



California Sea Grant College Program Progress Report

Project Information

Year _____ **Grant No.:** _____
Number R/SF-33 **Start Date:** 9/1/2009 **Completion Date:** 9/30/2012
Title Effects of Freshwater Flow and Population Connectivity on Benthic Community Dynamics in the San Francisco Estuary

Project Leader

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Project Hypothesis

Climate change and water diversions have greatly modified freshwater outflow into the San Francisco Estuary, changing the Estuary's salinity regime. These climate- and water diversion-driven changes in salinities may have a wide range of impacts on important components of the San Francisco Estuary including the distribution of threatened/endangered species, the success of habitat restoration and the management of invasive species. Previous work has shown significant variation in the recruitment and survival of numerous species throughout the Estuary linked to freshwater outflow levels.

We hypothesized that higher levels of freshwater outflow during wetter years (and/or due to water management practices) would stimulate higher levels of reproduction and/or recruitment in some populations, leading to mass recruitment events; conversely, recruitment will be relatively lower in these areas during dry years. Determining whether the observation of mass recruitment events is linked to parental environmental conditions (stimulating greater-than-usual reproduction) or to altered circulation patterns

Project Goals and Objectives

We examined two important, closely-linked questions with direct implications for restoration efforts of the native oyster *Ostrea lurida* and the management of invasive species in the Estuary, including the mussel *Mytilus galloprovincialis*: (1) How are local populations of these species connected to each other in the San Francisco Estuary? (2) How does low salinity exposure from climate change-driven winter storms affect the fitness and reproductive output of these species?

We used long-term survey sites to track the abundance of these focal species in the Bay. We then used trace elemental fingerprinting methods to determine the natal origin and fate of larvae of these taxa, and also conducted salinity stress tests to determine low salinity tolerances and examine effects of low salinity stress on reproductive output.

Briefly describe project methodology

native species that is currently the target of restoration efforts, while the bay mussel *Mytilus* spp. are composed of a widespread, dominant invasive species (*M. galloprovincialis*) and a native congener (*M. trossulus*) with which it hybridizes. We established long-term survey sites to track the abundance of these focal species in the Bay through repeated surveys, and measured growth rates, fecundity, survival, and biweekly recruitment levels to assess population structure and demography over time. We used trace elemental fingerprinting methods to determine the natal origin and fate of larvae of these taxa, and we also conducted salinity stress tests to try to determine low salinity tolerances and examine effects of low salinity stress on reproductive output.

Describe progress and accomplishments toward meeting goals and objectives.

We collected two years' worth of detailed demographic data on *Ostrea* populations, 1.5 years of data on *Mytilus* populations, and two years of detailed environmental measurements at 10 sites in the San Francisco Estuary. We have shown clear links between freshwater flow and geographic patterns of oyster mortality, fecundity, recruitment, and ultimately, population density and size-frequency structure at each site. We enumerated clear field-level relationships between oyster demography and environmental conditions. We used these data to parameterize models describing oyster population dynamics in response to freshwater flow, which we are testing with additional data from another project. We are constructing similar models for *Mytilus*. We have conducted analyses of historical and projected future freshwater flow in the San Francisco Estuary to project *Ostrea*'s likely population responses based on our data and models. Although this project only spanned three years (Sept 2009 - Sept 2012), our data link clearly to previous work (Grosholz 2007; Zabin 2010) with whom we maintain active and ongoing collaborations, and to current work (National Estuarine Research Reserve Science Collaborative grant to M. Ferner, A. Chang, E. Grosholz, C. Zabin, et al., 2011); and the ability to use these data together vastly increases our predictive power in assessing oyster population responses to environmental conditions.

We have completed trace element microchemistry analyses for 2009 and 2010; however, our results were inconclusive due to insufficient sample size despite extraordinary collection efforts. We increased our efforts following the wetter winter of 2010-2011, and were able to collect sufficient samples to assess connectivity. Analysis is in progress.

We have preliminary experimental assessments of salinity tolerances; due to significant problems with facilities and equipment, we were unable to complete full experimental runs. We have since secured additional funding to complete these tests.

PROJECT MODIFICATIONS: Explain briefly any substantial modifications in research plans, including new directions pursued and ancillary research topics developed. Describe major problems encountered and how they were resolved.

In year one, the project proceeded mostly as planned, despite uncertain funding. However, the delay in funding caused us to miss the recruitment season for 2009, and made connectivity studies largely fruitless as low fecundity levels meant that we had inadequate sample size to assess connectivity. This issue continued into 2010, where we still lacked adequate sample size to assess connectivity.

Equipment and facilities failures resulted in our being unable to successfully complete full experiments testing the salinity tolerances of *Ostrea* and *Mytilus* in 2010 and again in 2011. We have since secured additional funding (2012-2013) to complete these tests.

In late 2010-2011, we chose to focus our remaining funds on *Ostrea*, as this species was the original focus and main priority of the grant. We will seek additional funding to complete analyses of *Mytilus* populations. In the mean time, we continued to work up data and models of population density, recruitment, survival, and connectivity for *Mytilus*.

Data collection was originally scheduled for 2009 and 2010 only. However, the wet winter and spring in 2011 created a unique opportunity within the last 5 years to collect data on how oyster fecundity, recruitment, and connectivity patterns change in response to high freshwater flow entering San Francisco Bay (objective 2). Additional time was essential to completing data collection, preparing samples for trace element microchemistry analyses to determine the natal origins of newly settled oysters, and to analyze the data and prepare manuscripts and the final report. Since we were unable to collect data for most of the recruitment season in 2009 for reasons related to the availability of funds (which arrived in mid-September 2009), our additional data for summer 2011 ensured that we had at least two solid years of data (2010 and 2011). These data are essential to informing a broader understanding of *O. lurida* population dynamics and connectivity patterns as related to freshwater flow. We are completing

PROJECT OUTCOMES: Briefly describe data, databases, physical collections, intellectual property, models, instruments, equipment, techniques, etc., developed as a result of this project and how they are being shared.

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IMPACTS OF PROJECT: Briefly describe how this project has contributed to a discipline; to developing human resources; to developing physical, institutional or information resources; technology transfer; and society beyond science and technology. Please notify CASG of impacts that occur after your project ends; CASG may contact you after your project ends to learn about additional impacts that occur over time.

This work was a centerpiece of several undergraduate classes at Dominican University (San Rafael, CA) developed and taught by Dr. Lindsay Sullivan, a former CALFED postdoctoral fellow. In collaboration with Dr. Sullivan, we provided a framework for students to learn about estuarine environments, data collection, and the process of scientific research. Students gained hands-on experience in collecting, managing, analyzing, and presenting data that informed ongoing research into oyster population dynamics in the San Francisco Estuary.

BENEFITS, COMMERCIALIZATION, AND APPLICATION OF PROJECT RESULTS: Please list any companies, agencies, organizations or individuals who have used your project results, scientific/technical advice, etc., and provide names, emails and phone numbers. Briefly describe how results were used and quantify results and socioeconomic benefits, if possible.

This work has clearly demonstrated complex links between environmental conditions (freshwater flow) and population biology responses of oysters in the San Francisco Estuary. Every stage of the oyster's life cycle is affected by variation in freshwater flow, which is determined both by climate and watershed management.

Surprising patterns in demography (especially fecundity and recruitment) were documented, clearly identifying links between different life stages and between these life stages and environmental conditions that must be better understood to predict population responses to changing environmental conditions; all of this is a clear prerequisite to effective management of this important native species.

ECONOMIC BENEFITS generated by discovery, exploration and development of new, sustainable coastal, ocean and aquatic resources (i.e., aquaculture, marine natural products, foods, pharmaceuticals).

Issue-based **forecast capabilities** to predict the impacts of a single ecosystem stressor, developed and used for management (i.e., climate change, extreme natural events, pollution, invasive species, and land resource use).

Our data and models provide us with a first-pass attempt to forecast oyster (and mussel) population responses to freshwater flow variation in the San Francisco Estuary.

Tools, technologies and information services developed (i.e., land cover data, benthic habitat maps, environmental sensitivity index maps, remote sensing, biosensors, AUVs, genetic markers, technical assistance, educational materials, curricula, training).

Publications (list in appropriate category below) Each listing should be a stand-alone bibliographic reference, including all authors' names. For each Publication type, specify title, authors, date and journal details, where appropriate (repeat headers as necessary).

Technical Reports

Title	Authors	Date
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Conference Papers, Proceedings, Symposia

Conference Title	CALFED Bay-Delta Science Conference Going with the flow or staying close to home_ Population connectivity, freshwater flow, and native oyster restoration in	Location	Oakland, CA	Date	29 Sept 2010	▲
Conference Title	Western Society of Naturalists Annual Meeting Going with the flow or staying close to home_ Population dynamics and connectivity of bivalves in San Francisco Bay.	Location	San Diego, CA	Date	14 Nov 2010	
Conference Title	Ecological Society of America Annual Meeting	Location	Austin, TX	Date	12 Aug 2011	

	quality and population dynamics of Olympia oysters in San Francisco Bay		Morgan SG	
Conference	State of the San Francisco Estuary Meeting	Location	Oakland, CA	Date 20 Sept 2011
Title	Great place to live, but I wouldn't want to raise my kids there: Linking habitat quality and population dynamics of Olympia oysters	Authors	Chang AL, Deck AK, Malm PD, Willits K, Attoe S, Fisher JL, Morgan SG	
Conference	Delta Science Conference	Location	Sacramento, CA	Date 16 Oct 2012
Title	Location, location, location: What is the best place for Olympia oysters growing up in San Francisco Bay_	Authors	Chang AL, Deck AK, Malm PD, Willits K, Attoe S, Fisher JL, Morgan SG	

Peer-reviewed journal articles or book chapters

Non-peer Reviewed Reprints

Freshwater flow and population connectivity of <i>Ostrea lurida</i> in San Francisco Bay	Chang AL, Deck AK, and SG Morgan	8 Feb 2011	▲ ▼
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Publications, Brochures, Fact Sheets

Books & Monographs

Handbooks, Manuals, Guides

Electronic publications: (non-print formats).

Maps, Charts, Atlases

Theses, dissertations

Newsletters, periodicals

Program reports (annual/biennial, strategic plans, implementation plans)

Educational Documents

Topical Websites and Blogs

Miscellaneous documents (not listed above).

MEDIA COVERAGE: Select 'Yes' or 'No'. If yes, describe any radio, TV, web site, newspaper, magazine coverage your project has received. Send original clippings or photocopies to the Sea Grant Communications Office.

MEDIA NOTES: Brief description of the type media coverage your project has received.

DISSEMINATION OF RESULTS: List any other ways in which results of your project have been disseminated. Indicate targeted audiences, location, date and method.

Presentation and publication of summary handout describing project and results for the San Francisco Bay Native Oyster Working Group, a group of scientists, students, conservation / restoration practitioners, and others who meet on a regular basis to discuss and collaborate on research and restoration efforts for *Ostrea lurida* in San Francisco Bay.

Presentation to the Estuarine Ecology Team, a group of scientists and managers who meet regularly to discuss a range of scientific topics relating to San Francisco Bay-Delta ecology.

WORKSHOPS AND PRESENTATIONS: A brief description of location, date, time, topic, number of attendees and name of presenter.

San Francisco Bay Native Oyster Working Group, San Rafael, CA. 8 Feb 2011. 15 people, discussed *Ostrea lurida* research and restoration efforts in the San Francisco Estuary. Work from this project presented by Anna Deck.

COOPERATING ORGANIZATIONS: List those (e.g., county or state agencies, etc.) who provided financial, technical or other assistance to your project since its inception. Describe the nature of their cooperation.

Federal Organizations

NOAA

Regional Organizations

State Organizations**Nongovernment Organizations****International Organizations****Industry Organizations****Academic Organizations**

University of California Davis

Smithsonian Environmental Research Center

Sea Grant Organizations**Other Organizations****INTERNATIONAL IMPLICATIONS: Does your project involve any colleagues overseas or have international implications?**

The models and relationships between populations and environmental factors derived in this study may be applicable to a wide range of estuaries worldwide where freshwater flow is an ongoing concern for management and restoration.

AWARDS: List any special awards or honors that you, or any co-project leaders, have received during the duration of this project.**KEYWORDS: List keywords that will be useful in indexing your project.****PATENTS: Please list any patents or patent licenses that have resulted from this project, and complete the patent statement form available on the web site.****NOTES: Please list any additional information in the notes area****FOR ALL STUDENTS SUPPORTED BY THIS GRANT, PLEASE LIST:**

Volunteer Count 30

Graduate Student Info



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