Distribution, and abundance of shrimp, plankton and benthos in Suisun Marsh: Tidal marsh as a refuge for native species

Project Information

1. **Proposal Title:**

   Distribution, and abundance of shrimp, plankton and benthos in Suisun Marsh: Tidal marsh as a refuge for native species

2. **Proposal applicants:**

   Peter B. Moyle, University of California, Davis

3. **Corresponding Contact Person:**

   Ahmad Hakim-Elahi
   Regents of University of California
   Office of Vice Chancelor of Research Sponsored Programs 118 Everson 1 Shields Avenue
   University of California Davis, CA 95616
   530 752-2075
   vcresearch@ucdavis.edu

4. **Project Keywords:**

   Estuarine/Tidal Ecology
   Nonnative Invasive Species
   Trophic Dynamics and Food Webs

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:**

   University

9. **Location - GIS coordinates:**

Latitude: 38.182

Longitude: -121.998

Datum:

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

The project is located within Suisun Marsh, Solano County, California. Research activities will take place in numerous waterbodies of Suisun Marsh including Peytonia, Boynton, Suisun, Spring Branch (First Mallard Branch), Cutoff, Montezuma, Nurse, Denverton, Goodyear and Cordelia sloughs. The Suisun Marsh is located in the San Francisco Estuary and is approximately 60,000 acres in size.

10. **Location - Ecozone:**

    2.1 Suisun Bay & Marsh

11. **Location - County:**

    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:**

    7

15. **Location:**

    California State Senate District Number: 4

    California Assembly District Number: 8

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:	10
Total State Funds:	271804
Federal Overhead Rate:	48.5
Total Federal Funds:	0

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.

99-B190	**Linked hydrogeomorphic-ecosystem models to support adaptive management: Cosumnes-Mokolumne Paired Basin Project,**	**Habitat Restoration: Channels, Floodplains and Marshes**
99-B193	**McCormack-Williamson Tract Restoration Planning Design and Monitoring Program: I**	**Habitat Restoration: Channels, Floodplains and Marshes**

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)

Jim J. Orsi	**California Department of Fish and Game**	**(209) 951-3228**	**JJorsi@aol.com**
Anke Mueller-Solger	**Department of Water Resources**	**(916) 227-2194**	**amueller@water.ca.gov**
Wimm Kimmerer			

21. **Comments:**

    For #17 We are requesting state funds for the entire project cost of 271,804. This includes the University overhead rate of 10%.

Environmental Compliance Checklist

Distribution, and abundance of shrimp, plankton and benthos in Suisun Marsh: Tidal marsh as a refuge for native species

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.

      The proposed project is a research project which monitors the aquatic invertebrate community within Suisun Marsh and will not in any way modify or degrade the existing physical or chemical conditions found there.

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?

      Not Applicable

   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 Required

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 Required

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.**

5. Environmental Permitting and Approvals: This project will investigate the community composition of invertebrates living within Suisun Marsh, Solano County, California. It is unlikely that these activities will result in incidental take of ESA species. Any incidental take will likely be covered under our current IEP - Take limits for the UC Davis Suisun Marsh Fish Survey.

Land Use Checklist

Distribution, and abundance of shrimp, plankton and benthos in Suisun Marsh: Tidal marsh as a refuge for native species

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

Distribution, and abundance of shrimp, plankton and benthos in Suisun Marsh: Tidal marsh as a refuge for native species

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):

Peter B. Moyle, University of California, Davis

Subcontractor(s):

Are specific subcontractors identified in this proposal? No

Helped with proposal development:

Are there persons who helped with proposal development?

No

Comments:

None

Budget Summary

Distribution, and abundance of shrimp, plankton and benthos in Suisun Marsh: Tidal marsh as a refuge for native species

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.

State 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	Benthic Monitoring	2865	35600	5796	2160	5346		13675		62577.0	4665	67242.00
2	Mysid Monitoring	1668	21792	3864	2880	2864				31400.0	3140	34540.00
3	Zooplankton Monitoring	1668	21792	3864	2880	2464				31000.0	3100	34100.00
		6201	79184.00	13524.00	7920.00	10674.00	0.00	13675.00	0.00	124977.00	10905.00	135882.00

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	Benthic Monitoring	2865	37068	6085	2160	2196				47509.0	4751	52260.00
2	Mysid Monitoring	1668	22732	4057	2880	2064				31733.0	3173	34906.00
3	Zooplankton Monitoring	1668	22732	4057	2880	2064				31733.0	3173	34906.00
		6201	82532.00	14199.00	7920.00	6324.00	0.00	0.00	0.00	110975.00	11097.00	122072.00

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**
4	Final Report and Publication Preparation	522	9261	2130	500	200			500	12591.0	1259	13850.00
		522	9261.00	2130.00	500.00	200.00	0.00	0.00	500.00	12591.00	1259.00	13850.00

Grand Total=271804.00

Comments.
To allow for increased wages in year2 and 3 of this project, Cost of living increases were calculated for tasks 1-3 for years 1 and 2 and Task 4 in year 3. They are calculated as follows - 5% increase for Post Graduate Researchers and 2% for Undergraduate assistants. Task 4 (Year 4), includes the preparation and submission of the final report and also the generation of pertinent publications, newsletters and presentations at various conferences.

Budget Justification

Distribution, and abundance of shrimp, plankton and benthos in Suisun Marsh: Tidal marsh as a refuge for native species

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

Task 1 Undergraduate Assistants - 2600 hours (YR1 and YR2) Post Graduate Researcher A - 2086 hours (YR1 and YR2) Post Graduate Researcher B - 1044 hours (YR1 and YR2) Task 2 Undergraduate Assistants - 1248 hours (YR1 and YR2) Post Graduate Researcher A - 1044 hours (YR1 and YR2) Post Graduate Researcher B - 1044 hours (YR1 and YR2) Task 3 Undergraduate Assistants - 1248 hours (YR1 and YR2) Post Graduate Researcher A - 1044 hours (YR1 and YR2) Post Graduate Researcher B - 1044 hours (YR1 and YR2) Task 4 Post Graduate Researcher B - 522 hours (YR3)

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

Year 1 Undergraduate Assistants - 8.00 / hour Post Graduate Researcher A - $16.10 / hour Post Graduate Researcher B - $16.10 / hour Year 2 Undergraduate Assistants - 8.16 / hour Post Graduate Researcher A - $16.91 / hour Post Graduate Researcher B - $16.91 / hour Year 3 Post Graduate Researcher B - $17.76 / hour Benefits

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

Undergraduate Assistants - 0 Post Graduate Researcher - 23%

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

Travel listed in Tasks 1-3 includes the cost of gasoline for boat operation for research activities and the vehicle costs for transporting the research boat to Suisun Marsh from UC Davis. Task 1 Total - $4320 ($2160 gas and $2160 vehicle rental for YR1 and YR2) Task 2 Total - $5760 ($2880 gas and $2880 vehicle rental for YR1 and YR2) Task 3 Total - $5760 ($2880 gas and $2880 vehicle rental for YR1 and YR2) Travel in Task 4 includes transportation to conferences for presentation of findings Task 4 Total - $500

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

Task 1 - Field Supplies $6150, Lab $1392 Task 2 - Field Supplies $4000, Lab $928 Task 3 - Field Supplies $3600, Lab $928 Task 4 - Office Supplies $200

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.

None

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 is included under Task 1 (Benthic Sampling) A Hydrolab water quality meter will be purchased at the cost of $13,675

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.

No Cost

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

Task 4 - publication costs Total Cost = $500

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.

There is a 10% State Overhead Rate which includes costs associated with general office requirements such as rent, phones, furniture, general office staff, etc. If Federal Funding is allocated to the project the overhead rate will be 48.5%.

Executive Summary

Distribution, and abundance of shrimp, plankton and benthos in Suisun Marsh: Tidal marsh as a refuge for native species

The San Francisco Estuary is a critically important resource in California. The San Francisco Estuary serves as a nursery area for both marine and freshwater species and supports numerous populations of diverse and valuable aquatic species. The Suisun Marsh, a large tidal brackish marsh located at the upper end of the estuary, is an important component of this nursery area providing brackish shallow water tidal habitat for numerous species of aquatic organisms. However, in recent decades, a vast number of alien species have been introduced into the estuary and have dramatically altered the existing aquatic community. More specifically, the introduction of the overbite clam (Potamocorbula amurensis), into the San Francisco Estuary has had profound effects on the aquatic food web and is believed to have significantly altered the trophic dynamics and species composition of the aquatic community (Orsi and Mecum 1996; Kimmerer and Orsi 1996). Although the overbite clam and other alien species are likely to be a permanent component of the ?new? San Francisco Estuary community, it is possible that certain habitats within the system may actually be serving as refuge for native species which are adversely affected by these aliens. This is likely the case within shallow water tidal marsh habitat in Suisun Marsh based upon preliminary data on the distribution and abundance of the overbite clam and mysid shrimp. The following is a two-year research proposal, which will investigate the current distribution of native and alien shrimp, plankton and benthos within the diverse tidal marsh habitats of Suisun Marsh in the San Francisco Estuary. Consistent with the goals and priorities of CALFED, the information obtained from the proposed research will (1) greatly improve our understanding of the current distribution of native and nonnative invertebrates in the San Francisco Estuary, (2) provide information on the environmental and biological conditions which favor alien and native species, (3) elucidate impacts that alien species are having on native species in the diverse habitats of Suisun Marsh, and (4) improve our understanding of the effects of restoration activities and the resultant communities likely to be present within shallow water tidal marsh.

Proposal

University of California, Davis

Distribution, and abundance of shrimp, plankton and benthos in Suisun Marsh: Tidal marsh as a refuge for native species

Peter B. Moyle, University of California, Davis

DISTRIBUTION AND ABUNDANCE OF SHRIMP, PLANKTON AND BENTHOS IN SUISUN MARSH: TIDAL MARSH AS A REFUGE FOR NATIVE SPECIES

Proposal Submitted to the CALFED for 2002

PRINCIPAL INVESTIGATOR
Dr. Peter B. Moyle – University of California, Davis; *pbmoyle@ucdavis.edu* (530)752-6355

EXECUTIVE SUMMARY

The San Francisco Estuary serves as a nursery area for marine, brackish and freshwater species and supports numerous populations of diverse and valuable aquatic species. The Suisun Marsh, a large tidal marsh located at the upper end of the estuary, is an important component of this nursery area providing brackish shallow water tidal habitat for numerous species of aquatic organisms. In recent decades, a vast number of alien species have been introduced into the estuary and have dramatically altered the existing aquatic community. More specifically, the introduction of the overbite clam (*Potamocorbula amurensis*), into the San Francisco Estuary has had profound effects on the aquatic food web and is believed to have significantly altered the trophic dynamics and species composition of the aquatic community (Orsi and Mecum 1996; Kimmerer and Orsi 1996). Although the overbite clam and other alien species are likely to be a permanent component of the new San Francisco Estuary community, it is possible that certain habitats within the system may actually be serving as refuge for native species which are adversely affected by these aliens. Based upon preliminary data on the overbite clam and mysid shrimp abundance and distribution in Suisun Marsh, it appears that shallow water tidal marsh habitat in is likely an important refuge for native species.

In order to determine, with greater resolution, the importance of tidal marsh habitat as native species refugia, we propose to conduct a two-year research project, which will investigate the current distribution of native and alien benthos, mysid shrimp and plankton within the diverse tidal marsh habitats of Suisun Marsh in the San Francisco Estuary. Consistent with the goals and priorities of CALFED, the information obtained from the proposed research will (1) greatly improve our understanding of the current distribution of native and alien invertebrates in the San Francisco Estuary, (2) provide information on the environmental and biological conditions which favor alien and native species, (3) elucidate impacts that alien species are having on native species in the diverse habitats of Suisun Marsh, and (4) improve our understanding of the effects of restoration activities and the resultant communities likely to be present within shallow water tidal marsh.

To date, most aquatic research and monitoring efforts in the San Francisco Estuary have focused on the community present in the large channels and bay habitats. This proposed study would be the first community-level investigation into the distribution and abundance of important invertebrates within the small sloughs and channels in Suisun Marsh. In addition, this study will provide much needed information on the likely invertebrate assemblages that will result from tidal marsh restoration. Finally, the proposed study will contribute significantly to our understanding of food webs in the marsh, complementing our ongoing study of patterns of distribution and abundance of larval, juvenile and adult fish within the marsh (UC Davis -Suisun Marsh Fish Survey 1979 - Present).

A. PROJECT DESCRIPTION

The following is a research proposal to investigate the community composition of invertebrates within Suisun Marsh, located in the San Francisco Estuary.

A1. Problem

Description of Problem

The San Francisco Estuary is one of the largest and most modified estuaries on the west coast of North America. These modifications include the filling and conversion of vast expanses of tidal marsh as well as a high degree of anthropogenic alterations including water diversions, habitat alteration, pollution and introduction of alien species (Atwater et al. 1979, Nichols et al. 1986, Cohen and Carlton 1998). Although a combination of these factors have likely played a significant role in the loss of the natural physical and ecological function of the system, no single factor has likely been as influential in changing the aquatic community in recent decades as the vast number of alien species introduced into the estuary (Cohen and Carlton 1998).

Of these alien species, the overbite clam, *Potamocorbula amurensis*, is believed to have had the greatest ecological impact. The overbite clam underwent an explosive invasion following its introduction in 1986 (Carlton et al. 1990). The overbite clams high abundance (Hymanson 1991), broad tolerance of environmental conditions (Carlton et al. 1990) and high filtering capacity (Alpine and Cloern 1992; Werner and Hollibaugh 1993) have contributed to its success to the detriment of numerous native estuarine species. Within the San Francisco Estuary numerous groups of native species have exhibited sharp declines following the introduction, establishment and expansion of the overbite clam including phytoplankton (Alpine and Cloern 1992), bacteria (Werner and Hollibaugh 1993), zooplankton (Kimmerer and Orsi 1996), mysids (Orsi and Mecum 1996) and benthos (Nichols et al. 1990). The extended period of low abundance of fish captured within the San Francisco Estuary since the establishment of the overbite clam in 1986, is also believed to be due, at least in part, to the loss of system productivity at the plankton level and ultimately to reduced prey availability (Kimmerer 1998; Feyrer 2000).

While it is difficult to determine the exact cause for species declines, it is likely that the many direct and indirect effects of the overbite clam on estuarine food webs have been a major factor (Carlton et al 1990). One such indirect effect is the reduction in phytoplankton, a basic food source for numerous estuarine species including zooplankton and mysid shrimp (Kimmerer and Orsi 1996; Orsi and Mecum 1996; Werner and Hollibaugh 1993). Similarly, direct predation on the vulnerable life stages of zooplankton (nauplii or free floating eggs) is likely responsible for the reduction in abundance of zooplankton and may be resulting in significant reproductive failure in some instances (Kimmerer et al. 1994; Kimmerer and Penalva 2000). Together the effects of a reduced food supply and limited reproduction are likely exacerbating native zooplankton declines, in addition to competition with alien competitors.

Although numerous native invertebrates are exhibiting marked declines, some nonnative species may actually be increasing in abundance (see Orsi 1999 and 2000; Kimmerer and Penalva 2000). Thus, one possible scenario we are facing within the San Francisco Estuary is an *invasional*

meltdown (Simberloff and Van Holle 1999). An invasional meltdown is a process by which one or several alien species change the physical or biological conditions present in an ecosystem, which in turn facilitates the invasion of additional alien species. The overbite clam has demonstrated that it is a species capable of altering trophic dynamics within the San Francisco Estuary and, thus, could be responsible for such an invasional meltdown. Under this scenario, additional alien species entering the system may be at an advantage because they are either better adapted to handle the new ecological conditions or are less adversely affected. The continued introduction of alien species into the San Francisco Estuary (Cohen and Carlton 1998) will likely result in a new (but continually changing) San Francisco Estuary community composed of species better adapted to the existing conditions. Native species are likely to be at a significant disadvantage under the modified estuarine conditions because they have adapted to a system very different from what it is today. Thus, to preserve the San Francisco estuarine community, it is critical to understand (1) the distribution of native and alien species in estuarine habitats, (2) which habitats are favored by native species, (3) which habitats are favored by alien species, and (4) the conditions under which native species may be able to persist within this new community. Understanding these conditions within Suisun Marsh, an important nursery area for the San Francisco Estuary (Meng and Moyle, 1995; Meng and Matern in press; Matern and Moyle, submitted), is a key component to preserving the estuarine community.

Study Area

Suisun Marsh (Figure 1) is a large brackish tidal marsh (approximately 34,000 ha) at the downstream end of the Sacramento-San Joaquin Delta and at the upper end of the San Francisco Estuary. Approximately one-third of the marsh is tidally influenced and the remainder consists primarily of diked wetlands managed to attract waterfowl. Water inflow to the marsh is provided by a number of sources including tidal inflow from Grizzly Bay through lower Suisun and Montezuma Slough, direct river inflow via the Sacramento River through upper Montezuma Slough and from a number of local tributaries within the marsh including Green Valley, Suisun, Ledgewood, and Denverton Creek. Flow into the system is highly seasonal and is derived from winter rain pulses and increased flow in spring and early summer as a result of snowmelt from the Sierra Nevada.

Environmental conditions within the marsh vary depending upon freshwater inflow and slough location. Sloughs within the southwestern corner of the marsh have the highest salinities while sloughs in the southeastern portion of the marsh have the lowest salinities. Salinity within the northern areas of the marsh is generally intermediate and is seasonally influenced by local stream inflow. Salinity within Suisun Marsh has ranged from zero to near 17 ‰ during the course of our study of the fishes (1979 – present), peaking in the autumn of drought years and falling during periods of high outflow in spring. The proximity of Suisun Marsh to the large upper bay system (Grizzly, Suisun, Honker Bay) and the direct connection with the Sacramento River and numerous local tributaries has strongly influenced the diversity and abundance of the aquatic community (see Schroeter and Moyle 2000). There is also a large diversity of aquatic habitats found within Suisun Marsh including habitats with varying spatial and temporal gradients of salinity, spatial variability in size (small primary channels [e.g. First Mallard Branch 3-7 m wide and <1 m deep] to large deep sloughs [e.g. Montezuma Slough 100-150 m wide and greater than 7 m deep]), and sloughs with varying degrees of anthropogenic disturbance.

Suisun Marsh is thought to be part of the major nursery area for numerous species of fish (e.g. Sacramento splittail, delta smelt, longfin smelt, striped bass etc.), and outflow through the estuary is often managed so that the entrapment zone is located adjacent to Suisun Marsh. In addition, during periods of high salinity intrusion into the upper reaches of the San Francisco Estuary the California Department of Water Resources operates the Montezuma Salinity Control Gates to reduce salinities and maximize the freshwater inflow into Suisun Marsh.

Research Focus

The goal of the proposed research is to develop a better understanding of the abundance and distribution of shrimp, plankton and benthos within the diverse tidal marsh habitats of Suisun Marsh. Specific objectives are 1) to evaluate the relationships between presence of alien species, especially the overbite clam, on the local community structure and 2) to investigate the influence that habitat type and environmental conditions have on the type and abundance of species present in the tidal marsh community.

The proposed research specifically addresses the effects of the overbite clam on the San Francisco Estuary aquatic community and food web, with a focus on Suisun Marsh. The abundance of the overbite clam within Suisun Marsh appears to be low in certain habitats (see JUSTIFICATION for more details). Therefore, refugia may exist within Suisun Marsh for species vulnerable to the direct or indirect effects of the overbite clam. This appears to be the case for several species including native mysid shrimp (Carlson and Matern 2000; also preliminary UC Davis mysid catch results for 2000 and 2001; refer to JUSTIFICATION for more details). Additionally, in a time when it has become important to reverse the trends of tidal marsh and wetland loss (ERP Strategic Goal 4), we know surprisingly little about the aquatic communities found within natural tidal marshes and know even less about the communities which will colonize areas which have been or will be restored. It is particularly important to understand what kinds of habitats are favored by the few remaining native invertebrate species in the system and to determine what factors favor the production of invertebrates used as prey by native fishes, as well as by alien fishes important in fisheries (e.g., striped bass). Therefore, a great need exists to increase our understanding of the community composition within shallow water and slough habitats found within tidal marsh (ERP Strategic Goal 4), which are widely regarded as key habitats for restoration efforts. Suisun Marsh is an excellent location for these studies because not only are the diverse sloughs important habitats for fish and invertebrates, but they can serve as models for habitats that may be created in restoration projects.

To address the research objectives described above, the proposed research will answer the following questions:

(1) What are the patterns of abundance of overbite clam in different habitats and environmental conditions within Suisun Marsh?

(2) Is the abundance, composition and diversity of benthos, zooplankton and mysid shrimp within Suisun Marsh reduced in the presence of the overbite clam?

(3) Is the abundance of phytoplankton (estimated by chlorophyll a concentration) within Suisun Marsh reduced in the presence of the overbite clam, and if so can differences in concentrations be explained by overbite clam abundance and distribution.

(4) Is Suisun Marsh a refuge for native zooplankton, mysid shrimp and benthos, and if so which habitats and environmental conditions are important?

(5) Are prey species (zooplankton and benthos) equally distributed within and between sloughs with different physical habitats and water quality?

(6) Do the diverse tidal marsh habitats within Suisun Marsh support suitable densities of prey species to maintain its function as a nursery area for fish?

A2. JUSTIFICATION

The basic ***conceptual model*** behind this study is that small soft-bottomed sloughs support a higher diversity and abundance of invertebrates, especially native species, because they most resemble historic conditions in estuarine tidal sloughs and are largely unsuitable for establishment of high densities of overbite clams (Figure 2a and 2b). The small sloughs then become net exporters of invertebrates and phytoplankton, through tidal action and through fish production. The latter occurs because juvenile fishes, especially native fishes, rear most successfully in the sloughs because of the higher densities of food organisms. When they leave the rearing areas, they take the energy stored in their bodies into the main estuary. If this model of the system is correct, then restoration projects in the estuary may want to replicate conditions in the Suisun Marsh sloughs that favor invertebrates and native fishes, in an adaptive management framework.

Consistent with the goals and priorities of CALFED, the information obtained from the proposed research will (1) greatly improve our understanding of the current distribution of native and nonnative invertebrates in the San Francisco Estuary (ERP Strategic Goal 2), (2) provide information on the environmental and biological conditions which favor alien and native species (ERP Strategic Goal 5), (3) elucidate impacts that alien species are having on native species in the diverse habitats of Suisun Marsh (ERP Strategic Goal 5), and (4) improve our understanding of the effects of restoration activities and the resultant communities likely to be present within restored shallow water tidal marsh (ERP Strategic Goal 4).

At present, the effects of tidal marsh restoration on the target aquatic communities are largely unknown. This is because little is known about the species, which utilize the small channels and sloughs within existing tidal marsh. Most aquatic research and monitoring efforts in the San Francisco Estuary have focused on the species composition in the large channels and bay habitats (see Hymanson et al 1994; Peterson 1997; Orsi and Mecum 1996). However, restoration and rehabilitation projects within the Bay Region are focused on restoring tidal marsh habitats found adjacent to the bays and deepwater channels (e.g. Restoration Priority 1 - Bay Hill Slough West Tidal Wetland Restoration Project – Suisun Marsh and Bay; Tolay Creek Restoration Project – North Bay). Therefore, there is a current mismatch between existing ecological and biological

information and information needed to better understand the effects of proposed restoration activities.

This proposed research would be the first large-scale investigation into the distribution and abundance of important native and alien prey species within the small sloughs and channels present in Suisun Marsh. This information will provide a better understanding of the potential impacts of alien species and their distribution in channel and slough habitats of tidal marshes. In addition, this research will also provide much needed information on the likely community resulting from tidal marsh restoration projects within the system (Bay Region Restoration Priority [BRRP] 1 and 4). Such information will be important for making informed decisions on how best to prioritize resources for restoration projects, in order to provide the greatest benefit to the native aquatic community of the San Francisco Estuary (BRRP 8). Finally, this information will contribute significantly to our understanding of the current and historic patterns of distribution and abundance of larval, juvenile and adult fish within Suisun Marsh (UC Davis - Suisun Marsh Fish Survey 1979 – Present). The following section describes current patterns in benthos, mysid shrimp and select species of fish within Suisun Marsh.

Preliminary Supporting Data

Preliminary data supporting the proposed research was collected during the UCD Suisun Marsh Fish Survey. In addition, limited benthic sampling within Suisun Marsh was also conducted.

Benthos

The current distribution of the overbite clam within Suisun Marsh has not been well documented except within the larger Suisun and Montezuma sloughs (Hymanson 1991). Within these sloughs, Hymanson (1991) found varying densities of clams with abundances often exceeding 10,000 clams m^{-2}. Overbite clam abundance data collected by the UCD Suisun Marsh Fish Survey (Otter Trawl) is consistent with the results presented by Hymanson (1991) in that high densities of the overbite clam were observed in the large sloughs. However, catch of overbite clams in the smaller sloughs during this same time period was limited. Although otter trawls are not a good technique for sampling benthos, data collected during trawling efforts at least give an indication of the relative abundance of the overbite clam.

In order to verify the patterns observed from the otter trawl sampling data, a preliminary investigation into the species composition of the benthos was conducted in August 2001 with an Eckman Dredge within a variety of sloughs. Results from this preliminary survey revealed the greatest density of overbite clams was found within the large sloughs, intermediate numbers of clams within the middle sized sloughs and few to none found in the smaller sloughs and channels (Figure 3).

There was also a notable difference in size of clams collected with the largest clams (> 10 mm) collected in the largest sloughs at sites farthest downstream and smaller clams (< 3 mm) collected in upstream sloughs. Although the clearance rates of 10 mm clams, has been found to be greater than for the larger clams 20 mm clams, on a wet weight basis, the clearance rates on an individual basis are nearly two times greater for larger individuals (20 mm; Werner and Hollibaugh 1993). Within certain Suisun Marsh sloughs and the delta, overbite clams are

typically quite small (median size of 2.5 mm; Hymanson 1991) and thus may have even less of an impact on the aquatic community. Data is limited on the clearance rates of clams < 10 mm. However, if we assume clearance rates will continue to decrease linearly with decreasing size, we can calculate approximate clearance rates utilizing the regression relationships provided by Werner and Hollibaugh (1993). The results from these regression equations indicate that the filtering capacity of 10 and 20 mm clams is 16 and 36 times greater than that of 2.5 mm clams, respectively. Thus, the size class of overbite clams present within the local community will also strongly influence the impact on the aquatic community. Thus it is important to examine the size structure of clams present as well as determining abundance.

Another preliminary finding from our benthic survey which warrants further investigation is an inverse relationship between the size of slough and the total non-clam benthos (Figure 4). The evidence also suggests that there is likely an inverse relationship between the abundance of the overbite clam and the total non-clam benthos collected in a site (Figure 5). The observed inverse relationships between benthos and overbite clam abundance warrants further investigation, as does the fact that within Suisun Marsh the overbite clam is found in varying densities across a gradient of habitat types. Given this pattern of distribution and abundance, it is possible to evaluate the impact of the overbite clam on invertebrates at several trophic levels including phytoplankton, zooplankton, benthos and mysid shrimps. The distribution and abundance patterns exhibited by the overbite clam within Suisun Marsh also suggest that there may be some environmental or ecological constraints limiting the overbite clam. Developing a better understanding of these limiting factors will greatly improve our ability to effectively manage this ecosystem.

Shrimp

Mysid shrimp catch patterns suggest that native species may actually find refuge in Suisun Marsh. *Neomysis mercedis* and *N. kadiakensis* dominate the catch within the smaller Suisun Marsh sloughs sampled by UC Davis (Carlson and Matern 2000; UC Davis unpublished data). However, in the larger Suisun Marsh sloughs (Suisun and Montezuma sloughs) alien mysid shrimp, especially *Acanthomysis bowmani*, typically dominate the catch (Orsi 2000). Thus, there appears to be segregation between the native and alien mysid species within the sampled sloughs, with catch in the largest sloughs dominated by alien species and the smaller slough catch comprised mainly of native species. This pattern suggests that habitat preferences or differences in biological conditions may be differentially favoring either native or alien species.

In addition to differences in species composition within the various Suisun Marsh sloughs, there are also differences in abundance of mysids. Shallow sloughs sampled by our mysid-sampling program (Spring Branch, alternatively named First Mallard Branch and Denverton Slough) typically have three or more times as many mysids as the larger sloughs (Figure 6). Within the smallest slough, Spring Branch, the catch of mysids is also greatest within the farthest upstream site. Although much of this information is preliminary, it strongly suggests that there are differences in species composition and abundance of mysid shrimp within the various sloughs in Suisun Marsh and that size and distance upstream are important determinants in the abundance and species composition.

Fish

The preliminary benthos and shrimp data indicate that certain habitats within Suisun Marsh appear to be more productive, as measured by greater abundance of invertebrates, which may translate directly to greater numbers of prey species available to various fish species. By examining the historic Suisun Marsh Fish Survey data for trends in Sacramento splittail and tule perch catch, several interesting patterns emerge. First, Sacramento splittail and tule perch abundances between 1986 and 2000 were greatest within the small shallow sloughs. This catch pattern is most apparent for tule perch, which were predominantly captured within Spring Branch (First Mallard Branch) and Cutoff sloughs (Figure 7). Splittail catch was also high within Spring Branch, and Cutoff sloughs, as well as within Peytonia Slough (Figure 8). It is interesting that Cutoff and Spring Branch sloughs and even portions of Peytonia Slough are the most natural and unaltered tidal marsh habitats in Suisun Marsh. These results are interesting in that both splittail and tule perch are found to be most abundant in shallow water, natural tidal marsh habitat which also seems to have the greatest densities of mysid shrimp and the fewest overbite clam present.

Summary of Preliminary Supporting Data

Based on these preliminary data, shallow water habitat in Suisun Marsh is providing a positive benefit to at risk species (ERP Strategic Goal 1) and several important groups of prey species including benthos and mysid shrimp, which have been adversely affected in other areas of the estuary. This preliminary information also supports the effort toward increasing shallow water habitat by restoring tidal marsh (ERP Strategic Goal 4). Restoring natural tidal marsh will likely provide tangible benefits to numerous native species among many trophic levels including invertebrates and the ESA protected Sacramento splittail and the tule perch if similar tidal marsh habitat is restored. An important question that remains is what are the physical and biological characteristics within tidal marsh habitat, which result in high invertebrate and fish abundances. Once these characteristics are better understood, they can be used by the scientific community and resource managers within an adaptive management framework.

A3. APPROACH

An assessment of the biota (including the benthos, phytoplankton and zooplankton) within Suisun Marsh will provide a detailed look into the current state of the aquatic community in the largest tidal marsh found in the San Francisco Estuary. Utilizing this information, the complex relationships among native and alien species and the habitats in which they predominate can be determined. The current fish sampling dataset for Suisun Marsh (21 years) and the continued monitoring of the fish population during this proposed study will result in a greater understanding of the relationships between fish and prey abundance and how prey abundance might be influencing fish catch in the various sloughs in Suisun Marsh.

The basic research approach for the proposed study can be broken down into three general tasks. Task 1 includes field collection and identification of benthos. Task 2 includes the field collection and identification of mysid shrimp. Task 3 includes the field collection and identification of zooplankton. Specific methodology is discussed in the following section. The measurement of various physical and biological parameters will also be conducted at each site and water quality data will be collected at the time of each sample.

Methods

Field Collections and Laboratory Methods

At the onset of the study physical habitat measurements will be made at each site within each slough. Sites sampled will include 23 sites currently being sampled monthly by otter trawl by the UCD Suisun Marsh Fish Survey (Schroeter and Moyle 2000) with an additional 13 sites being distributed between Suisun, Montezuma, and Cordelia sloughs and Little Honker Bay (Figure 9). Transects will be established along the length of each site and depth, width, length of site and dominant substrate will be determined. Various measures of vegetative cover will also be determined. These data will be combined with water quality data to determine if habitat specific conditions exist within the sampled sloughs. These data will be critical in determining conditions, which may be limiting aquatic species distributions (both native and alien species). These data will contribute to our understanding of habitats which alien species are likely to occur in and could potentially colonize (i.e. given habitat restoration or expansion following change in environmental conditions) and will also contribute significantly to our understanding of native species biology and ecology.

Water quality data will be collected at each site during each visit with a Hydrolab® multi-meter. Data collected will include temperature, dissolved oxygen, salinity, specific conductance, pH, turbidity and Secchi disk depth. The Hydrolab® multi-meter will also be deployed periodically to determine if water quality conditions measured during sampling differ considerably from those present on a diel basis. Chlorophyll a concentrations, which will serve as an approximation of phytoplankton abundance, will be measured at one-meter depth at each sampling site using the Hydrolab® multi-meter. Temperature loggers will also be deployed throughout Suisun Marsh in order to better characterize the thermal characteristics both on a diel basis and also seasonally within the various sloughs.

Task 1: The Suisun Marsh benthos will be sampled bi-monthly between October 2002 and September 2004 (Task 1). Three replicate samples will be collected using an Eckman bottom grab (0.023 m^2 sampling area) at 36 sites distributed across Suisun Marsh (108 samples per month). Methods of collection and preservation will follow Hymanson et al 1994, except that a smaller (Eckman) bottom grab will be used because of the greater ease of use in the UC Davis Fisheries research boat used to sample the small sloughs within Suisun Marsh. The effectiveness of this sampling technique will be compared with samples from the Ponar dredge used elsewhere in the system prior to the start of the sampling program. The Ponar dredge will be used if the samples prove not to be readily comparable. In total, 648 benthic samples will be collected annually with a total of 1296 samples collected over the two-year study (October 2002 through September 2004).

Organisms collected in the benthic samples will be identified to the lowest possible taxonomic level and abundances will be reported as number of organisms collected m^{-2} (as reported by Hymanson et al 1994). If number of organisms collected per grab is high (> 400), then subsamples will be taken with a minimum subsample of 200 individuals and the total abundance

will be estimated according to the percent of sample processed. A reference collection of specimens captured prior to the start of this study (October 2002) will be made and verified by local taxonomy experts to ensure consistency and accuracy of identifications. Randomly selected samples will also be submitted to outside labs for quality control purposes.

Task 2: Mysid shrimp sampling (Task 2) will be conducted monthly at each of the sampling sites (see work schedule A8 below). This sampling schedule differs from current mysid sampling programs in that biweekly sampling will not be conducted during the spring and summer months (see Orsi and Mecum 1996). Based on our own mysid sampling results in Suisun Marsh the monthly catch does not differ substantially from the biweekly catch. Thus, it was determined that the benefits of obtaining a more spatially intensive survey throughout the varying habitats in Suisun Marsh would be of greater benefit than a more temporally intensive sampling regime. In order to ensure that the quality of data will not be jeopardized by this sampling regime, a comparison of catch with the California Department of Fish and Game mysid sampling program will be conducted after the third quarter results are analyzed. If large discrepancies exist within sloughs simultaneously sampled (Suisun and Montezuma), then a biweekly sampling regime will be included for year two (March 2004 – September 2004).

Mysid shrimp will be sampled via five-minute trawls with a 30 cm diameter conical sampling net (505 μm mesh) located within a rectangular towing frame similar to (Knutson and Orsi 1983). Sample times will need to be shorter (5 minutes versus ten minutes) than those used by Orsi and Mecum (1996), due to the smaller size and length of the sloughs which will be sampled in Suisun Marsh. In sloughs with depths greater than 4 X the net height (> 2 m), trawls will be stepped so shrimp residing in the bottom and middle portion of the water column are also sampled (Orsi and Mecum 1996). Mysid results will be reported in catch m^{-3} so that results from the various sampling programs will be comparable. Mysid shrimp will be identified to the lowest possible taxonomic level (usually species). Mysids will be subsampled if abundance per sample exceeds 400 individuals. A subdivided and numbered tray will be used for subsampling purposes.

Task 3: Zooplankton samples will also be collected monthly at each of the 36 sampling sites (Task 3) with a Clarke-Bumpus net (154 μm mesh) and a small pump based on methods in Orsi and Mecum (1996). Samples will be preserved and processed according to Kimmerer and Orsi (1996). The level of taxonomic identification in zooplankton samples will be based on Kimmerer and Orsi (1996). Adult copepods will be identified to species or genus and other taxa (cladocerans and rotifers) will be identified mainly to the generic level. Plankton samples will be subsampled if high abundance makes total identification prohibitive.

Attempts will be made to coordinate monthly collection dates with other sampling programs (IEP - California Department of Fish and Game – Zooplankton and Mysid Study; IEP – Department of Water Resources Benthic Monitoring Study) so that collected data will be comparable and some inferences can be made regarding differences in community structure and population densities between Suisun Marsh and other areas of the San Francisco Estuary.

In total, 648 benthic samples, 432 mysid samples and 432 zooplankton samples will be collected and processed each year. A total of 1296 benthic samples, 864 mysid samples and 864 zooplankton samples will be collected during this two-year investigation.

Analyses

Data will be analyzed using standard comparative techniques with analyses investigating differences in benthos, phytoplankton, and mysids in the presence and absence of overbite clam, in response to variation in habitat type and environmental variables. The specific analyses used to test the hypotheses previously listed will largely depend upon the pattern and type of distribution exhibited by the overbite clam and other species in the marsh. Cannonical correspondance analyses (CCA), a direct gradient analyses, will be used to identify factors, which may be controlling the distribution and abundance of both native and alien species within the marsh.

A4. FEASIBILITY

The sampling and sorting procedures are standard and can be performed by a number of individuals associated with the UC Davis Suisun Marsh sampling program. We have a back up boat available to us if something should happen to the boat we use for our regular sampling. We have a history of conducting regular sampling in the Marsh and see no reason why the present additional sampling should be difficult for us to perform. We also have a history of writing reports and publishing results in the peer-reviewed literature in a timely fashion.

A5. PERFORMANCE MEASURES

The required project reports (6 Quarterly Reports, 1 Annual Reports, and 1 Final Report) will serve as the basic performance measure. Quarterly project reports will be used to track sampling accomplishments and preliminary data trends and interpretation. Annual project reports will be used to present findings and project progress with respect to the specific research objectives. The ultimate performance measure will be the final report, publications and presentations that result from this research.

A6. DATA HANDLING AND STORAGE

Data will be stored in an Access database, either within the existing UC Davis, Suisun Marsh Fisheries Database or within a newly created database. Data from this project will be uploaded to the IEP server at the completion of the final report.

A7. EXPECTED PRODUCTS / OUTCOME

There will be multiple products produced by this investigation including peer-reviewed papers, presentations at scientific and public meetings and IEP Newsletter articles. We expect to continue to interact on a broad scale with individuals and groups conducting CALFED sponsored research and restoration projects, so they will be able to use the results of our study in a timely fashion.

A8. WORK SCHEDULE AND SCOPE

The proposed project is a two-year study with fieldwork beginning October 2002 and ending September 2004. Data entry will be conducted throughout the study and analyses will be conducted quarterly and annually on available data. The first annual report will be submitted by November 2003. The final report will be submitted by January 30, 2005. The following is a month-by-month breakdown of the work plan for Year 1 and Year 2:

YEAR 1 (October 2002 – September 2003)

Year	Month	Benthos (# Samples)	Zooplankton (# Samples)	Mysids (# Samples)	Other
2002	October	108	36	36	
	November		36	36	
	December	108	36	36	Quarterly Report
2003	January		36	36	
	February	108	36	36	
	March		36	36	Quarterly Report
	April	108	36	36	
	May		36	36	
	June	108	36	36	Quarterly Report
	July		36	36	
	August	108	36	36	
	September		36	36	Annual Report
	TOTAL	**648**	**432**	**432**	

YEAR 2 (October 2003 – September 2004)

Year	Month	Benthos (# Samples)	Zooplankton (# Samples)	Mysids (# Samples)	Other
2003	October	108	36	36	
	November		36	36	
	December	108	36	36	Quarterly Report
2004	January		36	36	
	February	108	36	36	
	March		36	36	Quarterly Report
	April	108	36	36	
	May		36	36	
	June	108	36	36	Quarterly Report
	July		36	36	
	August	108	36	36	
	September		36	36	Final Report
	TOTALS	**648**	**432**	**432**	

All components of the proposed research are critical in providing a solid understanding of the aquatic community present within tidal marsh habitat in Suisun Marsh and also the cumulative impacts on the food web in these habitats as a result of the effects of alien species. However the benthos and mysid shrimp are a critical component of the diets of *at risk species* such as the Sacramento splittail (Feyrer 2000) thus understanding their distribution throughout the various habitats in Suisun Marsh is greatly needed. Although UC Davis has been conducting fish research within Suisun Marsh for 21 years, the patterns of abundance of the various fish species are highly variable and are not entirely explained by variables such as outflow. Obtaining a more detailed understanding of the importance of the prey community for the species inhabiting Suisun Marsh is likely to provide greater explanatory power to current abundance and distribution trends observed in the marsh. The preliminary data collected thus far, indicates that prey species such as the benthos and mysid shrimp are strongly influenced by location and there is also a strong similarity in pattern exhibited by fish such as the Sacramento splittail and tule perch. Thus, if funds for the entire proposed study are not available, then it is highly recommended that Task 1 and Task 2 be funded together. Ecological studies with more than one year of study are more likely to detect "real" ecological paterns, and reduce the likelihood of reaching false conclusions. Thus it is recommended that the requested two years of funding are provided. However, if funding is not available then it is possible to shorten the proposed study to one year.

B. APPLICABILITY TO CALFED ERP STRATEGIC AND SCIENCE PROGRAM GOALS AND IMPLEMENTATION PLAN AND CVPIA PRIORITIES

B1. ERP, SCIENCE PROGRAM AND CVPIA PRIORITIES

Several of the CALFED ERP strategic goals will be addressed by this research. They include:

Goal 1: At Risk Species

The proposed study will have direct relevance to *At Risk Species* including Sacramento splittail and delta smelt. Results from the proposed study will provide information on the invertebrate communities typically used as prey by the Sacramento splittail and delta smelt and will further our understanding of the strong pattern of shallow water tidal marsh habitat use exhibited by splittail within Suisun Marsh. The proposed study will also shed light on the possible effects of proposed restoration activities on Sacramento splittail within shallow water habitats.

Goal 2: Ecosystem Properties and Biotic Communities

A main objective of the proposed study is to improve our understanding of the current distribution of native and alien species in the tidal marshes of the San Francisco Estuary and how those species are affected by various ecological conditions. This study will thus contribute substantially to our understanding of ecosystem properties and biotic communities within tidal marsh habitat for which little information is currently available. One major component of the proposed study which will greatly contribute to our understanding of ecosystem properties and biotic communities is the determination of overbite clam abundance patterns in tidal marsh habitats while investigating the abundance, composition and diversity of benthos, zooplankton

and mysid shrimp which may be adversely affected by this food web altering alien species. It is quite likely that tidal marsh habitat within Suisun Marsh is serving as a refuge for native zooplankton, mysid shrimp and benthos, and could also be an area of increased productivity as observed by increased abundance of mysid shrimp, benthos and fish abundance. Demonstrating that this is actually the case, will be invaluable in future restoration and management efforts within the San Francisco Estuary

Goal 4: Habitats: Protect and / or restore functional habitat types in the Bay-Delta estuary

The considerable loss of extensive tidal marsh habitat throughout the San Francisco estuary has undoubtedly had considerable effects on ecological system function and productivity. As stated within the ERP Implementation Plan, this loss of habitat is "assumed to be linked to declines in the *at risk species",* but little is known about the importance of shallow water tidal marsh habitat, the aquatic species. Thus, it is very difficult to determine the consequences of this habitat loss and even more difficult to predict the benfits of restoration activities. By providing detailed information on the invertebrate community present within shallow tidal marsh habitat within Suisun Marsh, this study will generate the much-needed information on the complexities and importance of this habitat type. Specific questions addressed by the proposed study which are relevant include: 4) Is Suisun Marsh a refuge for native zooplankton, mysid shrimp and benthos? 5) Are prey species (zooplankton and benthos) equally distributed within and between sloughs with different physical habitats and water quality? 6) Do the diverse tidal marsh habitats within Suisun Marsh support suitable densities of prey species to maintain its function as a nursery area for fish?

Because alien species have had such a large impact on the aquatic community present within the San Francisco Estuary one concern with any proposed habitat restoration project is, will it provide benefit to the species intended or to a host of alien species, which provide little or no benefit to the native aquatic community. Once again this information is limited for shallow water tidal wetland habitat. However the proposed study would provide the much-needed information on the likely community resulting and benefiting from such restoration activities within Suisun Marsh and similar habitat (Restoration Priority 1 - Bay Region " …restore tidal marsh in diked bay lands and shoreline along San Pablo Bay and the Napa and Petaluma rivers and Sonoma Creek especially in the Napa-Sonoma Marsh and Petaluma River marshes", "restore marshes along the northern and southern sides of Suisun Bay, Grizzly Bay and Honker Bay..", "In Suisun Marsh restore a continuous band from the confluence of Montezuma Slough and the Sacramento / San Joaquin rivers to the marshes western edge")

Goal 5: Non –native invasive species

The proposed research will specifically provide information on the distribution and extent of invasion of alien species within the shallow water tidal marsh habitats of Suisun Marsh. The proposed study will also shed light on the environmental and biological conditions, which favor alien and native species and will provide a better understanding of potential negative impacts that alien species, such as the overbite clam, may be having on native species.

The information obtained by this study will contribute significantly to our understanding of the concurrent and historic patterns of distribution and abundance of larval, juvenile and adult fish within Suisun Marsh (UC Davis -Suisun Marsh Fish Survey 1979 – Present). This information will specifically addresses several priorities listed in BRRP 4 and 8. The information collected should help in the design of future restoration projects and in the modification of existing projects, especially those using adaptive management procedures in their operation.

B2. Relationship to Other Ecosystem Restoration Projects

The results from this project can be used as a conceptual tool to assess the benefits and consequences of current tidal marsh restoration projects on the aquatic community including the Hill Slough West Tidal Wetland Restoration Project – Suisun Marsh and Bay and the Tolay Creek Restoration Project – North Bay. Furthermore, this project will shed light on the likely result of future tidal marsh restoration activities listed in and solicited by Restoration Priority 1 - Bay region. The results from this project will also greatly improve our understanding of the distribution, impacts and environmental conditions, which limit the many alien species found within the San Francisco Estuary (ERP Strategic Goal 2, 4, and 5). If results obtained after conducting extensive investigations into the abundance and distribution of benthos, mysids and zooplankton are in agreement with general patterns observed during preliminary analyses in Suisun Marsh, then it can be expected that tidal marsh restoration will greatly benefit a whole suite of native species including Sacramento splittail, tule perch and several species of native mysid shrimp.

B3. NEXT PHASE FUNDING REQUESTS

Not applicable

B4. PREVIOUS RECIPIENTS OF CALFED PROGRAM OR CVPIA FUNDING
Below are two multi-investigator projects that deal with the Cosumnes River and its floodplain. The focus of this work is on habitat use by the fish found within the surrounding community.

#99-NO6 Linked Hydrogeomorphic-ecosystem Models to Support Adaptive Management: Cosumnes-Mokelumne Paired Basin Project (ERP Program)

The second quarter was spent completing the 2001 floodplain sampling schedule, initiating the laboratory analysis of samples taken during the 2001 season and planning for the 2001 watershed sampling. In the second quarter we (1) completed our annual monitoring of the Cosumnes floodplain using seines, electrofishers, and fyke nets; (2) completed our annual monitoring of the river, sloughs and ditches adjacent to the Cosumnes floodplain using electrofishers; (3) continued monitoring of larval fishes in the floodplain ponds and in the rivers and sloughs adjacent to the floodplain using light traps and drift nets; (4) continued sorting and identifying larval fishes; (5) identified juvenile fish from sub-samples taken during the 2001 sampling season; (6) continued work on a paper on factors affecting distribution of Cosumnes River fishes; and (7) planned the 2001 watershed sampling and began sampling the lower river sites. Preliminary analysis of the 2001 floodplain season indicates that few native fishes utilized the floodplain during the 2001 season, likely a result of a short flooding season. The third quarter

was spent monitoring the upper and middle-lower watershed. In addition, laboratory analysis of fish samples from the floodplain during the first and second quarters also continued. During this time we (1) sampled 10 watershed sites using single pass electrofishing; (2) sampled five sites using 3 pass electrofishing; (3) collected quanitative macro-invertebrate samples for stable isotope analysis; (4) collected fish tissue samples in conjunction with macro-invertebrates for stable isotope analysis; and (5) began a micro-habitat analysis of redeye bass.
Accomplishments: presented 4 presentations at the CALFED Science conference.

#99-B193 McCormack-Williamson Tract Restoration Planning, Design and Monitoring Program I (ERP Program)

Sampling was initiated in the winter quarter of 2001 at 10 permanent elecrofishing sites and 7 trawling sites around the perimeter of the McCormack-Williamson Island. Fish monitoring around the perimeter of the tract began during the second quarter during which we: (1) Established and sampled 10 permanent electrofishing sites to be incorporated into a larger North Delta sampling regime with EBMUD and DFG; (2) conducted a second trawl effort around the perimeter of the tract; and (3) seined the interior pond located inside the eastern levee. Preliminary results showed that non-native fishes dominate the habitats surrounding the Tract during late spring conditions. In addition, a comprehensive analysis of habitat used by fish in the sloughs adjacent to the Tract was initiated.

Accomplishments: preliminary data will be presented at the IEP resident fishes meeting on November 8. 2001.

B5. SYSTEM-WIDE ECOSYSTEM BENEFITS

While this research project focuses mainly on Suisun Marsh, we anticipate that the findings will be applicable well outside the marsh because it will identify factors that favor native invertebrates and fish and will determine factors limiting the distribution of alien species. It will also suggest management strategies for existing tidal slough areas and for the design of restoration projects that focus on shallow-water habitat. The general approach the project takes, which is to examine communities of organisms, should also help in generating better understanding of ecosystem-level processes in tidal sloughs. In this respect, the proposed research fits in well with other UC Davis studies on fish communities in Suisun Marsh and the Delta.

C. QUALIFICATIONS

PETER B. MOYLE, PhD. Professor of Fish Biology, University of California, Davis, 1972-present.

Five selected publications.

1. Bennett, W.A., and P. B. Moyle. 1996. Where have all the fishes gone: interactive factors producing fish declines in the Sacramento-San Joaquin estuary. Pages 519-542 *in* J. T. Hollibaugh, ed. San Francisco Bay: the Ecosystem. San Francisco: AAAS, Pacific Division**.**

2. Yoshiyama, R. M., E. R. Gerstung, F. W. Fisher, and P. B. Moyle. 2000. Chinook salmon in California's Central Valley: an assessment. Fisheries 25(2):6-20.
3. Marchetti, M. P. and P. B. Moyle. 2000. Spatial and temporal ecology of native and introduced fish larvae in lower Putah Creek, California. Env. Biol. Fish. 58: 75-87.
4. Moyle, P. B., R. Pine, L. R. Brown, C. H. Hanson, B. Herbold, K. M. Lentz, L. Meng, J. J. Smith, D. A. Sweetnam, and L. Winternitz. 1996. Recovery plan for the Sacramento-San Joaquin Delta native fishes. US Fish and Wildlife Service, Portland, Oregon. 193 pp.
5. Moyle, P. B. 2001. Inland Fishes of California. 2nd edition. Berkeley: University of California Press (in press).

D. COST

D1. Budget

The total funds requested is $271,804.00. This cost includes two years of sampling the benthos, plankton and mysid shrimp (Tasks 1-3) and for the completion of the final report, publications, and presentations (Task 4).

See web forms for a detailed description of the budget.

D2. Cost Sharing

Not Applicable

E. LOCAL INVOLVEMENT

UC Davis has been involved in a 21 year Suisun Marsh fish monitoring project funded by the Department of Water Resources and therefore has an established presence within the local community.

F. COMPLIANCE WITH STANDARD TERMS AND CONDITIONS

The applicant agrees to comply with the standard State and Federal contract terms.

G. LITERATURE CITED

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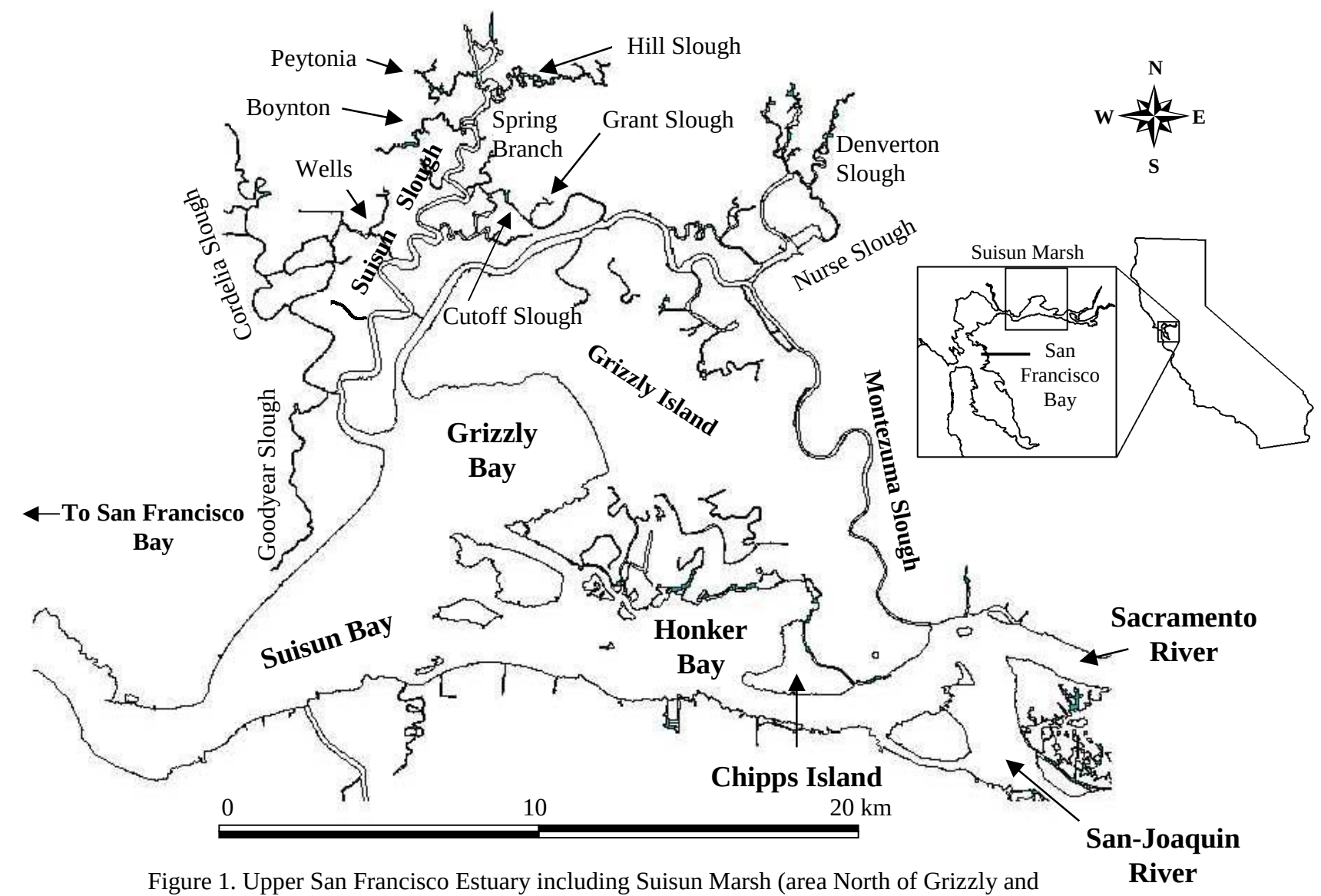
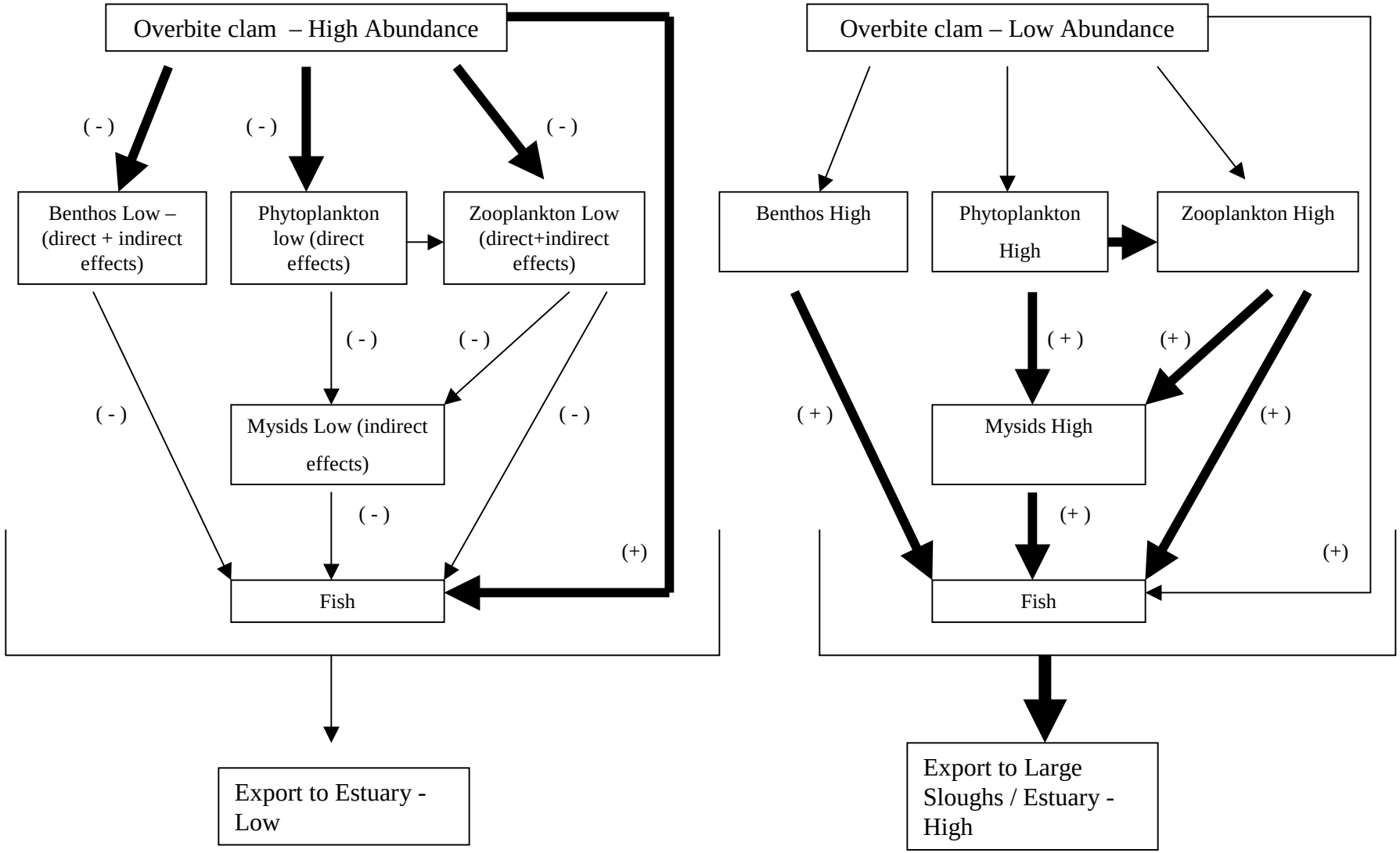


Figure 1. Upper San Francisco Estuary including Suisun Marsh (area North of Grizzly and Honker Bay).

Figure 2. Suisun Marsh Food Web Conceptual Model



A. Large sloughs with high overbite clam abundance and low non-clam invertebrate densities result in low export to the estuary and maintain low densities of native species and high densities of invasive species.

B. Small sloughs with low overbite clam abundance and high non-clam invertebrate abundance result in high export to larger sloughs and the estuary and maintain high native species and low alien species densities

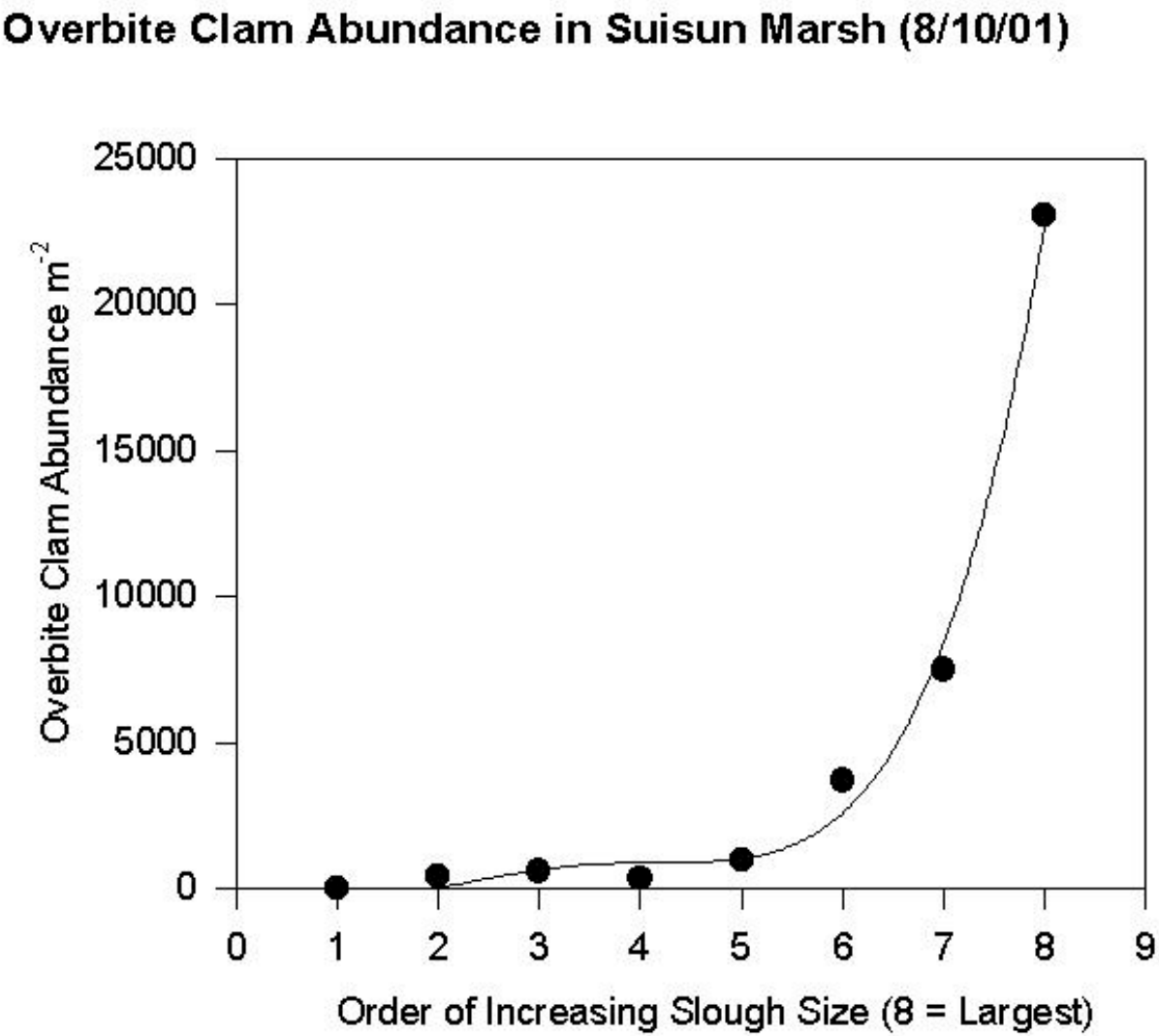


Figure 3. Abundance of overbite clam in benthic samples collected in Suisun Marsh sloughs. Sloughs are listed in order of increasing size (1 = smallest slough – Spring Branch and 8 = largest – Suisun Slough)

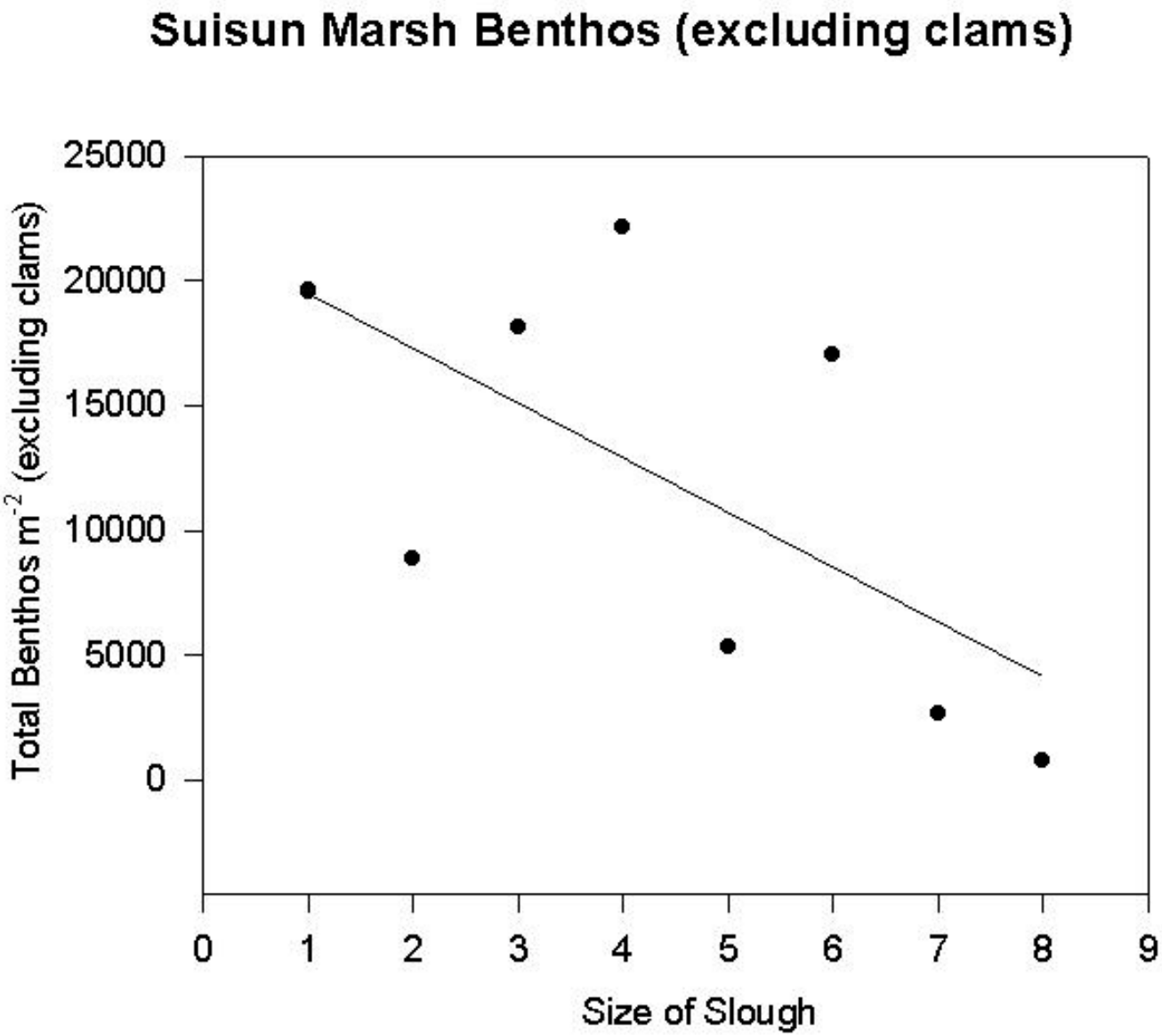


Figure 4. Abundance of non-clam benthos in in benthic samples collected in Suisun Marsh sloughs. Sloughs are listed in order of increasing size (1 = smallest slough – Spring Branch and 8 = largest – Suisun Slough)

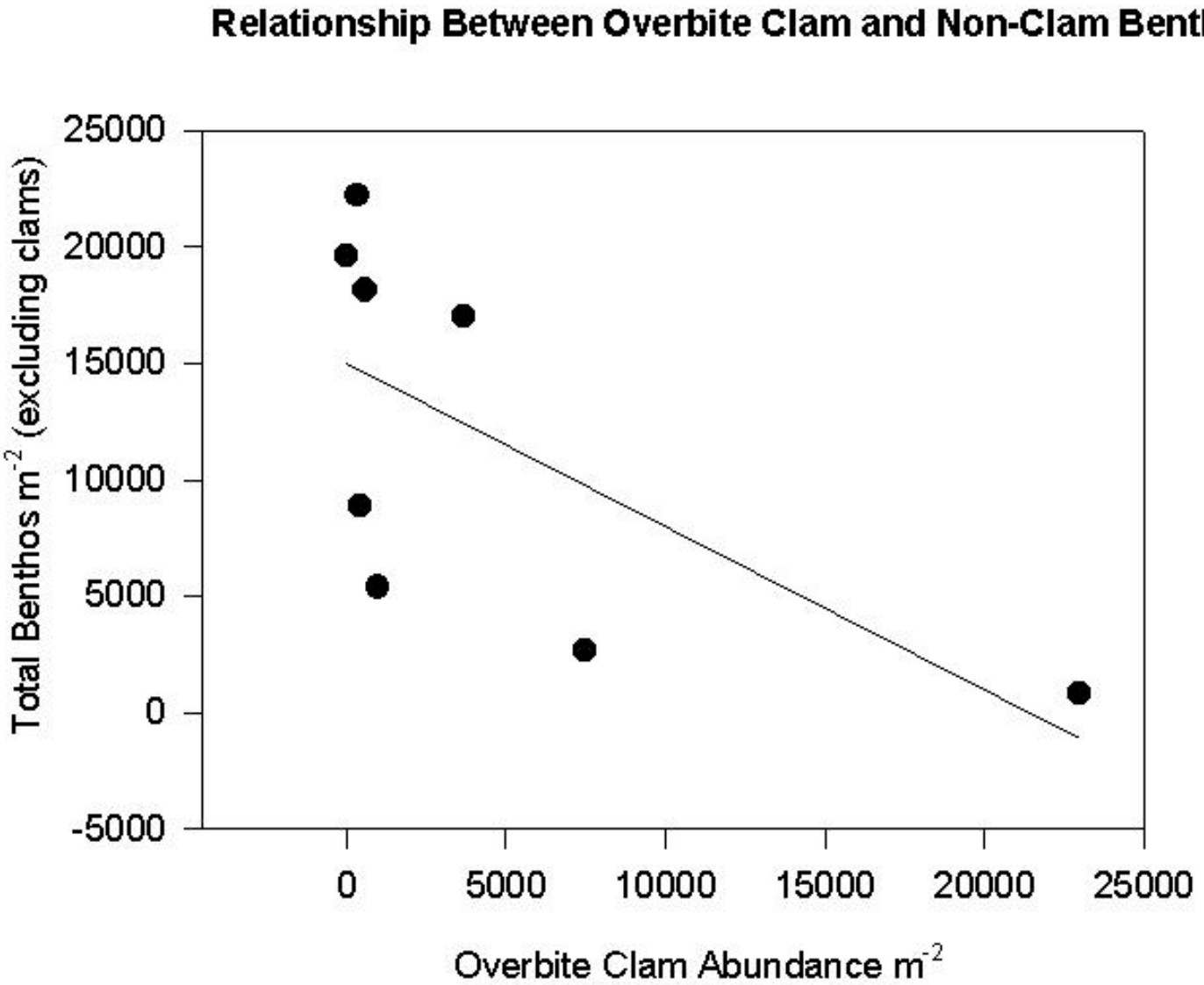


Figure 5. Relationship between non-clam benthos abundance and overbite clam abundance in Suisun Marsh sloughs.

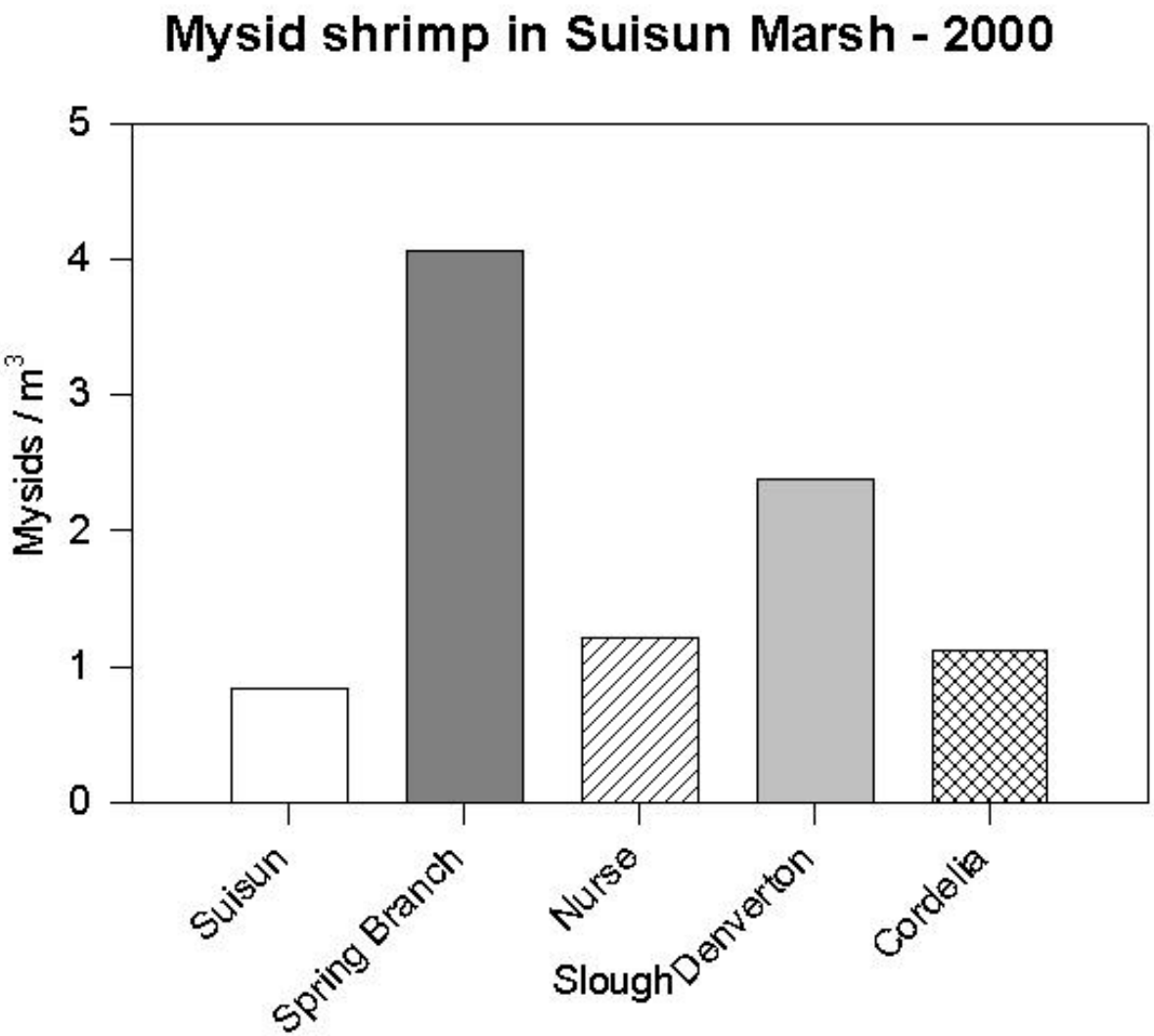


Figure 6. Mysid catch in Suisun Marsh sloughs (UC Davis Suisun Marsh Fish Survey). The smallest slough is Spring Branch followed by Denverton, Cordelia, Nurse and Suisun sloughs.

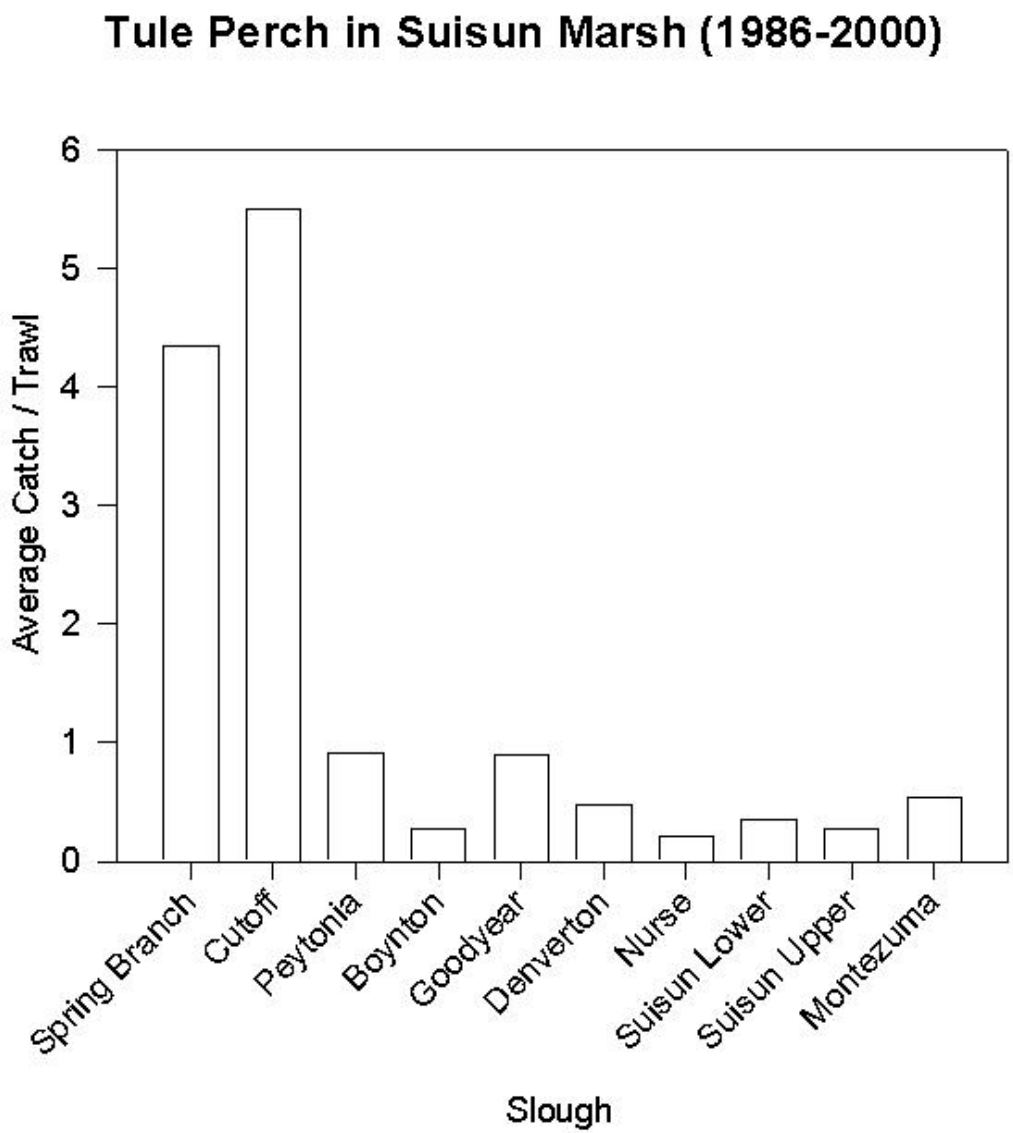


Figure 7. Otter trawl catch of Tule perch in Suisun Marsh sloughs (UC Davis Suisun Marsh Fish Survey). Sloughs are listed in order of increasing size with Spring Branch being the smallest.

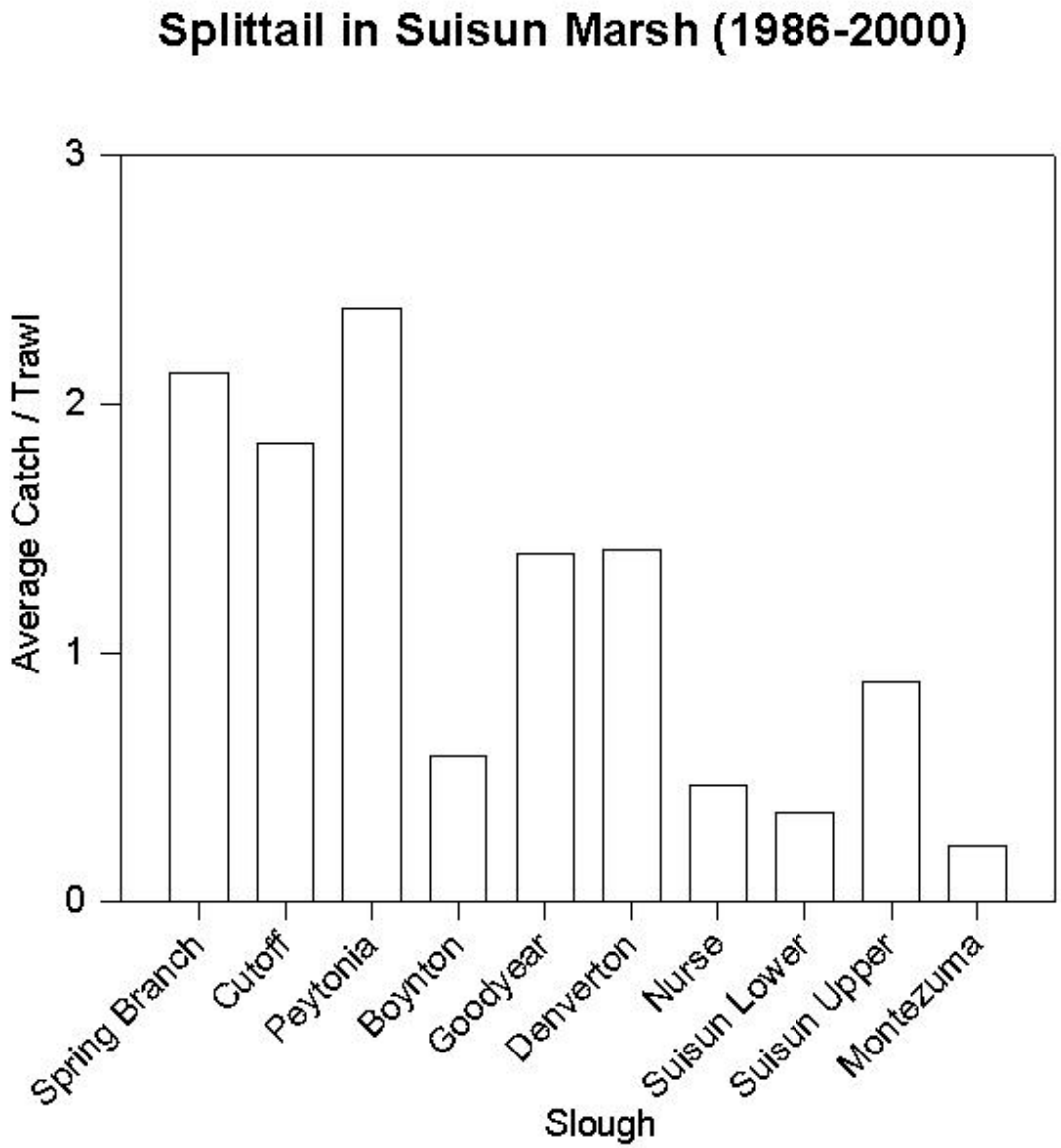


Figure 8. Otter trawl catch of Sacramento splittail in Suisun Marsh sloughs (UC Davis Suisun Marsh Fish Survey). Sloughs are listed in order of increasing size with Spring Branch being the smallest.

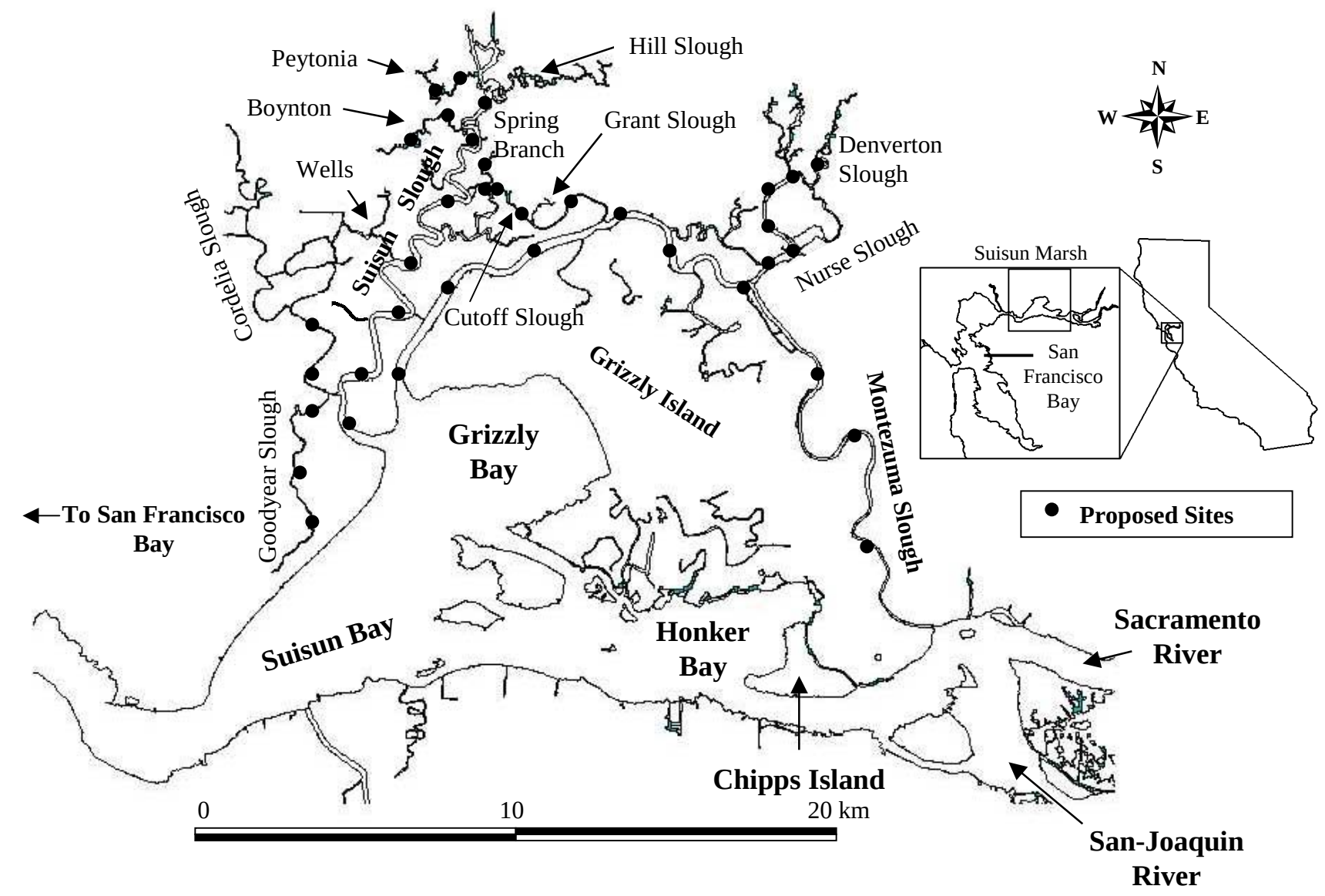


Figure 9. Proposed Suisun Marsh sampling sites.