CALFED BAY-DELTA PROGRAM

CALFED SCIENCE FELLOWS PROGRAM

Sea Grant California

In cooperation with the

California Sea Grant College Program

FELLOWSHIP APPLICATION COVER PAGE

APPLICANT TYPE [X] Postdoctoral Researcher [ ] Ph.D. Graduate Student

PROJECT NUMBER _____

PROJECT TITLE Temporal and spatial patterns in abundance and production of pelagic organisms in the low salinity zone (Suisun Marsh, Bay and Delta) of the San Francisco Estuary with insight into trophic position and impacts of alien invasive species.

FINANCIAL SUMMARY

First Year CALFED Funds Requested:	58,000
Total CALFED Funds Requested:	200,625
Duration:	3 Years
Proposed Start/Completion Dates:	12/1/2006 through November 31, 2009

APPROVAL SIGNATURES

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Will animal subjects be used? [X] Yes [ ] No
APPROVAL DATE: _____ PROTOCOL #: _____ PENDING: _____

Does this application involve any recombinant DNA technology or reseal [ ] Yes [X] No

II. CALFED SCIENCE POSTDOCTORAL FELLOWSHIP PROPOSAL
R.E. SCHROETER

TITLE: Temporal and spatial patterns in abundance and production of pelagic organisms in the low salinity zone (Suisun Marsh, Bay and Delta) of the San Francisco Estuary with insight into trophic position and impacts of alien invasive species.

The proposed research will provide a synthesis of the aquatic community in Suisun Marsh and will compare and contrast that community with the other habitats of the S.F. Estuary, primarily in the adjacent bay and river habitats. Several levels of investigation will take place including comparisons of primary production, production of zooplankton, and the abundance of zooplankton and fish. This work is particularly relevant now given the current state of the aquatic community in the S.F. estuary (Pelagic Organism Decline POD). In addition the proposed research will also explore some of the possible impacts of alien invasive species including *Exopaleomon modestus* and a suite of gelatinous zooplankton.

To conduct the proposed research, a 3-year CALFED Science Postdoctoral Fellowship is being requested in the amount of $200,625.

INTRODUCTION

Aquatic communities residing in estuaries are increasingly being affected by a suite of anthropogenic factors that are altering community composition, population abundances and overall system productivity. These factors typically include physical habitat modification, temperature and salinity changes, alteration of flow regimes, eutrophication, pollution, overharvest, and introduction of alien species. The combination of effects resulting from these factors can have profound ecological consequences, significantly affecting ecosystem health. Estuaries are critical rearing areas for a diverse assemblage of aquatic organisms; therefore, loss of system integrity and productivity can have wide ranging consequences at many trophic levels contributing to system instability and ultimately collapse.

The San Francisco Estuary (SFE) serves as a nursery area for marine, brackish and freshwater species and supports numerous populations of diverse and valuable aquatic species. The Suisun Marsh, a large tidal marsh located at the upper end of the estuary, is an important component of this nursery area providing brackish shallow water tidal habitat for numerous species of aquatic organisms (Meng and Matern 2001; Matern et al. 2002;). In recent decades, a vast number of alien species have been introduced into the estuary dramatically altering the existing aquatic community (Cohen and Carlton 1998). Recently, the SFE low salinity zone (Suisun Bay, Suisun Marsh, Delta) is reportedly experiencing a pelagic organism decline (POD) in which multiple species of pelagic organisms at both the primary consumer (copepods) and secondary consumer level (pelagic zooplanktivorous fishes) are declining. For example, pelagic fishes, such as the endemic delta smelt (ESA listed species – state listed as Threatened), longfin smelt (ESA species of special concern), and threadfin shad have all significantly declined in abundance (Manley reported at various POD meetings). Striped bass post larvae and early stage juveniles, which also feed on a pelagic food source, have also exhibited precipitous declines in many regions of the SFE, presumably as a result of a similar cause.

There is some indication that pelagic fish declines may be explained by low abundance of pelagic invertebrate prey, primarily calanoid copepods, especially in the summer and fall months

(Mecum personal communication). In support of this hypothesis, density dependant relationships for striped bass young-of-year and delta smelt juveniles in the SFE have been found and these relationships have been, in part, attributed to the reduced carrying capacity of the estuary as a result of reduced prey availability (Kimmerer 2000; Bennett 2005).

Given the observed declines, the proposed research seeks to better understand and characterize the aquatic community and population of fishes and invertebrates in the low salinity zone with the intent of improving our understanding of the ecological and physiological limitations of these species. Specifically, the proposed research will integrate existing data from various programs that have sampled aquatic organisms in both Suisun Marsh and the affected adjacent bay and river habitats in the larger SFE, compare patterns for fish and invertebrate abundance and evaluate fluctuations due to environmental conditions. In addition, the proposed research will examine the patterns and potential impacts of gelatinous zooplankton in the low salinitiy zone and describe their potential impact on pelagic zooplankton.

Contributing Factors for Pelagic Organism Decline

Numerous factors are likely contributing to the observed decline of pelagic organisms. Some factors that are currently being investigated include alien invasive species, contaminants, toxic algae and environmental constraints. A major factor for escosystem disruption and ultimately decline of some pelagic species is the introduction of the overbite clam, *Corbula amurensis*. The introduction of the overbite clam in the middle 1980s has likely played a significant role in the decline of pelagic species, due to its high abundance and efficient filtering capabilities that enables it to considerably reduce the availability of phytoplankton, a critical food source for pelagic organisms in the upper reaches of the SFE (Alpine and Cloern 1992; Werner and Hollibaugh 1993). Other major trophic pathways and groups of organisms have also been adversely affected by the overbite clams filtering activities including bacteria (Werner and Hollibaugh 1993), zooplankton (Kimmerer and Orsi 1996), mysid shrimp (Orsi and Mecum 1996) and benthos (Nichols et al. 1990). In addition to the overbite clam, other alien invasive species are also likely adversely affecting pelagic species. For instance, a suite of gelatinous zooplankton have been increasing in abundance during the same time period that the pelagic organism decline was first detected. It appears from preliminary data that these gelationous zooplankton are capable of consuming large numbers of zooplankton given their high feeding rates (*M. marginata*) or high abundance (*Moerisia sp*)

Control or Reference Conditions in the SFE

When attempting to elucidate factors responsible for system disruption and decline, it is particularly useful to identify areas or habitats that may be used as a control or reference for comparison to adversely affected regions or habitats. In the case of the SFE, it would be particularly useful to identify regions that may not be experiencing as significant of declines or no declines in pelagic species and then selectively remove potential factors that are shared in common between affected and non-affected regions. One potential control region within the SFE that is found in close proximity to affected habitats is Suisun Marsh, Solano County, California (Figure 1). Preliminary evidence suggests that phytoplankton biomass as measured by chlorophyll a concentrations and zooplankton abundance may not be as depressed, as in the adjacent bay and river habitats (Figure 2, and 3). In addition, the fish fauna found in Suisun Marsh includes pelagic species that have not declined or have not experienced as drastic a

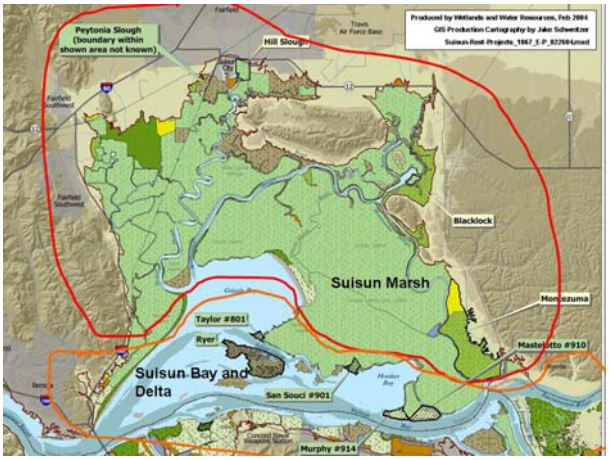

Figure 1 General Map of Bay Delta and Suisun Marsh

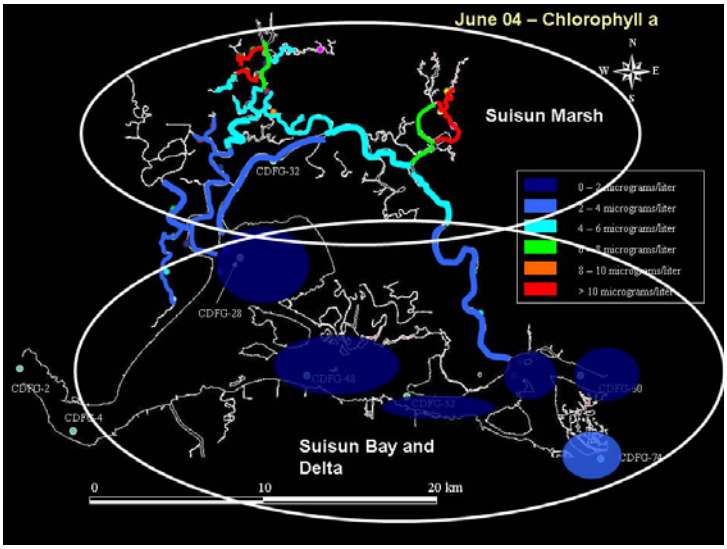

Figure 2 Chlorophyll a concentrations in Suisun Marsh and ajacent Bay and Delta habitats June 2004. High Chlorophyll a concentrations are indicated by red to orange color bands (8-10ppt respectively) and low concentrations = blue colors.

decline in abundance as those observed in adjacent bay and river habitats. The direct connectivity between Suisun Marsh and adjacent bay and river habitat where notable declines have occurred ensures that many factors that may affect the pelagic species in both regions should be similar. For instance, the same origin of source water to Suisun Marsh and Suisun and Grizzly Bay during summer and fall (Sacramento and San Joaquin River inflow and Marine incursion from Grizzly Bay) likely minimizes variation in contaminants, although other factors such as toxic algae and environmental constraints may be unique to each area. Given these circumstances and conditions, Suisun Marsh may well serve as a viable control or reference condition for the larger SFE.

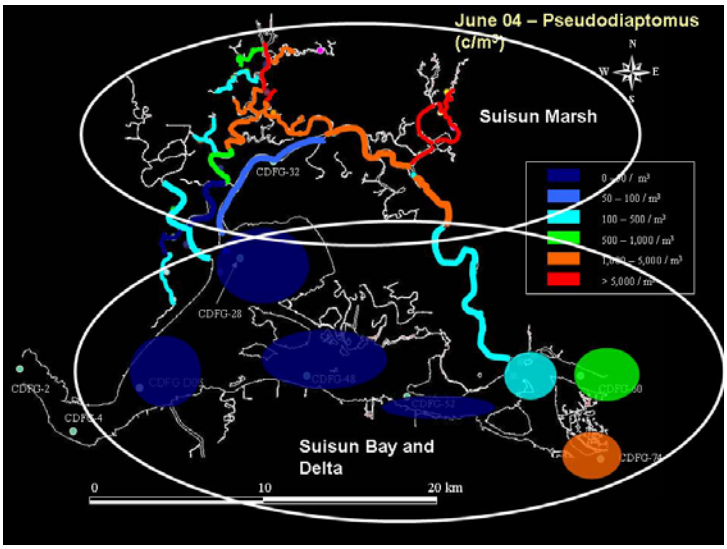

Figure 3 Pseudodiaptomus abundances in Suisun Marsh and adjacent Bay and Delta habitats in June 2004. Red indicates high abundances and blue low to absent .

RESEARCH APPROACH / PLAN OF WORK

The proposed research seeks to take advantage of the immense monitoring data collected and maintained by the various implementing agencies that have sampled both Suisun Marsh and the affected adjacent bay and river habitats in the larger SFE. Existing data to be utilized include, but may not be limited to, the following:

1) UC Davis Fish Monitoring Data (1980 – present);
2) CALFED Invertebrate Data;
3) California Department of Fish and Game Mysid and Zooplankton Data; and
4) Bay Study Fish Data

A rigorous analysis of these data will enable the ability to identify similarities and differences in patterns of abundance of fish, zooplankton and phytoplankton within and before the POD time period. In addition, this project will also investigate other stressors in the system that may be affecting the abundance of pelagic organisms, but for which we have little information, such as the impact of various introduced species on the pelagic organism decline. Specifically, the effect of the introduced Siberian prawn, *E. modestus* and several introduced gelatinous zooplankton (jellyfish). The additional ecological data on this alien invasive species will be instrumental in our ability to better understand the dynamics of the ecological system of the SFE.

Specific questions addressed by the proposed research include:

1) Given the significant declines of pelagic fishes in the bay and delta habitats of the SFE (POD) over the last 10 years, what are the trends and patterns in the adjacent brackish tidal marsh fish community in Suisun Marsh over this same time period? Given differences between the two are there regions of the marsh that more closely resemble the patterns observed in the bay and river habitats?
2) Given the low abundance of zooplankton in the bay and delta habitats of the SFE (POD) between 2004 and 2006, what are the abundances in the adjacent brackish tidal marsh

community in Suisun Marsh over this same time period? Are there regions within the marsh which have depressed abundances of pelagic organisms similar to the bay and delta?

3) Given the low levels of primary productivity observed in the greater SFE, what are the current levels of primary productivity in Suisun Marsh? If differences exist, can factors such as the abundance or absence of clams at the various sampled sites explain the differences? Does the productivity of pelagic zooplankton (specifically copepods) differ between Suisun Marsh and the adjacent bay and river habitats?
4) What are the potential impacts that gelatinous zooplankton may be having on the pelagic zooplankton in the system?
5) What are the trophic relationships of the recently invaded invertebrate species in the SFE?

Detailed Study Description

The proposed research includes five study components, described below:

Study Component 1) Spatial and Temporal Fish abundance trends

The proposed fellowship study will begin by examining the marsh data to determine whether or not the fish community in Suisun Marsh has undergone a similar recent decline in pelagic species as observed in the bay and delta habitats. A broad approach will be taken when investigating these data with analyses focusing on seasonal and annual differences as well as particular climatic characterizations (i.e. precipitation, water year type, and various parameters of outflow). In addition, estimates of spawning population size (mature adults) in current year and current year -1 will also be utilized to attempt to account for the large variation in spawning stock which can greatly affect observed abundances. In addition, large changes in abundance within each sampled habitat (Suisun Marsh and Bay and Delta) will be determined in order to account for influential sites. If more appropriate delineations of particular regions based upon population abundance are found, they will be employed in further analyses. This is particularly important given the large variety of habitats sampled within Suisun Marsh and across the adjacent bay and river habitats and is necessary to determine if there are any POD like declines observed in limited regions of habitats such as within either Suisun marsh or the Bay and or Delta. Fish data will be used from the complete Suisuin Marsh data set (1980-2005) and a comparable time period from the California Department of Fish and Game - Bay Study Fish Survey. Supplemental data may be used from other studies if deemed appropriate or seasonal comparisons may also be made from seasonal surveys (e.g. Fall Midwater Trawl).

Study Component 2) Abundance patterns of pelagic invertebrates in Suisun Marsh (SM) and adjacent bay and river habitats (BRH).

Based upon preliminary evidence, the abundance of pelagic invertebrates in SM is considerably higher than adjacent Bay and Delta habitats. These patterns will be explored both temporally and spatially for the common copepod species such as *Pseudodiaptomus forbesi* and *Eurytemora affinis* which can occur in very high densities. Temporal and spatial patterns of mysid shrimp and amphipods will also be explored in this study. Data will be obtained from the 2004 – 2006 UCD CALFED Invert study and the CDFG Mysid shrimp and zooplankton survey for the same time period. Special attention will be played to environmental relationships and seasonal trends. As in study component 1 the spatial variation in abundance will be thoroughly investigated to determine if more appropriate regional delineations are necessary. These spatial and temporal patterns will reveal in more detail the availability of prey to the important pelagic fishes in SM and the adjacent habitats.

Study Component 3) The biomass of phytoplankton, as measured by chllorophyll a concentrations at the sampled sites, will be used to determine differences between the tidal marsh habitats within Suisun Marsh and adjacent Bay and Delta habitats. The production of copepods and other pelagic invertebrates will be evaluated by examining abundance patterns and fecundity. There are 38 sites sampled monthly within Suisun Marsh with additional sites available from the CDFG Mysid and Zooplankton Surveys in adjacent waters of the S.F. Estuary. Establishing the levels of phytoplankton biomass and zooplankton productivity at sampled sites in Suisun Marsh and adjacent Bay and Delta habitats will provide insight into whether the current POD is related to decreased biomass of phytoplankton (i.e. low primary productivity) and / or due to low abundance and or productivity of primary consumers (zooplankton). The chlorophyll a concentrations in Suisun Marsh, as measured by our 2 year CALFED study and other sampling programs, are consistently higher and usually largely so, than the surrounding Bay and Delta (Figure 2). The same is true for the pelagic zooplankton (Figure 3). Obtaining the relationship between primary production and secondary production will be a useful screening tool in determining the role that limited primary production in the POD affected waters of the upper SFE plays in lower overall fish and invertebrate abundance. Relationships between salinity and other environmental parameters and phytoplankton biomass and copepod productivity will also be explored.

Study Component 4) Expanded evaluation of the risk of gelatinous zooplankton as predators on the pelagic invertebrate community.

To date, UC Davis has compiled the available *M. marginata* data and has characterized the environmental relationships, patterns of occurrence large individuals (> 20 mm), due to the size bias of our sampling gear (otter trawl mesh size is 6 mm stretch in the cod end). This study component will determine the abundance of all age classes (size class) of all three species common in the vicinity of Suisun Marsh including *Moerisia sp*., *M. marginata*, and *B. virginica*. The diets of these three gelatinous zooplankton have been well characterized (Mills and Sommer 1995; Schroeter unpublished data). Although *M. marginata* is only moderately abundant and *B. virginica* is only locally abundant, *Moerisia*, a very small hydromedusa (< 8 mm in bell dia.), is very abundant in many of the sampled sites in SM especially in late Summer to Fall. Collectively the density of all jellies can be as high as 150/m3. Given the high abundance of these species, and their demonstrated predaceous abilities especially on pelagic copepods it is important to establish the predatory effect they might have on the community of pelagic invertebrates commonly used as prey by fishes in the system.

The relationship between increasing jellyfish abundance and pelagic organism decline is largely unknown, but given the fact that the jellyfish diet is dominated by pelagic invertebrates (Mills and Sommer 1995; Purcell et al. 1999a), an important food source for the declining pelagic fishes, jellyfish may be depressing an already limited food source. However, it cannot be ruled out that jellyfish may merely be taking advantage of prey resources recently released from predation following observed fish declines, as has been suggested in other areas where jellyfish have increased in abundance following overfishing and fishery declines. None-the-less the current high abundance of jellyfish in the system may be further preventing recovery of the disturbed pelagic system.

Study Component 5) Determining the trophic interactions of the various fish and invertebrates in Suisun Marsh and adjacent Bay and Delta habitats. This study component will utilize field caught specimens of invertebrates and larval, postlarval and juvenile fishes from sampled sites

in Suisun Marsh and adjacent Bay and Delta habitats to perform isotopic analyses. The obtained isotopic ratios will be used determine the trophic associations of the sampled organisms. This study will be particularly useful for the species we have little diet data for, such as *E. modestus* which grinds its prey beyond recognition. This information will also be valuable for the various age classes of fishes, which may experience rapid ontogenetic shifts in diet during development such as striped bass. Including species such as the clam *Corbula amurensis,* may result in a better predictive ability of their potential predatory impact on the biota in the system, since it has been loosely hypothesized that they are partly to blame for recruitment failure of important copepod species (namely *Pseudodiaptomus forbesi*) due to their ability to capture and consume copepod nauplii. Additional introduced species that have had an unknown impact in the system, but are locally very abundant are the hydroid C*ordylophora caspia*, Cumaceans, the amphipod *Gammarus daiberi*, and the polycheaete worms *M. viridis* and *Laonome sp*. All isotopic preparation and analyses will be perfomed at UC Davis.

PROPOSED RESEARCH OUTPUT / ANTICIPATED PRODUCTS AND BENEFITS

The proposed research will provide a better understanding of the aquatic community and population of fishes and invertebrates in the SFE, particularly the low salinity zone. The research fellow (R. Schroeter), agency scientist (A. Mueller-Solger), and research mentor (P. B. Moyle) will collaborate on the proposed research to ensure that the proposed research objectives benefit the CALFED priorities and mission. Beyond the scientific benefits of the proposed research, each member of the research team will greatly benefit from the resulting inter-agency partnership and data-sharing.

The proposed research matches many aspects of both the PSP Priority Areas and the CALFED Implementing Agency Science Needs. **PSP Priority Areas** that are specifically addressed by the proposed research include:

- Aquatic Invasive (Exotic) Species
- Trends and Patterns of Populations and System Response to a Changing Environment
- Habitat Availability and Response to Change

The **CALFED Implementing Agency Science Need** that is specifically addressed by the proposed research is Pelagic Organism Decline (POD). Sub priorities within the Pelagic Organism Decline that will be specifically addressed include

- Do Suisun Bay and Suisun marsh (e.g. channels or restored marsh, or both) show different trends in the communities and habitat of aquatic organisms? If so, why? Organisms that we would like to address include fish, macroinvertebrates, zooplankton, phytoplankton and microbes.
- What are the trends in habitat for estuarine invertebrates and fish, and how do they overlap in space and time?
- Are characteristics such as health, growth, fecundity, etc. of POD species different in inshore areas (e.g. Suisun Marsh, littoral habitat) than in offshore areas (e.g. Suisun Bay, Delta channels)?
- What are flux or transport rates of aquatic organisms between marsh (or other inshore habitats) and channel areas? How do different flow conditions (i.e. X2) affect these

transport processes? Note that we are particularly interested in interactions between Suisun Marsh and the San Francisco Bay.

- What role do recent exotic species (e.g. Exopaleomon) play in the estuarine food web?

The proposed research coupled with an ongoing CALFED Project (ERP02-P32) and a DWR funded IEP fish monitoring project in Suisun Marsh allows for a full aquatic community approach in its investigation into the abundance, pattern of occurrence, and potential impacts of many invasive species in the SFE. The research specifically addresses the potential threat of gelatinous zooplankton on the pelagic zooplankton community in Suisun Marsh and adjacent habitats. The proposed research will also further our understanding of the trophic position of a number of introduced alien invasive species that have not been well studied or have difficult to distinguish diets. These species include the Siberian prawn, *E. modestus*, the amphipod, *G. daiberi*, and the polychaetes, *Laonome sp*. and *M. viridis*. In addition, the trophic position of the highly abundant hydrozoan, *Cordylophora caspia* will also be determined. The trophic position of other alien invasive species, such as the overbite clam will also be determined, providing basic but needed information on the potential role these invasive species play in the structure and function of the constantly changing aquatic community of the SFE.

The proposed research also provides insight into the trends and patterns of population response to a changing environment. The long term data analyses of the fish community in Suisun Marsh and adjacent bay and delta habitats will identify changes that may have occurred in the pelagic community over the sampled time period (1980-2006) which includes extended droughts, periods of above normal and normal precipitation and also changes in net outflow through the system as a result of changes in water management in the system. In addition, the population response of the various invertebrates to the seasonal fluctuations in environmental conditions in the highly variable Suisun Bay region will provide insight into potential factors that may be affecting population abundance.

Anticipated Products

Upon successful completion of the proposed research, a total of six manuscripts will be submitted for professional publication:

Year 1 – (Two manuscripts submitted for professional publication)

a) Complete gelatinous zooplankton study. Submit manuscript for publication;
b) Complete data collection, compilation, and analyses evaluation the differences in fish abundance trends (spatial and temporal) in Suisun Marsh and Bay habitats. Submit manuscript for publication;
c) Complete isotope sample collection, processing, and analyses.

Year 2 – (Three manuscripts submitted for professional publication)

a) Complete evaluation of the differences in primary productivity and the observed abundance of zooplankton in the various sites within Suisun Marsh, Suisun Bay, and Delta. Submit manuscript for publication;
b) Complete data compilation and analyses for different levels of zooplankton productivity in Suisun Marsh, Suisun Bay, and Delta. Evaluate the effect of

environmental variables and phytoplankton biomass as contributing factors leading to the varying levels of zooplankton productivity. Submit manuscript for publication;

c) Complete isotopic study. Submit manuscript for publication;

Year 3 – (One manuscript submitted for professional publication)

a) Complete synthesis paper on the ecology of Suisun Marsh using various datasets integrated as part of the proposed research. Submit manuscript for publication;

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