delta watershed, and how has the use changed over time? What are the most likely pathways for these pesticides to enter the Estuary? What factors influence the transport to and toxicity of these pesticides once in the Estuary? What is known about their toxicity to estuarine organisms? What concentrations are known to have lethal or sublethal effects on fish and zooplankton? Are there particular groups of estuarine organisms that are more sensitive to pyrethroids than others?
When: 2005
Cost: Funding for DFG's pesticide unit and/or USGS staff. Assuming two months of work, this will cost $15,000.
Feasibility: Expertise on this subject exists within the DFG pesticide unit and among USGS and SFEI staff. Much of the needed data and information has already been analyzed and summarized in other contexts. Other local expertise exists at UCD and UCB.

f. Use and toxicity of aquatic herbicides
Lead agencies: DWR-DES in cooperation with DBW
What: This is a literature review and data analysis for copper and other aquatic herbicides used to control nuisance aquatic plants in the Delta. Some of the data collected during and after herbicide applications by the California Department of Boating and Waterways (DBW) has been published in reports, while other data need to be entered into electronic databases and analyzed. Review of reports and additional data analyses are needed to assess the potential for these compounds to contribute to declines of pelagic species in the Delta and to help decide if additional studies are necessary. This work will also help us understand exotic plant dynamics in the Delta.
Questions addressed: What are the basic chemical and toxicological characteristics of the herbicides used to control aquatic nuisance species in the Delta? What is their use history? How and when are they applied? What is their toxicity to estuarine organisms and other effects on the aquatic environment? What concentrations, if any, have lethal or sublethal effects on fish and zooplankton? Is there evidence of or potential for toxicity to zooplankton or fishes in the upper estuary based on current data and literature? Are there any groups of estuarine organisms that might be more sensitive to these herbicides than others?
When: 2005
Cost: Four months of staff time using existing redirected staff and additional hired temporary staff for data entry and basic analyses. The additional would be $20,000.
Comments: This work would be conducted by redirected and additional hired temporary IEP staff to help with data entry and analyses; cooperation by DBW.
Feasibility: DBW has collected a large amount of data related to their herbicide treatments of aquatic weeds. Some of these data are summarized in reports and use permits available from DBW staff and/or on the internet. However, according to DBW staff, a considerable portion of

their data have not been entered into an electronic database. Part of this work will be to enter and analyze these data.

g. Evaluation of changes in pelagic fish habitat quality using the IEP long-term monitoring data
Lead agencies: DFG and DWR
What: This is a proposed new analysis of existing data. We propose to use striped bass and delta smelt catch and physical habitat data from the IEP fish data (FMWT, Townet, Bay Study, 20 mm Survey) to define the ranges of salinity, temperature, and water clarity in which these species occur. It is likely fish habitat can be better characterized by combinations of these variables than any one of them alone because fish need to make trade-offs among them. This multivariate habitat data will be entered into GIS software to develop areal estimates of suitable habitat for each species. These areal estimates can then be used as a response variable to search for time trends, hydrologic trends, etc. that may inform us whether habitat quality changes from year to year, or has changed through time.
When: Timing will be contingent on POD PWT priorities for staff redirection.
Questions addressed: Has the areal extent of suitable striped bass and/or delta smelt habitat quality changed? Does interannual variation in estuarine hydrology influence the areal extent of striped bass and/or delta smelt habitat? Have export changes affected the areal extent of striped bass and/or delta smelt habitat?
Cost: Two Environmental Scientists $110,000 (50% time). Additional assistance of redirected IEP staff may also be needed.
Feasibility: The analysis itself is highly feasible because it involves existing data and DFG/DWR staff can perform the necessary analyses. It is possible that pelagic fish habitat quality cannot be adequately described using the available data. For instance, it may be defined by zooplankton density more than physical variables. However, we suggest the FMWT, which has the highest number of stations sampled and which has sampled during late summer since 1967, has the highest potential to discern changes in physical habitat quality for upper estuary pelagic fishes.

h. Analysis/summary of recent changes in delta water operations
Lead agency: USBR
What: In the past few years, more water has been exported during the summer (July-September) than before, in part to compensate for conservation-driven export reductions in spring (April and May). There have been other changes in water project operation changes, which may also have had unexpected biological side-effects (e.g. export of more primary production). The purpose of this element is to closely examine recent changes in water project operations to identify effects potentially strong enough to account for the apparent step change in pelagic fish species abundances since 2001. Other historical changes in water project operations will also be studied to support the "Analysis of historical population dynamics" study element and advance our knowledge of the role of water project operations in the long-term decline of certain pelagic fish species. However, these analyses will be secondary to the investigation of recent changes.
Questions addressed: How have recent (1995 – 2004) water project operations policy changes changed delta hydrology? "Hydrology" is meant here to include the volume, timing, and pattern of input flows into the delta, delta outflow, exports, and operation of various water project gates and barriers. We also ask: which, if any, of the changes might plausibly have contributed to, or caused, a step change decrease in pelagic fishes abundance since 2001?
When: Over the next year

Cost: $15,000
Comments: The results will be reviewed by the POD PWT and other biologists, who will evaluate the strength of evidence that might connect water operations changes to the recent decline of pelagic fish species. The committee will recommend follow-up investigations to explore leading hypotheses, if appropriate.
Feasibility: High. The historical data needed for this assessment have already been compiled as part of the recent CVP OCAP reconsultation, and the investigators are intimately familiar with them.

i. Analysis of historical population dynamics
Lead agency: USBR
What: These investigations were begun with the observation that there appears to be a downward step change in several pelagic fish species indices after 2001. This element will undertake a general review of historical fish population dynamics in the estuary. Zooplankton and benthic invertebrate population density and biomass dynamics will also be explored where data series exist that have not been analyzed (for historical dynamics) elsewhere (for benthos biomass, see 3f). Several historical analyses of fish, plankton, or benthic invertebrate populations have been published, and their findings will be reviewed and incorporated into this investigation; however, there will be a de novo examination of pelagic and nearshore fish populations. Results from these analyses will also be integrated with the ongoing data analyses studies described in 4c and 4d.
Questions addressed: The examination will include, first, a review of historical IEP monitoring data to describe historical fluctuations. This will include the evaluation of, or search for, (i) long-term trends, (ii) discernable epochs in the data, (iii) notable point or short-duration events, and (iv) coordinated or contemporaneous changes in multiple species that suggest a common explanation. A simple model will be used at this stage to account for the known effects of gross hydrology. Second, the power of various hypotheses raised in the POD PWT investigation to explain historical fluctuations in pelagic and nearshore fish indexes will be investigated. Nearshore fishes (e.g., largemouth bass) are included because of the expected contrast in their responses to some possible stressors. In connection with hypotheses involving stressors imposed during a specific time period, the effort will focus particularly on determining whether the timing of response onset is plausible. As with other parts of the POD PWT investigation, the central focus will be on changes that may have occurred since 2001. However, the scope of the investigation will be wide, because a full explanation for recent changes may be complicated and reach much farther into the past.
When: Beginning in 2005, this element will proceed in parallel with the rest of the POD PWT investigation, and will be informed by it.
Cost: Initial work can be accomplished with redirection of existing staff and help from external sources. Some funds may be required for outside assistance in the future.
Comments: Statistician Bryan Manly has agreed to assist, at least with the early stages of the investigation. San Luis Delta Mendota Water District has generously agreed to support Dr. Manly's work. Other outside assistance may be required in the future.
Feasibility: High. Investigation does not depend on the availability of new field data. Special statistical analytical techniques that are required are well-known.

3. New Laboratory and Field Studies

While IEP monitoring is effective at tracking long term trends in species abundance, the core sampling programs do not provide information about certain types of organisms (e.g. blue-green algae), the health and status of fish and invertebrates, or fecundity. Hence, new laboratory and field studies are proposed to help provide insight into the type, timing and location of stressors.

a. Otolith analysis of pelagic fish
Lead Agency: UC Davis (Dr. Bill Bennett)
What: Analysis of otoliths from delta smelt, striped bass and inland silversides 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. This work has been done successfully on delta smelt (Bennett submitted). IEP has archived samples from 2003 and 2004 in hope that this work can be continued.
Questions: Do growth rates of any or all of these fishes decline either seasonally or geographically? When and from where in the estuary are the species of interest produced?
When: Work should be started as soon as practical and continue for at least one year.
Cost: Estimate is for $392,000 to process approximately 500-600 samples per year.
Comments: This work will be an extension of the delta smelt work (Bennett submitted) and striped bass work carried out by Dr. Bill Bennett and colleagues (Bennett et al. 1995). This work would be most effective if coupled with the histopathology work in item 3b and diet/condition work in 3c to provide a comprehensive timeline of the relative condition of the fish that we could compare to timing of potential stressors. Given the specific technology and expertise needed to do this work, it is recommended that this be done as a directed action. This work along with that in item 3b has been submitted to CALFED's ecosystem restoration PSP; however, the PSP proposal is limited to work on delta smelt. We propose to expand the work to striped bass and inland silverside.
Feasibility: High. This work will be an extension of the delta smelt work (Bennett submitted) and striped bass work carried out by Dr. Bill Bennett and colleagues (Bennett et al. 1995). Existing samples of delta smelt from 2003 and 2004 are already archived. Samples of all three fish can be obtained from the various monitoring efforts in 2005.

b. Liver histopathology (starvation and/or toxics) for pelagic fishes
Lead Agency: UC Davis (Dr. Swee Teh)
What: Histopathological examination of larval and juvenile delta smelt, striped bass and inland silverside. The relative quantity of glycogen and liver lesions in fish provides a good indication of their health (Bennett et al. 1995; Bennett submitted). Low glycogen indicates low feeding success, thus implicating food availability as a stressor. Liver lesions suggest sublethal exposure to toxic compounds. It is hoped this diagnostic tool will help pinpoint if, when, and where significant toxic exposure and/or food limitation occurs.
When: Work should be started as soon as practical and continue for at least one year.
Cost: Estimate is for $386,000 to process approximately 500-600 samples per year.
Questions addressed: Does histopathological information support hypotheses of recent increases in toxic exposures and/or food limitation? Do target fishes from the same locale exhibit similar responses? Does the histopathological condition vary in severity by life stage within or among species and/or geographic regions?

Comments: This work will be an extension of the work on delta smelt (1999 – Dr. Swee Teh) and striped bass larvae (Bennett et al. 1995). Given the specific technology and expertise needed to do this work, it is recommended that this be done as a directed action. This work along with that in item 3a has been submitted to CALFED's ecosystem restoration PSP; however, the PSP proposal is limited to work on delta smelt. We propose to expand the work to striped bass and inland silverside.
Feasibility: High. This work will be an extension of the delta smelt work (Bennett submitted) and striped bass work carried out by Dr. Bill Bennett and colleagues (Bennett et al. 1995). Perhaps the greatest obstacle will be contracting to UCD.

c. Quantitative analysis of stomach contents, body weight and parasite load for pelagic fishes
Lead Agency: DFG
What: Food habit studies have been done on many of the fish and zooplankton found in the estuary (IEP 1987; Orsi 1995; Lott 1998; Nobriga 2002; Feyrer et al. 2003); however, many of these studies were done more than ten years ago and the feeding habits of the local inland silverside and threadfin shad populations have only been studied in a limited geographical location (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). The IEP started a study of fish length-weight relationships needed to develop a program to monitor relative weight. This work should be continued.
Questions addressed: For striped bass, delta smelt and threadfin shad, is there evidence of reduced feeding success or increased parasite load at 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?
When: 2005.
Cost: This will require $70,000 for 2-3 scientific aides to process the samples and enter the data. Staff time to analyze the data and prepare a report can be done by redirecting existing staff.
Comments: DFG staff in the IEP can collect samples and process diet information; parasite examinations and identification may require some assistance from the DFG Pathology Laboratory.
Feasibility: The IEP has extensive experience with these techniques. Thus, feasibility is high.

d. *Field survey of Microcystis aeruginosa bloom biomass and toxicity*
Lead agencies: DWR-DES, DFG
What: A new field survey to measure *Microcystis aeruginosa* bloom biomass and toxicity. A single day study in 2003 and a seasonal study in 2004 indicated that a toxic *Microcystis aeruginosa* bloom was wide spread throughout the Delta (Lehman et al. in press). Furthermore, microcystins in tissue of zooplankton, amphipods, clams, and other benthic organisms collected in 2003 and 2004 indicated that the base of the food web contained *Microcystis* toxins that could impact organisms at higher trophic levels through bioaccumulation (Lehman et al. in press). This survey will build on the 2004 survey and be closely coordinated with the 2005 fish surveys (summer townet survey, fall midwater trawl) and toxicity assays. Sample collection at fish

survey stations will help elucidate the link between *Microcystis* biomass and toxicity and its direct effect on zooplankton and fish. Water samples for *Microcystis* biomass and both algal tissue and dissolved microcystins toxicity will be collected monthly by DWR-DES staff at selected fish survey and zooplankton and fish toxicity assay stations, as well as stations with high *Microcystis* biomass identified in the 2004 survey. Zooplankton, benthos, and fish toxicity will be evaluated based on microcystin content in whole animal (zooplankton and benthic) or liver and muscle tissue (fish). Animals for these analyses will be collected during fish surveys. Epibenthic and benthic organisms will be collected by ponar dredge or box sampler (C. Messer, personal communication) as a part of the bloom sampling effort or fish survey as appropriate. Environmental conditions associated with the bloom biomass and toxicity will be measured at each station with an YSI 6600 sonde and by water samples for a suite of discrete water quality measurements including nutrient concentration. Qualitative observations of *Microcystis* surface blooms will be recorded by fish survey staff during all fish survey dates and at all sites.
Questions addressed: Is *Microcystis* biomass or toxicity increasing over time in the Delta? Does *Microcystis* bloom biomass or microcystins toxicity occur in areas important to pelagic fish species in the Delta? Is there a relationship between bloom biomass and toxicity with zooplankton and fish abundance? Is there a relationship between the bloom biomass, microcystins in algal tissue or microcystins dissolved in the water column, and microcystins toxicity in zooplankton, benthic, epibenthic and fish tissue? Do regions of high zooplankton and benthic tissue microcystins toxicity coincide with high microcystin tissue content, lower density and poor health of planktonic feeding fish? Are dissolved microcystins produced during the decomposition phase of the bloom sufficiently toxic to impact fish and zooplankton survival and health based on densities at sampling stations and toxicity bioassays?
When: Summer and fall 2005.
Cost: Additional funds will be needed for the project: 2 Scientific aids full time 6 months $52,800; 1 Environmental Scientist $52,000 half time 6 months; Boat operator $6,400; Toxicity analysis $20,000; Equipment $1,000;
Comments: This work would be conducted by redirected and additional hired temporary DWR-DES staff including a boat operator; microcystins toxicity analyses by Dr. G. Boyer at State University of New York. Dr. Peggy Lehman also submitted a proposal to the CALFED Science program for additional funding for a *Microcystis* study starting in 2006.
Feasibility: DWR-DES staff under the direction of Dr. Lehman has successfully carried out *Microcystis* surveys in 2003 and 2004 and is experienced in field sampling and sample preparation methods (Lehman et al. in press). Toxicity analysis will be done by Dr. G. Boyer of the State University of New York, an expert on cyanobacterial toxicity. His group has extensive experience in determination of cyanobacterial toxins and routinely analyzes samples for NOAA, CDC, and departments of health and conservation for several states. They also participated in the 2003 and 2004 surveys. Future analyses may be possible at DFG's Water Pollution Control Laboratory.

3 e. Acute and chronic invertebrate and fish toxicity tests
Lead agencies: UCD in close collaboration with DWR-DES
What: This is a proposed new study to investigate toxicity of Delta water samples to invertebrates and fish in laboratory bioassays. This is a pilot-level study intended to assess the potential for contaminated water to contribute to the observed declines of pelagic species in the Delta and to help decide if additional studies, including studies to chemically identify toxins, are

warranted. Monthly water samples will be collected regularly at selected fish survey sites in the Delta and the Napa River from June through September 2005 during the *Microcystis aeruginosa* sample collections. Sampling will take place approximately simultaneously with fish sampling at sites characterizing primary inflows to the Delta as well as geographic regions important to pelagic fish of interest or known to receive agricultural runoff or herbicide treatments for aquatic weed control, and sites used for toxicity testing in 1993-1995 (Werner et al. 2000). Test organisms will include the invertebrates *Ceriodaphnia dubia*, *Pseudodiaptomus forbesi*, *Hyalella azteca*, as well as juveniles of the Delta fish species delta smelt (*Hypomesus transpacificus*) and juvenile striped bass (*Morone saxatilis*). *Ceriodaphnia dubia* is a common invertebrate test organism in biotoxicity studies (e.g. US EPA 2002) and has been used in a published toxicity study conducted in the Delta in 1993-1995 (Werner et al. 2000) as well as in studies conducted by the CA Department of Boating and Waterways as part of their aquatic weed control permit requirements and by the San Francisco Estuary Institute in the San Francisco Bay watershed. Similarly established assays with the amphipod *Hyalella azteca* will provide the opportunity to explore toxicity in more saline waters. While *C. dubia* and H. azteca occurs in the Delta, they are not known to be important food organisms for pelagic fishes. Thus, assays will also be conducted with *Pseudodiaptomus forbesi*, an important Delta fish food organism in the summer and fall. Juvenile delta smelt and striped bass are among the rapidly declining Delta fish species. In contrast to *C. dubia* and *H. azteca*,, standardized assays involving *P. forbesi,* juvenile delta smelt, *i* and striped bass do not currently exist. Therefore, they will need to be developed during this study. 7-day and 10-day bioassays will be conducted under standardized laboratory conditions. Mortality after 96 hours and invertebrate egg production and fish growth after seven or 10 days will be used as measures of acute and chronic toxicity, respectively. In invertebrate assays showing mortality, Invertebrate Toxicity Identification Evaluation (TIE) will be conducted to determine the responsible toxic agents. In the fish toxicity assays, sublethal effects including inhibition of acetylcholine esterase in the brain, quantification of vitellogenin and cytokine m-RNA, and stress proteins will be explored as more sensitive endpoints than fish growth.

Questions addressed: Is water in the Delta and the Napa River toxic to pelagic fish and fish food organisms? If yes, where and when? Is there a relationship between toxicity results and fish and zooplankton abundances? Is there a relationship between *Microcystis* blooms and results of the toxicity assays?

When: Summer and fall 2005.

Cost: Approximately $182,000 for UC Davis staff to develop and conduct assays, TIEs, and report results.

Comments: Sampling would be performed as for *Microcystis* field survey. Toxicity Assay work would be conducted by UC Davis Aquatic Toxicology Laboratory (ATL; http://www.vetmed.ucdavis.edu/apc/atl/) under the direction of Dr. Inge Werner (http://www.vetmed.ucdavis.edu/apc/wernerlab/).

Feasibility: Water sampling will be conducted along with *Microcystis* sampling. The UC Davis ATL specializes in toxicity testing, including *C. dubia* and *H. azteca* assays. Dr. Inge Werner is a well-published expert in the ecotoxicology of the San Francisco estuary and works closely with ATL staff. Cultured *C. dubia, H. azteca* and juvenile delta smelt and striped bass are readily available for use in toxicity assays from culture facilities. A protocol for culturing *P. forbesi* at various salinities was developed as part of a recently completed CALFED funded study at UC Davis (Hall et al, in prep.) and will be available for this study.

f. Develop and compare recent estimates of striped bass and delta smelt fecundity with historic information.

Lead Agency: DFG

What: Observed declines in fall juvenile fish abundance could result from poor survival of larval and early juvenile life stages, or could simply result from declining egg production. Declining egg production could result from a decline in the average size, age or total number of spawning females, or a reduction in individual female fecundity caused by degraded environmental conditions (e.g. exposure to contaminants or poor food availability). The specific purpose of this work plan action is to develop up-to-date relationships between female size/age and fecundity for striped bass and delta smelt. For both species, current fecundity relationships will be compared with historical relationships for indications of any significant change. Fecundity relationships were most recently developed for San Francisco Estuary striped bass and delta smelt in the mid 1980s and late 1990s, respectively (Knudsen and Urqhart 1988). For striped bass, the newly-derived fecundity relationships can be used in combination with adult population estimates to improve current estimates of overall egg production. Age- and sex-specific estimates of adult striped bass abundance in the Estuary have been made annually or semi-annually since the late 1960s. By combining these abundance estimates with established relationships between female size/age and fecundity, it has also been possible to produce annual or semi-annual estimates of egg production. These egg production estimates have commonly been used in analyses of factors influencing striped bass recruitment (Stevens et al. 1985; Kimmerer et al. 2000; 2001), and will be used in this current investigation of apparent delta fish declines. The delta smelt is a primarily annual species with relatively low fecundity, so a substantial reduction in fecundity could result directly in subsequent low juvenile or adult population levels.

Questions addressed: Has there been a recent decrease in the fecundity of striped bass or delta smelt?

When:

Striped Bass (2005) – Retain approximately 40 adult female striped bass from the IEP's 2005 adult mark-recapture sampling program for laboratory assessment of general ovary condition (mass, color, egg resorbtion levels, lesions, etc.) and estimation of live egg fecundity. Develop new size- and age-fecundity relationships.

Striped Bass (2006) – If the cursory examination of females in 2005 indicates poor ovary health and/or unusually low fecundity, develop and implement a more comprehensive investigation of female general condition and ovary health, incorporating additional factors such as inter-sex dysfunction, fat levels, contaminant burdens, and skeletal abnormalities. Investigate relationships between health parameters and fecundity.

Delta Smelt (2005) – Locate archived adult specimens from the 2001-2004 period. If sufficient numbers of archived specimens are available, examine them to assess general fish and ovary condition, and measure fecundity levels. Develop new size- and age-fecundity relationships.

Delta Smelt (2006) – If the 2005 effort fails to provide usable size-fecundity relationships for comparison with historical relationships, develop and implement a program in 2006 to retain adult female delta smelt from the IEP's Spring Kodiak Trawl Survey for laboratory assessments of general fish condition, ovary condition, and fecundity. Investigate relationships between health parameters and fecundity.

Cost: Delta Smelt and Striped Bass (2005) – Oversight, sample collection and specimen selection, and analysis accomplished through ongoing sampling and redirection. Laboratory processing: $25,000 for 2 Scientific Aides for 4 months each. Delta Smelt and Striped Bass

(2006) – Oversight, sample collection, and portions of the analysis accomplished through ongoing sampling and redirection.
Feasibility: The striped bass work is highly feasible. Since 2000, there may not be samples of adult smelt to compare with earlier work by Bradd Bridges and Randy Mager (UC Davis). Therefore, an important first step will be to determine if Fish and Game's Stockton laboratory may have appropriate archived specimens from 2001-2004. The earliest opportunity to collect new samples will be 2006. The 2006 striped bass results described above are potentially obtainable from a research proposal by Dr. Swee Teh (UC Davis) recently submitted to CALFED for funding.

3.g. Trends in benthic macrofauna biomass
Lead agency: DWR
What: Over the past three decades, the Interagency Ecological Program (IEP) Environmental Monitoring Program (EMP) has collected benthos community composition and abundance information at 22 sites, including four long-term monitoring stations. Long-term trends at the four long-term stations are the subject of an ongoing investigation (see *4 d*). Unfortunately, measurements of benthic macrofauna biomass have never been conducted by the EMP. Biomass data are crucial in determining the role of benthic organisms in the ecosystem and the ecological significance of changes in benthic community composition and abundance. Specifically, knowledge of benthos biomass is needed to improve our understanding of the role of benthos in the SFE, including the feeding potential of various functional groups, potential availability and transmission of contaminants bioaccumulated in benthos, and trends in production. Fortunately, the EMP has archived benthos samples dating back to 1975 which can be used for biomass estimation using a simple wet-weight method. The objective for 2005 is to measure and examine the biomass of benthic organisms collected quarterly from 1975 – 2004 at two long-term stations located in the central and northern Delta. Data analysis would be conducted as part of the ongoing study *4 d*.
Questions addressed: At central & northern Delta locations, what are the long term trends in biomass, production, and grazing rates of benthic species? How are these changes related to physical-chemical gradients? How do changes in benthic functions such as production and grazing affect the pelagic food web?
When: 2005
Cost: Total: $65,510 (2 Environmental Scientists (C. Messer & K. Gehrts): 365 hours = $31,400; 1 Scientific Aide: 550 hours = $21,110; Wayne Fields: 30 hours = $3000; Supplies: $10,000)
Comments: This work would be conducted by redirected and additional hired temporary DWR-DES staff including Dr. Dean Messer, Karen Gehrts, and Cindy Messer, a scientific aid. Wayne Fields of Hydrobiology would provide identification help and Dr. Janet Thompson, USGS, would provide additional expertise. These investigators along with UCD and SFSU researchers also submitted a proposal to the CALFED Science program for additional funding for a benthic biomass study starting in 2006. Data analysis would be conducted as part of the ongoing study *4 d* and also made available for the historical population dynamics study *2 i*.
Feasibility: High. Investigation does not depend on the availability of new field data. Special statistical analytical techniques that are required are well-known.

4. Ongoing Studies

IEP is particularly fortunate that several important studies are underway that will help to evaluate the effects of water exports on aquatic species. The first two studies are IEP-sponsored, and the third is funded by CBDA. We believe that these studies will be particularly important in determining regions of the estuary where fish entrainment is of greatest concern, and evaluating whether changes in the timing of exports over the past decade and longer have reduced primary production.

a. Learning from the DSM-2 particle tracking model
Lead agencies: SFSU/RTC and DWR
What: This is a previously-funded IEP study that will be completed in 2005. The goal of the project is to develop a theoretical baseline for understanding the spatial distribution of entrainment risk under differing hydrologic and operations scenarios. It may also be 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 productivity during summer.
When: Basic data collection will be completed during summer 2005; a manuscript for peer-review should be available by the end of 2005.
Questions addressed: How does the spatial distribution of entrainment risk vary under different hydrologic (flows and exports) and operations (DCC, south delta barriers) scenarios? Do recent year summertime water operations have the potential to significantly reduce lower trophic level productivity in the upper estuary?
Costs: no additional cost
Feasibility: High (in progress)

b. South Delta Fisheries-Hydrodynamics Studies
Lead agencies: USBR, USGS and DWR
What: This is an externally-funded (South Delta Barriers Project & USBR) IEP special study that was initiated in 2004. Its goal is to develop a theoretical baseline for understanding how larval fish behavior affects entrainment risk in the south Delta under differing hydrologic and operations scenarios.
When: The second phase of field data collection will be completed during spring 2005; a summary report should be available by the end of 2005
Questions addressed: What are the behaviors of larval fishes in the south Delta and how does behavior affect entrainment risk vary under different hydrologic (flows and exports) and operations (DCC, south delta barriers) scenarios? Do recent year summertime water operations have the potential to significantly increase mortality rates?
Costs: no additional cost
Feasibility: High (in progress)

c. Phytoplankton primary production and biomass in the Delta
Lead agencies: UCD, DWR-DES
What: This is an ongoing data analysis project with CALFED-ERP funding granted to Dr. Alan Jassby at UC Davis (ERP-02-P33) and collaborators at DWR-DES. The full title is "Primary Production in the Delta: Monitoring Design, Data Analysis and Forecasting." Phytoplankton

production is at the base of the pelagic food web leading to the zooplankton and fish species currently experiencing rapid declines. One goal of this ongoing project is to analyze available historical data on chlorophyll *a* concentrations and other water quality variables in Delta subregions or at specific long-term monitoring stations in order to determine processes underlying changes in primary production and biomass. This is an extension of similar analyses conducted at the Delta-wide scale (Jassby and Cloern 2000; Jassby et al 2002). Results from this study will help assess the potential for sub-regional and local bottom-up food web effects on pelagic zooplankton and fish, effects of changed export patterns on phytoplankton production in different Delta areas, etc.
Questions addressed: What are long-term patterns and trends in phytoplankton production and biomass and other water quality variables in different Delta subregions and at specific locations? How do they compare to Delta-wide trends? What factors may be responsible for these patterns and trends? How may the Delta food web be affected by these patterns and trends? Have changes in water exports affected phytoplankton in different Delta areas?
When: Ongoing through 2006.
Costs: No additional costs.
Comments: The key staff includes Dr. Alan Jassby, UC Davis, in collaboration with DWR-DES staff (Dr. Anke Mueller-Solger & Dr. Marc Vayssières)
Feasibility: High (Ongoing).

4 d. Retrospective analysis of long-term benthic community data
Lead agency: DWR & USGS
What: This is an ongoing data analysis project with IEP and CALFED-Science funding. The goal of this project is to investigate long-term trends and ecological processes involving benthic organisms from historical data collected by the IEP Environmental Monitoring Program (EMP) at its four long-term benthos monitoring stations. Specifically, this analysis seeks to uncover historical trends in community composition in relation to environmental variability, hydrology, and exotic species invasions.
Questions addressed: At the four core sites, how do benthic community assembly and structure change over time? How are these changes related to physical-chemical gradients? Can spatial or physical thresholds be identified for benthic macrofauna, especially for species of concern such as invasive species, species with important trophic effects, (e.g. *Corbicula fluminea* and *Potamocorbula 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? To facilitate integration with other parts of the POD PWT investigations, the investigators have agreed to pay particular attention to changes in the benthic community that may have occurred since 2001. The investigators will include the benthic biomass data provided in *3 f* in these analyses.
When: Ongoing through 2006.
Cost: No additional costs.
Comments: Key staff includes Dr. Marc Vayssieres (DWR), and Dr. Janet Thompson and Heather Peterson (USGS).
Feasibility: High (Ongoing).

Feasibility:

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

The 2005 study components have been carefully selected based on their feasibility and potential to help differentiate among potential stressors. 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 (Figures 2 and 3). The work in 2005 is 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 2005 work will be used to define and focus the efforts needed in 2006 and succeeding years. Thus, we expect that the work in 2006 and successive years will continue to be refined. For example, if in 2005 the bioassays of the delta water do not demonstrate toxicity and the histopathological examination of fish livers do not indicate widespread toxic effects, then the work in 2006 will greatly de-emphasize contaminants. If the statistical analysis of historical trends suggests other species or time period should be considered, they will be added to the 2006 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 2.

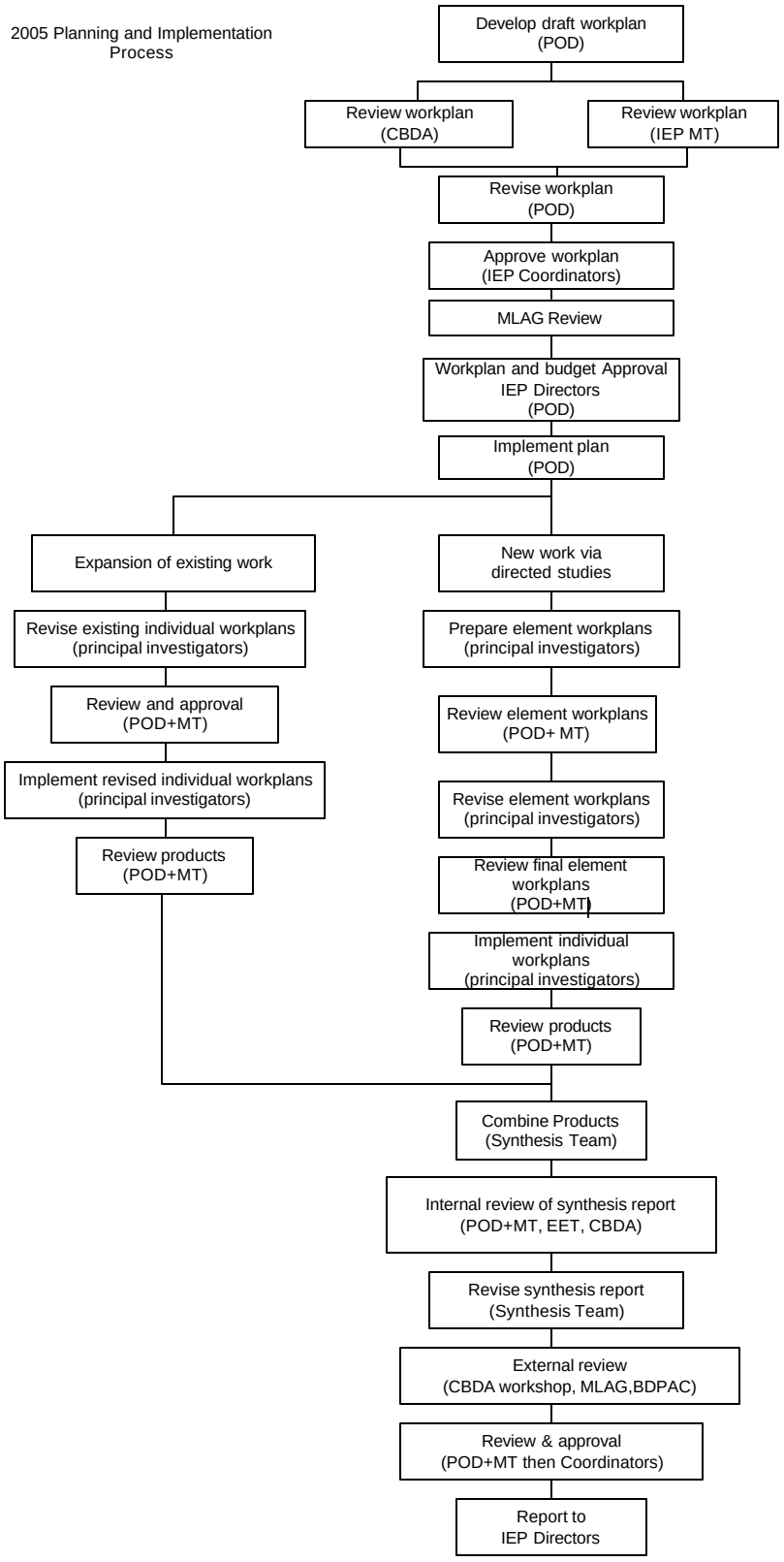
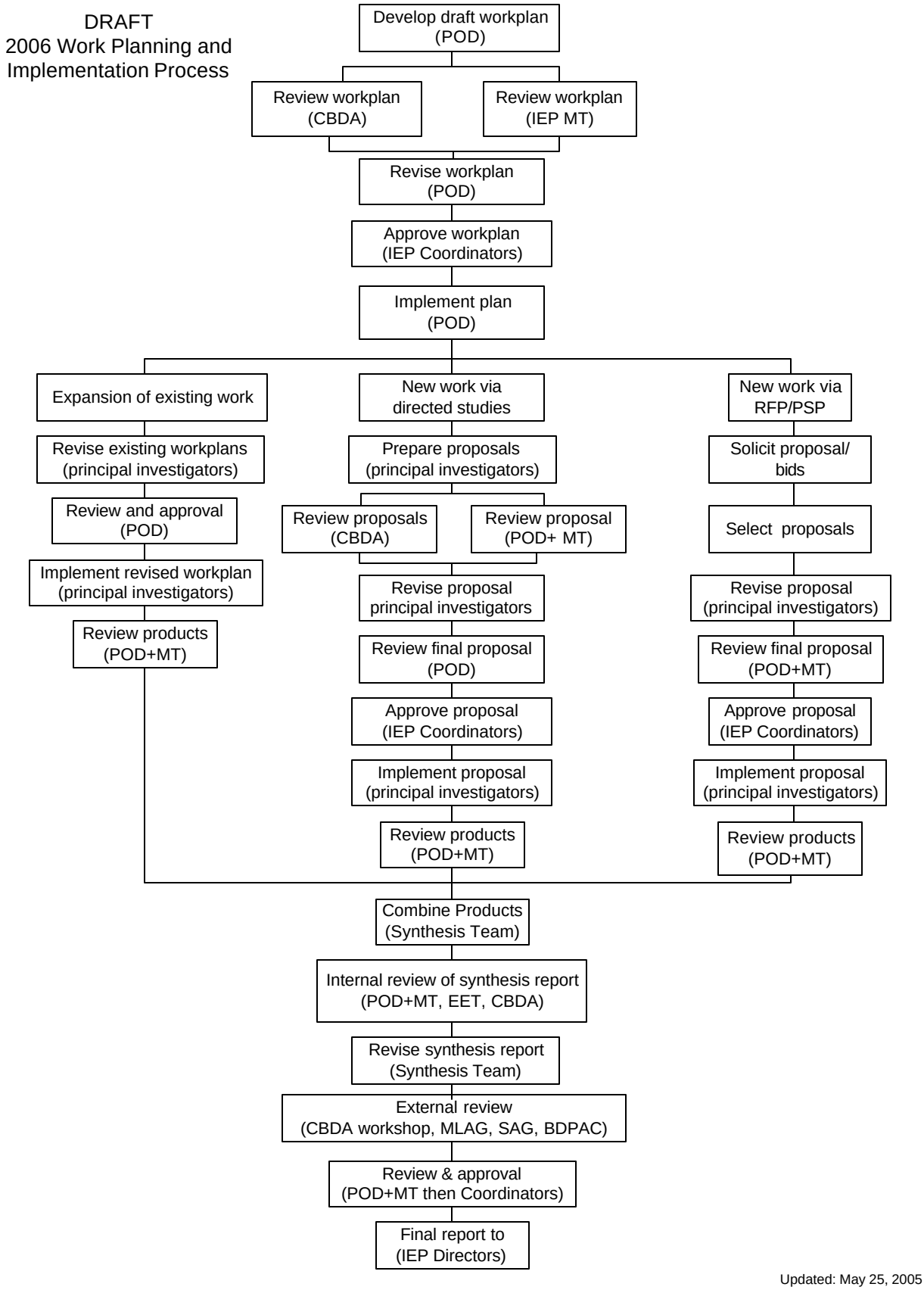

2005 Planning and Implementation Process
Develop draft workplan (POD)
Review workplan (CBDA)
Review workplan (IEP MT)
Revise workplan (POD)
Approve workplan (IEP Coordinators)
MLAG Review
Workplan and budget Approval IEP Directors (POD)
Implement plan (POD)
Expansion of existing work
New work via directed studies
Revise existing individual workplans (principal investigators)
Prepare element workplans (principal investigators)
Review and approval (POD+MT)
Review element workplans (POD+ MT)
Implement revised individual workplans (principal investigators)
Revise element workplans (principal investigators)
Review products (POD+MT)
Review final element workplans (POD+MT)
Implement individual workplans (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,BDPAC)
Review & approval (POD+MT then Coordinators)
Report to IEP Directors
Note: For work previously submitted to PSP, the existing peer reviews will be used
Updated: May 25, 2005

Figure 3.


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
New work via
directed studies
New work via
RFP/PSP
Revise existing workplans
(principal investigators)
Prepare proposals
(principal investigators)
Solicit proposal/
bids
Review and approval
(POD)
Review proposals
(CBDA)
Review proposal
(POD+ MT)
Select proposals
Implement revised workplan
(principal investigators)
Revise proposal
principal investigators
Revise proposal
(principal investigators)
Review products
(POD+MT)
Review final proposal
(POD)
Review final proposal
(POD+MT)
Approve proposal
(IEP Coordinators)
Approve proposal
(IEP Coordinators)
Implement proposal
(principal investigators)
Implement proposal
(principal investigators)
Review products
(POD+MT)
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 given the short timeline for the 2005 work.

Project Management Team: The project will be managed by a collection of State and Federal agencies: Chuck Armor (DFG), Randall Baxter (DFG), Mike Chotkowski (USBR), Pat Coulston (DFG), Bruce Herbold (EPA), Anke Mueller-Solger (DWR), Matt Nobriga (DWR) and Ted Sommer (DWR). The group will meet at least monthly 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 least three satellite project work teams will be formed based on the major three stressors. POD PWT Management Team members have been assigned responsibility to organize each of the satellite teams: 1) invasive species (Ted Sommer and Matt Nobriga); 2) Contaminants (Anke Mueller-Solger and Bruce Herbold); and 3) water exports (Mike Chotkowski). 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 2005 to discuss project results, synthesis, and further studies with POD PWT members.

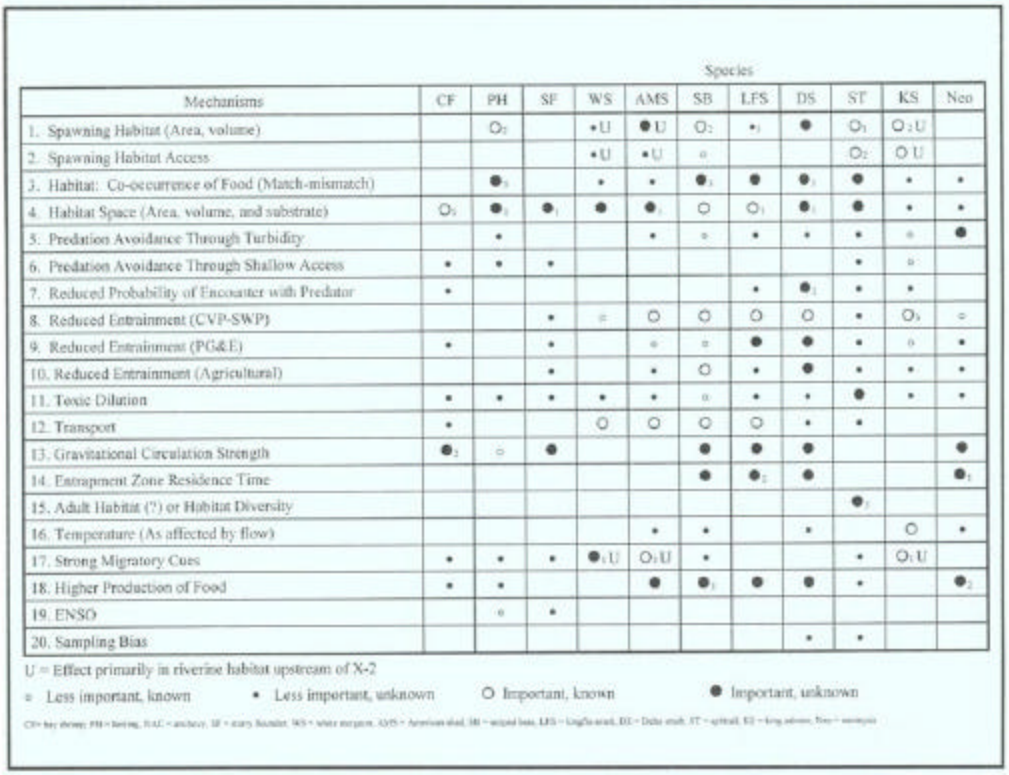
Outreach: Various products and deliverables (see below) will be completed as part of the project. Staff will give a presentation at the October 2005 State of the Estuary Conference to describe the status of the fish decline and the efforts to identify causes. In addition, the POD PWT will organize an IEP workshop by late 2005 to present preliminary results. A substantial portion of the 2006 IEP Annual Meeting will provide a later opportunity to update the results and present initial plans for 2006 studies.

Project Synthesis:

The goal of the triage approach is to better refine the major issues that need to be examined in greater detail in 2006 and beyond. While we anticipate that valuable information will be collected, we do not expect to be able to identify "the problem" at the end of 2005. Hence, the goal of the present effort is to provide basic information about the: 1) relative potential importance of each stressor; and 2) the degree of uncertainty for each. Project synthesis will be one of the major tasks of the POD PWT with additional help from the POD-Science group (see above).

Given the complexity of the problem and the resulting complexity of this study, the overall very short timeline for 2005, and the likelihood that the timelines for different study elements will vary substantially, a full synthesis of all study elements is a challenging task. We currently envision the 2005 synthesis effort to yield a mostly qualitative comparison of the results provided by the different study elements rather than a quantitative synthesis involving extensive numerical or statistical modeling. In other words, in keeping with our "triage" approach for 2005, we are aiming at rather coarse pattern recognition at this time. We fully recognize that the complexity of the problem ultimately warrants a much more extensive and refined synthesis approach. However, due to the difficulties mentioned above, we deem this type of approach not practicable for 2005. Instead, the POD PWT and POD-Science group will work to devise and propose a more refined synthesis plan for 2006 and beyond.

To carry out the triage goal in 2005, the POD PWT and POD-Science groups will work at a minimum to update the conceptual model in Figure 1. We also propose to develop a secondary conceptual model similar to the one developed by the IEP Estuarine Ecology PWT (IEP 1995). An example is provided in Figure 4, although the species and factors would be different. In addition, we intend to propose more extensive synthesis work as part of the work plan proposal for 2006 and beyond. We also expect that the results of the 2005 studies will eventually be integrated into species models for delta smelt, striped bass, silverside and perhaps zooplankton. Note that delta smelt life cycle modeling work by Kimmerer et al. has been proposed for CDBA funding as part of the Science Program's PSP. These models may be particularly useful for separating the relative effects of different stressors, and evaluating the effects of subtle changes in the estuary.



Mechanisms	Species										
	CF	PH	SF	WS	AMS	SB	LFS	DS	ST	KS	Neo
1. Spawning Habitat (Area, volume)		○		•U	●U	○	•	●	○	○U	
2. Spawning Habitat Access				•U	•U	◦			○	○U	
3. Habitat: Co-occurrence of Food (Match-mismatch)		●		•	•	●	●	●	●	•	•
4. Habitat Space (Area, volume, and substrate)	○	●	●	●	●	○	○	●	●	•	•
5. Predation Avoidance Through Turbidity		•			•	◦	•	•	•	◦	●
6. Predation Avoidance Through Shallow Access	•	•	•						•	◦	
7. Reduced Probability of Encounter with Predator	•						•	●	•	•	
8. Reduced Entrainment (CVP-SWP)			•	◦	○	○	○	○	•	○	◦
9. Reduced Entrainment (PG&E)	•		•		◦	◦	●	●	•	◦	•
10. Reduced Entrainment (Agricultural)			•		•	○	•	●	•	•	•
11. Toxic Dilution	•	•	•	•	•	◦	•	•	●	•	•
12. Transport	•			○	○	○	○	•	•		
13. Gravitational Circulation Strength	●	◦	●			●	●	●			●
14. Entrapment Zone Residence Time						●	●	●			●
15. Adult Habitat (?) or Habitat Diversity									●		
16. Temperature (As affected by flow)					•	•		•		○	•
17. Strong Migratory Cues	•	•	•	●U	○U	•			•	○U	
18. Higher Production of Food	•	•			●	●	●	●	•		●
19. ENSO		◦	•								
20. Sampling Bias								•	•		

U = Effect primarily in riverine habitat upstream of X-2

◦ Less important, known • Less important, unknown ○ Important, known ● Important, unknown

Figure 4: Conceptual model developed by the IEP Estuarine Ecology PWT (IEP 1995)

Budget:

The initial cost estimate for 2005 is approximately $1.67 million. Cost estimates for individual program components are provided in Table 2 and in the previous section as part of the project summaries. This estimate assumes many of the data analysis efforts and expanded monitoring will be carried out by redirected or re-tasked agency staff, that the stakeholders will continue to support the involvement of the Dr. Bryan Manly for the statistical analysis of the historical time series, that early estimates of the directed research are similar to those in the final workplan, and that the CBDA peer review does not greatly expand the proposed level of effort. There is a critical need to replace one of DFG's 30' research vessels and this process should be started in 2005. It is estimated this vessel will cost approximate $450,000 - $550,000. The cost of this vessel replacement has not been included.

Table 2 Delta Pelagic Fish Decline - 2005 Budget Estimates
(Amounts are in the $1,000)

Element	IEP #	Workplan #	Existing	Redirect	New	Who
Spring Kodiak trawl	2005-088		$198	$0	$0	DFG
Larval fish survey	2005-096	1.a.	$142	$0	$100	DFG
20mm survey	2005-033		$615	$49	$0	DFG
Townet survey	2005-007	1.b.	$200	$25	$75	DFG
Fall midwater trawl	2005-003	1.c.	$292	$19	$75	DFG
Delta outflow/San Francisco Bay study	2005-011, 012		$738	$31	$0	DFG
Adult striped bass	2005-002		$513	$15	$0	DFG
Environmental Monitoring Program	2005-072		$1,962	$0	$0	DWR
Neomysis/Zooplankton survey	2005-077		$209	$0	$0	DFG
Delta flows measurement	2005-030		$808	$0	$0	USGS
Suisun Marsh survey	2005-093		$45	$0	$0	UCD
Delta juvenile salmonid (seine only?)	2005-053		$530	$0	$0	USFWS
Other focused sample collections		1.d.	$10	$7	$49	DWR/DFG
Fish and zooplankton spatial and seasonal summary		2.a.		$2	$0	DFG
Pelagic fish apparent growth rates and abundance		2.b.		?	$0	DFG
Zooplankton fecundity and population structure		2.c.		?	$0	DFG, USBR, DMWD
Microcystis literature review		2.d.		?	$10	DWR
Use and toxicity of pyrethroid pesticides		2.e.			$15	DFG, USGS, (SFEI)
Use and toxicity of aquatic herbicides		2.f.			$56	DWR, DBW
Changes in pelagic fish habitat quality		2.g.			$129	DFG, DWR
Analysis of recent changes in delta water operations		2.h.			$15	USBR
Analysis of historical population dynamics		2.i.		$?	$0	USBR/DMWD
Otolith analysis		3.a.			$392	UCD
Liver histopathology		3.b.			$386	UCD
Fish diet and condition		3.c.			$70	DFG
Microcystis field survey		3.d.			$112	DWR, SUNY
Acute and chronic invertebrate and fish toxicity tests		3.e.			$205	UCD
Striped bass and delta smelt fecundity estimates		3.f.			$10	DFG
Benthic biomass trends		3.g.		$66	$0	DWR
DSM-2 particle tracking		4.a.	$91	$13		SFSU/RTC, DWR
South Delta Studies		4.b.	$1,200			DWR, USGS, USBR
Delta phytoplankton production and biomass		4.c.	$30			UCD, DWR
Analysis of long-term benthic community trends		4.d.	$65	$30		DWR, USGS

Management, planning, analysis, synthesis						
DFG				$135		
DWR			$54	$40		
USBR				$25		
USEPA				?		

Total		$7,702	$457	$1,699

Notes:
1. The first group includes all IEP monitoring that generates data useful to the analysis of the decline.
2. The second group is analysis of existing data.
3. The third group are new special studies.
4. The fourth group are other studies whose results will be used in the analysis of the decline.
5. The fifth group are the costs associated with the DPO oversight group
6. Some redirected costs have yet to be quantified and are denoted with a ?.

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 fifty 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.

*Proposal for 200*6. The first major written product from this study will be a proposal for work in 2006 and beyond. The screening level results from 2005 will be used to better define the topics that will need more focused research in 2006. This document will be submitted for IEP and CBDA review by the beginning of 2006.

Conferences and Workshops. The results of the 2005 work will be presented at a special session at the February 2006 IEP Annual Workshop. A special CDBA workshop is also being considered to discuss the project's 2005 synthesis report, particularly the initial management implications. Several members of the program will also present their results annually at either the State of the Estuary or the CALFED Science conference.

Publications and Reports. While the researchers in this effort place high value on the publication of peer-reviewed information, the short timeline and management importance of the

study effort limits our ability to produce journal articles in 2005. Hence, the primary product of the 2005 effort will be a synthesis report described in the Adaptive Management section of this proposal. However, at lest three of the study components are expected to produce papers for the peer-reviewed literature: 1) Regional analysis of factors affecting primary productivity (Jassby, UCD); 2) Particle-tracking modeling of diversion effects (Kimmerer SFSU, Nobriga DWR); and 3) Analysis of trends in estuarine species (Manly, POD PWT). Additional publications are likely in later years related to 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 2006.

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