Climate Change Impacts To San Francisco Bay−Delta Wetlands: Links To Pelagic Food Webs And Predictive Responses Based On Landscape Modeling

submitted to Science Program 2006

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lead investigators:
Parker, V. Thomas
Talley, Drew
Callaway, John
Kelly, Maggi

Project Information And Executive Summary

Climate Change Impacts To San Francisco Bay−Delta Wetlands: Links To Pelagic Food Webs And Predictive Responses Based On Landscape Modeling

This is proposal #0040 for the Science Program 2006 solicitation.

Frequently asked questions and answers for this PSP are now available.

The submission deadline for this proposal has passed. Proposals may not be changed.

Instructions

Please complete the Project Information and Executive Summary Form prior to proceeding to the other forms contained on this website and required to be completed as part of your PSP application submittal. Information provided on this form will automatically support subsequent forms to be completed as part of the Science PSP submission process. Information provided on this form will appear in the Contacts and Project Staff, Task and Budget Summary, and Conflict of Interest forms.

Proposal Title: **Climate change impacts to San Francisco Bay−Delta wetlands: Links to pelagic food webs and predictive responses based on landscape modeling**

This field is limited to 255 characters. All proposal titles must be entered in title case. No abbreviations or acronyms will be accepted.

Applicant Information

Applicant Organization Name: **San Francisco State University**

Please provide the name of the organization submitting the application as follows: Davis, California University of; Fish and Game, California Department of; California Waterfowl Association, etc.

Applicant Organization Type:
public institution of higher education
eligibility

Below, please provide contact information for the representative of the applicant organization who is authorized to enter into a contractual agreement with the State of California and who has overall responsibility for the operation, management, and reporting requirements of the applicant organization. (This should be the same individual who signs the signature page.)

Salutation: **AVP Research and Sponsored Programs**
First Name: **Ken**
Last Name: **Paap**
Street Address: **1600 Holloway Avenue, ADM 471**
City: **San Francisco**
State or Province: **CA**
Zip Code or Mailing Code: **94132**
Telephone: **(415) 338−7091**
E−mail Address: **kenp@sfsu.edu**

Below, please provide contact information for the primary point of contact for the implementation of the proposal. This person should be the same individual who is serving as the project Lead Investigator/Project Director.

Salutation: **Dr.**
First Name: **V. Thomas**
Last Name: **Parker**
Telephone: **(415) 338−2375**
E−mail Address: **parker@sfsu.edu**

Proposal Information

Total Amount Requested: $746,848

The figure represented above is provided by the total amount requested on your completed Task and Budget Summary Form. The applicant must ensure the amount indicated above is correct and equal to the total amount requested in the budget document uploaded via the Budget and Justification Form for this project.

Select one primary and up to three secondary topic areas that best apply to this proposal:

Trends and Patterns of Populations and System Response to a Changing Environment (Primary)

Habitat Availability and Response to Change

Select up to five keywords to describe this project.
− ***agriculture***
− ***agricultural economics***
− ***agricultural engineering***
− ***agronomy***
− ***agro−ecology***
− ***benthic invertebrates***
− ***benthos***
− ***biochemistry***
− ***biological indicators***
− ***birds***
− ***channels and sloughs***
X ***climate change***
− ***conservation or agricultural easements***
− ***conservation program management***
− ***database management***
− ***ecotoxicology***
− ***economics***
− ***engineering***
− ***erosion control***
− ***environmental education***
− ***evapotranspiration***
X ***fish biology***
− delta smelt
− salmon and steelhead
− other species
− otoliths
− tagging
− ***fish management and facilities***
− ***flooded islands***
− ***floodplains and bypasses***
− ***forestry***
− ***genetics***
− ***geochemistry***
X ***geographic information systems (GIS)***
− ***geology***
− ***geomorphology***
− ***groundwater***
− ***human health***
− ***hydrodynamics***
− ***hydrology***
− ***insects***
− ***integrated pest management***
− ***integrated resource planning***
− ***invasive species / non−native species / exotic species***
− ***irrigation systems***
− ***land use laws and regulations***
− ***land use management***
− ***land use planning and policy***
− ***levees***
− ***mammals***
− ***microbiology / bacteriology***
− conceptual
− quantitative
− ***oceanography***

– ***performance measures***
– ***phytoplankton***
– ***plants***
– terrestrial
– aquatic
– wetland
– ***remote sensing / imaging***
– ***reptiles***
– ***reservoirs and lakes***
– ***restoration***
– ***riparian zone***
– ***rivers and streams***
– ***sediment***
– ***soil science***
– ***statistics***
– ***subsidence***
– ***sustainable agriculture***
X ***trophic dynamics and food webs***
– ***water operations (diversions, pumps, intakes, exports, barriers, gates, etc.)***
– ***water quality***
– other
– temperature
– contaminants
– nutrients, organic carbon, and oxygen depleting substances
– salinity
– sediment and turbidity
– ***water supply***
– ***watershed assessment***
– ***watershed management***
X ***wetlands***
– ***zooplankton***

Provide the geographic coordinates that best describe the center point of your project. (Note: If your project has more than one site, provide a center point that best captures the central location.)

Example:	Latitude:	38.575; must be between 30 and 45
	Longitude:	−121.488; must be between −120 and −130

Help for finding a geographic location.

Latitude: **38.04**
Longitude: **−121.87**

Provide the number miles radius from the center point provided above, to demonstrate the radius of the entire project.
33

Provide a description of the physical location of your project. Describe the area using information such as water bodies, river miles and road intersections.

Wetland at China Camp State Park, Petaluma Marsh, Coon's Island (Napa River), wetland at Rush Ranch Open Space Browns Island, Sand Slough, other to be determined.

Successful applicants are responsible for complying with all applicable laws and regulations for their projects, including the National Environmental Policy Action (NEPA) and the California Environmental Quality Act (CEQA). Projects funded through this PSP that tier off the CALFED Programmatic EIS/EIR must incorporate applicable mitigation strategies described in the CALFED Programmatic Record of Decision to avoid or minimize the project's adverse environmental impacts. Applicants are encouraged to review the Programmatic EIS/EIR and incorporate the applicable mitigation strategies from Appendix A of these documents for their projects.

If you anticipate your project will require compliance of this nature (ie applications for permits, other environmental documentation), provide below a list of these items, as well as the status of those applications or processes, if applicable. If you believe your project will not require these regulatory actions, please provide one or two lines of text outlining why your proposed project will not be subject to these processes. Further guidance is available in The Guide to Regulatory Compliance for Implementing CALFED Activities.

Will only require extension of existing permits.

Is this proposal an application for next phase funding of an ongoing project funded by CALFED Science Program?
X No. **−** Yes.

If yes, identify the ongoing project:

Project Title: **IRWM, Monitoring landscape variables in San Francisco Bay wetlands**
CALFED Contract Management Organization: **Science**
Amount Funded: **$101,588**
Date Awarded: **2003−2006**
Lead Organization: **UC Berkeley**
Project Number:

Have primary staff and/or subcontractors of the project team (those persons listed on the Contacts and Project Staff form) received funding from CALFED for a project *not* listed above?
− No. **X** Yes.

If yes, list the projects below: (only list up to the five most recent projects)

Project Title: **Integrated Regional Wetland Monitoring Pilot Project, Vegetation Assessment**
CALFED Contract Management Organization: **Science**
Amount Funded: **$467,000 to Vegetation Team (IRWM)**
Date Awarded: **2003−2006.**
Lead Organization: **San Francisco State University**
Project Number:

Project Title:
CALFED Contract Management Organization:
Amount Funded:
Date Awarded:
Lead Organization:
Project Number:

Project Title:
CALFED Contract Management Organization:
Amount Funded:
Date Awarded:
Lead Organization:
Project Number:

Project Title:
CALFED Contract Management Organization:
Amount Funded:
Date Awarded:
Lead Organization:
Project Number:

Project Title:
CALFED Contract Management Organization:
Amount Funded:
Date Awarded:
Lead Organization:
Project Number:

Has the Lead Investigator, the applicant organization, or other primary staff or subcontractors of your project team ever submitted a proposal for this effort or a similar effort to any CALFED PSP?
X No. **−** Yes.

If yes, list the submission below: (only list up to the five most recent projects)

Project Title:
CALFED Program:
Date of PSP:

Project Title:
CALFED Program:
Date of PSP:

Project Title:
CALFED Program:
Date of PSP:

Project Title:
CALFED Program:
Date of PSP:

Project Title:
CALFED Program:
Date of PSP:

Note: Additional information on this or prior applications submitted −− or proposals funded −− may be required of applicants.

List people you feel are qualified to serve as scientific and/or technical reviewers for this proposal and are not associated with your organization or CALFED.

Full Name	Organization	Telephone	E−Mail	Expertise
Wayne R. Ferren	**Maser Consulting PA**	**732−383−1950 x3362**	**wferren@maserconsulting.com**	**wetlands**
Ronald Thom	**Battelle Marine Sciences Laboratory**	**360−681−3657**	**ron.thom@pnl.gov**	**climate change**
Carolyn Currin	**NOAA Center for Coastal Fisheries and Habitat research**	**252−728−8749**	**carolyn.currin@noaa.gov**	**fish biology**
Douglas Stow	**San Diego State University**	**619−594−5498**	**stow@mail.sdsu.edu**	**geographic information systems (GIS)**

Provide additional comments, information, etc. here:

Executive Summary

Provide a brief but complete summary description of the proposed project; its geographic location; project objective; project type, approach to implement the proposal; expected outcomes; and adaptive management approach and relationship to the Science Program goals. The Executive Summary should be a concise, informative, stand−alone description of the proposed project and be no longer than one page in length. Please note, this information will be made public on our website shortly after the closing date of this PSP.

The health of pelagic systems and wetlands are ecologically linked through a variety of mechanisms, but the extent of that linkage appears to vary geographically. The strength of this linkage is poorly understood for Pacific Coast sites, including the San Francisco Bay−Delta Estuary (SF Bay−Delta). Critically, wetlands are the most vulnerable habitats in California under a variety of climate change scenarios, and freshwater tidal and brackish wetlands, the most productive and diverse of the SF Bay−Delta wetlands, are the most sensitive of any tidal wetlands to climate changes. This proposal focuses on 1) evaluating the potential impacts of climate change on SF Bay−Delta tidal wetlands, 2) improving our understanding of the linkage between these wetlands and the pelagic food web, especially fish populations, and 3) using this information to make predictions about potential effects of climate change on Bay−Delta fish populations. Climate change predictions as they would impact the SF Bay−Delta system through an altered salinity regime, resulting from higher winter−spring floods and lower summer−fall flows, and increased sea−level rise. Over the long term, shifts in Bay−Delta salinity could lead to substantial shifts in the overall distribution of fresh, brackish and salt marsh ecosystems; increases in sea level could exacerbate these shifts and lead to the additional loss of wetlands due to increased rates of inundation. We will test the overall hypothesis that pelagic fish communities are critically linked to tidal wetlands and that processes involved in climate change will impact the quality and extent of these wetlands, negatively impacting fish population sizes and stability. We will

use existing literature and new field data to investigate this linkage. Surveys of plant diversity, primary production and decomposition studies will track carbon production and rates of movement out of the wetland systems. Stable isotope analysis of fishes, an intermediate invertebrate trophic level, and wetland plants will provide necessary data for interpreting the significance of any trophic pelagic−wetland linkage. We will measure wetland sedimentation rates to evaluate the ability of SF Bay tidal wetlands to withstand future increases in sea−level rise. Finally, using these data, we will model the potential impact to tidal wetlands and fish populations under a variety of climate change scenarios (varying salinity, sea−level rise, sediment availability) as a way to predict future impacts to these resources and to gain insight into potential management actions.

Contacts And Project Staff

This is proposal #0040 for the Science Program 2006 solicitation.

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INSTRUCTIONS

Use this form to provide titles, affiliations, qualifications, and descrptions of roles of the primary and secondary project staff. Include any consultants, subcontractors and/or vendors. The Lead Investigator or Project Director, as identified in the Project Information and Executive Summary Form, is required to upload a PDF version of their resume. To complete the qualification field of this form, please provide a bulleted list of relevant project/field experience and any publications/reports that support your participation in the proposed project.

Information provided on this form will automatically support subsequent forms to be completed as part of the Science Program PSP submission process. Please note tht information you enter in this form will appear in the Task and Budget Summary and Conflict of Interest forms.

Information on subcontractor services must be provided even if the specific service provider has not yet been selected. If the specific subcontractor has not been identified or selected, please list TBD (to be determined) in the last name field and the anticipated service type in the title field (example: Fish Biologist).

Please provide this information before continuing to the Tasks and Deliverables Form.

Applicant

San Francisco State University
AVP Research and Sponsored Programs Ken Paap
1600 Holloway Avenue, ADM 471
San Francisco CA 94132
(415) 338−7091
kenp@sfsu.edu

Lead Investigator/Project Director

Salutation: **Dr.**
Last Name: **Parker**
First Name: **V. Thomas**
Title: **Professor of Biology**
Organization: **San Francisco State University**
Responsibilities: **Budget lead PI, supervise field work, data analysis, primary writing**
Resume:

You have already uploaded a PDF file for this question. Review the file to verify that appears correctly.

Mailing Address: **Department of Biology, San Francisco State University**
City: **San Francisco**
State: **CA**
Zip: **94132**
Telephone: **(415) 338−2375**
E−Mail: **parker@sfsu.edu**

All Other Personnel

Salutation: **Dr.**
Last Name: **Talley**
First Name: **Drew**
Title: **Research Coordinator**
Organization: **San Francisco Bay National Estuarine Research Reserve**
Position:

Co-PI
Responsibilities: **Stable isotopes and fish biology.**
Qualifications:

In this proposed work, Drew Talley will organize and perform sampling of fishes and invertebrates; supervise processing of all stable isotope samples, and interpret and analyze stable isotope results. Talley has a Ph.D. in Biological Oceanography from Scripps Institution of Oceanography, and is currently adjunct faculty at SFSU and the Research Coordinator for the San Francisco Bay National Estuarine Research Reserve (SF Bay NERR). Talley will be based out of the NERR's lab and offices at the Romberg Tiburon Center for Environmental Studies. Talley's research has broadly focused on habitat connectivity, generally applying food web and stable isotope approaches to address a mechanistic understand of processes that affect linkages between often quite distinct habitats. Much of Talley's work has been applied to wetland fish communities on the Pacific coast, using stable isotopes and quantitative sampling to examine mechanisms through which wetland fishes mediate habitat connectivity. He also has contributed to our understanding of habitat connectivity at the terrestrial-aquatic interface more broadly, with studies including insular desert habitats and evaluating alterations to natural connectivity imposed by exotic species introductions. More information about his past and current research and publications is available at http://userwww.sfsu.edu/~dtalley/

List relevant project/field experience and publications/reports.

Salutation: **Dr.**
Last Name: **Callaway**
First Name: **John**
Title: **Associate Professor of Environmental Sciences**
Organization: **University of San Francisco**
Position:
Co-PI
Responsibilities: **Field and lab coordinator, Sedimentation, Wetlands**
Qualifications:

For the proposed research, John Callaway will coordinate the sedimentation measurements and the incorporation of these data into the landscape model, and he will interact with Parker and Vasey to complete the plant component of the research. Callaway received his Ph.D. in Oceanography and Coastal Sciences from Louisiana State University in 1994 and his Masters from San Francisco State University in 1990. Prior to his position at the University of San Francisco (USF), he was the Associate Director of the Pacific Estuarine Research Laboratory (PERL) at San Diego State University. His research expertise is in wetland restoration, specifically wetland plant ecology and sediment dynamics. Recent research projects focus on understanding the development of restored wetlands, including evaluations of the importance of plant species diversity and the role of physical heterogeneity in the development of ecosystem functions. His research includes projects in San Francisco Bay, Tijuana Estuary, and Louisiana. Dr. Callaway has over two decades of experience working with wetlands, with substantial experience in California and specifically San Francisco Bay wetlands. Currently, he is a principal member of the vegetation team for the CALFED funded Integrated Regional Wetland Monitoring Pilot Project (IRWM) and is also completing research on sediment dynamics of recently restored South San Francisco Bay salt ponds. He also serves as a number of editorial boards and scientific review panels, both locally and nationally. His work has been funded by the National Science Foundation, CALFED, and the Environmental Protection Agency. Callaway has published over 30 peer-reviewed publications, with most of his work focusing on plant and sediment dynamics of estuarine wetlands.

List relevant project/field experience and publications/reports.

Salutation: **Dr.**
Last Name: **Kelly**
First Name: **Maggi**
Title: **Associate Cooperative Extension Specialist and Associate Professor**
Organization: **University of California, Berkeley**
Position:
Co-PI
Responsibilities: **GIS and spatial modeling**
Qualifications:

Maggi Kelly will be based at UC Berkeley, and coordinate and oversee the GIS and spatial modeling components of the project through the College of Natural Resources Geospatial Imaging and Informatics Facility. Kelly will directly supervise the graduate student at UC Berkeley who will work on developing GIS maps and spatial models. Kelly has a Ph.D. from the University of Colorado in Boulder. Kelly's research and outreach program at UC Berkeley has several themes, and is informed by the disciplines of geography and landscape ecology. First, one research focus is linking ecological pattern with process in spatially heterogeneous and dynamic landscapes. A second theme embraces the evaluation of new technologies and development of best practices for ecological monitoring and landscape quantification using integrated geospatial technologies – GIS, remote sensing, GPS, spatial analysis, modeling and landscape ecology approaches. A third theme involves participatory and community-based research in natural resource research and management. To that end the Kelly lab has developed numerous web and GIS based tools for citizen participation and data delivery. Our final theme involves the dissemination of data and research results from these endeavors to clientele groups throughout California through presentations, training workshops, and innovative use of the Internet. Kelly has 19 relevant publications in this area in the last few years. These can be accessed at http://kellylab.berkeley.edu.

List relevant project/field experience and publications/reports.

Salutation: **Mr.**
Last Name: **Vasey**
First Name: **Michael**
Title: **Research Scientist/Lecturer; former Director Environmental Studies**
Organization: **San Francisco State University**
Position:
primary staff
Responsibilities: **Wetland fieldwork and data collection; diversity study and analysis.**
Qualifications:

Michael Vasey's role and responsibilities in this project will be a focus on field sampling, primary lead in plant species identification and lead in comparative ecological diversity analyses. Vasey, with an M.A. in botany from San Francisco State University, is a faculty lecturer in Conservation Biology and Environmental Studies at San Francisco State University. He has held this position since 1990. By training, Vasey is a botanist with expertise in ecology, evolution, and conservation biology. He is currently on the last year of his presidency of the California Botanical Society. Vasey's involvement with the San Francisco Bay estuary goes back to 1991 when be became the Acting Manager for the proposed San Francisco Bay National Estuarine Research Reserve (SFB NERR). While leading the successful effort to get the SFB NERR designated, he became the plant team chair for the San Francisco Estuary Regional Monitoring Program from 1999-2004. In 2002, he joined with Tom Parker and John Callaway to test a new wetland vegetation sampling program for the EPA's EMAP. In 2004, he was a Co-PI on the first phase of the CalFed funded Integrated Regional Wetland Monitoring (IRWM) Project where he helped to plan, implement, and analyze the vegetation component of that project. For the past two years, Vasey has taught a course on wetland plant indicators at the Romberg Tiburon Center. He has 13 peer-reviewed publications and co-authored several wetland vegetation posters at conferences over the past two years and is currently preparing manuscripts for future publication based upon the IRWM studies.

List relevant project/field experience and publications/reports.

Salutation: **Ms.**
Last Name: **Schile**
First Name: **Lisa**
Title: **Research Technician II**
Organization: **San Francisco State University**
Position:
primary staff
Responsibilities: **Primary person in charge of field work, data collection, field crew supervision.**
Qualifications:

Lisa Schile is an experienced wetland ecologist, who, with Parker, will oversee the hiring and coordination of field crews, organization of the field data collection, and processing of all the materials collected. Schile will also be responsible for initial data entry and quality control, the production of multiple backup files in several independent locations. At this point, our plan is to

maintain separate data sets at 3 locations in 3 different counties, the main office of the NERR (Marin Co.), in the Landscape Ecology Center at UCB (Alameda Co.) and in the research labs of Parker at SFSU (San Francisco Co.). Schile has acted in this capacity on the CALFED−sponsored IRWM project. Schile is a trained and an experienced boat captain as well as being familiar with all the research sites. Schile has a MS from the University of Louisiana, Lafayette, and has worked for the past 2 years on the IRWM project with Parker, Callaway and Vasey. She is a wetland specialist, both plants and animals, and already has several publications, with several in process.

List relevant project/field experience and publications/reports.

Conflict Of Interest

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Instructions

To assist Science Program staff in managing potential conflicts of interest as part of the review and selection process, we are requesting applicants to provide information on who will directly benefit if your proposal is funded. Please provide the names of individuals who fall in the following categories and are not listed in the Personnel Form:

- Persons listed in the proposal, who wrote the proposal, will be performing the tasks listed in the proposal, or who will benefit financially if the proposal is funded; and/or
- Subcontractors listed in the proposal, who will perform tasks listed in the proposal, or will benefit financially if the proposal is funded.

Applicant
Submittor
Lead Investigator/Project Director
Primary Staff
Secondary Staff
Subcontractor

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

Last Name	First Name	Organization	Role

Task And Budget Summary

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Instructions

Use the table below to delineate the tasks needed to carry out your proposal. Tasks in this form should support the narrative description of your project in your proposal document and the informa tion provided in your detailed budget spreadsheet. Each task and subtask must have a number, title, timeline, list of personnel or subcontractors providing services, and associated budget figure.

When creating subtasks, ensure that each activity is counted only once. Please note, the initial task of your table (Task 1) must present all project management/administrative activities supporting your overall proposal.

For proposals involving multiple agencies or organizations (including subcontractors), the table must clearly state the tasks and subtasks performed by each entity.

Task #	Task Title	Start Month	End Month	Personnel Involved	Description	Task Budget
1	Project Management	1	36	Parker, V. Thomas	Budget management, Personnel hiring, Equipment maintenance, Project organization and supervision, and Data quality and storage	65,506
2	Stable Isotope Analyses	1	36	Talley, Drew	Determine the extent to which fish populations directly or indirectly depend on tidal wetlands. Project will use stable isotopes as the experimental probe.	220,397
3	Wetland Analyses	1	36	Callaway, John	Experimentally determine the extent to which rising sea level and increased salinities will affect wetland productivity, decomposition and diversity.	327,494
4	Spatial Modeling	1	36	Kelly, Maggi	Using data from Tasks 2 and 3 as well as literature, model a variety of scenarios of rates of sea level rise and salinity increases as it affects overall ecosystem productivity and carbon flow to pelagic fish communities.	133,451

total budget=$746,848

Detailed Budget Upload And Justification

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Using the budget provided via this link as a guide, please complete a budget for your proposal in the software of your choice (e.g. Excel). This document must be in a format and software that can be converted to PDF prior to uploading on the web system.

It is incumbant upon the applicant to fully explain/justify the significant costs represented in the attached budget. This information can be provided either in a text document and uploaded below, or included in your proposal text in a clearly defined budget justification section. If it is not abundantly clear to reviewers what project costs are commensurate with which efforts and benefits, the proposal may receive a poor review and denied funding.

Costs for each task described in the Task and Budget Summary Form and each staff or subcontractor described on the Contacts and Project Staff Form, must be included in your budget. The budget for Task One should represent project management activities, including but not limited to cost verification, environmental compliance, data handling, report preparation, project oversight, and public outreach. The total amount of your budget must equal the total amount represented on your Task and Budget Summary Form and the total budget amount represented on your Project Information and Executive Summary Form.

In a separate text document to be uploaded below, identify any cost share and other matching funds available to support your proposed project. If you identify cost share or matching funds, you must also describe them in the text of your proposal (see explanation of "cost share and other matching funds" in Section Two of the solicitation document).

CBDA may request additional information pertaining to the items, rates and justification of the information presented in your budget. Applications without completed budgets will not be considered for funding.

Uploading The Completed Budget Template

First, convert your completed Budget to a PDF file. Then, use the browse function to locate the PDF version of your document, select the document and click on the upload prompt below.

You have already uploaded this document. View it to verify that it appears as you expect. You may replace it by uploading another document

Uploading The Completed Budget Justification

First, convert your completed Justification text to a PDF file. Then, use the browse function to locate the PDF version of your document, select the document and click on the upload prompt below.

You have already uploaded this document. View it to verify that it appears as you expect. You may replace it by uploading another document

Uploading The Description Of Cost Share/Matching Funds

First, convert your completed Description of Cost Share/Matching Funds text file to a PDF file. Then, use the browse function to locate the PDF version of your document, select the document and click on the upload prompt below.

You have already uploaded this document. View it to verify that it appears as you expect. You may replace it by uploading another document

Schedule Of Deliverables

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Use the table below to delineate the key deliverables and the time necessary to complete them (in months from the date the project's grant agreement is executed). Each Science Program 2006 PSP grant recipient must provide the required minimum deliverables for each project. The required minimum deliverables for each funded proposal are as follows:

- Semi−annual report(s)
- Final Report
- One page project summary for public audience at beginning of project
- One page project summary for public audience upon project completion
- Project closure summary report or copy of draft manuscript
- Presentation at CALFED Science Conference
- Presentations at other events at request of CALFED Science Program staff
- Copy of all published material resulting from the grant

Deliverable	Description	Delivered By: # (In Months From Project Start Date)
Project initiation	April 2007	1
1 page project summary	Presented to public audience at beginning of project	2
Semi−annual report	Summary of data collected	9
1st annual report	Data and analyses for each task	15
Presentation at CALFED Science Conference	Dependent upon scheduling	18
Semi−annual report	Summary of data collected including results of early experiments for tasks 2 and 3	21
2nd annual report	Data, analyses and preliminary results for task 4	27
Presentation at national meeting (SWS, ERF, ESA, etc.)	Dependent upon scheduling	28
Semi−annual report	Final data collections and literature summary	33
Project closure summary report	March 2010	36
Final Report	March 2010 (may be delayed subject to CALFED feedback)	36
1 page project summary	Presented to public audience upon project completion	36
Presentation at CALFED Science Conference	Month 42 (dependent upon scheduling)	36
Presentations at other events	At request of CALFED Science Program staff as available	36
Final Deliverables	Copy of all published material resulting from the grant as available	36

If you are unable to provide a Schedule of Deliverables as outlined above, please provide your justification of non−compliance in the text box provided below. The Science Program reserves the right to determine a proposal non−eligible based on an applicants inability to provide the materials requested above.

Letters Of Support Form

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Letters Of Support

Should you wish to provide letters of support for your proposed project, you must do so through use of this web form. Letters of support will be provided to independent, panel and public reviewers for reference as part of the overall review process. It is not mandatory to provide letters of support. Failure to do so will in no way affect the review or final determination of your application.

Submission Of These Materials.

To submit Letters of Support, you must do so as .PDF files. To upload these materials, use the browse function to locate the appropriate .PDF version of the documents, select the documents and click on the upload prompt below.

Please ensure your PDF file contains all letters you would like to submit. Individual files (or letters) will not be accepted by the system. The system is designed to receive one single file. Submittal of these documents are not mandatory for your application to be considered under the 2006 Science Program PSP. Failure to submit letters does not impact your ability to compile your proposal along with the supporting forms required for final submission and consideration under the Science Program 2006 PSP.

Letters Of Support *Please upload a PDF version of your letters of support. To upload a document, use the "Browse" button to select the PDF file containing the document.*

Climate change impacts to San Francisco Bay-Delta wetlands: Links to pelagic food webs and predictive responses based on landscape modeling

PROJECT PURPOSE

The health of pelagic systems and wetlands are ecologically linked through a variety of mechanisms, but the extent of that linkage appears to vary geographically. The strength of this linkage is poorly understood for Pacific Coast sites, including the San Francisco Bay-Delta Estuary (SF Bay-Delta). Critically, wetlands are the most vulnerable habitats in California under a variety of climate change scenarios, and freshwater tidal and brackish wetlands, the most productive and diverse of the SF Bay-Delta wetlands, are the most sensitive of any tidal wetlands to climate changes. This proposal focuses on 1) evaluating the potential impacts of climate change on SF Bay-Delta tidal wetlands, 2) improving our understanding of the linkage between these wetlands and the pelagic food web, especially fish populations, and 3) using this information to make predictions about potential effects of climate change on Bay-Delta fish populations. Climate change predictions as they would impact the SF Bay-Delta system through an altered salinity regime, resulting from higher winter-spring floods and lower summer-fall flows, and increased sea-level rise. Over the long term, shifts in Bay-Delta salinity could lead to substantial shifts in the overall distribution of fresh, brackish and salt marsh ecosystems; increases in sea level could exacerbate these shifts and lead to the additional loss of wetlands due to increased rates of inundation.

An altered salinity regime follows from two overall processes. One is the altered hydrology of the SF Bay-Delta watershed, with predictions clearly indicating a gradual shift to more rain and less snow, and an earlier melting of the snow pack. These changes will increase winter/spring flows into the Delta; however, critically, during the summer and fall, lower stream flows will result in saline water pushing farther up into the Delta, consequently increasing salinities and impacting many species that depend on different portions of the SF Bay-Delta at this time of the year. These processes combined will lead to greater variability of salinity within many reaches of the estuary. A second process combines the increase in average temperatures with the local summer-dry, Mediterranean climate. Especially in the context of increasing water salinities, with lower flows in the summer and fall, high marsh soils will experience a concentration of salts at a more rapid rate and for longer a duration of the growing season. Even in areas with trace water salinities, as in the western Delta, soil salinity in high marsh areas will begin to increase.

In addition, recent research indicates increasing rates of sea-level rise, with each new publication suggesting the possibility of ever more rapid increases due to melting of terrestrial ice sheets (Chen et al. 2006; Overpeck et al. 2006; Rignot and Kanagaratnam 2006). Sediment accumulation in tidal wetlands appears to be keeping pace with sea-level rise, but altered hydrology combined with faster sea-level rise places tidal wetlands in an especially vulnerable situation. Wetlands, especially freshwater tidal wetlands, are among the most productive habitats globally. Carbon and other resources move from wetlands into adjacent pelagic habitats either by direct consumption or indirectly from products of decomposition. Impacts from any loss of wetlands, or shifts in the distribution of fresh, brackish and salt marsh ecosystems, will cascade through food webs and potentially have significant effects on pelagic systems. Further, transformation of marsh vegetation from freshwater to saline will also affect habitat structure and quality for a sweeping diversity of wetland animal species including, potentially, fish species that utilize tidal wetland creeks and channels during portions of their life cycle.

Clearly, long-term management of the SF Bay-Delta resources requires an understanding of the potential linkages between these various systems in addition to a deeper understanding of each. Using existing literature and additional focused data collection, we propose that building spatial models of the impacts of wetland loss or conversion on the dynamics of pelagic food webs will provide insight into these critical linkages. In addition, these models will use results from other climate change work focused on the region, in particular the output of SF Bay-Delta salinities from the CASCADE model (http://sfbay.wr.usgs.gov/cascade/). We outline this approach and rationale in more detail below.

Objectives and Hypotheses

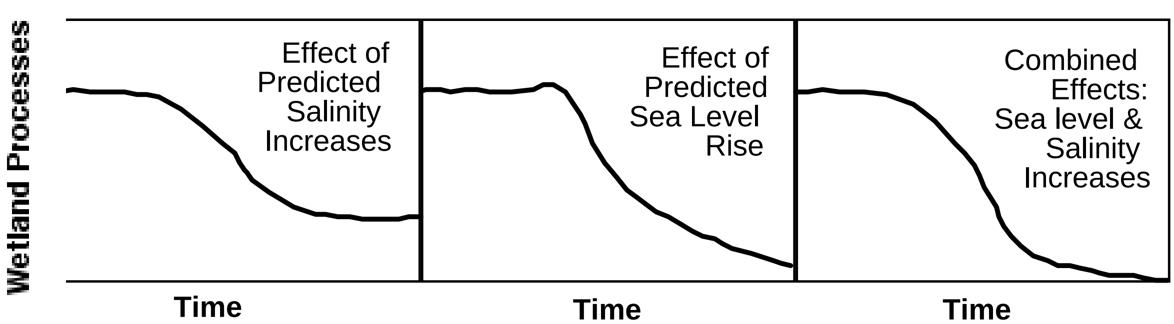
This project investigates the hypothesis that pelagic fish communities are critically linked to tidal wetlands and that processes involved in climate change will impact the quality and extent of these wetlands, negatively impacting fish population sizes and stability. To test this hypothesis, our overall goal is to develop a predictive model that will estimate the impact of global climate change on the tidal marshes and their relationship to fish communities. To achieve this, our more specific objectives are:

- To determine rates of vascular plant productivity and decomposition so that we can evaluate carbon input/output within fresh, brackish, and salt marsh systems under future climate change scenarios;
- To evaluate sedimentation rates across fresh, brackish and salt marshes within the SF Bay-Delta, as an indicator of potential impacts of global sea-level rise across these ecosystems;
- To determine if it is possible to differentiate among a range of freshwater and brackish marsh plant species using stable isotopes, both in terms of their own signal and their link to the fish (and invertebrate) food webs;
- To evaluate the extent to which estuarine fish communities are dependent on tidal wetlands;
- To develop relationships between productivity and diversity and food web and fishery dynamics that can be scaled over the SF Bay-Delta; and
- To apply these models with simulated salinity, inundation and sedimentation scenarios associated with climate change to qualitatively evaluate impact on marsh distributions fish populations across the SF Bay-Delta landscape.

BACKGROUND AND CONCEPTUAL MODEL

Our proposed research is based on the conceptual model that tidal marshes provide important food and habitat for fish, and that climate change will impact tidal marshes by increasing estuarine salinity and increasing rates of inundation, with cascading effects on fish populations. In order to evaluate these impacts on the scale of the SF Bay-Delta, it is necessary to use spatial models of habitat and food web dynamics.

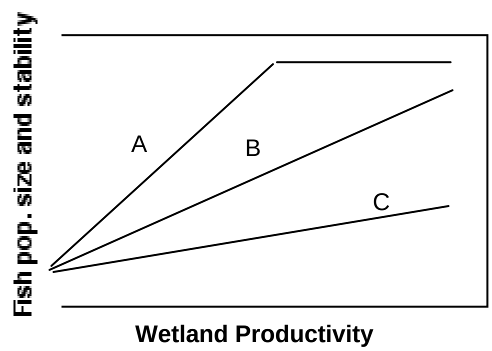
As we will go into in more detail below, predictions for the San Francisco Bay-Delta



systems in the context of climate change involve increases in salinity and its encroachment into the Delta (even without levee failure), and rising sea level, potentially drowning wetlands and reducing their spatial extent.

As indicted in the above figure, we hypothesize that the combined wetland processes of production, nutrient cycling, decomposition, and habitat support, all will be impacted to some extent by future climate changes. Over time, increases in salinity will have significant impacts on these wetland processes, as freshwater marshes are converted to brackish systems and brackish to saline. If sedimentation does not keep up with rates of sea level rise, initially large extents of high marsh will be converted to more productive low marsh, but over time there is likely to be a subsequent and dramatic loss of marsh extent (middle figure). With combined impacts of salinity and sea level rise, wetlands are like to be lost at a more rapid rate. We outline the details and background related to each of these issues below.

We propose that there is some degree of linkage between wetlands and fish populations, and we hypothesize potential scenarios describing this linkage.



In the above figure, three alternative degrees of linkage are suggested. In ‘A’, fish populations are highly dependent on wetlands for habitat and on their productivity directly or indirectly for their own populations. Lines ‘B’ and ‘C’ represent increasingly less dependent linkages. In all cases, we propose a positive influence of wetlands on fish populations or their stability, given the important link of these habitats to the rest of the estuary, through food webs, nutrients and other dynamics.

Importance of Wetlands for Fish

Tidal wetlands on the Atlantic and Gulf coasts of the United States have long been recognized to be critically important habitats for supporting a variety of fish species (e.g., Boesch and Turner 1984; Kneib 1997). The mechanisms of connection between wetland habitats and fish populations are varied, but broadly include trophic support and provision of habitat. Trophic support can be direct, through at least partial food-web dependence on primary production of emergent plants (e.g., Deegan et al. 1997) or indirectly, through emergent plants fueling the detrital food web (e.g., Peterson et al. 1986; Currin et al. 1995). Tidal marsh plants can also be crucial for providing non-trophic habitat support for fishes, such as protection from predation for juveniles, or simply providing substrate for the attachment of eggs (Boesch and Turner 1984; Minello et al. 1994; Gillanders et al. 2003).

Despite the wealth of information showing a strong connection between tidal marshes and fish and invertebrate populations on the Atlantic and Gulf coasts, these connections have not been well established for species on the Pacific coast (Brown 2003). While there are ecological reasons to suspect that wetland dependence might be weaker on the Pacific coast (e.g., a much lower percent of the Pacific coastline is covered with tidal wetlands), there have also been far fewer studies aimed at elucidating these relationships on the Pacific coast. Further, the relative lack of wetland habitat, coupled with the massive loss of wetlands in the SF Bay-Delta (80-95%; The Bay Institute), could be expected to have an even greater impact on wetland dependent fishes in this ecoregion – such a paucity of essential fish habitat could be expected to contribute to local extinctions. Those studies that have been performed, provide increasing evidence that there are indeed strong connections between wetland habitats and population dynamics of fishes (see Talley 2000; Simenstad et al. 2000 and references therein), even for species not traditionally considered wetland dependent (e.g., Fodrie and Mendoza 2006). In the SF Bay-Delta, the federally threatened species *Hysterocarpus traski* (tule perch) occurs in freshwater and brackish wetlands and is strongly associated with wetland habitats (Moyle 2002), and there is also evidence for wetland support for many salmonid species (Simenstad et al. 1996; Simenstad et al. 2000), as well as other SF Bay-Delta species of interest.

Size and Importance of the SF Bay-Delta

The SF Bay-Delta is the third largest estuary in the United States, covering approximately 4096 km^2 of the central California coastal region and includes a broad mix of salt, brackish, and fresh marsh ecosystems (Atwater 1979; Josselyn 1983). The SF Bay-Delta is characterized by a Mediterranean-climate, with precipitation limited to the winter season and prolonged summer droughts. The wetland landscape is a complex mosaic of remaining historic wetlands, recently developed wetlands, restored wetlands, and potentially restorable diked bayland sites (farms, former salt ponds, and managed and unmanaged seasonal and perennial wetlands), all arranged in one of the country's largest urban areas. Despite impacts from development and from exotic species, these ecosystems are of critical regional importance for biodiversity, harboring a number of rare plant and animal species, including almost 50 special status species (Goals Project 1999; Olofson 2000).

The Delta is the conduit for nearly all of the estuary's freshwater and additionally is the hub of California's freshwater management infrastructure. This freshwater storage and transport system is vital to the State's economy, providing water to meet agricultural, municipal, industrial, and environmental demands. Annually, the Sacramento–San Joaquin watershed generates an average 30–40 km^3 (~24–32 million acre-feet) of freshwater runoff derived from rain and snow (Knowles and Cayan 2004). The Sacramento River originates in the moderate-altitude Cascades and northern Sierra, while the San Joaquin begins in the high southern Sierra. California depends on artificial and natural storage to make this supply last the rest of the year. Snowmelt runoff accounts for at least 40% of the annual supply, as indicated by discharge occurring after April 1st (Roos 1989). Total artificial storage in the watershed's major reservoirs is about 35 km^3, roughly the size of the average annual freshwater endowment (Knowles and Cayan 2004). Highly variable winter and spring runoff is managed as a flood hazard, meaning it is released from reservoirs as quickly as necessary to maintain sufficient flood control storage space. After April, the management goal is reservoir recharge, accumulating the steady stream of snowmelt runoff for distribution later in the year. Approximately 80% of California's 'non-environmental' water use is due to agricultural irrigation, which peaks in the summer (CDWR 1998).

Prior to 1850, tidal marshes occupied 2200 km^2 within the SF Bay-Delta, of which a substantial majority, 1400 km^2, consisted of freshwater marshes in the Delta (Nichols et al. 1986; SFEP 1991). These extensive freshwater marshes have now been reduced by approximately 95%. Relatively little is known about the ecological impacts of these massive wetland losses on the trophic dynamics of the SF Bay-Delta; however, recent studies (e.g. Grimaldo et al. 2004; Howe and Simenstad 2005) suggest that marsh habitat can be of great importance to aquatic food webs that occur in this region. Evaluating these habitat linkages is one of the goals of this work.

Global Change Impacts on Wetlands in the SF Bay-Delta

General: Climate change combined with other anthropogenic influences is causing rapid shifts in species composition of local ecosystems throughout the world (Ostander et al. 2000; Scheffer et al. 2001; Scheffer and Carpenter 2003; Folke et al. 2004; Hughes et al. 2005). Such changes propagate through systems, and modifications to the lower trophic levels can rapidly impact the entire ecosystem (Dunne et al. 2002a, 2002b, 2005). These shifts may be long lasting and difficult to reverse (Ostander et al. 2000; Aronson and Precht 2000) and have been referred to as phase, regime, or catastrophic shifts (Scheffer et al. 2001; Hughes et al. 2005). Shifts to alternate and relatively stable states can cause major changes not only in species composition of systems, but also to ecological processes such as productivity.

The extent to which estuaries may be subject to catastrophic shifts is uncertain. These are highly productive systems characterized by spatial gradients in dominant physical processes such as tidal depths and frequencies and seasonal ranges in salinity and are also highly impacted by natural and anthropogenic disturbances (Cohen and Carlton 1998). Systems with strong underlying abiotic regimes have been suggested to be more likely to exhibit alternative stable states (Didham and Watts 2005). Managing estuaries to minimize the likelihood of catastrophic events must be based on knowledge of dominant processes at different scales, the interaction among those processes, and making decisions that maximize the resilience of the system (Scheffer et al. 2001; Peters et al. 2004). Estuaries are highly interconnected systems, however, which make control over processes difficult (Peters et al. 2004). Estuaries link together marine and freshwater aquatic systems, wetlands, and their extensive, often urbanized and agricultural, watersheds. Of particular importance are the wetlands because they serve as nurseries for many fish and invertebrates, often have high plant diversity, and are important for local and migratory birds. Changes in the vegetation structure of a wetland due to climate change could have critical, negative effects on a multitude of organisms, and understanding system-wide effects is crucial.

The SF Bay-Delta: Many studies have shown that the effects of a warmer global climate in this region would include reduced snowpack storage in the mountains, higher flood peaks during the winter rainy season, and reduced warm-season river flows after April (Gleick 1987ab; Roos 1989; Lettenmaier and Gan 1990; Gleick and Chalecki 1999; Knowles and Cayan 2002, 2004; Dettinger et al. 2004). Even with some contention about which model might be the best and which direction certain aspects may shift, most models are in coarse agreement for California (Dettinger 2005). Dettinger (2005) compared multiple models and contingencies and determined that the most likely result of climate shift is a more or less similar total precipitation regime, combined with warmer springs, reduced snowpack, higher winter floods, and lower summer flows.

Such climate-induced changes would adversely impact the SF Bay-Delta and those institutions that depend on California's freshwater supply infrastructure. These hydrologic changes would propagate downstream, resulting in an altered (i.e., increased) salinity regime (Knowles and Cayan 2002). During the summer and fall, the lower stream flows and increased salinities would impact many species that depend on the estuary and rivers. While studies are ongoing as to current conditions, few speculate about how ecological systems in the SF Bay-Delta would respond to these changing conditions.

Another critical influence on estuarine conditions is sea-level rise, which is projected to increase at a rate of 30 to 50 cm over the next 100 years (IPCC 2001), an acceleration of the recent rate of 10-20 cm/century. Sea-level rise adds several significant impacts to the SF Bay-Delta system. For wetlands, a critical impact will be the increased inundation rates associated with sea-level rise. Second, even without any changes in freshwater input, sea-level rise alone will cause salts to move upriver, affecting X2, the 2-ppt bottom isohaline. In addition, because most of the delta region is leveed and under agriculture, increasing sea level will exponentially increase pressure on levees, adding to the probability of their failure (Ingebritsen et al. 2000; Mount and Twiss 2005). The levees were mostly constructed before the 1920's and have been repaired sporadically over the last 140 years. A levee breach occurred at Jones' Tract near Stockton, CA in June 2004 that resulted in flood levels 3.6 meters deep across the 12,000 acre tract and was estimated to cost 90 million dollars to repair (CDWR 2004). A 5-ppt spike in salinity was registered in a wetland roughly 25 miles away shortly after the breach (Siegel et al. unpublished data). The increased possibility of levee failure that would result from higher wet-season flows and increased sea level could have additional impacts on the region's ecosystems, particularly by drawing more saline water farther into the SF Bay-Delta.

A final impact of climate change results from increased temperature. Soil salinities within tidal marshes are often quite high in the summer and fall due to evapotranspiration of water and the subsequent concentration of salt in our summer-dry, Mediterranean-climate. The gradual increase in spring/summer temperatures will raise wetland soil salinities at a faster rate than source waters in the estuary, shifting plant, invertebrate, and mycorrhizal fungal composition of wetlands even without other predicted impacts.

Impact of potential salinity and sea level changes: Predicted shifts in the extent of salinity entering the Delta, the rate of sea-level rise, and increases in temperature concentrating soil salinities will initially have the greatest impacts on non-mobile resources such as tidal wetlands. Long-term gradual or catastrophic shifts will ultimately depend on the extent of wetland conversion of fresh-water systems to brackish, and brackish systems to saline and the overall loss of tidal wetlands. Even if sedimentation rates and plant organic contributions keep up with accelerated sea-level rise, changes in Delta hydrology will permit the conversion of tidal freshwater and brackish wetlands toward less productive, tidal salt marshes. If wetland sediment accumulation does not keep up with sea-level rise, gradual loss of wetland systems will have catastrophic effects, both from habitat and productivity loss, as well as the secondary effects of those losses as they are propagated through the estuarine ecosystem.

Salinity and Inundation Effects on Plant Diversity and Productivity

General: Salinity and inundation are the two critical factors that drive vegetation community structure in estuarine tidal wetlands (Mitsch and Gosselink 2000). Salinity changes can lead to shifts among salt, brackish, and freshwater tidal communities (Atwater et al. 1979). Shifts in inundation or water level are driven by changes in elevation or sea-level rise and changes of 10 cm can lead to transitions from low to high marsh communities (Mahall and Park 1976a; Zedler et al. 1999). Larger shifts in inundation could lead to loss of marsh vegetation and creation of intertidal mudflats (increased inundation) or upland communities (no longer inundated). While changes in inundation will occur with global change due to changes in sea-level rise and precipitation, salinity is likely to lead to more immediate changes in tidal marsh vegetation, as evidenced by salt water intrusion impacts in coastal Louisiana wetlands, where there has been significant impacts on fresh and brackish marsh plant communities following changes in water salinity (Wang 1988; Flynn et al. 1995; Howard and Mendelssohn 2000).

Salinity impacts: Atwater et al. (1979) first reported that freshwater wetlands of the Delta are characterized by greater plant species diversity than the salt marshes of the lower SF Bay-Delta. Data from our previous research as part of the Integrated Regional Wetlands Monitoring Program (IRWM, www.irwm.org; funded by CALFED) demonstrate that there is a dramatic, non-linear increase in plant species diversity in the fresh region of the SF Bay-Delta (Vasey et al. unpublished data; Figure 1). Sites that are most saline have relatively low species diversity; however, even sites that are less saline in the upper part of the Napa River are not markedly more diverse. Wetlands located further up in the delta, on the other hand, are substantially more diverse and have greater numbers of locally uncommon and rare species than the four lower SF Bay-Delta sites (Vasey et al. unpublished data). Sanderson et al. (2000) suggests that the low species numbers found at Carl's Marsh, a relatively young restored marsh, are not so much a function of marsh age, as its position along the salinity gradient, because despite sampling a total of 1730 0.25 m^2 quadrats in the Petaluma Marsh, an ancient marsh larger than any of our sample sites, they only encountered a total of 14 species.

The greater plant diversity at freshwater sites and the rapid diversity decline to brackish and saline tidal wetlands underscores the ecological importance of freshwater tidal wetlands in the upper SF Bay-Delta and their potential vulnerability to salt water intrusion. Given the large number of locally uncommon and rare species in the freshwater tidal wetland ecosystem, as suggested by Lyons et al. (2005), the loss of these wetlands could have large consequences for ecosystem functions in this region. Critically, Atwater et al. (1979) also documented that during a drought (1976-1977) there were large-scale changes in brackish to near freshwater wetland plant communities, especially in the Carquinez Straits. That result parallels more recent studies from other wetland systems that have suffered temporary shifts toward more saline conditions, for example, along the Gulf Coast (Howard and Mendelssohn 1999, 2000; Thomson et al. 2001; Visser et al. 2002). Freshwater and oligohaline plant species will be the most sensitive to any increases in salinity (e.g., Baldwin et al. 1996).

A rich history of theoretical and empirical inquiry indicates some type of relationship between species diversity (richness and evenness) and ecosystem functions (e.g., primary productivity) (Hector and Hooper 2002; Lyons et al. 2005). The majority of these empirical analyses over the last decade have suggested that species diversity increases productivity (Naeem et al. 1994, 1995), nutrient retention (Ewel et al. 1991), resiliency (Tilman and Downing 1994), and reliability (Johnson et al. 1996; Naeem and Li 1997), while decreasing invasibility of non-native, exotic species (Tilman 1997; Symstad 2000; Zavaleta and Hulvey 2004). In addition, mycorrhizal fungal diversity (van der Heijden et al. 1998) and insect diversity (Knops et al. 1999) have been correlated with plant species diversity. These studies support models indicating increased plant diversity is associated with higher diversity levels at other trophic levels (e.g., Dunne et al. 2002a, 2002b, 2005). Zedler et al. (2001) found that within California wetlands, biodiversity and function are positively related. One relatively uncommon species (*Triglochin concinna*), for example, was found to play a keystone role in facilitating the co-occurrence of a more common species that, under undisturbed marsh plain conditions in this region, is an important member of the community.

In addition to shifts in plant distributions, significant decreases in primary productivity will result from gradual changes in water salinity, with lower productivity in saline marshes. Productivity data from the SF Bay-Delta are limited; however, Mahall and Park (1976a) estimated productivity for *Spartina foliosa* ranging from 270 to 690 g/m^2, and 550 to 960 g/m^2 for *Salicornia virginica*. In comparison, Atwater (1979) found end-of-year biomass ranging from 300 to 1700 g/m^2 for *S. foliosa* and 500 to 1200 g/m^2 for *S. virginica*. Similarly, in other estuarine marsh systems, production rates are consistently lower in salt marshes (Odum 1988), likely due to the added stress of high salinities in salt marsh soils. Our more recent data collected in the past two years indicate similar ranges in production, with a significant decline in biomass between freshwater to brackish, and brackish to saline tidal wetlands (Schile et al., unpublished).

Finally, most wetland plants are not eaten directly but enter the estuarine food web as detritus; therefore, it is important to consider decomposition rates of estuarine plants in order to evaluate available productivity for food-web support. Few data are available on decomposition rates of San Francisco Bay wetland plants; however, food-web studies from other regions indicate that *S.*

virginica is less labile and slower to enter the food web (Kwak and Zedler 1998). The non-linear shifts in diversity, productivity, and the concomitant changes in primary producer communities will likely have ecosystem level effects that are reflected in wetland plant species composition and structure.

Inundation impacts: Substantial work in estuarine wetlands has shown that plant zonation within a wetland is based primarily on inundation rates, largely as determined by elevation across the wetland. Mahall and Park (1976b, 1976c) showed that both salinity and soil aeration changed with elevation and that both were critical in determining the relative abundance of *S. foliosa* and *S. virgnica* in San Francisco Bay. Similar early work by Purer (1942) in southern California and Hinde (1954) in San Francisco Bay showed that elevation is a key factor in determining plant distributions. Detailed surveys at San Quintín Bay, Baja California found that salt marsh plants respond to elevation differences as small as 8 cm (Zedler et al. 1999). Sanderson et al. (2000) found similar sensitivity of salt marsh plant distributions to elevation in San Francisco Bay and also identified the importance of tidal channels in influencing plant distributions.

At the low end of the marsh, plants typically are stressed by excessive inundation and anaerobiosis, affecting both productivity and overall distributions (Chapman 1974; Mendelssohn and Morris 2000). Wetland plants have many specific adaptations that allow them to tolerate anaerobic conditions. Many species have well developed aerenchyma that allows oxygen to diffuse to roots and rhizomes (Armstrong 1979), and some species (including *Schoenoplectus*, and *Juncus* spp.) can transport oxygen to roots via pressurized ventilation and convective gas flow (Grosse et al. 1991). *Spartina alterniflora* and other species have physiological adaptations to deal with low oxygen levels (Mendelssohn et al. 1981). Even with these adaptations, increased inundation rates associated with increases in global sea-level rise will stress marsh plants and potentially shift plant distributions.

Furthermore, elevations within a wetland do not remain static over time. Estuarine wetlands tend to be depositional environments, with the accumulation of both mineral and organic matter that is delivered from the estuary through tidal channels and overbank flooding. Elevation in most coastal and estuarine wetlands remains relatively stable because sediment accumulation remains in relative balance with global sea-level rise, subsidence, decomposition of organic matter, and tectonic activity (Reed 1995; Callaway et al. 1996). Across the marsh, there may be varying contributions to sedimentation rates from outside inputs and local organic matter accumulation (Bricker-Urso et al. 1989; Culberson et al. 2004)

Mid-range predictions of increased sea-level rise associated with climate change range from 30 to 50 cm over the next 100 years, however, uncertainty in predicting climate change impacts are relatively large due to uncertainty in future emissions, as well as climate feedbacks (IPCC 2001). Most estuarine marshes accumulate 3-8 mm of sediment per year (Stevenson et al. 1986; Reed 1990; Callaway et al. 1996), and this compensates for sea-level rise and other processes listed above. However, substantial data from Louisiana, Chesapeake Bay and modeling studies have shown that as increases in relative sea level get close to 10 to 12 mm/yr most marshes can not keep pace and vegetation may be inundated and converted to open water/mudflats (Baumann et al. 1984; Kearney and Stevenson 1991; Boesch et al. 1994; Morris et al. 2002). Historic data from other systems has shown that slower increases in relative sea level (or loss in elevation) can lead to shifts in vegetation communities over time (Warren and Niering 1993). In addition, there has been growing concern recently that sea-level rise may be much greater due to more rapid melting of terrestrial ice sheets, primarily in Greenland and the Antarctic (Overpeck et al. 2006; Rignot and Kanagaratnam 2006). Substantial uncertainty remains concerning rates of melting for these ice sheets; however, large contributions to sea level from these sources are possible and would have dramatic effects on estuarine wetlands.

Landscape-Level Effects

While it has long been recognized that wetlands are ecotonal features between upland and open water, we also think of this complex of wetlands in the greater SF Bay-Delta as functioning across scales: as wetland patches displaying within-patch variability that is important for species (bird, fish, mammal, etc.) diversity and survival, as groupings of sites within a land-water interface, influencing water quality downstream from them, and being influenced by upland watersheds, and also as a larger bay and delta wetland ecosystem that responds to larger-scale gradients such as salinity and sediment availability. The diversity and configuration of wetlands within the SF Bay-Delta are additional considerations. The response of individual sites to changes in salinity, inundation and sedimentation will be influenced by connections between and among wetlands in a larger setting, and concentration on functional responses at individual sites can miss interactions between patches and flows between and across ecotones and patches. For example, changes in inundation and salinity will result in different shifts in local plant communities across the salinity gradient. Cumulatively, these local shifts will result in shifts in overall, estuarine-wide productivity from marshes that will influence productivity and habitat preferences for fish. A non-linear spatial modeling approach will be required to capture these complexities.

Effects on Estuarine Fish Communities

For estuarine animals, including resident fishes, salinity plays a critical role in determining not only community composition, but also behavior, growth, and reproductive success (Carpelan 1961; Rao 1977; Whitfield 1999; Matern et al. 2002). Current research on resident fish communities in the SF Bay-Delta suggests that there are strong shifts in the resident fish fauna as one moves from the high salinity bay into the fresher reaches of the SF Bay-Delta (e.g., Matern et al. 2002; Brown 2003). Embedded within this pattern of change for fish assemblages is the greater degree of invasion (as measured by percent of non-indigenous species) in fresher waters relative to higher salinity ones (Bay-Delta Science Consortium 2004). These differences in community structure likely both reflect and induce changes in food-web structure (e.g., see Leibold et al. 1997 and references therein).

Food-web structure is intimately related to biodiversity and species identity. For example, food webs have been empirically shown to be longer in systems with higher functional diversity (Vander Zanden 1997). Further, exotic species have been shown to often reduce biodiversity (Sala et al. 2000), which in turn should lead to lower connectance in food webs (Dunne et al. 2002). Recent theoretical models suggest that systems with few strong links are less stable than those with many reticulate connections, and thus might lead to chaotic or unstable ecosystems (McCann et al. 1998). One of our goals will be to determine how food chain length varies across the gradient of sites examined and to evaluate how these webs are structured as far as food-web dependence (source or sources of primary production supporting consumers).

Given the paucity of information on potential wetland dependence of fishes in the SF Bay-Delta, changes in salinity and flooding regime, and concomitant changes in presence and type of emergent vegetation, could potentially have dramatic effects on fish fauna. This work will not only provide us with much needed information about the degree of wetland dependence of resident fishes but will provide a foundation upon which we can develop a model for how this dependence (and fish communities broadly) might change in response to global climate change.

One approach that has greatly contributed to the understanding of food webs and habitat use in coastal wetland systems is measuring the natural abundance of the stable isotopes of carbon ($\delta^{13}C$), nitrogen ($\delta^{15}N$) and sulfur ($\delta^{34}S$)(see Michener and Schell 1994 for review). The use of stable isotope ratios in food-web ecology is based on the known existence of differences in the isotopic signatures of different types of primary producers (Fry and Sherr 1984; Owens 1987; Trust and Fry 1992). Since animals tend to reflect the isotopic composition of their food sources in a predictable manner (DeNiro and Epstein 1981; Peterson et al. 1986), variations in food-web structure among distinct habitats lead to differences in the isotopic composition of animals feeding in those systems. These isotopic signatures can be used to examine patterns of carbon flow, identify the sources of primary production supporting consumers and estimate the trophic level at which an animal is feeding.

Marine phytoplankton, benthic microalgae, and C-3 and C-4 marsh plants each tend to each exhibit characteristic isotopic signatures (Fry and Sherr 1984; Peterson and Fry 1987). Measurements of $^{13}C/^{12}C$ have proven particularly useful in distinguishing phytoplankton, C-4 marsh plants and C-3 marsh plant production, (Fry and Sherr 1984; Peterson et al. 1986; Hobson et al. 1994; Macavoy et al. 1998; Stapp et al. 1999; Herzka et al. 2002). Benthic carbon sources such as seagrass, benthic macroalgae and C-4 marsh plants tend to be enriched in ^{13}C compared to marine or estuarine phytoplankton, whereas C-3 terrestrial plants are usually more depleted (Fry and Sherr 1984). In the case of sulfur, the existence of large differences in the $\delta^{34}S$ of seawater sulfate and sulfides (ca. 30‰) allows $^{34}S/^{32}S$ to be used to distinguish between benthic and pelagic producers in estuarine systems (Peterson et al. 1986; Macavoy et al. 1998). In addition, the consistent enrichment (ca. 3.4‰) in ^{15}N between a consumer and its diet has led to the use of $\delta^{15}N$ values for estimating trophic level (DeNiro and Epstein 1981; Owens 1987; Hobson et al. 1994). Further, individual primary producer species within the same environmental milieu often have distinct signatures, providing researchers with the ability to discriminate various potential food resources from the isotopic composition of consumers (e.g., Peterson et al. 1985). However, since the isotopic composition of inorganic nitrogen can vary as a result of anthropogenic input or due to processes associated with nitrogen cycling in aquatic systems, the nitrogen isotopic composition of primary producers must be characterized before estimating the trophic level of an organism (Cabana and Rasmussen 1996; Fry 1999). It is the simultaneous use of multiple stable isotopes that has provided the most detailed characterization of the pathways of energy flow in coastal systems, and great success has been met with wetland systems even when using only two isotopes (carbon and nitrogen), let alone three, as proposed in this study (e.g., Peterson et al. 1986; Peterson and Fry 1987; Kwak and Zedler 1997). While other work demonstrates that there is wide variability in the C and N signatures of plants in the Bay-Delta, there were broad patterns based on plant and habitat type (Cloern et al 2002). We will be leveraging the additional information afforded by our decomposition experiments, another axis on which to analyze isotopic signatures (sulfur), primary consumer isotopes, and diet and modeling information to help us to discern the broad scale patterns of food webs in these wetlands. These methods are a powerful and rapid tool for investigating trophic relationships within habitats, and will allow us to test the trophic relationships in food webs under different salinity regimes.

APPROACH

Sampling Sites

We have selected six natural marsh ecosystems as the focus for this investigation (Figure 2). These six sites span the full salinity gradient of the SF Bay-Delta and represent some of best representatives of historic tidal wetland landscapes in the region. They also have a rich legacy of scientific investigation and baseline data. Our reason for choosing relatively undisturbed remnants of the SF Bay-Delta’s historic wetland ecosystem is because these sites should provide the greatest insight into how climate change will impact existing wetland conditions and also provide reference conditions to inform future restoration activities.

The first two sites represent the saline end of the spectrum. **China Camp State Park** is one of two components of the San Francisco Bay National Estuarine Research Reserve (SF Bay NERR). The salt marshes of China Camp consist of about 125 ha with an uncharacteristically intact upland transition and large expanse of tidal mudflats leading to the deeper portions of southern San Pablo Bay. **Petaluma Marsh** occurs along the middle reaches of the Petaluma River, a large tidal slough that drains into the northern part of west San Pablo Bay. This area represents the largest intact salt marsh in California, covering over 800 ha. It is managed as a wildlife refuge by the California Department of Fish and Game (CDFG). It is easily accessible by boat and has been the focus of many scientific wetland studies. Both China Camp and Petaluma Marsh present high ambient salinities (summer salinities around 25-45 ppt), and they collectively capture the richest concentration of salt marsh species and habitat diversity within the SF Bay-Delta.

Two sites have been chosen that represent brackish tidal wetlands. **Coon Island** is in the upper portion of the Napa River drainage in the eastern part of San Pablo Bay, a wildlife refuge managed by CDFG. It is one of the last undiked, large tidal wetland landscapes in the upper San Pablo Bay area. Coon Island covers about 175 ha and has received intensive investigation as part of the CALFED-sponsored IRWM project. **Rush Ranch Open Space Preserve** is in the upper portion of Suisun Slough in the Suisun Bay region. Rush Ranch Open Space Preserve is the second SF Bay NERR component. It contains the largest remnant brackish tidal wetland in the SF Bay-Delta, covering well over 400 ha. It also has a long history of scientific research because of its unique landscape setting and extent of undiked brackish wetland ecosystem. Both Coon Island and Rush Ranch share a high level of species richness and diversity. Ambient summer salinity regimes at both localities vary temporally and spatially within each site but average approximately 15 ppt.

The last two sites represent freshwater or near freshwater tidal marshes. **Browns Island** is in the western end of the freshwater delta created by the confluence of the Sacramento and San Joaquin rivers. Browns Island is owned by the California State Lands Commission but managed by the East Bay Regional Parks Agency. Browns Island covers about 200 ha and has received long-term scientific research as well as recent intensive investigation as part of the IRWM project. Its salinity regime is close to 0 ppt in low marsh areas, but water diversions, droughts and levee breaks have historically introduced rare saltwater influences creating areas of high marsh that can approach 10 ppt during the dry summers. **Sand Mound Slough** is farther up the gradient, and it represents a number of small, intra-channel remnants of historic Delta wetlands. Fresh water conditions (0 ppt salt) are almost always found around these islands, except for during rare levee breaks. The Sand Mound Slough islands cover about 25 ha in total and are owned by California State Lands Commission and under the management jurisdiction of the CDFG. There have been some scientific investigations of these wetlands (e.g. Atwater et al. 1979; Watson 2004); however, they are not as well known as the other five selected study sites. As most of the Delta region has been diked and converted to agriculture, these sites present some of the last, best remnant examples of this system.

Research Schedule

We are proposing a three-year study, beginning with field sampling for plant diversity, productivity, and elevational distributions that builds on previous work completed as part of the IRWM project (Task 3: *Determine the extent to which increased salinities and rising sea level will affect wetland diversity, productivity, decomposition, and sedimentation rates*). Sampling will be extended to additional fresh and salt marshes that were not sampled as intensively as brackish marshes during the IRWM project. In the first year we also will initiate field evaluations of decomposition and sediment accumulation rates (Task 3), and sampling for isotopes to better understand food-web linkages (Task 2: *Determine the extent to which fish populations are directly or indirectly dependent on tidal wetlands*).

In Year 2, we will complete the decomposition study and plant field work (Task 3), refine the isotope sampling for food-web analysis (Task 2), continue the sedimentation study (Task 3), and complete GIS-based estimates of SF Bay-Delta-wide production (Task 4: *Model a variety of scenarios of rates of sea-level rise and salinity increase as it affects overall ecosystem productivity and carbon flow to fish communities*), based on field sampling from Year 1, our previous research, and published values. In Year 3, we will complete isotope sampling (Task 2) and sedimentation study (Task 3), complete all data analysis, and complete GIS modeling predictions for productivity and food-web impacts for various global change scenarios (Task 4).

Field Sampling

Diversity: Through our vegetation surveys in IRWM, we have collected vegetation presence and cover data in over 300 randomly located plots at Coon and Browns Islands (Figure 1). We plan to continue this sampling at the remaining four sites (Task 3). At each site, we will generate a minimum of 100 random points using ArcMap, locate them in the field using GPS units, and record species presence and cover in a 3 m^2 diameter circular plot. We will then compare species diversity patterns within and between the sites using multivariate analysis and measures of similarity and dissimilarity indices (Magurran 2004). For all six sites, we will also use a method similar to Sanderson et al. (2000) that will measure 0.25 m^2 quadrats at 0.5 m intervals from the creek channel bank along perpendicular transects to 15 m into the interior away from the bank. The number of these transects will depend upon the nature of the drainage network at each site and the size of the site. This additional study should give us better insight into the species composition and habitat structure along creek banks, an element in juvenile fish habitat, and better insight into how plant species diversity patterns are organized in each different wetland ecosystem. Both broad scale and more locally stratified data sets will be compared using multivariate measures of similarity and clustering (Sanderson 2000). Our ultimate goal will be to construct an accurate picture of how diversity and productivity are connected to the food-web patterns across freshwater, brackish, and salt marsh systems.

Productivity: Our productivity measurements will focus on six vascular plants that are widespread across the bay-delta: *Salicornia virginica*, *Spartina foliosa*, *Bolboschoenus maritimus* (formerly *Scirpus maritimus*), *Schoenoplectus americanus* (formerly *Scirpus americanus*), *Schoenoplectus acutus* (formerly *Scirpus acutus*), and *Typha angustifolia* (Task 3). The first two species are dominant in salt marshes, the second pair are dominant in brackish marshes, and the last pair are prevalent in freshwater systems, although there is overlap in species distributions.

Over the past two years, we have developed and are calibrating non-destructive methods for estimating annual net primary productivity (ANPP) of a suite of dominant species within the SF Bay-Delta. We determined that total stem length, which incorporates stem density and individual stem height, is the best proxy for ANPP of *Typha*, *Bolboschoenus*, and *Schoenoplectus* species and leaf area index (LAI) significantly predicts total standing biomass of *S. virginica* (Schile et al. unpublished data). We will continue to calibrate our methodology in the first year of research and sample ANPP of all six species across all sites (Table 1). We will stratify our sampling by species and high/low marsh and randomly sample ANPP at five 0.25m^2 plots within each location beginning in July.

Additional sampling will be completed for the perennial subshrub, *S. virginica*. At the beginning of the growing season in all of the *S. virginica* plots, LAI will be measured using a LiCor Plant Canopy Analyzer and all biomass will be clipped to the ground. The horizontal coordinates will be recorded and the procedure will be repeated in a neighboring plot at the peak of the growing season, determined by the presence of inflorescences, and ANPP will be determined by subtracting the initial mass from the second. For all other species, each stem will be measured and grouped in 10-cm height classes, stem density counted, and all plant material within the plot removed. Samples will be brought back to the laboratory where they will be rinsed, sorted by species and live/dead material, dried at 60°C for 2 days, and weighed. The relative contribution of algal productivity to the food web will be evaluated through stable isotope studies in year 1 and 2. If macroalgal productivity contributes significantly to the food web, we will measure macroalgal productivity directly in years 2 and 3.

Decomposition: Most estuarine food webs are detritus based, and little vascular plant biomass is consumed directly (Day 1989). In order to evaluate the movement of vascular plant productivity into the food web, we will measure aboveground plant decomposition rates, data that have been lacking within San Francisco Bay (Task 3). Decomposition rates will be measured for all six species that are measured for productivity, and these measurements will be completed in both low and high marsh locations at each site.

Aboveground tissue (leaf and stem) of each species will be collected at the end of the growing season in 2006. Approximately 10-20 g of tissue of each species will be placed in separate mesh bags, and the bags will be staked to the ground in high and low marsh areas (Hemminga and Buth 1991). At each marsh/site there will be 8 replicate bags in low and high marsh locations. Bags will be collected at 1 mo, 6 mo and 1 yr. The remaining biomass will be rinsed, dried, weighed and compared to the initial biomass in order to determine rates of decay for each species. Species will be tested at all marshes in order to evaluate shifts in decomposition rates across salinity regimes. Stable isotope composition of detrital material will be evaluated in addition to fresh material, in order to develop an understanding of isotopic shifts during decomposition. This information will be useful for parameterizing the models of trophic dependence.

Elevation surveys and sedimentation rates: We will complete multiple elevation surveys from the marsh edge to the marsh-upland transition at each site in order to determine the range of elevations occupied by dominant marsh species across salt, brackish, and freshwater marshes and to identify the lower limits of vegetation in these marshes (Task 3). Three to five transects will be surveyed at each station, using a high-precision RTK (real-time kinematic) GPS receiver (Trimble 5800). RTK GPS receivers have an accuracy of 1-3 cm in the vertical axis, and surveys will be tied into established benchmarks at each location, so that elevations can be compared across sites. Along each transect, vegetation and elevation will be sampled every 1-5 meters, with more intensive sampling around any topographic transitions or breaks. Vegetation sampling will be similar to that outlined above for plant diversity. Similar surveying has been completed by Parker, Vasey, Callaway and Schile for the CALFED-sponsored IRWM project and for a project with the South Bay Salt Pond Restoration Project.

Along the surveying transects, we also will establish marker horizon stations to measure sediment accumulation rates (Task 3). A minimum of six marker horizon stations will be established at each site. At one or two stations per site, Surface Elevation Tables (SETs) will also be established so that we can measure changes in marsh surface elevation in relation to surface sediment accumulation rates (e.g., Cahoon et al. 1995, Reed 2002).

Marker horizons are used widely to measure short-term sedimentation on the wetland surface (Cahoon and Turner 1989; Stoddart et al. 1989; French et al. 1995). This method works well in depositional areas, as are typically found in estuarine wetlands. Bioturbation typically is not a problem in vegetated wetlands, so this should not affect marker horizons. To measure accretion, feldspar markers will be laid down over the existing wetland surface at each sampling station in summer 2007. Marker plots will be 0.5 x 0.5 m, and a thin layer of feldspar will be sprinkled over this area. Plots will be marked with small PVC pipes in each corner so that they can be easily relocated for future sampling. Over time markers can be washed out by erosion, PVC pipes can be removed, and sites can be impacted by unpredictable disturbances. In order to ensure that marker locations can be relocated over an extended time period and to ensure a good estimate of small-scale spatial variability, replicate marker plots will be established at each sampling station. Markers will be sampled in summer 2008 and summer 2009 by collecting a small core or plug of material within each 0.5 x 0.5 m area with a marker horizon. The depth of newly deposited sediment on top of the marker horizon is measured using a caliper. Following measurement, the soil plug is returned to its prior location. Two plugs will be measured within each plot, and mean values for each plot will be used for data analysis.

SETs offer a method of measuring wetland surface elevation with very high precision, e.g., within millimeters (Boumans and Day 1993; Cahoon et al. 1995). A permanent station is set up to establish a benchmark, and the portable SET instrument is attached to this benchmark to measure changes in the elevation of the wetland surface over time. To establish the permanent benchmark station, a 7.5 cm-diameter thin-walled aluminum pipe is driven into the ground until refusal (this is typically 3-6 meters depending on site conditions). The pipe is pounded into the ground with a pile driver that is operated manually rather than by machine, ensuring that impacts to the wetland from setting the pipe are minimal. After the pipe is set in the ground, it is cut off approximately 30 cm above the soil surface, and a specially machined 5 cm-diameter thick-walled aluminum insert pipe is cemented into the larger diameter pipe. This machined insert is designed to fit exactly the portable SET instrument; the insert establishes a permanent location with a stable elevation (at the top of the insert pipe) from which changes in elevation can be measured over time.

Once a station is established, measurements of wetland surface elevation relative to the pipe will be made on an annual basis. The first measurement will be made in summer 2007. At each station, the SET is designed to measure elevation at 36 points (9 points on a square grid at each of four different positions for a station). A large number of points is necessary in order to measure small-scale changes in elevation with a high degree of precision and accuracy. Mean changes in elevation over time at each station will be used for data analysis. In addition to data collected as part of the proposed research, we will also incorporate data from previous SET and marker horizon studies at the CALFED-sponsored BREACH study sites in the Delta, Suisun Bay, and San Pablo Bay (e.g., Reed 2002).

Sources of primary production supporting fishes and macroinvertebrates: During both the peak growing season (Spring/Summer) and during periods of plant senescence (Fall/Winter), we will collect plant and animal samples for stable isotope ratio analysis at the pre-selected wetland sites across a gradient of salinity within the SF Bay-Delta (Task 2). Collections of emergent vascular vegetation will be performed at each site. We will also collect macroalgae, live seagrass leaves, and samples of seagrass or macroalgal wrack if present. In order to minimize within-species variation of isotopic signature, which can result from differential discrimination of various tissues (Currin et al. 2003; Hobson and Bairlein 2003) or age or life-stage of tissues (Currin et al. 1995; Cloern et al. 2002), the same tissues (e.g., fresh leaves) will be sampled from plants at each location. Whole water samples will be collected for particulate organic matter (POM) during spring tides and vacuum filtered onto precombusted GFF filters (Herzka et al. 2002).

Multiple studies indicate that benthic microalgae are an important source of carbon for consumers in tidal marsh systems (e.g., Sullivan and Moncreiff 1990; Creach et al. 1997). Algal mats that display a strong degree of cohesion can be sampled by carefully removing the superficial sediment layer. Alternatively, we will use a previously developed vertical migration technique that allows for clean microalgal samples to be obtained (Currin et al. 2003). Samples for total sediment organic matter (SOM) will be collected by carefully removing the top 1-2 cm of sediments using a plastic syringe.

The three most abundant species of fishes and macroinvertebrates in each habitat type will be targeted for isotopic analysis. Particular attention will be paid to species that are either threatened (e.g., tule perch), commercially important (e.g., salmonids), or that represent known prey items for threatened species (e.g., *Corophium* spp, gobies). Isotopic analyses will be restricted to muscle tissue where practical. As is standard in the processing and of samples for stable isotope analysis, all samples will be placed on ice in the field immediately following their collection and frozen pending subsequent preparation for isotopic analyses. At least 5 replicates obtained from individuals will be analyzed, except where it is either impossible (benthic microalgae) or noted otherwise. In the laboratory, all samples will be examined under a dissecting microscope to remove attached organisms, target tissues will be dissected and thoroughly rinsed in distilled water prior to drying for 24-48 H at 60 °C. Dried samples will be finely ground and loaded into tin boats. For the primary producer and SOM samples that may contain carbonates, half the sample will be acidified in 1 N HCL prior to $\delta^{13}C$ isotopic analysis and the rest will be destined for $\delta^{15}N$ and/or $\delta^{34}S$. All the target taxa will be analyzed for $\delta^{13}C$ and $\delta^{15}N$. Due to the higher cost associated with $\delta^{34}S$ analyses, we will analyze only select set of samples chosen based on a thorough examination of $\delta^{13}C$ and $\delta^{15}N$ results. We foresee that as for previous studies (e.g. Peterson et al. 1986), sulfur analyses will be useful for distinguish benthic and pelagic production in wetland systems.

Fish distribution and abundance data: Our sampling will largely aim to characterize a subset of the fish community with regard to stable isotope ratios of their tissues, in order to assess trophic dependence. Nonetheless, relative abundance/occurrence of species will be noted during sampling. For a more comprehensive understanding of the relationship between fish community characteristics and wetland type, and to parameterize our models, we will rely on a thorough review of published data, including reports, peer-reviewed articles, and databases available through collaboration with other scientists (e.g., Peter Moyle) and expert opinion (Task 2).

Isotope Analysis

Isotope samples will be analyzed at the Stable Isotope Facility at the University of California, Davis for analysis of $\delta^{13}C$ and $\delta^{15}N$ (Task 2). Analyses will be carried out on a Europa Scientific Hydra 20/20 isotope ratio mass spectrometer using standard methods (Lajtha and Michener 1994). International standards obtained from the National Bureau of Standards, Gaithersburg, Maryland, USA will be used. Isotopic analyses for ^{34}S will conducted at the Analytical Facility of the Colorado Plateau Stable Isotope Facility. After combustion, sulfate will be precipitated as $BaSO_4$, converted to SO_2, and the isotopic ratio determined by mass spectrometry using a Finnigan MAT 251 stable isotope mass spectrometer.

Data Analysis

In order to evaluate effects of potential salinity shifts on diversity and productivity we will make comparisons for these parameters across salt marshes (China Camp and Petaluma Marsh), brackish marshes (Coon Island and Rush Ranch), and freshwater marshes (Browns Island and Sand Mound Slough), using Analysis of Variance (ANOVA) and various multivariate analyses, such as cluster analysis, and similarity dissimilarity index comparisons. In addition, we also will evaluate salinity effects on productivity, through the greenhouse experiments, with separate ANOVA tests for productivity of each of the six species of interest across the experimental salinity treatments. We will determine exponential decay rates for decomposition of plant material using standard approaches (e.g., Hemminga and Buth 1991).

In evaluating changes in food availability and food-web relationships for fish, we will use biplots of $\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$ in combination with end-member mixing models to identify sources of primary production supporting resident fishes in each wetland (Vander Zanden 1997). We will also use shifts in the N isotopes from primary production to consumers to determine relative food chain length (Michener and Schell 1994; Deegan and Garritt 1997; Connolly et al. 2004). These analyses will give insight into food-web dependence, variation in food chain length, and the degree of allochthonous vs autochthonous primary production supporting the food web at each site.

Spatial Modeling

Geographical Information Systems (GIS), landscape ecology and remote sensing provide useful tools for quantifying pattern across scales, linking pattern to process, and scaling-up these results to larger scales (Kelly 1996; Phinn et al. 1999; Tatu et al. 1999; Ozesmi and Bauer 2002; Cohen and Lara 2003; Silvestri et al. 2003; Töyrä et al. 2003; Byrd et al. 2004). The spatial modeling component of this work has two steps. First, we aim to develop relationships between productivity and diversity and food web and fishery dynamics that can be scaled over the Bay, producing detailed current distribution maps of wetland habitat diversity and productivity that can be linked to our analyses of food-web dynamics and fisheries use. Second, these models will be used with simulated salinity, inundation and sedimentation scenarios associated with climate change to qualitatively evaluate marsh distributions and fisheries response across the SF Bay-Delta landscape (Task 4).

We will use existing spatial data from the SF Bay EcoAtlas as a wetland base map. We will develop predictive multivariate models linking site productivity and diversity data with local and landscape variables, exploring a number of geospatial tools including geostatistics and non-parametric multivartiate models. Geostatistics have been used for wetland modeling: Horssen et al. (1999) demonstrated that wetland plant presence/ absence could be modeled to the species level using geostatistics combined with a regression model that included soil type, land use and hydrological conditions. Parametric or rule-based models such as simple and multiple regression, or GIS overlay analysis will not be useful in our study, as we will be evaluating nonlinear responses. Instead, we will utilize a range of non-parametric and nonlinear models supported by Geographic Information Systems. For example, we will evaluate Classification and Regression Trees (CART) (De'ath and Fabricus 2000, Feldesman 2002), Support Vector Machines (Vapnik 1995, Guo et al. 2005) and nonlinear kriging (Moyeed and Papritz 2002). These three models can be used to spatially interpolate across unknown areas, using points with known values, and do so in different ways. First, CART uses input variables to determine a series of thresholds of response, and allows for hierarchical relationships and interactions between data sources. Second, Support Vector Machines are a new generation of machine learning algorithms used to find optimal separability between classes within datasets, and can be used to predict response variables across scales. Finally, kriging estimates each unknown value using weights assigned to known point values, with higher weights assigned to closer points, following the principles of spatial autocorrelation (points closer together have a greater chance of being alike than those further away) (Isaaks and Srivastava 1989, Bailey and Gatrell 1995). Nonlinear kriging methods predictions are more precise when a Gaussian random process is inappropriate to model the observations (Atkinson et al. 1994, Moyeed and Papritz 2002). All models will be validated using the data from the site not included in the modeling.

Once validated, we plan to evaluate habitat response to different likely changes in estuarine drivers as a result of climate change through evaluation of a number of scenarios depicting changes in salinity, inundation and sediment availability. Our scenarios will be based on predicted SF Bay-

Delta salinities from current USGS research (CASCADE model - http://sfbay.wr.usgs.gov/cascade/) and IPCC estimates of SLR (IPCC 2001). Sediment scenarios will be based on estimates of sediment availability from published reports (e.g., recent USGS work of Schoellhamer and others) and will include a range of conditions where marshes are able to keep pace with SLR (high sediment availability), convert to lower elevations (mid-range availability), or face complete inundation (low availability). Model output will be predicted distributions of salt, fresh and brackish marsh habitats based on these scenarios, and these distributions will be used in conjunction with the relationships based on earlier modeling to predict impacts on fish populations. These predictions will be based both on productivity-food web relationship, as well as shifts in habitat distributions.

RELEVANCE TO THE CALFED SCIENCE PROGRAM

The proposed research directly addresses questions related to CALFED priority Topic 3 (Trends and Patterns of Populations and System Response to a Changing Environment) and Topic 4 (Habitat Availability and Response to Change). As outlined specifically in the CALFED PSP description of Topic 3, "*... climate change is expected to not only change the hydrology of watershed rivers, but also raise ocean levels. These two factors alone may alter the salinity balance of the Delta. The pattern of how species, structures and system water operations might respond to these changes is not well understood in that the response may be stepwise, eventually reaching thresholds that cause potential catastrophic changes, or gradual with concomitant gradual or linear responses of the attribute of concern.*"

Our proposed research will address almost every questions of interest outlined in the CALFED PSP for these two topics:

- *What are the driver/response relationships of key species? How are these relationships best described (e.g. continuous, stepwise, other)?*
- *What are the implications for management strategies of the type of response of species?*
- *What models are needed to describe these driver/response relationships?*
- *How will the extent and quality of Delta habitat for key species be affected by a variety of future scenarios such as climate change and sea-level rise?*
- *How will future scenarios affect abiotic and biotic drivers and how will these drivers, in turn, affect key species at different geographic and temporal scales? How will key species respond to these changes?*

In addition, our proposed work will include many key components outlined for these topics, including: *development of models; use and synthesis of existing information; an inventory and analysis of current habitat extent and condition; development and use of spatially-explicit models to analyze and map the potential effects of anticipated stressors on existing habitats; consideration of abiotic factors including salinity, water depth, and hydrologic regimes; consideration of future scenarios for climate change and its effect on abiotic and biotic factors.*

Finally, the CALFED PSP calls for proposals that include other important priorities, including: synthesis, integration, collaboration, and models. As outlined throughout our proposal, this research included synthesis of existing data on plant productivity and diversity, sediment dynamics, and fish populations, as well as new data to be collected in these areas. Our proposal also emphasizes integration across multiple areas from sediments and plants to fish and landscape ecology, with a broad range of collaborators from four institutions (SFSU, SF Bay NERR, USF, and UC Berkeley). The proposed work also incorporates the final priority area of modeling, with a centerpiece of the proposed research being the development of a model to evaluate potential impacts of climate change on SF-Bay Delta wetlands and fish populations.

EXPECTED RESULTS AND BENEFITS

The proposed research will provide data and knowledge about the SF Bay-Delta that will give insight into important management issues for the SF Bay-Delta and beyond. In particular, the research will provide information on patterns of wetland vegetation diversity and primary productivity rates across a range of salinity gradients for the Bay. Comparative tidal wetland plant diversity analyses spanning the full salinity gradient in the SF Bay-Delta have not yet been published. While data on vascular plant productivity have been collected widely in East and Gulf Coast estuaries, very few estimates are available from SF Bay-Delta or other Pacific Coast estuaries (e.g., Atwater et al. 1979; Mahall and Park 1976a; Covin and Zedler 1988; Callaway and Josselyn 1992). The data collected from this study will be valuable as a comparison with biomass data from other estuaries. They will provide the basis for evaluating non-linear shifts in productivity and for calculating landscape-scale productivity estimates for the SF Bay-Delta.

Similarly, the region is lacking in terms of data on decomposition rates. While rates are widely available from other ecosystems (Day et al. 1989; see Curcó et al. 2002 for a review of production and decomposition in Mediterranean tidal marshes), our estuaries differ in terms of tidal range, freshwater inputs, and temperature so it is not possible to directly convert measured rates from other estuaries to this region. These data, along with the isotopic analysis, will improve our understanding of food-web dynamics in the SF Bay-Delta and will provide the background for making predictions about non-linear shifts in food-web dynamics as salinities change and large areas of the freshwater delta become dominated by more brackish species. In addition, few data on sedimentation have been collected within the SF Bay-Delta (Patrick and DeLaune 1990; Reed 2002; Culberson et al. 2004), despite the importance of these data for evaluating potential impacts from sea-level rise and for understanding dynamics of future large-scale restoration projects.

Finally, the GIS modeling capabilities that will be developed from the project will improve our ability to model and evaluate estuarine impacts on landscape-scale. The results from the models will be used to visualize non-linear responses to landscape-scale future changes to the SF Bay-Delta. The modeling approach and tools developed as a part of this project could be applied not just to productivity and food-web impacts, but also to other large-scale impacts and drivers in the SF Bay-Delta.

In terms of connecting this knowledge to management issues, there are many benefits from the proposed research. First, the results from the field and modeling efforts will give insight into scenarios of potential progression of ecosystem characteristics within the SF Bay-Delta under global change. The model will allow us to make predictions about shifts in wetland habitats and productivity on a large-scale, as well as shifts in trophic interactions with changes in sea-level rise and precipitation. These predictions can be tested directly against observations over the next decade or two to improve our understanding of these large-scale ecosystem dynamics, giving improved guidance to resource managers. For instance, if the model predicts large-scale impacts to important species through the food-web analysis, it could be possible to shift the management of freshwater resources within the SF Bay-Delta to minimize salinity changes and ensuing impacts. Currently the CALFED Bay-Delta Authority is charged with water management decisions within the region, and the information generated from this project could be very valuable as they balance water needs of agriculture, industry, households, and natural ecosystems.

Similarly, the results from this project will give insight into management and restoration priorities for wetlands habitats within the SF Bay-Delta. Little research has been done to compare salt, brackish and freshwater systems within the SF Bay-Delta. The proposed research would help to identify benefits of these habitats on a larger scale, both through the direct observations and the modeling efforts. For example, a number of fish species, many of them commercially important, threatened, or endangered, rely on specific habitats within the SF Bay-Delta for reproduction or feeding, while others undergo ontogenetic shifts in habitat use, requiring distinct subsets of the bay/estuary habitats (and salinity regimes) at different life history stages (Matern et al. 2002; Brown 2003). Many of these species have undergone dramatic declines in recent years (e.g., the threatened Delta Smelt, *Hypomesus transpacificus)*, while other species have shown increases (e.g., some invasives) and others no detectable pattern (Matern and Fleming 1995; Matern et al. 2002). Efforts are being made to understand the mechanisms underlying these shifts in the ichthyofaunal communities, but many of them seem to be clearly related to environmental parameters associated with hydrologic changes (and the concomitant changes to salinity)(Meng and Matern 2001). This project could shed light on some of the trophic causes and consequences of these changes in the SF Bay-Delta. Finally, while the proposed research will give insight directly into SF Bay-Delta management concerns, the results would be applicable to other estuarine ecosystems on the west coast which are likely to be affected in a similar manner by global change.

In addition to semi-annual reports and project summaries that are outlined in the list of project deliverables, the proposed research will result in a number of peer-reviewed publications. In particular, we anticipate publishing manuscripts based on plant diversity, productivity and decomposition; food-web relationships, and model predictions. In addition, we will present the findings from this research at a national conference (such as the meeting of the Estuarine Research Federation, Society of Wetland Scientists, or Ecological Society of America) and at one or two local conferences (dependent on scheduling), including the CALFED Bay-Delta Program Science Conference and the State of the San Francisco Estuary Conference.

QUALIFICATIONS AND FEASIBILITY

The project team has an excellent publication record, and it is anticipated that the proposed research will result in three to five peer-reviewed publications as well as a number of conference presentations, both locally and nationally. In addition, the team has very strong connections with a wide range of local resource managers. Drew Talley has many agency contacts through his role as Research Coordinator for the SF Bay NERR. Through the NERR program, Drew will organize and stage workshops and related public outreach events; this will allow us to leverage the existing education and outreach infrastructure of the SF Bay NERR, and will allow us to provide timely and important findings to coastal decision-makers, managers, and the public. In addition, John Callaway currently serves on the Science Team for South Bay Salt Pond Restoration Project, and has worked on a number of projects with EPA, State Water Resources Control Board, California State Coastal Conservancy, and other state and federal agencies.

The team of PIs for this project has worked together closely over the last three years on an earlier large-scale project, IRWM. They have substantial experience with wetland plants, fish, food webs, and landscape ecology, including a large number of publications. In addition, outstanding facilities are available for the project from all supporting institutions, (SFSU, UCB, and USF). In terms of field work, all relevant equipment, such as Garmin GPS units, Trimbles, LiCor plant canopy analyzer, will be available either through SFSU, UCB, or USF. Boat access to field sites will be possible using Co-PI V.T. Parker’s Zodiac Mark II boat with a 25 hp motor. Research facilities at San Francisco State University include laboratory and greenhouse space, with full support for sample processing and preparation, from drying ovens to scales, and other instruments. Computers dedicated to this project include four Dell laptops capable of advanced data processing and analysis. The isotope analyses will be conducted at the Stable Isotope Facility at University of California, Davis.

All GIS modeling work will be supported through the UCB College of Natural Resources Geospatial Imaging and Informatics Facility (GIIF). The facility has numerous Dell Dimension 4700 with Intel Pentium 4 (3.2 GHz, 800MHz FSB, 1MB cache), w/ 1GB DDR2 400MHz SDRAM, coupled with 17" LCD Flat Panel Displays. These Windows machines host Erdas Imagine 8.7, ESRI ArcInfo Desktop / Workstation 8.3., PCI Geomatica 9.1, Google Earth, statistical packages such as S-Plus 7.0, Fragstats, SaTcan for space/time analysis, and include other open source projects like DIVA-GIS, uDig, NASA World Wind, R for statistics, and OpenOffice2 office. Additional statistical programs are also available for other data, including SAS, SPSS, PC-ORD, and SYSTAT.

As described in the Approach section, the proposed research will be completed over a three-year period, with a phased mix of field, greenhouse, laboratory, and computer GIS analysis. Tom Parker will coordinate the overall project; John Callaway and Mike Vasey will direct the plant component of the project; Callaway will direct the sedimentation study; Lisa Schile will coordinate field and greenhouse work for plant sampling; Drew Talley will oversee field and laboratory work for isotope sampling; and Maggi Kelly will coordinate the GIS component of the research. In addition, two graduate students will work on the project (one at SFSU, and one at UCB), and additional undergraduate and graduate students from SFSU will assist with field and laboratory work at SFSU. SFSU is a research-based academic institution that offers multiple opportunities for undergraduate internships, graduate research, and important job opportunities for career development.

Permission for access to sampling sites has already been obtained for two sites (Coon Island and Browns Island) through our previous IRWM project. Two additional sites are part of the SF Bay NERR (China Camp and Rush Ranch) and permission has been granted through Drew Talley's work at the SF Bay NERR. The other two sites (Petaluma Marsh and Sand Mound Slough) are both managed by CDFG; we do not anticipate any problems with access at these sites, based on our prior experience with CDFG through the IRWM project.

Tables and Figures

Table 1. Sampling strategy for ANPP estimates of dominant species in the San Francisco Bay-Delta.

	Site					
Species	China Camp	Petaluma Marsh	Coon Is.	Rush Ranch	Browns Is.	Sand Mound Slough
S. virginica	X	X	X			
S. foliosa	X	X	X	X		
B. maritimus		X	X	X		
S. americanus			X	X	X	
S. acutus			X	X	X	X
T. angustifolia			X	X	X	X

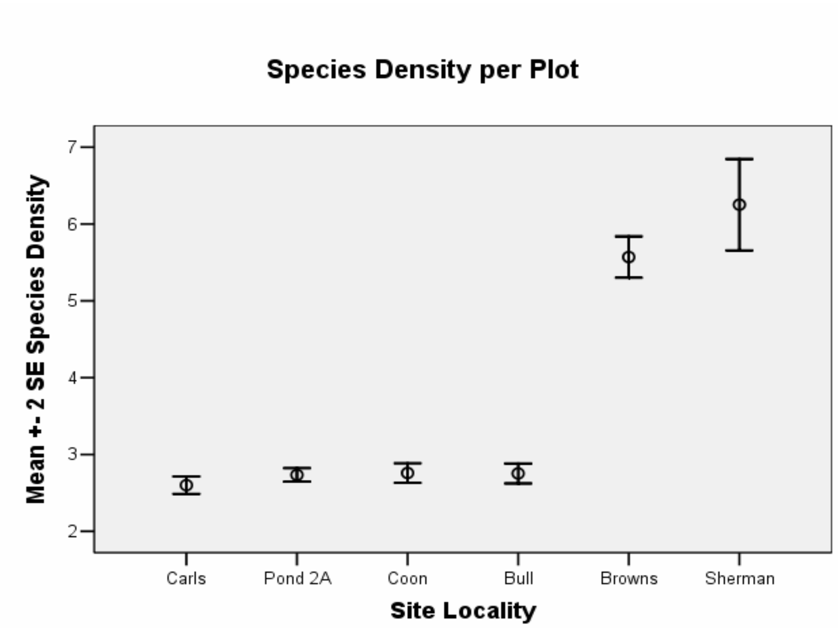


Figure 1. Average number of plant species per 3 m diameter plot (Number of random plots per site: Carls (412), Pond 2A (447), Coon (427), Bull (385), Browns (426), and Sherman (151). Browns and Sherman are significantly greater than Carls, Pond 2A, Coon, and Bull ($p<.001$)).

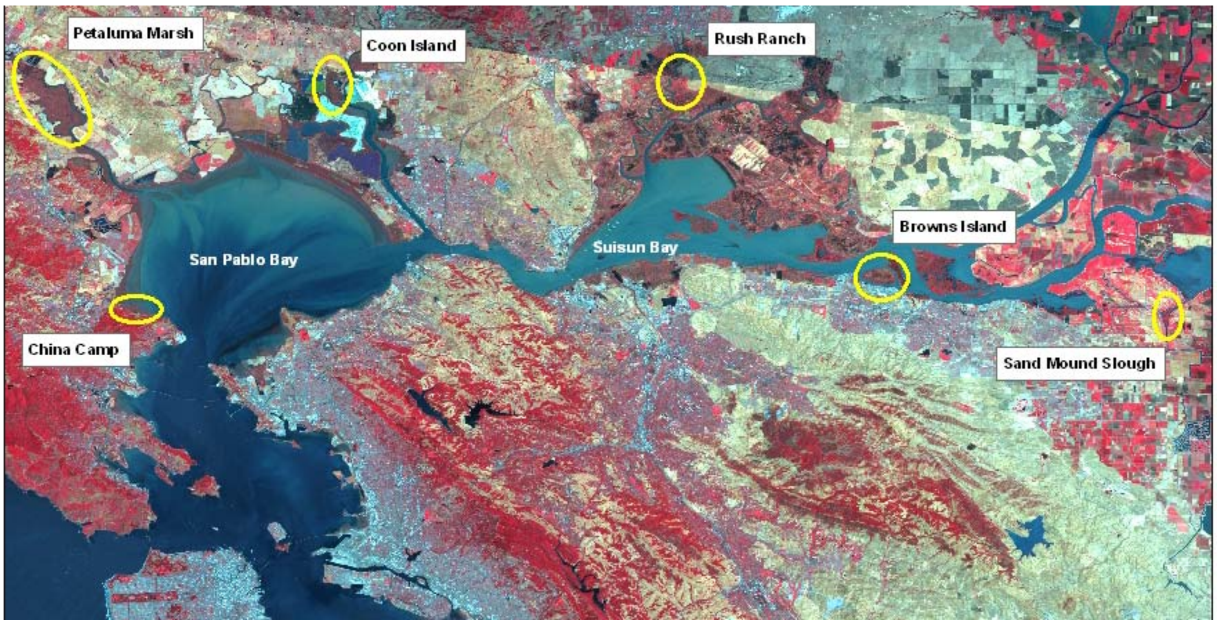


Figure 2. Locations of the proposed six study sites in the SF Bay-Delta.

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V. Thomas Parker

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BIOGRAPHICAL SKETCH

Tom Parker is broadly trained, principally as a plant ecologist, but also with a strong animal and fungal ecology background. He received his Ph.D. from the University of California at Santa Barbara. His research expertise is in community ecology, both theoretically, and empirically focusing on dynamics of communities, especially animal dispersal of seeds and seed bank dynamics, seedling establishment, mycorrhizal ecology, vegetation management and restoration. Parker also has strong interests in evolutionary aspects of ecology. Parker has investigated plant communities in a number of terrestrial systems, but pertinent to this proposal, a variety of wetland systems including freshwater tidal marshes (east and west coast), brackish tidal marshes and salt marshes. His research has been funded by a number of agencies including the California Bay-Delta Authority, National Science Foundation, and the USDA National Resource Initiative, Competitive Grants Program. He has edited 3 books, has over 60 journal publications, and has been the principal on over $3 million in direct research funding. Publications can be accessed at http://userwww.sfsu.edu/~parker/parkerweb/pages/publications.html.

RELEVANT EXPERIENCE

Parker has conducted basic and applied research in a number of plant communities. Currently, he is a principal member of the vegetation team for the CalFed funded Integrated Regional Wetland Monitoring Pilot Project (IRWM), and with John Callaway, on a project determining rates of sedimentation in South Bay Salt Ponds. In the short time of the IRWM project, 6 national presentations have been made, and multiple posters were presented at the recent CalFed conference and other conferences; several publications are currently in progress. Prior to IRWM, Parker was part of a team working on an intensification program for the EPA EMAP program for the SF Bay area wetlands. Other long-term wetland experience involves Pacific Coast salt marshes, brackish and freshwater tidal marshes, as well as East Coast freshwater tidal marshes. Parker has considerable experience in watershed management, especially involving chaparral, rare species, and restoration/conservation. He has actively worked with management and government agencies concerning the monitoring, management or conservation of natural areas, including the City of San Francisco, City of Pacifica, Marin Municipal Water District, National Park Service, National Forest Service, Nevada County (California).

EDUCATION

Ph.D.	University of California, Santa Barbara, 1977 (Ecology)
M.A.	University of California, Santa Barbara, 1975 (Ecology)
B.A.	University of Texas, Austin, 1973 (Biology) (Cum Laude, Phi Beta Kappa)

PROFESSIONAL EXPERIENCE

1980-	Full (1987-present), Associate (1984-87), and Assistant Professor (1980-84), Department of Biology, San Francisco State University; Director, Sierra Nevada Field Station, (1980-84); Acting Chair, Department of Biology (1998-99)
1977-1980	Assistant Professor, Biology Department, Rider College, Lawrenceville, NJ
1976-1977	Regent's Fellow, University of California

AWARDS OR HONORS

Cum Laude, University of Texas, Austin (1973)
Phi Beta Kappa, University of Texas, Alpha Chapter of Texas (1974)
Regent's Fellow, University of California (1976-1977)

Recording Secretary, California Botanical Society (Jan 1985-May 1988)
Fellow, California Academy of Sciences (elected 1989)

PUBLICATIONS

Books

Seedling Ecology and Evolution. *In process*. M. A. Leck, V. T. Parker and R. L. Simpson (eds). Cambridge University Press, Cambridge.

Ecological Scale: Theory and Applications. 1998. D. Peterson, and V. T. Parker (eds.). Complexity in Ecological Systems series. Columbia University Press, NY.

Ecology of Soil Seed Banks. 1989. M. A. Leck, V. T. Parker and R. L. Simpson (eds). Academic Press, NY.

Peer-reviewed Articles; (over 60 articles)

Last couple years:

Leck, M. A., A. Baldwin, V. T. Parker, L. M. Schile, and D. Whigham. *In press*. Freshwater tidal wetlands of North America. In: A. Barendregt, A. Baldwin, P. Meire, and D. Whigham (eds.) *Tidal Freshwater Wetlands*. Backhuys Publ; Leiden, The Netherlands.

Wahlert, G, V.T. Parker and M.C. Vasey. *In press*. The *Arctostaphylos bakeri* complex of Sonoma County. The Four Seasons.

Land, E., K. Withee, L. M. Schile, V. T. Parker. 2006. User centered rapid application development. In: N. Guelfi, A. Savidis (eds.) Rapid integration of software engineering techniques. (Springer-Verlag; Berlin). Lecture Notes in Comp. Sci. Vol. 3943: 34-49.

O'Neil, S. E. and V. T. Parker. 2005. Factors contributing to the seed bank size of two obligate seeding *Ceanothus* species in Northern California. Madroño 52 (3): 182-190.

Le Fer, D. and V. T. Parker. 2005. Effect of seasonality of burn on seed germination in chaparral; the role of soil moisture. Madroño 52 (3): 166-174.

Boykin, L. M., M. C. Vasey, V. T. Parker and R. Patterson. 2005. Two lineages of *Arctostaphylos* (Ericaceae) identified using the internal transcribed spacer (ITS) region of the nuclear genome. Madroño 52 (3): 139-147.

Clark, C. J., J. R. Poulsen, E.F. Connor, B. Bolker and V. T Parker. 2005. Comparative seed shadows of bird-, monkey, and wind-dispersed trees in a central African tropical rain forest. Ecology 86:2684-2694.

Douglas, R. B., V. T. Parker and K. W. Cullings. 2005. Belowground ectomycorrhizal community structure of mature lodgepole pine and mixed conifer stands in Yellowstone National Park. Forest Ecology and Management 208: 303–317

Parker, V. T. and M. C. Vasey. 2004. *Arctostaphylos gabilanensis*, a newly described auriculate-leaved manzanita from the Gabilan Mountains, California. Madroño 51: 322-325.

Clark, C. J., J. R. Poulsen, E. F. Connor and V. T. Parker. 2004 Fruiting trees as dispersal foci in a closed canopy tropical forest. Oecologia 139: 66-75.

Parker, V. T. 2004. Community of the individual: implications for the community concept. Oikos 104: 27-34.

Cullings, K.W., M. H. New, S. Makhija, and V. T. Parker 2003. Effects of litter addition on ectomycorrhizal associates of a lodgepole pine (*Pinus contorta*) stand in Yellowstone National Park. Appl. Envir. Microbiol. 2003 69: 3772-3776.

Hardesty, B. D. and V. T. Parker. 2003. Community seed rain patterns and a comparison to adult community structure in a West African tropical forest. Plant Ecology 164: 49-64.

Parker, V. T. 2002. The concept of the ecological community and a clash of perspectives: A reply to Looijen and van Andel. Persp. Plant Ecol. Evol. Syst 5:139-143.

Other relevant restoration and management articles:

Peterson, D. L. and V. T. Parker. 1998. Dimensions of scale in ecology, resource management and society, pp. 499-522. In: D. L. Peterson and V. T. Parker (eds.) Ecological Scale: Theory and applications. Columbia Univ. Press, NY.

Parker, V. T. and S. T. A. Pickett. 1998. Historical contingency and multiple scales of dynamics in plant communities, pp. 171-191. In: D. L. Peterson and V. T. Parker (eds.) Ecological Scale: Theory and applications. Columbia Univ. Press, NY.

Parker, V. T. 1997. The scale of successional models and restoration objectives. Restoration Ecology 5: 301-306.

Parker, V. T. and S. T. A. Pickett. 1997. Restoration as an ecosystem process: implications of the current ecological paradigm. In: Urbanska, K. M., N. R. Webb and P. J. Edwards (eds.) Restoration Ecology and Sustainable Development, pp 17-32. Cambridge: Cambridge University Press.

Parker, V. T. and S. T. A. Pickett. 1996. Understanding implications of the modern ecological paradigm: viewing restoration as a process. In: Peterson, D. L. and C. V. Klimas (eds.) The Role of Restoration in Ecosystem Management, pp. 15-22. Madison: Society for Ecological Restoration, Publ.

Brand, T. and V. T. Parker. 1995. Scale and general laws of vegetation dynamics. Oikos 73: 375-380.

Pickett, S. T. A. and V. T. Parker. 1994. Avoiding the old pitfalls: Opportunities in a new discipline. Restoration Ecology 2: 75-79.

Parker, V. T. 1993. Conservation issues in land management. In J. E. Keeley (coord. ed.) The Interface Between Ecology and Land Development, pp. 53-60. Southern California Academy of Sciences, Los Angeles.

GRANTS AND CONTRACTS
(over $3 million as principal directly for research)

Active during last 3 years:

South Bay Salt Pond Restoration. $60,000. J.C. Callaway & V.T. Parker. Sedimentation rates in newly restored salt ponds. April 2006-June 2007.

CALFED Bay-Delta Science Program. $439,000. Parker, V.T., J.C. Callaway, and M. Vasey. Influence of restoration on wetland vegetation processes in the San Francisco Estuary and Delta. September 2003 - December 2006.

Environmental Protection Agency, funded through the San Francisco Estuary Institute. $68,000. Callaway, J.C., V.T. Parker, and M. Vasey. West coast pilot 2002 intertidal assessment: California intensification for wetland sampling for EMAP (Environmental Monitoring and Assessment Program). August 2002 - January 2003.

National Science Foundation-Undergraduate Mentoring in Environmental Biology Program: $400,000, with E.F.Connor (PI) and G. Lebuhn. (funded February 2002) ($200k Math student supplement awarded summer 2003)

PROFESSIONAL ACTIVITIES (last few years)

Scientific Advisory Panels, San Francisco Natural Areas Program, and for the Nevada County Natural History 2020 program

Presentations to Long-term vegetation monitoring retreat, BLM, and Citizens Watershed Advisory Committee and Senior Management Retreat, Marin Municipal Water District

Vegetation Monitoring, Planning and Development Committee, National Forest Service

Committee of Visitors, external review panel for long-term projects programs, National Science Foundation (2000, 2003).

V. Thomas Parker / San Francisco State University / CALFED PSP 2006

Institution:	**San Francisco State University**
Program Director:	**V. T. Parker**
Title:	**Climate change impacts to San Francisco Bay-Delta wetlands: Links to pelagic food webs and predictive responses based on landscape modeling**
Sponser:	**CALFED**
Duration:	**3 years (04/01/07 - 03/30/10)**

SFSU Personnel are paid monthly so the participation is listed in months
The hourly rate is provided in the master table of salaries below
1 month is equivalent to 173.33 hours
Students are paid hourly - maximum of 80 hours a month
Salaries are estimated to increase by 5% in years 2 & 3

		Annual Salary	Monthly Salary	Hourly Salary	%Fringe	Comments
Project Director,	**V. Thomas Parker**	$ 100,800	$ 11,200	$ 64.62	12%	summer salary
Project Co-Director,	**Drew Talley**	$ 57,648	$ 4,804	$ 27.72	48%	
Project Co-Director,	**Michael Vasey**	$ 55,272	$ 6,141	$ 35.43	12%	summer salary
Research Technician,	**Lisa Schile**	$ 41,000	$ 3,417	$ 19.71	48%	
Undergraduate Student Assistants, TBD			$ 2,643	$ 15.25	1.5%	

TASK 1: PROJECT MANAGEMENT		**TOTAL AMOUNT salary+fringe**	**YEAR 1** amount per month	#months	total salary	fringe	salary+fringe	**YEAR 2** amount per month	#months	total	fringe	salary+fringe	**YEAR 3** amount per month	#months	total	fringe	salary+fringe
Personnel																	
Project Director,	V.T. Parker	**$ 19,772**	$ 11,200	$ 0.5	$ 5,600	$ 672	$ 6,272	$ 11,760	$ 0.5	$ 5,880	$ 706	$ 6,586	$ 12,348	$ 0.5	$ 6,174	$ 741	$ 6,915
Research Technician,	Lisa Schile	**$ 31,882**	$ 3,417	$ 2	$ 6,833	$ 3,280	$ 10,113	$ 3,588	$ 2	$ 7,175	$ 3,444	$ 10,619	$ 3,767	$ 2	$ 7,534	$ 3,616	$ 11,150
Personnel Salary Subtotal					$ 12,433					$ 13,055					$ 13,708		
Fringe Subtotal						$ 3,952					$ 4,150					$ 4,357	
Personnel total (salary and fringe)		**$ 51,655**					**$ 16,385**					**$ 17,205**					**$ 18,065**
Other Costs		**TOTAL AMOUNT**	**YEAR 1**				**Total Y1**	**YEAR 2**				**Total Y2**	**YEAR 3**				**Total Y3**
Operating Expenses (supplies, etc.)		**$ 750**					$ 250					$ 250					$ 250
Travel		**$ -**					$ -					$ -					$ -
Equipment		**$ -**															
Other Costs SubTotal		**$ 750**					**$ 250**					**$ 250**					**$ 250**
Total Direct Costs		**$ 52,405**					**$ 16,635**					**$ 17,455**					**$ 18,315**
Indirect Costs		**$ 13,101**					**$ 4,159**					**$ 4,364**					**$ 4,579**
Total Costs for Task 1		**$ 65,506**					**$ 20,794**					**$ 21,818**					**$ 22,894**

TASK 2: STABLE ISOTOPE ANALYSES		**TOTAL AMOUNT salary+fringe**	**YEAR 1** amount per month	#months	total salary	fringe	salary+fringe	**YEAR 2** amount per month	#months	total	fringe	salary+fringe	**YEAR 3** amount per month	#months	total	fringe	salary+fringe
Personnel																	
Project Co-Director,	Drew Talley	**$ -**	$ 4,804	$ -	$ -	$ -	$ -	$ 5,044	$ -	$ -	$ -	$ -	$ 5,296	$ -	$ -	$ -	$ -
Research Technician,	Lisa Schile	**$ 63,765**	$ 3,417	$ 4	$ 13,667	$ 6,560	$ 20,227	$ 3,588	$ 4	$ 14,350	$ 6,888	$ 21,238	$ 3,767	$ 4	$ 15,068	$ 7,232	$ 22,300
Undergraduate Students,	TBD	**$ 32,195**	$ 2,643	$ 4	$ 10,573	$ 159	$ 10,732	$ 2,643	$ 4	$ 10,573	$ 159	$ 10,732	$ 2,643	$ 4	$ 10,573	$ 159	$ 10,732
Personnel Salary Subtotal					$ 24,240					$ 14,350					$ 15,068		
Fringe Subtotal						$ 6,560					$ 6,888					$ 7,232	
Personnel total (salary and fringe)		**$ 95,960**					**$ 30,958**					**$ 31,970**					**$ 33,032**
Other Costs		**TOTAL AMOUNT**	**YEAR 1**				**Total Y1**	**YEAR 2**				**Total Y2**	**YEAR 3**				**Total Y3**
Materials and Supplies		**$ 3,600**					$ 1,200					$ 1,200					$ 1,200
Travel (Boat Supplies, Tolls and Mileage)		**$ 6,360**					$ 2,120					$ 2,120					$ 2,120
Equipment		**$ -**															
Stable Isotope Analyses		**$ 56,550**					$ 19,650					$ 18,450					$ 18,450
Other Costs SubTotal		**$ 66,510**					**$ 22,970**					**$ 21,770**					**$ 21,770**
Participant Support (Mileage, Grad Stipend Yr1)		**$ 17,310**					**$ 15,370**					**$ 970**					**$ 970**
Total Direct Costs		**$ 179,780**					**$ 69,298**					**$ 54,710**					**$ 55,772**
Indirect Costs		**$ 40,617**					**$ 13,482**					**$ 13,435**					**$ 13,700**
Total Costs for Task 2		**$ 220,397**					**$ 82,780**					**$ 68,145**					**$ 69,472**

V. Thomas Parker / San Francisco State University / CALFED PSP 2006

Institution:	**San Francisco State University**
Program Director:	**V. T. Parker**
Title:	**Climate change impacts to San Francisco Bay-Delta wetlands: Links to pelagic food webs and predictive responses based on landscape modeling**
Sponser:	**CALFED**
Duration:	**3 years (04/01/07 - 03/30/10)**

SFSU Personnel are paid monthly so the participation is listed in months
The hourly rate is provided in the master table of salaries below
1 month is equivalent to 173.33 hours
Students are paid hourly - maximum of 80 hours a month
Salaries are estimated to increase by 5% in years 2 & 3

		Annual Salary	Monthly Salary	Hourly Salary	%Fringe	Comments
Project Director,	**V. Thomas Parker**	$ 100,800	$ 11,200	$ 64.62	12%	summer salary
Project Co-Director,	**Drew Talley**	$ 57,648	$ 4,804	$ 27.72	48%	
Project Co-Director,	**Michael Vasey**	$ 55,272	$ 6,141	$ 35.43	12%	summer salary
Research Technician,	**Lisa Schile**	$ 41,000	$ 3,417	$ 19.71	48%	
Undergraduate Student Assistants, TBD			$ 2,643	$ 15.25	1.5%	

TASK 3: WETLAND ANALYSES		**TOTAL AMOUNT salary+fringe**	**YEAR 1** amount per month	#months	total salary	fringe	salary+fringe	**YEAR 2** amount per month	#months	total	fringe	salary+fringe	**YEAR 3** amount per month	#months	total	fringe	salary+fringe
Personnel																	
Project Director,	V.T. Parker	**$ 19,772**	$ 11,200	$ 0.5	$ 5,600	$ 672	$ 6,272	$ 11,760	$ 0.5	$ 5,880	$ 706	$ 6,586	$ 12,348	$ 0.5	$ 6,174	$ 741	$ 6,915
Project Co-Director	Michael Vasey	**$ 21,684**	$ 6,141	$ 1	$ 6,141	$ 737	$ 6,878	$ 6,448	$ 1	$ 6,448	$ 774	$ 7,222	$ 6,771	$ 1	$ 6,771	$ 812	$ 7,583
Research Technician,	Lisa Schile	**$ 95,647**	$ 3,417	$ 6	$ 20,500	$ 9,840	$ 30,340	$ 3,588	$ 6	$ 21,525	$ 10,332	$ 31,857	$ 3,767	$ 6	$ 22,601	$ 10,849	$ 33,450
Undergraduate Students,	TBD	**$ 24,146**	$ 2,643	$ 3	$ 7,930	$ 119	$ 8,049	$ 2,643	$ 3	$ 7,930	$ 119	$ 8,049	$ 2,643	$ 3	$ 7,930	$ 119	$ 8,049
Personnel Salary Subtotal					$ 40,171					$ 33,853					$ 35,546		
Fringe Subtotal						$ 11,368					$ 11,811					$ 12,402	
Personnel total (salary and fringe)		**$ 161,250**					**$ 51,539**					**$ 53,714**					**$ 55,997**
Other Costs		**TOTAL AMOUNT**	**YEAR 1**				**Total Y1**	**YEAR 2**				**Total Y2**	**YEAR 3**				**Total Y3**
Materials and Supplies		**$ 4,500**					$ 1,500					$ 1,500					$ 1,500
Travel (Boat Supplies, Tolls and Mileage)		**$ 6,360**					$ 2,120					$ 2,120					$ 2,120
Equipment (TRIMBLE R8 GNSS RTK)		**$ 56,416**		$ 56,342			$ 56,416					$ -					$ -
Other Costs SubTotal		**$ 67,276**					**$ 60,036**					**$ 3,620**					**$ 3,620**
Participant Support (Mileage, Grad Stipend Yrs 2&3)		**$ 31,710**					**$ 970**					**$ 15,370**					**$ 15,370**
Subcontractual Services																	
Project Co-Director,	John Callaway	**$ 19,385**					**$ 5,914**					**$ 6,430**					**$ 7,041**
Total Direct Costs		**$ 279,621**					**$ 118,459**					**$ 79,134**					**$ 82,028**
Indirect Costs		**$ 47,874**					**$ 15,268**					**$ 15,941**					**$ 16,664**
Total Costs for Task 3		**$ 327,494**					**$ 133,727**					**$ 95,075**					**$ 98,692**

TASK 4: SPATIAL MODELING		**TOTAL AMOUNT**	**YEAR 1**	**Total Y1**	**YEAR 2**	**Total Y2**	**YEAR 3**	**Total Y3**
Subcontractual Services								
Project Co-Director,	Maggi Kelly	**$ 127,201**		$ 40,989		$ 42,366		$ 43,846
Total Direct Costs		**$ 127,201**		**$ 40,989**		**$ 42,366**		**$ 43,846**
Indirect Costs		**$ 6,250**		**$ 6,250**		**$ -**		**$ -**
Total Costs for Task 4		**$ 133,451**		**$ 47,239**		**$ 42,366**		**$ 43,846**

TOTAL PROJECT COSTS	
PERSONNEL COSTS for ALL TASKS	**$ 308,864**
OTHER COSTS for ALL TASKS	**$ 134,536**
PARTICIPANT SUPPORT COSTS for ALL TASKS	**$ 49,020**
SUBCONTRACTUAL COSTS for ALL TASKS	**$ 146,586**
MODIFIED TOTAL DIRECT COST BASE	**$ 431,369**
TOTAL DIRECT COSTS for ALL TASKS	**$ 639,006**
TOTAL INDIRECT COSTS (25% per CalFed)	**$ 107,842**
TOTAL COSTS for ALL TASKS	**$ 746,848**

BUDGET JUSTIFICATION

1. Personnel: One month summer salary is requested for Dr. V. T. Parker (Principal Investigator) who will oversee all aspects of the project, particularly the sample site selection and measurements of wetland diversity and primary productivity. Dr. Parker has numerous years experience studying the plant and microbial ecology of the salt marsh at China Camp State Park (one the sites for this project) and was the lead P.I. for the vegetation research group of the Integrated Regional Wetland Monitoring Pilot Project, of which two sites are incorporated into this request. He will also be instrumental during the data analysis and interpretation phases of the project. Dr. J. Callaway is requesting one-half month summer salary within his subcontract to be a principal in the field collection of data and their analyses. Dr. Callaway has specialized on wetlands throughout his career, recently serving as a P.I. on an EPA EMAP intensification project in the SF estuary and a collaborator on the IRWM project. Both Dr. D. Talley and Dr. M. Kelly are contributing at no cost to the project as they are covered by their respective institutions for research activities (SF NERR; UC Berkeley); both have long-term experience in wetlands, Dr. Talley from work in the Tijuana Estuary and currently as research director for the SF NERR; while Dr. Kelly has worked on a number of wetland projects, including as a PI on the IRWM project in the SF Bay-Delta. In addition, a month summer salary is requested for M. C. Vasey, a long-term collaborator in the IRWM wetland research projects and a key member of the field data collection group.

Funding is requested for the support of a research technician, Lisa Schile, an experienced wetland ecologist, who, with Parker, will oversee the hiring and coordination of field crews, organization of the field data collection, and processing of all the materials collected. Schile will also be responsible for initial data entry and quality control, the production of multiple backup files in several independent locations. At this point, our plan is to maintain separate data sets at 3 locations in 3 different counties, the main office of the NERR (Marin Co.), in the Landscape Ecology Center at UCB (Alameda Co.) and in the research labs of Parker at SFSU (San Francisco Co.). Schile has acted in this capacity on the IRWM project and is an experienced boat captain as well as being familiar with all the research sites. Similarly, a graduate student research technician (to be named) is requested to oversee the data processing for the landscape analysis and modeling.

Student funding, both at the graduate and undergraduate level, is requested to act principally as assistants in field data collection and in laboratory processes of materials. The amount of time requested is based on our experience from previous and current projects.

2. Fringe Benefits: Fringe benefits and cost of living adjustments have been budgeted in accordance with University policy and applicable collective bargaining agreements.

3. Travel: Funding is requested to cover the cost of travel to the different research sites; the cost of tolls across bridges; and the cost of gas and maintenance for the research vessel. The closest of the research sites lies 45-50 km from the research laboratories while the farthest exceeds 160 km one way. The amount of our travel cost request is based on our best estimate number of trips to each of the research sites. In addition, some funding is requested for travel to national meetings to present results of the research; these costs would include registration, accommodation and travel expenses.

4. Equipment: The joint laboratories have the necessary computers, field and laboratory equipment and boat for this project. The only equipment requested is a Trimble RTK package for high precision elevation sampling at the different wetlands. We have experience with this type of equipment and require it for resolution of distribution patterns of plants along elevation gradients. Past experience at Coon Island has indicated that elevation distributions of plants vary depending on local hydrology; this equipment will permit the detailed elevation mapping to interpret plant distributions, sedimentation rates with respect to height above mean sea level, and to characterize wetland topographies at test locations.

5. Supplies: Funding is requested for office supplies (principally blank compact disks for data storage, paper for printers and printer cartridges), waterproof field notebooks, paper and plastic bags for collection of materials, batteries for GPS units, and replacement of broken or damaged field equipment. For the landscape ecology group, supplies for paper and ink are especially crucial, as are software licenses.

6. Contractual: Two subcontacts are a part of this proposal, one to the Co-PI John Callaway and one to the Co-PI Maggi Kelly. Dr. Callaway is a crucial member of the field and data analysis teams, while Dr. Kelly oversees all the landscape ecology spatial modeling component. Aspects of their subcontracts (one-half month summer for Dr. Callaway; graduate student research technician for Dr. Kelly, as well as some supplies and travel) have been discussed in other sections of the budget justification.

7. Other: A principal cost not covered in any other category involves those for stable isotope analysis. This is the method by which we are probing the linkages among different trophic levels in the aquatic food web and their differential connections to wetland species. A grinder is requested, because while the PI currently has a Wiley Mill, it will not last the extent of this project. Other costs associated with the isotope work involve sample preparation and their analysis by a stable isotope lab at UC Davis. We request $19,100 in for analytical services. This will include $8,300 for stable isotope analyses to be run by Dr. David Harris in the Stable Isotope Facility at UCD (~1,040 samples to be run for stable isotopes of Carbon and Nitrogen), and $10,800 for stable isotope analyses to be run by Dr. Robert Petty at the stable isotope facility at UC Santa Barbara (~600 samples to be run for Sulfur isotopes). Additional costs include a grinder for tissue samples ($1200), $500 in consumable supplies (vials, tin capsules, etc), and funds to cover Talley's travel to field sites and to attend one meeting per year.

Cost-Sharing

1. John Callaway: University of San Francisco is contributing salary and benefits for John Callaway during the summer month of each year. The total contribution (salary 11.11% of 9 mo salary), fringe benefits (USF rate of 34.5%), and F&A from USF is as follows:

	AY 07/08	AY 08/09	AY 09/10	Total
Total Contribution	**$16,946**	**18,425**	**20,174**	**55,545**

2. Co-Project Directors Drew Talley, V. Thomas Parker, and N. Maggi Kelly will all be provided time as required at no cost to the project by their respective institutions (SF Bay NERR; SFSU; UCB).

Signature

The applicant for this proposal must submit this form by printing it, signing below, and faxing it to +1 877-408-9310. Send exactly one form per transmission.

Failure to sign and submit this form will result in the application not being considered for funding. The individual submitting this proposal will receive e-mail confirmation as soon as this signature page has been processed.

The individual signing below declares that:

- all representations in this proposal are truthful;
- the individual signing the form is authorized to submit the application on behalf of the applicant (if applicant is an entity or organization);
- the applicant has read and understood the conflict of interest and confidentiality discussion under the Confidentiality and Conflict of Interest Section in the main body of the PSP and waives any and all rights to privacy and confidentiality of the proposal on behalf of the applicant, to the extent provided in this PSP; and
- the applicant has read and understood all attachments of this PSP.

Proposal Title:	Climate change impacts to San Francisco Bay-Delta wetlands: Links to pelagic food webs and predictive responses based on landscape modeling
Proposal Number:	2006.01-0040
Applicant Organization:	San Francisco State University
Applicant Contact:	AVP Research and Sponsored Programs Ken Paap

Applicant Signature K Page **Date** 08/31/2006

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