Section 1: Summary Information

1. **Project title:** Salinity effects on native and introduced SAV of Suisun Bay and the Delta
2. **Applicant name:** San Francisco State University, Romberg Tiburon Center for Environmental Studies
3. **Contact person:** Katharyn E. Boyer
4. **Address:** 3152 Paradise Drive
5. **City, State, Zip:** Tiburon, CA, 94920
6. **Telephone #:** 510-504-2424
7. **Fax #:** 510-558-0167
8. **Email address:** katboyer@sfsu.edu
9. **Agency Type:** University (CSU)
10. **Certified nonprofit organization:** No
11. **New grantee:** Yes
12. **Amount requested:** $412,410
13. **Total project cost:** $412,410 (University rules do not allow formal attribution of closely related projects as match; however, two projects funded in recent weeks by the Delta Science Program [$160K] and NOAA Fisheries [$10K] represent substantial leveraging of requested funds)
14. **Topic Area(s):** Primary: Shallow water and marsh habitat; Secondary: X2 (freshwater-seawater interface), Non-native invasive species
15. **ERP Project type:** Primary: Research; Secondary: Monitoring, Pilot/Demonstration
16. **Ecosystem Element:** Primary: Tidal perennial aquatic habitat; Secondary: Invasive aquatic plants, Essential fish habitat, Mid-channel islands and shoals
17. **Water Quality Constituent:** Primary: Salinity; Secondary: Turbidity, Nutrients
18. **At-Risk species benefited:** Delta Smelt, Central Valley Fall-/Late-Fall-Run Chinook Salmon ESU, and Green Sturgeon

19. **Project objectives:** Characterize salinity and other abiotic factors in and outside native *Stuckenia pectinata* beds with comparisons to four invasive *Egeria densa* beds, and use mescosom experiments to evaluate and predict the effects of increased salinity on *Stuckenia* and *Egeria*, and their invertebrate assemblages.

20. **Time frame:** 3 years, beginning fall 2011 (depending on award/contracting schedule)

Section 2: Location Information

1. **Township, Range, Section: and the 7.5 USGS <u>Quad map name</u>.** 7.5 USGS Quad Names: Vine Hill, Honker Bay, Antioch North, Jersey Island, Bouldin Island; closest towns: Port Chicago, Pittsburgh, Antioch, Oakley

2. **Latitude, Longitude (in decimal degrees, Geographic, NAD83):**
   Simmons Island: 38.100917, -122.003503
   Ryer Island: 38.081023, -122.025250
   Chipps Island: 38.064859, -121.920015
   Winter Island: 38.056713, -121.856051
   Central Delta locations, TBD (see text)

3. **Location description:**
   Shallow subtidal zone along islands in Suisun Bay, west Delta, Central Delta (see map)

4. **County(ies):** Solano, Contra Costa, Sacramento

5. **Directions:** Accessed by boat

6. **Ecological Management Region:** Bay Region, Delta Region

7. **Ecological Management Zone(s):** 3&4

8. **Ecological Management Unit(s):** Suisun Marshlands and Bay, Central and West Delta

9. **Watershed Plan(s):** San Francisco Bay Subtidal Habitat Goals Project

10. **Project area:** Salinity and other abiotic parameters will be measured at point locations; additional work will be accomplished in mesocosm experiments

11. **Land use statement:** Subtidal, offshore areas outside vicinity of watershed plans

12. **Project area ownership:**
    % Private_______ % State__100__ % Federal________

13. **Project area with landowners support of proposal:** State Land Commission ownership

Section 3: Landowners, Access and Permits

1. **Landowners Granting Access for Project:** (Please attach provisional access agreement[s]) State Lands Commission ownership

2. **Owner Interest:** State Lands Commission

3. **Permits:** Need to obtain waiver of SLC lease for research project that will not alter lands, need new or amended CA Department of Fish and Game collecting permit and research approval letter

4. **Lead CEQA agency:** This very low impact research project will be categorically exempt from NEPA/CEQA permitting

5. **Required mitigation:** No

Section 4: Project Objectives Outline

1. **<u>List task information:</u> Goal 2, Ecological Processes, Objective 1**: "Establish and maintain hydrologic and hydrodynamic regimes for the Bay and Delta that support the recovery and restoration of native species and biotic communities, support the restoration and maintenance of functional natural habitats, and maintain harvested species". To address this objective, this project will assess current salinity regimes that support native SAV beds dominated by *Stuckenia pectinata* in Suisun Bay and the West Delta (in comparison to central Delta *Egeria densa* beds), and use mesocosm experiments to predict the effects of increased salinity on these beds and their invertebrate assemblages. Our conceptual model is that increased salinity, possible under a number of scenarios (including sea level rise, unintentional levee failure, intentional levee breaches for restoration, or changes in management of water release timing or magnitude), will have no or minimal negative effects on native SAV beds in their current distribution, and will increase their distribution further into the Delta, while *Egeria* beds of the central Delta will decline. These native *Stuckenia* beds are likely to provide food or cover to native fish species of concern along their migratory paths, and to do so without providing non-native predators dark refuges from which to prey upon native fishes (as occurs in *Egeria*). This project will allow predictions of the outcomes of salinity changes on this native SAV habitat, thus informing management actions that are likely to improve conditions for both native SAV and special status fish species.

2. **<u>Additional objectives:</u> Goal 5, Nonnative invasive species, Objective 7**: "Limit the spread or, when possible and appropriate, eradicate populations of non-native invasive species through focused management efforts". See above; this project will characterize salinity regimes that could limit distribution and spread of the invasive SAV, *Egeria densa* and its poor support of (and facilitation of predators on) native fish species of concern. **Goal 4, Habitats, Objective 3**: "Protect tracts of existing high quality major

aquatic, wetland and riparian habitat types, and sufficient connectivity among habitats, in the Bay-Delta estuary and its watershed to support recovery of native species and biotic communities, rehabilitation of ecological processes, and public value functions." This project will help to determine conditions that support native SAV beds, thus informing management actions that could protect or increase acreages of these beds while decreasing lower quality habitats of non-native SAV in the central Delta that poorly support native fish species. **Goal 1, Endangered and other at-risk species and native biotic communities, Objective 1**: "Achieve, first, recovery, then large self-sustaining populations of the following at-risk native species dependent on the Delta, Suisun Bay, and Suisun Marsh….". This project will help to characterize and predict conditions that support native SAV beds in Suisun Bay and the west Delta and that may increase distribution of these beds into the central Delta. These beds are likely to improve habitat for a number of native fish species listed in this objective, particularly Delta Smelt, and perhaps others.

3. **Source(s) of above information:** Nobriga et al. (2005) found low abundances of special status fish species in *Egeria* beds, and hypothesized that more turbid waters outside of *Egeria* beds (which baffle particles out of the water) provide refuge from predation. Our preliminary data (unpublished) show open canopies and high turbidity in *Stuckenia pectinata* beds, high abundances of invertebrate epifauna, and observations of larval fish among the *Stuckenia* canopies (species unknown). Native *Stuckenia* beds are found in the low salinity zone in Suisun Bay and the west Delta (authors' preliminary surveys) and are likely to increase distribution in a west and central Delta with higher salinity levels.

Section 5: Conflict of Interest

Primary Contact for Proposal: Katharyn E. Boyer
Primary Investigator: Katharyn E. Boyer
Co-Primary Investigator: None
Supporting Staff: Stephanie L. Kiriakopolos, Evyan Borgnis
Subcontractor: None

Provide the list of names and organizations of all individuals not listed in the proposal who helped with proposal development along with any comments:

1) Last Name: Enright, First Name: Christopher

Organization: CA Dept of Water Resources and Delta Science Program

Role: Discussed project ideas

2) Last Name: Moyle, First Name: Peter

Organization: UC Davis

Role: Discussed project ideas and planned preliminary collaboration on fish use of *Stuckenia* beds

Section 6: Project Tasks and Results Outline

1. Detailed Project Description

The CALFED Bay-Delta Program's objective of achieving ecosystem restoration in a setting with numerous special-status fish species in the midst of California's major water supply system is challenged by both current conditions of invasive submerged aquatic vegetation (SAV) and uncertainty about species and community responses to changing salinity regimes. The introduced Brazilian waterweed *Egeria densa* thrives in the quiet, perennially fresh waters of the central Delta, providing habitat for non-native predatory fish, with negative consequences for native fish species (Nobriga et al. 2005, Brown and Michniuk 2007). In contrast, in the low salinity region of the western Delta and Suisun Bay, open canopies of native SAV composed primarily of sago pondweed, *Stuckenia pectinata* (Fig. 1) lie along the migratory path of several fish species of concern, including Delta smelt and Chinook salmon, perhaps providing food resources without the dense refuges for non-native predators afforded by *Egeria*. A number of possible scenarios, as a result of global climate change or local management actions, could lead to greater salinity in the west and central Delta region. We propose that future conditions of higher salinity in the central Delta will favor this native SAV species and lead to declines in freshwater exotics, including *Egeria densa*. **The purpose of this project is to evaluate the role of increased salinity on native versus introduced SAV beds**, in an effort to predict how native *Stuckenia* beds might contribute to restoration of native communities and functions in the Delta region.

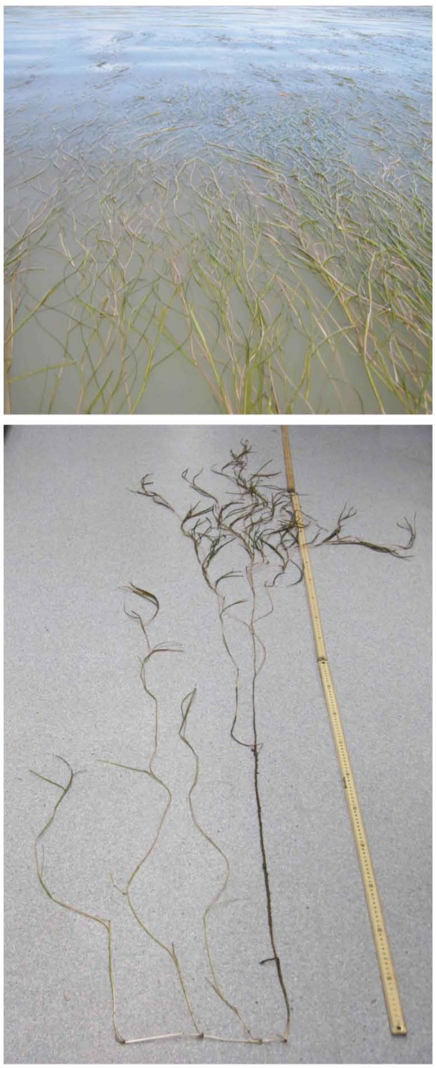

Figure 1. Native SAV beds dominated by *Stuckenia pectinata* are prominent features in the shallow subtidal zone of Suisun Bay and the west Delta, forming relatively open canopies up to 3m tall (preliminary data).

Stuckenia pectinata beds are an extensive feature in the shallow subtidal zone of Suisun Bay and the west Delta, but are little known; this is surprising considering their regional extent, size, position through major migratory paths of native fishes, and persistence through time, according to time series aerial imagery (Fig. 2). So little is known about these beds that the newly released (January 2011) report from the San Francisco Bay Subtidal Habitat Goals Project recommended the very basic science goal "assess the distribution and abundance of native SAV species other than eelgrass", and the protection goal "protect existing sago pondweed habitat"; this is in stark contrast to the many specific science, protection, and restoration goals for the better known eelgrass (*Zostera marina*) of the saline Bay regions (http://www.sfbaysubtidal.org/report.html, Chapter 8). A lack of information by no means minimizes the perceived importance of these *Stuckenia* beds; NOAA's

National Marine Fisheries Services considers them essential fish habitat for federally managed fish species (Korie Schaeffer, Northern California Habitat Coordinator for Coasts and Estuaries, NOAA NMFS, pers. comm.).

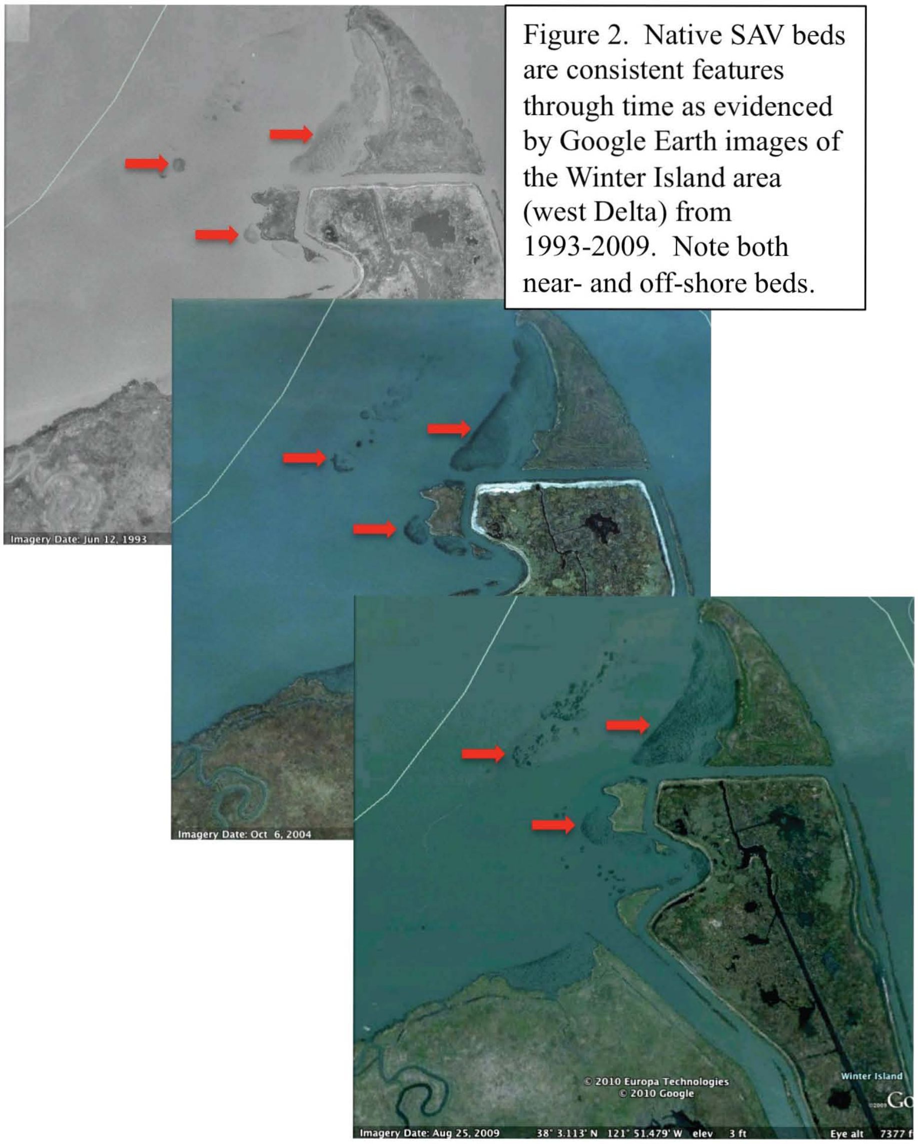

Figure 2. Native SAV beds are consistent features through time as evidenced by Google Earth images of the Winter Island area (west Delta) from 1993-2009. Note both near- and off-shore beds.

We will begin to remedy the paucity of information on these *Stuckenia* beds through a survey of their distribution in summer 2011 funded by NOAA Fisheries, and a new project funded by the Delta Science Program (pending public comment and final approval), for which we will characterize the habitat structure of these SAV canopies and the epifaunal invertebrate assemblages they support. The latter study will document some of the biotic features of the beds that are likely to influence native fishes under today's conditions. In concert with that study, we will begin preliminary collaboration with Peter Moyle (UC Davis) to assess fish use of these habitats.

In this proposal to the CALFED ERP, we ask a distinctly different and forward-directed question:

How will distribution and characteristics of these beds change under future scenarios of increased salinity?

The objectives of this project are to: 1) characterize the current range in salinity and other abiotic factors in and outside *Stuckenia* beds in four locations in Suisun Bay and the west Delta over a one year period, with comparisons to four *Egeria* beds in the central Delta, 2) use mesocosm experiments to evaluate the effects of increased salinity (parameterized to field conditions measured in the first year and long-term data sets) on *Stuckenia* and *Egeria* growth characteristics, and 3) use mesocosm experiments to assess the effects of salinity on common epifaunal invertebrate species associated with *Stuckenia* and *Egeria* beds.

Through this study, we will determine the conditions under which *Stuckenia* and associated invertebrates thrive, and also their ability to withstand higher salinity than found within the current *Stuckenia* bed distribution. Further, we will model thresholds of *Egeria* (and invertebrate community) persistence and decline with increased salinity. Together, and along with related concurrent projects described above, we will predict the geographic range where native SAV (*Stuckenia*-dominated) beds will persist or may be restored under future salinity scenarios, perhaps to the food web and predation refuge benefit of multiple native fish species of concern.

2. Background and Conceptual Models

Potential value of Stuckenia pectinata *beds in food provision and refuge for native fishes*

Generally speaking, submerged vegetation in estuaries throughout the world has important influences on biogeochemical cycling, sediment stability, and food web support (e.g., McGlathery et al. 2007; see review by Orth et al. 2006). SAV species often provide food and shelter for numerous fish and invertebrates, and serve as a nursery habitat, providing predation refuge for juvenile fishes (Orth et al. 1984; Rozas and Odum 1988; Bostrom and Bonsdorff 2000; Duarte 2000). Worldwide, they support myriad rare and endangered animals, as well as commercially important species (Hughes et al. 2009), but are in decline (Waycott et al. 2009).

In the San Francisco Bay-Delta, studies of non-native SAV beds dominated by *Egeria densa* show high fish abundances; however, the assemblages are dominated by non-native species (Nobriga et al. 2005). *Egeria* thrives in the perennially fresh, slow moving waters of the Delta, choking waterways and impeding movement of fish. It also must be removed to keep waterways open, either mechanically or using toxic copper compounds. The waterweed harbors numerous introduced freshwater predatory fish that may have negative impacts on some desirable native species (Brown and Michniuk 2007, Nobriga et al. 2005, Grimaldo et al. 2009). *Egeria* tends

Figure 3. Native SAV in the west Delta and Suisun Bay may enhance success of native pelagic fish species of concern through provision of structure for invertebrate food resources, without the dense, shadowy hiding places that support non-native predator success in invasive *Egeria* beds.

to increase water clarity, but the dense canopies may provide dark refuges for non-native predatory fish (Nobriga et al. 2005) (Fig. 3).

In contrast, the canopies of native SAV beds dominated by *Stuckenia pectinata* (formerly *Potamogeton pectinatus*, sago pondweed) in Suisun and the west Delta have relatively open canopies, owing to long slender shoots with branches bearing leaves primarily in the upper 1/3 of mature shoots (Fig. 1). Preliminary sampling suggests that turbid waters of *Stuckenia* beds could provide some visual refuge from predation for native fish (Boyer and Kirakopolos, unpublished), without the shadowy hiding places that may support non-native predator feeding success in *Egeria* beds (Nobriga et al. 2005). Further, our preliminary sampling shows high abundances of epifaunal invertebrates, including numerous amphipods, isopods, and spiders, which could provide food resources to native fishes (Fig. 4). While it has been hypothesized that tidal wetlands might provide food web support for pelagic fishes in the northern Estuary and Delta, there is little evidence to support this link (Brown 2003). Native SAV beds in the shallow but open waters of this region may serve this purpose to a much greater degree due to closer proximity to the migratory pathways of native fishes as well as the abundant food resources on and among these plants.

Figure 4. Hypothesized trophic support by native SAV beds. Top: direct consumption of plant tissues (note feeding scars) appears to contribute to the food web. Middle three photos: isopods, amphipods, and spiders are among the abundant invertebrate fauna on these plants. Bottom: hundreds of invertebrates were rinsed from a single shoot in preliminary sampling.

Stuckenia pectinata beds are a prominent and persistent feature in Suisun Bay and the west Delta, as seen by examining Google Earth images over several decades (e.g., Fig. 2 at Winter Island). In fact, these beds may be increasing in distribution; preliminary examination of many images suggests the beds are becoming a more prevalent habitat feature since the early 1990s, the timing coincident with increased salinity in this region (Enright and Culberson 2009). In view of the canopy characteristics and food resources we are beginning to document in *Stuckenia* beds, we propose that salinity changes that lead to a distribution further into the Delta may improve conditions for native fishes in this region.

Potential for higher salinity

Native fishes and vegetation evolving in the Sacramento-San Joaquin Delta and Suisun Bay may have experienced a more variable salinity environment than exists today with higher flow in winter (without reservoirs trapping the water) and lower in summer (without reservoirs releasing the water), and thus higher salinity conditions during the dry season (Knowles 2002). However, while a recent analysis of long-term salinity data shows some dampening of salinity variation related to water control projects, monthly and annual trends appear to be mostly driven by climate patterns and actually show increased salinity variation since water projects went into operation in the late 1960's (Enright and Culberson 2009). While we are interested in understanding how salinity variation influences SAV species composition and use by invertebrates and fishes, predicting how salinity will vary with future climate, water management, and watershed land use makes proposing a reasonable test of salinity variation very problematic. Hence we will focus on how average salinity over a range of levels influences plant and community responses rather than modeling the effects of future variation in salinity.

An increase in salinity in the Delta could come about through several mechanisms including: sea level rise leading to higher salinity waters moving up-estuary; extended periods of drought, which could lead to increased salt penetration not counteracted by reservoir releases during the summer months; levee failures, which could lead to a greater volume of tidal waters reaching the Delta and thus greater salinity in these waters; or management actions that inadvertently or deliberately reduce freshwater releases during the dry season. Higher salinity conditions are likely to have no adverse effects on native fishes that evolved in the northern Estuary, and may result in reductions in non-native freshwater SAV species and enhancement of habitat available for native (*Stuckenia pectinata*-dominated) SAV.

Currently, *Stuckenia* beds occur offshore of islands from Ryer Island in Suisun Bay to at least Winter Island in the west Delta (authors' preliminary survey in summer 2010). Long-term salinity monitoring has occurred at Port Chicago, near the western end of the plant's range, and at Collinsville, near the eastern end (Enright and Culberson 2009). At Port Chicago, salinities since 1988 have averaged 11 mmhos/cm (specific conductivity), and ranged from 0-24. At Collinsville, salinities during the same period averaged 3.3 mmhos/cm, and ranged from 0-11. These data give some indication of salinity preference or tolerance of *Stuckenia*, but do not consider other factors that could affect distribution, such as temperature, competition, or recruitment success (and dispersal distance is low according to one study in Chesapeake Bay; Koch et al. 2010). Experiments are needed to isolate the effects of salinity, but we know of only one study that directly tested growth responses of this plant (Chesapeake Bay), finding no difference in growth rates at salinities of 0 or 12 ppt (Murray et al. 2009).

Similarly, we have just one experiment to guide our expectations for how *Egeria densa* will respond to increased salinity. In the field in its native Chile, *Egeria* biomass was greatest at salinities from 0 to 1.2 ppt and its biomass was an order of magnitude lower at 5 ppt (Hauenstein and Ramirez 1986). It was not found at salinities >5‰. In a 6-week mesocosm experiment, growth of shoots and roots declined dramatically at salinities >4 ppt, whereas no growth occurred at ≥10 ppt (Hauenstein and Ramirez 1986). While this study gives us an idea of *Egeria*'s salinity tolerance, we do not know how the population in the Delta might respond to increased salt intrusion. For one thing, the local population is entirely clonal (i.e., no sexual reproduction occurs; Anderson 1999) and low genetic diversity may limit the resilience of the population to perturbations. It is also possible that the highly modified channels and hydrology of the Delta may enhance *Egeria*'s success relative to its native range, perhaps buffering other stressors to which it is exposed.

We have provided several conceptual models so far, but the one we will explicitly test in the proposed research is as follows. We hypothesize that a salinity increase of 5 ppt above the highest average salinity in the region where *Stuckenia* beds are found (~11 ppt at Port Chicago, but this baseline to be set according to measurements in the beds during the first year of this study) will have no negative effect on growth characteristics, thus allowing these beds to persist within their current geographic range as salinity increases. We expect these native SAV beds to expand further into the west and central Delta under a number of possible scenarios of increased salinity described above. In contrast, we expect *Egeria densa* to suffer declines in biomass and other growth parameters under salinity elevated above current average conditions by even 5 ppt.

We are also interested in the effects of increased on SAV-associated invertebrate communities because of their potentially important role in food webs of native fishes. We have no *a priori* expectations of salinity effects on associated invertebrate assemblages; it is possible that the community in native beds (if native) is co-adapted to a similar range of salinities as its host plants, while those species found on the invasive *Egeria* are not. A recent study identifying *Egeria* associated invertebrates (Grimaldo et al. 2009), and our related project through the Delta Science Program to identify and enumerate invertebrates in *Stuckenia* beds, will guide the choice of species to use in salinity tolerance experiments.

3. <u>Approach and Scope of Work</u>

1) *Characterize the current range in salinity and other abiotic factors inside and outside* Stuckenia *and* Egeria *beds* (Year 1)

To consider how future salinity increases will influence the growth characteristics and distribution of native SAV beds, we first need to understand the current conditions these plants experience. While salinity data is available from a few locations (see Enright and Culberson 2009), we need greater detail to ascertain the range of conditions present in the locations where *Stuckenia* occurs. Thus in four *Stuckenia* beds in Suisun Bay and the west Delta, we will measure salinity continuously for one year using Hobo Conductivity Data Loggers. We will install an additional set of these salinity sensors in four *Egeria* beds in the central Delta region. For both *Stuckenia* and *Egeria* beds, we will place one sensor inside and one outside each bed, as the plants themselves may influence water movement and thus salinity regimes and other abiotic variables (see Gruber and Kemp 2010 for effects of *S. pectinata* canopies in Chesapeake Bay, and Sereno and Stacey 2002 for *E. densa* in the Delta). We have selected *Stuckenia* beds across the range of potential conditions along the east-west axis of the area (based on our preliminary visits in summer 2010) (Fig. 5). We will wait to select the *Egeria* beds until the project begins, as control efforts and management around the Delta may influence the presence and management status of beds from which we can choose. The detailed salinity measurements we collect will inform the salinity range we utilize in our experiments in years 2 and 3 of the project.

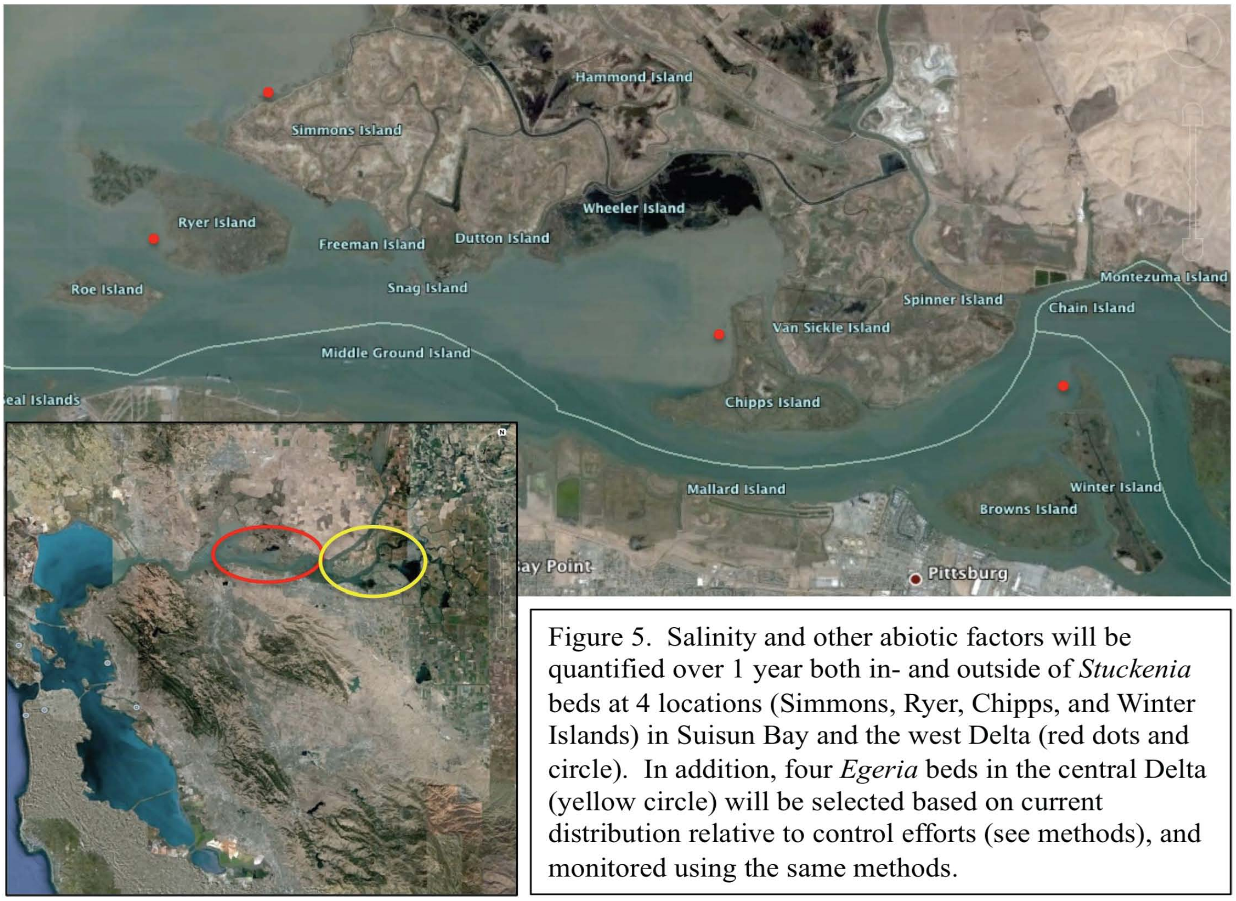

Figure 5. Salinity and other abiotic factors will be quantified over 1 year both in- and outside of *Stuckenia* beds at 4 locations (Simmons, Ryer, Chipps, and Winter Islands) in Suisun Bay and the west Delta (red dots and circle). In addition, four *Egeria* beds in the central Delta (yellow circle) will be selected based on current distribution relative to control efforts (see methods), and monitored using the same methods.

In addition to salinity, we will measure other abiotic conditions inside and outside of beds during year 1 to increase our understanding of these environments as well as to set realistic experimental conditions in our experiments in years 2 and 3. Temperature will be quantified continuously using the conductivity loggers described above (which also measure temperature). In addition, we will conduct quarterly measurements of several other parameters. At all eight beds (inside and out of beds due to potential effects of the plants on abiotic characteristics; Sereno and Stacey 2002, Gruber and Kemp 2010), we will quantify light levels with a LI-COR spherical PAR sensor, and collect samples for nutrient analyses (NO_3, NH_4, PO_4). We will install a CTD at one *Stuckenia* bed and one *Egeria* bed to continuously measure for two weeks during each quarter: conductivity, temperature, PAR (dual sensors at top and bottom to permit calculation of light attenuation), dissolved oxygen, and pH. Where both nearshore and offshore beds are present at each location, we will take additional quarterly environmental measurements in both locations (Fig. 2, 6). In addition, we will collect tissue samples for analysis of C and N and their ratio quarterly to determine the range found along the field salinity gradient, and the potential nutritional value to consumers.

2) Use mesocosm experiments to evaluate the effects of increased salinity on *Stuckenia* and *Egeria* growth characteristics (Year 2)

We will examine the responses of both plants to a range of salinities realistic to both current and future conditions in Suisun Bay and the west and central Delta. We will determine the exact salinities to assess based on our field measurements over one year at the four *Stuckenia* and four *Egeria* beds in the study.

Figure 6. Photos of offshore (near Winter Island) and nearshore (near Simmons Island) *Stuckenia* beds.

We will examine responses of *E. densa* fragments and rooted plants to three static salinity levels, 0, 5, and 10 ppt (or adjusted slightly upward based on field measurements). This range is expected to reflect optimal salinity conditions and up to levels that will greatly reduce biomass, if results from the Chilean study described above apply locally (Hauenstein and Ramirez 1986). Fragments are relevant experimental subjects since *Egeria* spreads through transport of fragments. As fragments require little space, we will conduct this experiment in a controlled temperature room where we will repeat the experiment at temperatures typical of the Delta (~20, 23, and 26°C; perhaps adjusted based on field measurements in year 1). In each experiment, three *E. densa* fragments will be placed in 20 L aquaria, with five replicates of each salinity. Each experiment will run for 6 weeks (adjusted according to speed of responses), after which we will measure biomass of the plants and conduct 1-way ANOVA to evaluate the effects of salinity at each temperature.

We will also conduct an experiment on *Egeria* consisting of several connected shoots, rooted in sediments collected from the Delta. *Egeria* and other clonal plants with rhizomatous connections between adjacent ramets can buffer impacts making them more resilient to stress (Amsberry et al. 2000). Furthermore, rooted *E. densa* may respond differently than fragments to abiotic changes such as increased salinity, because roots confer stability and provide access to resources such as nutrients in the sediment (as well as stressors such as low redox). Since the size of plants used in this experiment will be variable, we will record initial shoot lengths and fresh biomass as covariates to improve detection of responses. This experiment will be conducted in a greenhouse using clear plastic mesocosms (75 L) set into a water table to help maintain constant water temperature. Salinities and replication will be as in the study of fragments, and duration will be ~4 months, adjusted depending on speed of responses. In addition, will repeat the *Egeria* fragment experiment from the controlled temperature room in the greenhouse in the 20 L aquaria to permit comparison of responses with the greenhouse mesocosm experiment on whole plants.

For *Stuckenia*, we will conduct a similar, concurrent mesocosm experiment using rooted plants and sediments collected from the field. In this case, we will also test the effects of three salinity levels, but these will be adjusted upward to reflect the higher current salinity levels expected in *Stuckenia* beds. For example 5, 10, and 15 ppt would represent an average low, average high and ~5 ppt above the average high reported in Enright and Culberson (2009); however, field measurements in the first year of the project will be used to inform the range used in the experiments. Experimental mesocosms will be the same as for *Egeria* (75 L plastic tanks), and replication and duration will be the same.

In the greenhouse mesocosm experiments on whole plants for both species, shoot length will be measured weekly, and biomass of live and dead shoot tissue and roots and rhizomes will be determined at the end of each experiment. Plants negatively affected by increased salinity are expected to have higher dead:total tissue ratios and higher root:shoot ratios (Hester et al. 2001). We will also measure carbon (C) and nitrogen (N) in tissues: many estuarine plants counter osmotic stress by sequestering N in osmotica such as proline (Briens and Larher 1982), and changes in C:N ratios can have trophic implications through alteration of palatability to herbivores (e.g., Boyer et al. 2004). We will measure nutrients in the water as well to evaluate the effects of the plants on water column nutrient conditions (NH_4, NO_3, and PO_4) under different salinity scenarios. In addition, we will measure sodium: potassium ratios in leaf tissues as an indicator of salinity stress. Finally, we will measure net photosynthesis in the mesocosms using a Foxy fiber optic oxygen sensor (Ocean Optics; see attached quote with budget). We will use MANOVA to assess overall plant response relative to salinity treatments, and *post hoc* 1-factor ANOVAs on individual response variables, with experiment-wise error rate limited to ∂ = 0.05 (Bonferroni correction for the number of comparisons).

3) Use mesocosm experiments to assess the effects of salinity on common epifaunal invertebrate species on *Stuckenia* and *Egeria* (Year 3)

These final experiments are intended to highlight the community level effects of salinity intrusion into Suisun Bay and the Delta. The same larger mesocosms (75 L) will be used in the greenhouse water tables with rooted plants as above (either *Stuckenia* or *Egeria*), and the same salinity treatments applied with 5-fold replication. Many of the same parameters will be measured as in Phase 1 on the plants (biomass, photosynthesis, C:N, etc.). However, the primary objective of this experiment will be to test the effects of increased salinity on the common invertebrates found in each habitat. Two of the most common epifaunal invertebrate species found in our related work for the Delta Science Program (see above) and informed by Grimaldo et al. (2009) for *Egeria*, will be added to tanks at densities and size distributions reflective of field measurements.

After ~ 4 months, we will assess plant measures as in the Year 2 mesocosm experiments, and will determine abundance and biomass of invertebrates, as well as their size distribution, which could change relative to initial measures if there is reproduction or mortality. In addition, we will measure water nutrients as above as well as tissue nutrients (C, N) of both plants and animals. Our preliminary observations on *Stuckenia* and results of Grimaldo et al. (2009) suggest that common epifauna are likely to consume epiphytic algae or SAV tissue, thus stoichiometry of the animals would be expected to reflect that of plants, which, as described earlier, may change in response to salinity conditions. We will use MANOVA and *post hoc* ANOVAs as in the year 2 mesocosm experiments to assess salinity effects on plant and animal responses.

4. **Deliverables**

We will present the results of our field survey of abiotic conditions and our mesocosm experiments testing salinity effects on native and invasive SAV and associated epifaunal invertebrate assemblages at the biennial Delta Science Conference, other local meetings (e.g., State of the Estuary), and the biennial Coastal and Estuarine Research Federation meeting. We will submit a final report summarizing our findings, which will result in at least two peer-reviewed journal articles. We will develop predictions of the potential for persistence and up-estuary spread (or restoration) of *Stuckenia* with increasing salinity as well as the potential for decline of *Egeria*. Further, we will develop predictions for improved or reduced favorability for common invertebrate species under increased salinity conditions in both SAV habitats. We will compile GPS locations of field sampling locations and develop GIS maps to provide visual results of abiotic measures taken across *Stuckenia* and *Egeria* beds.

5. **Feasibility**

We will work in a step-wise fashion to insure that all project elements can be completed in 3 years, using results from previous years to inform next steps. While work in the subtidal zone is logistically difficult, all the components of this project are within reach of our research team. Much of this project will be conducted in the field utilizing the Romberg Tiburon Center's fleet of small boats, including a 21' C-Dory (Fig. 7), a 21' Twin-Vee Powercat and a 19' Boston Whaler. Our experienced team has the tools needed to conduct the proposed field work while wading, snorkeling or SCUBA diving; we all have advanced scientific diving certifications that can be utilized as needed. Field equipment that will be used in this project includes a LI-COR spherical PAR sensor, and we will purchase and install sensors to continuously log temperature and conductivity (Hobo Conductivity Data Loggers). Carbon and nitrogen analyses will be performed at the UC Davis Agriculture and Natural Resources Analytical Lab, which provides a reasonable turn-around time.

We do not expect any delays to the project resulting from permitting requirements. We will request a waiver of lease to the State Lands Commission to conduct this low-impact study. Our current scientific collecting permit from the CA Department of Fish and Game can be amended to include our proposed sampling. This project is not dependent on other projects for successful completion but will benefit from recent awards from both the Delta Science Program and NOAA Fisheries for related projects in these habitats. No other projects are being proposed by members of this research team in response to this current Proposal Solicitation Package. No special project management coordination is necessary for our small project team.

6. Relevance to the CALFED ERP

This proposal addresses key elements of the priority topics identified in the Proposal Solicitation Package. Primarily it addresses Priority 2, "research that tests hypotheses identified in the Delta Regional Ecosystem Implementation Plan evaluation of the BDCP conservation measures and the Operations Criteria and Plan Biological Opinion review and addresses uncertainties". In concert with this Priority, we are determining ecological characteristics of shallow water habitat likely to support native species, and testing the hypothesis that manipulating salinity can help to control invasive species. Specifically we address the uncertainty of the effects of increased salinity in Suisun Bay and the Delta, possible through multiple mechanisms, on conservation and restoration of native SAV and associated animal assemblages. Several special status fish species identified in the Multi-Species Conservation Strategy, including Delta smelt and Chinook salmon, may benefit from the relatively open canopies and food resources of native *Stuckenia* beds, without being subject to predation in the dark recesses of *Egeria* beds. This research will permit prediction of future distribution of these native *Stuckenia* beds under increased salinity scenarios, and thus the habitat it provides to native fishes. The ERP Strategic Plan presents the goal statement of "rehabilitation of natural processes in the estuary to fully support natural aquatic habitats, in ways that favor native members of those communities" (paraphrased); the results of this project can be used to inform management decisions that will influence salinity regimes and the resultant natural aquatic habitats and associated native species. In addition, this project will address the goal statement of reducing habitat for non-native species and their negative ecological effects, by assessing salinity conditions that in the future Delta are likely support native SAV instead of invasive *Egeria* and its promotion of predation on native special status fish species.

In addition to these identified focal areas for research, it is important to note how the proposed project sits geographically within an iconic region of the estuary, the low salinity zone, yet these native *Stuckenia* beds and their potential support of food webs that include native fishes have received almost no attention. The recently completed San Francisco Bay Subtidal Goals Project set a science goal to determine the distribution of these beds and a management goal to protect them due to their expected role as Essential Fish Habitat. Through an informal collaboration, we are beginning preliminary assessment of native fish use of these native SAV beds with Peter Moyle at UC Davis. Further, this project will integrate well with studies by the PI and collaborators in the lower estuary evaluating invertebrate community patterns (Carr et al. 2011) and fish use of eelgrass beds (unpublished data). As the up-estuary distribution of eelgrass ends in Carquinez Strait, native fishes migrating through the Estuary may switch from one native SAV species to another (eelgrass to pondweed and vice versa) for cover or food resources after the short break in this type of habitat feature. As sea level rise or other factors lead to greater salinities at mid-estuary, the physical location of this transition among native SAV species may be important in determining the degree to which submerged vegetation can offer cover and food web support for native fishes along their migratory routes.

7. **Expected quantitative results (project summary)**:

Activities under Quantitative Measures (Appendix E) address protection of native SAV beds as original habitat and restoration/conversion of invasive SAV beds to native SAV beds through various mechanisms (intentional or unintentional) that will increase salinity in the Delta region. As we will be evaluating the potential results of future salinity scenarios as opposed to actively engaging in restoration for this project, other quantitative measures do not apply.

Figure 7. The research team at the Romberg Tiburon Center has access to boats and equipment suitable for the proposed study (21' C-Dory shown here at Simmons Island), and extensive experience with the logistics of working in the subtidal zone (Research Technician Stephanie Kiriakopolos takes notes at Ryer Island preliminary visit).

8. **Other products and results**: Not applicable

9. **Qualifications**

Project leader Katharyn Boyer has worked extensively in estuarine habitats on the ecology of emergent and submerged communities for the past 18 years. She is considered an expert on SAV beds of San Francisco Bay (eelgrass) as a result of her work on many aspects of the ecology and restoration of these habitats, and recently completed as lead author a comprehensive document to guide conservation and restoration actions for eelgrass habitats for the San Francisco Bay Subtidal Habitat Goals Project (Boyer and Wyllie-Echeverria 2010, Appendix 8-1 at http://www.sfbaysubtidal.org/report.html). Many of the skills and methodologies she utilizes in eelgrass habitats are directly translatable to studies of SAV in the northern estuary and Delta. Dr. Boyer has mentored a series of highly motivated and skilled graduate students on this work. She and her students publish widely in ecology and management journals. Further, Dr. Boyer translates learning from these studies into hands-on experiences for undergraduate and graduate students in her Restoration Ecology and Wetlands Ecology courses.

In terms of organizational structure of the project, Dr. Boyer will be responsible for project management and overseeing all aspects of the project. Several research technicians (primarily Stephanie Kiriakopolos, and also Lara Martin or Chris Raleigh) will manage day-to-day activities and will report directly to Dr. Boyer. Graduate student Evyan Borgnis will assist with all aspects of the study and will focus especially on the salinity experiments for her thesis. Undergraduate student assistants, to be determined, will work with Dr. Boyer, the research technicians, and Ms. Borgnin on day-to-day tasks in the field and lab.

Research Technician Stephanie Kiriakopolos completed her master's thesis on abiotic and biotic constraints to eelgrass with Dr. Boyer in 2010 and now works as a Research Technician for Dr. Boyer at the Romberg Tiburon Center. Ms. Kirikopolos is highly accomplished at conducting ecological studies in difficult field conditions including on boats in rough conditions and on SCUBA (Fig. 7). She has become a scientific leader in her own right, as recognized by several organizations seeking her expertise in planning for conservation and restoration of subtidal habitats.

Either Lara Martin or Chris Raleigh will assist with instrumentation (conductivity/temperature loggers and CTDs). Both are research technicians at the Romberg Tiburon Center, and both have extensive experience working with water quality instruments in San Francisco Estuary.

Graduate student Evyan Borgnis has been a research technician in wetlands ecology and biogeochemistry labs at the University of San Francisco and San Francisco State University for several years. She joins the Boyer lab in the summer of 2011 with plans to put her considerable experience in field ecology toward this proposed project.

In addition, we are beginning an informal collaboration with Peter Moyle and his laboratory to assess fish utilization of *Stuckenia* beds, and hope to gather preliminary data through these initial studies to permit a more formalized and detailed collaboration to understand the food web and native fish habitat support afforded by these native SAV beds.

Our research team has the mixture of capabilities to maximize the likelihood of an outcome that will be useful in both the short term for understanding the system, and in the long term, for predicting changes in SAV beds under conditions of a saltier Delta.

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Section 7: Project Budget

1. **Detailed Project Budget**
2. **Budget Justification**
3. **Administrative Overhead**

These items are included in order on the following pages. Please see Budget Justification for notes on Administrative Overhead, and see the attached federally negotiated Indirect Cost Agreement for justification of overhead greater than 10%.

INSTITUTION:	San Francisco State University					
PROJECT DIRECTOR:	Katharyn Boyer					
TITLE:	Salinity effects on native and introduced SAV of Suisun Bay and the Delta					
SPONSOR:	CALFED Ecosystem Restoration Program					
DURATION:	3 yrs (10/1/11-9/30/14)					
			Total Requested Y1	Total Requested Y2	Total Requested Y3	Total Requested Total
PERSONNEL SERVICES						
Prinicipal Investigator, Katharyn Boyer						
$80,340	Academic Year Salary					
$6,695	Per Month					
$8,927	Summer Salary Per Month					
$412	Summer Salary Daily					
$51.50	Hrly Rate					
40	Summer Days (340 Hours)		16,480	16,974	17,483	50,937
9.5%	Faculty Benefits		1,566	1,613	1,661	4,840
Research Technician, Stephanie Kiriakopolos						
$36,828	Calendar Year Salary					
$3,069	Per Month					
$17.71	Hrly Rate					
6	Months (~1040 Hours)		18,414	18,966	19,535	56,915
56%	Staff Benefits		10,312	10,621	10,940	31,873
Research Technician, Lara Martin or Chris Raleigh						
$27,588	Calendar Year Salary					
$2,299	Per Month					
$13.26						
4	Months YR 1 only (~693 Hours)		9,196			9,196
80%	Staff Benefits		7,357			7,357
Stipends						
Graduate Student Assistant, Evyan Borgnin						
$16	Hrly					
1,200	Hrs		19,200	19,200	19,200	57,600
Undergraduate Student Assistant (2)						
$14	Hrly					
800	Hrs		11,200	11,200	11,200	33,600
Total Salaries			**74,490**	**66,340**	**67,418**	**208,248**
Total Faculty/ Staff Benefits	~34 - 44% of Salary (not including stipends)		**19,235**	**12,234**	**12,601**	**44,070**
TOTAL PERSONNEL SERVICES			**93,725**	**78,574**	**80,019**	**252,318**
OPERATING COSTS						
TRAVEL						
Domestic						
Trailering boat, 66 mi roundtrip @$.51/mi *20 trips YR1, 3trips YRS 2&3			673	101	101	875
Tolls, $5/trip			100	15	15	130
Travel to meetings, sites, etc			500	1,000	2,000	3,500
Travel Expense Subtotal			**1,273**	**1,116**	**2,116**	**4,505**
SUPPLY/ Services						
Refractometers	2@ $220		440	0	0	440
Temperature/salinity data loggers	16 @ $830		13,280	0	0	13,280
Supplies and maintenance for CTDs			1,200	0	0	1,200
Tank plumbing and maintenance supplies			0	800	300	1,100
Oxygen sensor for photosynthesis measures in mesocoms (see attached quote)			0	3,920	0	3,920
Bags, sample bottles, clipboards, U/W Paper, Snorkeling Supplies, handheld GPS, software for logger download, permit amendment, grow lights for CT room			2,500	1,000	450	3,950
Tissue analyses (C:N), field	8 locations *3reps*4time periods*$6*2 analytes		1,152	0	0	1,152
Water nutrients (NH4, NO3, PO4), field	16 locations *3reps*3analytes*4time periods*$12		6,912	0	0	6,912
Tissue analyses (C:N), mesocosms YR2	3 expts* 15 tanks*$6*2 analytes		0	540	0	540
Water nutrients (NH4, NO3, PO4), mesocosms YR2	3 expts* 15 tanks*$12*3 analytes		0	1,620	0	1,620
Tissue analyses (C:N), mesocosms YR3, plants	2 expts* 30 tanks*$6*2 analytes		0	0	720	720
Tissue analyses (C:N), mesocosms YR3, animals	2 expts* 30 tanks*$6*2 animal species*2 analytes		0	0	1,440	1,440
Water nutrients (NH4, NO3, PO4), mesocosms YR3	2 expts* 30 tanks*$12*3 analytes		0	0	2,160	2,160
Boat Use Fee (@ $200/day) 20 days YR 1, 3 days each YR 2&3			4,000	600	600	5,200
Supplies Expense Subtotal			**29,484**	**8,480**	**5,670**	**43,634**
TOTAL OPERATING COSTS			**30,757**	**9,596**	**7,786**	48,139
TOTAL DIRECT COSTS			124,482	88,170	87,805	300,457
OVERHEAD COSTS		53.5%	50,334	30,907	30,712	111,952
TOTAL COSTS			174,816	119,077	118,517	412,409
	Modified Total Direct Costs		94,082	57,770	57,405	209,257
Notes:						
Overhead not applied to stipends		Actual overhead request as percentage of direct costs:				37.3%
		(because overhead does not apply to stipends)				

Katharyn Boyer, CALFED Ecosystem Restoration Program PSP
Budget Narrative

Personnel Requested: $252,318
40 days of summer and intersession salary per year for three years (total salary $50,937) for Project Director Katharyn Boyer at a daily rate of $412. Dr. Boyer will lead and participate in all aspects of the project, help to train technicians and students, analyze data, and interpret results.

Six months per year of salary for Research Technician Stephanie Kiriakopolos at $3069 per month (total salary for 3-yr project = $56,915) to coordinate daily activities, train and work with graduate students on fieldwork, mesocosm experiments, sample processing, data analysis and interpretation of the project results.

Four months of salary in the first year for Research Technician Lara Martin or Chris Raleigh at $2299 per month (total salary = $9,196) to assist with salinity data loggers, CTD deployment and maintenance, and boat operation.

Stipend for graduate student Evyan Borgnin to assist with fieldwork and conduct mesocosm experiments, data entry, and analysis, at $16/hr for 1200 hours per year (total salary for 3-yr project = $57,600).

Stipend for two undergraduate students to assist with all of the above, $14/hr for 800 hours per year (total salary for 3-yr project = $33,600).

Fringe Benefits Requested: $44,070
Fringe benefit rates and totals for the 3-yr project (in parentheses) are as follows:
Boyer: 9.5% on summer and intersession salary ($4,840)
Kiriakopolos: 56% ($31,873)
Martin or Raleigh: 80% ($7,357)

Operating Expenses Requested: $43,634
Hobo Conductivity Data Loggers will cost $830 each, and a total of 16 are needed (1 inside and one outside of each of 8 SAV beds), for a total of $13,280. In addition, we will purchase two refractometers ($220 each, total $440) for use in salinity measurements in the mesocosm experiments. An Ocean Optics NEOFOX oxygen system for the mesocosm experiments will cost $3920 (see attached quote). Miscellaneous supplies, including bags, water sampling bottles, waterproof paper, snorkeling supplies, hand-held GPS, grow lights for the controlled temperature room and computer software to use with the conductivitey data loggers will cost $2500, $1000, and $400 per year, for the three years, respectively. Calibration chemicals and maintenance of the CTDs in year 1 will cost $1200. Tank plumbing and maintenance supplies will cost $800 in year 2 and $300 in year 3. Boat use fees for in-house users at RTC are $200 per day, thus 26 trips (20 in year 1 and 3 each in years 2 and 3) will total $5200 for the project. Analysis of water nutrients (NO_3, NH_4, and PO_4) will cost $12 per analyte for analysis at the Romberg Tiburon Center; costs for the year 1 field surveys will total $6912 (in and out of 8 beds, 3 reps, 3 analytes, 4 time periods), for the year 2 mesocosm experiments will be $1620 (3 experiments, 15 tanks each, 3 analytes), and for the year 3 mesocosms will be $2160 (2 expts, 30 tanks each, 3

analytes). Analysis of tissue carbon and nitrogen at UC Davis will cost $6 per analyte; costs for field survey tissues in year 1 will be $1152 (8 locations, 3 reps, 4 time periods), for the plant tissues in the year 2 mesocosm experiments will be $540 (3 experiments, 15 tanks each), for the plant tissues in the year 3 mesocosm experiments will be $720 (2 experiments, 30 tanks each) and for animal tissues in year 3 mesocosm experiments will be $1440 (2 experiments, 30 tanks each, 2 species of invertebrate each).

Travel Requested: $4,505
In addition, boat trailering for 20 trips in year 1 and 3 trips in years 2 and 3 will cost $673, $101, and $101, respectively (66 mi. RT @ $.5/mi) and bridge tolls @$5 per toll for the 26 trips will cost $130 for the project. $500, $1000, and $2000 per year for the 3 years, respectively, are requested for Dr. Boyer, techs, and students to travel to local, regional, and national meetings to present the results and outcomes of this project.

Indirect Costs Requested: $111,952
As no IDC rate cap was specified in the PSP, SF State's federally negotiated IDC rate of 53.5% necessarily applies to all direct costs except for the graduate and undergraduate stipends ($91,200). Because IDC does not apply to the student stipends, the actual request for indirect costs comes out to 37% of the direct costs. Documentation of SF State's federally negotiated IDC rate is provided as an attachment to this proposal. Please also note that all salary rates are actual, not "fully burdened", meaning there is no overhead hidden in these salary rates.

Matching Funds: In a related project recently awarded by the Delta Science Program, K. Boyer will receive $160,000 (pending public comment and final award) to characterize *Stuckenia pectinata* habitat structure and associated invertebrate assemblages. In addition, Dr. Boyer will be conducting a $10K survey of low salinity SAV throughout the San Francisco Estuary in summer 2011, funded by NOAA Fisheries. While university rules prevent counting these awards as match formally, they are very complementary studies that will leverage the requested funds for this proposal considerably.

Total Direct Costs Requested:	**$300,457**
Total Indirect Costs Requested:	**$111,953**
Total Budget Requested:	**$414,410**

Ocean Optics, Inc.
830 Douglas Avenue
Dunedin, FL 34698
Phone: (727) 733-2447
Fax: (727) 733-3962
E-Mail: Orders@Oceanoptics.com
www.OceanOptics.com

A HALMA COMPANY

Quotation 84062-1

Quote Expires: 23-MAR-2011

Bill To	Ship To
San Francisco State University **Department of Chemistry 1600 Holloway Ave** **San Francisco CA 94132**	**San Francisco State University** **Department of Chemistry 1600 Holloway Ave** **San Francisco CA 94132**

Bill To Contact	Phone	Ship To Contact	Phone
e-mail	Fax	e-mail	Fax
Customer Number 1232	Customer TAX/VAT IdNr	Supplier Number at Customer	Currency USD / Incoterms
Sales Rep Qhobosheane, Monde		e-mail monde.qhobosheane@oceanoptics.com	
Customer P.O. Number		Carrier	
Date 21-FEB-2011	Freight Terms	Payment Terms	

Line	Description of Item	UOM	QTY	Price	Total
1.0	**NEOFOX** NeoFox Phase Measurement System, Benchtop 0	ea	1	2499.00	2499.00
2.0	**NEOFOX-TP** NeoFox Temperature Probe 0	ea	1	130.00	130.00
3.0	**21-02** PN 905-120-5003 In-line splice bushing connects SMA 905-terminated items (KB 0	ea	1	14.00	14.00
4.0	**FOXY-R** Oxygen Sensor, 1000-micron fiber in 1/16" OD SS ferrule 0	ea	1	577.00	577.00
5.0	**FOXY-CAL** In-house calibration for FOXY Systems; 15-35 DEG C, 4-12PPM 0	ea	1	230.00	230.00
6.0	**BIFBORO-1000-2** 1000um spot size Bifurcated borosilicate fiber assembly, black PVC monocoil, 2m 0	ea	1	469.00	469.00

Net Price	**3919.00**
Taxes	**0.00**
Quote Total	**3919.00**

Thank you very much for your business.
Country of origin: USA
Payment terms: Net 30
Shipping terms: Ex works - Dunedin, FL
Please check your spectrometer order for accuracy.
Changes after 72 hours may incur build change fees.
Custom fibers are subject to a 50% cancellation fee.

DEPARTMENT OF HEALTH & HUMAN SERVICES

Program Support Center
Financial Management Service
Division of Cost Allocation

DCA Western Field Office
50 United Nations Plaza, Room 347
San Francisco, CA 94102

SEP 21 2005

Larry J. Ware
Assoc VP-Fiscal Affairs & Controller
San Francisco State University
and The Foundation, Inc.
1600 Holloway Avenue
Admin. Building, Rm. 350
San Francisco, CA 94132

Dear Mr. Ware:

A copy of an indirect cost Negotiation Agreement is attached. This Agreement reflects an understanding reached between your organization and a member of my staff concerning the rate(s) that may be used to support your claim for indirect costs on grants and contracts with the Federal Government. Please have the Agreement signed by a duly authorized representative of your organization and return it to me BY FAX, retaining the copy for your files. We will reproduce and distribute the Agreement to the appropriate awarding organizations of the Federal Government for their use.

An indirect cost proposal together with supporting information are required to substantiate your claim for indirect costs under grants and contracts awarded by the Federal Government. Thus, your next proposal based on your fiscal year ending 06/30/09, is due in our office by 12/31/09.

Sincerely,

David S. Low
Director

Attachment

PLEASE SIGN AND RETURN THE NEGOTIATION AGREEMENT BY FAX

Phone: (415) 437-7820 - Fax: (415) 437-7823 - E-mail: dcasf@psc.gov

COLLEGES AND UNIVERSITIES RATE AGREEMENT

DATE: September 19, 2005

INSTITUTION:
San Francisco State University
and The Foundation, Inc.
1600 Holloway Avenue
Admin. Building, Rm. 350
San Francisco CA 94132

FILING REF.: The preceding Agreement was dated March 23, 2004

The rates approved in this agreement are for use on grants, contracts and other agreements with the Federal Government, subject to the conditions in Section III.

SECTION I: FACILITIES AND ADMINISTRATIVE COST RATES*

RATE TYPES: FIXED FINAL PROV.(PROVISIONAL) PRED.(PREDETERMINED)

TYPE	EFFECTIVE PERIOD FROM	TO	RATE(%)	LOCATIONS	APPLICABLE TO
PRED.	07/01/05	06/30/06	50.0	On-Campus	Organized Research
PRED.	07/01/05	06/30/06	26.0	Off-Campus	Organized Research
PRED.	07/01/05	06/30/06	43.0	On-Campus	Instruction
PRED.	07/01/05	06/30/06	26.0	Off-Campus	Instruction
PRED.	07/01/05	06/30/06	28.0	On-Campus	Other Spons. Act.
PRED.	07/01/05	06/30/06	26.0	Off-Campus	Other Spons. Act.
PRED.	07/01/06	06/30/09	53.0	On-Campus	Organized Research
PRED.	07/01/06	06/30/09	26.0	Off-Campus	Organized Research
PRED.	07/01/06	06/30/09	53.6	On-Campus	Instruction
PRED.	07/06/06	06/30/09	26.0	Off-Campus	Instruction
PRED.	07/06/06	06/30/09	28.6	On-Campus	Other Spons. Act.
PRED.	07/06/06	06/30/09	26.0	Off-Campus	Other Spons. Act.
PRED.	07/01/09	06/30/10	53.5	On-Campus	Organized Research
PRED.	07/01/09	06/30/10	26.0	Off-Campus	Organized Research
PRED.	07/01/09	06/30/10	53.6	On-Campus	Instruction
PRED.	07/01/09	06/30/10	26.0	Off-Campus	Instruction
PRED.	07/01/09	06/30/10	28.6	On-Campus	Other Spons. Act.
PRED.	07/01/09	06/30/10	26.0	Off-Campus	Other Spons. Act.
PROV.	07/01/10	UNTIL AMENDED	Use same rates and conditions as those cited for fiscal year ending June 30, 2010.		

*BASE:
Modified total direct costs, consisting of all salaries and wages, fringe benefits, materials, supplies, services, travel and subgrants and subcontracts up to the first $25,000 of each subgrant or subcontract (regardless of the period covered by the subgrant or subcontract). Modified total direct costs shall exclude equipment, capital expenditures, charges for patient care, tuition remission, rental costs of off-site facilities, scholarships, and fellowships as well as the portion of each subgrant and subcontract in excess of $25,000.

INSTITUTION:
San Francisco State University
and The Foundation, Inc.

AGREEMENT DATE: September 19, 2005

SECTION II: SPECIAL REMARKS

TREATMENT OF FRINGE BENEFITS:
This organization charges the actual cost of each fringe benefit direct to Federal projects. However, it uses a fringe benefit rate which is applied to salaries and wages in budgeting fringe benefit costs under project proposals. The fringe benefits listed below are treated as direct costs.

TREATMENT OF PAID ABSENCES:
Vacation, holiday, sick leave pay and other paid absences are included in salaries and wages and are claimed on grants, contracts and other agreements as part of the normal cost for salaries and wages. Separate claims for the costs of these paid absences are not made.

DEFINITION OF OFF-CAMPUS: A project is considered off-campus if the activity is conducted at locations other than in University or Foundation owned or operated facilities and indirect costs associated with physical plant and library are not considered applicable to the project.

DEFINITION OF EQUIPMENT
Equipment is defined as tangible nonexpendable personal property having a useful life of more than one year and an acquisition cost of $5,000 or more per unit.

The following fringe benefits are treated as direct costs:
FICA, WORKERS COMPENSATION, HEALTH/LIFE INSURANCE, STATE UNEMPLOYMENT INSURANCE, STATE DISABILITY INSURANCE, AND RETIREMENT.

INSTITUTION:
San Francisco State University
and The Foundation, Inc.

AGREEMENT DATE: September 19, 2005

SECTION III: GENERAL

A. LIMITATIONS:
The rates in this Agreement are subject to any statutory or administrative limitations and apply to a given grant, contract or other agreement only to the extent that funds are available. Acceptance of the rates is subject to the following conditions: (1) Only costs incurred by the organization were included in its facilities and administrative cost pools as finally accepted: such costs are legal obligations of the organization and are allowable under the governing cost principles; (2) The same costs that have been treated as facilities and administrative costs are not claimed as direct costs; (3) Similar types of costs have been accorded consistent accounting treatment; and (4) The information provided by the organization which was used to establish the rates is not later found to be materially incomplete or inaccurate by the Federal Government. In such situations the rate(s) would be subject to renegotiation at the discretion of the Federal Government.

B. ACCOUNTING CHANGES:
This Agreement is based on the accounting system purported by the organization to be in effect during the Agreement period. Changes to the method of accounting for costs which affect the amount of reimbursement resulting from the use of this Agreement require prior approval of the authorized representative of the cognizant agency. Such changes include, but are not limited to, changes in the charging of a particular type of cost from facilities and administrative to direct. Failure to obtain approval may result in cost disallowances.

C. FIXED RATES:
If a fixed rate is in this Agreement, it is based on an estimate of the costs for the period covered by the rate. When the actual costs for this period are determined, an adjustment will be made to a rate of a future year(s) to compensate for the difference between the costs used to establish the fixed rate and actual costs.

D. USE BY OTHER FEDERAL AGENCIES:
The rates in this Agreement were approved in accordance with the authority in Office of Management and Budget Circular A-21 Circular, and should be applied to grants, contracts and other agreements covered by this Circular, subject to any limitations in A above. The organization may provide copies of the Agreement to other Federal Agencies to give them early notification of the Agreement.

BY THE INSTITUTION:

San Francisco State University
and The Foundation, Inc.
(INSTITUTION)

[signature]
(SIGNATURE)

Larry J. Ware
(NAME)

A.V.P. for Fiscal Affairs
(TITLE)

Nov. 1, 2005
(DATE)

ON BEHALF OF THE FEDERAL GOVERNMENT:

DEPARTMENT OF HEALTH AND HUMAN SERVICES
(AGENCY)

[signature]
(SIGNATURE)

David S. Low
(NAME)

DIRECTOR, DIVISION OF COST ALLOCATION
(TITLE)

September 19, 2005
(DATE) 0178

HHS REPRESENTATIVE: Cora Coleman
Telephone: (415) 437-7820

SAN FRANCISCO STATE UNIVERSITY

FACILITIES AND ADMINISTRATIVE RATES FOR THE PERIOD JULY 1, 2009 THRU JUNE 30, 2010

	RESEARCH			INSTRUCTION			OTHER SPON ACT		
		ON-CAMPUS	OFF-CAMPUS		ON-CAMPUS	OFF-CAMPUS		ON-CAMPUS	OFF-CAMPUS
BUILDING		5.5			3.0			0.2	
EQUIPMENT		3.0			0.7			0.1	
OPERATION & MAINT.		17.5			11.6			1.9	
LIBRARY		1.5			12.3			0.4	
GEN. ADMIN.	7.1			7.7			11.0		
DEPT. ADMIN.	5.9			7.5			8.9		
SPON. PROJ. ADMIN	12.5			0.4			6.1		
STUDENT SVS.	0.5			10.4					
ADMIN COMPONENTS		26.0	26.0		26.0	26.0		26.0	26.0
TOTAL		53.5	26.0		53.6	26.0		28.6	26.0

CONCUR:

[signature]
SIGNAUTRE

A.V.P. for Fiscal Affairs
TITLE

Nov. 1, 2005
DATE

Administrative Components Limited to 26.0% in accordance with OMB A-21, Dated July 26, 1993.

KATHARYN E. BOYER
San Francisco State University
Department of Biology
Romberg Tiburon Center for Environmental Studies
3152 Paradise Drive
Tiburon, CA 94920
(415) 338-3751
katboyer@sfsu.edu

EDUCATION

University of California, Los Angeles, Department of Ecology and Evolutionary Biology
Ph.D. Biology (June 2002, advisor: P. Fong)
Dissertation: Linking community assemblages and ecosystem processes in temperate and tropical coastal habitats.

San Diego State University, Department of Biology
M.S. Biology (June 1994, advisor: J. Zedler)
Thesis: Scale insect damage in constructed salt marshes: nitrogen and other factors.

University of Maryland, College Park, Department of Zoology
B.S. Zoology (December 1988)

PROFESSIONAL EXPERIENCE

Associate Professor, San Francisco State University, San Francisco, CA (9/09 – present)
Assistant Professor, San Francisco State University, San Francisco, CA (1/04 – 8/09)
Postdoctoral Researcher, The University of North Carolina at Chapel Hill, NC (8/02 – 12/03)
Co-lecturer, Marine Ecology, Barrier Island Ecology, UNC Chapel Hill, NC (8/02 – 8/03)
Co-lecturer, Ecology, University of California, Los Angeles, CA (4/00 - 7/00)
Teaching Assistant, Ecology, Marine Biology Field Quarter, UCLA (9/99 - 7/00)
Graduate Research Assistant, Institute of the Environment, UCLA (8/97 - 9/98)
Coordinator & Lecturer, Wetland restoration course for US Fish & Wildlife Service, San Diego, CA (3/96)
Consulting Wetlands Ecologist, California Environmental Litigation Fund, Leucadia, CA (Fall 1994)
Research Associate, Pacific Estuarine Research Laboratory, San Diego State University (6/94 - 8/97)
Environmental Scientist, Bechtel Corporation, Gaithersburg, MD (8/89 - 7/92)
Outdoor Adventure Leader and Instructor, Inner Quest, McLean, VA (1/89 - 8/89)

HONORS AND AWARDS

SFSU Sabbatical Leave Award (2010-2011)
SFSU Presidential Leave Award (2007-2008)
SFSU Vice President's Assigned Time Award (spring 2007)
SFSU Vice President's Assigned Time Award (spring 2005)
Scherbaum Award for Excellence in Research, UCLA Dept. of Ecology & Evolutionary Biology (2002)
Thomas James Memorial Award, UCLA Dept. of Ecology & Evolutionary Biology (2002)
Special Faculty Award for Service, UCLA Dept. of Ecology & Evolutionary Biology (2000)
Amy Lutz Award, Association for Women in Science, Los Angeles, CA (1998)
International Scholar, Phi Beta Delta, San Diego, CA (1992)
Inductee, Who's Who Among Students in US Colleges and Universities, College Park, MD (1988)
Inductee, Omicron Delta Kappa National Leadership Honor Society, College Park, MD (1987)

TEACHING

New courses developed:
* denotes an existing course number for which I developed all materials
** denotes an entirely new course that I proposed, designed, and developed

Biology 395*	Wetlands Ecology and Management (3 unit lecture), first taught Spring 04
Biology 531**	Restoration Ecology (3 unit lecture), first taught Fall 04 (course # later changed to 532)
Biology 863**	Aquatic Communities (2 unit graduate seminar), first taught Fall 04
Biology 534**	Wetlands Ecology (4 unit lecture/lab/field course), first taught Spring 05
Biology 9395**	Wetlands Restoration Ecology (2-day short course through CEL), taught May 05
Biology 9007**	Ecology of Invasive Species (1-day short course co-taught through CEL), taught Apr 07

Advisor for 13 SFSU graduate students (date MS received): Johanna Kertesz (May 2006), Brittany Huntington (December 2006), Anya Perron-Burdick (May 2007), Lindsey Carr (August 2008), Amelia Ryan (August 2009), Stephanie Kiriakopolos, Gavin Archbald, Gwen Santos, Autumn Cleave, Jeff Lewis, Rosa Schneider, Whitney Thornton, Kevin Stockmann.

Committee member for 23 Biology graduate students (year MS received):
Richard Johnson (05), Meredith Elliott (05), Florian Koch (05), Diana Benner (05), Dana Rogoff (06), Jennifer Yorty (06), Javier Silva (07), Janell Hillman (07), Maureen Auro (07), Zooey Diggory (07), Jennifer Murphy (08), Amy Langston (08), Pedro Morgado (08), Esa Crumb (08), Valerie Greene (10), Debbie Marcal, Martin Olson, Laura Cochrane, John Wilkinson, April Robinson, Xuman Tang, Chelsea Chen, Stephanie Bishop.

Undergraduates mentored on independent projects or internships:
NSF Undergraduate Mentoring in Biology (UMEB): Courtney Cacace, Siobhan Poling
NSF Undergraduate Biology/Math Program (UBM): Gavin Archbald, Gwen Santos, Stephanie Kiriakopolos, Melanie Williams
Independent research (BIOL 699): Liz Mendel, Gwen Santos, Bianca Dailey, Nishad Patel, Jolan Chau, Veronica Trujillo, Diana Singh, Sahar Waziri, Chandan Kular, Melanie Williams, Adam Lau, Cory Robinson, Patti Patterson, Suji Grant, Bryan Hongo, Katie Eskra, Jean-Claude Breach, Diana Hull, Ruben Echeverria, Colin Nelson, Matthew Snyder, Doug Clark, Theresa Lagman, Nicole Clark, Ace Crow, Joseph Spaulding, Hilary Finck
Cooperative Internships (BIOL 694): Joanne Connery, Morrigan Shaw, Melanie Williams
Environmental Studies senior project committee or internship advisor: Anne Senter, Clemens Roessner, Grant Willason
Science Writing project for COSE InterSci Magazine: Shannon Seaberg

PUBLICATIONS — *peer-reviewed*
** my graduate student

25. Carr**, L. A. , K. E. Boyer, and A. Brooks. 2011. Spatial patterns in epifaunal community structure in San Francisco Bay eelgrass (*Zostera marina*) beds. *Marine Ecology* 32:88-103.
24. Boyer, K. E. and A. P. Burdick**. 2010. Control of *Lepidium latifolium* (perennial pepperweed) and recovery of native plants in tidal marshes of the San Francisco Estuary. *Wetlands Ecology and Management* 18:731-743.
23. Reynolds, L. K. and K. E. Boyer. 2010. Perennial pepperweed (*Lepidium latifolium*): properties of invaded tidal marshes. *Invasive Plant Science and Management* 3:130-138.
22. Boyer, K. E., J. S. Kertesz**, and J. F. Bruno. 2009. Biodiversity effects on productivity and stability of marine macroalgal communities: the role of environmental context. *Oikos* 118:1062-1072.
21. Bruno, J. F., K. E. Boyer, S. C. Lee, and J. E. Duffy. 2008. Relative and interactive effects of plant and grazer richness in a benthic marine community. *Ecology* 89:2518-2528.
20. Huntington**, B. E. and K. E. Boyer. 2008. Evaluating patterns of nitrogen supply using macroalgal tissue content and stable isotopic signatures in Tomales Bay, CA. *Environmental Bioindicators* 3:180-192.
19. Huntington**, B. E. and K. E. Boyer. 2008. Impacts of red macroalgal abundance (*Gracilariopsis* sp.) on eelgrass (*Zostera marina*) in Tomales Bay, California. *Marine Ecology Progress Series* 367:133-142.
18. Armitage, A. R., K. E. Boyer, R. R. Vance, and R. F. Ambrose. 2006. Restoring assemblages of salt marsh halophytes in the presence of a rapidly colonizing dominant species. *Wetlands* 26:667-676.

17. Boyer, K. E., and P. Fong. 2005. Co-occurrence of habitat-modifying invertebrates: effects on structural and functional properties of a created salt marsh. *Oecologia* 143:619-628.
16. Boyer, K. E., and P. Fong. 2005. Macroalgal-mediated transfers of water column nitrogen to intertidal sediments and salt marsh plants. *Journal of Experimental Marine Biology and Ecology* 321:59-69.
15. Bruno, J. F., K. E. Boyer, J. E. Duffy, S. C. Lee, and J. S. Kertesz**. 2005. Relative effects of species identity and richness on primary production in benthic marine communities. *Ecology Letters* 8:1165-1174.
14. Boyer, K. E., P. Fong, A. R. Armitage, and R. A. Cohen. 2004. Elevated nutrient content of macroalgae increases rates of herbivory in coral, seagrass, and mangrove habitats. *Coral Reefs* 23:530-538.
13. Fong, P., K. E. Boyer, K. Kamer, and K. A. Boyle. 2003. Influence of initial tissue nutrient status of tropical marine algae on response to nitrogen and phosphorus additions. *Marine Ecology Progress Series* 262:111-123.
12. Lindig-Cisneros, R., J. Desmond, K. E. Boyer, and J. B. Zedler. 2003. Wetland restoration thresholds: can a degradation transition be reversed with increased effort? *Ecological Applications* 13:193-205.
11. Boyer, K. E., P. Fong, R. R. Vance, and R. F. Ambrose. 2001. *Salicornia virginica* in a southern California saltmarsh: seasonal patterns and a nutrient enrichment experiment. *Wetlands* 21:315-326.
10. Fong, P., K. Kamer, K. E. Boyer, and K. A. Boyle. 2001. Nutrient content of macroalgae with differing morphologies may indicate sources of nutrients to tropical marine systems. *Marine Ecology Progress Series* 220:137-152.
9. Boyer, K. E., J. C. Callaway, and J. B. Zedler. 2000. Evaluating the progress of restored cordgrass (*Spartina foliosa*) marshes: belowground biomass and tissue N. *Estuaries* 23:711-721.
8. Boyer, K. E. and J. B. Zedler. 1999. Nitrogen addition could shift plant community composition in a restored California salt marsh. *Restoration Ecology* 7:74-85.
7. Boyer, K. E. and J. B. Zedler. 1998. Effects of nitrogen additions on the vertical structure of a constructed cordgrass marsh. *Ecological Applications* 8:692-705.
6. Fong, P., K. E. Boyer, and J. B. Zedler. 1998. Developing an indicator of nutrient enrichment in coastal estuaries and lagoons using tissue nitrogen content of the opportunistic alga, *Enteromorpha intestinalis* (Link). *Journal of Experimental Marine Biology and Ecology* 231:63-79.
5. Zedler, J. B., K. E. Boyer, G. D. Williams, and J. C. Callaway. 1998. Creating intertidal habitat for endangered species in southern California: achievements and challenges. In A. McComb and J. Davis, eds. Wetlands for the Future. Gleneagles Publishing, Adelaide, Australia.
4. Haltiner, J., J. B. Zedler, K. E. Boyer, G. D. Williams, and J. Callaway. 1997. Influence of physical processes on the design, functioning and evolution of restored tidal wetlands in California (USA). *Wetlands Ecology and Management* 4:73-91.
3. Zedler, J. B., J. Desmond, S. Phinn, B. Nyden, G. Sullivan, G. D. Williams, J. C. Callaway, K. E. Boyer, and A. Powell. 1997. New tools for assessing coastal habitats. Proceedings of the 1997 California and the World Oceans meeting, San Diego, California.
2. Boyer, K. E. and J. B. Zedler. 1996. Damage to cordgrass by scale insects in a constructed salt marsh: effects of nitrogen additions. *Estuaries* 19:1-12.
1. Fong, P., K. E. Boyer, J. S. Desmond, and J. B. Zedler. 1996. Salinity stress, nitrogen competition, and facilitation: what controls seasonal succession of two opportunistic green macroalgae? *Journal of Experimental Marine Biology and Ecology* 206:203-221.

PUBLICATIONS — *in revision, review, or preparation*
** my student

In review:
Boyer, K. E. and W. J. Thornton**. In review. Natural and restored tidal marsh communities. In A. Palaima, ed., Ecology, Conservation, and Restoration of Tidal Marshes: The San Francisco Estuary. University of California Press.
Ort, B. S., C. S. Cohen, K. E. Boyer, and S. Wyllie-Echeverria. In review. Genetic diversity within and among eelgrass (*Zostera marina*) beds in the San Francisco Bay.
Ryan**, A. B. and K. E. Boyer. In review. Nitrogen further promotes a dominant salt marsh plant in an increasingly saline environment.

In revision:
Carr**, L. A., K. E. Boyer, and A. Brooks. In revision. Variation at multiple trophic levels modulates effects of an invasive seagrass grazer.

In preparation:

Boyer, K. E., A. R. Armitage, and P. Fong. In preparation. Macroalgal blooms as a tool to enhance restoration of salt marsh plants.

Boyer, K. E., L. K. Reynolds, and S. Wyllie-Echeverria. In preparation. Establishing eelgrass (*Zostera marina*) in mesocosms using a seeding technique: lessons for restoration in San Francisco Bay.

Fong, P, K. E. Boyer, and A. R. Armitage. In preparation. Isotope and nutrient content of macroalgae identify the relative importance of upwelling vs. terrestrial supplies of nutrients to coastal estuaries.

Ort, B. S., C. S. Cohen, K. E. Boyer, and S. Wyllie-Echeverria. In preparation. Conservation of eelgrass (*Zostera marina*) genetic diversity in a mesocosm-based restoration experiment.

Reynolds, L. K., L. A. Carr**, and K. E. Boyer. In preparation. Invasive amphipod (*Ampithoe valida*) consumption of eelgrass inflorescences in San Francisco Bay.

PUBLICATIONS — *not peer-reviewed*

** my student

Boyer, K. E. and S. Wyllie-Echeverria. 2010. Eelgrass Conservation and Restoration in San Francisco Bay: Opportunities and Constraints. Report for the San Francisco Bay Subtidal Habitat Goals Project. Included as Appendix 8-1. http://www.sfbaysubtidal.org/report.html

Boyer, K. E., S. Wyllie-Echeverria, S. Cohen, and B. Ort. 2008. Evaluating buoy-deployed seeding for restoration of eelgrass in San Francisco Bay. Final report submitted to the NOAA/UNH Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET).

Boyer, K. E. 2008. Eelgrass test plot project. Final report to Save the Bay for NOAA Community Restoration Program.

Boyer, K. E., L. K. Reynolds, and S. Wyllie-Echeverria. 2007. Establishing eelgrass (*Zostera marina*) in mesocosms using a seeding technique: lessons for restoration in San Francisco Bay. Final Report to the California Coastal Conservancy/Ocean Protection Council, Grant Agreement 05-102.

Boyer, K. E., L. K. Reynolds, and S. Wyllie-Echeverria. 2007. Restoring the seagrass, *Zostera marina* L., in San Francisco Bay: experimental evaluation of a seeding technique. Final Report to the NOAA Restoration Center Research Program.

Bruno, J. F., S. Lee, J. Kertesz**, R. Carpenter, K. E. Boyer, and J. E. Duffy. 2004. Is algal species identity or diversity related to primary production in benthic marine communities? *Ecological Society of America Annual Meeting Abstract*s 89:70.

Boyer, K. E., J. F. Bruno, and J. E. Duffy. 2003. Biodiversity and ecosystem functioning in plant-grazer systems: Experimental tests in a marine benthic community. *Ecological Society of America Annual Meeting Abstracts* 88: 42-43.

Boyer, K. E and J. B. Zedler. 1997. Species composition shifts with nitrogen enrichment in a constructed salt marsh. *Bulletin of the Ecological Society of America* 78 (suppl): 225.

Desmond, J. S., K. E. Boyer, A. Abeyta, C. Garrison, G. B. Noe, and J. B. Zedler. 1997. The status of constructed wetlands at Sweetwater Marsh National Wildlife Refuge (San Diego, CA). Annual Report to the California Department of Transportation and the U. S. Fish and Wildlife Service.

Boyer, K. E., J. B. Zedler, S. Phinn, G. D. Williams, G. B. Noe, S. Trnka, and B. Fink. 1996. The status of constructed wetlands at Sweetwater Marsh National Wildlife Refuge (San Diego, CA). Annual Report to the California Department of Transportation and the U. S. Fish and Wildlife Service.

Boyer, K. E. and J. B. Zedler. 1996. Producing tall cordgrass vegetation with multiple additions of nitrogen, Impacts of nitrogen fertilization on insect pests, and Recommendations for improving restoration of cordgrass. In J. B. Zedler, principal author. Tidal wetland restoration: A scientific perspective and southern California focus. Published by the California Sea Grant College System, University of California, La Jolla, California. Report No. T-038.

Zedler, J. B., J. C. Callaway, and K. E. Boyer. 1995. The challenge of creating wetlands functionally equivalent to natural ecosystems. *Bulletin of the Ecological Society of America* 76(suppl):293.

PRESENTATIONS since 2009

** my student

Boyer, K. E. Invasive species and the restoration of key habitats in San Francisco Bay. **Invited.** Sonoma Sate University Department of Biology Colloquium Series, November 2010.

Boyer, K. E. Restoration and conservation of eelgrass in San Francisco Bay. **Invited**. San Francisco Bay Conservation and Development Commission, November 2010.

Lewis**, J. T. and K. E. Boyer. Effects of epifaunal invertebrates on eelgrass (*Zostera marina*) in San Francisco Bay. Western Society of Naturalists meeting, San Diego, CA, November 2010.

Archbald**, G. and K. E. Boyer. Evaluating the potential for spread of an invasive forb, *Limonium ramosissimum*, in San Francisco Bay salt marshes. 6th Biennial Bay-Delta Science Conference, Sacramento, CA, September 2010.

Cleave**, A. and K. E. Boyer. Effects of invasive *Limonium ramosissimum* on native salt marsh communities in a changing environment. 6th Biennial Bay-Delta Science Conference, Sacramento, CA, September 2010.

Lewis**, J. T. and K. E. Boyer. Effects of heat waves on the macroinvertebrate community of San Francisco Bay eelgrass (*Zostera marina*) beds. 6th Biennial Bay-Delta Science Conference, Sacramento, CA, September 2010.

Kiriakopolos**, S. and K. E. Boyer. The role of herbivory by *Branta canadensis* (Canada geese) in the annual life cycle of a San Francisco Bay *Zostera marina* (eelgrass) population. Western Society of Naturalists Meeting, Monterey, CA, November 2009.

Archbald**, G. and K. E. Boyer. The role of an invasive forb, *Limonium ramosissimum*, in San Francisco Bay salt marshes. Biennial meeting of the Coastal and Estuarine Research Federation, Portland, OR, November 2009.

Boyer, K. E., S. Wyllie-Echeverria, L. Reynolds, L. Carr**, B. Ort, and S. Cohen. Field experiments to evaluate eelgrass (*Zostera marina*) restoration techniques, donor selection, and maintenance of genetic diversity. Biennial meeting of the Coastal and Estuarine Research Federation, Portland, OR, November 2009.

Santos**, G. and K. E. Boyer. Patterns in primary production across four San Francisco Bay eelgrass beds: implications for species interactions and trophic dynamics. Biennial meeting of the Coastal and Estuarine Research Federation, Portland, OR, November 2009.

Kiriakopolos**, S. and K. E. Boyer. The role of herbivory by *Branta canadensis* (Canada geese) in the annual life cycle of a San Francisco Bay *Zostera marina* (eelgrass) population. Biennial meeting of the Coastal and Estuarine Research Federation, Portland, OR, November 2009.

Ryan**, A. and K. E. Boyer. Nitrogen and salinity interactions in pickleweed dominated marshes of San Francisco Bay. Biennial meeting of the Coastal and Estuarine Research Federation, Portland, OR, November 2009.

Archbald**, G. and K. E. Boyer. The role of an invasive forb, *Limonium ramosissimum*, in San Francisco Bay salt marshes. 9th biennial State of the San Francisco Estuary conference, September 2009.

Boyer, K. E. Eelgrass in San Francisco Bay: Conservation and restoration of a habitat forming species. **Invited.** 9th biennial State of the San Francisco Estuary conference, September 2009.

Santos**, G. and K. E. Boyer. Patterns in primary production across four San Francisco Bay eelgrass beds: implications for species interactions and trophic dynamics. 9th biennial State of the San Francisco Estuary conference, September 2009.

Kiriakopolos**, S. and K. E. Boyer. The role of herbivory by *Branta canadensis* (Canada geese) in the annual life cycle of a San Francisco Bay *Zostera marina* (eelgrass) population. 9th biennial State of the San Francisco Estuary conference, September 2009.
(Received 2nd place student poster award)

Archbald**, G. and K. E. Boyer. The role of an invasive forb, *Limonium ramosissimum*, in San Francisco Bay salt marshes. American Association for the Advancement of Science Pacific Division meeting, August 2009.
(Received 2nd place student presentation award)

Boyer, K. E., S. Wyllie-Echeverria, S. Cohen, K. Merkel, N. Cosentino-Manning, and M. Fonseca. **Invited.** Restoring eelgrass in San Francisco Bay: a rapidly evolving understanding of limitations and opportunities. American Association for the Advancement of Science Pacific Division meeting, August 2009.

Blandino-Vargas**, J. and K. E. Boyer. The role of flow in eelgrass beds. Undergraduate Research Symposium, SF State, August, 2009.

Boyer, K. E. Eelgrass restoration and ecology in San Francisco Bay. **Invited.** Richardson Bay Audubon Center Lecture Series, March 2009.

Boyer, K. E. Laying the foundation: seagrass ecology and restoration in San Francisco Bay. **Invited.** Moss Landing Marine Laboratory seminar, February 2009.