Understanding the time scales of primary production responses to environmental perturbations in North San Francisco Bay

Project Information

1. **Proposal Title:**

   Understanding the time scales of primary production responses to environmental perturbations in North San Francisco Bay

2. **Proposal applicants:**

   Frances Wilkerson, San Francisco State University, Romberg Tiburon Center
   Richard Dugdale, Romberg Tiburon Center, SFSU

3. **Corresponding Contact Person:**

   Frances Wilkesron
   Romberg Tiburon Center, SFSU
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   415 338 3519
   fwilkers@sfsu.edu

4. **Project Keywords:**

   Phytoplankton
   Primary Productivity
   Water and Sediment Quality

5. **Type of project:**

   Research

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

   No

7. **Topic Area**:

   Decline in Productivity

8. **Type of applicant:**

   University

9. **Location - GIS coordinates:**

Latitude: 38.034

Longitude: -122.022

Datum:

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

Sampling in San Francisco Bay in Suisan, san Pablo and Central Bays

10. **Location - Ecozone:**

    2.1 Suisun Bay & Marsh, 2.5 San Pablo Bay

11. **Location - County:**

    Contra Costa, Marin, 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:**

    6th

15. **Location:**

    California State Senate District Number: 3

    California Assembly District Number: 6

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?

       No

       If no, list single overhead rate and total requested funds:

Single Overhead Rate: 50

Total Requested Funds: 470673

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?

No

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)

21. **Comments:**

Environmental Compliance Checklist

Understanding the time scales of primary production responses to environmental perturbations in North San Francisco Bay

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.

      Sampling water for chemical analysis only-no change to existing conditiosn will be made

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.**

Land Use Checklist

Understanding the time scales of primary production responses to environmental perturbations in North San Francisco Bay

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?**

   No

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).

   Resaerch only- in water column of San Francisco Bay

4. **Comments.**

Conflict of Interest Checklist

Understanding the time scales of primary production responses to environmental perturbations in North San Francisco Bay

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):

Frances Wilkerson, San Francisco State University, Romberg Tiburon Center
Richard Dugdale, Romberg Tiburon Center, SFSU

Subcontractor(s):

Are specific subcontractors identified in this proposal? No

Helped with proposal development:

Are there persons who helped with proposal development?

No

Comments:

Budget Summary

Understanding the time scales of primary production responses to environmental perturbations in North San Francisco Bay

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.

Independent of Fund Source

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	Acquisition and maintenance of mooring	640	13789	4964	1000	1000	6000	37455	250	64458.0	13501	77959.00
2	Field sampling of physical, chemical and biomass variables	800	15278	5500	1000	4000	9000		250	35028.0	17514	52542.00
3	Field sampling of productivity rate variables (ship time and sampling costs included within Task 2)	640	12222	4400		2000			250	18872.0	9436	28308.00
4	Project management	320	11312	2185					250	13747.0	6873	20620.00
		2400	52601.00	17049.00	2000.00	7000.00	15000.00	37455.00	1000.00	132105.00	47324.00	179429.00

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	Acquisition and maintenance of mooring	480	10859	3909	1000	1000	6000		250	23018.0	11509	34527.00
2	Field sampling of physical, chemical and biomass variables	800	16041	5775	1000	4000	9000		250	36066.0	18033	54099.00
3	Field sampling of productivity rate variables	640	12833	4620		2000		1500	250	21203.0	9851	31054.00
4	Project Mangement	320	11878	2294				5000	250	19422.0	7210	26632.00
		2240	51611.00	16598.00	2000.00	7000.00	15000.00	6500.00	1000.00	99709.00	46603.00	146312.00

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	Acquisition and maintenance of mooring	480	11402	4105	1000	1000	6000		250	23757.0	11878	35635.00
2	Field sampling of physical, chemical and biomass variables	800	16844	6064	1000	4000	9000		250	37158.0	18579	55737.00
3	Field sampling of productivity rate variables	640	13475	4851		2000			250	20576.0	10288	30864.00
4	Project Mangement	320	12472	2409					250	15131.0	7565	22696.00
		2240	54193.00	17429.00	2000.00	7000.00	15000.00	0.00	1000.00	96622.00	48310.00	144932.00

Grand Total=470673.00

Comments.

Budget Justification

Understanding the time scales of primary production responses to environmental perturbations in North San Francisco Bay

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

Al Marchi: In year 1 we request 640 hours of Al Marchi (Research Technician) time for Task 1. He will be responsible in Task I for acquisition and installation of the moored package in Suisun Bay. He will also be responsible for monthly visits to the mooring to swap in/out new/old package, any repairs to the mooring required and then monthly data interrogation when instruments are returned to the laboratory. In years 2 and 3 we have reduced the hours for Marchi in Task 1 to 4 months to cover monthly exchange of instruments and downloading of data. Al Marchi will also participate 160 hours per year in Task 4 (Project Management) and edit and analyze continuous and discrete data collected during the entire project and be partly responsible for disseminating data onto web sites and data storage. We request 800 hours each year for Victoria Hogue to participate and be responsible for research included in Task 2 and 640 hours per year for responsibilities and research included in Task 3. Frances Wilkerson will spend 160 hours per year in Project Management (Task 4) supervising the technicians, analyzing and archiving data and ensuring completion of quarterly reports, final reports and scientific presentations and manuscripts. Richard Dugdale will participate in this task at no cost to the project.

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

Salaries given are academic year (Wilkerson) and calendar year (Hogue and March) salaries that the named personnel have at SFSU with annual 5% raises.

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

Fringe benefits including medical and dental insurance, unemployment insurance; vacation and sick leave; retirement; Social Security; and worker’s compensation. Benefits factors for each position are determined in accordance with applicable SFSU policies based on the specific title and nature of each position and the expected number of hours per week to be worked on the project. Exact benefit figures are set annually in conjunction with faculty and staff contract negotiations. Hogue and Marchi as staff receive 36%, Wilkerson requesting faculty summer salary receives 12%.

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

We have requested $1000 each year for Task 1 and Task 2 to allow one PI and one technician for each task to present results at a national meeting (i.e. ERF, AGU or ASLO) and/or IEP workshops and CALFED meetings.

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

Each year we have requested $1000 for Task 1, $4000 for Task 2 and $2000 for task 3 to purchase chemicals, plasticware, lab expendables and computer supplies required to carry out and archive the data generated by this research.

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.

In this category we request ship-time on the R/V Questuary (RTC research vessel). The minimum charge for the R/V Questuary, capable of mooring installation, instrument retrieval (Task 1) and shipboard sampling required for Tasks 2 and 3 is $500 per day. We have requested 12 days each year for task 1 (monthly visits) and 18 days each year for Task 2. If Tasks 1 and 2 are both supported it may be possible to decrease the total dollar request for shiptime as it is expected to combine Task 1 and 2 cruises. No ship-time is requested for Task 3 as it is assumed the same water sampled in Task 2 can be used for Task 3.

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.

In Year 1 we request funds to acquire the installation hardware and two continuously measuring data packages and instruments. Each costs a total of $18727.25) and comprises: Seabird 16+ (salinity, temperature and data logger ($6250) LiCor Par Sensor ($1000) Turner Designs SCUFA II fluorometer ($5000) Pump ($1400) Wetlabs C+ transmissometer ($3650) Surface buoy, anchors, chain ($500) Total 17300 Tax $1427.25 Grand total $18727.25 Two are requested to enable monthly exchange of instruments to ensure no interruption in data acquisition. In year 2 funds are requested to purchase a new filtration pump ($1500) for task 3 and a dedicated computer and printer ($5000) in Task 4 for data archiving and report generation.

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.

Costs required with this are included in task 4 and have been included in the above explanations: Salary and Benefits for Al Marchi (160 hours) and Frances Wilkerson (160 hours) and equipment request of $5000 in Year 2 for a dedicated computer and printer for data archiving and report generation.

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

Each year $250 is requested for each task for communications and publication costs.

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.

This is on-campus research for which the indirect rate is 50% (date of agreement Sept 5, 2000, covering 07/01/00 to 06/30/04). Modified total direct costs, consist of all salaries and wages, fringe benefits, materials, supplies, services, travel and subgrants and subcontracts up to the first $25,000 of each subgrant or subcontract (regardless of the period covered by the subgrant or subcontract). Modified total direct costs shall exclude equipment, capital expenditures, rental costs of off-site facilities, scholarships, and fellowships.

Executive Summary

Understanding the time scales of primary production responses to environmental perturbations in North San Francisco Bay

This research project proposes to evaluate chlorophyll concentrations and primary productivity in North San Francisco Bay on time scales that will provide reliable phytoplankton biomass and primary production values such that changes can be evaluated in the context of CALFED activities/projects. The uncertainty regarding the appropriateness of monthly measured chlorophyll concentrations and model-derived productivity rates is sufficient to require research into relevant sampling regimes. We plan to acquire and install a moored data acquisition system in Suisun Bay, along with monthly shipboard measurements, including size-fractionated phytoplankton biomass and primary production rates, designed to study the role of diatoms in North Bay productivity and foodwebs. Data from another moored system in Central Bay will be used to look for synchrony and evaluate to what extent upstream conditions can be estimated from downstream data. This proposal offers key methodology and data that will benefit specifically CALFED Strategic Goals 2 (Ecological Processes concerning Bay Region productivity) and Goal 6 (Water and Sediment Quality). We propose to test the hypotheses that continuously measured chlorophyll enables data peaks to be measured that are likely missed with monthly monitoring, and that Bay productivity peaks are connected with increased diatom contribution, and preceded by ammonium decreases. Our objectives are to obtain continuous measurements of chlorophyll in Suisun Bay using a moored fluorometer (in vivo) for comparison with monthly (and weekly) shipboard measurements (in vivo and in vitro fluorescence). These data will be used with rate data for comparison with modeled productivity data and to monitor changes as restoration proceeds. To evaluate the role of diatoms in Bay productivity, size-fractionated chlorophyll, primary production and silicate uptake will be measured and compared with the variability of other parameters (e.g. salinity, ammonium, nitrate and silicate concentrations).

Proposal

San Francisco State University, Romberg Tiburon Center

Understanding the time scales of primary production responses to environmental perturbations in North San Francisco Bay

Frances Wilkerson, San Francisco State University, Romberg Tiburon Center
Richard Dugdale, Romberg Tiburon Center, SFSU

Proposal To CALFED Ecosystem Restoration Program

Understanding the Time Scales of Primary Production Responses to Environmental Perturbations in North San Francisco Bay

Frances P. Wilkerson and Richard C. Dugdale
Romberg Tiburon Center, San Francisco State University.

RESEARCH PROPOSAL:TABLE OF CONTENTS

A. Project Description

1. The Problem

The **problem** to be investigated by the proposed research is how to evaluate key changes in primary production in the North San Francisco Bay driven by environmental changes resulting from CALFED restoration efforts. This can be approached as the research problem of determining the most appropriate way to measure primary production, followed by the monitoring problem to evaluate if such changes occur in North San Francisco Bay as a result of restoration. This project proposes to address the research problem of how best to detect changes in primary production and phytoplankton biomass. The results can then be incorporated into further monitoring problems.

1.1. Background: Time-Scales of Measuring Chlorophyll and Primary Production in San Francisco Bay

The challenges in characterizing estuarine water quality due to high spatial variability have been rigorously addressed by Jassby et al. (1997). However the problems due to short-term temporal variability are less well described and merit further study (Li and Smayda, 2001). The problem of assessing the impacts of wetland and marsh restoration projects on water column phytoplankton is made difficult by the level of climate-driven variability (inter-annual). It is further compounded by food web changes, e.g. lower primary production in North Bay since the introduction of the clam *Potamocorbula* in the 1980's (e.g. Kimmerer et al., 1994). The data used to evaluate the standing stock and primary production of phytoplankton in North Bay (i.e. Suisun and San Pablo Bays) has been typically obtained from monthly sampling of the area, e.g. USGS water quality R/V Polaris cruises, our EPA funded "STAR-Indicators" project aboard the R/V Questuary. However, by adding weekly and daily sampling at certain times of the year, our current studies in San Francisco Bay show that episodic increases in chlorophyll may be missed with monthly and even weekly sampling. Data collected daily in summer 2001 in Central Bay (Fig. 1) show how peaks in chlorophyll may be missed by monthly monitoring. Our monthly collections (in red) indicate that chlorophyll ranged from 4-6 µg/l between June and mid-August whereas chlorophyll sampled daily (blue) showed double these levels on three separate occasions. Similarly, peaks in chlorophyll measured in Spring 2000 (in Suisun) and 2001 (in San Pablo) in the North Bay occurred on sampling days that were added to our original monthly monitoring scheme (Figs. 2a,b). If we had not sampled on these days (closed symbols), these higher concentrations, e.g. 30 µg/l in April 2000-almost pre-*Potamocorbula* levels, might not have been recorded. This figure (Fig. 2b) also shows that the cells typically contributing to the increase in chlorophyll during these peak conditions are the larger phytoplankton cells (> 10 µm in diameter). These large celled assemblages are often dominated by diatoms (Ball and Arthur, 1979; Cloern et al. 1983).

In summary, under-sampling of the variable environment leads to a serious underestimate of the mean or time-integrated chlorophyll biomass. Present models of primary production in San Francisco Bay use chlorophyll, incident light and water transparency (Cole and Cloern, 1984; 1987) that depend upon accurate chlorophyll measurements, and reported rates are based upon monthly sampling of these variables. Before changes in primary productivity due to restoration efforts and their impact on food webs can be correctly assessed, an accurate and meaningful way of measuring chlorophyll and primary production on the time scales appropriate to the phytoplankton response in the Bay is required. Additionally the role of larger cell-sized phytoplankton (typically diatoms) in contributing to higher productivity levels during short term peaks in chlorophyll needs to be understood, as these are typically algae with high growth rates and are good food items for higher trophic levels including zooplankton (e.g. Orsi, 1995) and benthic organisms (Thompson and Nichols, 1988).

1.2 Goal

Consequently our **goal** for CALFED ERP is to evaluate the chlorophyll concentrations in North San Francisco Bay on time scales that will provide reliable estimates of phytoplankton biomass and primary production such that changes can be evaluated in the context of CALFED ERP activities/projects. We plan to accomplish this in Suisun Bay using a moored data acquisition system including a fluorometer for *in vivo* measurements, along with conventional shipboard sampling measurements that will increase during times we have evidence that episodic increases or “blooms” in chlorophyll are likely to occur. Included in our measurements will be size-fractionated biomass data and productivity rates using ^{14}C, ^{15}N and ^{32}Si, designed to assess the role of diatoms in North Bay productivity and foodwebs. We will use continuously collected data available from an already funded mooring in the Central Bay at RTC to look for interconnections in time and space between North and Central Bays. This will allow us to evaluate the extent to which upstream conditions can be estimated from downstream data. It will also enable detection of special conditions in Suisun Bay when bloom events there fall out of step with those in San Pablo and Central Bays as may have been the case in Spring 2001 (Fig.2a,b).

We are aware that DWR has measured *in vivo* fluorescence with moored fluorometers at Rio Vista where peaks in chlorophyll were seen in Spring 1998 (10 µg/l), 1999 (6 µg/l) and 2000 (8 µg/l), (Sommer et al., 2000), and at the Benicia Bridge. But it is not clear whether 1) these data are still being collected and will be available to monitor future changes due to restoration efforts, and 2) the chlorophyll data available have been compared with monthly shipboard data. The proposed **research project** to install continuously measuring sensors for a range of phytoplankton related variables in Suisun Bay would accomplish this. The Rio Vista site appears to have been selected to assess the advection of phytoplankton from the Yolo Bypass and so is not appropriate for our investigation of Suisun Bay processes. The Benicia Bridge location is seaward of a sill and so exhibits increases in salinities that do not occur in Suisun Bay.

1.3 Objectives

1. To obtain continuous measurements of phytoplankton biomass (a proxy for primary production) in Suisun Bay using a moored fluorometer and data acquisition system.
2. To compare the peaks, mean and time-integrated chlorophyll data from the moored fluorometer with weekly or monthly measurements of chlorophyll collected shipboard.
3. To use these data to get a base-line of conditions before CALFED restoration projects begin, and to be able to detail changes in chlorophyll as restoration proceeds.

4 To measure primary production rates directly for comparison with a) the Cole and Cloern (1984, 1987) model of productivity that uses chlorophyll and light availability, and b) model results using chlorophyll and PAR data collected at different time scales.
5 To measure size-fractionated chlorophyll, primary production and silicate uptake to evaluate the contribution of diatoms to North Bay primary production and carbon flux.
6 To compare the variability of other parameters (e.g. salinity, ammonium, nitrate and silicate concentrations) with phytoplankton productivity and biomass.

2. Justification

2.1 Conceptual Model

The estuarine ecosystem of San Francisco Bay has been studied in detail, particularly the South Bay and Delta regions (for reviews and compilation of papers see Conomos, 1979; Cloern and Nichols, 1985; Cloern, 1996; Nichols et al., 1986; Hollibaugh, 1996). The food webs and productivity cycles in the water columns of Suisun, San Pablo and Central Bays are less studied (e.g., Jassby et al., 1996; Hollibaugh and Wong, 1996; Murrell and Hollibaugh, 1998; Cloern, 1996, Lehman, 2000). To provide a conceptual model for discussion here, we have chosen to use our data, collected at these three sites (Fig. 3) since late 1999 (Dugdale, 2000; Dugdale et al., 1999; Hogue et al., 2000, 2001; Wilkerson et al., 1999; 2000a; 2000b, 2000c).

2.2 Nutrients and Phytoplankton Response in Suisun, San Pablo and Central Bays

Our time series data (Figs. 2, 4, 5) show that many of these variables decrease in value going seaward from Suisun to the more oceanic-like Central Bay, e.g. silicate concentrations are always highest in Suisun Bay (Fig. 5c), with the highest concentrations typical of river runoff. Nutrients throughout most of the year are at levels assumed to be non limiting- i.e. nitrate greater than 15 µM, silicate often greater than 50µM and ammonium > 3 µM (Fig. 5a). These nutrients are supplied both by runoff, Delta outflow at certain times of year, and anthropogenic inputs (e.g. Peterson, 1979).

There is a clear seasonal cycle in water column properties, as represented here (Figs. 2, 4, 5) by the surface values. Following cool, winter conditions, there is warming in the spring, accompanied by lower salinity water (Fig. 4) and increased nutrients (Fig. 5). The ammonium and nitrate are high and strongly influenced by agricultural sources (Alexander et al., 2001). As stratification sets in, a spring bloom typically develops in each location, sometime in April, elevating the chlorophyll concentrations above the mean of 1-2 µg/l and reaching 30 µg/l in April 2000 in Suisun Bay (Fig. 2). In April 2001in San Pablo and Central Bays, the peaks in chlorophyll concentration were greater than that in April 2000 (16 vs. 15 µg/l, 13 vs. 7 µg/l). There was almost no increase above the average measured in Suisun Bay in 2001. However weekly sampling in Suisun Bay was missed over a two-week period in April 2001 due to bad weather conditions and availability of a suitable vessel. This may mean a peak in chlorophyll was not sampled, or it may be that Suisun Bay phytoplankton responded differently in 2001 than 2000. Typically, in the week preceding these chlorophyll peaks, the ammonium values (Fig. 5a) dropped to near-detection level, and often nitrate showed decreasing concentrations at the peak chlorophyll sampling date (Fig. 5b). This nutrient depletion is similar to that described for nitrate and silicate depletion that accompanied the annual bloom in South Bay (Hager and Schemel, 1996a,b). In our study phytoplankton in Suisun Bay, apparently assimilate ammonium for growth first until it runs out and then continue to grow using nitrate. This conclusion is supported by nitrogen tracer work using ^{15}N labeled nitrate and ammonium in studies of San Francisco Bay phytoplankton communities (Hogue, 2000). By May the chlorophyll is reduced back to 1-2 µg/l. During October 2000 similar trends were seen but with a smaller increase in chlorophyll and accompanying decreases in ammonium, nitrate and silicate concentrations.

In Spring, the cells making up the peak chlorophyll concentrations were larger cells, as shown by the fraction of chlorophyll contained in > 10 µm cells (Fig. 2b). Microscopic analysis showed many diatom chains and large numbers of the diatom *Skeletonema costatum* (Wilkerson et al. 2000c), similar to the earlier (1980) bloom community structure data of Cole et al. (1986). Cell number, using the Utermohl technique and inverted microscopy, are unavailable as the large amount of detritus makes counting these communities difficult, and diluting samples gives statistically inappropriate sample sizes. Use of a flow cytometer that can categorize chlorophyll-containing particles of different sizes may provide an alternative approach. The diatoms have an obligate requirement for silicate for growth and the result of diatoms pulling down silicate is apparent as a decrease in silicate concentrations before the peak chlorophyll in the time series data. Rather than measure silicate depletion (e.g. Peterson et al., 1978) we will measure silicate uptake using the ^{32}Si method in the proposed research. The percentage of larger cells making up the chlorophyll (i.e. most likely diatoms) in October was not as great as in the spring and this community was likely composed primarily of the smaller picoplankton.

2.3 Frequency of Events and Factors Affecting Phytoplankton Production

The chlorophyll concentration in the North San Francisco Bay system exhibits a background, quasi-steady state concentration with low frequency variation combined with strong peaks that create a high frequency component (Fig. 2). The peaks in the high frequency component are comprised primarily of diatoms, the most important component of the primary production for export up the food chain to higher trophic levels. From Figures 1 and 2, it is obvious that monthly sampling has a high likelihood of sampling only the less important low frequency background concentrations and missing the important high frequency peaks. That is to say, under a commonly used monthly sampling regime, the strongest effects on the ecosystem of perturbations due to restoration efforts which may be found in the poorly resolved high frequency components may be almost entirely missed.

The high frequency chlorophyll spectral element may be related to tidal forcing, e.g. in Fig 1, the peak chlorophyll in Central Bay in summer 2001 occurred at spring tides (3) and neap tide (1). Advection of populations of phytoplankton from bay to bay on tidal time scales may also be important. Lehman (1996, 2000) found the highest chlorophyll concentrations in the low salinity zone of Suisun Bay occurred at spring and neap tides. Neap tides in Puget Sound correlate with enhanced primary productivity events through increased stability of the water column (Winter and Banse, pers. comm) and could be expected to do the same in San Francisco Bay. Why peaks in chlorophyll should be associated more with spring tides and high turbulence conditions is unclear. Lucas et al. (1998, 1999) indicated that for San Francisco Bay, since the time scale for blooms is longer than for periodic stratification at the tidal time scale, there would be little interaction between increased chlorophyll and tides. Conversely Koseff et al. (1993) using numerical models reported that variations in mixing on time scales of hours may be crucial in determining phytoplankton growth rates. High frequency productivity events of a negative nature in San Francisco Bay may result as well from wind stirring in shallow waters with increased turbidity and reduced water column stability. Pulses of ammonium from external sources would be likely to have negative effects on short time scales (days) through depression of nitrate uptake.

The challenge is to understand how to make meaningful estimates of primary production, especially production of the larger diatom fraction of the phytoplankton, sufficiently well to measure key changes in the bay ecosystem resulting from restoration efforts. The major limitation on primary productivity in the Bay is light. Consequently anything changing the ambient light field to less than optimal for photosynthesis will impact productivity (Jassby et al., 1996). Consequently wind events, tidal effects and freshwater inflow will influence water column stability and turbidity and ultimately primary productivity. Climatological events such as El Niño and La Niña will also influence the water column stability, stratification and productivity (e.g. Wilkerson et al., 2000a,b; Jassby, 1999). A general decrease in chlorophyll a concentration throughout the estuary has been documented for the period beginning in the early 1980's with the decadal shift in the North Pacific climate (Lehman, 2000b). The most-commonly used primary productivity model used for San Francisco Bay is that of Cole and Cloern (1984, 1987) that empirically derives carbon fixation from values of chlorophyll, incident light and transparency and is based upon light limitation of production, and has been recently updated for use in the Delta (Jassby and Cloern, in press). Following the use of silicate depletion to approximate primary productivity in the North Bay (Peterson et al., 1978) Kimmerer (unpubl, white paper) more recently suggested this approach should also be re-visited to provide an integrated picture of primary production and the kinds of plankton involved in production. Whether productivity is measured directly or estimated from a particular model, allowances for the high frequency components or peaks that may occur on a daily timescale need to be made.

It is likely that the diatom growth in North Bay may also be limited by ammonium as well as light. High ambient levels of ammonium inhibit growth by inhibiting nitrate uptake (e.g. Glibert et al., 1982). During spring, when water column stability sets in and the light field becomes favorable, ammonium is first pulled down by the increasing phytoplankton populations, allowing high nitrate uptake resulting in a classical temperate spring bloom situation. Grazing is another factor influencing productivity and chlorophyll levels. Benthic, zooplanktonic and protozoan grazers may hold phytoplankton biomass low and add to the ambient ammonium concentrations. The first result was apparent following the 1987 introduction of *Potamocorbula*, a voracious grazer in Suisun Bay that lowered chlorophyll levels (Alpine and Cloern, 1992). Typically the time scales of chlorophyll response to optimal stability and nutrient and light availability are quicker than the response of benthic or zooplanktonic grazers, since for increased grazer biomass the life cycle of the organism that must be completed is much longer than diatom cell cycle turnover time. The protozoan response time is less clear, but may be short, on a similar time scale to phytoplankton growth.

Factors affecting productivity in North Bay are paralleled throughout San Francisco Bay and it is apparent that peaks in chlorophyll have been observed in Suisun, San Pablo, Central (Fig. 2) and South Bays (e.g. Cloern and Jassby, 1994) during Spring. However the level of synchrony in timing of these sporadic events and the interconnections between these areas of SF Bay (from Central Bay going northward) is unclear in the data collected since the *Potamocorbula*-linked decline in productivity. The proposed mooring at Suisin Bay, in collaboration with an another set of moored sensors in Central Bay (funded by NSF to the Romberg Tiburon Center, RTC) will provide data to evaluate these interconnections in space and time.

2.4 Hypotheses

The **key uncertainty** to be addressed by the following hypotheses is the optimal time scale for sampling North SFB to assess changes in primary productivity due to restoration efforts. The proposed research will collect chlorophyll and productivity data at different time scales ranging from continuous to discrete samples collected weekly and monthly for cross comparison.

H1 **Continuous measurements from moored instrumentation in Suisun Bay will show higher peaks, time-integrated values and mean levels of chlorophyll than data obtained just using monthly shipboard monitoring.** The proposed research will test this by comparing the spectral distribution of *in vivo* fluorometric data with *in vivo* and *in vitro* shipboard data.

H2 **Weekly shipboard sampling during spring and fall will detect peak concentrations of chlorophyll than would be missed with monthly sampling.** Proposed research will test this as above.

H3 **The phytoplankton community will be dominated by diatoms/larger cells (> 10 µm) during times of elevated chlorophyll conditions.** Proposed research will test this by examining size fractionation of biomass and productivity using ^{15}N, ^{14}C and ^{32}Si, at times of maximal and minimal chlorophyll concentrations.

H4 **High chlorophyll concentrations and high primary productivity will follow times of low ammonium concentrations in the North Bay.** Proposed research will test this by 1) constructing time series plots of the two variables, 2) plotting surface chlorophyll versus surface ammonium concentrations from shipboard sampling and 3) relating the uptake of nitrate to the ambient concentration of ammonium (i.e. to test for presence or absence of ammonium inhibition of nitrate uptake).

2.5 Project Type

This is a **research project** that leads to a monitoring project once the appropriate variables and time scales of sampling have been obtained from the research. At present the uncertainty regarding the appropriateness of monthly chlorophyll concentrations and model derived productivity rates using monthly data is sufficient to require research into relevant sampling regimes. Once the time scales and the directly measured productivity and uptake rates have been evaluated, the best scenario for measuring phytoplankton biomass and productivity will be available for implementation projects. Also the feasibility of measuring continuous chlorophyll within Suisun Bay waters has not been tested before to our knowledge and would need careful ground truth data and calibration before it is used in a full-scale restoration project. Previous moored fluorometers have been located at land sites either north or south of Suisun Bay. In relation to adaptive management, this is a targeted research project aimed at providing information to design appropriate monitoring programs that can be implemented by restoration projects to enable adaptive strategies to be employed and ensure continuation of the projects.

3. Approach

3.1 Overview- continuous and discrete sampling

Both continuous and discrete sampling approaches will be used to test our hypotheses and goal to evaluate the optimal time scale for sampling chlorophyll and primary productivity in North San Francisco Bay. Using a variety of time scales for sampling will maximize the information produced and provide decision makers with an accurate assessment of the appropriate sampling time scale to use to monitor maximal chlorophyll and productivity conditions. This will be accomplished by comparing the spectral distribution of fluorometric data and time-integrated data from the continuous measurements with the discrete samples measured weekly and monthly on shipboard. We propose to acquire a moored Seabird data acquisition package with sensors including fluorometer for the continuous sampling of Suisun Bay. Discrete sampling of Suisun, San Pablo and Central Bays will conducted monthly and weekly during maximal productivity times (most likely April and October), aboard the R/V Questuary.

3.2 Continuous Measurements (Moored Data Acquisition Package)

The instrument package for the mooring is designed for maximum compatibility with existing equipment at RTC and with the monitoring package to be installed dockside at RTC sometime in November, 2001. The basic instrument is the Seabird Electronics Model 16+ which acquires salinity and temperature data. This unit also controls the sampling and data logging of the other instruments in the package and controls a pump that furnishes seawater samples to the other instruments. The software controlling the pump includes a routine for controlling biofouling so that all instruments requiring seawater samples are included in a biofouling routine. Power for all instruments is provided from the Seabird 16+ from 7 D cell batteries, adequate for well over the 1 month scheduled deployment, with no land line power source required. The specific sensors proposed include a LiCor PAR (photosynthetically available radiation) sensor to measure light availability, a Turner Designs SCUFA II fluorometer (unit was chosen for presence of a turbidity channel, crucial for San Francisco Bay waters), and a Wetlabs C+ transmissometer to measure ambient turbidity. The mooring location, (122.02°W, 38.04°N) is shallow, about 6 meters. The package will be mounted just below the surface with a simple anchor connected to a surface float with Kevlar, non-toxic, non-metallic line.

3.3. Discrete Sampling and Analysis

Depth profiles of temperature, salinity, light availability and nutrient concentrations (nitrate, ammonium, silicate and phosphate) will be measured monthly at the 3 locations (Fig. 3, Suisan, San Pablo and Central Bays). Water samples will be collected for determination of concentrations of phytoplankton pigments, ambient nutrients, and phytoplankton using 2.5 liter Niskin bottles mounted on a SBE-33 carousel. Hydrographic data (temperature, salinity, pH, PAR) will be collected with a Seabird SBE-19 CTD attached to the carousel. *In vivo* fluorescence will be measured using a WETSTAR fluorometer mounted on the carousel. A standard oceanographic secchi disk and PAR sensor will be used to measure light penetration in the water column.

Samples for nitrate (nitrate + nitrite), phosphate and silicate analysis will be frozen in 20-ml polypropylene bottles until analysis using a Technicon Autoanalyzer II according to the procedures of Whitledge et al. (1981). Fresh ammonium samples will be measured manually according to the phenol hypochlorite method of Solorzano (1969) using a Hewlett Packard Model 8452A diode array spectrophotometer. Chlorophyll-a (and phaeopigment) concentrations will be determined by *in vitro* fluorometry using a protocol (Venrick and Hayward, 1984) adapted from Parsons et al. (1994) and Holm Hansen et al. (1965), water will be filtered onto either a Whatman 25-mm glass microfiber filter (GF/F) or a 25mm 5µm or 10 µm pore-sized polycarbonate filter. Acetone extracted fluorescence will be measured before and after acid additions with a Turner Designs model 10 fluorometer, calibrated using commercially available chlorophyll-a. Some samples will be taken for phytoplankton enumeration (stored in Lugols iodine) using the Utermohl (1958) technique, and for flow cytometry, preserved with 2% glutaraldehyde before analysis with a CytoBuoy instrument that discriminates between chlorophyll particles of 2 - 100 µm and gives their optical scattering characteristics and fluorescence bands.

Surface water samples (280 ml) for primary productivity measurements will be incubated with either ^{14}C, ^{32}Si or ^{15}N labeled nitrate or ammonium for 6 or 24 hours in ambient light and temperature in an outdoor flowing surface seawater incubation table. Following incubation, samples will be collected by filtration onto either GF/F filters or 5 µm or 10 µm pore-sized filters and prepared for either liquid scintillation counting of ^{14}C (see Wilkerson et al. 2000) or ^{32}Si (Brzezinski et al., 1998) or for ^{15}N enrichment with a Europa Scientific Roboprep-Tracermass mass spectrometer system (Dugdale and Wilkerson, 1986; Wilkerson and Dugdale, 1992).

3.4 Quality Assurance

Data quality will be assured through the use of standard, well-established procedures for sample and data collection, record keeping and appropriate calibration of instruments. Conductivity, temperature, PAR, turbidity and *in vivo* fluorescence sensors will be calibrated by the manufacturers each year. Discrete shipboard CTD measurements will be used to cross calibrate and check quality of the moored CTD. Fluorometers (both laboratory and *in situ*) will be calibrated against commercially available chlorophyll standard. Intercalibration of nutrient and chlorophyll analyses with IEP and USGS will be carried out. We already intercalibrate our nutrient analyses with Scripps Institute of Oceanography and our chlorophyll analyses with National Marine Fisheries Service.

4. Feasibility: Facilities and Equipment

The shipboard sampling and laboratory procedures proposed here are well established and have been used extensively by the PI's and technicians in our research laboratories at RTC, and we have all equipment necessary for the discrete sampling aspect of the proposed study. We have controlled-temperature water baths, ovens, spectrophotometers, Turner and Turner designs fluorometers, balances, high precision micropipettes in addition to a 3-channel Braun and Lube Computer Controlled Technicon 11 AutoAnalyzer, Europa Scientific RoboPrep Tracer-Mass spectrometer, a Nikon inverted microscope, a CytoBuoy flow cytometer and a liquid scintillation counter. The RTC research vessel R/V Questuary is available for water sampling. We will allow for bad weather days when scheduling the ship to ensure sampling schedules will be adhered to. We request funding to acquire the equipment necessary for the continuous measurements proposed. A similar package will be acquired this month at RTC (funded by NSF to Carpenter et al.) and we have confidence that using their experiences of installation and maintenance we will be successful in deploying and retrieving data from our proposed package. We will ensure that any permits (if required) will be applied for during the early part of the project (acquisition phase) so the schedule for data collection will not be disrupted.

5. Performance Measures

In addition to the **project outputs and outcomes** listed with the project deliverables (see Section 7), specific **performance measures** for the proposed objectives are:

1 Deployment of the moored data acquisition package in Suisun Bay.
2 Monthly update of continuous data resulting from successful retrieval of package and data.
3 Quarterly update of nutrient and *in vitro* chlorophyll data resulting from successful completion of monthly cruises and laboratory analyses.
4 Yearly completion of entire suite of productivity rate measurements (carbon, silicate, nitrate and ammonium uptake) resulting from incubations using shipboard sampled water, and from model determined results using *in vivo* and *in vitro* chlorophyll data.

6. Data Handling and Storage

Data from the recording electronic instruments (i.e. moored sensors) will be obtained after interrogation of the data logger in the laboratory and data will be backed up onto CD's and kept in a locked room in another building on the RTC site. Following nutrient analyses, any sample remainder will be stored in a locked freezer for up to 1 year in the event that re-analysis is required. Sample consumption usually results from processing of chlorophyll filters and samples for nitrate, ammonium, silicate and carbon uptake. Any residual will be discarded. Following examination of preserved samples (in Lugol's iodine for phytoplankton enumeration and 2% gluteraldehyde for flow cytometry samples) any remainder will be stored in locked cabinets, for re-examination if required. Standard data logs constructed in Excel will be used for recording the data. All data will be copied and copies will be stored off-site in the form that they were taken and on CDs. Preliminary data analyses will be conducted to check for outliers indicating errors in collection or entry. Data will be available through the RTC website and will be made available to the IEP data server within 3 months for continuous data collected, and within 1 year after collection for discretely collected data. The intended use of the data is to discern what the most appropriate time scales are for sampling productivity in Suisun Bay. This will allow the identification of any changes in environmental variables that may be associated with restoration efforts, and provide a suite of additional data to complement ongoing studies in North San Francisco Bay.

7. Expected Products/Outcomes

The large-scale **project outcome** is an increased knowledge base about the timing of chlorophyll increases in estuaries, and the quantity and quality of primary production in San Francisco Bay. The **deliverables** from this research project will be data reports, scientific presentations and publications (both peer-reviewed and newsletter articles). Specific **products to CALFED** are quarterly reports, annual and final reports, annual data submissions, newsletter articles, presentations and annual review meetings. In addition, data will be made available through an RTC and tentatively the IEP web sites (see Section 6). The principal investigators and technical staff will attend local and national meetings and workshops and report results. These meetings include the annual IEP Meetings at Asilomar, the Fall Estuarine Federation Meetings (Seattle 2002, Fall 2003), annual American Society of Limnology and Oceanography meetings and winter American Geophysical Union meetings (December 2002, 2003, 2004, San Francisco). Peer reviewed manuscripts (e.g. Estuaries, Limnology and Oceanography, Journal of Phycology Journal of Plankton Research) and IEP newsletters will be used to disseminate results.

8. Work Schedule

Following the guidelines for budget preparation the proposed research has been split into tasks based upon the sampling strategy to be used. These are not inseparable and overlap since the goal of the research is to compare different strategies of sampling, and consequently these inter-comparisons will be lost if a task is removed.

Task 1: Acquisition, Maintenance and Deployment of Seabird Data Acquisition Packages, Sensors and Mooring Gear. This task will start on July 1, 2002 with acquisition of the SeaBird package. It is anticipated that the first package will be installed in Suisun Bay early fall (September 2002). Following this, monthly visits with the R/V Questuary will be made to exchange the replacement package and return the deployed package to the lab for interrogation and downloading of data. It is hoped that the ship-time requested for this task will be combined with the shiptime requested for Tasks 2 and 3. This cycle of monthly collecting, data retrieval and redeployment will continue to the end of the proposed study (June 2005).

Task 2: Field Sampling Of Physical, Chemical And Biomass Variables. This task starts July 2002 and continues until June 2005 and covers monthly cruises (daylong) aboard the R/V Questuary to sample Suisun Bay, San Pablo Bay and Central Bay using the shipboard CTD with *in vivo* fluorescence measurements. Water at four depths will be collected to measure nutrient concentrations and *in vitro* fluorescence (chlorophyll) of the entire community and size fractionated samples to measure the contribution of larger (5 µm and 10 µm diameter) cells. At times (April) when chlorophyll peaks are likely (and indicated by data from prior years) weekly cruises will be added. This task includes minimal data analysis but no report generation that is included in Task 4, Project Management.

<u>Task 3: Field Sampling Of Productivity Rate Variables.</u> This task parallels Task 2 in timing (i.e. July 2002 - June 2005) and locations. No specific ship-time request has been made since the ship-time requested In Task 2 should also be used to perform Task 3. Task 3 also requires biomass measurements from Task 2 for completion. Task 3 will include carbon fixation, silicate uptake, and nitrate and ammonium uptake rates of the phytoplankton community to describe the quantity and quality (e.g. diatom dominated or microbial web dominated) of primary production.

<u>Task 4: Project Management</u>. This includes supervising technical staff, organizing ship time requests, data quality control and most importantly processing, archiving and reporting the data. This task includes data report generation and data submission to CALFED and IEP.

<u>Annual Time Line</u>

D represents deployment of mooring
E represents moored SeaBird package exchange and data retrieval
X represents 1-day R/V cruises to collect discrete water samples
**** represents continuous data collection from moored package
R represents report (data or final)

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
2002						Purchase SeaBird		D		EXXX	EX	EX
										**********************		
2003	EX	EX	EX	EXXXX	EX	EX	EX	EX	EX	EXXX	EX	EX
	***											
			IEP			R						AGU
2004	EX	EX	EX	EXXXX	EX	EX	EX	EX	EX	EXXX	EX	EX
	***											
		ASLO	IEP			R			ERF			
2005	EX	EX	EX	EXXXX	EX	EX						
	********************************											
			IEP			R						

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

1. Science Program and CVPIA Priorities.

This proposal meets at least two of the four CALFED Bay-Delta Program Plan objectives concerning a) ecosystem quality and b) water quality in that it will give water column monitoring data for the Bay Region (a region identified in the Implementation Plan). Since the region is located in the San Francisco Bay it does not address the CVPIA goals and priorities. More specifically this proposal offers key methodology and monitoring data that will benefit many of the six **CALFED Strategic Goals**, in particular **Goal 2** (Ecological Processes) that lists objectives concerning the decline in productivity in the Bay Region that are pertinent to the proposed research and, **Goal 6** (Water and Sediment Quality) by monitoring a variety of water column variables in the Bay region.

The expected data and results from this combined continuous and discrete sampling North and Central Bays meet the following specific **PSP Priorities**, listed in order of applicability, for the Bay Region:

BR-6. Protect at-risk species in the Bay using water management and regulatory approaches, by providing a better understanding of a) primary productivity within Suisun Bay, North Bay, and Central Bay and linkages among internal and external inputs and b) the linkages between North and South Bay that might affect restoration or productivity in either, and c) the poorly known aspects of the food webs in these regions. In addition the study will demonstrate effective techniques for monitoring the phytoplankton base of the food web.

BR-8. Use monitoring, evaluations of existing monitoring data and new investigations to develop improved strategies for restoring Bay fish populations and at-risk species. The proposed research will provide chlorophyll data, to help examine how trends in chlorophyll, zooplankton and pollutants impact different fish species locally (in Suisun Marsh) and across the Bay region landscape (interconnections between Bay segments). It will develop new data and monitoring approaches to supplement those currently measured monthly, and to be available to measure any changes as a result of restoration efforts.

BR-4. Understand performance of wetlands restoration efforts on a local and regional scale. Our proposed study will document changes in the water column and primary production that may be impacted by restoration efforts, particularly small but important changes that might be missed with conventional monthly shipboard sampling. By collecting data on a different time scale from existing monitoring programs, the proposed research will also enhance interpretations of existing aquatic system monitoring information from the Bay.

1. Relationship to Other Ecosystem Restoration Projects (past and future).

The proposed research will add data to existing monthly data collected in North Bay, by ourselves (funded by EPA until Sept 2002), USGS, DWR and IEP scientists, and to existing continuous chlorophyll data that may be available from *in situ* fluorometers maintained by DWR. It will complement future monitoring programs and provide benchmarks for interpretation of changes due to efforts made by restoration projects likely to be funded by the CALFED ERP. In addition the continuous data set that we will collect from the moored sensors will enable us and others to re-evaluate the prior data collected and help direct sampling stategies of future projects to establish accurate measurements to assess productivity in the North Bay. Comparing our data with similar data collected at an already funded moored monitoring system in Central Bay (at RTC) will allow interconnections along the N-S transect of SFB to be evaluated.

2. Next Phase Funding - not applicable

3. Previous Recipients - not applicable

5. System Wide Ecosystem Benefits

This proposal will complement other projects in San Francisco Bay and estuaries in general by identifying the correct time scales to sample peaks in chlorophyll and productivity. The data produced will benefit projects both upstream and downstream from the mooring site by providing continuous hydrographic and chlorophyll measurements.

6. Additional Info re Land Acquisition - not applicable

C. Qualifications/Abbreviated Biographical Sketches and Some Relevant Publications /Presentations

1. Frances Wilkerson is a phytoplankton ecologist studying the role of algae in biogeochemical nutrient cycles. She has more than 20 years experience studying coastal oceans and estuaries around the world. Her current position is Senior Research Scientist at RTC, Lecturer and Adjunct Faculty in Dept. Biology, SFSU. She previously was Associate Research Professor at University of Southern California. She received her B.A. (1977) and M.A. (1980) in Natural Sciences from University of Cambridge, UK and her Ph.D. at University of Bristol, UK (1980).

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. Accepted, Progress in Oceanography.

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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.

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Wilkerson, F.P. R.C. Dugdale, A. Marchi, V. Hogue, 2000. Hydrography, nutrients, phytoplankton biomass and productivity across central San Francisco Bay from October 1997-99: the effect of El Niño vs. La Niña conditions, IEP, Asilomar, CA.

Wilkerson, F.P., R.C. Dugdale, V. Hogue, A. Marchi, A. Lassiter 2000. A comparison of phytoplankton bloom dynamics in North and Central San Francisco Bay (Suisun, San Pablo and Central Bays). CALFED Scientific Conference, Sacramento, CA.

2. Richard Dugdale is a biological oceanographer studying the distribution and effects of nutrients on estuarine and oceanic productivity. He has more than 40 years experience studying limnological and coastal ecosystems around the world and has been involved in several major oceanographic research programs. In recognition of his work, he received the Hutchinson Award from the American Society of Limnology and an Honoris Causae from University of Marseilles, France. His current positions are Senior Research Scientist, RTC, Adjunct Professor, SFSU and Emeritus Professor at University of Southern California, where he was previously Professor. He received his B.S., M.S. and Ph.D. (1955) from University of Wisconsin.

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.

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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.

Dugdale, R.C., 2000. Integrative Indicators of Ecosystem Condition and Stress Across Multiple Trophic Levels in the San Francisco Estuary EPA Workshop, May 2000, Las Vegas.

3. Technical Staff

Two research technicians will carry out the proposed research. Albert Marchi, M.A. SFSU, Dept of Biology (1996), has been a technician in our lab since 1997, primarily responsible for measuring nutrients and data entry. Victoria Hogue, M.A. SFSU, Dept of Biology (2000). Thesis Title: *UV radiation effects on natural phytoplankton assemblages of Central San Francisco Bay*, has worked in our lab as a graduate student and recently as research technician and was responsible for gathering the data collected as part of our EPA funded project (Figs. 2,3,4,5).

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.

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D. Cost Plan and Budget Justification-see separate forms

E. Local Involvement

At present scientists at RTC interact with the immediate Tiburon and Marin County residents through an annual open house, occasional articles in the local newspaper “The Ark” and outreach efforts that include High School Teacher Workshops and judging science fairs. The headquarters of the proposed San Francisco Bay National Estuarine Research Reserve (NERR), although incorporating science and outreach at a number of sites around SF Bay, is based at the Romberg Tiburon Site with the acting Program Manager Todd Hopkins, a research scientist and administrator at RTC. The NERR designation is expected by the end of 2001, and will include an Education Specialist. This is the ideal avenue for outreach to groups and individuals that might be affected by our proposed research would be through the outreach activities of the NERR. Concerning local negative impacts, our previous work in the proposed study areas has not affected facilities or landowners, and it is expected that the proposed study will have no impact.

F. Compliance

We plan to comply with the Standard State and federal contract terms described in Attachments D and E.

G. Literature Cited

(authors in bold are personnel that will carry out the proposed research)

Alexander, R.B., R.A. Smith, G.E. Schwartz, S.D. Preston, J.W. Brakebill, R. Srinivasan and P.A. Pacheco. 2001. Atmospheric nitrogen flux from watersheds of major estuaries of the United states: an application of the SPARROW watershed model. In: Valigura, R.A., R.B. Alexander, M.S. castro, T.P. Meyers, H.W. Paerl, P.E. Stacey and R.E. Turner (eds). Nitrogen Loading in Coastal Water Bodies: An Atmospheric Perspective. Coastal and Estuarine Studies Vol 57, AGU, pp. 119-171.

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Cloern, J.E. and F.H. Nicholas. 1985. Editors. Temporal Dynamics Of An Estuary: San Francisco Bay. Junk. (Hydrologia Volume 129).

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Wilkerson
Fig 1

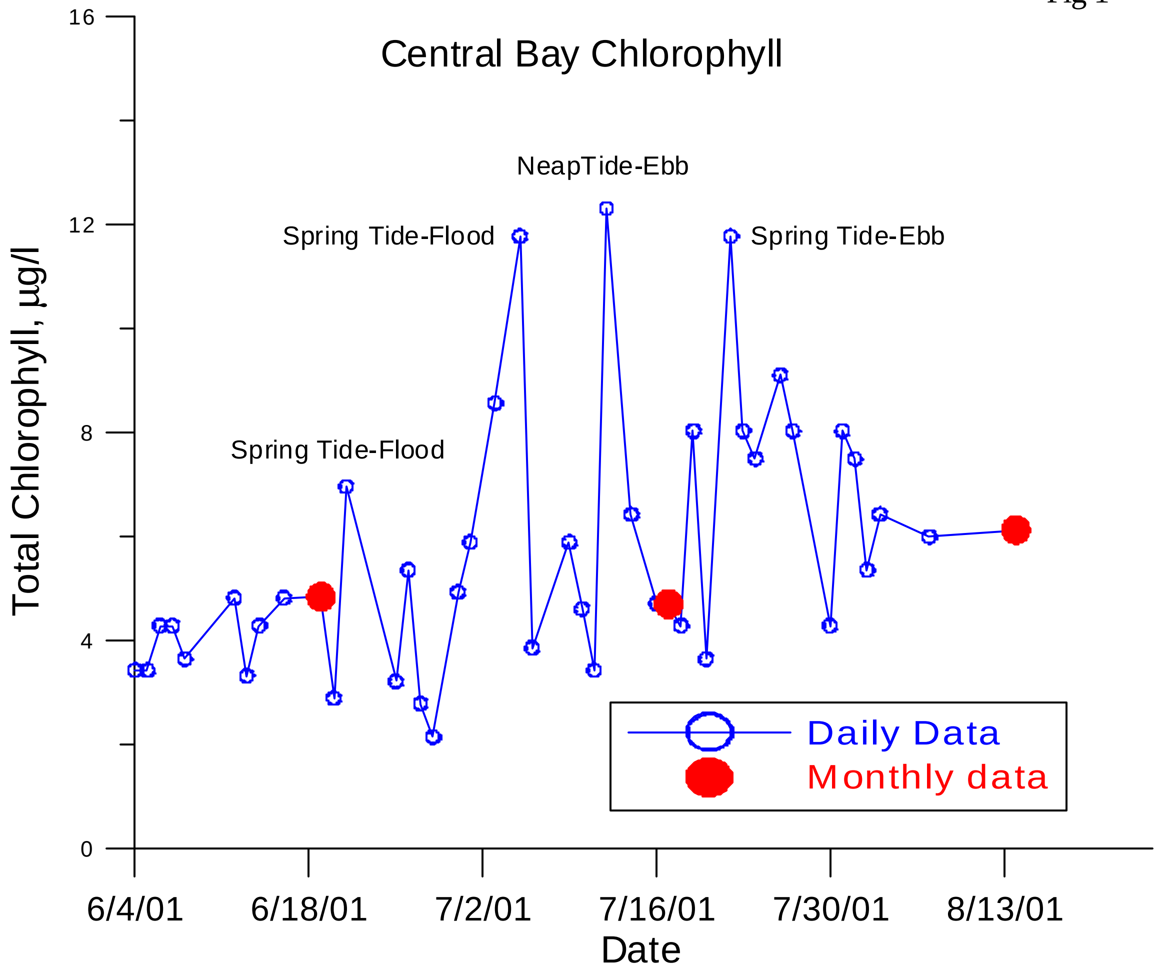

Figure 1. Daily (blue) and monthly (red) sampled chlorophyll data collected from Central San Francisco Bay, measured using *in vitro* analysis (Parsons et al. 1984). Our monthly collections (in red) indicate that chlorophyll ranged from 4 - 6 µg/l between June and mid-August whereas chlorophyll sampled daily (blue) showed double these levels on three separate occasions. Monthly sampling is likely to miss the high frequency peaks in chlorophyll that may occur.

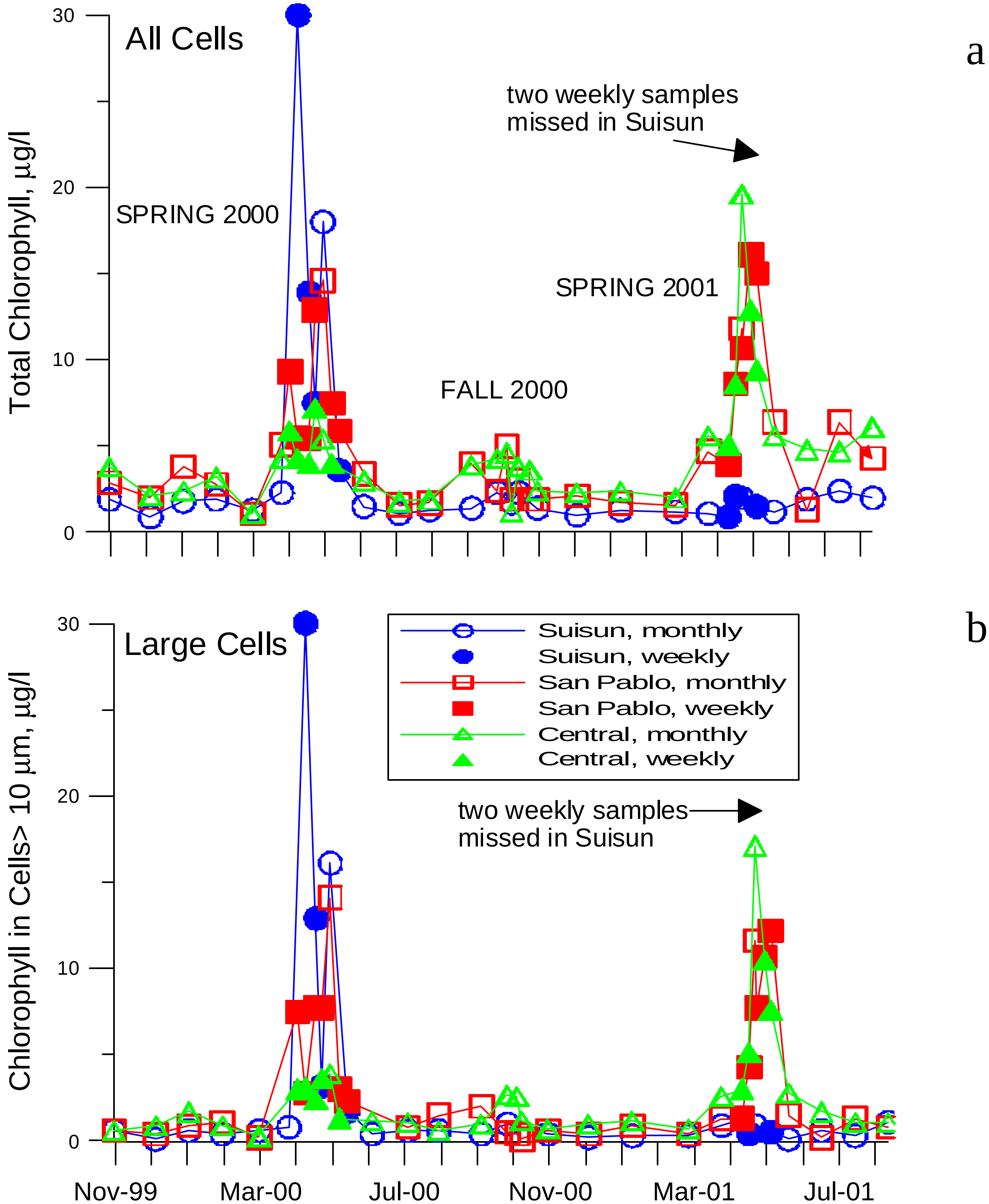

Figure 2. Weekly (closed symbols) and monthly (open symbols) sampled chlorophyll data for a) all phytoplankton and b) cells >10 µm diameter (b) collected from Suisun (blue), San Pablo (red) and Central (green) Bays shows peaks in Spring 2000 (30 µg/l in Suisun) and 2001 (in San Pablo) that occurred on weekly sampling days that would not have been observed with the monthly sampling regime.

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Fig 3

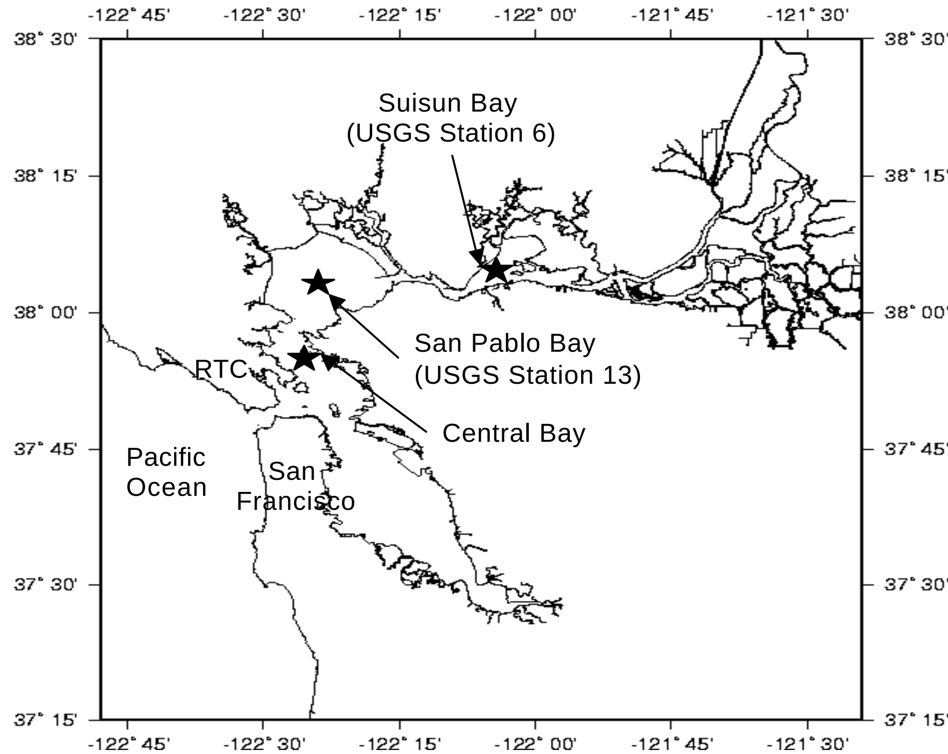

Figure 3. Map to show study site of monthly sampled shipboard locations carried out presently with EPA funding and proposed for 2002 - 2005 with CALFED support The proposed mooring will be deployed near the Suisin Bay station, south of the channel at 122.02°W, 38.04°N.

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Fig 4

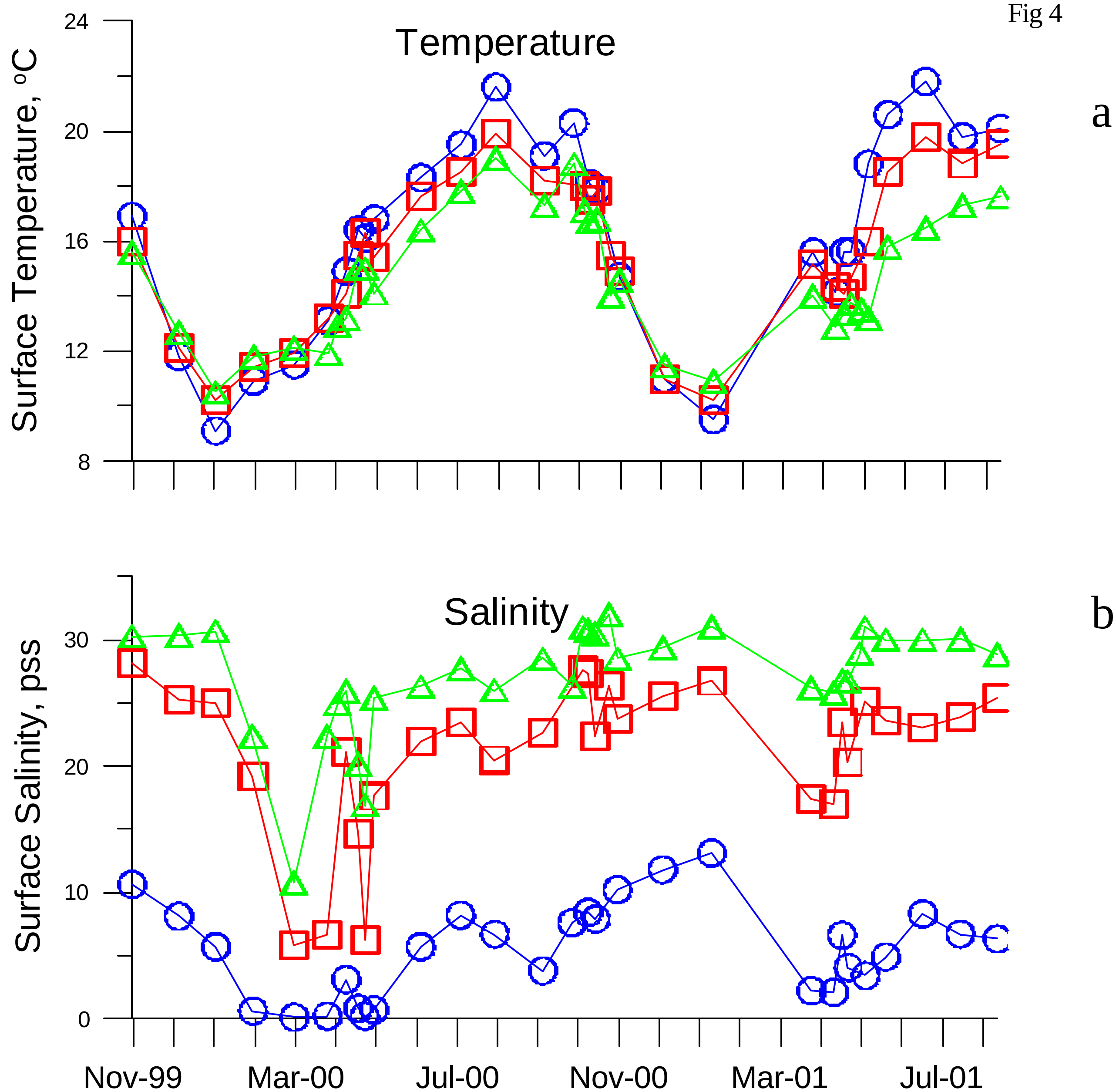

Figure 4. Surface temperature and salinity measured in Suisun (blue), San Pablo (red) and Central (green) Bays at location shown in Fig. 3.

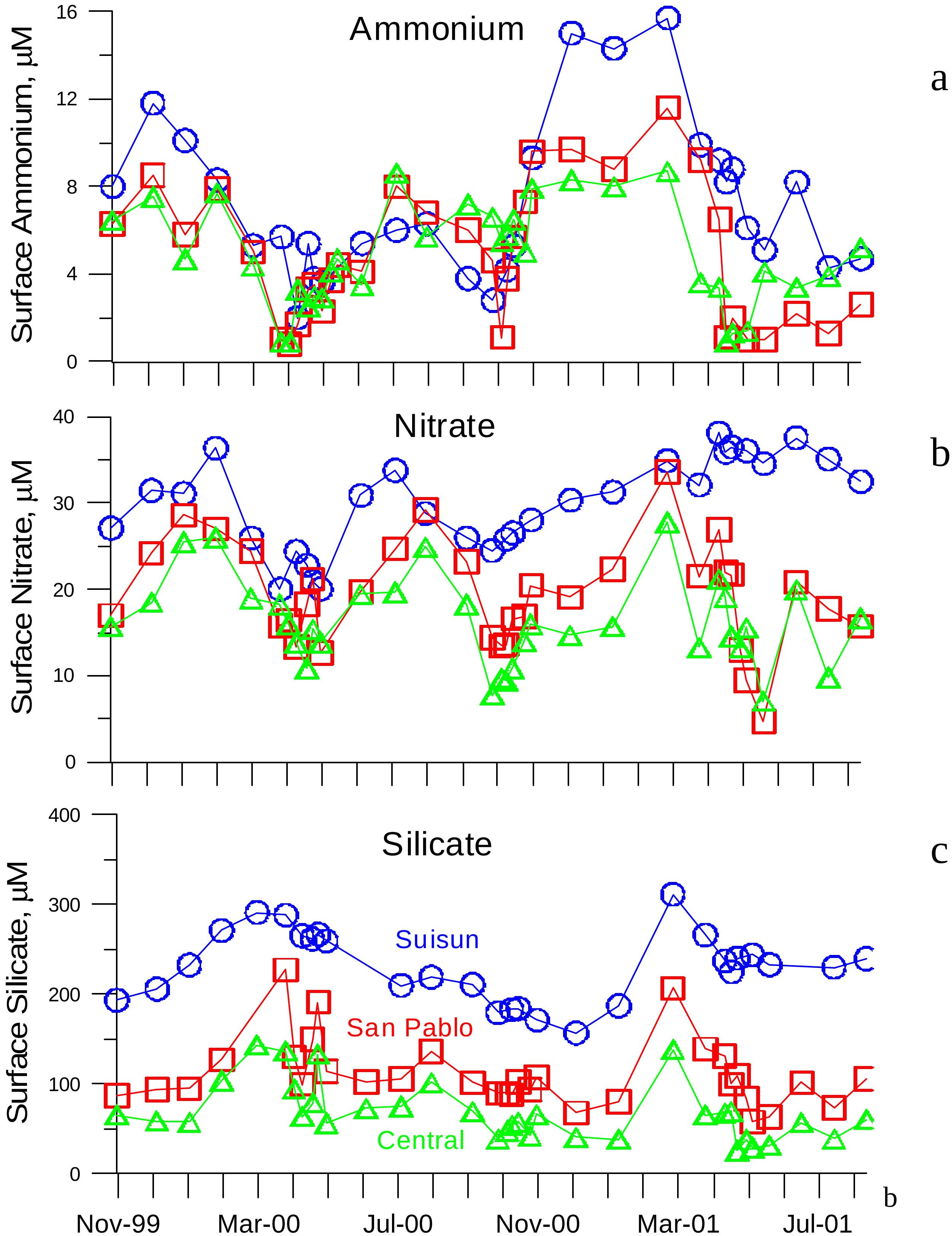

Figure 5. Surface nutrients measured in Suisun (blue), San Pablo (red) and Central (green) Bays. Note the decrease in ammonium, then nitrate in Spring 2000 and 2001.