

4.5 PSP Cover Sheet (Attach to the front of each proposal)

Proposal Title: Effects of Introduced Species of Zooplankton and Clams on the Bay-Delta Food Web
Applicant Name: San Francisco State University: Romberg Tiburon Center
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Amount of funding requested: \$ 826,930 for 3 1/4 years

Indicate the Topic for which you are applying (check only one box).

- Fish Passage/Fish Screens
- Habitat Restoration
- Local Watershed Stewardship
- Water Quality
- Introduced Species
- Fish Management/Hatchery
- Environmental Education

Does the proposal address a specified Focused Action? yes no
(none listed for "introduced species")

What county or counties is the project located in? N/A to open water research (see text)

Indicate the geographic area of your proposal (check only one box):

- Sacramento River Mainstem
- Sacramento Trib: _____
- San Joaquin River Mainstem
- San Joaquin Trib: _____
- Delta: _____
- East Side Trib: _____
- Suisun Marsh and Bay
- North Bay/South Bay: San Pablo Bay
- Landscape (entire Bay-Delta watershed)
- Other:

Indicate the primary species which the proposal addresses (check all that apply):

- San Joaquin and East-side Delta tributaries fall-run chinook salmon
- Winter-run chinook salmon
- Late-fall run chinook salmon
- Delta smelt
- Splittail
- Green sturgeon
- Migratory birds
- Other: Various Introduced Species of Zooplankton and Clams
- Spring-run chinook salmon
- Fall-run chinook salmon
- Longfin smelt
- Steelhead trout
- Striped bass
- All chinook species
- All anadromous salmonids

Specify the ERP strategic objective and target (s) that the project addresses. Include page numbers from January 1999 version of ERP Volume I and II:

Introduced species and system productivity (ERP Vol I, P. 98)
Ecosystem Restoration (ERP Vol I, P. 46)

Indicate the type of applicant (check only one box):

- | | |
|--|---|
| <input type="checkbox"/> State agency | <input type="checkbox"/> Federal agency |
| <input type="checkbox"/> Public/Non-profit joint venture | <input type="checkbox"/> Non-profit |
| <input type="checkbox"/> Local government/district | <input type="checkbox"/> Private party |
| <input checked="" type="checkbox"/> University | <input type="checkbox"/> Other: |

Indicate the type of project (check only one box):

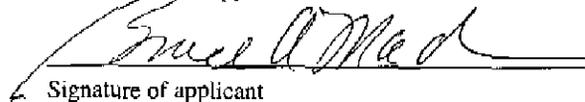
- | | |
|--|---|
| <input type="checkbox"/> Planning | <input type="checkbox"/> Implementation |
| <input type="checkbox"/> Monitoring | <input type="checkbox"/> Education |
| <input checked="" type="checkbox"/> Research | |

By signing below, the applicant declares the following:

- 1.) The truthfulness of all representations in their proposal;
- 2.) The individual signing the form is entitled to submit the application on behalf of the applicant (if the applicant is an entity or organization); and
- 3.) The person submitting the application has read and understood the conflict of interest and confidentiality discussion in the PSP (Section 2.4) and waives any and all rights to privacy and confidentiality of the proposal on behalf of the applicant, to the extent as provided in the Section.

Bruce Macher, Associate Dean, Research, San Francisco State University

Printed name of applicant


Signature of applicant

1. Executive summary

We propose a research project on the effects of introduced species in the food web supporting several fish species of concern of the San Francisco Bay-Delta estuary. The research will focus on the early life stages of delta smelt, longfin smelt, and striped bass.

The estuarine ecosystem has been greatly altered through introductions of exotic species which may limit the effectiveness of rehabilitation actions. Most of the alterations have occurred in the lower foodweb, and effects on the lower foodweb are reasonably well-understood. What remains unknown, and is the topic of our research, is how these foodweb alterations influence the key fish species that depend on that foodweb, and what rehabilitation actions might be effective in the context of the altered foodweb.

CALFED documents justifiably emphasize rehabilitation actions in preference to research. However, for fish species of concern in open waters of the estuary, few actions have been identified, and none with much certainty about their effectiveness. The reason is the lack of knowledge about the function of this ecosystem, the likely outcome of different, alternative actions, and the role that introduced species have in limiting options for rehabilitation. Our proposed research will fill key gaps in knowledge and help to suggest ideas for actions that might result in improvements for these key species.

CALFED Ecosystem Restoration Program documentation strongly supports the need for research on effects of introduced species on the estuarine foodweb. First, the Strategic Plan for Ecosystem Restoration includes as Goal 5 prevention of establishment of non-indigenous introduced species (NIS), and reducing their negative biological and economic impacts, but the negative impacts of NIS in the estuary have yet to be determined. Second, according to Strategic Plan Goal 2, the ecosystem is to be rehabilitated through the use of natural processes to support native species. However, we understand very poorly the capacity of the estuarine ecosystem to support natives, and how the numerous introductions have altered this capacity.

The need for research on the effects of NIS is spelled out repeatedly in CALFED ERP documents. For example, *"...it is important to initiate an early program that: ... develops a better understanding of how non-native species affect ecological processes and biological interactions, ..."* (Strategic Plan). *"A major obstacle to solving problems of estuarine productivity is our poor understanding so solutions will have to come from research and monitoring ..."* (ERP Vol. 1 p. 46). *"(The reduction in estuarine foodweb productivity) implies a limit on the extent to which Bay-Delta fish populations can be restored unless creative solutions can be found to increase foodweb productivity"* (ERP Vol. 1 p. 98).

The creative solutions called for have not yet been found, to our knowledge. Thus, the need for the research that we propose has been clearly indicated by the CALFED ERP,

and is clearly supported by the current state of scientific knowledge about the estuarine foodweb.

The objectives of the proposed research are to answer the following questions:

1. *How has the Asian clam *Potamocorbula amurensis* altered the feeding environments of fish species of interest?*
2. *How are native and introduced zooplankton species used as food by these fish?*
3. *What are the competitive and predatory relationships among the native and introduced species that explain their persistence?*
4. *What is the production rate of food, both native and introduced, for young fish in the Bay/Delta, and could it be increased?*

The three species of fish were chosen not only for their importance in restoration of the estuarine ecosystem. They also provide a contrast in life histories and likely responses to environmental conditions and introduced species, particularly the clam *P. amurensis*. This contrast should enable us to distinguish among responses to these influences.

We plan to emphasize the use of existing data and samples and relatively simple models over more expensive field data collections and experiments. We also expect to take a staged approach, roughly in the order of the research questions, to maximize learning at each stage and make the succeeding stages as efficient as possible.

The proposed research will comprise 5 broad tasks: 1) *Analysis of existing data* on co-occurrence of fish and their prey, and on the inputs of various sources of organic matter to the estuarine ecosystem; 2) *Modeling* to set up a framework for the analyses and experiments, and to investigate the limits that system productivity places on increases in fish populations; 3) *Fish sample analyses* to increase information on the feeding relationships among the fish and their zooplankton prey and how those have changed since the spate of introductions; 4) *Experiments* on interactions between fish and their prey, and among the various zooplankton species; and 5) *Synthesis* of the overall results into a comprehensive and detailed conceptual model.

Products from this research program will include reports detailing the role of introduced species in the foodweb, the effects of these species on the fish species of interest and the estuarine ecosystem as a whole, and the potential for lifting limits on system productivity or population abundance within the system as it now exists.

The research team submitting this proposal is uniquely suited to carry out the research, and to provide an interpretation relevant to CALFED's goals. The Lead Principal Investigator (PI), Wim Kimmerer, has extensive experience in all aspects of the proposed research in the Bay-Delta estuarine ecosystem and elsewhere. His experience as a member of the Core Team for the ERP Strategic Plan gives him the perspective to ensure that this project is not merely an academic research project, but that it has direct relevance to the ERP. Dr. Steve Bollens is a world-renowned expert on zooplankton and on interactions between fish and zooplankton. Dr. Bill Bennett is well known for his research on various aspects of Bay-Delta fish populations, particularly on environmental and human factors controlling early survival and population abundance.

2. Project Description

We propose a research project on the effects of introduced species in the food web of the San Francisco Bay-Delta. Emphasis is on the forage organisms for species inhabiting brackish parts of the estuary, particularly several species of concern, delta and longfin smelt, as well as early life stages of striped bass.

Radical changes in the estuarine foodweb due to introduced species may affect growth or survival of these key species of fish. This issue is of central importance to CALFED's efforts to restore the Bay-Delta ecosystem using natural processes: if the foodweb has become less productive or less efficient at supporting fish, then the scope for restoration may be greatly reduced. As discussed in the next section, a clear understanding of the functioning of the currently-existing ecosystem can help CALFED spend its limited restoration budget on activities most likely to have positive effects.

The proposed research has a tight focus in geographic scope and subject matter. We intend to concentrate on the northern estuary in and seaward of the Low-Salinity Zone (LSZ, or Entrapment Zone, Kimmerer et al. 1998a). The research emphasis will be on effects of the clam *Potamocorbula amurensis*, and several key introduced zooplankton species, in altering the foodweb of the three selected fish species.

The clam *P. amurensis* has been the most significant introduction to the foodweb of the brackish estuary in several decades. Since this clam became abundant in 1987, chlorophyll levels in the Low-Salinity Zone (or Entrapment Zone) have been roughly 5-fold lower than before, evidently because of filtering by the clam (Alpine and Cloern 1992, Kimmerer and Orsi 1996). There is good evidence that *P. amurensis* is also capable of filtering bacteria from the water column at a moderately high rate, reducing the biomass of bacteria available to convert dissolved organic matter to living biomass (Werner and Hollibaugh 1993). Thus, productivity at the base of the food web in the northern estuary has apparently been severely reduced by the introduction of this clam.

Severe declines in several native (or naturalized) zooplankton species coincided with the arrival of *P. amurensis*, probably due either to competition for food, or to inadvertent predation by *P. amurensis* on young stages of the zooplankton (Kimmerer et al. 1994, Kimmerer and Orsi 1996). At around the same time that *P. amurensis* became abundant, several introduced zooplankton species appeared and became highly abundant, possibly reducing the impact of the decline in natives (Orsi 1995). However, some of these new zooplankton species have different seasonal patterns and life histories from species in the previous community (Kimmerer 1999), which may affect the rate of trophic transfer from phytoplankton and exogenous organic carbon through zooplankton to fish.

Thus, we have ample evidence that various important aspects of the estuarine foodweb have changed, including at least a reduction in overall productivity and a change in species and size composition of important prey of young fish (Figure 1A). However, the evidence for the link to fish has not been developed and at this point is based mainly on correlative data. Specifically, a decrease in abundance of some species has been

observed that more-or-less coincides in time with the changes in the food web (Figure 1B). The evidence overall is inadequate to support decisions about how best to spend limited restoration funds in the estuary. Thus, CALFED needs to know how the link between fish and their zooplankton prey has been altered by these introductions.

An ongoing research project funded by IEP is investigating the effect of the clam on abundance of various zooplankton species, with the principal objective being to understand the mechanisms by which some species are much more affected by the clam than others (Kimmerer). *This proposal to CALFED represents a logical extension of that research to develop an understanding of the quantitative implications of the introduction of the clam, as well as other foodweb changes, for fish species of concern.*

Objectives of the proposed research are to answer the following questions:

5. *How has the clam *P. amurensis* altered the feeding environments of fish species of interest?*
6. *How are the various native and introduced zooplankton species (copepods, mysids, and amphipods) used as food by larvae and juveniles of longfin and delta smelt and striped bass?*
7. *What are the competitive and predatory relationships among the native and introduced species that explain their persistence?*
8. *What is the production rate of food, both native and introduced, for young fish in the Bay/Delta, and could it be increased?*

These questions will be answered through a combination of field sampling, laboratory studies, data analysis, and modeling. We expect to collaborate with researchers investigating sources of organic carbon into the upper estuary (e.g. USGS, UC Davis), and those investigating various aspects of fish ecology and abundance patterns (e.g. UC Davis, CDFG).

The three species of fish were chosen not only for their importance in restoration of the estuarine ecosystem. They also provide a contrast in their apparent responses to environmental conditions and to introduced species, particularly the clam *P. amurensis*. Longfin smelt has the strongest relationship to X_2 of all species in the estuary and declined the most strongly in the late 1980's (Kimmerer 1998, see Figure 1), following years of drought and the introduction of *P. amurensis* and several new planktonic species. This decline suggests that food resources for longfin smelt have declined. Delta smelt do not show such a decline, possibly because their abundance fluctuates wildly and because they do not have a strong X_2 relationship from which deviations can be measured. However, larval delta smelt feed mainly on the native (or long-term naturalized) copepod *Eurytemora affinis* and to a much lesser extent on the introduced copepod *Pseudodiaptomus forbesi* (Nobriga 1998), and thus delta smelt may be vulnerable to the effects of introductions. Survival of young striped bass is closely related to X_2 , but did not show a decline when the food web changed (Kimmerer 1997; Kimmerer et al. submitted), and it may feed effectively on many species (see Gartz 1999 for juveniles).

The CALFED Non-Indigenous Introduces Species (NIS) team has recommended the portion of this study dealing with *P. amurensis* (Question 1) for funding as a directed program. We believe the four questions are closely linked and should be investigated as a single project. For example, an assessment of the effect of *P. amurensis* through its effects on the forage organisms of delta smelt would logically be conducted as part of a study of all food organisms of delta smelt, including the introduced zooplankton species that have supplanted those most heavily reduced by *P. amurensis*.

General research approach: We discuss details of methods in Section 5. Overall approaches for each research question are given below. We plan to emphasize the use of existing data and samples and relatively simple models over more expensive field data collections and experiments. We also expect to take a staged approach, roughly in the order of the research questions, to maximize learning at each stage and make the succeeding stages as efficient as possible.

Question 1 (effect of *P. amurensis*): We will examine existing data on distribution patterns of the fish species, their zooplankton prey, and sources of organic carbon to determine the likely degree of co-occurrence during the larval and early juvenile stage. We will develop a box model of energy flow and trophic transfer through the food web, based on existing data, to estimate the upper limit on energy supply to the fish and how that has changed with the introduction of *P. amurensis*.

Question 2 (native and introduced zooplankton as food) : Using fish collected in existing sampling programs, we will examine gut contents to determine the extent to which fish prey on introduced vs. native species. Where data are available from before 1987 (mainly for striped bass), we will compare gut contents and condition indices to determine the extent to which feeding conditions have changed. Laboratory experiments will be conducted using fish obtained from culture facilities (delta smelt, striped bass) or from the field (longfin smelt) to determine the basis for food preferences.

Question 3 (interactions among zooplankton): Laboratory experiments on predation and feeding will be conducted to determine the trophic positions of the key zooplankton species and their interactions. The results will be interpreted using field data on seasonal and spatial abundance patterns.

Question 4 (production rate): Growth rate of key species will be measured in the field or the laboratory, and the degree of food limitation will be determined. Production rates will be determined as the product of growth and biomass, and the foodweb model developed under Question 1 will be updated with these results. This model will then be used to explore the effects of alternative scenarios for rehabilitation of system productivity.

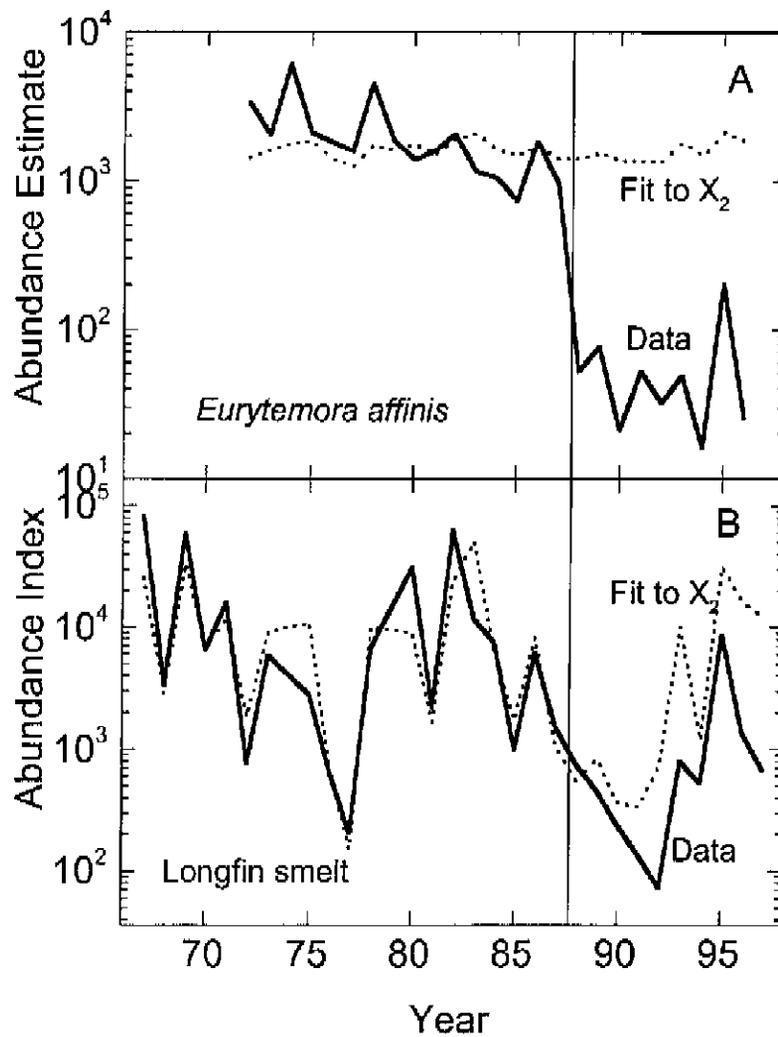


Figure 1. Time series of abundance data and data fit to a linear model in X_2 determined on data through 1987. A, the copepod *Eurytemora affinis*. B, longfin smelt. Solid lines, annual average data; dashed lines, model fit. The vertical line gives the approximate time of spread of the clam *Potamocorbula amurensis*. Data and analyses from Kimmerer 1998.

3. Ecological/Biological benefits

The overall mission of the CALFED Ecosystem Restoration program is to rehabilitate the ecosystems of the Bay-Delta and watershed. Why should CALFED fund research such as this, which will result in no direct improvement of the estuarine ecosystem? We argue below that, for open waters of the estuary, *rehabilitation actions are not yet warranted because of a lack of knowledge*. This proposed research will fill some key gaps in knowledge, and should provide insights to help develop effective rehabilitation actions.

Our proposal addresses the ecological effects of introduced species, which are clearly important to CALFED. Several species introduced during the last 12 years may limit the possibility to achieve CALFED objectives for rehabilitation of estuarine-dependent species. Future introductions will have unknown effects but they could be serious. For this reason, the Strategic Plan for Ecosystem Restoration lists as Goal 5: *Prevent establishment of additional non-native species and reduce the negative biological and economic impacts of established non-native species*. Other actions will address controls on new introductions; our proposal will determine what the negative biological impacts of certain non-native species are, and if possible suggest ways to reduce them.

This proposal also speaks to Strategic Plan Goal 2: *Rehabilitate the capacity of the Bay-Delta system to support, with minimal ongoing human intervention, natural aquatic and associated terrestrial biotic communities, in ways that favor native members of those communities*. The basic problem is that we have only a poor understanding of the capacity of the estuarine ecosystem to support natives, nor do we understand how the numerous introductions have altered the functioning of this ecosystem.

CALFED has clearly recognized the need for research on issues relating to non-indigenous species (NIS) and their effects on the estuarine foodweb. The need for research on the effects of NIS is spelled out repeatedly in the CALFED ERP. For example, *"...it is important to initiate an early program that: ... develops a better understanding of how non-native species affect ecological processes and biological interactions, ..."* (Strategic Plan). CALFED has formed a committee to recommend research and other projects on NIS for funding as directed programs; portions of our proposed project have been recommended for inclusion as a directed program.

Natural ecosystem processes in the tidal reaches of the Bay-Delta system have been heavily altered by the introduction of non-native species. Introduced species, particularly the clam *Potamocorbula amurensis*, have had significant negative effects on system productivity (ERP Vol. 1 p. 98). Most of the demonstrated effects have affected lower trophic levels for which mechanisms of direct effects have been identified (Alpine and Cloern 1992, Werner and Hollibaugh 1993, Kimmerer et al. 1994). There is also evidence for effects, presumably indirect, on higher trophic levels including longfin smelt, a species of concern to CALFED, as well as other important forage species such as bay shrimp, herring, and starry flounder (Kimmerer 1998). Mechanisms are unknown, but probably include competition with and predation on native species, and alteration of the feeding environment of natives (e.g. Kimmerer and Orsi 1996).

The need for research on the functioning of the estuarine food web also was recognized in the ERP as a practical, rather than academic, need: *A major obstacle to solving problems of estuarine productivity is our poor understanding so solutions will have to come from research and monitoring of effects of various ecosystem restoration projects* (ERP Vol. 1 p. 46). Although this statement refers to restoration projects, we suggest that in the absence of sufficient understanding to decide what those projects should be, the research should be conducted on the basic structure and function of the ecosystem. This too was recognized in the ERP: *"(The reduction in estuarine ecosystem productivity) implies a limit on the extent to which Bay-Delta fish populations can be restored unless creative solutions can be found to increase foodweb productivity"* (ERP Vol. 1 p. 98).

The "creative solutions" referred to above have not yet materialized, to our knowledge, and with good reason: in contrast to rivers and marshes, only a limited number of actions are likely to affect the open-water estuarine region. We are aware of only two suggestions for enhancing productivity of the estuarine food web. The first is to use freshwater flow to increase the benefits provided by the X_2 standard, which was proposed in the Anadromous Fisheries Restoration Plan. Although this action might enhance abundance of longfin smelt and early survival of striped bass, it is expensive in terms of water and would have only limited effectiveness, and is therefore controversial.

The second proposal is to increase the extent of tidal marsh habitat throughout the brackish estuary (as well as upstream), increasing the area of nursery habitat for some fish species, and might enhance the estuarine foodweb by increasing production and export of organic carbon. This potential benefit is based on several assumptions that have been controversial for decades in regions where tidal marshes form a much larger part of the landscape than in the San Francisco Estuary; recent research suggests that a significant export may occur in the form of fish biomass (Kneib 19xx). However, the magnitude of the benefit is completely unknown here. Furthermore, organic carbon exported as detritus from marshes must still make its way through the foodweb, and is therefore subject to the same constraints in the foodweb as we have identified above.

How might the results of our research be used to develop strategies for rehabilitation of the estuarine ecosystem? This is difficult to answer: if we knew the answers to the four questions posed above, we would not need to do the research. For example, if our research showed that delta smelt have a lower early growth rate because of reduced abundance of the copepod *Eurytemora affinis* in late spring-summer, and that feeding on the introduced species *Pseudodiaptomus forbesi* is low because of a spatial or temporal mismatch in abundance, rehabilitation actions might include: 1) adjusting the X_2 standard within the spring season to prolong the high abundance of *E. affinis* by suppressing the spring settlement of *P. amurensis*; 2) adjusting the X_2 standard between years to maximize food production when *P. amurensis* is less abundant; or 3) emphasizing other rehabilitation efforts (e.g., flow pulses, export reductions) in years when the mismatch between delta smelt and its prey can be reduced. These hypothetical actions illustrate the general principle that *management actions are most effective if they are based on detailed understanding of the system being managed.*

Related Projects: Several existing or proposed projects may provide synergistic benefits to this study. Two of us (WK, BB) are working on several projects on productivity in the lower foodweb of the estuary, particularly on the effects of *P. amurensis* on zooplankton and the effects of inland silversides and contaminants on delta smelt. One of us (SB) is collaborating with the USGS to study effects of selenium on zooplankton, and another (WK) is collaborating with the San Francisco Estuarine Institute on a CALFED proposal on contaminant effects on foodweb species supporting fish of concern. RTC has submitted a proposal to EPA to investigate potential ecological indicators, including growth and condition of larval herring and reproductive rate of copepods (SB, WK). RTC will collaborate with several institutions in a proposal to the National Science Foundation for the Long-Term Ecological Research program, for a project on the capacity of the estuarine ecosystem to support higher trophic levels. If funded, that project will complement the project proposed here by examining related issues further seaward in the estuary.

Issues not addressed: Several issues are relevant to our proposed research but are beyond the scope of the current proposal.

The first such issue is contaminants, which may play a role in the variability of zooplankton prey or the survival of larval fish (e.g., Bennett et al. 1995). Investigating this complex and diverse issue would require a much broader research effort than we have proposed, and would increase our budget by a substantial factor. One of us (BB) has been funded by CALFED to investigate the potential influence of contaminants on delta smelt. Another (WK) is a collaborator on a proposal to CALFED to address effects of contaminants on foodweb organisms. These or similar projects might help us identify contaminant effects. The effects of contaminants may be less important in the brackish region of the estuary than biotic relationships. First, pulses of contaminants from agricultural drainage may be reduced through dilution and mixing in this region (Chris Foe, Sacramento RWQCB, pers. comm.). Second, the observed changes in zooplankton and longfin smelt (Figure 1) have been large and persistent, and therefore unlikely to have arisen from sporadic and variable inputs of contaminants. *Nevertheless, we will be alert to results suggesting that contaminant effects are important, and will respond by altering our work plan in consultation with CALFED and investigators in contaminant-effects work.*

The second issue is the effects of introduced species in other parts of the watershed. For example, there is good reason to expect an effect of mitten crabs on the food web of the rivers and Delta. Also, the clam *Corbicula*, abundant in the Delta for several decades, may affect the planktonic foodweb in that region in a way similar to *P. amurensis* in the brackish estuary. We think both of these issues should be addressed, but that including them in this proposal would dilute our effort excessively.

4. Technical feasibility and timing

Regarding feasibility, all of the methods to be used in the proposed research have been tested and all of them are feasible. Furthermore, at least one and in most cases all Principal Investigators on our research team have conducted research using each of these methods. Of course, research often uncovers surprises, and there is no guarantee that results will be unequivocal. Nevertheless, our conservative choice of scientific approach, and the extensive experience of our research team, will maximize the likelihood that the outcome will provide the needed knowledge.

We plan to conduct the research in stages, roughly corresponding to the four questions above. The duration of the project is 3-1/4 years, which we believe is a reasonable duration to achieve the results anticipated. We anticipate beginning work in October 1999.

Year 1: In the last 3 months of 1999, we will work with CALFED staff, member agencies, and university scientists to review and flesh out our project, and develop collaborative relationships with other projects. We will also determine the sample design for gut analyses and experimental design for laboratory work, prepare and submit a detailed work plan, and purchase supplies and equipment for the laboratory and field work.

Year 2: we will conduct analyses of existing data and set up productivity and box models. Samples of fish for gut analysis will be obtained from the relevant sampling programs and the analysis will begin. Based on results of data analysis and modeling, we will publish an analysis of the likely effect of *P. amurensis* on key fish species. We will conduct pilot experiments on feeding relationships.

Year 3: We will finish the analysis of fish gut contents and analyze data for the model. We will also begin full-scale experimental work on fish predation and zooplankton interactions.

Year 4: We will complete experimental work, calculate the productivity data, and refine the box model. We will then use the model to investigate alternative ideas about the role of introduced species in the foodweb, and about the potential for improving system productivity.

We will prepare results for presentation to CALFED management and for publication in technical journals. Quarterly reports will be brief summaries of work completed in the previous quarter, with copies of any interim reports or publications based on our work. Annual reports including data reports will summarize progress to date. The final report will comprise a compilation of scientific papers submitted or published, along with a synthesis of the results and an interpretation of the implications of these results for rehabilitation of the estuarine ecosystem, and data in MSAccess format. Throughout the project, but particularly during this wrap-up phase, we will be available to make presentations or otherwise to discuss our results and the implications for rehabilitation of the estuarine ecosystem.

5. Monitoring and data collection methods

Five research tasks are identified below, with initials indicating which Principal Investigator (PI) has primary responsibility, although all PI's will participate in all tasks. Table 1 shows each component of the research in relation to the four research questions.

Analysis of existing data (WK) will use modern methods of data analysis to discern patterns of distribution and co-occurrence of fish and prey (Cleveland 1993, Venables and Ripley 1997). Existing data are readily available from IEP and other sources, and the PI's have extensive experience in analyzing these data (e.g., Bennett and Moyle 1996, Kimmerer et al. 1998a). Sources of organic carbon will be determined according to Cole and Cloern (1984) and Jassby et al. (1993) and from the current USGS study of sources of organic carbon to the estuary.

Modeling: (WK) We will develop a simple model of energy flow and trophic transfer through the food web. Initially based on existing information, this model will be updated using new data from this and other studies. We expect to draw on the results of the USGS study to provide some inputs to the model. This model should provide valuable insights into the limits on system productivity imposed by introduced species. The Lead PI on this task has extensive experience in various kinds of models (e.g., Smith et al. 1986, Kimmerer 1987, Jassby et al. 1995, Kimmerer et al. 1991, 1998a, b, Rose et al. in prep.).

Fish sample analyses: (BB) Gut contents and condition of fish from ongoing collections by IEP and others will be used to assess the extent to which fish prey on introduced vs. native species (e.g., Nobriga 1998, Lott 1998). Such analyses are useful in determining the prey being used by the fish, but less useful in determining the rate of predation or the degree of food-limitation. Consumption rates will be estimated using standard bioenergetics models (e.g., Brandt 1993) for insertion into the trophic model above.

Experiments (SB) will be conducted on selective predation by fish on alternative zooplankton prey, predatory and other feeding relationships among the zooplankton, and growth rates of zooplankton (e.g., Kimmerer and McKinnon 1987, 1989; Bollens and Frost 1991, Bollens et al. 1993; Bennett 1993). These experiments will be conducted under controlled conditions in culture tanks at the Romberg Tiburon Center, or in containers in the estuary. Feeding and growth rates of freshwater zooplankton are being measured at UC Davis under the USGS program, and we will continue close contact with those investigators. We will also determine body weights of common zooplankton species to develop biomass estimates from existing field data on abundance of zooplankton.

Synthesis (all) will be an open and collaborative effort involving the PI's of this project and other scientists at RTC and UC Davis. We will present preliminary results of our work at meetings of the Estuarine Ecology Team and at the annual conference of the Interagency Ecological Program, as well as at national scientific meetings. Results will be published in peer-reviewed journals to ensure quality control at conceptual and synthetic level.

Table 1. Monitoring and data collection information

Question	Data collection	Data evaluation	Comments
All four questions	Existing data	Exploratory analysis	Some data are available for all aspects
1. <i>P. amurensis</i>	Existing data on phytoplankton	Cole and Cloern (1984) productivity model	
1. <i>P. amurensis</i> , 4. System productivity	Existing data	Box model	Based on above analyses
2. Fish diet	Existing samples	Gut content and condition analyses	
2. Fish diet	Existing samples	Abundance data; electivity	
2. Fish diet	Feeding experiments	Selection for or against each species	Fish from existing culture facilities
2. Fish diet	Existing data and gut analyses above	Bioenergetics model	
3. Zooplankton interactions	Feeding and predation experiments	Selection for or against different food/prey types	
4. System productivity	Laboratory or field experiments	Growth rate	
4. System productivity	Plankton samples	Abundance-biomass conversions, production	

6. Local Involvement

As a research project, the proposed effort would not benefit by local involvement, nor is it associated with any particular jurisdiction. All of the work will take place either in laboratories or in the open waters of the estuary (Delta, Suisun, San Pablo Bays), with access gained by boats. Although these regions fall within the geographic boundaries of several counties, to our knowledge the counties have not exercised jurisdiction over research in estuarine waters.

We anticipate no third-party impacts of this work.

7. Cost

Detailed budgeted costs, broken down by task and quarter, are provided in the tables below. A brief justification of these costs is as follows.

The Co-Principal Investigators, W. Kimmerer, S. Bollens, and B. Bennett will each devote from 1.0 to 3.5 months of time each year to the project. They will be responsible for overseeing all aspects of the project, including field collections, laboratory experiments, sample analyses, data reduction, statistical analyses, and writing of final reports and manuscripts reporting results of the research.

Two Research Technicians, Mr. Sean Avent and Ms. Carolina Penanua, will each devote 6.0 months to the project in each year. They will assist with all aspects of the research, but will focus on the field and laboratory studies. They have more than 10 yrs experience in marine ecology and fisheries, including extensive work in SF Bay.

Support is requested for three graduate students. One will focus on data analysis and modeling (supervised by Kimmerer), one will focus on experimental fish-zooplankton studies (supervised by Bollens), and one will focus on diet studies (supervised by Bennett). It is anticipated that some aspect of the proposed research will develop into these students' MS theses

Funds are requested under travel for (1) local, in-state travel of 2 trips per month between Sacramento, RTC and/or MBL (24 trips x 200 miles RT x \$0.31 per mile = \$1,500 per year) and (2) one national scientific meeting (e.g., Estuarine Research Federation or American Society of Limnology and Oceanography) per PI per year (\$1,500 per trip x 3 PIs = \$4,500 per year).

Funds are requested under Equipment for the purchase of (1) a desk-top computer, (2) a dissecting microscope, and (3) two plankton incubators. These items are essential to the successful completion of the proposed research.

Funds are requested under Materials and Supplies for purchase of miscellaneous field (e.g., plankton nets, glassware, preservative, etc.), laboratory (e.g., microscope bulbs, glassware, sorting trays, etc.) and computer supplies (e.g., software upgrades, computer diskettes, printer cartridges, paper, etc.) each year.

Funds are requested under Other Direct costs for (1) ship time for the 38-ft Questuary (\$500 per day represents a 50% discount on the full rate), (2) communications such as telephone, FAX, and express mail, (3) graduate student tuition, (4) publication costs (e.g., page charges in *Journal of Marine Research* @ \$35/page), and (5) the Bodega Marine Lab sub-contract to support Dr. Bill Bennett and his graduate student.

Indirect costs rates are prescribed by the University (51% federal; 15% state), in negotiation with the cognizant federal or state agency.

Project Management costs have been budgeted within the PI salaries and represent a modest (10%) fraction of overall costs.

The schedule of tasks and payments can be seen in the detailed budgets below, as well as under the "Technical Feasibility and Timing" section above.

PROJECT DIRECTOR: Wim Kimmerer
 TITLE: Effects of Introduced Species of Zooplankton and Clams on the Bay-Delta Food Web
 SPONSOR: Cal-Ped
 DURATION: 10/1/1999-12/31/02

		Requested Year 01	Requested Year 02	Requested Year 03	Requested Year 04
		10/1/99-12/31/99			
A.	Personnel				
	Wim Kimmerer, Sr. Research Scientist Step 16, PI				
	\$78,614 12 month Salary				
	\$5,948 Per Month				
	.875 mos. in YR 1, 3.5 Months in YRS 2-4	\$5,205	\$21,859	\$22,952	\$24,099
	37% Fringe	\$1,946	\$8,176	\$8,584	\$9,013
	Stephen Bollens, Assoc. Professor, Step 18, Project Director				
	\$68,179 Academic Year (AY)				
	\$7,575 Per Summer Month				
	.25 Month in YR 1, 1 Month YRS 2-4	1,989	8,362	8,769	9,208
	12% Fringe	229	960	1,008	1,059
	William Bennett, Co-PI, See sub-contract: Madega Bay (1 month YR 1, 2 months YRS 2-4)				
	Research Technician, Sean Avert				
	\$35,557 12 month Salary				
	\$2,822 Per Month				
	6.00 Months	N/C	16,032	17,779	18,668
	41% Fringe		6,942	7,289	7,654
	Research Technician, Carolina Pananua				
	\$26,208 12 month Salary				
	\$2,080 Per Month				
	5.00 Months	N/C	12,460	13,104	13,759
	45% Fringe		5,616	5,997	6,182
	Graduate Student Assistants				
	2 Students				
	\$12.00 Hourly				
	\$1,440.00 Hours (FT summer, 20 hrs/wk AY)	8,640	34,560	36,288	38,102
	2% Fringe	130	518	544	572
A.	Total Salaries	\$15,833	94,163	98,892	103,837
B.	Fringe Benefits	2,305	22,212	23,323	24,489
	Total Salaries and Benefits	18,138	116,385	122,215	128,325
C.	Travel				
	Local	375	1,500	1,500	1,500
	Out of State: 1 National meeting/yr, per PI	0	4,500	4,500	4,500
	Travel Subtotal	375	6,000	6,000	6,000
D.	Equipment				
	Computer	3,000			
	Microscope	5,000			
	(2) Plankton Incubators: \$3,000/ea		6,000		
	Equipment subtotal	8,000	6,000		
E.	Supplies				
	Materials and Supplies	0	5,000	5,000	5,000
	Supplies subtotal	0	5,000	5,000	5,000
H.	Other				
	Ship time 0/10/20/10 days at \$500/day	0	5,000	10,000	5,000
	Communications	125	500	500	500
	Graduate Tuition: \$1000/Student, YR1, \$2000/student x 2 YRS 2-4	2,000	4,000	4,000	4,000
	Publications	0	1,000	1,000	1,000
	Sub-contract: Madega Marine Lab	10,000	34,000	33,000	32,000
	Other Subtotal	12,125	44,500	48,500	42,500
I.	Total Direct Costs	\$39,638	\$177,895	\$181,715	\$181,825
J.	Indirect Costs (excludes equipment) 51% mtdc**	\$15,625	\$77,976	\$75,845	\$76,411
K.	Total Costs	\$55,263	\$255,871	\$257,559	\$258,236
L.	Total Direct Costs	\$39,638	\$177,895	\$181,715	\$181,825
M.	Indirect Costs (excludes equipment) 15% mtdc*	\$4,596	\$22,934	\$23,307	\$22,474
K.	Total Costs	\$44,233	\$200,829	\$204,022	\$204,299

PROJECT DIRECTOR: Wim Kimmeer
 TITLE: Effects of Introduced Species of Zooplankton and Clams on the Bay-Delta Food Web
 SPONSOR: Cal-Fed
 DURATION: 10/1/1999-12/31/02

TOTAL BUDGET BY QUARTER

WITH FED INDIRECT COSTS (51%)

TASK	Year 01	Year 02	Year 02	Year 02	Year 02	Year 03	Year 03	Year 03	Year 03	Year 04	Year 04	Year 04	Year 04
	4th QTR	1st QTR	2nd QTR	3rd QTR	4th QTR	1st QTR	2nd QTR	3rd QTR	4th QTR	1st QTR	2nd QTR	3rd QTR	4th QTR
Analysis of existing data	\$10,000	\$5,000	\$5,000	\$5,000	\$5,000	\$2,500	\$2,500	\$2,500	\$2,500	\$2,500	\$2,500	\$2,500	\$2,500
Modeling	\$10,000	\$5,000	\$5,000	\$5,000	\$5,000	\$2,500	\$2,500	\$2,500	\$2,500	\$2,500	\$2,500	\$2,500	\$2,500
Fish sample analyses	\$10,904	\$21,808	\$21,808	\$21,808	\$21,808	\$21,808	\$21,808	\$21,808	\$21,808	\$10,904	\$10,904	\$10,904	
Experiments		\$10,904	\$10,904	\$10,904	\$10,904	\$10,904	\$10,904	\$10,904	\$10,904	\$10,904	\$10,904	\$10,904	\$10,904
Synthesis	\$0	\$10,904	\$10,904	\$10,904	\$10,904	\$10,904	\$10,904	\$10,904	\$10,904	\$32,712	\$32,712	\$32,712	\$32,712
Project Management	\$5,592	\$5,592	\$5,592	\$5,592	\$5,592	\$5,592	\$5,592	\$5,592	\$5,592	\$5,592	\$5,592	\$5,592	\$5,592

WITH STATE INDIRECT COSTS (15%)

TASK	Year 01	Year 02	Year 02	Year 02	Year 02	Year 03	Year 03	Year 03	Year 03	Year 04	Year 04	Year 04	Year 04
	4th QTR	1st QTR	2nd QTR	3rd QTR	4th QTR	1st QTR	2nd QTR	3rd QTR	4th QTR	1st QTR	2nd QTR	3rd QTR	4th QTR
Analysis of existing data	\$10,000	\$5,000	\$5,000	\$5,000	\$5,000	\$2,500	\$2,500	\$2,500	\$2,500	\$2,500	\$2,500	\$2,500	\$2,500
Modeling	\$10,000	\$5,000	\$5,000	\$5,000	\$5,000	\$2,500	\$2,500	\$2,500	\$2,500	\$2,500	\$2,500	\$2,500	\$2,500
Fish sample analyses	\$8,301	\$16,602	\$16,602	\$16,602	\$16,602	\$16,602	\$16,602	\$16,602	\$16,602	\$8,301	\$8,301	\$8,301	
Experiments		\$8,301	\$8,301	\$8,301	\$8,301	\$8,301	\$8,301	\$8,301	\$8,301	\$8,301	\$8,301	\$8,301	\$8,301
Synthesis	\$0	\$8,301	\$8,301	\$8,301	\$8,301	\$8,301	\$8,301	\$8,301	\$8,301	\$24,902	\$24,902	\$24,902	\$24,902
Project Management	\$4,257	\$4,257	\$4,257	\$4,257	\$4,257	\$4,257	\$4,257	\$4,257	\$4,257	\$4,257	\$4,257	\$4,257	\$4,257

1-019692

1-019692

PROJECT DIRECTOR: Wim Kimmerer
TITLE: Effects of Introduced Species of Zooplankton and Clams on the Bay-Delta Food Web
SPONSOR: Cal-Fed
DURATION: 10/1/99-12/31/02

TOTAL BUDGET BY TASK

WITH FEDERAL INDIRECT COST							
TASK	Salaries and Benefits	Travel	Equipment	Supplies	Other	IDC	TOTAL
Analysis of existing data	23,283	1,111	907	907	8,926	14,866	50,000
Modeling	23,283	1,111	907	907	8,926	14,866	50,000
Fish sample analyses	101,552	4,846	3,956	3,956	38,932	64,838	218,079
Experiments	101,552	4,846	3,956	3,956	38,932	64,838	218,079
Synthesis	101,552	4,846	3,956	3,956	38,932	64,838	218,079
Project Management	33,851	1,615	1,319	1,319	12,977	21,613	72,693

WITH STATE INDIRECT COST							
TASK	Salaries and Benefits	Travel	Equipment	Supplies	Other	IDC	TOTAL
Analysis of existing data	29,468	1,406	1,148	1,148	11,297	5,534	50,000
Modeling	29,468	1,406	1,148	1,148	11,297	5,534	50,000
Fish sample analyses	97,841	4,669	3,811	3,811	37,509	18,373	166,015
Experiments	97,841	4,669	3,811	3,811	37,509	18,373	166,015
Synthesis	97,841	4,669	3,811	3,811	37,509	18,373	166,015
Project Management	32,614	1,556	1,270	1,270	12,503	6,124	55,338

8. Cost-sharing

The three PIs have several on-going projects and pending proposals that will allow them to leverage and make more efficient use of the funds being requested of CALFED. The relevant current and pending proposals are given below.

Current

- W. Kimmerer: Potamocorbula Revisited: a further look at effects of species introductions; Interagency Ecological Program; 4 month time commitment; 10/01/98 – 12/31/00; \$80,259: SFSU/Tiburon.
- W. Kimmerer: Zooplankton monitoring pilot study; 3 month time commitment; 8/1/98-12/31/99; \$60,283: SFSU/Tiburon.
- S.M. Bollens: Selenium Effects on SF Bay Zooplankton; USGS/CALFED ; No Salary Requested; 9/1/98-8/31/00; \$50,100: SFSU.
- S.M. Bollens, L. Maddin: U.S. GLOBEC: Predation Impacts on Target Species: Roles of Frontal Processes and Small Predator Species; NSF; 1 month time commitment; 1/1/99-12/31/01; \$287,355: SFSU.
- B. Frost (UW), J. Cordell (UW), & S.M. Bollens - Effects of the Invasive Asian Copepod Pseudodiaptomus on Pacific Northwest Estuaries; NOAA/SeaGrant; No Salary Requested; 1/1/98-12/31/00; \$182,462: SFSU.
- W. Bennett, W. Kimmerer Effects of exotic inland silversides on delta smelt; \$70K. 8/1/98--12/31/99: UW.
- W. Bennett, W. Kimmerer, Jon Burau: Entrapment Zone Studies '98; USGS. \$43K. 4/1/98--3/31/99: UW.

Pending

- R. Dugdale, S.M. Bollens, W. Kimmerer, J. Thompson, D. Julian F. Wilkerson, A. Arp: Integrative Indicators of Ecosystems Condition and Stress Across Multiple Trophic Levels in the San Francisco Estuary.; EPA; ; 1 month time commitment; 10/1/99-9/30/02; \$881,062: SFSU.
- S.M. Bollens: CO-OPEffects of Wind Driven Transport in Zooplankton; NSF; 1 month time commitment; 1/1/00-12/31/04; \$799,190: SFSU.

9. Qualifications

The proposed research will be conducted at the Romberg Tiburon Center (RTC), a research and teaching facility of San Francisco State University (<http://rtc.sfsu.edu/>), and at the Bodega Marine Laboratory (BML), associated with the University of California at Davis. Both laboratories are equipped with laboratory space, seawater systems, and other facilities suitable for the experimental work proposed.

This effort will be led by Dr. Wim Kimmerer; other Principal Investigators are Dr. Steve Bollens (RTC) and Dr. Bill Bennett (BML). Dr. Kimmerer was a member of the CALFED Strategic Planning Core Team, which could represent a potential conflict of interest; however, that role was advisory and at a very general level. Each PI will take the lead in one or more of the elements of the project, as described in Section 5.

Principal Investigators:

Dr. Wim Kimmerer, Senior Research Scientist, Romberg Tiburon Center. Dr. Kimmerer received his Bachelor's degree in chemistry from Purdue University and his PhD in biological oceanography from the University of Hawaii. Dr. Kimmerer has conducted research in Hawaii, Australia, several tropical Pacific islands, Alaska, and California. Dr. Kimmerer's research interests include the influence of predation on community structure, population dynamics of zooplankton and fish, the interaction of plankton with their physical environment, and the influences of species introductions and other human activities on estuarine environments. He has published several papers on the influence of introduced species on the ecosystem of San Francisco Bay. He is an expert on the effects of varying freshwater flow on the estuarine ecosystem, and has worked with various technical teams to resolve complex issues regarding management of the estuarine ecosystem. He led a team of agency and university scientists studying interactions between circulation and movement of organisms in the low-salinity zone of the estuary. He has also conducted extensive analyses and modeling studies of the population dynamics of chinook salmon and striped bass in the Bay and its watershed. He is Chair of the Interagency Ecological Program's Estuarine Ecology Team.

Representative publications:

- Kimmerer, W.J., E. Gartside, and J.J. Orsi. 1994. Predation by an introduced clam as the probable cause of substantial declines in zooplankton in San Francisco Bay. *Marine Ecology-Progress Series* 113:81-93.
- Kimmerer, W.J. and J.J. Orsi. 1996. Causes of long-term declines in zooplankton in the San Francisco Bay estuary since 1987. pp. 403-424 in *San Francisco Bay: The Ecosystem*. J.T. Hollibaugh (ed.). AAAS, San Francisco.

Dr. Stephen Bollens is Associate Professor, Department of Biology and Romberg Tiburon Center for Environmental Studies, and Assistant Dean, Office of Research and Sponsored Programs, San Francisco State University. He received his Ph.D. in Biological Oceanography from the University of Washington in 1990, and spent two years as a Postdoctoral Scholar ('90-'92) and 4 years as Assistant Scientist ('92-'96) in the Biology Department, Woods Hole Oceanographic Institution. Dr. Bollens' research interests include behavioral ecology, population dynamics, and community ecology of

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zooplankton and fishes, and ecosystem dynamics of estuaries and coastal oceans. Recent field sites have included San Francisco Bay, Puget Sound, Georges Bank, the Bering Sea, the Arabian Sea, and the Antarctic Ocean, and have been supported by funding agencies including NSF, ONR, and NOAA. He is currently a member of the Interagency Ecological Program's Estuarine Ecology Team, the Romberg Tiburon Center's Board of Directors, and the Moss Landing Marine Laboratories' Board of Governors, and has previously served on the Executive Committee, GLOBEC Georges Bank/Northwest Atlantic Program ('93-'96), and Executive Committee, Bering Sea Fisheries Oceanography Coordinated Investigations Program ('93-'96).

Representative publications:

- Bollens, S. M. and B. W. Frost. 1989. Zooplanktivorous fish and variable diel vertical migration in the marine planktonic copepod *Calanus pacificus*. *Limnol. Oceanogr.* 34: 1072-1083.
- Bollens, S. M., B. W. Frost, K. Osgood, and S. D. Watts. 1993. Vertical distributions and susceptibilities to vertebrate predation of the marine copepods *Metridia lucens* and *Calanus pacificus*. *Limnol. Oceanogr.* 38: 1841-1851.
- Francis, R.C., R. Merrick, K. Aydin, and S.M. Bollens. 1998. Modeling and Management of the Bering Sea Ecosystem. In: "The Bering Sea: Physical, Chemical and Biological Dynamics" (Eds: Loughlin, T. and K. Ohtany). Fairbanks: University of Alaska Sea Grant Press.
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Dr. Bill Bennett, Assistant Research Scientist, U.C. Davis and the Bodega Marine Laboratory. Dr. Bennett has more than ten years of research experience on the ecology of Bay/Delta fish populations during which he has been a frequent collaborator with IEP member agencies. This work includes identifying factors affecting the survival of larval striped bass and delta smelt, the interaction of larval fish behavior and hydrodynamics of the Bay-Delta entrapment zone, and the effect of ocean conditions on the decline of the striped bass population. Dr. Bennett has also worked as an Environmental Specialist for the USEPA, completing a review of the potential effects of pesticides on Bay/Delta fish populations and has been an active member of IEP's Estuarine Ecology Project Work Team (EET), and Contaminant Effects Project Work Team. Dr. Bennett has also worked on various CALFED-related committees and has been a speaker at several workshops on Bay-Delta resources, universities, and national conferences.

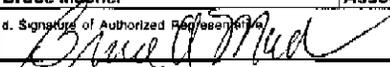
Representative publications:

- Bennett, W. A. and P. B. Moyle. 1996. Where have all the fishes gone? Interactive factors producing fish declines in the Sacramento-San Joaquin Estuary, p. 519-542. In J. T., Hollibaugh [ed.], *San Francisco Bay: The Ecosystem*, Pacific Division, American Association for the Advancement of Science
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- Bennett, W. A. and P. B. Moyle. 1996. Where have all the fishes gone? Interactive factors producing fish declines in the Sacramento-San Joaquin Estuary, p. 519-542. *In* J. T., Hollibaugh [ed.], San Francisco Bay: The Ecosystem, Pacific Division, American Association for the Advancement of Science.
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APPLICATION FOR FEDERAL ASSISTANCE		2. DATE SUBMITTED 15-Apr-99	Applicant Identifier
1. TYPE OF SUBMISSION: <input type="checkbox"/> Application <input checked="" type="checkbox"/> Construction <input checked="" type="checkbox"/> Non-Construction		3. DATE RECEIVED BY STATE N/A	State Application Identifier
<input type="checkbox"/> Preapplication <input type="checkbox"/> Construction <input type="checkbox"/> Non-Construction		4. DATE RECEIVED BY FEDERAL AGENCY	Federal Identifier
5. APPLICANT INFORMATION			
Legal Name: SAN FRANCISCO STATE UNIVERSITY		Organizational Unit: Office of Research and Sponsored Programs	
Address (give city, county, state, and zip code): 1600 HOLLOWAY AVENUE SAN FRANCISCO, CA 94132		Name and telephone number of the person to be contacted on matters involving this application (give area code) Wim Kimmerer (415) 338-3515	
6. EMPLOYER IDENTIFICATION NUMBER (EIN): 93 - 11137247		7. TYPE OF APPLICANT: (enter appropriate letter in box) I A. State B. County C. Municipal D. Township E. Interstate F. Intermunicipal G. Special District H. Independent School Dist I. State Controlled Institution of Higher Learning J. Private University K. Indian Tribe L. Individual M. Profit Organization N. Other (Specify): _____	
8. TYPE OF APPLICATION: <input checked="" type="checkbox"/> New <input type="checkbox"/> Continuation <input type="checkbox"/> Revision If Revision, enter appropriate letter(s) in box(es): <input type="checkbox"/> <input type="checkbox"/> A. Increase Award B. Decrease Award C. Increase Duration D. Decrease Duration Other (Specify): _____		9. NAME OF FEDERAL AGENCY: Cal Fed Bay Delta Program	
10. CATALOG OF FEDERAL DOMESTIC ASSISTANCE NUMBER: <input type="checkbox"/> - <input type="checkbox"/> N/A: see attached cover sheet CALFED: Bay Delta Ecosystems Restoration Projects		11. DESCRIPTIVE TITLE OF APPLICANT'S PROJECT: Effects of Introduced Species of Zooplankton and Clams on the Bay-Delta Food Web	
12. AREAS AFFECTED BY PROJECT (cities, counties, states, etc.): Nationwide			
13. PROPOSED PROJECT: Start Date: 1-Oct-99 Ending Date: 31-Dec-02		14. CONGRESSIONAL DISTRICTS OF: a. Applicant: 12th b. Project: Various	
15. ESTIMATED FUNDING:		16. IS APPLICATION SUBJECT TO REVIEW BY STATE EXECUTIVE ORDER 12372 PROCESS?	
a. Federal	\$826,930 .00	a. YES. THIS PREAPPLICATION/APPLICATION WAS MADE AVAILABLE TO THE STATE EXECUTIVE ORDER 12372 PROCESS FOR REVIEW ON: DATE: _____	
b. Applicant	.00	b. <input checked="" type="checkbox"/> PROGRAM IS NOT COVERED BY E.O. 12372	
c. State	.00	<input type="checkbox"/> OR PROGRAM HAS NOT BEEN SELECTED BY STATE FOR REVIEW	
d. Local	.00		
e. Other	.00		
f. Program Income	.00	17. IS THE APPLICANT DELINQUENT ON ANY FEDERAL DEBT?	
g. TOTAL	\$826,930 .00	<input type="checkbox"/> Yes If "Yes" attach an explanation. No <input checked="" type="checkbox"/>	
18. TO THE BEST OF MY KNOWLEDGE AND BELIEF, ALL DATA IN THIS APPLICATION/PREAPPLICATION ARE TRUE AND CORRECT. THE DOCUMENT HAS BEEN DULY AUTHORIZED BY THE GOVERNING BODY OF THE APPLICANT AND THE APPLICANT WILL COMPLY WITH THE ATTACHED ASSURANCES IF THE ASSISTANCE IS AWARDED			
a. Typed Name of Authorized Representative Bruce Macher		b. Title Associate Dean, ORSP	c. Telephone number (415) 338-7091
d. Signature of Authorized Representative 		e. Date Signed	

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I-019700

BUDGET INFORMATION – Non-Construction Programs

OMB Approval No. 0348-0043

SECTION C – NON-FEDERAL RESOURCES					
(a) Grant Program	(b) Applicant	(c) State	(d) Other Sources	(e) TOTALS	
8.					
9.					
10.					
11.					
12. TOTALS (sum of lines 8 and 11)					
SECTION D – FORECASTED CASH NEEDS					
	Total for 1st Year	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
13. Federal	\$248,667	\$55,263	\$68,468	\$62,468	\$62,468
14. Non Federal					
15. TOTAL (sum of lines 13 and 14)	\$248,667	\$55,263	\$68,468	\$62,468	\$62,468
SECTION E – BUDGET ESTIMATES OF FEDERAL FUNDS NEEDED FOR BALANCE OF THE PROJECT					
(a) Grant Program	FUTURE FUNDING PERIODS (Years)				
	(b) First	(c) Second	(d) Third	(e) Fourth	
16.					
17.					
18.					
19.					
20. TOTALS (sum of lines 16 - 19)					
SECTION F - OTHER BUDGET INFORMATION (Attach additional Sheets if Necessary)					
21. Direct Charges:			22. Indirect Charges:		
23. Remarks See attached detail budget.					

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Standard Form 424A (4-88) Page 2
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1-019701

BUDGET INFORMATION – Non-Construction Programs

SECTION A – BUDGET SUMMARY						
Grant Program Function or Activity (a)	Catalog of Federal Domestic Assistance Number (b)	Estimated Unobligated Funds		New or Revised Budget		
		Federal (c)	Non-Federal (d)	Federal (e)	Non-Federal (f)	Total (g)
1. Cal Fed ERP	N/A			\$826,930		\$826,930
2						
3						
4						
5. TOTALS				\$826,930	\$0	\$826,930
SECTION B – BUDGET CATEGORIES						
6. Object Class Categories	GRANT PROGRAM, FUNCTION OR ACTIVITY				Total (5)	
	(1)	(2)	(3)	(4)		
a. Personnel	\$312,744				\$312,744	
b. Fringe	72,329				\$72,329	
c. Travel	18,375				\$18,375	
d. Equipment	15,000				\$15,000	
e. Supplies	15,000				\$15,000	
f. Contractual	109,000				\$109,000	
g. Construction	0				\$0	
h. Other	38,625				\$38,625	
i. Total Direct Charges (sum of 6a-6h)	581,073				\$581,073	
j. Indirect Charges	245,857				\$245,857	
k. TOTALS (sum of 6i and 6j)	\$826,930				\$826,930	
7. Program Income						

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Standard Form 424A (4-88)
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1-019702

1-019702

BUDGET INFORMATION – Non-Construction Programs

SECTION C – NON-FEDERAL RESOURCES					
(a) Grant Program	(b) Applicant	(c) State	(d) Other Sources	(e) TOTALS	
8.					
9.					
10.					
11.					
12. TOTALS (sum of lines 8 and 11)					
SECTION D – FORECASTED CASH NEEDS					
	Total for 1st Year	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
13. Federal	\$248,667	\$55,263	\$68,468	\$62,468	\$62,468
14. Non Federal					
15. TOTAL (sum of lines 13 and 14)	\$248,667	\$55,263	\$68,468	\$62,468	\$62,468
SECTION E – BUDGET ESTIMATES OF FEDERAL FUNDS NEEDED FOR BALANCE OF THE PROJECT					
(a) Grant Program	FUTURE FUNDING PERIODS (Years)				
	(b) First	(c) Second	(d) Third	(e) Fourth	
16.					
17.					
18.					
19.					
20. TOTALS (sum of lines 16 - 19)					
SECTION F - OTHER BUDGET INFORMATION (Attach additional Sheets if Necessary)					
21. Direct Charges:			22. Indirect Charges:		
23. Remarks See attached detail budget.					

1-019703

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ASSURANCES-NON-CONSTRUCTION PROGRAMS

Note: Certain of these assurances may not be applicable to your project or program. If you have questions, please contact the Awarding Agency. Further, certain federal assistance awarding agencies may require applicants to certify to additional assurances. If such is the case, you will be notified.

As the duly authorized representative of the applicant I certify that the applicant:

1. Has the legal authority to apply for Federal assistance, and the institutional, managerial and financial capability (including funds sufficient to pay the non-Federal share of project costs) to ensure proper planning, management and completion of the project described in this application.
2. Will give the awarding agency, the Comptroller General of the United States, and if appropriate, the State, through any authorized representative, access to and the right to examine all records, books, papers, or documents related to the assistance; and will establish a proper accounting system in accordance with generally accepted accounting standards or agency directives.
3. Will establish safeguards to prohibit employees from using their positions for a purpose that constitutes or presents the appearance of personal or organizational conflict of interest, or personal gain.
4. Will initiate and complete the work within the applicable time frame after receipt of approval of the awarding agency.
5. Will comply with the Intergovernmental Personnel Act of 1970 (42 U.S.C. §§ 4728-4763) relating to prescribed standards for merit systems for programs funded under one of the nineteen statutes or regulations specified in Appendix A of OPM's Standards for a Merit System of Personnel Administration (5 C.F.R. 900, Subpart F).
6. Will comply with all Federal statutes relating to non-discrimination. These include but are not limited to: (a) Title VI of the Civil Rights Act of 1964 (P.L. 88-352) which prohibits discrimination on the basis of race, color or national origin; (b) Title IX of the Education Amendments of 1972, as amended (20 U.S.C. §§ 1681-1683, and 1685-1686) which prohibits discrimination on the basis of sex; (c) Section 504 of the Rehabilitation Act of 1973, as amended (29 U.S.C. § 794) which prohibit discrimination on the basis of handicaps; (d) the Age Discrimination Act of 1975, as amended (42 U.S.C. §§ 6101-6107) which prohibits discrimination on the basis of age; (e) the Drug Abuse Office and Treatment Act of 1972 (P.L. 93-255), as amended, relating to non-discrimination on the basis of drug abuse; (f) the Comprehensive Alcohol Abuse and alcoholism Prevention, Treatment and Rehabilitation Act of 1970 (P.L. 91-616), as amended, relating to nondiscrimination on the basis of alcohol abuse or alcoholism; (g) §§ 523 and 527 of the Public Health Service Act of 1912 (42 U.S.C. 290 dd-3 and 290 ee-3), as amended, relating to confidentiality of alcohol and drug abuse patient records; (h) Title VIII of the Civil Rights Act of 1968 (42 U.S.C. § 3601 et seq.), as amended, relating to non-discrimination in the sale, rental or financing of housing; (i) any other non-discrimination provisions in the specific statute(s) under which application for Federal assistance is being made, and (j) the requirements on any other non-discrimination Statute(s) which may apply to the application.
7. Will comply, or has already complied, with the requirements of Titles II and III of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970 (P.L. 91-646) which provide for fair and equitable treatment of persons displaced or whose property is acquired as a result of Federal or federally assisted programs. These requirements apply to all interests in real property acquired for project purposes regardless of Federal participation in purchases.
8. Will comply with the provisions of the Hatch Act (5 U.S.C. §§ 1501-1508 and 7324-7328) which limit the political activities of employees whose principal employment activities are funded in whole or in part with Federal funds.
9. Will comply, as applicable, with the provisions of the Davis-Bacon Act (40 U.S.C. §§ 276a to 276a-7), the Copeland Act (40 U.S.C. § 276c and 18 U.S.C. § 874), the Contract Work Hours and safety Standards Act (40 U.S.C. §§ 327-333) regarding labor standards for federally assisted construction subagreements.

10. Will comply, if applicable, with the flood insurance purchase requirements of Section 102(a) of the Flood Disaster Protection Act of 1973 (P.L. 93-234) which requires recipients in a special flood hazard area to participate in the program and to purchase flood insurance if the total cost of insurable construction and acquisition is \$10,000 or more.
11. Will comply with environmental standards which may be prescribed pursuant to the following: (a) institution of environmental quality control measures under the National Environmental Policy Act of 1969 (P.L. 91-190) and Executive Order (EO 11514; (b) Environmental Policy Act of 1969 (P.L. 91-190) and Executive Order (EO) 11514; (b) notification of violating facilities pursuant to EO 11738; (c) protection of wetlands pursuant to EO 11990; (d) evaluation of flood hazards in floodplains in accordance with EO 11988; (e) assurance of project consistency with the approved State management program developed under the Coastal Zone Management Act of 1972 (16 U.S.C. §§ 1451 et seq.); (f) conformity of Federal actions to State (Clean Air) Implementation Plans under Section 176(c) of the Clean Air Act of 1955, as amended (42 U.S.C. § 7401 et seq.); (g) protection of underground sources of drinking water under the Safe Drinking Water Act of 1974, as amended, (P.L. 93-523); and (h) protection of endangered species under the Endangered Species Act of 1973, as amended, (P.L. 93-205).
12. Will comply with the Wild and Scenic Rivers Act of 1968 (16 U.S.C. §§ 1271 et seq.) related to protecting components or potential components of the national wild and scenic rivers system.
13. Will assist the awarding agency in assuring compliance with Section 106 of the National Historic Preservation Act of 1966, as amended (16 U.S.C. 470), EO 11593 (identification and preservation of historic properties), and the Archaeological and Historic Preservation Act of 1974 (16 U.S.C. 469a-1 et seq.).
14. Will comply with P.L. 93-348 regarding the protection of human subjects involved in research, development, and related activities supported by this award of assistance.
15. Will comply with the Laboratory Animal Welfare Act of 1966 (P.L. 89-544, as amended, 7 U.S.C. 2131 et seq.) pertaining to the care, handling, and treatment of warm blooded animals held for research, teaching, or other activities supported by this award of assistance.
16. Will comply with the Lead-Based Paint Poisoning Prevention Act (42 U.S.C. §§ 4801 et seq.) which prohibits the use of lead based paint in construction or rehabilitation of residence structures.
17. Will cause to be performed the required financial and compliance audits in accordance with the Single Audit Act of 1984.
18. Will comply with all applicable requirements of all other Federal laws, executive orders, regulations and policies governing this program.

SIGNATURE OF AUTHORIZED CERTIFYING OFFICIAL 		TITLE	
Bruce Macher		Associate Dean, Research & Sponsored Programs	
APPLICANT ORGANIZATION		DATE SUBMITTED	
SAN FRANCISCO STATE UNIVERSITY		4/15/99	

SF 424D (4-88) Back

Certification Regarding Debarment, Suspension, Ineligibility and Voluntary Exclusion - Lower Tier Covered Transactions

This certification is required by the Department of Education regulations implementing Executive Order 12549, Debarment and Suspension, 34 CFR Part 85, for all lower tier transactions meeting the threshold and tier requirements stated at Section 85.110.

Instructions for Certification

1. By signing and submitting this proposal, the prospective lower tier participant is providing the certification set out below.
2. The certification in this clause is a material representation of fact upon which reliance was placed when this transaction was entered into. If it is later determined that the prospective lower tier participant knowingly rendered an erroneous certification, in addition to other remedies available to the Federal Government, the department or agency with which this transaction originated may pursue available remedies, including suspension and/or debarment.
3. The prospective lower tier participant shall provide immediate written notice to the person to which this proposal is submitted if at any time the prospective lower tier participant learns that its certification was erroneous when submitted or has become erroneous by reason of changed circumstances.
4. The terms "covered transaction," "debarred," "suspended," "ineligible," "lower tier covered transaction," "participant," "person," "primary covered transaction," "principal," "proposal," and "voluntarily excluded," as used in this clause, have the meanings set out in the Definitions and Coverage sections of rules implementing Executive Order 12549. You may contact the person to which this proposal is submitted for assistance in obtaining a copy of those regulations.
5. The prospective lower tier participant agrees by submitting this proposal that, should the proposed covered transaction be entered into, it shall not knowingly enter into any lower tier covered transaction with a person who is debarred, suspended, declared ineligible, or voluntarily excluded from participation in this covered transaction, unless authorized by the department or agency with which this transaction originated.
6. The prospective lower tier participant further agrees by submitting this proposal that it will include the clause titled "Certification Regarding Debarment, Suspension, Ineligibility, and Voluntary Exclusion-Lower Tier Covered Transactions," without modification, in all lower tier covered transactions and in all solicitations for lower tier covered transactions.
7. A participant in a covered transaction may rely upon a certification of a prospective participant in a lower tier covered transaction that it is not debarred, suspended, ineligible, or voluntarily excluded from the covered transaction, unless it knows that the certification is erroneous. A participant may decide the method of frequency by which it determines the eligibility of its principals. Each participant may, but is not required to, check the Nonprocurement List.
8. Nothing contained in the foregoing shall be construed to require establishment of a system of records in order to render in good faith the certification required by this clause. The knowledge and information of a participant is not required to exceed that which is normally possessed by a prudent person in the ordinary course of business dealings.
9. Except for transactions authorized under paragraph 5 of these instructions, if a participant in a covered transaction knowingly enters into a lower tier covered transaction with a person who is suspended, debarred, ineligible, or voluntarily excluded from participation in this transaction, in addition to other remedies available to the Federal Government, the department or agency with which this transaction originated may pursue available remedies, including suspension and/or debarment.

Certification

- (1) The prospective lower tier participant certifies, by submission of this proposal, that neither it nor its principals are presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from participation in this transaction by any Federal department or agency.
- (2) Where the prospective lower tier participant is unable to certify to any of the statements in this certification, such prospective participant shall attach an explanation to this proposal.

NAME OF APPLICANT San Francisco State University	PR/AWARD NUMBER AND/OR PROJECT NAME
PRINTED NAME AND TITLE OF AUTHORIZED REPRESENTATIVE Bruce Macher, Associate Dean, Research	
SIGNATURE 	DATE 4/15/99

ED 80-0014, 9/90 (Replaces GCS-009 (REV. 12/88), which is obsolete)