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Title

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Publication Date

2010-02-23

Supplemental Material

<https://escholarship.org/uc/item/8zr5h69f#supplemental>

**California Sea Grant Sea Grant
Final Project Progress Report**

02/23/2010

R/ENV-203

02/01/2007-6/30/2010

Investigating the Limits of Native Oyster Recovery and Restoration

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Project Hypotheses

- A. Oyster recruitment will be higher at inner bay sites than the outer bay sites and density of recruits will be positively associated with adult oyster density.
- B. Mortality due to predators will be greater in the inner bay than the outer bay sites.
- C. Introduced predators have a greater per capita impact on oysters than native predators.
- D. Growth rates of oysters will be higher in the inner bay than the outer bay.
- E. Mortality due to overgrowth by space competitors will be higher in the inner bay than the outer bay.
- F. Oyster growth and survival will be higher at inner bay sites and will show a positive linear increase with increasing temperature and phytoplankton abundance.

Project Goals and Objectives

The objectives for 2006-2007 are:

Quantify site specific variation in recruitment (Objective 1)

Quantify the relationship between water column variables and native oyster demography (Objective 4)

The objectives for 2007-2008 are:

Quantify the impacts of introduced and native predators on native oyster growth and survival (Objective 2)

The objectives for 2008-2009 are:

Quantify the impacts of space competitors on native oyster survival (Objective 3)

Briefly describe project methodology

We tested fundamental predictions emerging from studies of invasive species on native communities. Current literature reviews showed that introduced consumers had a greater impact on native species than do native consumers. The experiments we used provided an important extension of these predictions by explicitly testing whether the impacts of exotic predators are significantly greater than their native counterparts. We also experimentally tested the influence of space competitors on the recruitment, growth and survival of native oysters under a

variety of conditions. Finally, we used a mensurative experimental approach to examine the influence of water column parameters including temperature, salinity and phytoplankton biomass on oyster recruitment, growth and survival. We determined how these processes varied along the physical and biogeochemical gradients present in both Tomales Bay and San Francisco Bay. The data generated by this project has not only provided information about the basic ecology of this influential foundation species and tested important hypotheses in benthic ecology and invasion biology, but has also provided critical information for prioritizing sites for future oyster restoration projects in both San Francisco and Tomales Bays.

Describe progress and accomplishments toward meeting goals and objectives

We have demonstrated the importance of native predators, specifically whelks (a.k.a. oyster drills) on the survival of native oysters. Our work showed that in the lower bay (closer to the ocean), the presence of native crabs and whelks resulted in a trophic cascade that supported healthy native oyster populations. Native crabs preyed on native whelks and inhibited their foraging on oysters, thus controlling overall predation on the oysters. In the upper bay (closer to river outflows), where invasive crabs and whelks have replaced native crabs and whelks, the trophic cascade broke down, introduced crabs did not control introduced whelks, which preyed freely on native oysters, thus decimating these oyster populations. Similar experiments in San Francisco Bay documented a reduced role of whelk predation on oysters due to a much more limited distribution, which occurred in only a few North Bay sites. We found that space competitors had a very minor impact on native oyster demography in Tomales Bay. Our experiments from this site showed that the space competitors had little impact on oyster growth and survival with fairly modest colonization of experimental substrata. Similar experiments in San Francisco Bay showed more extensive fouling by space competitors and a more significant effect of these species on the growth and survival of oysters. Finally, our data from Tomales Bay showed a clear and strong coupling between benthic and pelagic processes. Our data demonstrated that oyster growth was strongly associated with a predictable phytoplankton maximum in the middle of the bay. Oyster growth did show a significant association with gradients in temperature and salinity. Recruitment, however, did show a predictable pattern with the temperature/salinity gradient and was substantially higher recruitment moving from lower to upper bay associated with increasing water residence time.

Project modifications

Because of budget constraints, we opted not to purchase a spectrophotometer in the first year. We instead were able to use a fluorometer that was available at Bodega Marine Lab adequate for quantifying chlorophyll a in the water column.

Project outcomes

We have created lists of introduced species on hard substratum for both bays as well as site-based descriptions of the distributions of native and introduced species in both Tomales and San Francisco Bay. We have also pioneered a range of techniques from spawning, settling and raising oysters in the lab to outplanting, marking and tracking oysters over multiple years. Many of these techniques can be directly used by groups attempting to restore native oyster populations in these bays. Finally, we are currently finishing a numerical model of oyster demography for Tomales Bay that examines the effects interannual variation in recruitment, growth and survival along the estuarine gradient and the impacts this has on oyster density and size distributions.

Impacts of project

This project has helped develop the thesis projects for three graduate students, one who has now completed their Ph.D., another working towards finishing a Ph.D. and a third working towards finishing a Master's degree. This project has also supported a postdoctoral researcher and junior specialist and aided in their professional experience and development.

Benefits, commercialization and application of project results

There are no immediate commercial applications of our results. However, our results are immediately applicable to native oyster restoration and should be the basis for any decisions by resource managers regarding the location and protocols for conducting oyster habitat restoration. This information is immediately available to all resource managers and stakeholders.

Economic benefits generated by discovery

There are no direct economic benefits currently derived from this project.

Issue-based forecast capabilities

We can predict the impacts of invasive predators and space competitors on a per site basis on the future and fate of native oyster restoration efforts.

Tools, technologies and information services developed

We can provide site rankings in terms of the abundances of invasive predators, native and non-native space competitors and other taxon based lists of importance for oyster restoration. This information is freely available to any group needing this information for native oyster restoration in San Francisco or Tomales Bays.

Publications**Technical reports**

Title: Shellfish Restoration Goals: Final Report for the Subtidal Goals Committee

Report to NOAA and Association of Bay Area Governments (ABAG)

Authors: C.J. Zabin, S. Attoe, E. D. Grosholz, C. Coleman-Hulbert

Date: June 1, 2009

Title: Sublethal Effects of the November 2007 Cosco Busan Oil Spill on Native Oysters

Report to California Dept. of Fish and Game

Authors: C. Zabin, E. Grosholz and S. Attoe

Date: Sept. 28, 2009

Conference papers, proceedings, symposia

Title: Patterns of Native Oyster Growth, Recruitment, and Survival in Tomales Bay, CA

Authors: A. Deck and E.D. Grosholz

Date: March 2009

Conference Title: California Estuarine Research Society

Location: Bodega Bay, CA

Title: Changing salinity regime may affect oyster survival and restoration potential

Authors: S. Attoe and E.D. Grosholz

Date: March 2009

Conference Title: California Estuarine Research Society

Location: Bodega Bay, CA

Title: Olympia oyster (*Ostrea lurida*) recruitment, growth, and survival along physical and biological gradients in a central California estuary

Authors: A. Deck and E.D. Grosholz

Date: November 2009

Conference Title: Western Society of Naturalists

Location: Monterey, CA

Title: Invasive species alter food webs by simplifying and eliminating trophic cascades

Authors: D. L., Kimbro, E. D. Grosholz, A. Baukus, N. Nesbitt, N. Travis

Date: August 2008

Conference Title: Ecological Society of America

Location: San Jose, CA

Title: Invasive species alter food webs by simplifying and eliminating trophic cascades

Authors: D. L., Kimbro, E. D. Grosholz, A. Baukus, N. Nesbitt, N. Travis

Date: November 2007

Conference Title: Western Society of Naturalists

Location: Ventura, CA

Title: Invasive species cause large-scale loss of native California oyster habitat by disrupting trophic cascades.

Authors: Kimbro, D. and E.D. Grosholz

Date: August 2009

Conference Title: International Marine Bioinvasions Conference

Location: August 2009

Peer-reviewed journal articles or book chapters

Title: Coastal oceanographic processes influence the growth and size of a key estuarine species, the Olympia oyster

Authors: Kimbro, D.L., J.L. Largier and E.D. Grosholz.

Date: 2009

Journal Name: Limnology and Oceanography

Issue/Page Numbers: 54: 1425 -1437

Title: Invasive species cause large-scale loss of native California oysters by disrupting trophic cascades.

Authors: Kimbro, D.L., E.D. Grosholz, A.J. Baukus, N.J. Nesbitt, N.M. Travis, S. Attoe and C. Coleman-Hulbert.

Date: 2009

Journal Name: Oecologia

Issue/Page Numbers: 160: 563-575.

Theses, dissertations

Title: Evolutionary history, predation, and coastal upwelling interactively influence native oyster habitat in Tomales Bay, California
Authors: David Kimbro
Schools: University of California, Davis
Date: 2008

Media coverage

Name of publication/radio station, etc: *West Marine Citizen*
City: Pt. Reyes Station
State: CA
Date of publication/broadcast: July 2009
Headline or topic: Oysters in Tomales Bay

Name of publication/radio station, etc: KGO Television
City: San Francisco
State: CA
Date of publication/broadcast: October 2009
Headline or topic: Invasive snails and oysters in Tomales Bay, CA

Name of publication/radio station, etc: Local radio station and Pt. Reyes Learning Center
City: Pt. Reyes Station
State: CA
Date of publication/broadcast: January 2010 (broadcast and podcast)
Headline or topic: Oysters in Tomales Bay

Students

David L. Kimbro
University of California, Davis
Department of Environmental Science and Policy
Degree program enrolled in: Ph.D.
Theses/dissertation title: Evolutionary history, predation, and coastal upwelling interactively influence native oyster habitat in Tomales Bay, California
Supported by Sea Grant funds? yes no
Start date: 01/01/2008
End date: 06/30/2008

Anna K. Deck
University of California, Davis
Department of Environmental Science and Policy
Degree program enrolled in: Master's
Theses/dissertation title: in progress
Supported by Sea Grant funds? yes no
Start date: 07/01/2007
End date: 06/30/2010

Brian Cheng
University of California, Davis
Department of Environmental Science and Policy
Department
Degree program enrolled in: Ph.D.
Theses/dissertation title: in progress
Supported by Sea Grant funds? yes no
Start date: 04/01/2009
End date: 09/01/2009

How many students/volunteers were involved in the project? 6

Cooperating organizations

Federal

National Marine Fisheries Service Habitat Restoration Program

Nongovernmental

Point Reyes National Seashore Association

International implications

none

Keywords

European green crabs, eastern oyster drill, competition, predation, recruitment, phytoplankton