Foodweb Support For The Threatened Delta Smelt And Other Estuarine Fishes In Suisun Bay And The Western Sacramento−San Joaquin Delta

prepared by Kimmerer, Wim J.

submitted to Science Program 2004

compiled 2005−01−06 14:10:30 PST

Project

This proposal is for the Science Program 2004 solicitation as prepared by Kimmerer, Wim J..

The submission deadline is 2005−01−06 17:00:00 PST (approximately 169 minutes from now).

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Instructions

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Proposal Title	***Foodweb support for the threatened delta smelt and other estuarine fishes in Suisun Bay and the western Sacramento−San Joaquin Delta***	
Institutions	San Francisco State University U.S. Geological Survey University of Connecticut	*List each institution involved, one per line.*
Proposal Document		*You have already uploaded a proposal document. View it to verify that it appears as you expect. You may replace it by uploading another document*
Project Duration	***36 months***	

Is the start date a determining factor to the successful outcome of the proposed effort?
X No.
− Yes. Anticipated start date of this effort:

Select all of the following study topics which apply to this proposal.
X life cycle models and population biology of key species
X environmental influences on key species and ecosystems
− relative stresses on key fish species
− direct and indirect effects of diversions on at−risk species
− processes controlling Delta water quality
X implications of future change on regional hydrology, water operations, and environmental processes
− water management models for prediction, optimization, and strategic assessments
− assessment and monitoring
− salmonid−related projects
X Delta smelt−related projects

Select as many keywords as necessary to describe this proposal (minimum of 3).
− adaptive management
X aquatic plants
X benthic invertebrates
X biological indicators
− birds
− neotropical migratory birds
− shorebirds
− upland birds
− wading birds
− waterfowl
X climate
− climate change
− precipitation
− sea level rise
− snowmelt
X contaminants / toxicants / pollutants
− contaminants and toxicity of unknown origin
− emerging contaminants

− mercury
X nutrients and oxygen depleting substances
X organic carbon and disinfection byproduct precursors
− persistent organic contaminants
− pesticides
X salinity
X sediment and turbidity
− selenium
− trace metals
− ***database management***
− ***economics***
− ***engineering***
− civil
− environmental
− hydraulic
− ***environmental education***
− ***environmental impact analysis***
− ***environmental laws and regulations***
− ***environmental risk assessment***
− ***fish biology***
− bass and other centarchids
X delta smelt
− longfin smelt
− other species
− salmon and steelhead
− splittail
− striped bass
− sturgeon
− ***fish management and facilities***
− hatcheries
− ladders and passage
− screens
− ***forestry***
− ***genetics***
X geochemistry
− ***geographic information systems (GIS)***
− ***geology***
− ***geomorphology***
− ***groundwater***
X habitat
X benthos
X channels and sloughs
− flooded islands
− floodplains and bypasses
− oceanic
− reservoirs
− riparian
− rivers and streams
X shallow water
− upland habitat
− vernal pools
X water column
− wetlands, freshwater
− wetlands, seasonal
− wetlands, tidal
− ***human health***
− ***hydrodynamics***
− ***hydrology***
− ***insects***
X invasive species / non−native species / exotic species
− ***land use management, planning, and zoning***
− ***limnology***
− ***mammals***
− large
− small

X microbiology / bacteriology
− modeling
X conceptual
− quantitative
− monitoring
− natural resource management
− performance measures
X phytoplankton
X plants
X primary productivity
− reptiles
− restoration ecology
− riparian ecology
− sediment
− soil science
X statistics
− subsidence
X trophic dynamics and food webs
− water operations
− barriers
− diversions / pumps / intakes / exports
− gates
− levees
− reservoirs
− water quality management
− ag runoff
− mine waste assessment and remediation
− remediation
− temperature
− urban runoff
− water quality assessment and monitoring
− water resource management
− water supply
− demand
− environmental water account
− water level
− water storage
− watershed management
− weed science
− wildlife
− ecology
− management
− wildlife−friendly agriculture
X zooplankton
− administrative

Indicate whether your project area is local, regional, or system−wide. If it is local, provide a central ZIP Code. If it is regional, provide the central ZIP Code and choose the counties affected. If it is system−wide, describe the area using information such as water bodies, river miles, and road intersections.	
− local	ZIP Code:
X regional	ZIP Code: ***94920*** counties: ***Alameda*** ***Contra Costa*** ***Marin*** ***Sacramento*** ***San Francisco***

	San Mateo ***Solano*** ***Yolo***
− system−wide	

Does your project fall on or adjacent to tribal lands?
No.

(Refer to California Indian reservations to locate tribal lands.)
If it does, list the tribal lands.

Has a proposal for this effort or a similar effort ever been submitted to CALFED for funding or to any other public agency for funding?
No.

If yes, complete the table below.

Status	Proposal Title	Funding Source	Amount	Comments

Has the lead scientist or principal investigator of this effort ever submitted a proposal to CALFED for funding or to any other public agency for funding?
Yes.

If yes, provide the name of the project, when it was submitted, and to which agency and funding mechanism if was submitted. Also describe the outcome and any other pertinent details describing the proposal's current status.

I list here only CALFED funding. Please contact me at Kimmerer@sfsu.edu if you really want information on proposals to "any other public agency"

Kimmerer has received ERP and Science Program funding as listed below. In addition, Kimmerer is a member and Co−Chair of the ERP Science Board, and had ERP support for completion of the "Open Water Processes" white paper (Kimmerer 2004). Kimmerer is also co−advisor to the CBDA Lead Scientist on the Environmental Water Account.

ERP−00−F10 "Determining the Biological, Physical and Chemical Characteristics of Ballast Water Arriving in the San Francisco Bay/Delta Estuary", in progress. One paper has been submitted for publication, one Masters thesis has been completed and being prepared for publication, and work is proceeding toward two other publications. A spin−off project has been funded by the National Science Foundation, providing leverage for the original project. This project has also benefited from collaboration with Dr. Greg Ruiz of the Smithsonian Environmental Research Center, a recognized expert on introduced species. A request for additional funding to expand sampling of ballast water is being processed; this extension will enable us to investigate the larval forms that arrive in ballast water, and the viability of various planktonic organisms in ballast water.

ERP−00−E109 "Effects of Introduced Clams on the Food Supply of Bay−Delta Fish Species." This modeling/data analysis study has been completed. Three papers have been published, one with partial funding and two with full funding from the ERP. Two additional papers have been submitted for publication and a final report has been submitted.

(With W. Bennett and S. Bollens): ERP 99−N09: "Effects of Introduced Species of Zooplankton and Clams on the Bay−Delta Food Web." This experimental study has supported one Ph.D. dissertation and two Masters' theses, one of which is completed and the other has been delayed somewhat (the student took a job) and is now scheduled for completion in early 2005. In addition, numerous presentations and newsletter articles have been completed, and several journal articles are in various stages of completion. A synthesis of the information has been submitted as a final report.

Proposals submitted:

ERP (Nov 2004): Monitoring Responses Of The Delta Smelt Population To Multiple Restoration Actions In The San Francisco Estuary (Sub to UC Davis)
Science Program, Jan 2005: Foodweb Support for the Threatened Delta Smelt and other Estuarine Species in Suisun Bay and the Western Delta (with USGS and U. of Connecticut)

Science Program, Jan 2005: Ecological Consequences of Elevated Salinity in the Sacramento−San Joaquin Delta (with USGS and Department of Water Resources)

Science Program, Jan 2005: Ecological Consequences of Elevated Salinity in the Sacramento−San Joaquin Delta (with Louisiana State University, UC Davis, and Stanford University

Science Program, Jan 2005: Model−Based Guidance For Restoring Chinook Salmon: River, Estuary, And Ocean Influences On Populations Spawning In The Sacramento And San Joaquin Basins. (Sub to Oak Ridge National Labs, with CDFG, University of Tennessee)

Science Program, Jan 2005: Long−Term Trends in Benthic Macrofauna Biomass in the Upper San Francisco Estuary (Sub to DWR with USGS)

All applicants must identify all sources of funding other than the funds requested through this solicitation to support the effort outlined in their proposal. Applicants must include the status of these commitments (tentative, approved, received), the source, and any cost−sharing requirements. Successful proposals that demonstrate multiple sources of funding must have the commitment of the non−Science Program PSP related funding within 30 days of notification of approval of Science Program PSP funds. If an applicant fails to secure the non−Science Program PSP funds identified in the proposal, and as a result has insufficient funds to complete the project, CBDA retains the option to amend or terminate the award. The California Bay−Delta Authority reserves the right to audit grantees.

Status	Proposal Title	Funding Source	Period Of Commitment	Requirements And Comments

Are you specifically seeking non−federal cost−share funds for this proposal?
No.

In addition to the general funds available, are you targeting additional funds set aside specifically for collaborative proposals?
Yes.

List people you feel are qualified to act as scientific reviewers for this proposal and are not associated with CALFED.

Full Name	Organization	Telephone	E−Mail	Expertise
Hans W. Paerl	***Institute of Marine Sciences, University of North Carolina***	***(252) 222−6346***	***hans_paerl@unc.edu***	***microbiology / bacteriology***
Dan Baird	***University of Port Elizabeth***	***+27 (0141) 5042342***	***dan.baird@upe.ac.za***	***modeling***
Edward D. Houde	***University of Maryland***	***410−326−7224***	***ehoude@cbl.umces.edu***	***fish biology***
Merryl Alber	***University of Georgia***	***706) 542−5966***	***malber@arches.uga.edu***	

Executive Summary

Provide a brief but complete summary description of the proposed project; its geographic location; project objective; approach to implement the proposal; hypotheses being tested; expected outcomes; and relationship to Science Program priorities. The Executive Summary should be a concise, informative, stand−alone description of the proposed project. *(This information will be made public on our website shortly after the closing date of this PSP.)*

We propose a program of collaborative research to determine the productivity base of the foodweb of the Low−Salinity Zone (LSZ) of the northern San Francisco Estuary. The proposed research would address two critical issues for CALFED: foodweb support for the threatened delta smelt, and the basis for the relationships between abundance of estuarine fish species and freshwater flow. Delta smelt spend their lives from late larval to early adult stages in and near the LSZ, feeding on copepods. There is evidence that they can be severely food limited, as are the copepods on which they feed. In addition, several other estuarine−dependent species that rear in the LSZ have abundance relationships to freshwater flow. One possible mechanism for these relationships is a positive response of the foodweb to freshwater flow.

Exogenous organic carbon likely provides important support to the LSZ foodweb. Primary productivity has been low since the estuary was invaded in 1987 by the introduced clam Potamocorbula amurensis. A summer−long phytoplankton bloom occurred in most years before 1987, but since then, phytoplankton biomass is high only during brief, unreliable spring blooms when clams are scarce. The roughly 5−fold decline in phytoplankton biomass and production since 1987 led to substantial changes in the LSZ foodweb, but declines in copepods and some fish were considerably smaller than might have been expected. This implies compensation by the microbial foodweb, supported by exogenous carbon, most likely from freshwater phytoplankton that release dissolved organic carbon upon entering brackish water. Mass balance suggests a substantial seaward flux of freshwater phytoplankton, yet freshwater species are not abundant in the LSZ.

Our proposed research will examine the base of the foodweb, from phytoplankton and bacteria to copepods, in the LSZ to address the following issues: · Controls on phytoplankton production, survival, and species composition including benthic grazing, turbidity, salinity, and nutrients. · The response of bacterial production to changes in organic inputs with freshwater flow · The role of the microbial foodweb in supporting higher trophic levels · The contributions of alternative energetic pathways in supporting copepods.

We propose a 3−year project in which field and laboratory work will occur in the first two years, leaving the third year for analysis and synthesis. Fieldwork will focus on two periods when larval, juvenile and adult delta smelt are present. During spring we will conduct weekly cruises to observe whatever spring bloom occurs. Research during this period will include phytoplankton experiments on the potential influence of ammonium concentration on nitrate uptake and therefore growth, and measurements of grazing, light limitation, and other losses. In the summer period of low chlorophyll we will measure bacterial abundance and production, microzooplankton abundance and feeding, copepod feeding on alternative food sources, and benthic grazing.

Synthesis of the results of our study will take advantage of the vast amount of historical data on some of the foodweb components, with which the lead PI has extensive experience. The outcome will be a foodweb model with quantitative functional relationships among components, and estimates of the likely

response of the foodweb to flow.

Give additional comments, information, etc. here.

Alber's expertise is estuaries − not in the list

Applicant

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All information on this page is to be provided for the agency or institution to whom funds for this proposal would be awarded.

Applicant Institution	***San Francisco State University***	*This list comes from the project form.*
Applicant Institution Type	***public institution of higher education***	

Institution Contact

Please provide information for the primary person responsible for oversight of grant operation, management, and reporting requirements.

Salutation	***Dr.***
First Name	***Kenneth***
Last Name	***Paap***
Street Address	***1600 Holloway Avenue; ADM 469***
City	***San Francisco***
State Or Province	***CA***
ZIP Code Or Mailing Code	***94132***
Telephone	***(415) 338−7091*** *Include area code.*
E−Mail	***kenp@sfsu.edu***

Additional information regarding prior applications submitted to CALFED by the applicant organization or agency and/or funds received from CALFED programs by applicant organization or agency may be required.

Personnel

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Instructions

Applicants must provide brief biographical sketches, titles, affiliations, and descriptions of roles, relevant to this effort, of the principal and supporting project participants by completing a Personnel Form. This includes the use of any consultants, subcontractors and/or vendors; provide information on this form for all such people.

Information provided on this form will automatically support subsequent forms to be completed as part of the Science PSP submission process. Please be mindful of what information you enter and how it may be represented in the Task and Budget forms.

Information regarding anticipated subcontractor services must be provided regardless if the specific service provider has been selected or not. If the specific subcontractor has not been identified or selected, please list TBD (to be determined) in the Full Name field and the anticipated service type in the Title field (example: Hydrology Expert).

Please provide this information before continuing to those forms.

Kimmerer, Wim J.

*This person is the **Lead Investigator**. Contact information for this person is required.*

Full Name	***Kimmerer, Wim J.***	example: Wright, Jeffrey R., PhD.
Institution	***San Francisco State University***	*This list comes from the project form.*
Title	***Research Professor***	*example: Dean of Engineering*
Position Classification	***primary staff***	
Responsibilities	Overall project management Zooplankton dynamics	
Qualifications		*You have already uploaded a PDF file for this question. Review the file to verify that appears correctly.*
Mailing Address	***3152 Paradise Drive***	
City	***Tiburon***	
State	***CA***	
ZIP	***94920***	
Business Phone	***415 338 3515***	
Mobile Phone	***510 555 1212***	
E−Mail	***kimmerer@sfsu.edu***	

Describe other staff below. If you run out of spaces, submit your updates and return to this form.

Dugdale, Richard

Full Name	***Dugdale, Richard***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***San Francisco State University***	*This list comes from the project form.*
Title	***Senior Research Scientist***	*example: Dean of Engineering*

Position Classification	***primary staff***	
Responsibilities	Phytoplankton and nutrients	
Qualifications		***This is only required for primary staff.*** *You have already uploaded a PDF file for this question. Review the file to verify that appears correctly.*

Wilkerson, Frances

Full Name	***Wilkerson, Frances***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***San Francisco State University***	*This list comes from the project form.*
Title	***Senior Research Scientist***	*example: Dean of Engineering*
Position Classification	***primary staff***	
Responsibilities	Phytoplankton and nutrients	
Qualifications		***This is only required for primary staff.*** *You have already uploaded a PDF file for this question. Review the file to verify that appears correctly.*

Carpenter, Edward

Full Name	***Carpenter, Edward***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***San Francisco State University***	*This list comes from the project form.*
Title	***Professor***	*example: Dean of Engineering*
Position Classification	***primary staff***	
Responsibilities	Phytoplankton production and losses	
Qualifications		***This is only required for primary staff.*** *You have already uploaded a PDF file for this question. Review the file to verify that appears correctly.*

Cohen, Risa

Full Name	***Cohen, Risa***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***San Francisco State University***	*This list comes from the project form.*
Title	***Post−doctoral associate***	*example: Dean of Engineering*
Position Classification	***primary staff***	
Responsibilities	Phytoplankton production and losses	
Qualifications		***This is only required for primary staff.*** *You have already uploaded a PDF file for this question. Review the file to verify that appears correctly.*

Parker, Alex

Full Name	***Parker, Alex***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***San Francisco State University***	*This list comes from the project form.*
Title	***Postdoctoral associate***	*example: Dean of Engineering*
Position Classification	***primary staff***	
Responsibilities	Bacterial dynamics	
Qualifications		***This is only required for primary staff.*** *You have already uploaded a PDF file for this question. Review the file to verify that appears correctly.*

Thompson, Janet K.

Full Name	***Thompson, Janet K.***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***U.S. Geological Survey***	*This list comes from the project form.*
Title	***Research Scientist***	*example: Dean of Engineering*
Position Classification	***primary staff***	
Responsibilities	Invasive clams	
Qualifications		***This is only required for primary staff.*** *You have already uploaded a PDF file for this question. Review the file to verify that appears correctly.*

McManus, George

Full Name	***McManus, George***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***University of Connecticut***	*This list comes from the project form.*
Title	***Associate Professor***	*example: Dean of Engineering*
Position Classification	***primary staff***	
Responsibilities	Microzooplankton, microbial foodweb	
Qualifications		***This is only required for primary staff.*** *You have already uploaded a PDF file for this question. Review the file to verify that appears correctly.*

Research Technician #1 (WK)

Full Name		example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***San Francisco State University***	*This list comes from the project form.*
Title	***Research Technician #1 (WK)***	*example: Dean of Engineering*

Position Classification	***secondary staff***	
Responsibilities	Field work, lab assistant	
Qualifications		***This is only required for primary staff.*** *Upload a PDF version of this person's resume that is no more than five pages long. To upload a resume, use the "Browse" button to select the PDF file containing the resume.*

Student Assistant #1 (WK)

Full Name		example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***San Francisco State University***	*This list comes from the project form.*
Title	***Student assistant #1 (WK)***	*example: Dean of Engineering*
Position Classification	***secondary staff***	
Responsibilities	Zooplankton	
Qualifications		***This is only required for primary staff.*** *Upload a PDF version of this person's resume that is no more than five pages long. To upload a resume, use the "Browse" button to select the PDF file containing the resume.*

Research Technician #2 (RC)

Full Name		example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***San Francisco State University***	*This list comes from the project form.*
Title	***Research Technician #2 (RC)***	*example: Dean of Engineering*
Position Classification	***secondary staff***	
Responsibilities	Lysis experiments	
Qualifications		***This is only required for primary staff.*** *Upload a PDF version of this person's resume that is no more than five pages long. To upload a resume, use the "Browse" button to select the PDF file containing the resume.*

Research Technician #3 (DW)

Full Name		example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***San Francisco State University***	*This list comes from the project form.*
Title	***Research Technician #3 (DW)***	*example: Dean of Engineering*
Position Classification	***secondary staff***	
Responsibilities	Nutrients, uptake	
Qualifications		***This is only required for primary staff.***

		Upload a PDF version of this person's resume that is no more than five pages long. To upload a resume, use the "Browse" button to select the PDF file containing the resume.

Research Technician (USGS)

Full Name		example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***San Francisco State University***	*This list comes from the project form.*
Title	***Research Technician (USGS)***	*example: Dean of Engineering*
Position Classification	***secondary staff***	
Responsibilities	Benthos	
Qualifications		***This is only required for primary staff.*** *Upload a PDF version of this person's resume that is no more than five pages long. To upload a resume, use the "Browse" button to select the PDF file containing the resume.*

Parchaso, Francis

Full Name	***Parchaso, Francis***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***U.S. Geological Survey***	*This list comes from the project form.*
Title	***Research Scientist***	*example: Dean of Engineering*
Position Classification	***primary staff***	
Responsibilities	Benthic Fieldwork	
Qualifications		***This is only required for primary staff.*** *You have already uploaded a PDF file for this question. Review the file to verify that appears correctly.*

Postdoctoral Associate

Full Name		example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***University of Connecticut***	*This list comes from the project form.*
Title	***Postdoctoral Associate***	*example: Dean of Engineering*
Position Classification	***secondary staff***	
Responsibilities	Microzooplankton experiments	
Qualifications		***This is only required for primary staff.*** *Upload a PDF version of this person's resume that is no more than five pages long. To upload a resume, use the "Browse" button to select the PDF file containing the resume.*

UNdergraduate Student

Full Name		example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution		*This list comes from the project form.*

	University of Connecticut	
Title	***UNdergraduate student***	*example: Dean of Engineering*
Position Classification	***secondary staff***	
Responsibilities	Assist with microzooplankton	
Qualifications		***This is only required for primary staff.*** *Upload a PDF version of this person's resume that is no more than five pages long. To upload a resume, use the "Browse" button to select the PDF file containing the resume.*

Conflict Of Interest

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To help Science Program staff manage potential conflicts of interest in the review and selection process, we need some information about who will directly benefit if your proposal is funded. We need to know of individuals in the following categories:

- Applicants 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;
- Subcontractors listed in the proposal who will perform some tasks listed in the proposal and will benefit financially if the proposal is funded.

Applicant	San Francisco State University
Submittor	Kimmerer, Wim J.
Primary Staff	Kimmerer, Wim J.
Primary Staff	Dugdale, Richard
Primary Staff	Wilkerson, Frances
Primary Staff	Carpenter, Edward
Primary Staff	Cohen, Risa
Primary Staff	Parker, Alex
Primary Staff	Thompson, Janet K.
Primary Staff	McManus, George
Secondary Staff	*Research Technician #1 (WK)
Secondary Staff	*Student assistant #1 (WK)
Secondary Staff	*Research Technician #2 (RC)
Secondary Staff	*Research Technician #3 (DW)
Secondary Staff	*Research Technician (USGS)
Primary Staff	Parchaso, Francis
Secondary Staff	*Postdoctoral Associate
Secondary Staff	*UNdergraduate student

Are there other persons not listed above who helped with proposal development?
No.

If there are, provide below the list of names and organizations of all individuals not listed in the proposal who helped with proposal development along with any comments.

Tasks

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Instructions

Utilize this Task Table to delineate the tasks identified in your project description. Each task and subtask must have a number, title, brief description of the task (detailed information should be provided in the project description), timeline, list of personnel or subcontractors providing services on each specific task, and list of anticipated deliverables (where appropriate). When creating subtasks, information must be provided in a way that avoids duel presentation of supporting tasks within the overall task (i.e. avoid double counting). Information provided in the Task Table will be used to support the Budget Form. Ensuring information regarding deliverables, personnel and costs associated with subtasks are only provided once is imperative for purposes of avoiding double counting of efforts within the Budget Form.

For proposals involving multiple institutions (including subcontractors), the table must clearly state which institutions are performing which tasks and subtasks.

Task ID	Task Name	Start Month	End Month	Personnel Involved	Description	Deliverables
1	*Phytoplankton dynamics*	*1*	*36*	*Dugdale, Richard* *Wilkerson, Frances* *Carpenter, Edward* *Cohen, Risa* **Research Technician #2 (RC)* **Research Technician #3 (DW)*	Phytoplankton dynamics including nutrients, productivity, and release of DOC to bacteria	At least two papers in the scientific literature. One paper synthesizing results (all participate). One talk at the CALFED Science Conference and presentations at other venues. analysis of relative importance of benthic grazing and nutrient composition. Analysis of interaction between phytoplankton and bacteria.
2	*Benthos*	*1*	*36*	*Thompson, Janet K.* **Research Technician #1 (WK)* **Research Technician (USGS)* *Parchaso, Francis*	Grazing rate and grazing impact on phytoplankton, zooplankton, and bacteria	At least one paper in the scientific literature. One paper synthesizing results (all participate). One talk at the CALFED Science Conference and presentations at other venues. Analysis of relative importance of benthic grazing and nutrient composition.
3	*Bacteria*	*1*	*36*	*Parker, Alex* **Research Technician #3 (DW)*	Bacterial dynamics including growth rate and uptake of DOC	At least one paper in the scientific literature. One paper synthesizing results (all participate). One talk at the CALFED Science Conference and presentations at other venues.
4	*Microzooplankton*	*1*	*36*	*McManus, George* **Research Technician #1 (WK)* **Postdoctoral Associate* **UNdergraduate student*	Role of microzooplankton in transferring food energy to zooplankton from bacteria or phytoplankton	At least one paper in the scientific literature. One paper synthesizing results (all participate). One talk at the CALFED Science Conference and presentations at other venues. Joint papers with Tasks 3 and 5.
5	*Mesozooplankton*	*1*	*36*	*Kimmerer, Wim J.* **Research Technician #1 (WK)* **Student assistant #1 (WK)*	Growth and food supply of mesozooplankton	At least one paper in the scientific literature. One paper synthesizing results (all participate). One talk at the CALFED Science Conference and presentations at other venues. Joint paper with Task 4. Progress reports.

Budget

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Proposal updates will be disabled immediately after the deadline. All forms, including the signature form, must be completed, compiled and acknowledged in order to be eligible for consideration and review. Allow at least one hour for Science Program staff to verify and file signature pages after they are received.

Instructions

All applicants must complete a budget for each task and subtask. The Budget Form uses data entered in the Task Form, thus tasks should be entered before starting this form. Failure to complete a Budget Form for each task and/or subtask will result in removal of the application from consideration for funding.

CBDA retains the right to request additional information pertaining to the items, rates, and justification of the information presented in the Budget Form(s).

Supporting details on how costs were derived for each line item must be included in the justification section for each item. The cost detail for each item should include the individual cost calculations associated with each line item to provide the basis for determining the total amount for each budget category.

Following are guidelines for completing the justification section of this form:

Labor (Salary &Wages)

Ensure each employee and associated classification is correctly identified for each task and subtask. This information will automatically be provided once the Staff Form has been completed. Provide estimated hours and hourly rate of compensation for each position proposed in the project.

Employee Benefits

Benefits, calculated as a percentage of salaries, are contributions made by the applicant for sick leave, retirement, insurance, etc. Provide the overall benefit rate and specify benefits included in this rate for each employee classification proposed in the project.

Travel

Travel includes the cost of transportation, subsistence, and other associated costs incurred by personnel during the term of the project. Provide purpose and estimated costs for all travel. Reoccurring travel costs for a particular task or subtask may be combined into one entry. The number of trips and cost for each occurrence must be clearly represented in the justification section for reoccurring travel items of this nature.

Any reimbursement for necessary travel and per diem shall be at rates specified by the California Department of Personnel Administration for similar employees (www.dpa.ca.gov/jobinfo/statetravel.shtm).

Equipment

Equipment is classified as any item of $5,000 or more and has an expected life of three years or more. Equipment purchased in whole or in part with these grant funds must be itemized. List each piece of equipment and provide a brief description and justification for each.

Supplies

Provide a basic description and cost for expendable research supplies. Costs associated with GIS services, air photos, reports, etc. must be listed separately and have a clear justification associated with each entry. Postage, copying, phone, fax and other basic operational costs associated with each task and subtask may be combined unless the cost associated with one particular service is unusually excessive.

Subcontractor Services

Subcontractor services (Professional and Consultant services) include the total costs for any services needed by the applicant to complete the project tasks. Ensure the correct organization is entered in the Personnel Form so that it appropriately appears on the Budget Form. The applicant must provide all associated costs of all subcontractors (i.e. outside service providers) when completing this form. Applicants must be able to demonstrate that all subcontractors were selected according to an applicant's institutional requirements for the selection of subcontractors (competitive selection or sole source justification).

CBDA retains the right to request that a subcontractor provide cost estimates in writing prior to distribution of grant funds.

CBDA retains the right to request consultant, subcontractor, and/or outside service provider cost estimates in writing prior to distribution of grant funds.

Indirect Costs (Overhead)

Indirect costs are overhead expenses incurred by the applicant organization as a result of the project but are not easily identifiable with a specific project. The indirect cost rate consists of a reasonable percentage of all costs to run the agency or organization while completing the project. List the cost and items associated with indirect costs. (These items may include general office expenses such as rent, office equipment, administrative staff, operational costs, etc. Generally these items are represented by the applicant through a predetermined percentage or surcharge separate from other specific costs of items necessary to complete a specific task or subtask.)

If indirect cost rates are different for State and Federal funds, please identify each rate and the specific items included in the calculation for that rate.

Task 1, Phytoplankton Dynamics: Labor	**Justification**	**Amount**
Dugdale, Richard	***30% time for 1 mo/year @ $9062/mo***	***8750***
Wilkerson, Frances	***30% time for 1 summer mo @ $8400/mo***	***7944***
Carpenter, Edward	***30% time for 1 mo/year (no cost to grant)***	***0***
Cohen, Risa	***100% time for 12 mos @ $4167/month (6 mos in Year 3)***	***130062***
***Research Technician #2 (RC)**	***$16.03/hr x 200 hrs in Year 1 and 775 hrs in Year 2***	***15629***
***Research Technician #3 (DW)**	***$3366/mo x 50% time for 1.4 mos/yr***	***9424***
Task 1, Phytoplankton Dynamics: Benefits	**Justification**	**Amount**
Dugdale, Richard	***fringe benefits (medical, dental, vision, social security, etc.) @ 12%***	***1028***
Wilkerson, Frances	***fringe benefits (medical, dental, vision, social security, etc.) @ 12%***	***953***
Carpenter, Edward	***(no cost to grant)***	***0***
Cohen, Risa	***fringe benefits (medical, dental, vision, social security, etc.) @ 48%***	***62430***
***Research Technician #2 (RC)**	***fringe benefits (worker's compensation and social security) @ 1.5%***	***234***
***Research Technician #3 (DW)**	***fringe benefits (medical, dental, vision, social security, etc.) @ 48%***	***4523***
Task 1, Phytoplankton Dynamics: Travel Expenses	**Justification**	**Amount**
Air/Train	***airfare***	***4500***
Conferences	***annual scientific conferences, collaborative research***	***300***
Meals	***per diem @ $46/day***	***1500***
Lodging	***hotel accommodations***	***1700***
Parking/Tolls	***parking and local bridge tolls***	***100***
Mileage	***mileage @ $0.345/mi***	***650***
Task 1, Phytoplankton Dynamics: Supplies And Expendables	**Justification**	**Amount**
Reproduction	***publication costs***	***5000***
Telephone	***disposable lab supplies and centrifuge for bacterial production***	***24500***
Task 1, Phytoplankton Dynamics: Subcontractors	**Justification**	**Amount**
No subcontractor was assigned to this task.		
Task 1, Phytoplankton Dynamics: Equipment	**Justification**	**Amount**
Task 1, Phytoplankton Dynamics: Other Direct	**Justification**	**Amount**
Boat Time	***usage fee***	***5184***
Task 1, Phytoplankton Dynamics: Indirect (Overhead)	**Justification**	**Amount**
Indirect Costs − SFSU	***25% on Direct Costs for Task 1***	***75912***
	Task 1 Total	$360,323
Task 2, Benthos: Labor	**Justification**	**Amount**
Thompson, Janet K.	***240 hrs x $52.16/hr***	***13155***
***Research Technician #1 (WK)**	***$3000/mo x 25% time for 12 mos***	***22500***
***Research Technician (USGS)**	***1280 hrs x $19.57/hr***	***26112***
Parchaso, Francis	***160 hrs $37.02/hr***	***6169***
Task 2, Benthos: Benefits	**Justification**	**Amount**
Thompson, Janet K.	***fringe benefits (medical, dental, vision, social security, etc.)***	***2894***

*Research Technician #1 (WK)	*fringe benefits (medical, dental, vision, social security, etc.) @ 48%*	*10800*
*Research Technician (USGS)	*fringe benefits (medical, dental, vision, social security, etc.)*	*5745*
Parchaso, Francis	*fringe benefits (medical, dental, vision, social security, etc.)*	*1358*
Task 2, Benthos: Travel Expenses	**Justification**	**Amount**
Air/Train	*airfare for scientific meetings and collaborative research*	*3800*
Lodging	*hotel accommodations*	*1200*
Meals	*per diem*	*600*
Conferences	*fees for scientific meetings*	*400*
Mileage	*$0.345/mi*	*1000*
Task 2, Benthos: Supplies And Expendables	**Justification**	**Amount**
Other	*Field/Lab Supplies*	*2500*
Task 2, Benthos: Subcontractors	**Justification**	**Amount**
No subcontractor was assigned to this task.		
Task 2, Benthos: Equipment	**Justification**	**Amount**
Task 2, Benthos: Other Direct	**Justification**	**Amount**
Boat Time	*usage fee*	*5184*
Task 2, Benthos: Indirect (Overhead)	**Justification**	**Amount**
Indirect Costs − USGS	*57% on Direct Costs for Task 2*	*37011*
Indirect Costs − SFSU	*25% on the first $25,000 of subaward to USGS*	*6250*
	Task 2 Total	$146,678
Task 3, Bacteria: Labor	**Justification**	**Amount**
Parker, Alex	*$3500/mo x 100% time for 6 mos/year*	*66203*
*Research Technician #3 (DW)	*$3366/mo x 50% time for 1.4 mos/yr*	*9424*
Task 3, Bacteria: Benefits	**Justification**	**Amount**
Parker, Alex	*fringe benefits (medical, dental, vision, social security, etc.) @ 48%*	*31777*
*Research Technician #3 (DW)	*fringe benefits (medical, dental, vision, social security, etc.) @ 48%*	*4523*
Task 3, Bacteria: Travel Expenses	**Justification**	**Amount**
Air/Train	*airfare for scientific meetings and collaborative research*	*5000*
Conferences	*fees for scientific meetings*	*5000*
Lodging	*hotel accommodations*	*5000*
Meals	*per diem*	*5000*
Mileage	*$0.345/mi*	*5000*
Task 3, Bacteria: Supplies And Expendables	**Justification**	**Amount**
Other	*Disposable Lab Supplies and/or Field/Research Supplies*	*12500*
Task 3, Bacteria: Subcontractors	**Justification**	**Amount**
No subcontractor was assigned to this task.		
Task 3, Bacteria: Equipment	**Justification**	**Amount**

Task 3, Bacteria: Other Direct	**Justification**	**Amount**
Boat Time	***usage fee***	***5184***
Task 3, Bacteria: Indirect (Overhead)	**Justification**	**Amount**
Indirect Costs − SFSU	***25% on Direct Costs for Task 3***	***41292***
	Task 3 Total	$195,903
Task 4, Microzooplankton: Labor	**Justification**	**Amount**
McManus, George	***1 mo/year in Years 1 &2 and 0.5 mos in Year 3***	***22632***
***Research Technician #1 (WK)**	***$3000/mo x 25% time for 12 mos***	***22500***
***Postdoctoral Associate**	***$3333/mo x 100% time in Years 1 &2***	***81669***
***UNdergraduate Student**	***$10/hr x 450 hrs***	***4500***
Task 4, Microzooplankton: Benefits	**Justification**	**Amount**
McManus, George	***fringe benefits (medical, dental, vision, social security, etc.) @ 24%***	***5619***
***Research Technician #1 (WK)**	***fringe benefits (medical, dental, vision, social security, etc.) @ 48%***	***10800***
***Postdoctoral Associate**	***fringe benefits (medical, dental, vision, social security, etc.) @ 26%***	***21651***
***UNdergraduate Student**	***fringe benefits (medical, dental, vision, social security, etc.) @ 3%***	***135***
Task 4, Microzooplankton: Travel Expenses	**Justification**	**Amount**
Air/Train	***airfare to scientific meetings and collaborative research***	***1000***
Conferences	***fees for scientific meetings***	***100***
Lodging	***hotel accommodations***	***450***
Meals	***per diem***	***138***
Mileage	***$0.345/mi***	***1062***
Task 4, Microzooplankton: Supplies And Expendables	**Justification**	**Amount**
Other	***Lab/Field Supplies***	***11500***
Task 4, Microzooplankton: Subcontractors	**Justification**	**Amount**
No subcontractor was assigned to this task.		
Task 4, Microzooplankton: Equipment	**Justification**	**Amount**
Task 4, Microzooplankton: Other Direct	**Justification**	**Amount**
Boat Time	***usage fee***	***5184***
Task 4, Microzooplankton: Indirect (Overhead)	**Justification**	**Amount**
Indirect Costs − University Of Conneticut	***48% on Direct Costs for Task 4***	***82899***
Indirect Costs − SFSU	***25% on the first $25,000 of subaward to USGS***	***6250***
	Task 4 Total	$278,089
Task 5, Mesozooplankton: Labor	**Justification**	**Amount**
Kimmerer, Wim J.	***$7800/mo x 100% time for 3 mos***	***73769***
***Research Technician #1 (WK)**	***$3000/mo x 50% time for 12 mos***	***45000***
***Student Assistant #1 (WK)**	***$14.00/hr x 1400 hrs in Years 1 &2, 700 hrs in Year 3***	***49000***
Task 5, Mesozooplankton: Benefits	**Justification**	**Amount**
Kimmerer, Wim J.	***fringe benefits (medical, dental, vision, social security, etc.) @ 48%***	***35409***
***Research Technician #1 (WK)**	***fringe benefits (medical, dental, vision, social security, etc.) @ 48%***	***21600***
***Student Assistant #1 (WK)**	***fringe benefits (worker's compensation and social security) @ 1.5%***	***735***
Task 5, Mesozooplankton: Travel Expenses	**Justification**	**Amount**
	airfare	***1000***

Air/Train		
Conferences	***fees for annual scientific conferences***	***200***
Meals	***per diem @ $46/day***	***600***
Lodging	***hotel accommodations***	***1000***
Mileage	***mi rate of $0.345/mi***	***1500***
Parking/Tolls	***parking and local bridge tolls***	***200***
Task 5, Mesozooplankton: Supplies And Expendables	**Justification**	**Amount**
Reproduction	***Publication Costs***	***1500***
Other	***Lab/Field/Measurement Supplies***	***13000***
Task 5, Mesozooplankton: Subcontractors	**Justification**	**Amount**
No subcontractor was assigned to this task.		
Task 5, Mesozooplankton: Equipment	**Justification**	**Amount**
Task 5, Mesozooplankton: Other Direct	**Justification**	**Amount**
Boat Time	***usage fee***	***5184***
Student Tuition	***student assistant***	***7200***
Task 5, Mesozooplankton: Indirect (Overhead)	**Justification**	**Amount**
Indirect Costs − SFSU	***25% on Direct Costs for Task 5***	***68610***
	Task 5 Total	$325,507
	Grand Total	$1,306,500

− The indirect costs may change by more than 10% if federal funds are awarded for this proposal.

What is the total of non−federal funds requested?

PROJECT PURPOSE

This proposal addresses two distinct but related topics:

1. Foodweb support for the threatened delta smelt, and
2. Potential mechanisms underlying relationships of abundance or survival of some fish to freshwater flow

These two topics are related through the productivity of the foodweb of the estuarine Low-Salinity Zone (LSZ) or oligohaline zone. This region, which encompasses a salinity of ca. 0.5 – 6 psu, is a key region of the estuary and the rearing area for numerous estuarine-dependent fishes.

Topic 1: The threatened delta smelt (*Hypomesus transpacificus*) is now the principal species of concern for management of freshwater flow and diversions in the Sacramento-San Joaquin Delta, and the principal target for restoration in the upper San Francisco Estuary. The abundance of this federally-listed threatened species has been low since the early 1980s, and it has not recovered to the point where it can be considered for delisting; indeed, the 2004 abundance index was the lowest on record. Potential reasons for its low abundance are many, but evidence points to the direct and indirect effects of export pumping of freshwater in the south Delta, toxic substances, and low food supply as likely contributing factors (Bennett, submitted). We believe that the feeding environment of delta smelt may be implicated in the continued low abundance of this species. Delta smelt feed for their entire lives on zooplankton, principally copepods, mainly in the brackish waters of the western Delta and Suisun Bay. As discussed below, copepod abundance is depressed in this region.

Topic 2: Previous work on the responses of the estuarine ecosystem to interannual variation in freshwater flow has demonstrated a decoupling between the abundance of lower trophic levels and that of fish and shrimp (Kimmerer 2002a, b, 2004). This decoupling may imply that variability in foodweb support is unimportant to variability of higher trophic levels, but there are some important pieces missing from the puzzle. Chief among these is the fact that the supply of labile organic matter from freshwater to the LSZ varies with freshwater flow, and this flux has not been accounted for in analyses of the estuarine foodweb.

We propose a research project aimed at understanding and possibly improving the foodweb supporting delta smelt and other estuarine species. *This project will address the following key questions regarding this foodweb, focusing on the Low-Salinity Zone of the northern estuary:*

1. How do benthic grazing, available solar irradiance, and the concentrations of and composition of nitrogenous nutrients interact to influence the species composition and production of phytoplankton?
2. How does bacterial production respond to changes in particulate and dissolved organic carbon (POC & DOC) delivered primarily through river flow?
3. What is the role of the microbial foodweb in supporting higher trophic levels?
4. To what extent is copepod production dependent on these alternative energetic pathways (phytoplankton and bacterial production)?

This project responds to two of the priority topics identified in the PSP: “Ecological Processes and Their Relationship to Water Management and Key Species”, and in ways that we explain below, “Water Operations and Biological Resources.”

BACKGROUND AND CONCEPTUAL MODEL

Our conceptual model is summarized in Figure 1, which depicts flow of material within the LSZ foodweb and from the freshwater regions into the LSZ.

Why study the foodweb of delta smelt? Most of the present management emphasis for delta smelt is on the influence of freshwater export flows, particularly in application of the Environmental Water Account (Kimmerer 2002b). Nevertheless, to manage this fish effectively requires an understanding of its ecology. Both on general principles and on the basis of specific evidence, feeding ecology of this small, annual, planktivorous fish may be a key to its interannual variability and therefore the likelihood of its persistence. Although knowledge of the biology of delta smelt is growing rapidly, we still are at a loss to explain year-to-year fluctuations in abundance and the reason for the long-term decline (see Kimmerer 2002a Figure 7). Delta smelt abundance probably responds to multiple, interacting factors (Bennett and Moyle 1996), and these influences may be subtle and difficult to detect (Houde 1989).

Although delta smelt spawn in freshwater in the Delta and, in wet years, the Napa River, much of their life is spent in brackish water. Larvae move downstream to the Low-Salinity Zone (LSZ, salinity of 0.5-6) when they reach ~30 mm length, generally in July (Figure 2). Over all samples, 53% of the delta smelt in summer and 72% in fall have been taken in the LSZ. As with other estuarine species, relating abundance patterns to salinity rather than to geographic location provides for clearer interpretation of data, and we follow this practice in our experimental design.

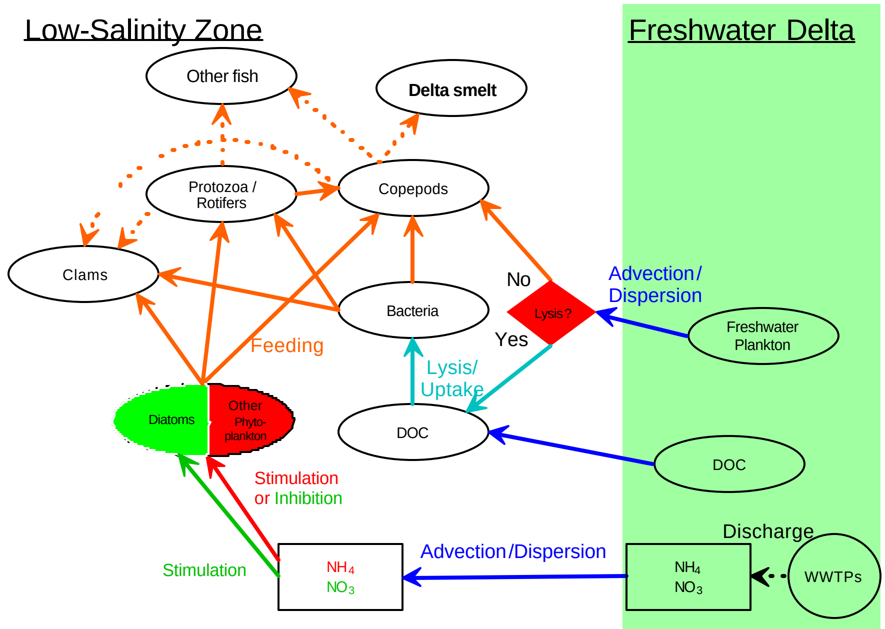

Figure 1. Simplified material flow diagram for the pelagic foodweb of the upper San Francisco Estuary. For clarity we include principally the components and links we propose to investigate. Links shown as solid lines will be investigated in field or laboratory work, while those shown as dotted lines will be inferred from literature data or results of other projects. We focus on events and effects in the Low-Salinity Zone (LSZ), with a salinity range of roughly 0.5 – 6. Material enters the LSZ from the freshwater Delta through advection (predominantly due to river flow) and tidal dispersion; the advective term implies increasing loading of all substances as river flow increases. We are concerned particularly with nitrogenous nutrients (particularly ammonium supplied by wastewater treatment plants, WWTP), dissolved organic carbon (DOC), and freshwater phytoplankton. The foodweb of the LSZ depends for its energy on some combination of imported DOC and local production of phytoplankton. Bacterial production depends on DOC, much of which must be exogenous; therefore bacterial uptake is likely to vary with freshwater flow, and lysis of freshwater phytoplankton may be an important pathway. Ammonium, derived partly from WWTPs and partly from local recycling, may cause reduced growth rate in diatoms relative to nitrate, with consequences for the rest of the foodweb. The present-day foodweb of the LSZ is likely more dependent on the bacterial than the phytoplankton pathway. Not shown: advective and dispersive losses; important foodweb components such as mysids and shrimp; other nutrients; complicating details of the microbial foodweb.

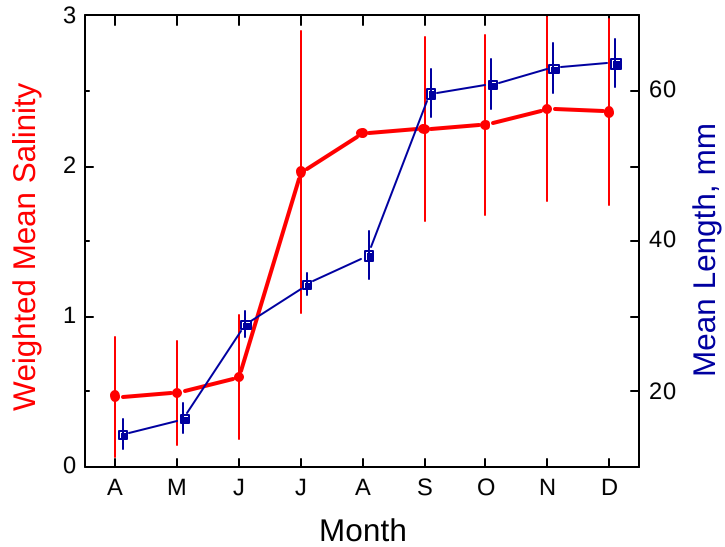

Figure 2. Delta smelt distribution patterns by season. Mean salinity weighted by abundance (left axis) and mean length (right axis) of delta smelt from three monitoring programs. Data are means with 95% confidence limits of the mean among all surveys during a given month.

Delta smelt feed on copepods, particularly calanoids, both as larvae (Lott 1998) and as juveniles and adults (Nobriga 2002). Thus, these fish depend mainly on the pelagic foodweb of the LSZ. Several important changes in this foodweb have occurred in the last 2 decades. Chief among these is the sharp decline in phytoplankton productivity in 1987, particularly during late spring through summer, which has been attributed to grazing by the introduced clam *Potamocorbula amurensis* (Alpine and Cloern 1992). The decline in phytoplankton in 1987 was accompanied by changes in the species composition of the copepods, but total biomass and production of copepods during spring and summer changed much less than phytoplankton (Kimmerer in prep.). Nevertheless, there are several reasons to believe that food for delta smelt is in short supply. First, limited histopathological studies have shown that a large proportion of delta smelt larvae are in a starved condition (Bennett submitted). Second, zooplankton abundance in the San Francisco Estuary is low compared to other estuaries (Kimmerer and Orsi 1996). Third, numerous lines of evidence show estuarine zooplankton to be food limited (Müller-Solger et al. 2002, Kimmerer et al. in prep.), and the present low chlorophyll concentrations in the LSZ suggest that this situation is continuing. Finally, the abundance of calanoid copepods is depressed in late spring to early summer, the time when delta smelt move into the LSZ (Figure 2).

Although total copepod production did not change much between pre-clam (i.e. up to 1987) and post-clam periods, there was a substantial change in species composition of copepods, and in particular a decline in biomass of calanoid copepods in spring (Figure 3). Some of the biomass deficit was made up during summers beginning in 1993 by the cyclopoid copepod *Limnoithona tetraspina*, but this copepod is not heavily preyed upon by delta smelt, presumably because it is small (about 10% the weight of the calanoid copepods) and cryptic (Bouley, in prep.). *Thus, there is reason to believe that low copepod production and biomass may be inhibiting the recovery of delta smelt.*

<u>The influence of freshwater flow:</u> Freshwater outflow into the estuary is regulated most of the year by retention and release of water in reservoirs throughout the watershed, and diversion pumping in the south Delta by the state and federal water export facilities. The approximate center of the LSZ is indicated by "X2", the distance in km from the mouth up the axis of the estuary to the 2 psu (practical salinity units) isohaline. This index has proved useful in providing a geographic or habitat-based view of the physical response of the estuary to changes in freshwater flow: X2 varies either linearly with the log of outflow (Jassby et al. 1995) or by a power function (Monismith et al. 2002).

The principal interest in X2 has arisen because abundance or survival of several estuarine biological populations in the San Francisco Estuary is positively related to freshwater flow, or negatively to X2 (Jassby et al. 1995). The reasons for these relationships have been discussed (EET 1997, Kimmerer 2002a, b, 2004) but not resolved. It is likely that several different mechanisms are operating in different parts of the estuary.

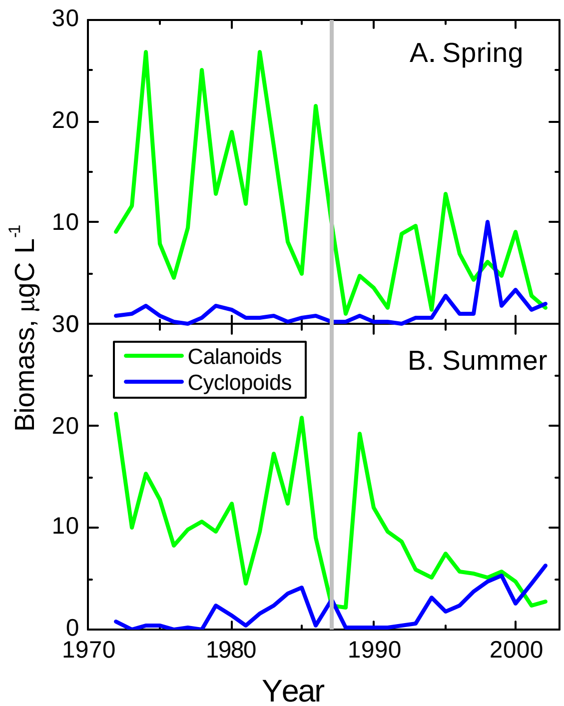

Figure 3. Copepod biomass in spring and summer in the LSZ. Calanoids comprise mainly Eurytemora affinis in spring and Pseudodiaptomus forbesi in summer, with three other species abundant at times. Cyclopoids included a variety of species until 1993; since then the zooplankton has been dominated numerically by Limoithona tetraspina. Data from Kimmerer, in prep. based on abundance data from the IEP zooplankton survey.

The "fish-X2" relationships form an important basis for management of the estuary using a salinity standard (Kimmerer 2002b). The salinity standard is an ecosystem management tool, in that it appears to benefit a variety of estuarine species. However, meeting the standard comes at a high cost in water, leading to dissatisfaction with the standard in the water user community. Furthermore, some of the fish-X2 relationships on which the standard is based have considerable statistical uncertainty, so the realized benefits of the salinity standard are not clear. Finally, some of the relationships have changed in the last several years (Kimmerer 2002a, b). Thus, there is a great deal of interest in improving and refining the standard, which will require a better understanding of the mechanisms underlying the fish-X2 relationships.

A current project funded by the CALFED Ecosystem Restoration Program and led by Kimmerer is developing a work plan for investigating the mechanisms underlying the fish-X2 relationships, and conducting model studies to investigate the physical dynamics that may underlie some of these relationships. The draft work plan will be prepared in mid- to late 2005 and Kimmerer is drafting the findings of those studies. Furthering our understanding of the basic food web issues that are described in the current proposal will strengthen our ability to intelligently implement these plans. Results from the proposed study will be made available immediately to those implementing and prioritizing the work plan due to the connection between the two projects.

Previous analyses showed that the fish-X2 relationships were unlikely to arise through a traditional stimulation of the foodweb by nutrients, known as an "agricultural model" (Kimmerer 2002a, b). However, one aspect of the foodweb not addressed in previous studies is the potential role of particulate and dissolved organic carbon (POC and DOC) entering the LSZ from the freshwater Delta. A recent CALFED-funded study led by the US Geological Survey demonstrated clearly that phytoplankton production was the most important source of organic matter that actually entered the foodweb of the Delta, and that terrigenous and marsh sources were unimportant (Sobczak 2002, in press, Muller-Solger 2002, Jassby et al. 2002). Since transport of phytoplankton to the LSZ may be a major source of organic carbon to that region, this implies a potential relationship between flow and the flux of organic matter to the LSZ.

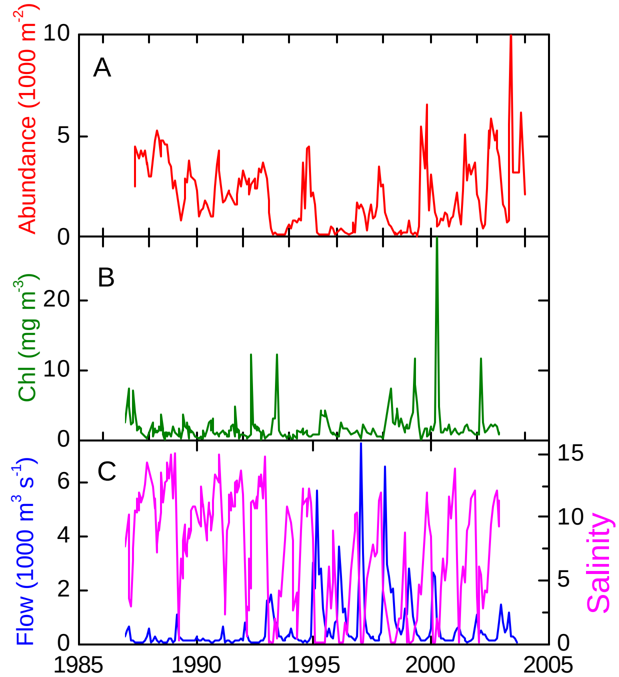

Figure 4. Time course of monthly values for: A) Abundance and biomass of P. amurensis at a monitoring station in Grizzly Bay, northern arm of Suisun Bay; B) chlorophyll concentration at the same station; C), Net freshwater outflow from the Delta and salinity in Grizzly Bay. All data from the IEP server except clam biomass from J. Thompson (unpubl.)

Benthic grazing The importance of benthic grazing in controlling the buildup of phytoplankton biomass is well established in the San Francisco Estuary (Cloern 1982, Alpine and Cloern 1992, Thompson in press). In particular, grazing by the introduced Amur River clam *Potamocorbula amurensis* has had a striking effect on phytoplankton (Thompson in press), zooplankton (Kimmerer et al. 1994, Kimmerer and Orsi 1996), and bacteria (Werner and Hollibaugh 1993). Clams may consume a larger fraction of diatoms than other (particularly smaller) phytoplankton because clam grazing is selective for larger particles (Werner and Hollibaugh 1993) and possibly because of more rapid settling by diatoms (Lucas et al. 1998). Silicic acid uptake in summer in the LSZ is now indistinguishable from zero (Kimmerer in press), indicating very low diatom production.

Abundance of *P. amurensis* in Grizzly Bay, a shallow region within the Suisun Bay complex, has fluctuated with annual maxima of > 1000 m^{-2} since 1987 (Kimmerer 2004; Figure 4). During the drought that followed its invasion, the apparent lack of winter mortality (seen in later years following the drought) resulted in longer-lived individuals and little seasonal variability of biomass (Figure 4A). The longer-lived individuals resulted in seasonally persistent grazing pressure and phytoplankton biomass was severely depressed during these years except during 1992 (Figure 4B). Since the drought ended, short periods of increase in chlorophyll are coincident with relatively small biomass numbers for *P. amurensis* (e.g., 1993, 1998, and 1999). These declines in clam biomass followed freshwater flow events which reduced the population biomass by increasing mortality in older individuals in 1993, at the end of the drought, and by reducing all age groups due to the high freshwater flow in 1998. *P. amurensis* has recovered quickly from seasonal population reductions presumably due to its presence throughout north bay, the ability of larvae to withstand large, rapid changes in salinity (Nicolini and Penry 2000), and its apparent ability to live in most substrates and depths (Carlton et al 1990).

Limits on phytoplankton production Two factors are known to regulate phytoplankton production in the northern estuary. First, specific growth rate is limited by the availability of light (Cole and Cloern 1984, 1987), and this limitation is likely to be most severe in the turbid waters of the LSZ. Second, phytoplankton biomass is reduced through benthic grazing. Conservative grazing rates (assuming two thirds of the population are feeding at one time and that there is a concentration boundary layer near bottom) in Grizzly Bay had a strong seasonal pattern with low values in winter and a summer median of about 0.5 m d^{-1} from 1988 through 1999 (J. Thompson unpublished). If we assume the upper water column is well mixed, this grazing rate means the clams are capable of filtering a 2m water column 4 times a day. Given the measured doubling rate for phytoplankton in this system (0.1 d^{-1}, Alpine and Cloern 1992) this grazing rate appears sufficient to limit local phytoplankton production.

In recent years in the LSZ, brief, unreliable spring blooms have occurred in wet years when clam grazing is low (Figure 4). There have also been dry spring periods when clam grazing was low (1989, 1994) and no bloom developed. An additional mechanism for limitation of diatom growth rate during this period may result from the interaction of the two principal forms of available nitrogen, nitrate and ammonium (Dugdale, Wilkerson, and Hogue in prep.). Uptake of ammonium by phytoplankton is energetically advantageous and suppresses uptake of nitrate (e.g. Conway 1977; Dortch, 1990). However, maximum nitrate uptake is more rapid than maximum ammonium uptake under the conditions in SFE (Dugdale, unpublished data), particularly for diatoms. The logical consequence of this is that maximum phytoplankton growth rate is higher when the phytoplankton are growing on nitrate than when they are growing on ammonium, provided light is adequate. Therefore blooms in less turbid water (e.g., Central Bay) may occur only when ammonium is below a value at which it inhibits nitrate reductase synthesis and hence nitrate uptake. The waters of the LSZ are turbid, but before *P. amurensis* became abundant, phytoplankton blooms were common, indicating that light was previously adequate for positive net growth rate. Thus, at present it is possible that the above mechanism (high NH_4 concentrations) may limit bloom development in spring.

Previous field and laboratory work clearly supports the hypothesis that blooms occur only when ammonium concentration is low (Dugdale, Wilkerson, and Hogue in prep.). Stations in Suisun, San Pablo, and Central Bay were sampled regularly from 1999 to 2003. Spring blooms were observed in Central and San Pablo Bays in each year, but only in 2000 in Suisun Bay see Figure 4). All three bays showed high concentrations of NH_4, declining from Suisun to Central Bay. Blooms did not occur above an ammonium concentration of 4 µM. Furthermore, the ratio of nitrate to ammonium uptake was related to occurrence of blooms, and also was high only when ammonium concentration was low (Figure 5).

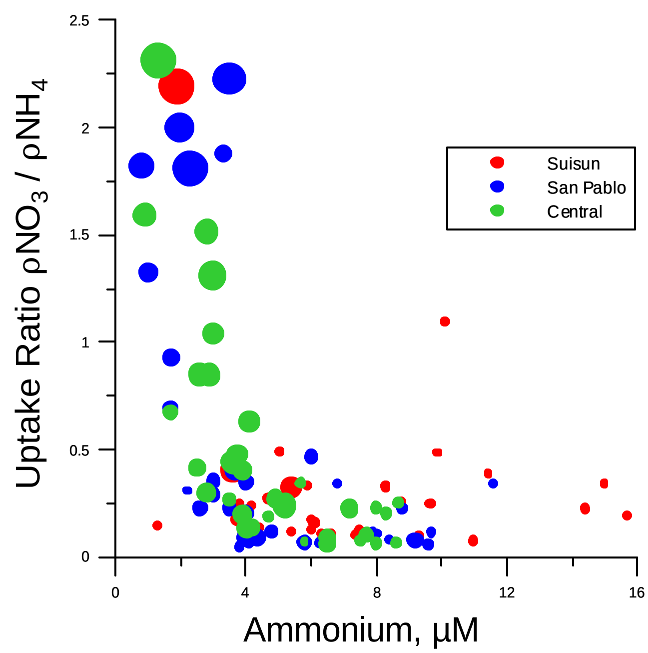

Figure 5. Ratio of nitrate to ammonium uptake as a function of ammonium concentration for three sites in the San Francisco Estuary. The diameter of the circles is proportional to chlorophyll concentration. R. Dugdale unpublished data, 1999-2002.

An alternative explanation for an inverse relationship between chlorophyll concentration and ammonium is that blooms reduce ammonium concentration through uptake. However, that mechanism would result in a negative linear relationship between total DIN concentration and chlorophyll concentration, not the threshold pattern observed (Figure 5). In addition, the amount of ambient ammonium is insufficient to support the concentration of chlorophyll observed in blooms. Recent studies by Dugdale et al. (in prep) showed that phytoplankton uptake of ammonium occurs in the pre-bloom period helping to reduce ammonium concentrations to non-inhibiting levels.

NH_4 comes from local recycling, agricultural runoff, and the discharge from wastewater treatment plants (WWTPs, Hager and Schemel 1992). In addition, clams consume phytoplankton and other organic matter, rapidly converting much of the nitrogen to ammonium. Since our enclosure experiments have shown the initial stage of a diatom bloom results in the reduction of ambient ammonium concentration, the clam population may act through grazing to prevent the buildup of a phytoplankton population , so the initial phytoplankton growth required to reduce the ammonium concentration does not occur and the blooms do not develop. Whether the early spring clam population has the capacity to overwhelm the growth of diatoms on ammonium, i.e., to prevent a positive population growth, is the question to be answered by this research. If this is true the grazing and excretion rates of clams need only be large enough to limit the production of phytoplankton to less than some minimum, but as yet unknown, level for the bloom to be inhibited.

Freshwater phytoplankton are transported to the LSZ by advective net flow and dispersion. Species composition of phytoplankton changes from a freshwater suite of species to a brackish-water suite somewhere near the LSZ (Lehman 2000), so some process that eliminates freshwater phytoplankton must be operating in the LSZ. A likely process is osmotic stress due to increasing salinity followed by loss of function, loss of DOC to the water, and lysis. These processes are moderately well-understood in general (Morris et al. 1978, Fisher et al. 1998) but have not been studied in the San Francisco Estuary.

The input of freshwater phytoplankton or their byproducts to the LSZ represents a supply of organic carbon for the higher trophic levels through several alternative pathways (Figure 1). First, the phytoplankton, alive or dead, could be consumed by mesozooplankton, or by microzooplankton which are then consumed by mesozooplankton. Second, the phytoplankton could lyse and the resulting DOC could be taken up by bacteria, which would then either be consumed by heterotrophic protists, or the bacteria could be consumed directly if they are attached to organic particles large enough to be consumed by mesozooplankton. At the same time, every one of these foodweb components can be consumed by clams (Werner and Hollibaugh 1993, Kimmerer et al. 1994). The form of organic carbon has important consequences for trophic efficiency and overall system productivity, in that direct ingestion of POC results in a more efficient estuarine food web than indirect transfer through DOC.

Controls on microbial production

Heterotrophic bacteria may represent an important source of energy to higher trophic levels in the LSZ. The transfer of organic matter to higher trophic levels via bacteria occurs through the microbial loop, a well established concept in oceanic systems, but a poorly understood component of estuarine foodwebs. It has been suggested that in coastal systems where primary production is usually high the microbial loop plays only a minor role in organic matter cycling. However, because phytoplankton biomass is considerably below the average for coastal systems (Cloern 2001) in the brackish northern San Francisco Estuary, bacteria and the microbial loop may represent a more significant process, and one that is common in turbid coastal systems.

Several estuaries have been characterized as net heterotrophic (e.g. Hoch and Kirchman, 1993, Jassby, 1994, Smith and Kemp, 1995, Revilla, et. al., 2000). Estuaries support high bacterial biomass, particularly when there are significant terrestrial organic matter inputs (Carlsson, et. al., 1999, Conan, et. al., 1999). Sobczak et al. (2002) found that on an annual basis, river inputs of organic matter to the San Francisco Delta represented 69% of the total organic matter supply; in situ primary production accounted for <15%, but a much higher proportion of the bioavailable DOC. Hollibaugh and Wong (1996) estimated that annual mean bacterial biomass was 30mg C m^{-3} in the North Bay. Rudek and Cloern (1997) found ratios of planktonic respiration to production in the lower Sacramento River that were consistently greater than 1 (mean 6.1). The combination of low phytoplankton biomass and high organic matter inputs to the upper San Francisco Estuary would suggest a dominance of bacterial biomass and a shift towards the microbial loop. However, significant uncertainties about net community metabolism remain (Rudek and Cloern, 1997).

Persistently high NH_4 concentrations may inhibit phytoplankton growth in the San Francisco Estuary. As a corollary, anthropogenic NH_4 may increase bacterial growth rates and further enhance microbial loop processes. Several investigators have shown significant uptake of NH_4 by bacteria (see Kirchman 2000). A model of bacterial NH_4 use predicts that as the C:N of the dissolved organic matter (DOM) substrate being used by the bacteria increases, bacteria will use NH_4 (Goldman and Dennett 1991). Terrestrial organic matter inputs typically have high C:N ratios, leading to low bacterial growth efficiencies. Hollibaugh and Wong (1996) hypothesized that variability in bacterial production in the northern estuary was due to periodic pulses of labile organic matter superimposed on relatively low production rates supported by refractory DOM. Significantly less is known about bacterial NO_3 uptake (Kirchman and Wheeler, 1998), particularly in estuaries. Middelburg and Nieuwenhuize (2000) found high bacterial NO_3 uptake in response to very high NO_3 concentrations in the Thames River Estuary. Parker et al. (1975) found NO_3 assimilation by heterotrophic bacteria in response to carbon rich pulp mill effluent.

The transfer of bacterial biomass to higher trophic levels probably occurs through the microbial loop rather than direct ingestion by zooplankton. However, Hollibaugh and Wong (1996) reported that between 10 - 67% of measured bacterial production was found in particle-associated cells with the highest rates of particle-associated bacteria in the North Bay. The degree to which zooplankton can directly ingest bacteria that are associated with larger particles is unknown. However, *P. amurensis* is capable of filtering and consuming bacteria and thus bivalves may be a sink for some of this production (Werner and Hollibaugh 1993). Work by Thompson et al (in prep) shows that when *P. amurensis* production rates are adjusted for assimilation efficiencies the amount of primary production from phytoplankton was only marginally sufficient to support the populations of bivalves seen in Suisun and Grizzly Bays between 1988 and 1999 if the sampling stations are representative of the system.

If bacterial production in the LSZ is supported by exogenous DOC from the Delta, then bacterial production should respond to freshwater flow which increases the rate of delivery of material from the Delta to the LSZ. However, the response is complicated by the negative relationship between phytoplankton biomass (and therefore production of labile DOC, Sobczak et al. 2002) in the Delta and flow during winter-spring (Jassby et al. 2002). Based on Figure 8A in Jassby et al. (2002) we calculate that at Delta outflow values above ~1000 $m^3 s^{-1}$ (about 20% of all daily outflow values) the transport of phytoplankton-derived material from the Delta should increase more or less linearly with flow; below that level it is difficult to tell whether the increasing biomass at long residence time offsets the reduced delivery rate. Nevertheless, we anticipate some flow response of bacterial production.

<u>Copepod biomass and production</u> Previous studies, some still in progress, have revealed a lot about the dynamics of copepod populations in the LSZ. The native (or naturalized) calanoid

copepod *Eurytemora affinis* was once the numerical and biomass dominant throughout the year. Since the invasion of the clam *Potamocorbula amurensis*, its abundance has declined in late spring of each year so that it is rare throughout the summer; this decline has been attributed to grazing by clams on the nauplius larvae of the copepods (Kimmerer et al. 1994), although food limitation may still be occurring. (Kimmerer unpublished). In 1989 another calanoid copepod, *Pseudodiaptomus forbesi*, became abundant and it has essentially replaced *E. affinis* through summer. Then in 1993 the tiny introduced cyclopoid copepod *Limnoithona tetraspina* became the most abundant copepod in the estuary, although its biomass is actually slightly less than that of the calanoids (Figure 3).

Copepods are generally considered particle-feeders, but feeding habits and modes are varied and complex. Food sources for copepods may include phytoplankton, microzooplankton, detritus, other zooplankton, or bacteria. Bacterial cells are generally too small for copepods to consume efficiently, but the substantial fraction of bacteria on organic aggregates (Hollibaugh and Wong 1996, 2000) may be available for copepod grazing. *E. affinis* is the most traditional of the LSZ copepods: it can survive on a variety of particles (including detritus, Heinle et al. 1977) but we have been able to rear it for several years on diatoms. Conversely, *P. forbesi* will not grow on diatoms and appears to require at least some flagellates or ciliates in its diet. A recently completed Master's project at the Romberg Tiburon Center, funded by the CALFED Ecosystem Restoration Program, showed that *L. tetraspina* feeds almost exclusively on moving particles such as ciliates, and does not appear to eat diatoms (Bouley in prep.). These results are not surprising in an ecosystem from which most of the diatom production has been eliminated; they further hint that the chief trophic pathway is through the microbial loop (i.e., bacteria and microzooplankton, Figure 1), an inefficient pathway.

Other aspects of population dynamics differ among these species as well. For their populations to be maintained at constant levels with declining food supply, copepods must compensate for the reduced food supply by reducing losses to predation. Predatory gelatinous zooplankton are uncommon in this part of the estuary (Orsi and Mecum 1986, Kimmerer and Orsi 1996, Kimmerer et al. 1999), mysids much less common than before 1987 (Orsi and Mecum 1996), and filter-feeding anchovies have vacated the area (Kimmerer in prep.), so visual planktivory by small fish is probably the dominant predatory mode on copepods. *L. tetraspina* apparently avoids predation by being small and minimizing movement, making it difficult for visually-feeding planktivores to detect. We are still working on the mechanisms by which *P. forbesi* can survive in this environment, but its reproductive rate in the LSZ is very low and it seems to be subsidized by inputs of larvae from the freshwater Delta, where food concentrations are higher and *Potamocorbula* is uncommon.

Current status and critical unknowns

Although knowledge about the foodweb of this estuary has progressed substantially in the last decade, significant remaining gaps prevent us from making more than a guess at the relative importance of the alternative pathways in Figure 1. Yet the multiplicity of potential pathways for organic matter has several implications for management. First, several alternative processes could affect the supply of available organic carbon to the foodweb of the LSZ. Some of these processes can be influenced by human activities, some may be influenced indirectly, and some are effectively uncontrollable. Knowing the relative contribution of each process to the food supply of delta smelt seems important for management.

The abundance of clams is uncontrollable from a practical perspective. Their distribution varies somewhat with salinity (i.e., abundance of *P. amurensis* declines as salinity goes below about 1, Hymanson 1991), but the flow required to significantly alter their distribution would be prohibitively expensive (Kimmerer 2002b). Turbidity is not under direct control but has been decreasing over the past few decades, perhaps because of the reduction in sediment supply from the rivers (Kimmerer 2004, Wright and Schoellhamer 2004) or trapping by the introduced freshwater plant *Egeria densa*. The flux of organic carbon into the LSZ likely depends on freshwater outflow, which may explain the relationship of flow to bacterial production (Murrell et al. 1999). Finally, if the occurrence or magnitude of the spring bloom is affected by ammonium concentration, there may be opportunities for reduction in source load, or dilution with freshwater, to reduce NH_4 to the apparent threshold for bloom formation.

How can we develop an interpretation consistent with the above observations, and what are the management implications of this interpretation? It seems clear that the foodweb of the LSZ is no longer a traditional, diatom-dominated system. Therefore to develop our interpretation we will need to answer the following questions:

1. *To what extent is abundance and biomass of phytoplankton, particularly diatoms, controlled by benthic grazing, light limitation, salinity stress, or nutrient composition in the LSZ?* It has seemed clear since 1988 that benthic grazing was having an overwhelming effect on phytoplankton in Suisun Bay, particularly given the low growth rates possible in that turbid water. However, it is not clear whether clams have the filtration capacity to suppress the development of blooms during all seasons We do not anticipate an "either-or" answer to this question; rather, we propose to determine the relative importance of these two mechanisms and examine their inter-dependence.

2. *What is the relative importance of each of the alternative trophic pathways in Figure 1?* This question is of very broad interest among aquatic scientists. We have a good chance of answering it here for several reasons. The first is the extensive background information available on the northern estuary, from which we can draw general information as well as specifics. The second is the intensive, ongoing monitoring programs run by the Interagency Ecological Program and the USGS. The third is our study design which includes all of the key elements of the foodweb, and will allow us to measure the relevant material fluxes on samples from the same water body at the same time.

Study site

The LSZ, generally located in eastern Suisun Bay and the western Delta (Figure 6), has been the subject of considerable research focusing on phytoplankton (Arthur and Ball 1979, Cloern et al. 1983), hydrodynamics and the interaction of vertical position of larval fish and zooplankton with the flow field (Kimmerer et al. 1998, 2002, Bennett et al. 2002), and on the impacts of the introduced clam *Potamocorbula amurensis* (Kimmerer et al. 1994). It is the center of abundance of several zooplankton and fish species including delta smelt and several of the species that respond strongly to freshwater flow (Kimmerer and Orsi 1996, Kimmerer 2004).

Low-salinity regions of estuaries are sites of fundamental chemical and biological transformation (Morris et al. 1978), commonly associated with a turbidity maximum (ETM, Postma and Kalle 1955, Kimmerer et al. 1998) and high microbial activity, particularly by bacteria associated with organic particles (Hollibaugh and Wong 1996). In the San Francisco Estuary, turbidity maxima are produced by bathymetric features (Schoellhamer 2001), and stratification and gravitational circulation are uncommon when the LSZ is in the shallow Suisun Bay (Kimmerer et al. 1998).

Nevertheless, turbidity is higher in the LSZ than either landward or seaward of it (Kimmerer et al. 1998), apparently because of interactions between tidal currents and the mean flow (Schoellhamer 2001). Thus, the LSZ in this estuary has some features in common with other estuaries (the salinity regime, turbidity maximum) but not others (stratified flow, gravitational flow).

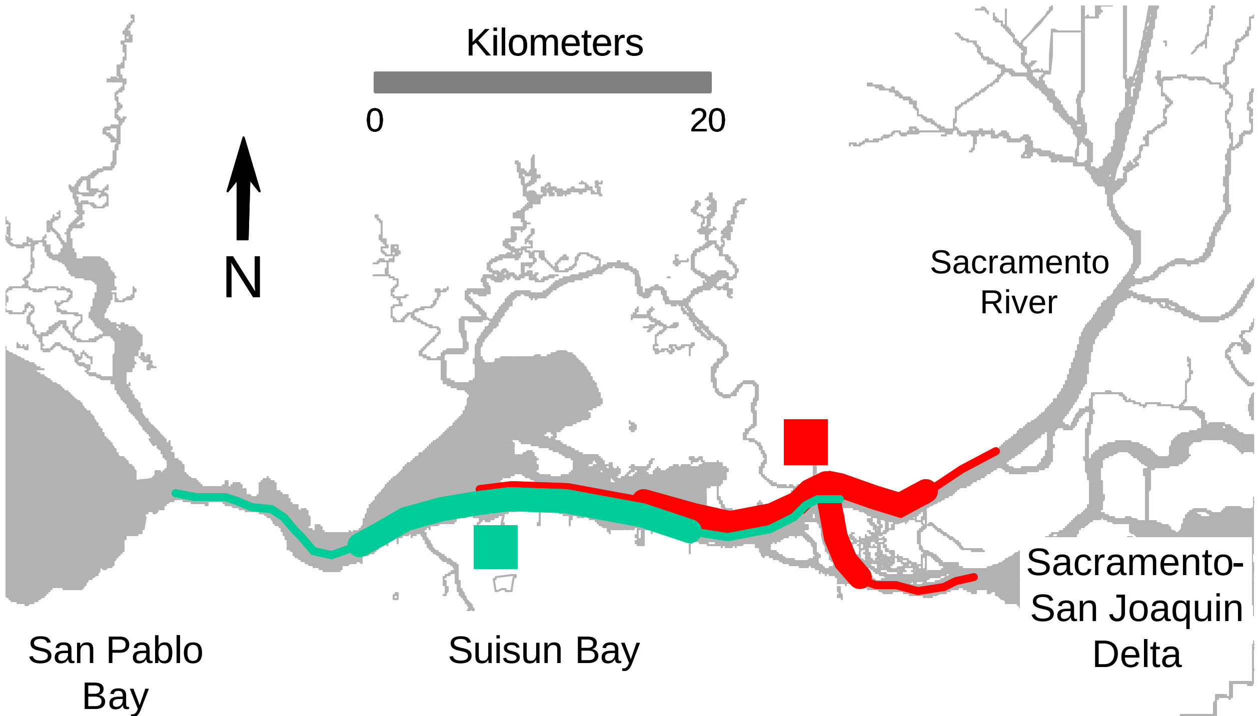

Figure 6. Position of the LSZ in the northern San Francisco Estuary. Lines and symbols show position of the LSZ as indexed by X2 during spring (green) and summer (red) during 1955-2003. Thin lines show range of 10th to 90th percentiles of daily position, heavy lines show quartiles, and solid squares show medians.

PROJECT DESCRIPTION

We propose a collaborative program of field and laboratory research focused on lower trophic levels in the Low-Salinity Zone of the western Delta and Suisun Bay. Fundamentally we hope to understand better how the degraded foodweb supports fish, principally delta smelt. The research will comprise four major components each addressing one of the research questions posed above.

Our frame of reference in this study will be predominantly salinity rather than geography. That is, we propose to sample for plankton at stations defined by selected salinity ranges rather than at fixed stations. Planktonic organisms are incapable of swimming against tidal currents, and are less likely to be oriented to geography than to salinity (Laprise and Dodson 1993, Kimmerer et al. 1998). Estuarine fish, too, appear to orient to salinity ranges (Baxter et al. 1999, Kimmerer 2004). In addition, we are interested in the chemical and biological conditions in the transition between the freshwater environment and brackish water (Morris et al. 1978).

Although it is appropriate to sample the water column at stations defined by salinity, the same is not true for the benthos. We need information on how grazing by the clam *Potamocorbula amurensis* affects biota in the LSZ. Since the effect of the clam operates at a time scale longer than a tidal cycle (e.g, turnover time of water column chlorophyll), effects of clams on the overlying water column are smeared out over a broad region by tidal dispersion (see Kimmerer and Orsi 1996, Jassby et al. 2002). Therefore sampling for clams will be by a stratified random sampling design in Suisun Bay and the western Delta. The calculated grazing rate in the LSZ will be an average of rates determined in sub-regions of this area, weighted by the time the LSZ spends in each area. In this way we will be able to link variability at two different temporal scales.

The proposed research will provide a quantitative basis for the model depicted in Figure 1. This model will be developed using available data as a framework, including data to develop advective and dispersive fluxes of materials and organisms.

We list here several hypotheses to be tested, organized by the fundamental research questions above. Although stated as hypotheses, in many of these cases we aim not so much to test these hypotheses formally as to compare among competing (or complementary) models of how the system works (Hilborn and Mangel 1997). The complexity of the LSZ foodweb (Figure 1) suggests that multiple mechanisms operate simultaneously, and that therefore simple yes/no hypothesis tests must be supplanted with quantitative estimates of model parameters. Except where noted, these hypotheses apply during times when delta smelt are likely to be in the LSZ (Figure 2). The hypotheses incorporated in these models are:

1. **Phytoplankton dynamics**
   a. Suppression of the spring bloom varies with freshwater flow into the LSZ through its transport of NH_4
   b. Lysing of freshwater phytoplankton in brackish water contributes DOC to the LSZ foodweb.
2. **Benthic grazing effects**
   a. Suppression of the spring bloom varies with freshwater flow into the LSZ through its influence on biomass of clams
   b. Summer diatom biomass continues to be suppressed by clam grazing.
3. **Bacterial production**
   a. Bacterial production is controlled by the supply of phytoplankton-derived DOC
   b. Bacterial production is controlled by clam grazing
4. **Microbial foodweb**
   a. Microzooplankton production is fueled by bacteria
   b. Microzooplankton production is fueled by phytoplankton
5. **Copepod production**
   a. Copepod production is supported by local phytoplankton production
   b. Copepod production is supported by exogenous carbon

Overall work plan

We propose a staged sequence of field work, laboratory studies, and synthesis. Our field program will focus on the spring bloom (April-May), and on the mid- to late-summer period of low phytoplankton biomass and production. We anticipate two years of field work, with an initial emphasis on evaluating longitudinal gradients and a subsequent focus on two salinity regimes; the third year will be used for analysis and synthesis. Laboratory work will use incubations for various measurements, including nitrogenous nutrient interactions, phytoplankton production, bacterial production, microbial foodweb production, and consumption of various components by copepods.

During years 1 and 2 we plan weekly cruises to the LSZ during spring (mid-March to mid-May), then every three weeks through August, using RTC's 38-foot research vessel, R/V Questuary. Spring trips will focus on bloom dynamics, and summer trips on alternative food sources for copepods. Two additional trips will be taken to sample clams. The clam cruises will also require a small boat operating simultaneously to collect in shallow regions inaccessible to the Questuary. We also plan to take 8 trips by small boat during each year to fill in samples between the main cruises. In general, cruises will depart early enough to return samples to RTC for processing and incubation; this approach worked well during our recent EPA-funded study of Suisun, San Pablo, and Central Bays.

Because much of our work depends on the timing of specific events (e.g., spring bloom or no bloom, spring minimum in copepod biomass, summer movement of delta smelt), we will be flexible about cruise dates and adjust them as necessary. Information on conditions in the LSZ will be monitored through continual checks of online data for salinity and temperature, and examination of data as they become available from the DFG 20mm survey for late larval delta smelt. Our sampling will be partially scheduled and partially event-driven. To the extent possible we will also coordinate our cruises with monitoring surveys of the USGS vessel R/V Polaris and the DWR vessel R/V San Carlos, as well as DFG vessels taking fish samples.

Detailed approach

Water column data (temperature, salinity, fluorescence, PAR, transmittance) will be recorded using a Seabird SBE-19 CTD equipped with WETSTAR fluorometer and beam transmissometer and PAR sensor. Water column samples for phytoplankton, bacteria, and microzooplankton will be taken using 10 L Niskin bottles mounted on an SBE-33 carousel or with a bucket. Surface water will be used to fill 3.8 L cubitainers that will be immediately returned to RTC along with samples to be analyzed for ambient nutrients, phytoplankton, bacteria, and microzooplankton. If significant stratification in water column properties is observed, additional samples will be taken deeper in the water column.

Task 1. Phytoplankton dynamics

Nutrients will be measured on freshly collected samples from field or enclosures. NO_3 and PO_4 concentrations will be determined according to the procedures of Whitledge et al. (1981), and $Si(OH)_4$ following the protocol outlined in Bran and Luebbe Method G-177-96 using a Bran and Luebbe AutoAnalyzer II. If samples are frozen before analyses they will be thawed 24 hours prior to analysis to avoid polymerization effects on $Si(OH)_4$ measurements, and thus poor reproducibility (Macdonald et al. 1986). NH_4 will be measured spectrophotometrically according to the phenolhypochlorite method of Solorzano (1969) using a Hewlett Packard Model 8452A diode array spectrophotometer and 10 cm cell.

In field collected samples and in some enclosure experiments, phytoplankton samples will be counted. Phytoplankton will be identified to genus or to species where possible, and their density will be determined using two methods, one for picoplankton and one for larger phytoplankton. Picoplankton (*Synechococcus* spp.) density will be determined by filtering an appropriate volume (10-50 ml) of water onto a 0.6 μm pore size Nuclepore filter, fixing it with 4% paraformaldehyde for 20 min, then freezing the filter at – 80^{o}C until cells are counted using blue or green excitation with a Zeiss epifluorescence microscope at 1000 X magnification. For larger phytoplankton, a 250 ml volume of water will be preserved with Lugols solution, and cells will be concentrated by centrifugation (Sukhanova 1978) then identified to species and quantitatively counted with a

Sedgwick Rafter counting chamber (Guillard 1978) at 400X. Another estimate of diatom abundance is to measure biogenic silica which will be measured in water filtered on 2 µm pore sized nucleopore filters using a protocol modified from Brzezinski and Nelson (1989).

^{15}N and ^{14}C uptake incubations will be carried out on shipboard samples and during enclosure experiments in 280ml polycarbonate bottles, maintained for 24 hours in filtered SFE water-cooled incubation tables, under window screening to expose them to selected light levels. Typically DIN inoculations will be made with trace additions of either $K^{15}NO_3$ or $^{15}NH_4Cl$ (99 atom% ^{15}N). In some experiments, unlabelled KNO_3 or NH_4Cl will also be added for incubations. Upon completion of the incubations, samples will be collected by filtration onto pre-combusted (450°C for 4 hours) GF/F filters, frozen until analysis for ^{15}N enrichment (Wilkerson and Dugdale, 1992) with a PDZ Europa 20/20 mass spectrometer system. The transport rate (?) and specific uptake rate (V) will be calculated according to Dugdale and Wilkerson (1986). The uptake kinetic parameters V_{max} and K_S and K_{LT} will be calculated after linear transformations or iterative curve fit programs are applied (e.g. Kudela et al. 2000, Cochlan et al. 2001). To evaluate NO_3 uptake when ambient NO_3 concentrations are saturating, it may be necessary to repeat the experiment after one to several days, to allow the phytoplankton within the cubitainer samples to reduce the ambient NO_3 to lower levels. NH_4 regeneration rates will be measured at selected stations and enclosures by a ^{15}N dilution method using the diffusion-concentration method of Slawyk et al. (1990) and calculated using the equations of Blackburn (1979) and Caperon et al. (1979) as outlined by Slawyk et al. (1990).

Phytoplankton primary productivity will be measured using the ^{14}C light-dark bottle method (JGOFS IOC 1996) with modifications for use with Bay phytoplankton. Twenty µCi of ^{14}C in the form of bicarbonate will be added to 250-ml baywater samples. Bottles will be placed in a flow through water table under light conditions similar to those of the LSZ. Following a 24-h incubation, 100 ml of the contents of each replicate will be filtered onto a GF/F glass fiber filter. The filters will be fumed over HCl, placed in scintillation cocktail, and counted in a scintillation counter. Chlorophyll a will be determined by *in vitro* fluorometry using a Turner Designs Model 10 fluorometer and the protocol of Arr and Collins (1992) on samples filtered onto Whatman 25 mm GF/F filters. Dissolved CO_2 (DIC) in the water (required to calculate C fixation) will be measured using a Monterey Bay Research Institute-clone DIC analyzer with acid-sparging and NDIR analysis (Walz & Friederich1996) following preservation with $HgCl_2$.

Enclosure experiments will be used to study the interaction of light, nutrients, and salinity on phytoplankton growth and contributions to DOC (Table 1) . The enclosures will be 3.8L polycarbonate cubitainers. These enclosures have been very successful both in SFE (our preliminary studies) and in coastal waters (e.g. Kudela et al., 2000). The enclosures will be transported to RTC and held in filtered bay-water cooled incubators under natural light.. Enclosures will be sampled daily over 5 days for chlorophyll, nutrients, diatom abundance and species composition, ^{14}C fixation, DOC, and $^{15}NO_3$ or $^{15}NH_4$ uptake.

To determine the salinity at which freshwater phytoplankton lyse, water from the Delta with the natural phytoplankton assemblage will be subjected to a salinity of 0 (control), 1, or 2 psu, ambient nutrients, and adequate light (50% of surface irradiance). This salinity range was chosen because it is representative of what phytoplankton normally encounter in the LSZ, and freshwater phytoplankton have been found to lyse in 0.1-1.0 psu (Morris et al. 1978). At intervals of 1, 6, 12 and 24 hours, we will measure primary and bacterial production, chlorophyll, and cell lysis as determined by quantitative microscopic counts and examination. Bacterial productivity will be measured as described under Task 3. To examine whether nutrient availability affects salinity tolerance of phytoplankton, and therefore potential to lyse, similar experiments will be run with high NO3, high NH4, and adequate light (50% of surface irradiance).

Table 1 Summary of enclosure experiments for phytoplankton dynamics.

Manipulation	Expected outcomes
LSZ water with ambient nutrients, high NO_3, high NH_4, adequate light (50% of surface irradiance, LPD)	Determine NH_4 inhibition of NO_3 uptake and chl accumulation. Quantify time scale and lag for NO_3 depletion, measure NH_4 regeneration rate.
LSZ water with ambient nutrients, high NO_3, low NH_4, adequate light (50% LPD)	Quantify the time scale and intensity for NO_3 depletion and bloom development by phytoplankton with optimal conditions. Measure NH_4 regeneration
Different light conditions (0 to 100%LPD) ambient nutrients, high NO_3, high NH_4 or low NH_4.	Light conditions required for NO_3 uptake to increase, measure light impact on time scale for NO_3 uptake.
LSZ water with ambient nutrients, salinity 0, 1 or 2 psu, adequate light (50% of surface irradiance).	Determine salinity at which freshwater phytoplankton lyse or release DOC. Measure productivity, DOC, cell lysis.
LSZ water with high NO_3, high NH_4, 0, 1 or 2 psu, adequate light (50% of surface irradiance).	Nutrient effects on salinity tolerance and potential to lyse. Measure productivity, DOC, cell lysis.
Different NH_4 additions: LSZ water with ambient nutrients, high NO_3, adequate light (50% LPD)	Test the threshold NH_4 concentration, quantify any inhibition of NH_4 on NO_3 uptake

We will also monitor dissolved organic carbon concentrations at the beginning and end of the enclosure experiments to assess any gross changes in the DOC pool over the course of the experiment. Samples will be filtered (0.2 µm) and frozen (-80^{o}C) until being processed using a DOC analyzer at UC Santa Barbara. Because we assume that the products of phytoplankton lysis (DOC) will be labile, we do not anticipate any significant accumulation of DOC over the time scale at which we will be sampling. However, increases in bacterial abundance and production will indicate whether increases in DOC supply have occurred.

Task 2. Benthic biomass and grazing

Forty samples, distributed randomly within strata that are representative of known habitat types for *Potamocorbula* (depth, salinity, and substrate) will be collected at the beginning of the spring sampling period and at the end to evaluate the grazing rate in the LSZ during the "spring bloom period". An additional 5 stations will be sampled monthly (in addition to 4 stations currently sampled by the USGS) to confirm the grazing rate trajectory between spring and summer and to calculate secondary production at those locations for both years. Four sites are located in the channel and the remaining five in the shallow water (4 in Grizzly Bay and 1 in Honker Bay which is poorly represented since it has not had a seasonally persistent *Potamocorbula* population since 1993). Samples will be collected with a 0.05 m^2 van Veen grab, sieved on a 0.5mm screen, preserved in formalin, and transferred to 70% ethyl alcohol stained with Rose Bengal. A subsample of live bivalves will be collected in each habitat to estimate weight as a function of length; animals will be sized, dried, weighed, ashed and reweighed to determine ash-free-dry-weight which is convertible to carbon (0.41 gC = 1g dry tissue weight, Cloern and Canuel 1993). Bivalves will be removed from preserved samples and measured, and tissue dry weight will be estimated from the length-weight regressions. Biomass will be calculated for each sample and grazing rate estimated as described in Thompson (in press)

In addition to the samples for biomass described above, seasonal samples will be collected at five historical stations to estimate secondary production to evaluate previous hypotheses that *Potamocorbula* production is fueled by a combination of phytoplankton and bacterial producers. These new data will be compared to secondary production rates during previous years (since *Potamocorbula* was introduced in 1986) when we have secondary production estimates but no measurements of bacterial or phytoplankton production. We will use these new secondary production data to 'normalize' our previous estimates of bacterial consumption rates. This will allow us to evaluate the influence of *Potamocorbula* consumption on bacteria and phytoplankton and ultimately the long-term trends in zooplankton biomass.

Secondary production will be calculated using the Crisp (1971) method which is made possible by the semi-annual spawning period and the presence of distinctive cohorts. Errors for all methods will be calculated as described by Bevington and Robinson (1992).

Nitrogen remineralization rates will be estimated from our grazing and production rate estimates using assimilation efficiencies from the literature (Werner and Hollibaugh 1993). The enclosure experiments in Task 1 will determine the potential of the ambient phytoplankton to reduce upper estuary ammonium concentrations to non-inhibitory level, with the effects of clam grazing and remineralization excluded. We will then examine these data to determine whether the early spring clam population has the capacity to overwhelm the growth of diatoms through a combination of grazing and excretion.

Task 3. Response of bacterial production to inputs

Bacterial biomass and production will be measured during field sampling as well as in enclosure experiments to estimate the relative importance of bacterial biomass in supporting the LSZ foodweb. The basic approach will be to estimate bacterial production using radioactive tracers and bacterial biomass by direct counts and then convert these estimates to carbon units to make comparisons with other components of the microbial food web.

Estimates of bacterial production will be made using tritiated leucine (Kirchman, 1984) with the microcentrifuge method described in Kirchman (2001), which requires smaller incubation volumes and therefore significantly less radioactive isotope than traditional methods. Bacterial leucine incorporation will be converted to bacterial carbon assimilation by empirically derived Carbon : leucine conversion factors. Carbon : leucine conversion factors will be made by simultaneous estimates of bacterial abundance and leucine incorporation in incubations in which grazers have been excluded by filtration (<1 µm). Increases in cell numbers will be directly related to leucine incorporation.

Estimates of bacterial biomass will be made using direct counts with an epifluorescence microscope after addition of a fluorescent DNA stain (Hobbie et al. 1977). Cell counts will be converted to carbon biomass using previously published values (Fukuda et al. 1998).

Task 4. Microbial foodweb

In most marine and estuarine food webs, microzooplankton (20 – 200 µm in length) are the principal herbivores (Calbet & Landry 2004). Although copepods and other mesozooplankton can also be significant direct grazers on phytoplankton, it is now recognized that the link from phyto- to microzoo- to mesozooplankton is significant in the overall flows of energy and material in estuarine and coastal ecosystems (Gifford & Dagg 1988, Gifford 1991, Gifford & Dagg 1991).

In addition, small particle feeders such as ciliates and other protozoan microzooplankton can pass detrital and bacterial organic matter up the food chain to metazoan grazers as part of the "microbial loop", a pathway through which dissolved organic matter is utilized in marine and estuarine food webs (Fenchel 1988, McManus 1991, Vezina & Savenkoff 1999). For a detritus-dominated ecosystem such as Suisun Bay and the Western Sacramento-San Joaquin Delta, this pathway may be particularly significant (Murrell et al. 1999).

We will measure two important fluxes related to the flow of energy from microbes to metazoans: microzooplankton herbivory and bacterivory. To estimate herbivory, we will use two independent approaches. We will measure herbivory directly using the dilution technique (Landry & Hassett 1982). This method requires minimal disruption of delicate microzooplankters and has become the standard for measuring this flux. It will also allow us to measure direct ingestion of detrital POC by microzooplankton. However, there are indications that some of the key assumptions of the dilution method may not hold in turbid estuarine environments (Murrell & Hollibaugh 1998, Dolan et al. 2000). Thus, our second approach will be to measure microzooplankton species composition and abundance and estimate herbivory using published specific clearance rates. This approach will also give much finer temporal and spatial resolution than would have been possible with the dilution method alone.

To estimate bacterivory, we will use the fluorescently-labeled bacteria (FLB) method (Sherr et al. 1987, Pace et al. 1990). In this method, monodisperse, fluorescently-stained bacteria are added to a sample from the environment. Disappearance of the FLB's is monitored over time to estimate the mortality rate of the natural bacterioplankton. Because the FLB's are unable to grow, they are not subject to viral lysis and hence their disappearance should be due only to grazing. Since the FLB's are not a good proxy for particle-attached bacteria, we will estimate the grazing mortality of the latter by difference, using the results of the bacterial growth measurements being made for task 3 (i.e. particle-attached bacterial mortality = growth of unattached bacteria + growth of particle-attached bacteria – mortality of unattached bacteria). Because we will have separate growth measurements for unattached and attached bacteria, we will be able to test the implicit assumption that these rates are in balance on short time scales. As with the herbivory estimates, we will independently estimate bacterivory using abundances of bacterivores (small heterotrophic flagellates and bacterivorous ciliates) and published clearance rates.

All of the measurements for task 4 will be coordinated closely with those for task 3 (bacterial dynamics) so that we will have as complete a picture as possible of stocks and fluxes within the microbial food web, as well as links to higher trophic levels.

<u>Task 5. Copepod production</u>

The hypotheses for copepod production will be examined through a combination of field and laboratory work in collaboration with researchers on other tasks. We want to know how much of the copepods' growth is based on phytoplankton and how much on bacteria, either directly or through the microbial foodweb. This suggests a variety of approaches, since the various measurements required must be made by different methods and at different scales (duration of experiments, container size, copepod density, use of various labels, termination method). Experiments designed to measure uptake (e.g., feeding on phytoplankton vs. feeding on bacteria) will be run as close to simultaneously as possible so that results can be compared.

A principal focus in this task will be to contrast the cyclopoid *Limnoithona tetraspina* with the calanoid copepod *Pseudodiaptomus forbesi* and, if present, *Eurytemora affinis* and *Sinocalanus* *doerrii*. Copepods will be collected by gentle net tows using a mesh suitable for the species being examined: 120 µm for *L. tetraspina* and 250 µm for calanoid copepods. Samples will be diluted immediately upon capture into 20-liter insulated carboys for transport to the laboratory. Copepods will be sorted as soon as feasible using a dissecting microscope, and will be kept and incubated at a temperature close to ambient.

Grazing and production by copepods will be measured using techniques that have been applied either in the Kimmerer or McManus laboratories. Grazing on phytoplankton will be measured in incubations using the disappearance of chlorophyll, and grazing on phytoplankton and ciliates will be measured by direct cell counts (Bouley in prep.). Bottle sizes, densities within the bottles, and duration of experiments will all be varied to ensure an adequate signal:noise ratio and to account for any bottle effects.

Grazing on bacteria will be determined using short-term labeling experiments. The purpose of short-term experiments is to minimize egestion and excretion of label, which should begin ~1 hour after ingestion. Water with particle-attached bacteria will be collected from the field by gently dipping with buckets (Hollibaugh and Wong 1996). Tritiated leucine or thymidine will be added and uptake will be allowed for ~1 hour. Copepods will then be introduced to the containers and allowed to feed for 15-30 minutes. Copepods will then be removed and processed for scintillation counting. Samples of the water taken before and after copepods are introduced will be filtered on GF/F filters and also on 5 µm Nuclepore filters using gravity flow to concentrate bacteria-laden aggregates. These samples will also be counted and the activity per ml (total and on aggregates) will be determined. Clearance rate on bacteria will then be determined as the rate of increase of copepod activity divided by activity per unit volume. Several controls and ancillary experiments will be required for this approach. Some bottles will be treated with antibiotics to reduce bacterial uptake of label, to determine the extent of direct uptake by copepods. Some bottles will have copepods added that have been killed using carbon dioxide to determine uptake in the absence of feeding. In addition, copepods will be incubated in containers that have been filtered to remove aggregates before labeling. Several range-finding experiments will be necessary to establish the appropriate experimental duration, volume, and density. In addition, various alternative methods will be tried to keep particles in suspension, including the use of a plankton wheel with end-over-end rotation at 1 rpm.

"Cascade" experiments will be conducted to evaluate copepod ingestion of detrital POC directly and as a tool for integrating the results of individual experiments (Calbet & Landry 1999). In these experiments, 1 L bottles of <200 µm screened water are incubated (24h) with no copepods, ambient concentrations of copepods, 2X ambient copepods, 4X ambient copepods, and 8X ambient copepods. Adding more copepods should increase the rate at which detrital POC disappears if the copepods are eating the POC, unless there is a stronger cascading effect of copepods eating protozoa that are eating the POC. In the latter case, adding more copepods prevents the POC from being ingested by reducing protozoan populations, and there should be more POC in treatments with more copepods. The endpoint of these experiments will include measurements of chlorophyll, POC, and bacterial abundance in several size fractions.

Results of these experiments will be interpreted by incorporating information from the phytoplankton and bacteria measurements. We will be able to calculate the consumption rate of the copepods (from their production rate and gross growth efficiency from the literature), and will then use clearance rates on alternative food sources from individual experiments to estimate the fraction of ingestion that is due to each source. Ingestion will then be portioned into the various pathways shown in Figure 1. This partitioning will differ among species, and with the relative abundance of alternative food sources, since copepods are opportunistic feeders.

Synthesis

All participants in this project have agreed that in addition to the work outlined above, they will participate in a synthesis effort to combine the entire suite of results into a coherent story about the foodweb of delta smelt. This synthesis will begin at project inception: we will re-examine and analyze the available data on phytoplankton to calculate rates of transport of freshwater phytoplankton to the LSZ. To a first approximation this can be calculated from the net river-derived flow and freshwater chlorophyll concentrations, but we will also estimate dispersion using available results from hydrodynamic models and salt flux studies.

The flux data will be used to interpret the data being developed by the various tasks. After the first year's results have been calculated we will hold a working session to place initial bounds on the fluxes in Figure 1. These calculations may lead us to refine our approach in Year 2. After the Year 2 data are available the synthesis will enter a more formal stage, culminating in a quantitative model of carbon flow in the LSZ. A synthesis paper will be prepared reporting these results. In addition, a report will detail the significance of these findings for management of the estuary, as discussed above.

Feasibility

The feasibility of a research project such as this depends on the capabilities of the participants, the organization of the team, the availability of suitable facilities, and the availability of the necessary equipment. The leaders of our research team include scientists with decades of research experience in a wide variety of environments, and talented and energetic postdoctoral associates. Previous experience suggests that this team can accomplish the proposed tasks. In addition, most of the members of this team have worked with at least one other member on significant research projects. The team's organization (see Management below) is relatively straightforward and this has been successful in projects of similar scope in the past.

Facilities and equipment at RTC The bulk of the laboratory work will be done at RTC. RTC's main laboratory building has a total area of some 20,000 ft^2 of improved space and an open bay of 12,000 ft^2. We have just begun phase II of the renovation of this building, a $3.2 million project that will add new laboratories, offices, classrooms and needed infrastructure. An additional bay-front building (12,000 ft^2) houses the Ecology and Aquarium Facility with space for seawater tables and tanks. The RTC seawater system has been upgraded with a 300 foot tethered intake line, and water delivery to the main building and mixing facilities are being planned. In addition to a large research wet lab (1500 sq. ft.) with running bay water, the Center has constructed an animal culture room (700 sq. ft.), which is temperature- and light-controlled.

General use equipment includes constant temperature rooms, balances, spectrophotometers, centrifuges, refrigerators and freezers (-80 & -20^{o}C), fume hoods, a PCR thermocycler, and a laminar flow hood. A Zeiss Axioskop epifluorescent microscope is available for phytoplankton, picoplankton and bacterial counts and a Turner fluorometer is on hand for chlorophyll *a* measurements. We recently acquired a low background liquid scintillation counter (Winspectral Guardian LSC from PerkinElmer) and a Europa gas chromatograph-stable isotope analyzer (20-20 mass spectrometer, ANCA GSL elemental analyzer and Agilent 6890N GC combination, and previously a Technicon II Autoanalyzer for nutrient analysis. These instruments are housed in a joint-use Nutrient Analysis Laboratory with additional instruments to measure rates of nutrient uptake, carbon and $Si(OH)_4$ uptake with scintillation counting, and nitrogen uptake with mass spectrometry. Additionally, a molecular biology research laboratory was constructed three years ago at the Center. RTC students and staff have access to other equipment available at specialized laboratories at SFSU (e.g. the GIS Facility in the Geography Department, the Electron Microscope facility and the Conservation Genetics Laboratory in the Biology Department).

RTC owns and operates a 38' aluminum-hulled shallow draft research vessel capable of a maximum speed of 20 knots and equipped with an A-frame, adequate a/c power, a hydraulic system, a hydrographic winch with conducting cable, instrumented rosette sampling system, depth sounder/bioacoustic sampler, acoustic doppler current profiler (ADCP), differential global positioning system (GPS), and a data acquisition computer system. In addition, RTC has a number of smaller vessels such as the new Twin Vee Powercat and a 17-foot Boston Whaler.

Permitting Field personnel will obtain Scientific Collector's Permits issued by the State. We expect zero take of all species of special status native fishes during field sampling.

Relation to other projects, current and pending This project does not depend on other projects for successful completion. Kimmerer is currently lead PI of a CALFED ERP-funded project, "Determining the mechanisms relating freshwater flow and abundance of estuarine biota" with E. Gross and W. Bennett. This project is the first formal step in unraveling the basis for the "fish-X2" relationships. It has two components: first, we are using the 3-dimensional hydrodynamics model TRIM3D to explore the response of the estuary to changing freshwater flow. In particular we are focusing on the distribution of physical habitat as defined by salinity, depth, temperature, and other characteristics, with the goal of assessing the possibility that increasing physical habitat with increasing flow could underlie some of the fish-X2 relationships. The second component is an effort to develop a plan, working with members of the IEP Estuarine Ecology Team, for a program of research to determine what mechanisms are actually operating in the estuary. That work will finish by the end of 2005, i.e., about the time this proposed project would begin if funded. Although the plan is not yet complete, several themes have emerged from the discussions to date and will be in the final plan. *One of these is the need to look more carefully at the base of the foodweb for potential effects of flow*.

Dugdale and Wilkerson are funded by Sea Grant to determine the role of ammonium inhibition in SFE in suppressing phytoplankton blooms. The project is focused on Central Bay with the specific hypothesis that reducing ambient NH_4 to less than 4 µM makes the high ambient levels of NO_3 accessible to SFE primary producers, resulting in healthy diatom-dominated ecosystems. Enclosure experiments are being made with Central Bay water to understand the interaction between NH_4 inhibition of NO_3 uptake and light limitation in the initiation/formation of diatom blooms in SFE, sufficiently well to predict the effects of variation in NH_4 inputs and dilution. The results of this research will be used to test and improve an existing simulation model of phytoplankton production with NH_4 inhibition; incorporating kinetic parameters for light and nutrient uptake obtained from the enclosure experiments.

Kimmerer is participating in two related proposals. The first, submitted (with W.A. Bennett, UC Davis) in November to the CALFED Ecosystem Restoration Program, is for enhancements in monitoring of delta smelt. The RTC component of that project is to examine feeding by delta smelt, in particular their selectivity and feeding rate. In addition, Kimmerer is leading a proposal to this PSP involving Bennett as well as researchers from Louisiana State University and Stanford University to develop a suite of models of delta smelt biology. If either of those two projects is funded, there will be significant advantages to all projects in terms of the increased scope and opportunity for synthesis available with a number of distinct but related projects.

Data management

Products will be made available as indicated below; computer codes and files will be made available upon request to any of the project team members. In addition, input and output files will be provided to the IEP data web page no later than 1 year after completion of the manuscripts.

Expected Products/Outcomes

Anticipated products include (Table 2):

- Presentations at the Estuarine Ecology Team, CALFED Science Conference, and at least one national conference..
- Articles in the IEP Newsletter describing progress.
- At least six manuscripts submitted to peer-reviewed journals. One of these will be a synthesis prepared by the entire project team, to be submitted to the online journal San Francisco Estuary and Watershed Science.
- A report to the CALFED Science Program summarizing the results and making recommendations about next steps.

Table 2. Tasks with key personnel, deliverables, and data anticipated for each. The first row gives the deliverables and data anticipated from each task, or all tasks together in the case of the synthesis article. Names in parentheses indicate that these people will provide key assistance and information in the course of working on their own task.

Task	Description	Key Personnel	Deliverables
Each		All	At least one paper **per task** in the scientific literature. One paper synthesizing results (all participate). One talk per task at the CALFED Science Conference Presentations at the Estuarine Ecology Team and other venues
1	Phytoplankton	Dugdale, Wilkerson, Carpenter, Cohen	As listed above; analysis of relative importance of benthic grazing and nutrient composition.
2	Benthic Grazing	Thompson	As listed above and under 1
3	Bacteria	Parker	As listed above, and a joint paper with 4
4	Microbial foodweb	McManus	Joint papers with 3 and 5
5	Copepods	Kimmerer	As listed above, and joint papers with all other

PROJECT ORGANIZATION

Management plan

Table 2 lists the tasks and personnel assigned to each task, along with expected deliverables for each task. The leader for each component will be responsible for ensuring that the component meets its goals. However, we also propose a synthesis paper combining the results of all components, as well as a summary report to CALFED. We believe this is an essential part of the project, and that the synthesis should lead to insights not available from any one component.

This organization provides clarity in budgeting and in assignment of responsibility: the lead person for each task is responsible for ensuring that task is completed and deliverables are provided on time. The lead PI (Kimmerer) will be responsible for gathering information and developing semiannual Progress Reports, for liaison with contracting personnel, and for ensuring coordination among tasks.

Each of the components (tasks) is linked to the others through the passing of specific information (Figure 7). In terms of process, this linkage will be largely informal (through email and personal contacts), with meetings of the entire project team at least twice yearly. Each task leader will be responsible for ensuring the information is passed in a timely manner.

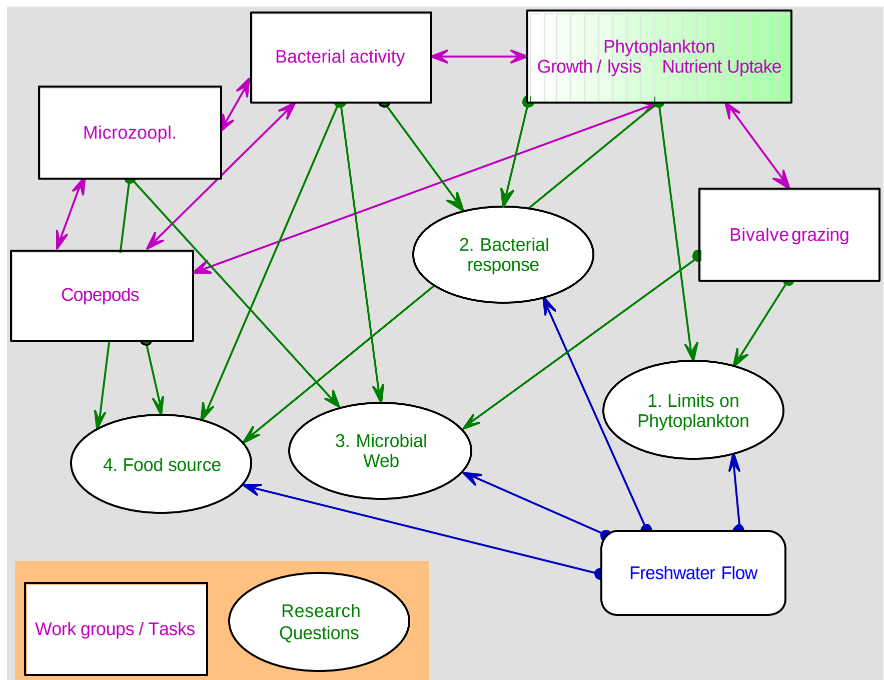

Figure 7. Project organization. Magenta lines show linkages between work groups each focusing on separate tasks; these linkages represent collaborative experiments or analyses. Green arrows linking work groups to research questions indicate the key inputs to answering those questions. The influence of freshwater flow plays a role in all research questions, so information on flow is required for all.

We have not provided for formal public outreach. However, SFSU and RTC are strongly committed to providing outreach and other non-traditional educational opportunities to the community. This commitment is embodied in the Education Coordinator at RTC. Opportunities are frequent for RTC scientists to engage in public speaking, lecturing to teachers or community organizations, and other such activities. We will work with the Educational Coordinator to seek such opportunities as our research unfolds, and present results of our research whenever possible.

Schedule

The schedule for this project is based on an assumed start date of 1 January 2006. However, our past experience suggests that actual start dates could be greatly delayed (i.e., over a year) by contracting difficulties. This could lead to difficulties because of the seasonal component of our proposed research. Should it appear that the start date will be pushed back too far to allow us to accomplish the first year's biological fieldwork, we will delay some of that work a year; however, provided the start date occurs by summer 2006 we will be able to start the physical-dynamics work on time.

As with all scientific research having a field component, conditions may arise that interfere with our work or confound interpretation. Since most of our proposed work will occur in late spring and summer, it is unlikely that adverse weather conditions will have much of an effect. Furthermore, the schedule of our field work is flexible enough to allow for short delays due to storms, boat breakdowns, and other short-term exigencies.

Principal milestones are listed in Table 3. In addition, semiannual progress reports will be developed on the 6-month anniversary of project initiation and every six months thereafter.

Table 3. Schedule based on a start date of 1 January 2006. Dates of events are approximate.

Date	Activities / Milestones
1/06	Initial project meeting to begin planning for field season
3/06	Project meeting to finalize planning for field season
9/06	Project meeting to discuss results and prepare presentations for CALFED Science Conf.
1/07	First annual report
3/07	Project meeting to finalize planning for field season
9/06	Project meeting to discuss results and map out papers to be written.
1/08	Second annual report
6/08	Draft papers circulated for internal review
7/08	Project meeting to develop synthesis and final report
12/08	Final report submitted
12/08	Papers submitted for publication

Justification

This project addresses two topics central to CALFED's concerns in the Delta: the biology of delta smelt, and the effect of water management to support the current salinity standard. We believe that an understanding of foodweb support for delta smelt and other estuarine species is essential to effective management.

Delta smelt are now the principal canary in the Delta coal mine. Much of the protective activity in the Delta focuses largely on delta smelt. Yet to date there is no evidence that any of this activity is having a measurable benefit on population size or any other measure of success; indeed, the 2004 fall abundance index was the lowest on record. This implies that other factors are limiting the abundance of delta smelt.

The leading suspect among the limitations on delta smelt is food supply. Preliminary studies have indicated poor feeding condition in a large proportion of larval smelt (Bennett submitted); the abundance of calanoid copepods on which the smelt feed is low and has become lower; food limitation seems to be rampant among the plankton in this estuary; and the base of the foodweb has been very unproductive since 1987.

We do not suggest that this situation can necessarily be fixed. Rather, we believe that understanding how this foodweb works will help management in two ways. First, it will provide a reason why the best efforts at restoration and water management may not always provide a measurable benefit to delta smelt. And second, together with proposed modeling and monitoring efforts, it may provide tactical and strategic operations by which protective efforts are focused on times when delta smelt will receive the maximum benefit. We cannot know that without understanding the foodweb of the smelt.

But delta smelt are not the only fish in the estuary. The existing salinity standard is designed to protect the estuarine ecosystem, on the basis that abundance of many estuarine-dependent species varies with outflow. If we understood the basis for those relationships, the salinity standard could possibly be made more effective or more efficient. Several of these species pass their early life stages in the Low-Salinity Zone. Phytoplankton production and biomass in the LSZ appears not to vary with flow, but the input of organic carbon from the freshwater Delta must vary with flow, and this presents a possible mechanism by which fish production could increase with flow.

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Current Position

Research Professor, Romberg Tiburon Center for Environmental Studies, San Francisco State University.

Education

University of Hawaii, Ph.D. 1980, Biological Oceanography
U.S. Navy Nuclear Power School, 1968.
Purdue University, B.S. 1967, Chemistry

Research and Professional Experience

1994-present	Senior Research Scientist and Research Professor, Romberg Tiburon Center
1986-1995	Senior Scientist, BioSystems Analysis Inc.
1982-1985	Research Fellow, University of Melbourne (Australia), Zoology Dept.
1980-1982	Research Associate/Assistant Director, Hawaii Institute of Marine Biology
1976-1980	Research Assistant, University of Hawaii
1973-1980	Graduate student, University of Hawaii
1972-1973	Flight instructor
1967-1972	U.S. Navy submarine force, final rank Lieutenant

Research Interests

The ecology of estuaries and coastal waters, with emphasis on the San Francisco Estuary. Influence of physical environment including freshwater flow, tidal currents, and turbulence on behavior, movement, and population dynamics of plankton and fish. Predatory control of species composition and abundance of plankton populations. Modeling of ecosystems, populations, and material cycling. Modeling and analyzing salmon populations in California's Central Valley. Human impacts on aquatic ecosystems and the interaction of science and management.

Other Professional Activities

- Member, Strategic Planning Core Team, CALFED Bay-Delta Program, 1998-99
- Co-Chair, Independent Science Board, CALFED Bay-Delta Ecosystem Restoration Program, 2000-present
- Co-founder and President-Elect, California Estuarine Research Society, the newest affiliate society of the Estuarine Research Federation.

- Chair, Estuarine Ecology Team, Interagency Ecological Program for the San Francisco Estuary.
- Member of organizing committee, State of the Estuary Conference, 1997 through 2001
- Advisor to the CALFED Lead Scientist for the Environmental Water Account
- Advisory committee, Georgia Coastal Estuaries LTER Program, J.T. Hollibaugh, PI.
- Invited participant in workshops at the University of Rhode Island (effects of freshwater flow on estuaries), Louisiana Universities Marine Consortium (coastal restoration), and the University of British Columbia (science needs for coastal management).
- Member, Journal Working Group for the Estuarine Research Federation, working to improve the quality of the international journal Estuaries.
- Reviewer for professional journals including Limnology and Oceanography, Marine Biology, Marine Ecology Progress Series, Estuaries, Estuarine, Coastal, and Shelf Science, ICES Journal of Marine Science, Hydrobiologia, Environmental Biology of Fishes.
- Reviewer of grant proposals for the National Science Foundation, EPA, and numerous Seagrant offices.
- Steering committee, Bay-Delta Modeling Forum, 1995-2001
- Co-convenor, CALFED Ecosystem Restoration Program workshop on adaptive management, 2002
- Co-convenor, CALFED Environmental Water Account workshops on salmonids and delta smelt, 2001 and 2003.
- Co-convenor, CALFED workshop on hatchery impacts on Battle Creek, California, 2003.

Recent and Current Students

Keun-Hyung Choi (research associate), Diego Holmgren (post-doc); Heather Peterson, Lenny Grimaldo, Jena Bills, Paola Bouley, John Durand, Renny Talianchich, Allegra Briggs, and Debbie Marcal (all Masters' students).

Selected Publications

Kimmerer, W.J., and A.D. McKinnon. 1987. Growth, mortality, and secondary production of the copepod *Acartia tranteri* in Westernport Bay, Australia. Limnol. Oceanogr. 32:14-28.

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Sommer, T, B. Harrell, M. Nobriga, R. Brown, P. Moyle, W. Kimmerer, and L. Schemel. 2001. California's Yolo Bypass: Evidence that flood control can be compatible with fisheries, wetlands, wildlife, and agriculture. Fisheries 26:6-16
Kimmerer, W.J., J.H. Cowan Jr., L.W. Miller, and K.A. Rose. 2001. Analysis of an estuarine striped bass population: Effects of environmental conditions during early life. Estuaries 24:556-574.*
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Kimmerer, W., D. Murphy, and P. Angermeier. A landscape-level model of the San Francisco Estuary and its watershed. In press, San Francisco Estuary and Watershed Science

Kimmerer, W.J. Long-term changes in apparent uptake of silica in the San Francisco Estuary. In press, Limnology and Oceanography.

Submitted

Choi, K-H., W. Kimmerer, G. Smith, G.M. Ruiz, and K. Lion. Post-exchange zooplankton in ships ballast water coming to the San Francisco Estuary. Submitted, Biological Invasions

Holmgren, D., K.A. Hieb, and W.J. Kimmerer. Interannual variability in abundance of fish and crustaceans in the San Francisco Estuary. Submitted, Estuaries

Grimaldo, L., W. Kimmerer, and A.R. Stewart. Diets and carbon sources of fishes from open-water, intertidal edge, and SAV habitats in restored freshwater wetlands of the San Francisco Estuary. Submitted, Estuaries

* Available in pdf format at http://online.sfsu.edu/~kimmerer/Files/

In preparation

Kimmerer, W.J. Regime change in an estuarine foodweb responding to an invasive bivalve. In preparation, Proceedings of the National Academy of Sciences

Kimmerer, W.J. S. Bollens, C. Peñalva, and S. Avent. Decade-scale shifts in abundance patterns of the zooplankton of the lower San Francisco Estuary: introductions, floods, and benthic competitors.

Kimmerer, W.J., M.H. Nicolini, N. Ferm, and C. Peñalva. Chronic food limitation in estuarine copepod populations. In preparation, Limnology and Oceanography.

Selected Presentations

Kimmerer, W.J. 2003. Yogi Berra was right: Predicting the effects of climate change on the San Francisco Estuary. Invited, CALFED Science Conference, Sacramento, January 2003.

Kimmerer, W.J. 2003. Ecological lessons from a non-coevolved assemblage of estuarine zooplankton. Third International Symposium on Marine Zooplankton. Gijon, Spain, May 2003.

Kimmerer, W.J. 2003. Physical, Biological, and Management Responses to Variable Freshwater Flow and Diversions in the San Francisco Estuary. Invited, Coastal Restoration and Enhancement through Science and Technology program (CREST) Symposium. Thibodaux, Louisiana, July 2003.

Kimmerer, W.J. 2003. Estuarine zooplankton as ecological filters. Invited, American Fisheries Society Early Life History symposium, Santa Cruz, CA, August 2003.

Kimmerer, W.J. 2003. Paradoxes in the response of zooplankton to freshwater flow in the San Francisco Estuary. Invited, Estuarine Research Federation, Seattle, September 2003.

Kimmerer, W.J. 2004. Ecosystem-level changes following disruption of lower trophic levels by an introduced clam in the San Francisco Estuary. California Estuarine Research Society second annual conference, Bodega Bay, March 2004.

Kimmerer, W.J. 2004. Ecosystem-level changes following foodweb disruption by an introduced clam in the San Francisco Estuary. CALFED Science Conference, Sacramento, October 2004.

Kimmerer, W.J. 2004. Population trends and the influence of restoration actions on winter-run Chinook salmon. Invited, CALFED Science Conference, Sacramento, October 2004.

Kimmerer, W.J. 2004. Assessing the CALFED Bay-Delta Ecosystem Restoration Program: Racing to Catch Up. Invited plenary talk, First National Conference on Ecosystem Restoration, Orlando

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HONORS AND AWARDS:

Honoris Causae, University of Marseilles
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PROFESSIONAL EXPERIENCE:

1996	Senior Research Scientist, Romberg Tiburon Center,
1997	Adjunct Professor, San Francisco State University.
1988-	Consultant, Ocean Sciences, Jet Propulsion Laboratory
1984-85	Consultant, Woodward Clyde Associates
1981-86	Director, Allan Hancock Foundation, University of Southern California
1979-	Professor of Biological Sciences, University of Southern California (USC)
1979-83	Assoc. Director for Marine Sci., Institute for Marine and Coastal Studies, USC
1975-79	Research Scientist, Bigelow Lab. for Oc. Sciences, W. Boothbay Harbor, Maine
1967-75	Research Professor, Department of Oceanography, University of Washington
1962-67	Associate Professor of Marine Science, University of Alaska
1960-62	Assistant Professor of Zoology, University of Pittsburgh

SOME OTHER PROFESSIONAL ACTIVITIES:

Chairman, UNOLS Advisory Council, 1977-1979, Panel Member, NRC Board on Long-term Archiving of Ocean Data, Jun 1993, Former Chairman, Ocean Sciences Executive/Advisory Committee, NSF, Natural Sciences Coordinator of Sea Grant Institutional Program at USC, Past Member, JGR Ocean Editor Selection Panel, 1994, Hutchinson Award Committee, 1993-

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Students: R. M. Kudela, T. Hayden, K.K. White, S.R. Yang

SELECTED RECENT PUBLICATIONS:

Dugdale, R.C., C.O. Davis and F.P. Wilkerson. 1997. Assessment of new production at the upwelling center at Point Conception, California using nitrate estimated from remotely-sensed sea-surface temperature. Journal of Geophysical Research. 102, 8573-8585.

Kudela, R.M., W.P. Cochlan and R.C. Dugdale. 1997. Carbon and nitrogen uptake in response to light by phytoplankton during an upwelling event. J.Plankton Research. 19: 609-630.

Wilkerson, F.P. and R.C. Dugdale. 1997. The effect of El Niño on coastal new production. In "California and the World Ocean '97, pp. 1554-1562.

Dugdale, R.C. and F.P. Wilkerson. 1998 Silicate regulation of new production in the equatorial Pacific upwelling. Nature. 391: 270:273.

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Chu, Shaoping, L. A. McNair, S. Elliott, C-C A. Lai, O.A. Hurricane, R.P. Turco and R.C. Dugdale. 1999. Ecodynamics and dissolved gas chemistry routines for ocean circulation models. Computers and Chemistry 23 : 447-467.

Kudela, R.M. and R.C. Dugdale. 2000. Nutrient regulation of phytoplankton productivity in Monterey Bay, California. Deep-Sea Research Part II 47: 1023-1055.

Wilkerson, F.P., R.C. Dugdale, R.M. Kudela and F.P. Chavez. 2000. Biomass and productivity in Monterey Bay, CA: Contribution of the large phytoplankton. Deep-Sea Research Part II 47: 1003-1023.

Ragueneau, O., P. Treguer, A. Leynaert, R.F. Anderson, M.A. Brzezinski, D.J. DeMaster, R.C. Dugdale, J. Dymond, FG. Fischer, R. Francois, C. Heinze, E. Maier-Reimer, V. Martin-Jezequel, D.M. Nelson and B. Queguiner. 2000. A review of the Si cycle in the modern ocean: recent progress and missing gaps in the application of biogenic opal as a paleoproductivity proxy. Global and Planetary Change 26: 317-365.

Dugdale, R.C. and F.P. Wilkerson. 2001 Sources and fates of silicon in the ocean: the role of diatoms in climate and glacial cycles. Scientia Marina 65: (Suppl. 2: A Marine Science Odyssey Into the 21st Century, J.M. Gili, J.L. Pretus and T.T. Packard, eds.) 141-152.

Hogue, V., F. Wilkerson, R. Dugdale and A. Marchi. 2001 Nutrients and phytoplankton dynamics in Suisun, San Pablo and Central Bays. October 2001 IEP Newsletter.

Chai, F., R. C. Dugdale, T-H Peng, F. P. Wilkerson, and R. T. Barber. 2002. One dimensional ecosystem model of the equatorial pacific upwelling system, Part I: Model development and silicon and nitrogen cycle, In press, Deep-Sea Research II.

Dugdale, R.C., R. T. Barber, F. Chai, T.H. Peng, and F.P. Wilkerson, One dimensional ecosystem model of the equatorial pacific upwelling system, Part II: sensitivity analysis and comparison with JGOFS EqPac Data. In press, Deep-Sea Research II.

Dugdale, R. C. A. G. Wischmeyer, F.P. Wilkerson, R.T. Barber, F. Chai, M. Jiang and T-H. Peng. Meridional asymmetry of source nutrients to the equatorial upwelling ecosystem and modeling of the impact on ocean-atmosphere CO_2 flux. In press, Deep-Sea Research II.

Wilkerson, F.P., R. C Dugdale, A. Marchi and C.A. Collins. 2002.Hydrography, Nutrients and chlorophyll measured during El Niño and La Niña compared to normal years in the Gulf of the Farallones, CA. In press, Progress in Oceanography

ABBREVIATED RESUME – FRANCES WILKERSON, PH.D

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CURRENT POSITION: Snr. Research Scientist, Romberg Tiburon Center
Lecturer and Adjunct Professor, San Francisco State University

EDUCATION:

1977 B.A. Natural Sciences (Honors), University of Cambridge, U.K.
1980 M.A. University of Cambridge, U.K.
1980 Ph.D. University of Bristol, U.K., Advisor: Sir David C. Smith F.R.S.

HONORS/AWARDS:

Natural Environment Research Council (NERC) Research Scholarship, 1977-80
NERC-NATO Postdoctoral Fellowship, 1980-83
Pauley Foundation Grant-In-Aid, 1981,

PROFESSIONAL EXPERIENCE:

1996- Snr. Research Scientist, Lecturer and Adjunct Professor, San Francisco State University
1996- Associate Research Professor, Department of Biological Sciences, University of Southern California
1989-96 Assistant Research Professor, Department of Biological Sciences, USC
1994 Visiting Scientist, Institute of Marine Biology of Crete
1985 Visiting Scientist, Station Zoologique, Villefranche-sur-Mer, France
1985 Consultant, Woodward Clyde Associates
1984-89 Research Associate, Allan Hancock Foundation, University of Southern California
1983 Postdoctoral Fellow, University of California, Santa Barbara, CA
1981-82 Postdoctoral Fellow, University of California, Los Angeles, CA,

SOME OTHER PROFESSIONAL ACTIVITIES:

Editor, Advances in Space Research, Journal Reviewer for Limnology & Oceanography, Biological Bulletin, Marine Biology, Marine Ecology Progress Series, Coral Reefs, J of Exp. Marine Biology & Ecology etc, Proposal Reviewer for NSF Biological Oceanography, Chemical Oceanogr. JGOFS, Polar Programs, SeaGrant, NOAA, Panel Member ECOHAB Program

RECENT COLLABORATORS (IN ADDITION TO CO-AUTHORS):

W. Kimmerer, J. Thompson, S. Bollens, B.Ward, J. Zehr, J. Largier, E. Dever, C. Dorman, L. Botsford

RECENT STUDENTS:

Students: V. Hogue, A. Lassiter, L. Righetti-Judah, A. Johnson

SELECTED RECENT PUBLICATIONS:

Wilkerson, F.P. and R.C. Dugdale. 1997. The effect of El Niño on coastal new production. In "California and the World Ocean '97, pp. 1554-1562.
Dugdale, R.C. and F.P. Wilkerson. 1998 Silicate regulation of new production in the equatorial Pacific upwelling. Nature. 391: 270:273.
Wilkerson, F.P., R.C. Dugdale, R.M. Kudela and F.P. Chavez. 2000. Biomass and productivity in Monterey Bay, CA: Contribution of the large phytoplankton. Deep-Sea Research Part II 47: 1003-1023.
Dugdale, R.C. and F.P. Wilkerson. 2001 Sources and fates of silicon in the ocean: the role of diatoms in climate and glacial cycles. Scientia Marina 65: (Suppl. 2: A Marine Science Odyssey Into the 21st Century, J.M. Gili, J.L. Pretus and T.T. Packard, eds.) 141-152.
Hogue, V., F. Wilkerson, R. Dugdale and A. Marchi. 2001 Nutrients and phytoplankton dynamics in Suisun, San Pablo and Central Bays. October 2001 IEP Newsletter.
Chai, F., R. C. Dugdale, T-H Peng, F. P. Wilkerson, and R. T. Barber. 2002. One dimensional ecosystem model of the equatorial pacific upwelling system, Part I: Model development and silicon and nitrogen cycle, In press, Deep-Sea Research II.
Dugdale, R.C., R. T. Barber, F. Chai, T.H. Peng, and F.P. Wilkerson, 2002 One dimensional ecosystem model of the equatorial pacific upwelling system, Part II: sensitivity analysis and comparison with JGOFS EqPac Data. In press, Deep-Sea Research II.
Dugdale, R. C. A. G. Wischmeyer, F.P. Wilkerson, R.T. Barber, F. Chai, M. Jiang and T-H. Peng. 2002 Meridional asymmetry of source nutrients to the equatorial upwelling ecosystem and modeling of the impact on ocean-atmosphere CO_2 flux. In press, Deep-Sea Research II.
Wilkerson, F.P., R. C Dugdale, A. Marchi and C.A. Collins. 2002.Hydrography, Nutrients and chlorophyll measured during El Niño and La Niña compared to normal years in the Gulf of the Farallones, CA. In press, Progress in Oceanography

Abstracts for relevant presentations

Wilkerson, F.P., R.C. Dugdale, A. Marchi, V. Hogue, J. Tustin, 1999. High silicate:nitrate conditions in central San Francisco Bay, Estuarine Research Federation 99, New Orleans, LA. Abstract.
Wilkerson, F.P., A. Marchi, V. Hogue, J. Tustin, R.C. Dugdale, 2000.Comparing the impact of the 1998 El Nino versus the 1999 La Nina on the spring bloom in Central San Francisco Bay ASLO-Ocean Sciences, San Antonio TX Abstract
Dugdale, R.C., A. Marchi, V. Hogue, J. Tustin, and F.P. Wilkerson. 1999. Nutrient concentrations and nutrient utilization in Central San Francisco Bay ASLO. Ocean Sciences, Santa Fe, NM. Abstract
Marchi, A., R.C. Dugdale, F.P. Wilkerson, C.A. Collins, V. Hogue, J. Tustin, B. Jarvis 2000. Nutrient dynamics between Central San Francisco Bay and the Gulf of the Farallones: A comparison of El Nino and La Nina years, ASLO, San Antonio TX. Abstract
Hogue, V. A.M. Lassiter, A. Marchi, F. Wilkerson, R. Dugdale. 2000. Phytoplankton and nutrient dynamics in North and Central San Francisco Bay (Suisun, San Pablo and Central Bays). ASLO, Albuquerque, NM. Abstract

EDWARD J. CARPENTER December, 2004

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CURRENT POSITION:
Professor, Biology Department, San Francisco State University

EDUCATION:
B.S. State University of New York, College at Fredonia, 1964
M.S. North Carolina State University, 1966
Ph.D. North Carolina State University, 1969

BIOGRAPHICAL SKETCH:
Woods Hole Oceanographic Institution, 1969-1975 (Postdoc & Asst. Scientist)
Marine Sciences Research Center, Assistant, Associate & Full Professor, SUNY at Stony Brook, 1975-2000
Associate Program Manager, Office of Polar Biology and Medicine, National Science Foundation, 1995-1997.
Sabbatical, Botanical Institute, Stockholm University, Sweden, 1991 & 1997
Romberg Tiburon Center, San Francisco State University, Professor, 2000-present
PhD *honoris causa* Stockholm University, Sweden 2001
Editorial Board, Journal of Phycology 2004-2007
Fellow, California Academy of Sciences 2004

Advisors: PhD: J.E Hobbie, presently at Ecosystems Center, MBL, Woods Hole
Postdoctoral: R.R.L. Guillard, presently at Bigelow Lab for Ocean Science

Research Interests:
Phytoplankton ecology, nutrient cycling in marine waters, photosynthesis, nitrogen fixation by marine cyanobacteria & bacteria, phytoplankton nuisance blooms, cyanobacterial symbioses, bacterial ecology. Biology of snow microbes. Carpenter has extensive experience on research ships and has logged over 50 research cruises. He has been Principal Investigator on over 50 Federal government (NSF, NASA) grants. Courses have been taught in Biological Oceanography, Microbial Ecology, Phytoplankton Ecology, Phycology, Marine Biology and Introductory Oceanography.

Collaborators in last 48 months: Bergman, Birgitta, U. Stockholm, Campbell, Lisa, Texas A & M, Capone, Douglas, USC, Falkowski, Paul, Rutgers U. Hood, Raleigh, U. Maryland, Michaels, Tony, USC, Montoya, Joe, Georgia Tech, Sanudo-Wilhelmy, Sergio, Stony Brook U. Villareal, Tracy, U. Texas, Karl, Dave, U. Hawaii, Zehr, Jon, UCSC, Ron Siefert, U Maryland

Graduate Students and Postdoctoral Investigators in last 5 years: Lin, Senjie, U. Connecticut, Kustka, Adam, Princeton Univ., M. Mulholland, Old Dominion Univ, Subramaniam, Ajit, LDEO, Columbia Univ., Chang, Jeng, Taiwan Ocean Sciences U. Luisa Falcon, Atonom. U. Mexico.

RECENT PUBLICATIONS (since 2000): (author of ca. 100 reviewed papers and editor of 5 books)

2000

Dupuoy, C., J. Neveux, A. Subramaniam, M.R. Mulholland, J.P. Montoya, L. Campbell, D.G. Capone & E.J. Carpenter. SeaWiFS captures a persistent bloom in the southwest tropical Pacific Ocean: a link to *Trichodesmium*. EOS 81:14-16.

Zehr, J., E.J. Carpenter, and T. Villareal. New perspectives on nitrogen fixation in the open ocean: evidence for new sources of fixed nitrogen in the marine environment. Trends in Microbiology 8:68-73.

Carpenter, E.J. and S. Janson. Intracellular symbionts in the marine diatom *Climacodium frauenfeldianum* Grunow. J. Phycology 36:540-544.

Carpenter, E.J., S. Lin, and D.G. Capone. 2000. Bacterial activity in South Pole snow. Applied & Environmental Microbiology. 66:4514-4517.

Lin, S., E. Magaletti, and E.J. Carpenter. Molecular cloning and antiserum development of cyclin box in the brown tide alga *Aureococcus anophagefferens*. Molecular Biotechnology 2, 577-586.

2001

Sanudo-Wilhelmy, S.A., A. Kustka, D.G. Capone, D. Hutchins, C. Gobler, M. Yang, & E.J. Carpenter. Phosphorus limitation of N_2 fixation in the central Atlantic Ocean. Nature, 411:66-69.

Carpenter, E.J., and S. Janson. *Anabaena gerdii* (sp. nov.), a new heterocystous, filamentous cyanobacterium from the South Pacific Ocean and Arabian Sea. Phycologia. 40:105-110.

Lin, S., C.J. Gobler, and E.J. Carpenter. Cytological and biochemical responses of *Dunaliella tertiolecta* (Volvocales, Chlorophyta) to iron stress. Phycologia. 40:403-410.

Lundgren, P., E. Soderbak, B. Bergman, and E.J. Carpenter. *Katagnymene*.: characterization of a novel marine diazotroph. J. Phycology 37:1001-1009.

Subramaniam, A., C.W. Brown, R.R. Hood, E.J. Carpenter and D.G. Capone. Detecting

Trichodesmium blooms in SeaWiFS imagery. Deep-Sea Res. II 49:107-121.

2002

Hood, R. A. Subramaniam, L. May, E.J. Carpenter and D.G. Capone. Remote estimation of nitrogen fixation by *Trichodesmium*. Deep-Sea Res. II 49/1-3:123-147.

Mulholland, M., S. Floge, E.J. Carpenter and D.G. Capone. Phosphorus dynamics in cultures and natural populations of *Trichodesmium* spp. Marine Ecology Progress Series. 239:45-55.

Karl, D., A. Michaels, B. Bergman, D. Capone, E.J. Carpenter, R. Letelier, F. Lipschultz, H. Paerl, D. Sigman, & L. Stal. Nitrogen Fixation in the world's oceans. Biogeochemistry. 57/58:47-98

Carpenter, E.J. and R. Foster. Marine Cyanobacterial Symbioses. IN: A.N. Rai, B. Bergman and U. Rasmussen`(eds). Pp. 11-17, IN: Cyanobacteria in Symbiosis. Kluwer Academic Publishers.

Carpenter, E.J. Marine Cyanobacterial Symbioses. Biology and Environment, Proceedings of the Irish Royal Academy. 102B: 15-18.

Kustka, A., E.J. Carpenter & S. Sanudo-Wilhelmy. Iron and marine nitrogen fixation: progress and future directions. Research in Microbiology, 153:255-262.

Falcon, L. A. Chistocerdov, F. Cipriano & E.J. Carpenter. Nitrogen fixation by picoplanktonic cyanobacteria in the tropical North Atlantic Ocean. Applied & Environmental Microbiology. 68:5760-5764.

Montoya, J. E.J. Carpenter and D.G. Capone. Nitrogen fixation and nitrogen isotope abundance in zooplankton of the oligotrophic North Atlantic Ocean. Limnology and Oceanography 47:1617-1628.

2003

Villareal, T. and E.J. Carpenter. Buoyancy regulation and potential for vertical migration in the oceanic cyanobacterium *Trichodesmium*. Microbial Ecology. 45:1-10.

Kustka, A., S.A. Sanudo-Wilhelmy, D.G. Capone, J.A. Raven, E.J. Carpenter. A revised estimate of the iron use efficiency of nitrogen fixation, with special reference to the marine N_2 fixing cyanobacterium, *Trichodesmium* spp. J. Phycology 39:12-25.

Lin, S., T.A. Feinstein, Huan Zhang, and E.J. Carpenter. Development of an immunofluorescence technique for detecting *Pfiesteria piscicida*. Harmful Algae 2:223-231.

Kustka, A., S. Sanudo-Wilhelmy, E.J. Carpenter, D.G. Capone, J. Burns & W.G. Sunda. Iron requirements for dinitrogen and ammonium supported growth in cultures of *Trichodesmium* (IMS 101): comparison with nitrogen fixation rates and iron:carbon ratios of field populations. Limnol. Oceanogr. 48:1869-1884

Cronberg, G., E.J. Carpenter, and W.W. Carmichael. Taxonomy of harmful cyanobacteria. pp. 523-562, IN: G.M. Hallegraeff, D.M. Anderson, and A.D. Cembella (eds) Manual on Harmful Microalgae UNESCO Intergovernmental Oceanographic Commission.

2004

Carpenter, E.J., A. Subramaniam & D.G. Capone. Biomass and primary productivity of the cyanobacterium *Trichodesmium* spp. in the tropical N Atlantic Ocean. Deep-Sea-Res. I 51:173-203.

Falcon, L., E.J. Carpenter, F. Cipriano, B. Bergman & D.G. Capone. Bacterioplankton from the Atlantic and Pacific Oceans: Phylogeny and *in situ* rates. Appl. Envir. Microbiol 70:765-770.

Hewson, I., S.R. Govil, D.G. Capone, E.J. Carpenter, & J.A. Fuhrman. Evidence of *Trichodesmium* viral lysis and potential significance for biogeochemical cycling in the oligotrophic ocean. Aquatic Microbial Ecology. 36:1-8

Sañudo-Wilhelmy, S., A. Tovar-Sanchez, F. Fu, D.G. Capone, E.J. Carpenter, & D.A. Hutchins. The impact of surface adsorbed phosphorus on phytoplankton Redfield stoichiometry. Nature 432:

Lin, S., M.R. Mulholland, H. Zang, T.N. Feinstein, F.J. Jochem & E.J. Carpenter. Intense grazing and prey-dependent growth of *Pfiesteria piscicida* (Dinophyceae). J. Phycology 40:1062-1073

In Press:

Falcon, L., S. Pluvinage & E.J. Carpenter. Phosphorus uptake kinetics of unicellular N_2 fixing cyanobacterial isolates from the tropical N Atlantic and subtropical N Pacific grown in continuous culture. Mar. Ecol. Prog. Ser.

Falcon, L., S. Lindvall, K. Bauer, B. Bergman & E.J. Carpenter. Ultrastructure of unicellular N_2 fixing cyanobacteria from the tropical North Atlantic Ocean and subtropical North Pacific Ocean. J. Phycol.

CURRENTLY FUNDED PROJECTS:

NSF Biocomplexity Initiative: "Biocomplexity: Factors affecting, and impact of, diazotrophic microorganisms in the western Equatorial Atlantic Ocean." OCE 9981618,

$3,500,000 for 5 years. EJC is PI. Co-PI is D.G. Capone from USC. (EJC Budget is $795,000 for 5 years). Start January 2000

NSF Biocomplexity Initiative: "Biocomplexity: Oceanic N_2 fixation and global climate." A.E. Michaels and D.G. Capone (from USC) are PIs. OCE 9981662, Carpenter budget is total of $200,000 for 5 years. Start January 2000.

NSF "FSML: An environmental monitoring system for the Romberg Tiburon Center". $75,000 EJC is PI, co PIs Alissa Arp & Stephen Bollens, DBI 0121998, Start Oct 1, 2001, for 5 years.

NSF, Biological Oceanography, Collaborative Research: Biology and phylogeny of marine planktonic cyanobacterial symbioses. OCE 0132638, $178,334 for 3 years. EJC is PI. Start Feb 26, 2002. Collaboration is with Jon Zehr at UC Santa Cruz.

CALFED, Integrated Regional Wetland Monitoring Pilot Project (IRWM). Start 1/1/03 for 3 years. $205,458. EJC is Co-PI, S. Bollens is PI.

Risa A. Cohen

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Education:

1996-2003 University of California, Los Angeles
1992-1996 Tufts University

Degrees:

Ph.D. (June 2003) University of California, Los Angeles, CA 90095
Dissertation Title: "Physiological responses of a bloom-forming macroalga to eutrophic conditions: implications for use as a bioindicator of freshwater and nutrient influx to estuarine areas."

B.S. (May 1996) Tufts University, Medford, MA 02155
Biology, Environmental Studies "*Summa Cum Laude with High Thesis Honors*"
Thesis: "Factors affecting settlement and metamorphosis in the marine polychaete *Capitella* sp.I."

Research Grants:

2003 Departmental Fellowship - ($6,000) – University of California, Los Angeles
2002 Departmental Research Award ($450) – University of California, Los Angeles
2002 Departmental Fellowship - ($6,000) – University of California, Los Angeles
2001-2002 University of California Coastal Initiative Research Grant ($8,761)
2001 Departmental Research Award ($1,000) – University of California, Los Angeles
2001 Departmental Travel Grant ($238) – University of California, Los Angeles
1999-2002 EPA Science to Achieve Results (STAR) Fellowship ($78,051)
1999 Tinker Field Research Grant ($1,600) – University of California, Los Angeles
1999 UCLA Latin American Center Grant ($700) – Univ. of California, Los Angeles

Awards and Honors:

2003 Scherbaum Award for Outstanding Research (UCLA)
2002 Best Student Paper Award ($200), Southern California Academy of Sciences
1995 Phi Beta Kappa
1995 Golden Key National Honor Society

Research Experience:

Aug 2003-present	Postdoctoral Researcher Romberg Tiburon Center for Environmental Studies, San Francisco State University Primary productivity in natural vs. breached marshes in the San Francisco Bay area.
Aug 2000-June 2003	Dissertation project: Quantifying the response of *Enteromorpha intestinalis* to changes in environmental factors associated with runoff; decreased salinity and light availability, nutrients, and nutrient source (marine or terrestrial).
July-August 2001	Field Research Assistant, Florida Keys, FL Studied the effects of nutrients on common species of algae and aided with the set-up for a long-term coral monitoring project looking at growth and health.
May 2000	Field Research Assistant, R.V. Urraca, Panama Monitored coral populations for species diversity and health in a post El Niño year.
1998-2000	Studied the expulsion of symbiotic dinoflagellates from anemones and corals in response to changes in salinity. Performed laboratory experiments at UCLA and field experiments at the Hawaii Institute of Marine Biology and Cayos Cochinos Marine Reserve, Honduras.
September 1998	Field Research Assistant, University of Puerto Rico Marine Station Assisted with development of an algal bioassay to measure nutrient influx into tropical marine systems.
September 1997	Field Research Assistant, R.V. Urraca, Panama Collected marine algae for nutrient analysis to examine the differences among algae from sites with differential nutrient loading.
1995-1996	Senior Honors Thesis Research, Tufts University Identification of environmental cues that influence settlement and metamorphosis in the marine polychaete, *Capitella* species I, a pollution indicator species.

Publications:

Cohen, R.A. and P. Fong. 2004. Physiological responses of a bloom-forming green macroalga to short-term change in salinity, nutrients, and light help explain its ecological success. *Estuaries*. 27(2): 209-216.

Cohen, R.A. and P. Fong. 2004. Nitrogen uptake and assimilation in *Enteromorpha intestinalis*: Using ^{15}N to determine preference during simultaneous pulses of nitrate and ammonium. *J. Exp. Mar. Biol. Ecol*. 309(1): 67-77.

Cohen, R.A. and J.A. Pechenik. 1999. Relationship between sediment organic content, metamorphosis, and postlarval performance in the deposit-feeding polychaete, *Capitella* sp.I. *J. Exp. Mar. Biol. Ecol*. 240(1): 1-18.

Cohen, R.A. and P. Fong. In press. Experimental evidence supports the use of $\delta^{15}N$ of the opportunistic green macroalga *Enteromorpha intestinalis* to determine nitrogen sources to estuaries. *J. Phycol.*

Boyer, K. E., P. Fong, A. R. Armitage, and R. A. Cohen. 2004. Elevated nutrient content of macroalgae increases rates of herbivory in coral, seagrass, and mangrove habitats. *Coral Reefs*. 23(4): 530-538.

In Review:

Cohen, R.A. and P. Fong. In review. Using opportunistic green macroalgae as indicators of nitrogen supply and sources to estuaries. *Ecol. App*.

Manuscripts:

Cohen, R. A. and E. J. Carpenter. In prep. Partitioning of primary productivity among four groups of estuarine primary producers in San Francisco Bay.

Presentations:

Oct. 2004 CALFED Conference – Poster Presentation
Evaluating nutrient regimes and primary productivity in wetlands in the San Francisco Estuary.

Sept. 2003 Estuarine Research Federation – Oral Presentation
Using macroalgae as an indicator of terrestrial influences in a southern California estuary.

April 2003 California Estuarine Research Society Meeting – Oral Presentation
Using macroalgae as an indicator of anthropogenic influences in southern California estuaries.

Feb. 2003 Southern California Coastal Water Research Project – Invited Seminar Speaker
Physiological responses of bloom-forming macroalgae to eutrophic conditions: Implications for use as a bioindicator of freshwater and nutrient influx to estuarine areas.

Nov. 2002 Western Soceiety of Naturalists Conference – Oral Presentation
Factorial experiments of increasing complexity to quantify physiological responses of a bloom-forming green macroalga to short-term change in salinity, nutrients, and light.

June 2002 Southern California Academy of Sciences Conference – Oral Presentation
Physiological Responses to Variations in Salinity, Nutrients and Light Availability of the Bloom-Forming Macroalga *Enteromorpha intestinalis*: Implications for Use as a Bioindicator of Freshwater and Nutrient Influx to Estuarine and Coastal Areas.

Nov. 2001 Estuarine Research Federation – Poster Presentation
The Physiological Effects of Salinity Reduction and Nutrient Enrichment on the Bloom-Forming Macroalga *Enteromorpha intestinalis*.

July 2001 EPA Science to Achieve Results Conference – Poster Presentation
The Effects of Runoff on the Physiology of the Green Macroalga *Enteromorpha intestinalis*: Implications for Use as a Bioindicator of Freshwater and Nutrient Influx to Estuarine and Coastal Areas.

Professional Service and Memberships:

Reviewer for Estuaries, Marine Biology
Western Society of Naturalists (2002)
Southern California Academy of Sciences (2002)

CURRICULUM VITAE – ALEXANDER E. PARKER, Ph.D.

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CURRENT POSITION: Post Doctoral Research Scientist, Romberg Tiburon Center

EDUCATION:

2004	Ph.D., University of Delaware, Oceanography
1995	B.A., University of Colorado at Boulder, Environmental, Population and Organismal Biology

HONORS AND AWARDS:

2003-2004	Delaware Mobile Surf Fishermen Association Graduate Fellow
2003	Student Travel Award – Estuarine Research Federation
2002	Student Travel Award – American Society of Limnology and Oceanography
2000-2003	NOAA National Estuarine Research Reserve Graduate Research Fellow
1999-2000	NSF Graduate Research Traineeship Fellow

PROFESSIONAL EXPERIENCE:

2004 -	Post Doctoral Research Scientist – Romberg Tiburon Center, SFSU – Richard Dugdale, Advisor
1998-2004	Research Assistant, Graduate College of Marine Studies-Jonathan Sharp, Advisor
1998	Teaching Assistant – Introduction to Ocean Science – University of Delaware
1997-1998	Intern, NOAA Office of Coast Survey, National Shoreline Data Standard

PRESENTATIONS AND PUBLICATIONS:

Parker, A.E. , Sharp, J.H. "The contribution of NH_4^+, NO_3^-, and phytoplankton-released dissolved organic nitrogen to bacterial nitrogen requirements in the Delaware Estuary" In Prep.

Parker, A.E., Yoshiyama, K., Sharp, J.H. "A comparison of estimates of primary production by stable and radioactive isotope techniques in estuarine and coastal waters." In Prep.

Parker, A.E. "Differential transfer of organic carbon and nitrogen in the microbial loop of the Delaware Estuary". Submitted: Estuaries.

Sharp JH, Beauregard AY, Burdige D, Cauwet G, Curless SE, Lauck R, Nagel K, Ogawa H, **Parker AE**, Primm O, Pujo-Pay M, Savidge WB, Seitzinger SP, Spyres G, Styles R (2004) A direct instrument comparison for measurement of total dissolved nitrogen in seawater. Marine Chemistry 84:181-193

Parker, A.E., Curless, S.E., Yoshiyama, K., Sharp, J.H. 2004 "Ammonium suppression of primary production in the Delaware Estuary: evidence from mesocosm experiments." American Society of Limnology and Oceanography Ocean Science Meeting, Honolulu, HI

Curless, S.E., **Parker, A.E**., Yoshiyama, K., Sharp, J.H. 2003 "Accurate and precise analysis of primary biological elemental pools to support estuarine mesocosm experiments" American Society of limnology and Oceanography Ocean Science Meeting, Honolulu, HI

Parker, A.E. 2003. "Direct measurement of carbon and nitrogen cycling within the estuarine microbial loop". American Society of Limnology and Oceanography Aquatic Science Meeting, Salt Lake City, UT

Parker, A.E. 2003 "^{13}C and ^{15}N isotope tagging experiments to assess the importance of the microbial loop in estuarine systems". Estuarine Research Federation Meeting, Seattle WA.

Parker, A.E 2003. "The Microbial loop within a salt marsh estuary: The St. Jones River, DE ". NOAA National Estuarine Research Reserve Research Coordinators meeting, Lewes, DE

Parker, A.E. 2003 "Carbon and nitrogen cycling within the microbial loop" Graduate College of Marine Studies, Graduate Student Symposium, Lewes, DE

Sharp, J.H.. Beauregard, A.Y., **Parker, A.E.**, Curless, S.E. 2002 "A high temperature combustion instrument comparison for measurement of dissolved organic nitrogen in seawater." American Society of limnology and Oceanography, Ocean Science Meeting, Honolulu, HI

Parker, A .E., and Sharp, J.H.2001. "Differential Carbon and Nitrogen Transfer in the Estuarine Microbial Loop: The Role of Nitrogen Concentration and Quality". ASLO/AGU Ocean Science Meeting, Albuquerque, NM

Sharp, J.H. Beauregard, A.Y. and **Parker, A.E**. 2001 "Recent changes in nutrient ratios in estuaries and coastal waters: What is the impact?" Estuarine Research Federation Conference, Miami, Fl

Schwartz, M., **Parker,A.E**., Beauregard, A.Y., Sharp, J. H. 2000 "Temporal and Spatial Variations in Microbial Biogeochemistry of a coastal plain estuary". ASLO Aquatic Science Meeting. Copenhagen, Denmark

Parker, A.E., Beauregard,A.Y., Chandler, E , Schwartz, M,, Sharp, J.H. 2000 "Evaluating microbial loop using dual isotope tagging" AGU/ASLO Ocean Science Meeting, San Antonio, TX.

Beauregard, A.Y., **Parker, A.E**., Schwartz, M, Sharp, J.H. 2000 "Evaluating estuarine health through nutrient and gas stoichiometry" .AGU/ASLO Ocean Science Meeting, San Antonio, TX

Parker, A.E. and Lockwood, M. 1998 "Classification of Shoreline Data for GIS Applications". Coastal Society Meeting. Williamsburg, VA.

CURRICULUM VITA

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Education

- Stanford University, Stanford, California, Ph.D., Environmental Fluid Mechanics: Civil and Environmental Engineering
- California State University, San Francisco, California, M.A. Marine Biology
- Lewis and Clark College, Portland, Oregon, B.S. Biology

Experience

- 1982-present: Research Scientist, U.S. Geological Survey Menlo Park, California:
- 1972: Teaching Assistant, Oregon Institute of Marine Biology, University of Oregon; Lewis and Clark College
- 1971: Teaching Assistant, Lewis and Clark College

Research Interest:

Ecology and physical dynamics of aquatic systems based on long term (30 year) investigations of the San Francisco Bay and freshwater Delta that has included studies of the following: the coupling between, and interdependence of benthic and pelagic communities; biogeochemical processes related to benthic organism accumulation of natural and anthropogenic elements; the physical dynamics of organic and inorganic particle transfer to the bed; the study of benthic community dynamics in response to natural and anthropogenic stress; and the response of aquatic ecosystems to non-indigenous species. I have worked on the aquatic ecology of the San Francisco Bay and Freshwater Delta for over 30 years in addition to work in Willipa Bay (Washington), Coos Bay (Oregon), and offshore California.

Highlights:

U.S. Department of the Interior, Superior Service Award, 2003
Special Achievement Award for Outstanding Performance, USGS, 1989
Science Advisory Committees: California Bay/Delta Food Chain Committee-1999-present: California Sea Grant Committee on Exotic Species 1996-present; Interagency Ecological Program Review of Long-term Fish Monitoring Program; CALFED Exotic Species Program 2000-present
Editorial Board: Aquatic Nuisance Species Digest (1999-present)
Session Chair: AAAS National 2001, ERF National 2005

Postdoctorates: Dr. Laurent Chauvaud, Dr. Rene Takesue

Academic Committees: Dr. Rachel Simons, Stanford University; Nicole Jones, Stanford University (in progress), Michelle Shouse (California State University, SF), Heather Peterson (California State University, SF), Leo Winternitz (University of San Francisco), Bernie Kaplan (California State University, Monterey)

<u>Relevant Publications:</u>

Nichols, F.H., and Thompson Janet K., 1985b. Time Scales of change in the San Francisco Bay benthos: *Hydrobiologia*, v. 129, p. 121-138.

Thompson, Janet K. and Nichols, F.H., 1988. Food availability controls the seasonal cycle of growth in the bivalve *Macoma balthica*. *Journal Exp. Marine Biol. Ecol.*, v. 116, p. 43-61.

Carlton, J.T., Thompson, J.K., Schemel, L.E., Nichols, F.H., 1990. Remarkable invasion of San Francisco Bay (California, USA) by the Asian clam *Potamocorbula amurensis*. I. Introduction and dispersal, *Marine Ecology Progress Series*, 66, pp. 81-94.

Nichols, F.H., Thompson, J.K., Schemel, L.E., 1990. Remarkable invasion of San Francisco Bay (California, USA) by the Asian clam *Potamocorbula amurensis*. II. Displacement of a former community, *Marine Ecology Progress Series*, 66, pp. 95-101

Monismith, Stephen G., Koseff, J. R., Thompson Janet K., O'Riordan, Catherine A., and Nepf, Heidi M. 1990. A study of Model Bivalve Siphon Currents: *Limnology & Oceanography* v. 35, no. 3, p. 680-696

Cole, B.E., J.K. Thompson, and J.E. Cloern. 1992. Measurement of filtration rates by infaunal bivalves in a recirculating flume. Marine Biology, 113: 219-225.

Lucas, L.V., J.E. Cloern, J.R. Koseff, S.G. Monismith, and J.K. Thompson. 1998. Does the Sverdrup critical depth model explain bloom dynamics in estuaries? *Journal of Marine Research*, 56:375-415

Lucas, L.V., J.E. Cloern, J.R. Koseff, S.G. Monismith, and J.K. Thompson. 1999. Processes governing phytoplankton blooms in estuaries. Part I: The local production-loss balance. *Marine Ecology Progress Series* v. 187, pp. 1-15

Lucas, L.V., J.E. Cloern, J.R. Koseff, S.G. Monismith, and J.K. Thompson. 1999. Processes governing phytoplankton blooms in estuaries. Part II: The role of horizontal transport. *Marine Ecology Progress Series* v. 187, pp. 17-30

Thompson, J. K., 1999. The effect of infaunal bivalve grazing on phytoplankton bloom development in South San Francisco Bay, PhD Thesis, Stanford University, Dept. of Civil and Environmental Engineering, Stanford, CA: 419p.

Lucas, L.V., J. E. Cloern, J.K. Thompson, and N.E. Monsen. 2002. Functional variability of shallow tidal habitats in the Sacramento-San Joaquin Delta: restoration implications. *Ecological Applications* 12(5): 1528-1547.

Crimaldi, J.P. J.K. Thompson, J.H. Rosman, R. J. Lowe, J. R. Koseff. 2002. Hydrodynamics of larval settlement: The influence of turbulent stress events at potential recruitment sites. *Limnology and Oceanography*. 47(4):1137-1151

Parchaso, F. and J.K. Thompson, 2002, The influence of hydrologic processes on reproduction of the introduced bivalve *Potamocorbula amurensis* in Northern San Francisco Bay, California, *Pacific Science*, 56(3):329-345

Brown, C.L., F. Parchaso, J.K. Thompson, S.N. Luoma. 2003. Assessing toxicant effects in a complex estuary: A case study of effects of silver on reproduction in the

bivalve, *Potamocorbula amurensis*, in San Francisco Bay. *Human and Ecological Risk Assessment*. 9(1):95-119

Chauvaud, L., J. K. Thompson, J. E. Cloern, and G. Thouzeau. 2003. Clams as CO_2 generators: The *Potamocorbula amurensis* example in San Francisco Bay. *Limnology and Oceanography* 48(6):2086-2092

Thompson, JK. 2004. One estuary, one invasion, two responses: phytoplankton and benthic community dynamics determine the effect of an estuarine invasive suspension feeder. *In press*, The comparative Roles of Suspension Feeders in Ecosystems, S. Olenin and R. Dame Editors.

Manuscripts in Review:

Thompson, J.K., J.R. Koseff, and S.G. Monismith. Concentration boundary layer development over infaunal bivalves: a synthesis of laboratory and field experiments. Post-submission, revision, Limnology and Oceanography

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Education

AB 1973	Biological Sciences	Cornell University
MS 1981	Marine Environmental Sciences	Stony Brook University
PhD 1986	Coastal Oceanography	Stony Brook University

Professional Experience

1986-1988 Post-doctoral associate, Institute of Ecosystem Studies, Millbrook, NY
1988-1991 Asst. Research Scientist, Chesapeake Biological Lab, University of Maryland
1991-1995 Senior Scientist, Dauphin Island Sea Lab, Mobile AL
1995- Associate Professor, Dept Marine Sciences, University of Connecticut

Representative Publications

Pace, M. L., G. B. McManus, and S. E. G. Findlay. 1990. Planktonic community structure determines the fate of bacterial production in a temperate lake. **Limnol. Oceanogr. 35(4):795-808.**

McManus, G.B. 1991. Flow analysis of a planktonic microbial food web model. **Mar. Microb. Food Webs 5: 145-160**.

McManus, G.B. and M.C. Ederington-Cantrell. 1992. Phytoplankton pigments and growth rates, and microzooplankton grazing in a large temperate estuary. **Mar. Ecol. Prog. Ser. 87: 77-85**.

McManus, G.B. 1993. Growth rates of natural populations of heterotrophic nanoplankton. In: P.F. Kemp, B.F. Sherr, E.B. Sherr and J.J. Cole (eds.), Current Methods in Aquatic Microbial Ecology. **Lewis Publishers. pps. 557-562**.

McManus, G.B. and R. Dawson. 1994. Phytoplankton pigments in the deep chlorophyll maximum of the Caribbean Sea and the western tropical Atlantic Ocean. **Mar. Ecol. Prog. Ser. 113: 199-206**.

McManus, G.B. 1995. Phytoplankton abundance and pigment changes during simulated in situ dilution experiments in estuarine waters: possible artifacts caused by algal light adaptation. **J. Plankton Res. 17: 1705-1716**.

McManus, G. B. and C. A. Foster. 1998. Seasonal and fine-scale spatial variations in egg production and triacylglycerol content of the copepod Acartia tonsa in a river-dominated estuary and its coastal plume. **J. Plankton Res. 20:767-785**.

McLeroy-Etheridge, S.L. and G.B. McManus. 1999. Food type and concentration affect chlorophyll and carotenoid destruction during copepod feeding. **Limnol. Oceanogr. 44:2005-2011**.

MccManus, G.B., H Zhang, and S Lin. 2004. Marine planktonic ciliates that prey on macroalgae and enslave their chloroplasts. **Limnol. Oceanogr. 49:308-313**

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Education

- San Francisco State University, San Francisco, California, M.S. Marine Biology
- San Francisco State University, San Francisco, California, B.A. Marine Biology

Experience

- 1989-present: Research Scientist, U.S. Geological Survey Menlo Park, California:
- 1988-89: Biologist, Entrix, Walnut Creek, CA
- 1986-88: Teaching Assistant, San Francisco State University
- 1983-84: Field Biologist, California Fish & Game, Monterey, CA

Research Interest:

Ecology of aquatic systems and physiology of benthic invertebrates. Special studies on exotic species and how they have adapted to their new environment. Invertebrate eco-physiology and reproduction of bivalves in San Francisco Bay: including physiological and reproductive responses to physical dynamics.

Relevant Publications:

Parchaso, F. and J.K. Thompson, 2002, The influence of hydrologic processes on reproduction of the introduced bivalve *Potamocorbula amurensis* in Northern San Francisco Bay, California, *Pacific Science*, 56(3):329-345

Brown, C.L., F. Parchaso, J.K. Thompson, S.N. Luoma. 2003. Assessing toxicant effects in a complex estuary: A case study of effects of silver on reproduction in the bivalve, *Potamocorbula amurensis*, in San Francisco Bay. *Human and Ecological Risk Assessment*. 9(1):95-119

Foodweb Support For The Threatened Delta Smelt And Other Estuarine Fishes In Suisun Bay And The Western Sacramento-San Joaquin Delta: Signature

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

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 confidentiality1 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: Foodweb support for the threatened delta smelt and other estuarine fishes in Suisun Bay and the western Sacramento-San Joaquin Delta

Proposal Number: 2004.01-0107

[signature] 1/06/05

Applicant Signature **Date**

Kenneth R. Paap, Ph.D.
Associate Vice President for Research

San Francisco State University

Printed Name Of Applicant **Applicant Organization**