Shallow open water habitats: Hydrodynamics and benthic grazing

Project Information

1. **Proposal Title:**

   Shallow open water habitats: Hydrodynamics and benthic grazing

2. **Proposal applicants:**

   Stephen Monismith, Stanford University
   Jan Thompson, USGS WRD NRP
   Jeffrey Koseff, Stanford University

3. **Corresponding Contact Person:**

   Stephen Monismith
   Stanford University
   Dept of Civil and Env. Eng. Stanford University Stanford, Ca. 94305-4020
   650 723 4764
   monismit@ce.stanford.edu

4. **Project Keywords:**

   Estuarine/Tidal Ecology
   Habitat Restoration, Estuarine shallow water
   Hydrodynamics

5. **Type of project:**

   Research

6. **Does the project involve land acquisition, either in fee or through a conservation easement?**

   No

7. **Topic Area**:

   Shallow Water, Tidal and Marsh Habitat

8. **Type of applicant:**

   Joint Venture

9. **Location - GIS coordinates:**

Latitude:	38.117
Longitude:	-122.333
Datum:	

Describe project location using information such as water bodies, river miles, road intersections, landmarks, and size in acres.

Grizzly Bay, Franks Tract

10. **Location - Ecozone:**

    1.4 Central and West Delta, 2.1 Suisun Bay & Marsh

11. **Location - County:**

    Santa Clara, Solano

12. **Location - City:**

    Does your project fall within a city jurisdiction?

    No

13. **Location - Tribal Lands:**

    Does your project fall on or adjacent to tribal lands?

    No

14. **Location - Congressional District:**

    14

15. **Location:**

    California State Senate District Number: 11

    California Assembly District Number: 21

16. **How many years of funding are you requesting?**

    3

17. **Requested Funds:**
    a) Are your overhead rates different depending on whether funds are state or federal?

       Yes

       If yes, list the different overhead rates and total requested funds:

State Overhead Rate:	15
Total State Funds:	0
Federal Overhead Rate:	57
Total Federal Funds:	616,605

b) Do you have cost share partners already identified?

No

c) Do you have potential cost share partners?

No

d) Are you specifically seeking non-federal cost share funds through this solicitation?

No

If the total non-federal cost share funds requested above does not match the total state funds requested in 17a, please explain the difference:

18. **Is this proposal for next-phase funding of an ongoing project funded by CALFED?**

No

Have you previously received funding from CALFED for other projects not listed above?

Yes

If yes, identify project number(s), title(s) and CALFED program.

none	**Assessment of organic matter in the habitat and its relationship to the food chain**	**Ecosystem restoration COORDINATION PROJECTS**
2001-F200	**Transport, transformation and effects of Se and C in the Delta: Implications for restoration COORDINATION PROJECTS**	**Ecosystem restoration**

19. **Is this proposal for next-phase funding of an ongoing project funded by CVPIA?**

No

Have you previously received funding from CVPIA for other projects not listed above?

No

20. **Is this proposal for next-phase funding of an ongoing project funded by an entity other than CALFED or CVPIA?**

No

Please list suggested reviewers for your proposal. (optional)

Larry Sanford   Horn Point Lab, U of Maryland   lsanford@hpl.umces.edu

Rocky Geyer   WHOI   rgeyer@whoi.edu

Marcel Frechette   IML, Rimouski   frenettem@dfo-mpo.gc.ca

21. **Comments:**

Please do not use Dr. Cheryl Ann Zimmer (formerly Burman) at UCLA as a reviewer - We would be happy to elaborate further over the telephone to explain our reasons

Environmental Compliance Checklist

Shallow open water habitats: Hydrodynamics and benthic grazing

1. **CEQA or NEPA Compliance**
   a) Will this project require compliance with CEQA?

      No
   b) Will this project require compliance with NEPA?

      No
   c) If neither CEQA or NEPA compliance is required, please explain why compliance is not required for the actions in this proposal.

      This is a research proposal that will involve no actions to change the Bay/Delta system at this time

2. **If the project will require CEQA and/or NEPA compliance, identify the lead agency(ies).** *If not applicable, put "None".*

   CEQA Lead Agency:
   NEPA Lead Agency (or co-lead:)
   NEPA Co-Lead Agency (if applicable):

3. **Please check which type of CEQA/NEPA documentation is anticipated.**

   CEQA
   -Categorical Exemption
   -Negative Declaration or Mitigated Negative Declaration
   -EIR
   Xnone

   NEPA
   -Categorical Exclusion
   -Environmental Assessment/FONSI
   -EIS
   Xnone

   If you anticipate relying on either the Categorical Exemption or Categorical Exclusion for this project, please specifically identify the exemption and/or exclusion that you believe covers this project.

4. **CEQA/NEPA Process**
   a) Is the CEQA/NEPA process complete?

      None

   b) If the CEQA/NEPA document has been completed, please list document name(s):

5. **Environmental Permitting and Approvals** (*If a permit is not required, leave both Required? and Obtained? check boxes blank.*)

LOCAL PERMITS AND APPROVALS

Conditional use permit

Variance

Subdivision Map Act

Grading Permit

General Plan Amendment

Specific Plan Approval

Rezone

Williamson Act Contract Cancellation

Other

STATE PERMITS AND APPROVALS

Scientific Collecting Permit

CESA Compliance: 2081

CESA Compliance: NCCP

1601/03

CWA 401 certification

Coastal Development Permit

Reclamation Board Approval

Notification of DPC or BCDC

Other

FEDERAL PERMITS AND APPROVALS

ESA Compliance Section 7 Consultation

ESA Compliance Section 10 Permit

Rivers and Harbors Act

CWA 404

Other

PERMISSION TO ACCESS PROPERTY

Permission to access city, county or other local agency land.
Agency Name:

Permission to access state land.
Agency Name:

Permission to access federal land.
Agency Name:

Permission to access private land.
Landowner Name:

6. **Comments.**

Use of the D7 dolphin will require US Coast Guard permission

Land Use Checklist

<u>Shallow open water habitats: Hydrodynamics and benthic grazing</u>

1. **Does the project involve land acquisition, either in fee or through a conservation easement?**

   No

2. **Will the applicant require access across public or private property that the applicant does not own to accomplish the activities in the proposal?**

   Yes

3. **Do the actions in the proposal involve physical changes in the land use?**

   No

   If you answered no to #3, explain what type of actions are involved in the proposal (i.e., research only, planning only).

   research only

4. **Comments.**

Conflict of Interest Checklist

Shallow open water habitats: Hydrodynamics and benthic grazing

Please list below the full names and organizations of all 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.
- Individuals not listed in the proposal who helped with proposal development, for example by reviewing drafts, or by providing critical suggestions or ideas contained within the proposal.

The information provided on this form will be used to select appropriate and unbiased reviewers for your proposal.

Applicant(s):

Stephen Monismith, Stanford University
Jan Thompson, USGS WRD NRP
Jeffrey Koseff, Stanford University

Subcontractor(s):

Are specific subcontractors identified in this proposal? Yes

If yes, please list the name(s) and organization(s):

Jan Thompson USGS

Helped with proposal development:

Are there persons who helped with proposal development?

Yes

If yes, please list the name(s) and organization(s):

Jan Thompson USGS

Jeff Koseff Stanford University

Comments:

collaborators listed in cv section of proposal

Budget Summary

Shallow open water habitats: Hydrodynamics and benthic grazing

Please provide a detailed budget for each year of requested funds, indicating on the form whether the indirect costs are based on the Federal overhead rate, State overhead rate, or are independent of fund source.

Federal Funds

Year 1												
Task No.	**Task Description**	**Direct Labor Hours**	**Salary *(per year)***	**Benefits *(per year)***	**Travel**	**Supplies & Expendables**	**Services or Consultants**	**Equipment**	**Other Direct Costs**	**Total Direct Costs**	**Indirect Costs**	**Total Cost**
1	Monismith	160	11100	7136	6800	5000	37378	64200	26528	158142.0	75530	233672.00
		160	11100.00	7136.00	6800.00	5000.00	37378.00	64200.00	26528.00	158142.00	75530.00	233672.00

Year 2												
Task No.	**Task Description**	**Direct Labor Hours**	**Salary *(per year)***	**Benefits *(per year)***	**Travel**	**Supplies & Expendables**	**Services or Consultants**	**Equipment**	**Other Direct Costs**	**Total Direct Costs**	**Indirect Costs**	**Total Cost**
1	Monismith expeiment	160	11544	6484	11600	5000	45692	5000	23191	108511.0	51798	160309.00
		160	11544.00	6484.00	11600.00	5000.00	45692.00	5000.00	23191.00	108511.00	51798.00	160309.00

Year 3												
Task No.	**Task Description**	**Direct Labor Hours**	**Salary *(per year)***	**Benefits *(per year)***	**Travel**	**Supplies & Expendables**	**Services or Consultants**	**Equipment**	**Other Direct Costs**	**Total Direct Costs**	**Indirect Costs**	**Total Cost**
1	Monismith	160	11891	6246	3000	5000	8006	0	4912	39055.0	38625	77680.00
		160	11891.00	6246.00	3000.00	5000.00	8006.00	0.00	4912.00	39055.00	38625.00	77680.00

Grand Total=471661.00

Comments.

These numbers have been created from standard NSF style budget. The work is not easily apportioned into separate divisible tasks. Benefits and indirect costs for all pieces of proposal have been assigned to Monismith. Standard rates are 57% ic rate on everything except: permanent equipment; tuition; undergraduate salaries; and subcontracts over $25,000

Budget Justification

<u>Shallow open water habitats: Hydrodynamics and benthic grazing</u>

Direct Labor Hours. Provide estimated hours proposed for each individual.

Prof. S.G. Monismith Lead PI in charge of all phases of project approximately 1 month (160h) per year Prof. J.R. Koseff senior collaborator, will assist with all phases of project approximately 2 weeks/year PhD student (first year) 1000 h (50% time) in year 1 responsible for initial design of experiments and development of instrument frame PhD student (all three years) 1000 h (50% time)/year responsible for biological sampling and coupled biological/physical sampling Dr. Derek Fong 1 month (160h) per year responsible for REMUS operations Bob Brown year 1:120h; year 2: 40 h Science and engineering associate responsible for design and fabrication of frames/sampler etc. Undergraduate helper (included in other direct cost) 600h ea. year 1 and year 2 responsible for performing Chlorophyll extractions, and assisting with experiments

Salary. Provide estimated rate of compensation proposed for each individual.

Rates for year 1 (other years at 3% inflation) Monismith $99,900 per academic year (9 mo.) Koseff - $125,712 per academic year (9 mo.) PhD student $24028 per caleendar year (post quals); $22,433 (pre-quals, post ms) Fong: $76,080 per calendar year Brown: $85,661 per calendar year Undergraduate helper $11/hr

Benefits. Provide the overall benefit rate applicable to each category of employee proposed in the project.

Other than students: 24% Students: 0%

Travel. Provide purpose and estimate costs for all non-local travel.

Year 1 Field experiment $1800 for travel to and from Benecia and per diem during field experiment, based on 15 days at $120/day standard per diem Attend CALFED?IEP meetings in Sacramento/Monterey - $1000 Foreign travel Dr. Amatzia Genin, Hebrew University, Israel travel to California and participate in field experiments $4000. Dr. genin is an expert on benthic-pealgic coupling and this type of experiment in particular. He and Monismith have collaborated extensively on the application of the methods discussed in this proposal for coral reef environments. His cv is available upon request. Year 2 Field experiment $1800 for travel to and from Benecia/Delta and per diem during field experiment, based on 30 days at $120/day standard per diem plus $3000 for two-week houseboat rental for Franks Tract Attend CALFED?IEP meetings in Sacramento/Monterey - $1000 Foreign travel Dr. Amatzia Genin, Hebrew University, Israel travel to California and participate in field experiments $4000 Year 3 Attend CALFED?IEP meetings in Sacramento/Monterey - $1000 Foreign travel Dr. Amatzia Genin, Hebrew University, Israel travel to California to analyze data and work on papers $2000

Supplies & Expendables. Indicate separately the amounts proposed for office, laboratory, computing, and field supplies.

year 1: field supplies $4500; office supplies $500 year 1: field supplies $4500; office supplies $500 year 3: field supplies(repair) $4500; office supplies $500

Services or Consultants. Identify the specific tasks for which these services would be used. Estimate amount of time required and the hourly or daily rate.

USGS subcontract - provide boats for field work; J. Thompson to collaborate on research and help supervise PhD students Year 1: Jan Thompson (1/2 mo) @ 7400/month; 12 days RV Frontier with operator -$1000/day plus 54% ic rate = $24,178 Year 2: Jan Thompson (1/2 mo) @ 7600/month; 16 days RV Frontier with operator - $1000/day plus 54% ic rate = $30,492 Year 3: Jan Thompson (1/2 mo) @ 7800/month; Benthic samples count and size organisms in benthic grabs 66 samples/year @200/year. Several contractors exist for this task none specified at present. Rates based on experience of Thompson with these samples 13,200/year years 1 and 2

Equipment. Identify non-expendable personal property having a useful life of more than one (1) year and an acquisition cost of more than $5,000 per unit. If fabrication of equipment is proposed, list parts and materials required for each, and show costs separately from the other items.

Equipment (not subject to ics) Year 1: 2 Nortek ADVs w. 100 m cables - $40,000 required for self-contained turbulence measurements (have 1 now) 2 D&A OBS sensors - $4000 for sediment measurements (have 1 now) 2 Tiqit (minature) computers for field data acquisition $3000 Sampler array: 40 submersible pumps @30/ea = $1200 & 2000m tubing $2000 = $3200 2 Turner Designs SCUFA Chlorophyl fluorometers with internal logging and turbidity compensation $14000 Year 2 Dell workstation for data analysis $5000 based on current purchases of similar machines.

Project Management. Describe the specific costs associated with insuring accomplishment of a specific project, such as inspection of work in progress, validation of costs, report preparation, giving presentatons, reponse to project specific questions and necessary costs directly associated with specific project oversight.

$2000 years 2 and 3 for publication costs including page charges for papers and reproduction of reports

Other Direct Costs. Provide any other direct costs not already covered.

Tuition (not subject to ics): Year 1: 4 quarters Terminal Graduate Registration (TGR) tuition for PhD student 1 $4456; 4 quarters regular tuition for PhD student 2: $15,472 Year 2: 4 quarters regular tuition for PhD student 1: $16,261 Year 3: 4 quarters TGR tuition for PhD student 1: $4912

Indirect Costs. Explain what is encompassed in the overhead rate (indirect costs). Overhead should include costs associated with general office requirements such as rent, phones, furniture, general office staff, etc., generally distributed by a predetermined percentage (or surcharge) of specific costs.

57% is the standard ic rate negotiated by Stanford with the Federal government according to the cost principles included OMB circular A-21. It applies to all direct costs other than permanent equipment, tuition, subcontracts over 25,000, and salaries paid to undergraduates.

Executive Summary

Shallow open water habitats: Hydrodynamics and benthic grazing

Shallow water regions of San Francisco Bay are thought to be of central ecological importance because they support high rates of primary production and because they may offer valuable habitat for many species of estuarine fish. However, primary production in shallow waters can be easily limited by benthic grazing by siphonate bivalves or by reduced light availability due to the resuspension of the fine bottom sediments found in these regions. Despite the obvious importance to ecological processes in the Bay/Delta system of these habitats, data on the structure of flows, mixing, light variability and benthic grazing in shallow waters are extremely limited. Consequently models of these regions that might be constructed to understand how primary production in Suisun and San Pablo Bays has been affected by the invasion of Potamocorbula amurensis may be incomplete or inaccurate. Accordingly, the objective of the study we propose is to develop, via field observation and modeling, a detailed view of how tides and wind-generated waves determine the physical structure and hydrodynamics of shallow estuarine waters, and how these physical processes can act to constrain net primary production through their effects on grazing and light. We will carry out field experiments in the shallows of Grizzly Bay and in Franks Tract. We will make simultaneous measurements of turbulence, flows, salinities, temperatures, sediment concentration, and chlorophyll concentrations for a series of intensive sampling periods. The specific aims of the epxeriments are to quantify the rate of benthic grazing as a function of bivalve density and physical conditions, and to quantify the effects of waves on shallow-water flows, mixing and sediments. Synthesis of these observations will provide crucial information to estuarine scientists and managers for assessing the effects of grazers like Portamocorbula and Corbicula on the estuarine food web, and for evaluating the effects of restoration activities on shallow water habitat.

Proposal

Stanford University

Shallow open water habitats: Hydrodynamics and benthic grazing

Stephen Monismith, Stanford University
Jan Thompson, USGS WRD NRP
Jeffrey Koseff, Stanford University

A. PROJECT DESCRIPTION: PROJECT GOALS AND SCOPE OF WORK

1. Problem Statement

Shallow water regions of San Francisco Bay are thought to be of central ecological importance because they support high rates of primary production (Cloern 1996) and because they may offer valuable habitat for many species of estuarine fish. However, primary production in shallow waters can be easily limited by benthic grazing by siphonate bivalves or by reduced light availability due to the resuspension of the fine bottom sediments found in these regions. Despite the obvious importance to ecological processes in the Bay/Delta system of these habitats, data on the structure of flows, mixing, light variability and benthic grazing in shallow waters are extremely limited. Consequently models of these regions that might be constructed to understand how primary production in Suisun and San Pablo Bays has been affected by the invasion of *Potamocorbula amurensis* may be incomplete or inaccurate. Accordingly, the objective of the study we propose is to develop, via field observation and modeling, a detailed view of how tides and wind-generated waves determine the physical structure and hydrodynamics of shallow estuarine waters, and how these physical processes can act to constrain net primary production through their effects on grazing and light.

1.1 Background

The massive alteration of the San Francisco Bay and the Sacramento/San Joaquin Delta over the last 150 years, through a combination of accidental and directed filling of the wetlands, diking of the tidal freshwater Delta, and deepening of the channels in the system, has resulted in a reduction of the tidal wetlands from it's original area of 1400 km2 by 97% (Bennett and Moyle 1996). Although the effects of the reduction in shallow water habitat which resulted from this activity have not been clearly defined, we do know the following: (1) Most migratory and resident fishes in the Bay/Delta are found in the shallow water for at least some portion of their life cycles; (2) Some species, such as the northern anchovy, the white croaker, and the American shad, use this habitat but the shallow water is not critical for their survival; (3) Many other species exploit this habitat for part or all of their life history and the availability of appropriate shallow water habitat "is likely to be important for maintaining their abundance and distribution of Bay-Delta populations" (Chotkowski, et al CALFED CMARP Working Group on Fishes in Shallow Water Habitat[1]). The use of the shallow water by these species is dependent on seasonal cues, such as temperature, that are associated with the increased presence of food during some seasons. However, our understanding of the food dynamics in these systems is limited by our understanding of phytoplankton growth and grazing dynamics in the shallow water.

Phytoplankton dynamics and benthic grazing in shallow water

Benthic grazing has been hypothesized to be a limiting factor on system-wide phytoplankton blooms in San Francisco Bay (Alpine et al 1992; Cloern 1982) as well as in other estuaries and coastal systems (e.g. Cohen et al 1984, Dame 1996; Newell 1990). Notably, the systemic effects of benthic grazing have been shown to be particularly

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[1]See http://calfed.ca.gov/programs/cmarp/shf1102.html

crucial to phytoplankton dynamics and geochemical cycles within the shallow water portions of coastal estuaries (Lucas 1999a,b; Chauvaud 2000). In San Francisco Bay, these regions are particularly important because phytoplankton growth is often light-limited (Cloern 1987), and hence the shoals may be the only place where net positive phytoplankton production can take place in the Bay/Delta system(Koseff et al 1993, Lucas et al 1998).

Despite a number of studies that have shown that a localized depletion of phytoplankton develops near the bottom over a bed of epifaunal filter feeders (referred to as a concentration boundary layer, CBL) in the field (Dame et al 1980; Dame 1992; Fréchette, M. and Bourget 1985; Fréchette et al. 1989; Newell 1993) and in the lab (Wildish and Kristmanson,1984; Butman et al 1994), near-bottom depletion is rarely incorporated into the grazing rate estimates used in system level benthic studies. The existing literature on benthic grazing (summarized in Wildish and Kristmanson 1999) results show that one of the primary challenges in incorporating the effects of a CBL into system grazing rates is our lack of knowledge about the temporal and spatial variability of CBL's in relation to physical and biological factors. Physical factors that are expected to be important to CBL development include vertical mixing rates, which are a function of current and wind velocity and bottom roughness, and phytoplankton settling rates. The biological constraints on CBL development for bivalves are likely to include animal density and organism size, pumping rate, physiological on pumping due to current speed, suspended sediment concentrations, food type and concentration, and temporal variability in filtration due to metabolic demands, assimilation efficiency, and behavior.

Some of these issues have been addressed in laboratory experiments with model clams by Monismith et al (1990), O'Riordan et al (1993), and Oriordan et al (1995). Using uniform pumping rates for the model clams, these studies have shown that the important factors in determining CBL development include freestream velocity, mean shear velocity, excurrent jet velocity, siphon height and diameter, and animal spacing. Many of the factors shown to be important in these studies are not consistent in time or space in the field. Moreover, it is well known that filter feeders like *P. amurensis* will stop feeding altogether when sediment concentrations (zero in the idealized experiment) are sufficiently high to interfere with particle sorting and oxygen uptake on the fill surface. O'Riordan (1993) observed this behavior in *P. amurensis* during lab experiments on filtration behavior carried out using the flume described in Cole et al (1992). Nonetheless, limited measurements of chlorophyll *a* concentration profiles made on a shoal in South San Francisco Bay by Thompson et al (2001) show the clear presence of CBLs, although they appear to vary significantly in time and space.

The existing literature on benthic grazing suggests that important issues remain to be assessed before observations of the biomass of benthic grazers can be used to make predictions of community filtration rates that are sufficiently accurate to quantiatively assess the real impacts of bivalves such as *P. amurensis* and Corbicula fluminea on SF Bay/Delta phytoplankton populations. We pose the following questions that our study is designed to address through a series of field experiments:

1) Do CBL's exist over beds of *P. amurensis* in the in North Bay? If so, what is the temporal variability of the CBL?
2) Is there a relationship between physical and biological factors and temporal and spatial variability in these CBL's? i.e., can near-bed variations in phytoplankton

biomass concentrations as observed by Thompson et al (2001) be explained solely in terms of variations in turbulent mixing?

3) Are laboratory-derived pumping rates applicable to the field? Is there a relationship that can be used to convert pumping rates to field grazing rates? How large are errors in estimates of community filtration rates if we assume no CBL is present?

Finally, while much of the discussion above has focussed on *P. amurensis*, which prefers salinities between 2 and 32 psu, the extensive shallows of the Delta are also home to large populations of the freshwater clam, *C. fluminea*. Recent work by Lucas et al (2001) shows that grazing by *C. fluminea* is a primary factor in determining if shallow systems are net phytoplankton exporters or net phytoplankton sinks. Thus, to more fully assess the impacts of benthic grazing on primary production systemwide, and in particular how the impacts of benthic grazing might be altered by the creation of new shallow water habitat, it is necessary to answer the following question:

4) Do relationships found for *P. amurensis* hold for *C. amurensis*?

Thus, in addition to studying grazing in an open shallow water habitat in Northern San Francisco Bay, we will carry out an experiment in Frank's Tract, one of the open water areas of the Delta.

Shallow water physics

The discussion above points to the importance of hydrodynamic processes in governing phytoplankton dynamics in shallow waters. Shallow water hydrodynamics is also central to sedimentation, and because many contaminants of interest, e.g. PAHs, or metals are sorbed to fine sediments, ultimately to contaminant transport.

In general, estuarine waters are generally subject to forcing from barotropic pressure gradients due to tidal changes in water level, baroclinic pressure gradients associated with horizontal salinity gradients, and surface shear stresses exerted by winds. The response of the water column, i.e., the mean flows and the rates of mixing that result generally reflect a complex balance of these forces with accelerations, which may reflect unsteady velocity fields (Stacey et al 1999) or spatially varying flow fields including curvature (Geyer 1993, Lacy and Monismith 2001) , or most often, bottom friction (Stacey et al 1999, Trowbridge et al 1999). In the deep channels that typify coastal plain estuaries like the Chesapeake or San Francisco Bay, inertia, particularly in the presence of stratification often dominates, whereas, as mainly borne out by numerical computation (Gross et al 1999), shallow shoals are thought to be largely frictional.

From a practical standpoint this distinction is important because generally it is bottom friction, whether expressed as a roughness length or as Mannings *n* (Cheng et al 1993), that is adjusted to calibrate circulation models used to compute transport of sediments (McDonald and Cheng 1997), contaminants (Shrestha, and Orlob 1996), or, in models of primary production and eutrophication (Lucas et al 1999a,b). Thus, the physics of flow resistance are particularly central to accurate prediction of horizontal transport to and from shallow regions of estuaries.

Bottom friction also plays a central role in sedimentation dynamics because sediment erosion is generally parametrized in terms of the local bottom shear stress. For example, in traditional formulations, the rate of erosion is typically set to be proportional to the shear stress that is in excess of a critical, material-specific value (e.g. Mehta 1989). Setting aside the inherent difficulties of defining appropriate parameters in this formulation, it is clear that accurate stress prediction is essential to prediction of any changes in an estuary that might be linked to sediments.

In short, much of what is of concern or of interest in managing or restoring estuarine ecosystems is tied to the physics of bottom stresses and frictional effects on flows. Unfortunately, our ability to predict bottom stresses from mean currents in the water column is not so secure, even in the absence of stratification The law of the wall

$$\frac{U(z)}{u_*} = \frac{1}{\kappa} \ln\left(\frac{z}{z_0}\right) \quad (1)$$

where u_* is the shear velocity, κ is von Karman's constant (0.41), and z_0 is the bottom roughness (often multiplied by 30 to convert to equivalent sand-grain roughness), is often assumed to hold in tidal flows. From the standpoint of prediction, z_0 is assumed to be constant and known, or at least adjustable during calibration. However, recent measurements of the bottom boundary layer in the channel in South San Francisco Bay by Cheng et al (1999) cast doubt on this assumption. Using an acoustic Doppler current profiler (ADCP), they accumulated several weeks of relatively high resolution (5 cm near the bed) profiles of the mean flow which they then fitted to the law of the wall to determine the time variability of z_0 . Their results show a 100-fold change in z_0 with current speed, with the smallest values of z_0 found for the strongest currents they were able to resolve. They hypothesize that this behavior reflects changes in small-scale roughness due to the erosion of the fine sediments found at the site.

In shallow water, there is an additional factor: windwaves that modify the bottom boundary layer flow. When waves are present, wave-current interactions can also act to enhance the bottom friction felt by mean flows (Grant and Madsen 1979), and can dramatically enhance rates of sediment erosion (Sanford 1994; Schoelhammer 1996; Inagaki 2000), something that is easily observed to be the case in the shallow portions of San Francisco Bay. Finally, wind waves also break, a process known to dramatically increase the intensity of water column turbulence (Rapp and Melville 1990; Terray et al , Pidgeon et al 2001).

We recently (May 2000 and May 2001) made measurements of vertical profiles of currents comparable to those of Cheng et al (1999) in shallow waters where wind waves can also be important (discussed in Inagaki 2000). The first set of measurements were made in shallow (ca. 2m deep waters) off Coyote Point and included velocity profiles made with a special High resolution (Nortek) Acoustic Doppler Profiler (HR-ADP) that could record velocity profiles with 3 cm vertical resolution., as well turbulence and weave data measured using a pair of Acoustic Doppler Velocimeters (ADVs) While analysis of the HR-ADP and ADV data is not yet finished, several points are clear:

- z_0 does not depend uniquely on wave orbital motions as postulated by theory
- Stresses derived from law-of the wall fitting do not match up with those computed directly from the ADV data (using the wave-turbulence separation technique outlined in Trowbridge 1998)
- From visual observation, wave breaking appears important

The second experiment, carried out in collaboration with Dave Schoelhammer of the USGS, involved use of similar instrumentation in a shallow (ca. 1m depth) salt pond in the Napa Marsh. Again this data, with which we have just begun to work, shows the possible importance of breaking waves to vertical mixing of momentum, sediment and heat.

All in all, the evidence in hand suggests that shallow water regions function physically somewhat differently than do regions where waves are not important. Thus, given this major gap in knowledge of ecologically important shallow water flows, we propose to make, in parallel with our benthic grazing experiments, a series of detailed measurements of current structure and turbulence variability at shallow water stations in Suisun Bay and the Delta. In particular, we propose to:

- Assess the accuracy of the law of the wall formulation for shallow, depth-limited boundary layers. Do the mean flows and stresses scale as expected? Does z_0 vary with mean flow speed as well as with "sea state"?
- Do sediment concentration profiles follow the Rouse law in ways that we could predict given knowledge of the flow structure?
- Test the ability of current models of wave-current interaction and of flows driven by wind stresses to describe mean flows, bottom stresses, and rates of turbulent mixing

Finally, we note that notwithstanding the importance of shallow water physics to sediment dynamics, reasonably accurate estimates of vertical mixing rates are essential to estimating grazing rates from chlorophyll profile data and, in the context of predictive modeling, (at least partially) to translate benthic grazer biomass into effective grazing rates.

2. Justification

Shallow water habitats like that found in the shallows of Grizzly Bay are thought to be important to a wide range of ecological processes including, habitat for fish spawning and larval fish rearing, and habitat for bottom feeding birds. Accordingly, much of the emphasis in CalFed restoration actions has been placed on creation, restoration and management of shallow water regions. Nonetheless, the largest shallow water habitats extent in San Francisco Bay/Delta system, the shallows of South San Francisco Bay, San Pablo Bay, and Suisun Bay have received little attention, possibly because of the logistical difficulties of working there. It is known that prior to the arrival of *P. amurensis* in 1986, the shallows of Northern San Francisco Bay supported spring phytoplankton blooms (Cloern 1996). Several proposals to manage freshwater inflows into San Francisco Bay in fact focussed on positioning the so-called entrapment zone (ETZ) or estuarine turbidity maximum (ETM) in Suisin Bay so as to maximize exchange between the ETM and these shallow regions (Williams and Hollibaugh 1989). Since the arrival of *P. amurensis*, however, phytoplankton blooms in the shallows of Northern San Francisco Bay have only been observed for very short periods in San Pablo Bay in 1998, and to a lesser extent in Suisun Bay and San Pablo Bay, in 2000 (see data at http://sfbay.wr.usgs.gov/access/wqdata/).

Benthic grazers like *P. amurensis* are not the only constraint on primary production in the shallows; light availability is also important. In this case, resuspension of fine sediments, often by wind waves, controls absorption of incident light and hence, like benthic grazing, can regulate net primary production (Lucas et al 1999a,b). Conversely, when shallow regions are productive, their exchange with deeper channel regions that are net sinks for phytoplankton biomass can also control bloom formation.

Overall CALFED planning documents are rife with discussion of the importance of understanding how shallow water habitats work. For example, the CMARP working group on "Fishes in Shallow Water Habitats identified their highest priority research question as "How dependent are resident fishes of management concern (including native and non-indigenous species) on the abundance, distribution, and seasonal development of shallow water habitats for the successful maintenance of their populations? What are the mechanisms underlying these dependencies?" We state here that one of those mechanisms, availability of primary producers, will be difficult to assess until we understand the mechanisms limiting the success of that community. That is, it is clear that if one wants to understand how primary production in San Francisco Bay functions and how it responds to physical forcing like variations in freshwater flow, it is crucial to understand how the large, shallow open water areas that dominate San Francisco Bay behave physically and how this behavior modulates the two factors most important to regulating primary production in the Bay/Delta system: light availability and benthic grazing. This is the focus of this proposal.

3. Approach

The primary effort during this project will be two sets of experiments that will be carried out with *P. amurensis* in Grizzly Bay near DWR long-term monitoring station D7 and a single continuous set of experiments that will be carried out in Franks Tract to test our conclusions with another bivalve, *C. fluminea*, as well as with a system in which tidal currents are weaker.

Site location

The two sites we will use are shown in figure 1. Both sites will be in approximately 2m of water (MLLW). Both sites are known to have substantial bivalve populations (depending on hydrology and time of year). DWR's station D7 is their longest monitored benthic station , with complete benthic community and shallow water chlorophyll *a* data dating from 1977. This benthic community is dominated by *P. amurensis* with few other filter feeders present. *P. amurensis* from D7 have been measured by Thompson as part of a data sharing agreement with DWR. Since pumping rates are dependent on animal size, this data will allow us to accurately assess historic grazing rates of *P. amurensis* in Grizzly Bay. This will further our understanding of how *P. amurensis* has "overgrazed" the system such that the phytoplankton, which historically bloomed for 3-5 months from summer into fall, have disappeared except for short periods in spring during some years.

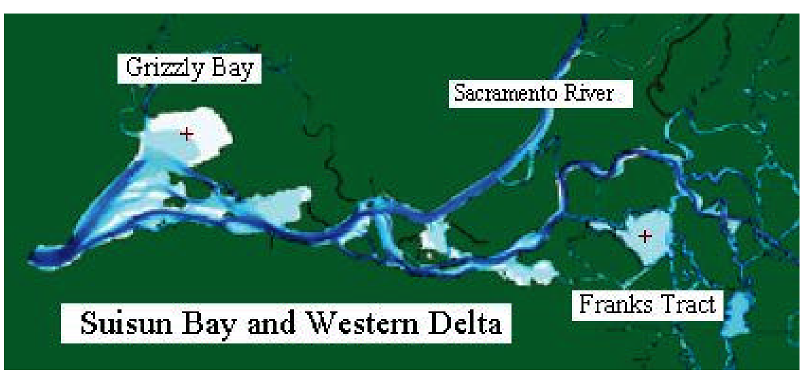

Figure 1: Sketch of Northern San Francisco Bay/ Western Delta

Franks Tract, created by a levee failure in 1938, is typical of the flooded islands found in the Delta. One station has been sampled by DWR's environmental monitoring program for benthic communities and phytoplankton biomass from 1977 through 1995. The benthic community in Frank's Tract was and continues to be (based on unpublished data of Thompson) dominated by the filter feeder *C. fluminea*. The *C. fluminea* at D19 have been measured by Winnernitz (1995), throughout the lake in 1999 (Thompson unpublished data) and will be measured throughout the lake in 2002 as part of a CalFed study (2001-F200-1) so we will be able to assess the historic and present day grazing rates in this system. Phytoplankton biomass has historically, and continues to peak in mid summer and sometimes in fall with peaks being greater during wet years (DWR 1996).

Experiment design

The basic design of the experiments is to combine detailed hydrodynamic measurements with detailed and replicated measurements of phytoplankton and benthic grazer biomass.

Our experimental strategy will be to carry out 4 single day (12 hour) at station D7 in Grizzly Bay experiments; 2 days in summer and in fall. Experiments will be done for one day during a spring and a neap tide for each season. During these intensive experiments, each of which will actually last 3 days (1 day to deploy, 1 day to sample, and 1 day to recover), we will deploy 4 sampling rakes with sets of 50m long sampling tubing and a frame of current meters and other sensors with 100 m long cables. These cables and tubing will be physically secured to the dolphin at D7 and then connected to computers or sample bottles on board the USGS RV Frontier, a 25 foot Boston Whaler, that will be anchored nearby. The reasons for repeated deployment and recovery of the instruments are (a) safety – large-scale deployments of the type we propose are very much at risk for vandalism; and (b) our experience suggests that if the sample tubing is left out for more than a few days they will become fouled and hence not work properly. In addition to these short intensive experiments, the current meter/sensor frame (described in detail below) will be deployed autonomously (at substantially lower data rates) for 1 month before each experiment to obtain a fuller set of measurements of physical conditions.

In Franks Tract we will carry out a single, two-week long experiment in the summer prior to the annual bloom of *Egeria*, including both a neap and spring tide. Our sampling strategy will be different in this case, since it will be possible to work from an anchored houseboat (a strategy we first used in Suisun Cut in 1999, and this past September in Mildred Island). In this case, we will still deploy the instrument frame in advance of the experiment, but instead of a series of day-long experiments, we will be able to work more or less continuously (depending on the stamina of the experimenters!).

Measurements

The measurements we will make are designed to

(1) Measure the flux of phytoplankton biomass to the benthos using turbulence and concentration measurements and the relation

$$Flux = w_s C - K_z \frac{\partial C}{\partial z} \qquad (2)$$

where w_s is an assumed settling velocity (Thompson et al 2001), K_z is the eddy diffusivity deduced from measurements of heat and momentum fluxes (as described below), and $C(z)$ is the concentration of chlorophyll *a* measured at height z

(2) Obtain vertical profiles of mean horizontal velocity and sediment and chlorophyll concentrations as functions of tidal velocity, wind and wave conditions, and the density of bivalve grazers.

(3) Determine the vertical fluxes of salt, heat, sediment and momentum (i.e., stresses) from/to the benthos as functions of tidal and wind-wave forcing. We expect the vertical fluxes of heat and salt will not be dynamically significant but instead will be useful for determining rates of scalar mixing and hence to compute K_z as

$$K_z = \frac{-\overline{w'T'}}{\partial \bar{T}/\partial z} \text{ or } K_z = \frac{-\overline{w'S'}}{\partial \bar{S}/\partial z} \qquad (3)$$

where $\bar{T}$ and $\bar{S}$, and T' and S' are measured mean and fluctuating salinities and w' is the fluctuating vertical velocity.

(4) Obtain estimates of the horizontal patchiness of chlorophyll a concentration for various physical conditions and during the period of historic peaks in the phytoplankton biomass (summer) and during a period when bivalve biomass is at its annual peak (fall).

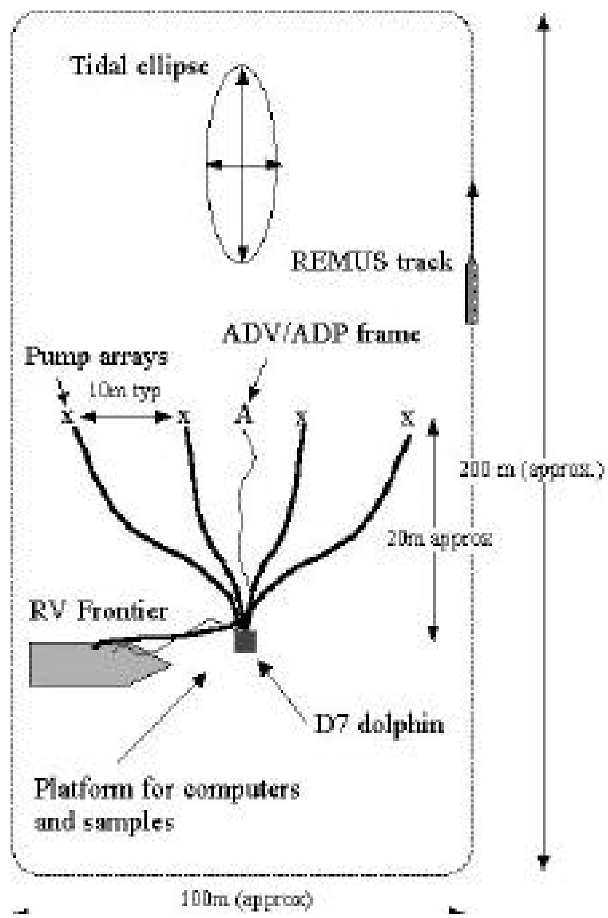

Figure 2: Sketch of experimental layout at D7. At Franks Tract a houseboat will replace the Frontier and the D7 dolphin

The data we will collect during our studies will be of several types:

(1) Intensive time series of velocities, turbulence, wave height, sediment concentration, and chlorophyll *a* concentration at several heights. We will deploy a frame carrying 3 Nortek Vector ADVs with measuring volumes located 10 cm, 30 cm and 100 cm above the bed. The Vectors provide all 3 velocity components at 16 Hz in a measuring volume that is approximately 16 mm long by 15 mm in diameter. Fluctuating sediment concentrations in the measurement volume and hence sediment fluxes can be inferred from measurements of acoustic backscatter (Brennan et al 2001). Fast conductivity-temperature sensors (manufactured by Precision Measurement Engineering) measuring fluctuating salinities and temperatures will be mounted so as to be coincident with the ADV measuring volumes. This will permit us to compute heat and salt fluxes used in eq. 3 to compute mixing coefficients. In addition to the ADVs, a Nortek HR-ADP will be mounted approximately 2 m above the bed looking down and recording velocity profiles with 3 cm resolution. Single ping data recorded at 0.5 Hz will be averaged to produce mean velocity profiles. The instrument frame will also carry 3 DA optical backscatter sensors (OBS), at the same heights as the ADV measurement volumes to provide a second measure of sediment concentration. These will be connected to a Ocean Sensors CTD that will also record temperature and salinity. Two Turner Designs SCUFA chlorophyll a fluorometers located at 10 cm and 100 cm height will be used to record time series of chlorophyll *a*. These will be calibrated using the water samples discussed below. It is important to note that the SCUFA's include internal compensation for turbidity. To measure waves, a Seabird SBE 26 Seagauge pressure logger will be installed on the frame near the bottom.

(2) Repeated sets (at approximately 15 minute intervals) of chlorophyll *a* profiles will bemeasured with a set of 4 sampling rakes. The rakes will be spread out at 10 m intervals across the principal axis of tidal flow and will serve to provide simultaneous replicates. Each rake will carry 10 small underwater pumps with intakes at heights of 3, 5,10, 15, 20, 30, 40, 60, 80, and 100 cm. Each sample will involve sampling 10 l of water over a 5 minute period of time, from which a 300 ml sub-sample will be drawn for chlorophyll *a* analysis. This water will be filtered through 45 μm glass fiber filter and chlorophyll *a* will be extracted from the filtrate using the acidification method of EPA (1997) and measured fluorometrically using a Turner Designs fluorometer. By combining turbulence and chlorophyll *a* data we will estimate fluxes to benthic grazers using eq. (2).

(3) Profiles of salinity, temperature, sediment concentration, and chlorophyll *a* fluorescence will be taken every 10 minutes during the intense experiments using a SeaBird SBE-19 SeaCat hand-lowered from the RV Frontier. Besides measuring salinity and temperature, our instrument also carries a D&O OBS to measure sediment concentration and a Wetlabs Wetstar fluorometer to measure chlorophyll *a* via fluorescence. These profile data will be used to help interpret the fixed height data.

(4) Repeated spatial transects of velocity, sediment and chlorophyll *a* concentrations will be made using a REMUS autonomous underwater vehicle (AUV – see http://adcp.whoi.edu/REMUS/) during intensive sampling in order to characterize horizontal variability and patchiness in chlorophyll *a* and sediments. REMUS is approximately 2 m long and will carry up and downwards looking 1200 KHz ADCPs, a

600 KHz sidescan sonar, a CTD, and in the nose cone, a SCUFA chlorophyll *a* fluorometer. Powered by lithium batteries, REMUS can transect at about 1 m/s for up to 10 hours. We will attempt to use the side-scan sonar to characterize changes in bottom texture and hence to help define patch size for bivalve populations.

Figure 4: (left) REMUS onshore and (right) transecting through a kelp bed of San Clemente Island, California (photos by J. Skadberg)

(5) The instrument frame will be deployed for 1 month with all instruments running autonomously and logging internally. This will require burst sampling the ADVs and pressure logger. The OBS and the SCUFAs will be set to record at regular intervals. More importantly they may require cleaning at least once during deployment. The OBS will be calibrated with water samples taken from the site (Buchanan and Schoellhamer 1995).

(6) The benthic community will be sampled before, during and after the intense experiments to measure benthic bivalve biomass. A minimum of three replicates will be taken upstream of each profiler with a 0.05 m^2 van Veen grab. Samples will be washed through a 0.5 mm screen, preserved in formalin for a week, and stored in ethyl alcohol. All filter feeders (expected to be the bivalves *P.amurensis* and *C. fluminea* in these communities) will be measured and a pumping rate estimated based on literature relationships between biomass or length, temperature, and pumping rate (Cole et al. 1992, Lauritsen 1986).

4. Feasibility

This project relies on two things: having appropriate conditions in Grizzly Bay during the proposed experiments; and, obtaining permission to work off the Dolphin at D7.

The first issue is that we need a sufficient number of benthic grazers at D7 for the biological component of this work to succeed. Due to the life history cycle of *P. amurensis*, which recruits its young in winter and early spring, the best period of time for the Grizzly Bay experiments will be in summer and fall. The best time to do the Franks Tract experiments, early summer, is more dependent on the life cycle of the submerged aquatic vegetation, *Egeria*, as the experiment needs to be done prior to it's annual expansion into the system and prior to the annual spraying that kills the *Egeria* and might interfere with our phytoplankton biomass.

The second issue, that of being permitted to use the Dolphin and to deploy an instrument for up to one month is one that must be negotiated with the Coast Guard. Past

USGS experience has been that such permission is willingly given if conditions necessary for boating safety are met, namely not interfering with the basic function of the navigational aid (the Dolphin). If this project is funded we will obtain the necessary permission from the Coast Guard as soon as possible and work with them to modify our designs for attachments to the dolphin so that they meet their criteria while still maintaining our needed functionality.

5. Performance Measures

The principal products of this work will be two PhD student theses, and consequent archival peer-reviewed journal publications. In addition to these publications, w e would propose to submit at least one article per year to the IEP newsletter for dissemination to the Bay/Delta research community. We will also give talks and posters at CalFed Science meetings and at the annual IEP and Bay/Delta Modeling forum meetings held at Asilomar. Synopses of our data and results will be made available from a web site hosted at Stanford and linked to the USGS Water resources Division San Francisco Bay web sites. Results from the data collection effort will be used to modify the hydrodynamic code TRIM3D used by Stanford, the USGS, and recently several consultants including URS for modeling San Francisco Bay. Biological results will be used to alter the TRIMBIO code used at Stanford and now the USGS for modeling primary production in the Bay/Delta system (e.g., Lucas et al 1999a,b).

6. Data Handling and Storage

As well as being offered via a Stanford-hosted web site, subject to USGS regulations concerning data dissemination, all data will be made available for inclusion in IEP web-based databases. We will explore how to best present data that includes time series data (e.g. Reynolds stress, mean flows etc.) as well as profile data (e.g. Chlorophyll a) and the results of benthic surveys. The Stanford group will be responsible for processing and analyzing all physical data. The USGS group will deal with the biological data (Chla and benthic survey data).

7. Expected Products/Outcomes

Firstly, by combing physical and biological data sets we will we will be able to derive a reasonably complete picture of benthic grazing and the way it varies (or not) with changes in physical conditions, namely suspended sediment concentration and flow in the two main types of shallow water habitat found in the Bay/Delta system. This major result will enable surveys of benthic grazer biomass to be translated into good estimates of rates of grazing on phytoplankton and hence will provide crucial information to estuarine scientists and managers for assessing the effects of grazers like *Portamocorbula* and *Corbicula* on the estuarine food web.

Secondly, we will obtain a very good picture of the physics of these shallow water flows, information that will be incorporated into circulation models, most notably, TRIM3D (Gross et al 1999, Monsen 2000), a three-dimensional hydrodynamics code which is currently be used to model primary production and selenium transport in the Delta by Nancy Monsen, Lisa Lucas and Jim Cloern all of the USGS, as well as being used by Dr. Ed Gross with URS-Greiner to evaluate some potential impacts of proposed SFO runways modifications. This is important to CALFED because these more advanced hydrodynamic and coupled biogeochemical models can play an important role in assessing restoration actions such as flooding islands, widening large channels etc.

The principal products of this project will be two PhD theses, one of which focus on measurements of the physical environment, including detailed interpretation of the data and modeling of the effects of wind waves on shallow water flows. The second thesis will focus on the results of the benthic grazing experiments, and in particular on the connection between physical variability and grazing rates. The work described in these theses will be reported in the peer-reviewed archival literature. Papers stemming from the first thesis will appear in J. Geophys. Res., J. Physical Oceanography, ASCE Hydraulic J., or Estuaries.. We expect to publish the work described in the second thesis in Limnology and Oceanography, Estuaries, or Marine Ecology Progress Series. We also will submit at least one article per year to the IEP newsletter to keep our Bay/Delta colleagues appraised of our progress.

8. Work Schedule

We assume that this project will start October 1, 2002 and extend until September 30, 2005. The first experiment in Grizzly Bay will not be performed until June 2003, and will be followed by a second experiment in October 2003. The Franks Tract experiment will be performed in June 2004. Overall the schedule will look like this:

October 2002- March 2003	Design and construct sampling frames and ADV/ADP frame. Obtain permission to use D7 dolphin to secure cables/tubes.
March 2003	First field trial deployment of AUV near D7. Carry out preliminary reconnaissance of D7 area using the RV Frontier and a CTD.
April 2003	Deploy Vector/SCUFA/CTD package for 1 month deployment.
May 2003	Trial deployment of sampling frames and tubing
June 2003	First field experiment at D7
July 2003-Sept 2003	Preliminary analysis of data from first experiment.
September 2003	Re-deploy Vector/SCUFA/CTD package for 1 month deployment
October 2003	Second field experiment at D7
Nov. 2003 – April 2004	Analyze D7 data
April 2004	Carry out preliminary reconnaissance of Franks Tract using the RV Frontier and a CTD. Deploy AUV to examine and map areas of interest.
May 2004	Deploy Vector/SCUFA/CTD package for 1 month deployment.
June 2004	Two-week field experiment in Franks Tract
July 2004-Dec 2004	Analyze data from Franks Tract experiment
Jan 2005-Sept 2005	Synthesize data from two experiments and finish new models of shallow water hydrodynamics and grazing.

B. Applicability to CALFED ERP and Science Program Goals and Implementation Plan and CVPIA Priorities

1. ERP, Science Program and CVPIA Priorities.

The physical and biological work we propose applies broadly to CALFED and its restoration activities, addressing simultaneously a number of CALFED priorities including (drawn from PSP):

"BR-6.) Protect at-risk species in the Bay using water management and regulatory approaches.

- Better understand primary and secondary productivity within Suisun Bay, North Bay, and South Bay and linkages among internal and external inputs (Strategic Goal 2, decline in productivity).
- Understand poorly known aspects of the food webs of Grizzly Bay, San Pablo Bay and South Bay. "

"BR-7.) Improve scientific understanding of the linkages between populations of at-risk species and inflows, especially relative to regulatory measures like "X2".

- Hydrologic/sediment transport models as restoration tools. Develop methodologies, including a combination of simulation models and physical measurements, to evaluateflow, sediment transport and hydrodynamic patterns in the Suisun Marsh, Grizzly Bay, the Sacramento River-Montezuma Slough complex, Napa-Sonoma Marsh and tributaries to the San Pablo Bay, related to the freshwater-seawater interface. Apply such approaches to understand how engineering changes in the Delta and actions in the Bay (including restoration) might affect X2, water quality and ecosystem processes (Strategic Goal 2 X2 relationship).
- Improve understanding of how physical processes affect ecological processes in the sloughs, bays, tidal flats and associated marsh plains (Strategic Goal 2, channel dynamics).
- Understand short-term to long-term sediment deposition patterns throughout the Bay."

"DR-5.) Implement actions to prevent, control and reduce impacts of non-native invasive Species.

- Document the distribution and abundance of Corbicula fluminea, as well as the trophic impacts of their populations in fresh, shallow water habitat, which may be targeted for restoration work. Initial investigation indicates that this species may be the fresh water counterpart to Potamocorbula amurensis and may seriously impact our attempts to restore shallow water habitat (Strategic Goal 5, non-native invasive species).
- Methods for comprehensive mapping, system-wide surveys and/or on-going monitoring of specific invasive species actions (Strategic Goal 5, non-native invasive species)."

2. Relationship to Other Ecosystem Restoration Projects.

This project is an outgrowth of two lines of NSF, EPA,USGS, CALFED and IEP sponsored research on estuarine hydrodynamics and on benthic grazing and phytoplankton dynamics. This ongoing collaboration between the USGS and Stanford, which started in approximately 1988, has resulted in 8 PhD theses, with 4 more currently in progress). 6 of the 8 finished PhDs currently work on the Bay/Delta system. Currently, both PIs are involved in a CALFED sponsored study of selenium transport and transformation in the Delta (2001-F200-1 "Transportation & Effects of Se and C in the Delta"). Monismith's role in this work is to help with numerical modeling of transport processes (using TRIM3D) while Thompson is responsible for the benthic component of this project.

4. Previous Recipients of CALFED Program or CVPIA funding.

Monismith participated in the CALFED-sponsored project, "Assessment of the Sacramento-San Joaquin River Delta as Habitat for Production of Food for Fish Species" for which Jim Cloern of the USGS was the lead PI. This grant from the CALFED Ecosystem Restoration program partially supported the PhD theses of Nancy Monsen and Jessica Lacy, both of whom now work for the USGS as postdocs.

Monsen's work focused on the application of TRIM3D to the Delta, and involved developing bathymetry grids, calibrating the model, and interrogating the model results to understand the dynamics of the Delta at tidal and subtidal time scales. This modeling was used by Cloern and Jassby to help generate estimates of residence times and pf organic carbon fluxes for various parts of the Delta. Modeling of shallow water areas like Franks Tract and Mildred Island showed the enormous variability of current regime possible in these semi-enclosed domains. This information played a central role in redefining the sampling strategies for the field component of this work as well as the current work on selenium. Monsen also showed that harmonic tide data cannot be used to drive models of Northern San Francisco Bay.

The topic of Lacy's thesis was interactions between shoals, principally those of Honker Bay, and the channels of Suisin Bay. CALFED funds supported completion of this thesis which focused the mechanisms by which Honker Bay exchanges water with the rest of Suisun Bay. Her hydrographic observations showed clearly that physical residence times in Honker Bay are quite short (< 24 h), suggesting that organisms that are resident there must act to remain there. Measurements of tidal flows through Snag channel, a channel that connects Grizzly and Honker Bay, show that channel curvature can be quite important, and that even narrow channels like Snag channel can support a significant fraction of the total salt flux, something that has important implications for numerical modeling. This work is described in Lacy and Monismith (2001).

5. System-Wide Ecosystem Benefits.

Overall the results of our study should significantly advance our ability to predict how shallow regions in the Bay/Delta system influence a wide range of physical and chemical processes of concern to CALFED.

C. QUALIFICATIONS

Stephen G. Monismith

Academic History

1973- 1977 B.S., University of California at Berkeley, Civil Engineering
1978-1979 M.S., University of California at Berkeley, Civil Engineering
1979-1983 Ph.D., University of California at Berkeley, Civil Engineering

Professional Experience

9/99 - present **Professor**, Dept. of Civil and Env. Eng., Stanford University.
1/97 – present **Associate Editor**, Limnology and Oceanography
9/96 - present **Director,** Environmental Fluid Mechanics Laboratory
9/93 – 9/99 **Associate Professor**, Dept. of Civil Eng., Stanford University.
1/87 - 9/93 **Assistant Professor**, Dept. of Civil Eng., Stanford University.
8/83 - 12/86 **Postdoctoral Research Fellow**, Centre for Water Res., Univ. of Western Australia.

Honors and Awards

Einstein Memorial Fellowship, academic year 1981-1982
NSF Presidential Young Investigator, 1989

Selected publications

O'Riordan, C.A., Monismith, S.G., and Koseff, J.R. (1993) An experimental study of concentration boundary layer formation over bivalve assemblages, *Limnol. Oceanogr.*, **38**(8): 1712-1729.

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STUDENTS

PHD STUDENTS (finished): Heidi Nepf, Cathy O'Riordan, Mark Stacey, Todd Cowen, Rajat Garg (with J. Ferziger), Lisa Lucas (w. J Koseff), Ed Gross (w. J. Koseff), John Crimaldi (w. J. Koseff), Jenny Zhou (w. J. Ferziger), Emily Pidgeon, Jessica Lacy, and Nancy Winters
PHD STUDENTS (current) Jon Burau, Alex Horner, Matt Brennan, Rachel Simons, Jeremy Bricker, Greg Shellenberger, Cara Tobin, and Sandy Chang.
ENGINEERS DEGREE STUDENTS: Brian McDonald, Shari Kimmel, and Satoshi Inagaki
POSTDOCTORAL STUDENTS: Todd Cowen, Derek Fong, Jessica Lacy

ADVISORS:

Thesis advisor: Hugo B. Fischer (dec.)
Postdoctoral advisor: Jorg Imberger

Janet Kay Thompson

Education

1999 Stanford University, Stanford, California, Ph.D. Civil and Environmental Engineering
1979 California State University, San Francisco, California, M.A. Marine Biology
1972 Lewis and Clark College, Portland, Oregon, B.S. Biology

Experience

1986-present Biologist, Water Resources Division, U.S. Geological Survey
Menlo Park, California: research on estuarine benthic community structure and ecosystem function
1972-1986 Biologist, Office of Marine Geology, U.S. Geological Survey
Menlo Park, California: research on estuarine, coastal, shelf benthic community structure and ecosystem function
1972 Laboratory Instructor, Oregon Institute of Marine Biology
University of Oregon, Eugene, Oregon; Lewis and Clark College, Portland, Oregon

Research Interest:

Benthic community structure and response to stress; dynamics of organic and inorganic particle transfer to the bed; benthic-pelagic coupling

Relevant Publications:

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Graduate Advisors

Professor Jeffrey Koseff, Stanford University - PhD advisor
Professor James Nybaken, California State University, Moss Landing - M.S. advisor

D. COST

Please note that the travel budget includes funds for Dr. Amatzia Genin, an expert in the ecological consequences of benthic pelagic coupling through grazing, to participate in the experiments. Much of the approach for studying grazing that we describe was developed by Dr. Genin. Dr. Genin's cv is available upon request.

F. COMPLIANCE WITH STANDARD TERMS AND CONDITIONS

The applicant agrees to the standard terms and conditions, except for
Attachment D 13. Termination Clause: Stanford University cannot comply with a re-procurement clause. The University is a not-profit organization which performs research at cost with no fee.

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