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West Coast

Native Oyster Restoration:

2006 Workshop Proceedings

September 6-8, 2006
San Rafael, CA

West Coast Native Oyster Restoration: 2006 Workshop Proceedings

NOAA Restoration Center
Office of Habitat Conservation
National Marine Fisheries Service

June 2007

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Save San Francisco Bay Association
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Foreword

The Olympia oyster[1] was once a profitable commercial commodity along the Pacific coast, as well as an important contributor to estuarine health and species diversity. However, overharvesting, urban development, pollution, siltation, and the introduction of non-native species have caused significant declines in native oyster populations. Today remnant, reproductive populations of native oyster still exist throughout much of the historic range from Alaska to Baja California, Mexico, although the northern range limit may be northern British Columbia.

Through the National Oceanic and Atmospheric Administration's (NOAA) Community-based Restoration Program (CRP), efforts to revive native oyster populations in Washington, Oregon, and California have gained popularity with local community groups, tribes, and state coastal managers, as well as the press. To date, over $900,000 in federal funding has been spent on implementing pilot oyster restoration projects in these states. Data gathered from these projects have demonstrated that reseeding efforts and the placement of suitable substrate for larval settlement have been successful.

These successes have encouraged practitioners to continue growing restoration efforts, both in scale and number, but with limited science to guide and document success. Only scant information is available on genetic variation, historical distribution, habitat needs, and ecosystem services.

In an attempt to provide sound guidance for oyster restoration efforts and to answer questions about native oyster ecology, the NOAA CRP and partners convened the first *West Coast Native Oyster Restoration Workshop*. This three-day workshop (September 6–8, 2006), held at the Marin Rod and Gun Club (MRGC) on the shores of San Francisco Bay, provided a perfect venue to discuss and debate the many aspects of native oyster restoration. Support for the workshop came from the NOAA CRP; California Sea Grant; University of California, Davis; the MRGC; California Coastal Conservancy; Save San Francisco Bay Association; Drakes Bay Family Farms; Taylor Shellfish Farms; Puget Sound Restoration Fund; Pacific Coast Shellfish Growers Association; and the Center for Collaborative Policy (a program of California State University). Leading experts from academia, industry, nonprofit organizations, and local, state, and federal government were invited to present and discuss the science, policy, and practice of restoring the West Coast's only native oyster.

Over the three days, presentations addressed historic and current distributions, genetics, larval recruitment, habitat preferences, disease, predation, restoration techniques, monitoring, ecosystem services, permitting, and community involvement. In panel discussions, participants recognized that there were similarities among the three states' efforts to restore the native oyster, but many questions still need to be resolved.

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[1] Throughout these proceedings, the Olympia oyster may be referenced as the West Coast native oyster, *Ostrea lurida*, *Ostrea conchaphila, or Ostreola conchaphila*. Currently these names can be used interchangeably, as the proper usage is being debated. It is hoped that future discussions and research will resolve this issue, as well as the question of whether the Olympia oyster may represent more than one species.

In addition, David Lewis of the Save San Francisco Bay Association started off the workshop with welcoming remarks and a perspective on the history of the native oyster. Jonathan Davis of Baywater Inc., presented the keynote address, and discussed the oyster's history of exploitation, restoration, and conservation.

The results of the presentations and discussions are presented in these proceedings, organized by session. The abstracts and presentations contain both previously published and unpublished work, as well as summaries from panel discussions, on a wide range of issues concerning the native oyster and its habitat. We hope this information will help guide future scientific investigations and restoration efforts along the West Coast. In an effort to convey the overarching messages that came from the meeting, we have compiled a list of primary conclusions, research priorities, and recommended actions on the following page.

We extend our great appreciation to the Marin Rod and Gun Club for the use of their beautiful facility on the Bay, and to all the funders, presenters, and other workshop participants for their enthusiasm and dedication to furthering our understanding of the native oyster. We look forward to the next workshop to be held in Washington State in August 2007.

The 2006 West Coast Native Oyster Restoration Committee:

NOAA Restoration Center
Natalie Cosentino-Manning, Summer Morlock,
Kerry Griffin, Megan Callahan-Grant, Kay McGraw
I. M. Systems Group, Inc./NOAA Restoration Center
Polly Hicks, Natalie Badrei

University of California, Davis
Edwin Grosholz

Outcomes from the 2006 West Coast Native Oyster Workshop:

Primary Conclusions:

- Populations of native oysters still exist at most sites throughout the historic range, but only at a small fraction of the historic abundance.
- Limiting factors that affect native oyster restoration are poorly understood.
- Adjacent habitat can affect restoration success.
- Native oysters can provide a positive effect on benthic diversity.
- Invasive predators can represent a significant obstacle to restoration.
- Relying on natural local recruitment is the most conservative option in the absence of any genetic data.
- Little is known about subtidal oyster beds and how these populations affect intertidal populations.
- Large scale (greater than 1 acre) restoration may be appropriate in some estuaries, but needs to proceed with caution.

Research Priorities:

- Research limiting factors to native oyster restoration.
- Investigate the ecological services provided by native oyster beds. Both small and large sized beds need to be examined.
- Test and compare other (beyond *Crassostrea gigas* shell) substrate types.
- Develop a microsatellite library for native oysters.
- Acquire estimates of genetic diversity within large estuaries as well as among estuaries.
- Document subtidal populations.
- Investigate the impacts of disease on native oyster populations including the role of physical, biological, and temporal factors of disease expression.
- Formalize monitoring protocols along the West Coast.
- Investigate spatfall and larval interactions.
- Research ecological interactions with eelgrass.

Recommended Actions:

- Use the term oyster “bed,” rather than oyster “reef,” when describing congregations of native oysters.
- Define what historic native oyster beds were like in each estuary.
- Form working groups to tackle next steps.
- Develop standardized monitoring protocols for entire West Coast.
- Develop techniques to document subtidal oyster populations.
- Develop new techniques for restoration and look to historic practices for ideas.
- Tell the oyster story to the public to garner support for these efforts.
- Reach out to broad sectors of the community.
- Maintain and maximize participation with researchers, restoration practitioners, and stakeholders.
- Develop permitting guidelines for individuals/organizations interested in developing an oyster restoration plan.
- Convene another workshop in Washington in 2007.

Keynote Address

Restoration of West Coast native oysters: history of exploitation and recent restoration efforts

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The native West Coast oyster, *Ostrea conchaphila,* has been the focus of intense fisheries throughout much of its range in the last century with accompanying large declines in many locales. Efforts to develop restoration planning for this oyster have evolved in Washington State, Oregon, and California. An understanding of this species' natural history, habitat requirements, and history of exploitation may help guide restoration efforts and perhaps focus public restoration efforts on ecosystem benefits provided by suspension feeding bivalves. The chronology of exploitation of this oyster in Puget Sound represents a classic example of how not to manage a fishery. Massive over-harvesting, inattention to habitat needs, intense impacts due to pollution, the introduction of non-native predators, and a refocusing by industry on alternative oyster species conspired to bring the fishery of native oysters to a virtual halt. It is likely that the focus on other oysters for cultivation was particularly important as efforts including habitat modifications designed to enhance *Crassostrea gigas* culture and lack of interest in native oyster culture were in part responsible for the slow recovery of oysters to date. From a restoration perspective, the addition of favorable substrate appears to be a relatively simple method to enhance recruitment of oysters. Liberty Bay, Washington appears to be a site that, having had an historical abundance of native oysters, is amenable to this approach. The addition of clean Pacific oyster shell as settlement material resulted in a recruitment response in 2005 of up to about 80 seed oysters per square meter and the density of shell material appeared related to recruitment success. The public benefit of newly developed and edible shellfish resources that are coupled to broad-based understanding of water column benefits associated with suspension feeding bivalves may be integral to public shellfish restoration efforts on the West Coast.

Presentation (pdf)

Session: Olympia Oyster Distribution

Olympia Oyster Distribution – Session Summary

Panel members:
Maria Polson (California State University, Fullerton)
Mike McGowan (Maristics)
Scott Groth (Oregon Department of Fish and Wildlife)
Betsy Peabody (Puget Sound Restoration Fund)

Presentation Summary

Maria Polson presented research on West Coast-wide intertidal distribution. The study sampled 25 sites from Cabo San Lucas, Mexico to Sitka, Alaska. No intertidal populations were found at the northernmost and southernmost sites, and varying densities were found at sites in between. Polson noted that intertidal range could be limited by temperature extremes, and that subtidal populations could presently or historically exist at the extremes of the range. Southern California, where studies of populations and restoration have been neglected, seemed to have great potential for future restoration projects due to the presence of intertidal populations at all sites and evidence for recruitment. Future research will consider the taxonomic issues between *O. lurida* and *O. conchaphila*.

Mike McGowan presented information on San Francisco Bay distribution. His team sampled intertidal and subtidal populations, and correlated oyster density with sediment size, predators, and salinity. He noted the difficulty in determining whether sampled oysters were native to San Francisco Bay or brought in from other bays, which was a common practice in an earlier era. Further investigation found a much higher density of oysters on dock pilings than on adjacent shoreline, with fine sediments and some presence of the non-native predator, *Urosalpinx cinerea*.

Scott Groth presented distribution in Oregon's bays and estuaries. Historic populations occurred in several estuaries, but were less dense in others, perhaps due to high freshwater input. Coos Bay populations were likely extirpated by massive fire-related sedimentation, but populations have been increasing. Commercial harvest in the late 1800s and early 1900s depleted native stocks, and sporadic repopulation efforts have taken place over time, most recently in Netarts, Yaquina, and Coos Bays. Eastern oysters were introduced in Yaquina Bay in 1878, but apparently did not persist.

Betsy Peabody presented information on distribution in Puget Sound, Washington. *O. conchaphila* is still present in most of its historic range, but not necessarily in the same abundances. Wild harvest peaked in the 1880s; it declined in the 1920s, probably due to a new pulp mill near Shelton that created poor water quality conditions. She noted some natives in up to +5.0 ft MLLW tidal elevation, and that some of the best places were in artificial environments, such as constructed lagoons or behind tidegates. In addition, factors influencing distribution and abundance in Puget Sound may be quite different from coastal estuaries, such as Willapa Bay. Also, several commercial operations still grow native oysters in Puget Sound.

Discussion Summary

Panelists reminded conference participants to consider the bigger picture of oyster restoration: ecosystem benefits, multiple species benefits, etc. One panelist stated that dense beds of native oysters exist on the west coast of Vancouver Island, perhaps presenting a model for what unaltered native oyster beds should look like. Another panelist noted it is difficult to ascertain when we have achieved populations that will be self-sustaining. In addition, it was noted that regulatory agencies need to do a better job of identifying priorities and making permitting easier when a restoration activity fits what is considered a desired outcome.

Current geographic distribution and intertidal population status for the native West Coast oyster, *Ostrea conchaphila*, from Alaska to Baja

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Despite the recently renewed interest by ecologists and government agencies to reestablish historical populations of the native West Coast oyster, *Ostrea conchaphila*, focus has been limited to projects located at the north of this species' range with little or no attention to southern California and Baja populations. In addition, historical information on the status of natural populations across the range has been mainly qualitative in nature. Thus, there is no comprehensive information on the current status of natural populations. The focus of this study was to conduct the first large scale quantitative survey of intertidal populations for *O. conchaphila* by establishing presence/absence and providing data on densities and percent cover across the entire range. We surveyed intertidal populations at 25 historical sites during spring and summer 2005 and summer 2006. Each site was surveyed using a two hour timed search and was limited to areas with favorable habitat for oyster settlement. At each site, during the two hour search, the area with the highest density of oysters was identified and maximal densities and percent cover were quantified using ten replicate quadrants. Further, we recorded the presence and identities of predators, the substrate type, size frequency distribution of oysters, the presence of other oyster species, and when possible, the tidal height of the oyster distribution.

Preliminary results indicate that average maximal densities range from 0.0 to 36.7 per 0.25 m^2 and are the highest in Bahia de San Quintin, Baja, Mexico (20.7 ± 6.5), Mission Bay, CA (22.8 ± 3.4), and Point San Quentin, San Francisco Bay, CA (36.7 ± 11.6). Even though densities were low at most sites in southern California, intertidal populations are still present at all bays and estuaries south of Morro Bay. Thus, all southern California sites could present favorable opportunities for restoration projects. At the north end of the range, intertidal populations were more often absent from sites, such as Netarts Bay, OR, Willapa Bay, WA and Grays Harbor, WA, though there is evidence for the presence of subtidal populations. *Ostrea conchaphila* is absent from intertidal sites in Sitka, AK and Cabo San Lucas, the two end points of its distribution. We speculate that the current northern range limit of this species is located in northern British Columbia and that if any intertidal populations were ever present in Cabo San Lucas, Baja, they were/are subtidal. Intertidal populations are also absent at two California sites, Morro Bay and Big Lagoon; anecdotal evidence further suggests that subtidal populations are also absent. This study represents the first comprehensive biogeographic survey of intertidal populations of the native oyster, *Ostrea conchaphila*, and identifies sites in southern California as suitable locations for future restoration projects.

Presentation (pdf)

Survey of native oyster, *Ostrea conchaphila*, distribution in San Francisco Bay in 2001-2003 with observations on population-limiting factors

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Population density of native oyster, *Ostrea conchaphila*, in San Francisco Bay, California was surveyed intertidally from the shore at low tide and subtidally with an oyster dredge from a research vessel during 2001-2003. Observations on sediment type, salinity, and known oyster predators, such as drills, were taken to assess physical and biological habitat quality by analyzing correlations between environmental variables and oyster density (catch per unit effort) and size (shell diameter). Native oysters were widespread in San Francisco Bay over the sixteen nautical mile north-south distance surveyed from Pinole Bayfront Park to the Palo Alto Baylands. Water salinity ranged from 9.5-31.2 psu. Population density was highest in the northern, lower salinity regions. Mean size was largest in high salinity regions with few of the predacious non-native gastropod, *Urosalpinx cinerea*. Larger oysters were found on hard substrate such as rock, cement piles, and rip-rap than on rocks on mud or sand.

An observational field experiment was conducted to further test the observed negative relationship of native oysters to fine sediment and to the non-native drill, *U. cinerea*. Oyster abundance and size were measured on boat docks at twelve marinas and at nearby open bay shorelines. The shoreline sites had rock on fine sediment and oyster drills, while the boat docks were in clear water above the bottom where drills were absent. Mean density of oysters on the docks was 17.5 m-2; mean density on the nearby shorelines was 1.65 m-2. Oyster drills, *U. cinerea*, were present at four of twelve shoreline sites but absent at all of the docks surveyed. These experimental observations add further support to the hypothesis that fine sediment and non-native predators have a negative effect on native oyster populations in San Francisco Bay.

Presentation (pdf)

Historic and current distribution and abundance of Olympia oysters in Oregon

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Olympia oysters (*Ostrea conchaphila*) are native to several of Oregon's larger estuarine systems. Yaquina Bay and Coos Bay historically had large populations as indicated from commercial fisheries in Yaquina Bay and shell masses found in Coos Bay. Netarts Bay also had populations, but likely in lower numbers than Yaquina and Coos bays due to comparatively smaller habitat areas. Other bays such as Tillamook and Alsea may have had populations, but none had readily apparent abundances and no commercial harvest records exist.

Yaquina Bay was depleted of its original stocks by commercial harvesting that began in the 1860s. Harvest began tapering off in the 1890s and ended in the 1940s. Some populations seem to have persisted in Yaquina Bay from the end of the fishery to the present. Various supplementation and habitat enhancement efforts in Yaquina Bay have taken place from the early years of the fishery to present.

Netarts Bay supported a commercial fishery simultaneous with the Yaquina Bay fishery, but commercial landings and the duration of the fishery in Netarts Bay were decidedly less than that of Yaquina Bay. For much of the last century, populations in Netarts Bay were barely existent, and in 1992 believed to be absent. Reintroductions and enhancement projects in this bay during the mid 1990s reestablished some populations from Yaquina Bay stocks. The Nature Conservancy has made recent efforts to restore populations of native oysters in Netarts Bay.

In Coos Bay, despite massive shell deposits, live *O. conchaphila* were noted as absent upon European settlement. This appeared to be a recent event and is commonly attributed to the degradation of water quality from a massive fire in 1846. Reintroduction efforts were considered in Coos Bay simultaneous with initial enhancement efforts in Yaquina. Only one reintroduction effort is known to have occurred; that, in 1914, is thought to have failed. In 1986, a few live *O. conchaphila* were found in Coos Bay, near areas of commercial *Crassostrea gigas* aquaculture beds. Presumably, the Olympia oysters were brought in as fouling organisms of *C. gigas* from other bays that had *O. conchaphila* populations. Since that time, *O. conchaphila* populations in Coos Bay have expanded in range and abundance. Surveys performed in 1997 confirmed recruitment and established baseline ranges of distribution. Surveys performed in 2006 confirmed continuing recruitment and expansion of abundance and range. Current work by the Oregon Department of Fish and Wildlife in Coos Bay focuses on establishing indices for future documentation of changes in range, abundance, and recruitment patterns.

Presentation (pdf)

Historic and current distribution of Olympia oysters in Puget Sound

Brady Blake
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Olympia oysters in Puget Sound today are still present throughout most of their historic range—but presence does not necessarily equate to abundance. For instance, in Samish Bay today, commercial growers out on their beds year round are lucky to find a few native oysters each year—compared to the tens of thousands produced annually before 1900. What we know about historic distribution comes from a variety of sources including: commercial growers, landing reports, Fish Commission reports dating back to statehood, archaeological and ethnographic information from tribes, and anecdotal information, among other sources. What we know about current distribution has been gathered through field surveys and personal communications, or deduced using orthophotos and aerials that are later ground-truthed with field surveys. The most important factor in assessing current distribution is simply that we are going out and looking for them—and therefore developing the knack of finding them. A natural resurgence beginning as early as the 1980s and first noticed by WDFW staff and growers in the mid to late 1990s is most likely the result of several El Nino episodes causing excellent natural sets throughout nearly all of the oyster's historic range. Populations in South Sound, Hood Canal, and some portions of the Central Basin seem to be doing well. A noted exception to this resurgence has been observed in the North Sound. Samish Bay was likely the center of the population historically—with larvae distributed throughout the North Sound. Once the Samish population was overharvested, the population likely became fragmented with no significant larval source to maintain remnant populations. Expanding our knowledge of current distribution has become a bigger priority for WDFW in recent years, and surveys for remnant populations are playing an important role in developing restoration strategies that are appropriate for local areas and protective of potential genetic sub-populations.

Presentation (pdf)

Session: Biology, Genetics, and Dispersal

Biology, Genetics, and Dispersal – Session Summary

Panel members:
Edwin Grosholz (University of California, Davis)
Brent Vadopalas (University of Washington)
Danielle Zacherl (California State University, Fullerton)
Mark Camara (USDA – Agricultural Research Service)

Presentation Summary

This session started with a general overview of the basic biology and ecology of Olympia oyster populations provided by Edwin Grosholz. Olympia oysters are found in bays and estuaries along the U.S. West Coast and generally can tolerate a wide range of salinities (< 15 ppt in CA; < 20 ppt in WA). Freezing and long exposures to freshwater result in increased mortality. Olympia oyster populations have been found at depths of 20 m, but generally do not occur above +1 to 2 ft MLLW. There are a few occurrences of populations above +5 ft MLLW in Puget Sound, but these populations are in elevated lagoons that retain water. Olympia oysters do not form extensive reefs, but rather small aggregates of clumped oysters that are easily broken apart. Although morphological and habitat differences among Olympia oyster populations were noted along its current range—including shell morphology (color, size, and shape), optimum spawning temperature, and desired substrate (shell vs. rock vs. mudflats)—it is unknown whether these differences indicate genetic differences.

Unlike other oysters, Olympias brood their larvae up to two weeks before releasing them into the water column. Oyster larvae, which can tolerate ocean salinity levels, can stay suspended in the water for three to six weeks, but with abundant food the larvae typically will settle in a couple days. Some studies on genetics have indicated that larval dispersal may not be a random process, but very little is known about this key life stage. Two new mechanisms have been developed to provide insight into dispersal processes and patterns of Olympia oysters. Using qPCR to amplify larval DNA, Vadopalas et al. developed a method to count mitochondrial genomes in a water sample and determine the number of larvae present in the water column at one point in time. There are a few more issues to refine with this method, but it has the potential to help identify and quantify pelagic marine invertebrate larvae in the water column. Zacherl et al. developed a method to identify dispersal trajectories and origin locations of settled oysters. Before the larvae are released into the water, they form a calcified larval shell that retains the elemental concentrations of the surrounding water. Because the shells of oysters record these elemental changes, sampling the shell near the umbo and conducting a chemical analysis has the potential to indicate in which estuary or bay it originated and, therefore, elucidate how reliant some estuaries may be on neighboring populations for larvae.

Mark Camara discussed genetic considerations for native oyster restoration. The significant decline and fragmentation of Olympia oyster populations and lack of genetic information about past populations poses a number of challenges to the restoration of this species. Genetic differences between populations could indicate either adaptations to local conditions (e.g., temperature, spawning times, and pathogens) or poor genetic health due to genetic drift and/or inbreeding. If the latter, hatchery-based enhancements could further skew allele frequencies. Camara discussed the potential options, consequences, and best practices for hatchery-based enhancement if these methods must be used, which are further noted in the panel discussion summary below.

Discussion Summary

To help prevent restoration activities from creating skewed allele frequencies or genetically unhealthy populations, a number of recommendations were identified during the panel discussion, including:

- Where possible, conduct substrate enhancement activities and allow for natural recruitment, which is the most conservative approach to restoration
- Where natural recruitment is *not* an option, practitioners should take a precautionary approach to raising juveniles in the hatchery, as this can unintentionally skew allele frequencies
    - Use local populations for broodstock
    - Use broodstock parents only once
    - Equalize the individual contributions of parents to a stock population
    - Maintain local genetic patterns through smart husbandry methods

The panel also identified the following research needs to help improve future restoration activities:

- Determine where the best locations and habitat conditions exist for Olympia oysters
- Identify 'triggers' for spawning and larval recruitment
- Determine whether morphological differences among populations result from genetic differences and local adaptation
- Develop more microsatellite markers for genetic analysis
- Identify genetic bottlenecks and genetically unhealthy populations

The life and times of the Olympia oyster

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The Olympia oyster, *Ostreola conchaphila*, is the only oyster native to western North America. Based on museum specimens and recent systematic distinctions, the historical distribution of Olympia oysters extended from Sitka, AK (57° N) to Panama (9° N) with fossil representation extending back to the Pliocene. The current distribution is made up of a disjunct series of reproductive populations between southeastern Alaska and Baha California. Smaller than most other oysters (up to 80 mm), the external shell coloration ranges from purple to gray and white, with internal shell coloration ranging from green to white. The native oyster can be distinguished from the introduced *Crassostrea* species by the ridge of crenulations or chromata on the shell near the hinge. Olympia oysters will experience significant mortality with exposure to salinities >15 ppt over periods of months and requires water temperatures of greater than 12° C to reproduce. This species is a protandrous hermaphrodite that broods its larvae for up to twelve days after which the larvae swim for 3-4 weeks before they settle. They are reproductive within six months and will reach maximum size in four years. Olympia oysters are commonly preyed on by a wide range of predators including crabs, snails, flatworms, ducks, stars, and rays. However, they have comparatively few parasites and pathogens relative to other oysters. Olympia oysters are generally found attached to rocks and cobbles from lower intertidal areas to waters up to several meters deep. Although they don't form extensive reefs, they can form dense aggregations that can support other invertebrate and fish species. This species is believed to have been very abundant prior to the extensive exploitation that began in the mid-19th century.

Presentation (pdf)

*****Schedule change. Presenter unable to attend workshop*****

Genetic structure of native Olympia oyster (*Ostrea conchaphila*) from four sites in Coos Bay, Oregon

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The Olympia oyster, *Ostrea conchaphila*, is the only oyster species native to the Pacific Northwest. Historically, the species ranged from southeastern Alaska to Baja, California and supported both tribal subsistence fisheries and large commercial harvests. Over-exploitation, habitat degradation, and competition and predation from non-native species have drastically depleted densities and extirpated many local populations, but a few remnant populations persist. This is perhaps most pronounced in Oregon where there are only two extant populations, one in the Yaquina Bay and another in Coos Bay. Archaeological evidence such as shell middens indicate that large populations of the Olympia oyster existed in both of these bays prior to historical documentation, but surveys performed in the 1980s found no Olympia oysters in the Coos Bay watershed. It is unclear, therefore, whether the current population of Olympia oysters in Coos Bay is a recent re-expansion of a surviving remnant population missed by the 1980s surveys or a re-introduction from some other source population.

Due to the species' historical significance and the ecological services provided by oyster reef habitats, restoration efforts are underway in both bays, but these efforts are proceeding without a full understanding of either the existing or historical population structure, largely due to the lack of appropriate molecular markers. We have recently developed a number of microsatellite DNA markers in *O. conchaphila* and have used eight of these to conduct preliminary analyses for genetic structure on samples collected from four sites in Coos Bay, all of which are located in a 12 km section of the Eastern Arm of the bay's watershed. At the phenotypic level, oysters from the southernmost collection site (Shinglehouse Slough) are significantly larger than all other sample locations, including the most probable site for re-introduction as a hitchhiker on *Crassostrea gigas*, which is raised commercially in production beds near the North Bend California Avenue public boat ramp. These size differences are a suggestive, but far from a definitive indication, that the extant populations of Olympia oysters in Coos Bay may be truly native, since one might expect that a re-introduction would result in older, larger animals closest to the site of the primary introduction and smaller, younger oysters at sites colonized secondarily from the source. We will present an analysis of the degree of differentiation among the Coos Bay sample populations and a comparison of these populations with Willapa Bay, WA, the most likely source population for a re-introduction because it is the main source of *C. gigas* seed for commercial culture in Coos Bay.

No presentation available

Using quantitative PCR to understand Olympia oyster larval dispersal

Brent Vadopalas, Jason E. Suzuki, Nathan A. Wight, and Carolyn S. Friedman
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Our understanding of the relationship between behavior and dispersion in marine invertebrate larvae has been hampered by the lack of suitably rapid techniques for identification and quantification from field samples. The need to understand larval dispersal dynamics of Olympia oysters (*Ostrea conchaphila*) to a) site productive restoration projects, and b) increase our knowledge of this critical life history stage, motivated the development of a high-throughput method for identification and quantification of Olympia oyster larvae in seawater samples. Our assay essentially counts mitochondrial genomes and correlates this information to numbers of larvae using standard curves constructed from different size classes of Olympia oyster larvae.

We size-fractionated seawater samples through a series of filters (105, 150, 200, and 250 µm), extracted DNA from all organisms present in retentate, and used primers and a dual-labeled hydrolysis probe specific to Olympia oyster Cytochrome Oxidase I (COI) mitochondrial DNA sequence to conduct quantitative PCRs (qPCR). Using light microscopy, we enumerated spiked samples of each size class of larvae to verify quantity estimates derived from qPCR standard curves. Partial or full PCR inhibition can give spurious results, so to avoid bias from either underestimation of quantity or false negatives, we multiplexed Olympia oyster-specific reactions with primers, probe and exogenous template as an internal positive control (IPC).

We estimate that 70 samples can be processed from DNA extraction through qPCR in about four hours at a cost of approximately $3/sample for reagents. Our results demonstrate that qPCR can have utility for high-throughput identification and quantification of pelagic marine invertebrate larvae in seawater samples. By shedding some light on Olympia oyster larval dispersal, we may increase the likelihood of success by restoring source, rather than sink, aggregations.

Presentation (pdf)

A shell of its former self. Can *Ostrea conchaphila* larval shells reveal information about a recruit's birth location?

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Examining the chemistry of calcified structures can provide a wealth of information about the temperature and chemistry of both historic and modern oceanic seawater. In a relatively recent application of this tool, fishery scientists can use calcified structures of fish and invertebrates to reconstruct the environmental histories of individual organisms. In particular, the prospects to use the chemistry of larval calcified structures as 'flight recorders' of larval movements are now being explored and promise to elucidate much useful information about dispersal trajectories and birth locations of incoming settlers.

The life history of *Ostrea conchaphila* would be ideally suited to examining patterns of larval transport using calcified tags. First, this species is distributed among discrete populations in bays and estuaries that are likely to exhibit unique seawater characteristics due to differences in watershed usage and differences in temperature and salinity profiles. Second, because females brood the larvae for 10-12 days before they are released into the plankton, larvae form their calcified larval shell (prodissoconch) at their birth location and retain this structure after settlement. *O. conchaphila* larvae are thought to spend 21 days to 8 weeks in the plankton, providing adequate time for exchange among distantly placed estuaries, though several studies have showed evidence for self-recruitment in species whose planktonic larval duration provides the potential to disperse widely. Last, the larvae settle gregariously on hard substrate, including on conspecific shells, making settlers easy to locate. In this study, we explored the prospects for using larval and settler shells of the native oyster, *Ostrea conchaphila*, as proxies of environmental history. If larval shells do record shifts in seawater temperature and chemistry, the portions of the shells formed prior to release into the plankton might act as tags of birth location useful for identifying productive source populations of recent settlers and for examining within and among-estuary exchange of larvae.

These specific research questions were addressed:

- Does seawater elemental concentration influence the chemistry of larval and settler shells for the elements Ba, Pb, Mn, Cu, and Ce?
- Do shells undergo an ontogenetic shift in element uptake between planktonic and settler stages for the elements Mg, Sr, Ba, Pb, Mn, Cu, and Ce?

- Does the chemistry of the shell formed during brooding (at the birth location) change as a function of environmental conditions experienced during the planktonic and post-settlement phases?

We tested whether the shells of planktonic oyster larvae and recent settlers can record changes in seawater chemistry, and whether shells undergo ontogenetic shifts in element uptake using controlled laboratory culturing experiments. Native oysters brooding larvae were collected from Tomales Bay, CA in June 2003, rinsed with 0.2 m filtered seawater, and then cracked open to yield 'black sic' veliger larvae that were competent for release into the plankton. Black sic larvae from several broods were mixed and then split into 18 culture jars. Groups of two culture jars were randomly assigned to each of three spiking levels (ambient, 3X and 6X) of element concentration for Ba, Pb, Mn, Cu, and Ce. Larvae were cultured at 21° C until several days after settlement onto glass slides.

In a separate culturing experiment, we also examined whether the chemistry of the shell formed during brooding (at the birth location) changes as a function of environmental conditions experienced during the planktonic phase. The chemistry of the brooded shell must remain 'intact' in order to act as a tag of birth location. Black sic larvae from several broods were again mixed and then split into eight culture jars. Groups of two culture jars were randomly assigned to each of two spiking levels (ambient, 6X) of element concentration for Ba, Pb, Mn, Cu, and Ce. Larvae were cultured until competent to settle.

After culturing, larval shells from both experiments were cleaned using a peroxide cleaning solution of an equal volume mixture of 30% H_2O_2 buffered in 0.1 N NaOH. All of the isolation steps were performed using acid washed glassware in a clean laboratory equipped with class 100 laminar flow hoods. Cleaned shells were mounted onto acid washed plastic slides and their chemistry analyzed using laser ablation inductively coupled plasma mass spectrometry (ICP-MS).

Results from a two-way ANOVA examining the effect of seawater element concentration and ontogeny showed that elemental concentrations in the shell increased in response to increasing seawater elemental concentrations for Ba, Ce, Pb, and Mn, while shell Cu did not change. *Ostrea conchaphila* shell chemistry also showed strong ontogentic shifts in elemental concentrations during the transition from larva to settler. Settler shell Mg strongly increased in concentration compared to planktonic shell, while Sr, Mn, and Cu showed the opposite pattern. This ontogenetic shift in element concentration parallels a shift from aragonite to calcite mineral forms of calcium carbonate in the shell, and indicates that the chemistry of juvenile or adult shell cannot be used as a proxy for a larval tag of birth location.

The chemistry of the shell formed during brooding (at the birth location) does change as a function of environmental conditions experienced during the planktonic phase for the elements Ba, Ce, and Mn, but that change is limited to regions of the brooded shell just adjacent to the planktonic shell. When the brooded portions of larval shells are sampled closer to the umbo, the brooded shells' chemistry remains intact.

The combined results suggest that larval *Ostrea conchaphila* shells act as recorders of environmental change and thus show promise as tools to track larval movements. To implement this tool, researchers would sample brooded larvae from potential source populations and establish a 'map' of site-specific shell chemistry. Once settlers are collected at a site, laser ablation techniques can sample the portion of the shell formed during brooding, and the chemistry of this brooded shell can then be matched to the birth location. To establish the map of potential source populations, one must sample brooded larvae and cannot rely upon source tags generated by settler or adult shells. This poses logistical challenges for a species undergoing restoration efforts because it requires sacrifice of reproductive females in order to sample brooded larvae. Thus, we stress the importance of pinpointing exact reproductive windows for this species in areas of interest for larval tracking studies.

Presentation (pdf)

Genetic considerations for hatchery-based enhancement of native oyster populations. Are good intentions enough?

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Native oyster populations have, through a combination of over-fishing, habitat degradation, and introductions of non-native competitors, predators, and diseases, been either locally extirpated or drastically reduced in numbers in many U.S. estuaries. The realization that these filter-feeding bivalves provide a variety of ecological services ranging from water filtration to reef-building has generated a great deal of interest in restoring oyster populations; and, given that it's possible to grow millions of juveniles in hatcheries, population supplementation is an attractive strategy for re-building decimated oyster populations. Ecologically, this approach seems straightforward, and it is difficult to see how enhancing local populations could be anything but beneficial. From a genetic perspective, however, things are more complicated. In this presentation, I will briefly outline the ways in which hatchery-based population supplementation may affect the genetics of remnant oyster populations. My purpose is not to criticize current restoration efforts, but to emphasize the importance of understanding current patterns of genetic diversity, the evolutionary forces that may have generated these patterns, and the ways in which hatchery-based restoration might change them for better or worse. I argue that despite the obvious good intentions behind hatchery-based population supplementation efforts, unless we better understand the genetic context in which they occur, hatchery-based population enhancement could have negative genetic impacts on the populations they seek to benefit.

As a matter of necessity, hatchery-based population supplementation of native oyster populations is, in most instances, proceeding with very little, and in some cases no genetic information. Even the best case scenario is one in which local populations have been sampled and genetically characterized using presumably neutral genetic markers such as allozymes, RAPDs, AFLPs, or microsatellite DNA, providing a description of the current distribution of molecular genetic diversity within and among populations. The most crucial decision in any program of hatchery-based restoration is which parents should be used in the hatchery, and the typical default approach is to use parents from local stocks. However, this strategy is based on at least three untested assumptions:
1) molecular genetic variation is a reasonable proxy for quantitative genetic variation,
2) population differentiation at neutral markers is indicative of local adaptation, and
3) larger populations are always better than small populations. I'll address each of these in turn:

1. Molecular genetic variation is a reasonable proxy for quantitative genetic variation, and maintaining high levels of molecular genetic diversity also maintains the capacity of a population for adaptive change.

Several fairly recent literature reviews have addressed this question, and the findings are not encouraging. There simply doesn't seem to be any evidence to support the idea that populations with high levels of molecular genetic variation also have high levels of quantitative genetic variation. Since natural selection acts not directly on genes, (especially not on presumably neutral markers) but indirectly on the specific genes that control phenotypes, one possible explanation for this is that only a small subset of the genome actually contributes to variation in evolutionarily meaningful phenotypes. As a result, genome-wide, population-level surveys of randomly chosen loci are unlikely to reflect patterns of differentiation at the loci that control phenotypes of interest.

2. Population differentiation at neutral markers is indicative of local adaptation.

This requires not only that the assumption above holds, but a further assumption that the patterns we can observe today have been produced by natural selection and that differences in allele frequencies between populations somehow reflect differences in which alleles are favored under differing local conditions. The biggest problem with this is that differences in allele frequencies among populations can also be caused by other forces such as random genetic drift, which can be a powerful force in small populations. As a thought experiment, let's consider two alternative historical scenarios for native Olympia oysters.

It seems reasonable to assume that native oysters once occurred in large, possibly even continuous populations within individual estuaries. Given that, depending on the relative strength of gene flow and local selection, these populations could either have been relatively homogeneous in terms of their genetic makeup due to high levels of gene flow among them and relatively weak selection, or they could have been highly differentiated to suit local conditions due to strong selection and limited gene flow. Along comes the white man, harvesting oysters like there's no tomorrow and cutting down every tree in the watershed, and before long these once large populations are tiny fragments, probably isolated from each other. Perhaps some of these populations have recovered some since, but even if they have, what we have now is still a smallish number of smallish populations that are not very connected.

Now suppose we grab a bunch of samples from these populations and genotype them at a bunch of marker loci, and we find that these remnants are very different from each other. It's tempting to interpret this kind of pattern as local adaptation, and if that's correct, it leads to the argument that any hatchery-based supplementation efforts should be very careful to avoid disrupting the existing structure because 'foreign' genotypes are likely to be poorly adapted. However, it's also plausible that the differences we see today among populations result from genetic drift and inbreeding, and if that's true, then local populations would not be locally adapted, but rather genetically unhealthy due to reduced genetic diversity and possibly even suffering from inbreeding depression. The solution to these problems is to restore their former genetic diversity by mixing them together, exactly the opposite tactic from the local adaptation scenario.

The $64 thousand dollar question is, of course, which scenario is correct? Unfortunately, the truth is that at this point nobody knows, which would seem to make finding out a priority. One promising approach to do this is to compare Fst, a measure of how molecular genetic variation is distributed among populations to Qst, an analagous measure for quantitative genetic variation. The general idea is that if Qst > Fst for a given trait, then that trait is likely to be under locally variable selection. Another way to address both local adaptation and whole-population inbreeding depression simultaneously is to create both within-population and among-population crosses in the hatchery, plant them at all of the sites from which the parents were collected, and measure appropriate performance traits. If among-population crosses generally outperform within-population crosses at all sites, this is evidence for inbreeding depression. If local within-population crosses perform better in their native habitats than non-locals, this is evidence of local adaptation.

3. Larger populations are always better than small populations.

It may be counter-intuitive, but adding hatchery-reared animals to a local population, *even if they are derived from local parents*, can actually result in a lower 'effective population size' and increased inbreeding. These problems arise if the hatchery-reared animals consist of large groups of related individuals and are abundant enough to raise the overall probability of matings among relatives. Fortunately, most of these issues can be dealt with in simple ways such as avoiding re-using the same parents over and over again to produce juveniles for out-planting, and taking precautionary measures in the hatchery that help to equalize the contributions of individual parents to the hatchery-produced population.

Presentation (pdf)

Session: Limitations to Restoration and Recovery

Limitations to Restoration and Recovery - Session Summary

Panel members:
Alan Trimble (University of Washington)
Carolyn Friedman (University of Washington)
Jim Moore (California Department of Fish and Game)
Eric Buhle (University of Washington)
Edwin Grosholz (University of California, Davis)
Andy Cohen (San Francisco Estuary Institute)

Presentation Summary

Limiting factors for native oyster restoration and recovery are generally poorly understood, and are likely site-specific and seasonal. Some examples of these factors may include reproductive and dispersal limitation, substrate availability, intraspecific and interspecific competition, predation, sedimentation, pollution, salinity, and disease. Presenters in this session reported on several studies examining potential limitations.

Studies in Willapa Bay, Oregon, indicated that recovery has been affected by the removal of dense subtidal native oyster shell, and by direct competition from exotic species (Trimble). In addition, introduced oyster shell settlement substrate in the intertidal zone appeared to be a recruitment sink. Buhle's research on predation by the Japanese oyster drill (*Ocinebrina inornata*) in Puget Sound, Washington suggested that oyster restoration may be possible in the presence of drills, if their feeding becomes saturated due to oyster abundance or if alternative prey are available. In Tomales Bay, California, non-native crab and gastropod predators (the European green crab, *Carcinus maenas,* and the Atlantic oyster drill, *Urosalpinx cinerea*) can significantly influence native oyster survival (Grosholz).

In an attempt to characterize diseases that may affect recovery and captive rearing programs, studies conducted by Friedman observed three diseases/disease agents along the western shores of San Francisco Bay. Moore also presented results of a California survey that found the disease, Disseminated neoplasia, in Drake's Estero and some sites in San Francisco Bay, in addition to noting a historic presence in Yaquina Bay, Oregon; although, neoplasia was nearly absent in Tomales Bay and absent entirely in Humboldt Bay and Elkhorn Slough. The impacts of these diseases on native oyster populations—including the relative role of physical, biological, and temporal factors on disease expression—need to be investigated further. Presenters recommended taking a precautionary approach and using disease management, which would include restricting the movement of oysters to avoid the spread of disease. Cohen also discussed developing a standard protocol in San Francisco Bay for shell management to minimize the risk of introducing non-native species.

Discussion Summary

During the panel discussion, participants also talked about the importance of "intelligent tinkering," and the need to view all restoration as experiments. The lack of information on limiting factors results in a need for more basic biology, as well as site-specific, studies. We should not assume an understanding of relevant interactions and impacts, and our efforts should be guided by our level of true knowledge. It was noted that monitoring should be long-term and broad, looking at many factors, including more water quality parameters.

Among other issues, more research is needed on population distribution and genetics, long-time series of spatfall data, larval distribution (i.e., looking at shell microchemistry) and larval interactions (e.g., predation, food supply), parasites and disease, competition (including interactions with eelgrass), and sedimentation. Recommendations included monitoring current populations and conducting studies in locations where larvae, predators, water level, etc. could be controlled. In addition, identification of source and sink populations and setting experiments are also needed, as well as more general information on subtidal populations. A better understanding of historical populations, conditions, and limiting factors is also essential. Many agreed that efforts should be made to increase the integration of the scientific and restoration practitioner communities.

Participants also discussed the risks of conducting restoration without enough knowledge of impacts and interactions. For example, some concern was expressed regarding the use of non-native shell and other long-lasting exotic materials for habitat enhancement. Discussions included avoiding materials that would leave a legacy by using those that will degrade in less than a year (e.g., egg cartons covered in cement). Standardized protocols also need to be developed for monitoring, as well as protocols for disease, pest, and predator management. This process should analyze any protocols currently in place (e.g. shellfish transfer permit in Washington State).

During this session participants also shared their thoughts on social and management limitations, or challenges to restoration and recovery. These issues included permitting, funding, multiple agency involvement, seed production, coordination with restoration efforts for other species, commercial oyster farms, and conservation leasing. The need to strategically build and maintain support and to share accurate and candid information with the public was also emphasized.

Listed below are some of the potential limiting factors discussed during this and other sessions. This list should not be considered comprehensive, as it merely reflects information provided in presentations and discussions.

<u>Potential limiting factors presented during workshop discussions</u>
Reproductive/fertilization limitation

- Unlikely in Willapa Bay (Trimble)
- Evidence from California (Tomales Bay, Mission Bay) shows little support for fertilization limitation (Grosholz); need information from low-density populations
- Availability of larvae key factor (Peabody; Puget Sound—see Distribution session)

Dispersal limitation

- May occur in outer areas of Tomales Bay (larvae advected out of bay), but little evidence in San Francisco Bay (Grosholz)

Substrate

- Historic removal of dense subtidal shell; newly introduced oyster shell in intertidal recruitment sink (Trimble; Willapa Bay, Washington)
- Substrate and perhaps predation by non-native drills are important limiting factors (McGowan; San Francisco Bay—see Distribution session)
- Recruitment improved on shell, in comparison to bare and gravel substrates (Ruesink; Puget Sound—see Restoration session)

Water level

- Water retention key factor (Peabody; Puget Sound—see Distribution session)
- Recruitment improved at low tidal elevations (Ruesink; Puget Sound—see Restoration session)
- Even short emersion times are deadly (Trimble; Willapa Bay)

Salinity

- Protracted low salinity appeared to be a factor at one site (Abbott; San Francisco Bay)
- Estuarine salinity was related to oyster abundance but confounded by other factors (McGowan; San Francisco Bay—see Distribution session)

Competition

- Oysters are poor space competitors; post-settlement survival requires either: limited size substrate (< $0.5 cm^2$) or poor recruitment of competitors or extant adults (periostracum) (Trimble; Willapa Bay)
- Will be examining in San Francisco and Tomales Bay (Grosholz)

Predation

- Non-indigenous Japanese oyster drill (*Ocinebrina inornata*) (Buhle; Puget Sound); restoration possible where oyster or alternative prey abundance/recruitment saturate feeding
- Introduced crab and gastropod (e.g., oyster drills) predators can significantly influence native oyster survival, directly and indirectly (Grosholz; Tomales Bay)
- Abundance of oyster drills did not appear to affect one site in San Francisco Bay (Abbott; San Francisco Bay—see Restoration session)

Disease

- Three diseases/disease agents (*Mikrocytos*-like protist (microcell), a haplosporidian and hemic neoplasia) on western shores of San Francisco Bay (Friedman; San Francisco Bay)

- Disseminated neoplasia in Drake's Estero and some sites in San Francisco Bay; although nearly absent in Tomales Bay and absent entirely in Humboldt Bay and Elkhorn Slough (Moore)

Genetics

- Lack data to determine when populations are locally adapted versus genetically unhealthy (Camara—see Biology, Genetics, and Dispersal session)

Factors preventing the recovery of a historically overexploited shellfish species - *Ostreola conchaphila*, the native oyster of the Pacific Coast of North America

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The native oyster in estuaries along the Pacific coast of North America, *Ostreola conchaphila*, experienced overexploitation throughout its range in the late 1800s, resulting in commercial extinction before 1930. Significant harvest restrictions and marine reserves were established in Washington State by 1897 to protect new recruits, and harvest pressure has been negligible for the past eighty years. Nevertheless, *O. conchaphila* remains locally rare. This study focuses on the contemporary dynamics of the remnant population of *O. conchaphila* in Willapa Bay, Washington, historically home to the largest native oyster fishery on the coast, with a broad focus on factors preventing recovery. Failed recovery could be due to reproductive limitation, or to poor post-recruitment performance. In this case, reproductive limitation appears unlikely, because historical (1947-1983) and modern (2002-2006) records reveal five-fold higher annual spatfall for *O. conchaphila* than introduced Pacific oysters (*Crassostrea gigas*). However, *O. conchaphila* remains rare and *C. gigas* is commercially exploited from natural recruitment. To evaluate the effects of abundant *C. gigas* in intertidal areas on *O. conchaphila* settlement patterns, strings of *C. gigas* shell were placed at two tidal elevations in three habitat types—open mud, eelgrass beds of *Zostera marina*, and C. *gigas* reefs. Settlement of *O. conchaphila* was significantly higher on the shell strings placed in the *C. gigas* reefs at both tidal heights. To evaluate post-recruitment demography, juvenile *O. conchaphila* were outplanted at three tidal elevations at five sites, and fouling organisms were manipulated to test for competition. Short emersion times (8% greater exposure) reduced survival by 80% relative to subtidal treatments, but did not affect growth rates of survivors. Naturally-setting competitors, mostly nonindigenous, depressed survival by 50% and growth by 20%. In a third experiment, manipulating the density and stability of shell substrate, *O. conchaphila* was easily moved or buried when outplanted in a thin, unconsolidated layer. These results indicate that recovery has been hampered by the removal of dense subtidal native oyster shell accumulations during exploitation, by direct competition from exotic species, and by the appearance of novel introduced oyster shell settlement substrate in the intertidal zone. This altered web of interactions influencing *O. conchaphila* serves as a model for understanding the failed recovery of overfished species in rapidly changing coastal systems.

Presentation (pdf)

Restoration and diseases of Olympia oysters in San Francisco Bay

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Olympia oysters, *Ostrea conchaphila*, have declined markedly during the last century and are a focus of restoration in many embayments, including the San Francisco Bay (SFB) estuary as well as locally in Washington State. Oysters were collected from 17 sites in SFB and nearby Tomales Bay in an effort to characterize diseases that may impact recovery of this species and captive rearing programs. Oysters were sampled for histological analysis; the stress response of selected oysters was also examined.

Three diseases/disease agents including a *Mikrocytos*-like protist (microcell), a haplosporidian, and hemic neoplasia were observed from several sites along the western margins of the SFB estuary suggesting the potential for a geographic localization of disease presence. Based on FISH assays, the microcell is distinct from *M. mackini* and *Bonamia* spp.

The influence of hemic neoplasia on the stress response of adult *Ostrea conchaphila* from San Francisco Bay, California was investigated through an examination of the thermal tolerance and heat shock response of both affected and unaffected populations. The lethal temperature of unaffected animals was 39^{o} C (one hour exposure), like that described previously for the species (Brown et al. 2004), while *O. conchaphila* with hemic neoplasia did not tolerate 38^{o} C. Electrophoretic profiles of the 70 kD heat shock protein family (Hsp70) revealed that intensity of hemic neoplasia positively correlated with post-heat shock (at 37^{o} C) Hsp69 levels.

These data highlight the need for further elucidation of the microcell and other diseases and for careful health management of a declining species destined for captive rearing and supplementation.

Presentation (pdf)

Disseminated neoplasia in *Ostrea conchaphila*

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Disseminated neoplasia is a disease of numerous species of bivalve mollusks. It consists of the uncontrolled proliferation of large, undifferentiated cells throughout the circulatory system, resulting in emaciation and ultimately death in most instances. Many features of the disease are very similar to those of leukemia in mammals, with one exception: it is readily transmissible between individuals by injection of the cells or even by simple cohabitation; it is an infectious disease. The etiology of the disease remains unclear, although there is some evidence for the role of a retrovirus in one species. Prevalence in bivalve populations has been reported as high as 90% and mortality due to the disease can be significant.

Disseminated neoplasia was first described in *O. conchaphila* in 7% of native oysters sampled from Yaquina Bay, Oregon in approximately 1969. Later samplings from Yaquina Bay in the 1970s showed much lower prevalence (<1%). No additional studies in *O. conchaphila* were reported until Friedman et al. (2005) found it to be present in native oysters at Candlestick Point and Strawberry Point in San Francisco Bay, and not present from other locations within San Francisco Bay and Tomales Bay.

As part of a statewide oyster health survey, from 2004-2006, we surveyed eight populations of *O. conchaphila* ranging from Humboldt Bay to Elkhorn Slough (Table 1). Disseminated neoplasia was found in (portions of) Tomales Bay, Drakes Estero, and San Francisco Bay. Prevalence varied greatly between sites. Intensities of the disease within individuals also varied widely, ranging from the neoplastic cells being very rare to comprising greater than 90% of the cells in circulation.

Whether disseminated neoplasia plays a role in the current distribution of native oysters and what impact it may have on restoration efforts remains unclear. In Atlantic Canada soft shell clams, *Mya arenaria*, epidemic occurrence of the disease was associated with mass population mortality. In contrast, Puget Sound mussel, *Mytilus trossulus*, populations can thrive even while the disease causes significant individual mortality. The wide range in prevalence of disseminated neoplasia in the *O. conchaphila* populations sampled suggests that physical, biological, and temporal factors may play important roles in disease expression. Movement of oysters from regions where the disease has been identified should be restricted to other areas where it is known to occur. This work was supported in part by the California Sea Grant College and the California Department of Fish and Game.

Table 1. Prevalence (# positive/# examined) of *Ostrea conchaphila* with disseminated neoplasia.

Site	**Shell Height Range, mm**	**Collection Date**	**Substrate**	**Disseminated Neoplasia**
Humboldt Bay- Mad River Estuary	46-65	Feb 2004	Oyster Raft	0/60
Tomales Bay- North End	37-55	Aug 2004	Cobble/Rocks	2/60
Tomales Bay- South End	36-64	April 2004	Oyster Racks	0/60
Drake's Estero	10-58	July 2004	*C. gigas* shell	27/63
Fort Mason Marina, SF Bay	22-35	June 2006	Rip-rap	1/60
Candlestick Park, SF Bay	9-40	Jan 2005	Cobble/Rocks	13/48
Sailing Lake, Mountain View	17-86	Jan-Feb 2005	Rock	0/72
Elkhorn Slough	38-71	May 2004	Cobble/Rocks	0/60

Presentation (pdf)

Impacts of invasive drills on Olympia oysters in Puget Sound: implications for restoration

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The native Olympia oyster (*Ostrea conchaphila*) once supported important commercial and subsistence fisheries in Puget Sound, Washington, but suffered drastic declines due to overexploitation and pulp mill pollution. Recovery has been slow, and one potentially limiting factor is the effect of nonindigenous species, in particular predation by the Japanese oyster drill (*Ocinebrina inornata*). Japanese drills historically caused significant economic losses to Olympia oyster aquaculture, but their impact on recent restoration efforts remains largely unknown. If drills have a saturating (e.g., Type I or II) functional response, they could keep local oyster populations suppressed at low levels. However, the magnitude of drill impacts may depend on the availability of alternative prey species, such as barnacles and nonindigenous bivalves.

To test these hypotheses, we measured drill predation rates by transplanting Olympia oysters into several sites in Puget Sound. At some sites, drills were responsible for a large fraction (up to 100%) of total oyster mortalities over a three- to four-month period, but predation pressure was highly variable within and among sites and was only weakly related to drill density. The per capita interaction strength of drills diminished with increasing density of naturally occurring Olympia oysters, indicating that drill feeding rates saturate when prey are abundant. In addition, there was an indirect effect of alternative prey: drill per capita interaction strength was negatively related to densities of barnacles (*Balanus* spp.) and Pacific oysters (*Crassostrea gigas*). We performed enclosure experiments manipulating drill, Olympia oyster, and barnacle (*Balanus glandula*) densities to directly estimate the shape and parameters of the drill functional response. The data strongly support a saturating, but not sigmoid (Type III) response, consistent with the oyster transplant study.

These results suggest that controlling Japanese drills would benefit Olympia oyster recovery or restoration efforts in some areas; however, drill eradication is notoriously difficult and labor-intensive. Native oyster restoration may be possible even in the presence of drills if local abundance and recruitment are sufficient to saturate drill feeding rates, or if alternative prey are available.

Presentation (pdf)

Top down obstacles to native oyster recovery and restoration in California

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Despite the lack of fishery exploitation of the Olympia oyster, *Ostreola conchaphila,* for nearly a century, native oyster populations have not returned to the densities they are believed to have achieved historically. The same forces that have prevented recovery of this species in the 20th century may also hinder future restoration efforts. We summarize our recent work in a central California estuary, Tomales Bay, CA, which indicate that both crab and gastropod predators can significantly influence native oyster survival. We found that both native crabs, *Cancer productus* and *C. antennarius*, and the introduced European green crab, *Carcinus maenas*, can be a significant predators consuming significant numbers in experimental trials. Green crabs may be particularly important in the areas of more variable salinity that can exclude cancrid crabs. We also found a significant predation due to the non-native whelk, *Urosalpinx cinerea*, with higher rates of predation relative to the native whelk, *Acanthina spirata*, in both field and lab experiments. The introduced *Urosalpinx* is the dominant whelk in portions of the bay with more variable salinity. Predation rates of these native and non-native predators do not act independently as our work demonstrates that crabs also prey heavily on whelks. Ultimately rates of predation in field and lab experiments show that predation rates on native oysters are determined by a trophic cascade (crab, whelk, oyster), which shifts predictably from native to introduced predators across an estuarine gradient. Our data suggest that these predators may present a substantial obstacle to future recovery. Given the rapidly changing mixture of old obstacles (oyster drills) and new obstacles (green crabs, other oyster species), mitigating predator impacts may need to be a fundamental requirement of restoration planning.

Presentation (pdf)

Preventing the introduction of non-native species with imported oyster shell used for cultch in restoration projects: an inspection, and consideration of future protocols

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Quantities of Pacific oyster (*Crassostrea gigas*) shell, taken from oyster farming operations in other bays on the Pacific Coast, have been placed in San Francisco Bay beginning around 2000 for a variety of purposes, including research programs aimed at restoring native oysters and habitat enhancement in mitigation for construction projects. In January 2006, NOAA held a meeting of agency staff, restoration workers, and area scientists to discuss the development of a protocol for handling oyster shell to be placed in San Francisco Bay to minimize the risk of introducing novel exotic species. While most participants agreed that a protocol was needed, funding to develop a protocol has not yet become available.

In the absence of an agreed-upon protocol, in July, 2006 we were contacted by MacTec, a consulting firm, to inspect a pile of oyster shells at Drakes Estero that was expected to be used as cultch for an experimental native oyster restoration project at the Marin Rod and Gun Club. After consulting with the California Department of Fish and Game (CDFG) we conducted a qualitative inspection for live marine invertebrates, and found none. CDFG subsequently allowed the placement of the shell in San Francisco Bay.

While the inspection seemed a reasonable approach given the specific circumstances in this case, we believe that for future use of potentially large quantities of imported oyster shell it would be better to develop and implement standard protocols (that could, for example, specify shell processing methods or drying times) to reduce the risk of introducing non-native species. We will discuss the value and limits of shell inspections, and describe a scheme for developing appropriate shell management protocols.

Presentation (pdf)

Session: Ecological Interactions and Ecosystem Services

Ecological Interactions and Ecosystem Services – Session Summary

Panel members:
Hunter Lenihan (University of California, Santa Barbara)
Jonathan Grabowski (Gulf of Maine Research Institute)
David Kimbro (University of California, Davis)

Presentation Summary

This session addressed the ecosystem services provided by oysters and oyster reefs, and the ecological interactions between oysters and their surrounding natural environment. Note that the first two presentations reported on East Coast oyster reef habitat of *Crassostrea virginica*; these findings can help inform West Coast restoration efforts, but may not be considered directly applicable. Hunter Lenihan discussed the changes in reef structure over time, and the role that harvest plays in structure and function of oyster reefs. He found that increased flow over reefs decreased disease prevalence, and that higher vertical structure of reefs elevated the top-most oysters above hypoxic conditions closer to the benthos. He also addressed the economics of restoration, pointing to a case study in which $1 million was spent to restore $300,000 worth of commercial production.

Jonathon Grabowski presented information on the trophic and economic value of oyster reefs, as an argument for incorporating oyster reefs into ecosystem restoration efforts. A recent study concluded that the presence of oyster reefs added tertiary productivity, especially in the form of non-piscivorous fish. However, this increase was not absolute, and was more evident in some cases than others. He noted that the most evident increase in benefits to fish occurred when an oyster reef was isolated in a mudflat, as compared with a reef adjacent to marsh or seagrass.

David Kimbro presented work that examined species diversity in relation to disturbance levels, in the context of native oysters as a foundation species. Kimbro and Grosholz (2006) found that increasing oyster abundance due to decreased disturbance resulted in higher species richness (number of species) of benthic invertebrates. However, this increase in richness of mobile and sessile species was offset by decreasing evenness, depending on the functional group. This work highlights the complex effects of disturbance and oyster structure on species richness and evenness, and suggests that the consequences of oyster restoration on species diversity will vary among functional groups.

Discussion Summary

The panel discussion explored several fundamental issues and questions about *O. conchaphila*. For example, what did an unaltered native oyster bed look like? *O. conchaphila* individuals are easily broken apart, even by weather events, and did not tend toward reef-building. Also, significant differences would be likely between intertidal and subtidal populations. There was recognition that adjacent habitat types can significantly affect oyster restoration, and different ecosystem benefits require different scales of restoration (i.e., water quality improvements would require a relatively large restoration project); but that smaller scale benefits are possible even at small spatial scales. Finally, panelists noted the need for standard sampling protocols and a need to continue research to answer the fundamental questions about ecological interactions among various estuarine species in West Coast bays and estuaries.

Habitat restoration to recover ecosystem function in the southeastern U.S.

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The decline of the oyster fishery in the eastern United States continues despite extensive restoration efforts. While other emergent biogenic estuarine habitats such as seagrass beds and salt marshes have received both legal and regulatory protection for performing valuable ecosystem functions (e.g., they act as nutrient sinks, stabilize sediments, and provide critical nursery grounds for fish and invertebrates), oyster reef habitat, which provides similar ecosystem goods and services, traditionally was managed as a resource to exploit. More recently coastal management plans have recognized the need to further our understanding of the services provided by oyster reefs rather than permit continued overexploitation of oysters. A review of the studies providing quantitative measurements of fish and large crustacean densities on oyster reefs versus adjacent sedimentary habitat in the southeastern U.S. determined that restored oyster reefs are expected to yield an additional 2.6 Kg per yr of tertiary productivity. In order to understand better how this ecosystem service varies as a function of the landscape setting in which an oyster reef is set, we assessed the biological and economic value of fish and crustacean recruitment to, and utilization of, restored intertidal oyster reef habitat in the different landscapes in which they historically occurred. We found that oyster reefs provided critical habitat for juvenile fish when reefs were isolated from vegetated habitats and that oyster reefs generally contained higher densities of several groups of prey (bivalves, gastropods, and crustaceans). These results are being incorporated into an economic assessment of the ecosystem goods and services associated with oyster reef habitat.

Presentation (pdf)

Eastern oysters, restored reefs, and food web interactions: the role of habitat structure in modifying effects of disturbance

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The eastern oyster, *Crassostrea virginica*, creates structurally complex biogenic reefs that provide habitat for demersal and highly mobile fishes, crustaceans, and their prey in estuaries like the Neuse River, North Carolina, U.S.A. We (1) sampled fishes and invertebrates on natural and restored reefs, and on sand bottom to compare fish and crab utilization of reef habitats with different structural characteristics, (2) described the trophic relations among reef-associated fishes and benthic invertebrates, and (3) tested how disturbances caused by fishing, reduced water quality, and sedimentation influenced trophic interactions. We found that oyster reef food webs were relatively complex, included several species of high economic value, and the structure of reefs can control predator-prey interactions by modifying the intensity of physical disturbances. Our results provide models for how oyster reefs can be restored in different environmental settings to enhance oyster production and the abundance of reef associated species. Our results also have implications for the design of Marine Protected Areas, showing that reserves placed in proximity to disturbed areas may be impacted indirectly but may serve a critical refuge function on a scale that matches the mobility of consumers.

Presentation (pdf)

Maintenance of biodiversity in a native California oyster community: the relative importance of disturbance, competition, and facilitation

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Current theory regarding the maintenance of species diversity has not been fully integrated and experimentally tested in communities with foundation species. The Intermediate Disturbance Hypothesis (IDH) suggests sessile species diversity will be greatest at intermediate disturbance levels, whereas facilitation theory predicts that overall diversity will be highest at low disturbance levels that maximize facilitation by foundation species. We used a field experiment to assess how disturbance, competition for space, and facilitation may interact to affect species diversity in a native California oyster community. As predicted by IDH, the competitively dominant native oyster (*Ostreola conchaphila*) reduced species richness and evenness of intertidal sessile organisms at low disturbance levels. Intermediate levels of disturbance created space, increasing richness and evenness of sessile species. In accordance with facilitation theory, oyster structure under low disturbance enhanced species richness and abundance of mobile invertebrates and organisms attached to oysters. However, species evenness decreased as disturbance subsided. Because this decline in evenness counteracted increases in richness and abundance, we found no support for the prediction that facilitation by a foundation species enhances overall species diversity under low disturbance. Rather, differential responses of functional groups to disturbance, competition, and facilitation produce a balance between species richness and evenness, maintaining equal diversity across a disturbance gradient.

Presentation (pdf)

Session: Restoration Past, Present, and Future

Restoration Past, Present, and Future – Session Summary

Panel members:
Jennifer Ruesink (University of Washington)
Betsy Peabody (Puget Sound Restoration Fund)
Dick Vander Schaaf (The Nature Conservancy)
Steve Rumrill (South Slough National Estuarine Research Reserve)
Dave Couch (City of Arcata)
Bud Abbott (MACTEC Engineering and Consulting, Inc.)
Loren Coen (South Carolina Department of Natural Resources)

Presentation Summary
During this session the speakers discussed various Olympia oyster restoration projects occurring from Northern Puget Sound to San Francisco. Presenters focused on the success rate of various restoration techniques and shared lessons learned about implementing oyster restoration projects. In addition, Loren Coen discussed some lessons learned from *Crassostrea virginica* restoration efforts conducted along the U.S. East Coast.

Common themes among most of the presentations included the need to locate remnant populations of Olympia oysters, learn more about the structure of historical beds, and identify locations of historic populations that still have naturally high spatfall. Tidal elevation was consistently found to have a strong influence on restoration success. Along the coast, Olympia oysters were observed to naturally set on a variety of substrates, including shell, rock, rubble, eelgrass, and mudflats.

Washington

Jennifer Ruesink presented studies examining the effectiveness of restoration techniques tested in Willapa Bay and North Bay in Puget Sound. In Willapa Bay, loose shell placed on the mudflats were either washed away or covered in silt, whereas more stable treatment, such as bagged shell and shell rosettes, had native oyster recruitment. In North Bay various loose substrate enhancements were tested, including Olympia oyster shell and live oysters, whole and crushed Pacific oyster shell, gravel, and bare tideflat. There was no statistical difference between the shell treatments, but Olympia oyster shell proved to be better substrate than gravel.

Betsy Peabody and the Puget Sound Restoration Fund (PSRF), in partnership with a suite of governmental and non-governmental organizations, have been restoring oysters throughout Puget Sound since 1999. In order to maintain local genetic populations, PSRF has moved from seeding with hatchery-set oysters to primarily conducting substrate enhancement in areas with good recruitment. They found that suitable sites must have a relatively firm substrate, protection from environmental conditions, consistent water source, and mixture of saline and freshwater, as well as remnant populations of oysters. Helping communities understand the importance of oysters to the larger ecosystem has enabled PSRF to expand their partnership and gain access to private tidelands.

Oregon
Dick Vander Schaaf discussed The Nature Conservancy's (TNC) effort to restore oysters in Netarts Bay. TNC placed shell with spat from local broodstock in the bay, using both bagged and loose shell. TNC is monitoring the restored oysters and adjacent eelgrass populations to examine interactions between these species. To date the main hurdles for this project have been regulatory issues and acquiring conservation leases on submerged lands, as well as sedimentation, predation from Japanese oyster drills, and invasive species.

Steve Rumrill of the South Slough National Estuarine Research Reserve is working in Coos Bay, where isolated populations of Olympia oysters have re-established after becoming locally extinct. These re-established populations have not been able to spread throughout the bay. The project will identify an appropriate genetic source of broodstock. The potential to restore self-sustaining populations to the South Slough estuary will be investigated by identifying the limitations to recruitment, survivorship, and growth. The project will also examine potential eelgrass–oyster interactions.

California
In Humboldt Bay, Dave Couch constructed oyster beds similar to those in Willapa Bay; however, oyster drills and highly varying sets precluded establishment of self-sustaining populations. His team found Olympia oysters naturally setting on construction rubble and quarry rock, and on some beds in tidal channels. They are now experimenting with various settling substrates, including a mixture of gravel and oyster shell 'flour' into which paper egg cartons are dipped to be placed as substrate in the bay.

Bud Abbott discussed potential limiting factors at three restoration projects in San Francisco Bay. Bair Island supported a strong population of oysters, even with large populations of predators and invasive species at the site. Low dissolved oxygen levels at Sailing Lake may have helped to exclude space competitors and predators, thus allowing oysters to have high populations in the deeper portions of the lake. Prolonged inputs of freshwater to the Bay may have caused 90 percent oyster mortality at the North Bay site.

East Coast - *C. virginica* lessons learned
Loren Coen recommended that, at this early stage, Olympia oyster restoration practitioners establish clear and realistic restoration goals, standardized monitoring methods, and long-term population assessments. In addition, research should focus on determining the structure and function of historical shellfish beds and examining whether recruitment or substrate is the prime limiting factor for potential restoration areas. Coen also stressed that practitioners should not oversell the water quality benefits and other services of oysters, as this may result in public disillusionment with oyster restoration activities.

Discussion Summary

During the panel discussion, important areas of research to help guide and inform future restorations were identified, including:

- Historical oyster bed structure
- Assessment of different habitat enhancement materials
- Assessments of age class structure within natural and restored populations
- Coordinated coastal monitoring of spatfall

The panel agreed on the importance of setting standard metrics for monitoring. There were some concerns about using non-native oyster shell as a substrate, because it will take a long time to break down and can potentially alter the subtidal environment. It is also important to involve and educate the public about the need to restore native oysters, without setting expectations too high.

Evaluation of native oyster (*Ostreola conchaphila*) status and restoration techniques in Puget Sound, Washington, U.S.A.

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The native oyster of Washington state, U.S.A. (*Ostreola conchaphila*) was heavily exploited (1850-1940), declined dramatically, and has subsequently failed to recover, although it still supports small aquaculture operations. This paper documents the distribution and abundance of *O. conchaphila* in one of the last remaining locations where it forms extensive beds: the North Bay Oyster Reserve in Puget Sound. *O. conchaphila* at North Bay cover an area of approximately 0.2 km^2, generally between -1 and +0.3 m relative to mean lower low water. In June and July 2005, we assessed bed characteristics in 38 quadrats (50 x 50 cm) placed haphazardly throughout the area occupied by oysters. Median density was 134 m^{-2}, with a range of 8 to 852 m^{-2}. Density was not related to any other environmental characteristics measured in the quadrats (silt, sand, gravel, or shell). Oysters ranged in size from 4 to 64 mm, with two distinct peaks visible in the size-frequency distribution. Oysters were particularly common between 30 and 50 mm in size, and a smaller peak occurred between 5 and 15 mm.

We monitored recruitment every two weeks between May and September 2004 and found a small recruitment peak in late July, which was much later than reported for these oysters when they were abundant throughout Puget Sound. The lower tidal elevation sampled (MLLW) received consistently greater numbers of recruits than the higher elevation (+0.6 m MLLW).

We also experimentally tested two factors that could influence recovery: tidal elevation and substrate type. We established 1 m^2 plots at three tidal elevations (-0.3, 0, +0.3 m MLLW) with six substrates: bare, gravel, crushed shell of *Crassostrea gigas* (Pacific oyster), whole *C. gigas* shell, whole shell of *O. conchaphila*, and live *O. conchaphila*. The plots were set up 21 May 2004 and measured for recruitment on 16 October and 11 April 2005 by collecting material from a 0.0125 m^2 area of each plot. Recruitment improved at low tidal elevations and on shell, with the greatest abundance of total recruits on *O. conchaphila* shell, followed by live *O. conchaphila*, whole *C. gigas* shell, crushed *C. gigas* shell, gravel, and bare tideflat. *O. conchaphila* shell provided a better recruitment substrate than gravel, but shell treatments could not be distinguished statistically. These results remained generally consistent over one year, and suggest that the restoration of *O. conchaphila* should be aided by the creation of subtidal shell areas where natural recruitment still occurs. Although oyster density declined over time in the experiment due to post-recruitment mortality, there was no evidence of differential survival by treatment; that is, treatment effects were established during recruitment or soon after. For live recruits in October 2004, the median size (length of longest measurable dimension) was 2 mm over all plots. In April 2005 the median size of live recruits was 5 mm. This shift to slightly larger oysters in April indicates that the surviving recruits did grow over the winter.

Oyster restoration has been carried out in two ways: addition of individuals and restoration of habitat. The advantage of restoring habitat is that no hatchery rearing needs to take place, which can alter genetic composition through poor choice of broodstock or selection in the hatchery. This study indicates habitat restoration needs to occur at low tidal elevations, and with shell substrate.

Presentation (pdf)

Native oyster restoration in Puget Sound - 1999-2006

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A collaborative approach to restore native oysters has been underway in Puget Sound since 1999—involving public and private sectors and tribal communities. Spurred initially by the publication of WDFW's Olympia Oyster Stock Rebuilding Plan, the restoration effort is increasingly driven by 1) broader community support—from funders, university scientists, tideland owners, reporters, federal, state and local governments, and other nonprofit groups; 2) a growing understanding that restoring native oysters improves the ecosystem; and 3) a recognition that oyster restoration projects are substantive and newsworthy and therefore fit neatly within the broader context of Governor Gregoire's push to restore Puget Sound by 2020. Since the late 1990s, our collective knowledge of remnant populations has increased, restoration methods have evolved, the science of monitoring has become more complex, and priorities have shifted as we learn more about current distribution. For instance, restoration efforts have shifted away from seeding and toward habitat enhancement so that remnant populations can recolonize historic ground and the genetic make-up of potential sub-populations can be preserved. In recent years, new partnerships and additional funding have enabled larger-scale efforts to restore native oyster abundance and the ecological benefits associated with that abundance.

Presentation (pdf)

Native oyster restoration in Netarts Bay, Oregon

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The Olympia oyster (*Ostrea conchaphila)* once inhabited many of the larger bays and estuaries in the Pacific Northwest and was thought to be a keystone species in these estuarine systems. In Oregon, the species was known from Netarts Bay on the north coast as well as two other bays to the south. Netarts Bay lies between Cape Lookout to the south and Cape Meares to the north and is characterized by being a saltwater dominated bay that has only minor freshwater inputs. The bay is known for its excellent water quality and has a number of commercial oyster farms operating within it. This project initiated the restoration of the Olympia oyster to Netarts Bay in 2005 under a grant from the NOAA—TNC Community-based Restoration Program. Broodstock was collected from Netarts Bay and spawned at the Whiskey Creek Shellfish Hatchery. The larvae were settled onto oyster shell in bags that were then moved into the bay in early summer with assistance from local oystermen. In 2006, after several bureaucratic hurdles, the oysters were removed from the shellbags and placed directly onto the substrate. Studies to determine the interaction of native oyster restoration on eelgrass are being conducted at the site by Oregon State University. Efforts are also being undertaken to reduce stressors to native oyster recovery by removing nonnative oyster predators from the bay.

Presentation (pdf)

Restoration of Olympia oysters in the South Slough estuary, Oregon: planning as a precursor to population recovery

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Olympia oysters (*Ostrea conchaphila*) were historically abundant in the Coos estuary and South Slough (Oregon) where they were utilized extensively as a food source by the indigenous people. Several shell middens that contain Olympia oysters occur along the shoreline of the South Slough, and Olympia oyster shells are commonly included in the dredged materials removed from the estuarine channels. Beds of *O. conchaphila* became locally extinct in Coos Bay and South Slough prior to written history due to basin-wide changes in the inputs and distribution of fine sediments. Over the first century following colonization of the shoreline of the Coos estuary by Euro-western settlers (ca. 1850-1950), aquatic and estuarine habitats within portions of Coos Bay were chronically degraded by growing urbanization and the cumulative effects of sedimentation, log storage, bark decay, dredging, deposition of dredge spoils, diking, filling, domestic and industrial pollution, commercial mariculture of non-native Pacific oysters (*Crassostrea gigas*), and by the colonization of estuarine habitats by non-indigenous aquatic species. Despite these alterations and degradation of the shoreline (and reduction of the entire wet surface area of the Coos estuary by 26%), water column and benthic habitat conditions have improved considerably over the past thirty years within particular regions of the tidal basin to the point where they are now conducive to the recovery of native oysters. In 1988, following several years of inadvertent inoculations via commercial shellfish culture activities, discontinuous populations of Olympia oysters became re-established at low intertidal and shallow subtidal elevations within the polyhaline (22-28 psu) region of the Coos estuary.

Although the isolated populations of Olympia oysters have established a toe-hold within the Coos estuary, widespread recovery of *O. conchaphila* populations has not occurred due to several potentially limiting factors. These factors include: (a) sub-optimal biotic and physical conditions that may hamper feeding, survivorship, growth, and reproduction; (b) inadequate production and retainment of larval supplies; (c) decreased availability of adequate shell substratum for settlement; (d) poor recruitment and survival of post-settled juveniles; and (e) predation, competition, and ecological interactions with other established native and non-native species.

The purpose of this project is to investigate the potential to restore self-sustaining populations of *Ostrea conchaphil*a in the South Slough estuary. Our primary goal is to determine the suite of intrinsic and ecological factors that will contribute to the success of Olympia oyster restoration efforts in the South Slough. The specific objectives for the initial phase of the project are to: (1) establish the genetic signature of existing oyster populations and identify potential brood stock sources, and (2) conduct an experimental on-site assessment of oyster survivorship, growth, and reproduction of Olympia oysters transplanted into the South Slough. Small isolated populations of *O. conchaphila* that currently exist in Coos Bay are most likely the result of previous (historic) and inadvertent imports of non-native Pacific oysters for the purpose of commercial cultivation, and the existing populations of Olympic oysters may have originated in the past from areas well outside of Coos Bay (i.e., Willapa Bay, Puget Sound). Consequently, selection of the initial brood stock oysters that will be the source of progeny (juveniles on shell cultch) transplanted into South Slough will have important genetic consequences for the future populations of oysters that may become established in South Slough, Coos Bay, and perhaps elsewhere. Variability in the genetic signature of the Coos Bay oysters will be compared with information about several potential sources of brood stock oysters. In 2006, our project collaborators (M. Camara, C. Langdon, and D. Stick) will conduct DNA microsatellite analysis to document repetitive DNA sequences and establish the distinctive genetic signature for the local Coos Bay oysters. These results may provide information about the history of *O. conchaphila* re-introductions within Coos Bay, and will offer guidance regarding the specific choice of brood stock oysters that may serve as the source for our subsequent transplants and restoration efforts in South Slough.

During the second year of the project (2007) we will transplant experimental populations of *Ostrea conchaphila* cultch (living juveniles attached to non-living oyster shells) into the lower intertidal and shallow subtidal habitats of the South Slough estuary. The transplant site is located within the marine-dominated polyhaline region of the South Slough estuary (salinity range 19-30 psu). The South Slough National Estuarine Research Reserve (NERR) maintains an automated water quality datalogger (YSI-6600 EDS) in the tidal channel near the study site, and high-resolution time-series data will be available for several water quality parameters including water level, temperature, salinity, conductivity, pH, dissolved oxygen, turbidity, chlorophyll, nitrates, nitrite, ammonium, and ortho-phosphate. An historic oyster midden is located at the base of Younker Point and indicates that native oysters historically existed very near the proposed transplant site. We will conduct periodic field assessments and monitoring to determine the survivorship, growth, and reproduction of the transplanted oysters. We will transplant about thirty bags of oyster cultch into the South Slough, and each bag will contain about 500-750 juvenile oysters (total transplanted is 15,000 to 22,500 native oysters). The benthic substratum at the transplant site is a mixture of sand-mud-eelgrass, and the site is located across the estuarine tidal channel from an area of active commercial oyster mariculture (Brown's Cove). The transplanted oysters will initially be contained within Norplex bags to exclude predatory crabs (*Cancer magister* and *C. productus*) that are seasonally abundant in the tidal channel. We will place wooden plates (cedar shakes) beneath the substratum to stabilize the stakes and oyster bags, and will explore the need to add additional shell or gravel as a substratum for new recruits. We will measure the survivorship and growth of the transplanted oysters on a monthly basis over a period of 12 months (June 2007 to May 2008). During each monthly census, we will examine the shells of dead oysters closely to determine the likely cause of death (i.e., shell breakage as evidence of predation by crabs, drill holes caused by predatory gastropods, smothering by colonial tunicates, burial in mud, etc.). On a quarterly basis, we will also collect a subsample of the transplanted oysters for determinations of biomass and gonad development. Smears of gonadal tissue will be examined under a microscope to determine oyster gender and the development of oocytes and sperm. Brooding oysters will be noted, and we will also conduct counts of the number and stages of veliger larvae retained within the mantle cavity. We will also conduct an analysis of biodiversity data from spatfall monitoring devices (deployed previously throughout the Coos estuary and South Slough in 2003-2004 in cooperation with the Smithsonian Environmental Research Center) to determine whether natural larval settlement of *O. conchaphila* occurs in different regions of South Slough. Information collected from local oyster growers will be coupled with the analysis of epifouling invertebrate communities to infer differences in larval supplies and settlement in Coos Bay, and to help locate potential sites for future reintroduction efforts.

It is anticipated that once the hurdles to successful recruitment are understood and perhaps overcome, it may be possible to initiate recovery of native oysters on a spatial scale that will allow the oyster populations to maintain themselves on a self-sustaining basis. Re-establishment of self-sustaining populations of *O. conchaphila* is desirable because, in addition to the recovery of the oysters, the growing physical structure of the oyster beds will serve to restore some of the lost ecological functions to the estuarine tidal basin, and the living oysters may reach a point in the future where they can provide substantial benefits for diverse communities of invertebrates, fish, shorebirds, and humans.

Presentation (pdf)

Native oysters in Humboldt Bay and Arcata's native oyster project

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No abstract is available for this presentation.

Presentation (pdf)

Limiting factors at three habitat restoration sites in San Francisco Bay

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Studies at three locations in San Francisco Bay in 2005-2006 suggest a variety of biotic and abiotic limiting factors drive native oyster (*Ostrea conchaphila*) abundance. Two studies were focused on the creation of habitat on featureless mudflats and a third was a study on a large concentrated population located in an artificial lagoon. A salinity decline associated with an abnormal rainfall pattern in March 2006 appears to have reduced the population by 90% in the northwest side of San Francisco Bay. The Bair Island site in south San Francisco Bay developed and maintained a robust population of native oysters in spite of an abundance of oyster drills, an abundance of benthic invasive species, and the same rainfall regime. A narrow band of benthos in the Shoreline Sailing Lake is exclusively populated with *O. conchaphila*. Seasonal low dissolved oxygen levels in the deepest part of the lake may exclude other species of bivalves, and the relative absence of oyster drills and other predators has allowed the population to flourish. The vertical growth rate of the oyster community has tended to barely exceed the rate of sediment accumulation.

Presentation (pdf)

Lessons from the study of the Eastern oyster, *Crassostrea virginica* Gmelin restoration efforts: some learned and some forgotten

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Prior to the 1990s, managers focused their attention almost exclusively on the restoration or enhancement of the Eastern oyster, *Crassostrea virginica*, as a fishery resource. It was only then that we broadened our perspective and invested significant dollars and energy on oyster restoration for the beneficial 'ecosystem services' they provide in their native ecosystems (e.g., Peterson et al. 2003). As an example, in their updated compendium on the biology of the *C. virginica*, Kennedy et al. (1996) made little reference to these additional 'services,' despite extensive work by Wells, Dame, Ulanowicz, Newell, Bahr and others from the 1960s through the 1980s on their role in filtering vast quantities of water (summarized in Dame 1996) and other important functions. In the southeast, intertidal reefs also serve critical roles for many bird and mammal species, and our work in SC suggests that they also protect fringing *Spartina alterniflora* marshes from natural and anthropogenically-generated erosion.

Despite a diverse and extensive literature on *C. virginica* throughout its range (Canada to Gulf of Mexico-Brazil), there are relatively few attempts to generate U.S. datasets that have statistically-comparable methodologies (Coen and Brumbaugh, pers. obs.) for meta-analyses, nor are there appropriate ecological data on reefs prior to their decline in areas with subtidal or intertidal reefs. Hence we have inadequate 'reference' data or sites to assess restoration 'success' to some historically-healthy reef condition (e.g., Thayer et al. 2005, Brumbaugh et al. 2006, ASMFC 2006). In a strange twist of fate, the current EIS for introducing a non-native oyster (*C. ariakensis*) into the Chesapeake has galvanized funding and the political will to invest in large-scale, collaborative efforts that can develop and evaluate the ecosystem services that oysters provide, along with efforts to restore those services lost through its (*C. virginica*) demise (Coen et al. pers. obs., recent NSA dedicated session and JSR volume). These new data and associated modeling efforts would never have been supported and integrated without it being compelled by the EIS process.

In comparison to the Eastern oyster, restoration and related efforts for the Olympia oyster, *Ostreola conchaphila, (e.g.,* Peter-Contesse and Peabody 2005) seem manifoldly more complex in that there is: (1) little detailed historical information of any kind from its pre-exploited days (pre-1890s, no 'reference reefs') nor (2) abundant extant natural populations along its former broad-range to utilize for either (a) captive breeding/remote setting, or (b) simply studying them for the ecological roles they might serve (e.g., Baker 1995, Peter-Contesse and Peabody 2005, Ruesink et al. 2005, pers. comm., M. Camara pers. comm., other speakers at this workshop). Additionally, the Olympia oyster has a very different life history and associated unknowns (e.g., impacts from *C. gigas,* small size and fecundity relative to *Crassostrea* spp., small effective population sizes, 'best' stocks to use for each bay or region, internal brooding, novel diseases, to name just a few hurdles). Recent work on *C. ariakensis* in NC has highlighted a poorly-studied, native oyster, the crested oyster, *Ostreola* (*Ostrea) equestris*. This work discovered both a new *Bonamia* sp. and collected data on an endemic *Bonamia* sp. that may impact *C. ariakensis'* introduction, with *O. equestris* potentially acting as an unexpected parasite reservoir (Bishop et al. in press, Carnegie et al. 2006, Carnegie et al. in review, pers. comm., see http://www.bayjournal.com/article.cfm?article=1234).

Critical for all shellfish restoration efforts are explicit goals and appropriate metrics for their assessment. This has been a major flaw for many restoration efforts in general and probably for most, if not all *C. virginica* restoration efforts. In fact, we as researchers have promised many restored 'services,' but demonstrated few if any of these empirically or rigorously (e.g., Coen and Luckenbach 2000, Coen et al. 2004, Luckenbach et al. 2005, Grizzle et al. 2006). Although some ecologically-derived restoration benefits are evident immediately after shell ('cultch') is planted, many benefits/ecosystem services come only after oyster populations are well-established and functioning with oysters at or near their natural densities (e.g., Coen et al. 1999, Luckenbach et al. 2005). For example, much in the same way that offshore artificial fishing reefs attract fish almost immediately after they are created, planted shell immediately supports an enhanced-assemblage of plants and animals, fulfilling some of the potentially forecasted benefits. However, on the East Coast, longer-term, temporal patterns are only just beginning to be assessed for restoration efforts that are now reaching 5-10 years of age (see Powers et al. manuscript summarizing success for NC restoration efforts). Larger-scale ecosystem impacts have yet to be assessed in any rigorous manner.

For our SC studies, we have demonstrated (Coen et al. 2006, ASMFC 2006) that intertidal constructed reefs initially attracted a similar transient assemblage (fishes and invertebrates), when compared with natural oyster reefs in the same system. Hence, live oysters themselves may not be critical to establish a simple transient intertidal reef community (see Lehnert and Allen 2002, Coen et al. 2006). In contrast, resident associates and the oyster/mussel assemblage require significantly more time to establish themselves (> five or more years, Walters and Coen 2006, Coen et al. in press). Additionally, after removing live oysters from intertidal creeks in SC, Dame et al. (2002) demonstrated biogeochemical coupling benefits were maintained via nekton feeding in creeks where shell bases remained, along with the flora and fauna that the established shell base continued to support. Unfortunately, most restoration efforts are long forgotten and proclaimed a success or failure well before these larger-scale impacts can be assessed.

Using inappropriate metrics to assess oyster restoration progress can also be problematic. Palmer et al. (1997) previously pointed out the importance of correctly choosing restoration endpoints and Zedler and Calloway (2000) and Craft et al. (1999) emphasized that habitat restoration success should not be solely dependent on the growth/survival of the targeted species. For instance, after only two years, restored subtidal reefs in the Chesapeake Bay did not yet support any 'market-sized' (75 mm or 3") oysters, but they did support extensive resident and transient assemblages of organisms, many of which were correlated with oyster size and density on the reefs (Luckenbach et al. 2005). Comparing all of our SC natural sites sampled over the last ten years, market-sized oysters (3" elsewhere, SC has no minimum size) made up less than 10% of all oysters at most sites, with a maximum of 18% at only two sites. Using our work and that of our colleagues, in 2004 we identified a set of potential restoration goals and discussed and ranked the value of all current approaches, sampling/monitoring methods, and associated metrics for *C. virginica* (Wilber et al. 2006). Although there is an International Conference on Shellfish Restoration (ICSR) annually, the only other organized and funded workshop/symposium that included a group meeting focused on oyster habitat restoration from such a broad geographic range prior to our 2004 workshop was in 1995 at VIMS (see resulting publication, Luckenbach et al. 1999).

The 'Oyster Restoration Working Group' an outgrowth of the 2004 workshop will have a website up and running quite soon that will allow for open discussions and sharing of restoration data and approaches. We (NC, GA, SC, FL) also have a pending grant to utilize identical approaches and metrics for all related grants funded in the southeastern U.S. through NOAA CRP's Partnership Program. The data will be centralized and analyzed uniformly at SCDNR for comparison. Other efforts including a TNC-led NCEAS proposal and a smaller Shellfish@Risk study are currently gearing up.

With all this said, I would now like to provide some lessons learned or lost, and related observations (not in order of priority). These include what was generated from our 2004 workshop, but also responses solicited by me from current practitioners along the East Coast, most of who were at our 2004 Sea Grant-supported workshop in SC (http://www.coastal.edu/marine/sgoyster):

1. Minimize user conflicts on the front-end. Don't pit ecological restoration against fishery restoration. This requires planning for the two to coexist without legislation that might threaten the livelihoods of the stakeholders. Include both fishery and aquaculture stakeholders, as well as environmental/ecological service proponents. Deal with permitting issues early;
2. Understand your restoration partners, their 'constituencies' and constraints. For large-scale restoration efforts (planting shell, adding larger broodstock, relaying oysters, or spat on shell) most conducted by state fisheries managers, ACOE, or large NGOs. Each group is responding to different constituencies, face different monetary constraints, expectations, and have different timeframes. Each often interprets the same results differently;
3. Invest in solid science (teams of collaborators for example) and develop the rigorous data using identical methods to better understand your systems and to assess eventually success. Have workshops early.
4. Take the time to develop clear, realistic goals for restoration at all levels (be it project, bay-wide, state-wide, or regional scales). Identify the most likely areas for success and tackle them first. Focus a lot of effort at a few research sites with a lot of control and potential 'reference' sites. If 'success' is achieved (requires many years), then expand to other areas;
5. Develop relevant and accepted (cost-effective) metrics to evaluate your goals. Also, don't oversell the 'services' (e.g., water quality benefits);
6. Start educating grant agencies immediately that monitoring is a critical phase for restoration efforts and that these efforts often require monitoring for periods >3-5 years (beyond the life of a normal grant cycle, Coen and Luckenbach 2000, Thayer et al. 2003, 2005);
7. Design the monitoring (=research) program, along with the restoration program, so that the two are seamless and robust;

a. Consider: bottom types, DO, sediment deposition rates, local hydrodynamics, water quality, HABs, introduced species, predators, competitors, diseases, etc. Follow changes in reef architecture/complexity over time. These will impact the success (or failure) of restoration projects be it with a non-native or native species;

b. Look at resident and transient species assemblages by utilizing novel methods. For the latter, there was vigorous debate at our 2004 workshop as to the level of this effort due in large part to the cost;

8. Justify monitoring for adaptive management or as a means to provide an understanding of why a particular effort worked or failed--this is critical. Are differences due in part to different approaches or different 'ecologies'? (cf. Underwood and Fairweather 1984);

9. Put significant effort into assessing appropriate site selection criteria early on (e.g., flow and/or sediment type, etc.) when identifying candidate sites for restoration. Often contractors or state resource agencies have a difficult time following through planting material correctly when timing and/or an experimental design is required;

10. Many of the science-based 'lessons learned' are difficult to translate into public policy because of #2, missions of agencies/organizations vary (e.g., low DO, rays);

11. Don't succumb to early failures, or simplistic cost-benefit analyses that 'demonstrate' that restoration efforts are a losing strategy. Plan to invest long-term; our valuation of 'services' is in its infancy, hence estimates are probably undervalued (Powers et al.'s The Myth of Failure);

    a. Don't underestimate the resiliency of natural oyster populations. This gets back to the issue of metrics, and giving things time to show results;

12. Choose stocks carefully. Don't assume that stocks selectively bred for aquaculture are the most appropriate for restoration. For *O. conchaphila*, it appears that an emphasis has been placed on population genetic architecture in your restoration strategies. The East Coast (especially the mid-Atlantic) has generally ignored this;

    a. We may be deliberately obliterating natural genetic structure/variation, in favor of 'terraforming' our systems with domesticated stocks-at our peril;

13. Be open to new ideas (e.g., alternative substrates, shell planting methods, different reef architectures, remote sensing for intertidal and subtidal populations, shell capping of other more available materials, underutilized labor resources), think 'outside the box,' and learn from failures (share them with your colleagues and publish them). Oysters on non-traditional substrates significant in urbanized areas (cf. Ross et al. 2006, NSA meeting, 'sanctuaries');

14. Start looking for potential native or introduced diseases. There is some evidence that *O. conchaphila* is not susceptible to *Bonamia ostreae (*West Coast sp.), but there are other microcells such as *Mikrocytos mackini* (C. Friedman et al. 1989, 2005 in CA, R. Carnegie, pers. comm.) that we know little about (cf. recent *Bonamia* spp. effects on *C. ariakensis* in NC);

15. Natural disease resistance. For *C. virginica*, places where MSX and Dermo are most intense, we are seeing very promising signs: Clear resistance to MSX and growing tolerance of Dermo, the latter demonstrated by (a) significant oyster populations emerging in waters where *Perkinsus* is most intense, and (b) a remarkable number of large, disease-free, fecund oysters. Look for signs of natural selection/adaptation to current West Coast conditions. Do you need to invest in a directed breeding program to select the best stocks (e.g., DEBYs, CROSBreeds)?;
16. Be mindful of the manifold threats/factors that can influence a project's success or failure;
    a. e.g., increased ray predation, exotic introductions (often a long time frame for observed impacts), timing can be critical
    b. Minor differences in materials and timing of substrate(s) planting can determine what colonizes and ultimately dominates the reef community
17. Capture and use the community's interest for restoration (e.g., http://score.dnr.sc.gov) and to address larger issues (e.g., water pollution, land-use/land conservation of coastal watersheds, fisheries management, etc.) to build constituencies. NGOs can be especially helpful and effective at fulfilling these tasks (e.g., TNC's new Shellfish Initiative). Early on, too few states involved public 'buy-in' for restoration other than for enhanced resources;
18. Employ novel strategies such as 'oyster gardening' or shell recycling (e.g., http://saltwaterfishing.sc.gov/oyster.html) to involve the public (but QUARANTINE shell before putting overboard, Bushek et al. 2004, JSR) and finally;
19. Don't be afraid to use 'Administrative Closures' (Prohibited or Restricted classifications) as enforced sanctuaries, these can be invaluable (closure signs are not all bad, #13).

Given the above, it is clear that we still have a long way to go for *C. virginica* and that efforts for restoring the Olympia oyster have added challenges and potentially even more hurdles. By far, the most important lesson is that restoration efforts should be designed in a scientifically-sound manner, with enough data on restored and reference (control) sites taken, so that it is possible to learn what does and does not work. We still have yet to make a strong enough case for oyster reef habitat as a 'biodiversity protector' (R. Brumbaugh), the way that we have for, say, coral reefs and we still have a long way to go to build consensus in management and the general public that oyster reef habitat is a critical element necessary for conserving diverse species assemblages in coastal waters.

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SC vertical cluster of oysters, many over 100 mm, coming off of a single 'seed' piece of shell. Note all of the densely-growing oysters are growing vertically to minimize the effects of sedimentation/ smothering (Coen 2006).

Proposed Six Restoration Goals

http://www.coastal.edu/marine/sgoyster

Presentation (pdf)

Session: Permitting

Permitting – Session Summary

Panel members:
Kerry Griffin (NOAA Restoration Center)
Russell Rogers (Washington Department of Fish and Wildlife)
Matt Hunter (Oregon Department of Fish and Wildlife)
Tom Moore (California Department of Fish and Game)
Jennifer Feinberg (San Francisco Bay Conservation and Development Commission)

Presentation Summary

This session focused on local, state, and federal regulations that apply to shellfish restoration. Although the primary regulatory vehicle in the past has been the individual states, the U.S. Army Corps of Engineers (Corps) recently increased its involvement in regulating shellfish in bays and estuaries.

Kerry Griffin discussed the federal permitting system that regulates 'fill' in U.S. waters through the Clean Water Act, implemented by the Corps. Currently, most commercial and restorative shellfish operations do not have permits. However, scrutiny will likely increase because the Corps has proposed adding a new nationwide permit (NWP) regulating commercial shellfish projects, and has modified NWPs 4 and 27, which traditionally would have covered restoration projects. Restoration practitioners must remain aware of changes in the permitting system, and use federal and state staff as resources to help guide the process.

Russell Rogers presented the permitting regime in Washington State, where the primary permitting vehicle for activities on public lands is the Hydraulic Project Approval (HPA). However, the HPA does not apply to privately owned tidelands, which account for most of Washington's commercial production and a significant percentage of its restoration activities. Changes may be made to the HPA soon, which could subject shellfish restoration activities to a Shellfish Transfer Permit and Shellfish Import Permit from the Washington Department of Fish and Wildlife, as well as a Shoreline Permit administered by the counties.

Matt Hunter presented Oregon's permitting regime—a mixed jurisdictional bag. At the state level, the Department of Agriculture manages the shellfish leasing program on state lands, but the Department of State Lands handles most other activities in bays and estuaries. Oregon Department of Fish and Wildlife also administers permits for shellfish transport, and requires that transported shellfish have a health certificate.

Tom Moore addressed permitting in California, where two sets of regulations govern shellfish restoration. California Fish and Game (CDFG) Code 6400 applies to the placement of plants and animals into state waters by non-CDFG entities for purposes other than aquaculture, such as shellfish restoration activities. A benefit-risk assessment is used in determining whether a permit will be issued. Section 15200 controls the placement of live plants and animals into state waters for aquaculture purposes, and gives

CDFG the authority to permit such activities. The application process includes guidelines designed to minimize the transfer of disease and invasive species.

Jennifer Feinberg described permitting in San Francisco Bay, where the San Francisco Bay Conservation and Development Commission has responsibility for permitting fill activities. Activities affecting less than 10,000 square feet qualify for a minor permit, but those affecting more than 10,000 square feet require a major permit subject to the public review process and Commission vote. Small projects have been exempt from fees, but this will likely change, which may raise the costs associated with shellfish restoration projects.

Federal permitting for oyster restoration projects

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Shellfish restoration projects, while clearly intended for the ecological benefit of local systems, are nonetheless required to obtain federal permits in most cases, depending on the exact nature of the restoration activities. The most common federal nexus is under section 404 of the Clean Water Act (CWA), which delegates to the U.S. Army Corps of Engineers (Corps) the authority to regulate 'fill' in 'waters of the United States.' This essentially means that any time any material is placed in a wetland, stream, or estuary, the activity requires a 404 permit. The Corps also implements the federal River and Harbors Act (RHA), which addresses primarily those activities that may affect navigation.

In either case, an application for a CWA or RHA permit constitutes a federal action, and the action agency must therefore consult with NOAA (and/or Department of the Interior) if the permitting action may affect a listed species or its habitat. The Corps must also consult with NMFS under the Essential Fish Habitat (EFH) provisions of the Magnuson Act if their action ‘may adversely affect’ EFH.

Federal permitting of shellfish restoration projects, as well as commercial shellfish operations, has historically been fairly inconsistent. However, the Corps is renewing its Nationwide Permits (NWP) that address many common actions affecting waters of the U.S. One of those NWPs is specific to habitat restoration activities, and may provide a streamlined vehicle for federal permitting of native oyster restoration projects. The NWPs will be available for public review and comment in fall 2006.

Consistent with the goal of regulatory streamlining, the Northwest Region of the NOAA Fisheries Restoration Center issued a programmatic Biological Opinion in 2004 that covers many restoration activities, including shellfish restoration. The Opinion includes EFH consultation, and provides a consistent, efficient mechanism for consultations with NOAA Fisheries.

Anyone embarking on a shellfish restoration project should contact their local Corps office to discuss obtaining a CWA permit. A complete listing of Corps Districts is available at http://www.usace.army.mil.

Summary of Major Statutes

The Clean Water Act (CWA) (33 *U.S.C.* 1251-1387) is a very broad statute with the goal of maintaining and restoring waters of the United States. The CWA authorizes water quality and pollution research, provides grants for sewage treatment facilities, sets pollution discharge and water quality standards, addresses oil and hazardous substances liability, and establishes permit programs for water quality, point source pollutant discharges, ocean pollution discharges, and dredging or filling of wetlands (or 'waters of the United States' as it says in the statute). The U.S. Army Corps of Engineers (USACE) has permitting authority under section 404 of the CWA (dredging or filling of wetlands), and therefore must consult with NOAA (and/or DOI) if the permitting action may affect a listed species or its habitat. The Corps must also consult with NMFS under the Essential Fish Habitat provisions of the Magnuson Act if their action 'may adversely affect' EFH.

Elevation mechanism: If NOAA Fisheries determines that a proposed action will result in 'substantial and unacceptable adverse impacts on aquatic resources of national importance,' the Assistant Secretary for Oceans and Atmosphere may request that the decision be reviewed at a higher level in the USACE. A 404(q) elevation pauses the permit process for about two months while the two departments exchange information to address concerns about the proposed project. While outright permit denials are rare, there are often modifications to the project proposal resulting in a less harmful action.

Endangered Species Act

The purpose of the 1973 Endangered Species Act (ESA) (16 *U.S.C.* 1531-1543) is to provide a means whereby the ecosystems upon which endangered or threatened species depend may be conserved, and to provide a program for the conservation of such endangered and threatened species. If a Federal action may affect ESA-listed species, the action agency must initiate consultation with NOAA Fisheries under section 7 of the ESA. Other pertinent sections of the ESA include section 9 (direct take) and section 10 (all Federal departments and agencies shall seek to conserve endangered and threatened species and shall utilize their authorities in furtherance of the purposes of the ESA).

Fish and Wildlife Coordination Act

The Fish and Wildlife Coordination Act (FWCA) (16 *U.S.C.* 661-666c) requires that wildlife, including fish, receive equal consideration and be coordinated with other aspects of water resource development. This is accomplished by requiring consultation with the U.S. Fish and Wildlife Service, NOAA Fisheries and appropriate state agencies, whenever any body of water is proposed to be modified in any way and a Federal permit or license is required. These agencies determine: (1) the possible harm to fish and wildlife resources; (2) the measures needed to both prevent the damage to and loss of these resources; and (3) the measures needed to develop and improve the resources, in connection with water resource development. NOAA Fisheries submits comments to Federal licensing and permitting agencies on the potential harm to living marine resources caused by the proposed water development project, and recommendations to prevent harm.

Magnuson-Stevens Fishery Conservation and Management Act

The Magnuson-Stevens Fishery Conservation and Management Act, first passed in 1976 and most recently amended in 1996, is the primary legislation governing marine fisheries. This legislation established eight regional Fishery Management Councils to manage fishery resources in the Exclusive Economic Zone under Fishery Management Plans (FMPs) for Federally managed fisheries. Plans may include one or several species and are designed to achieve specified management goals for a fishery.

The 1996 re-authorization of the Magnuson-Stevens Act included a provision for Essential Fish Habitat (EFH). The act states: "One of the greatest long-term threats to the viability of commercial and recreational fisheries is the continuing loss of marine, estuarine, and other aquatic habitats. Habitat considerations should receive increased attention for the conservation and management of fishery resources of the United States" (16 U.S.C. 1801 (A)(9)). The definition of EFH in the legislation covers: "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." The legislation mandates that NOAA Fisheries and the Councils implement a process for conserving and protecting EFH. Key features of this process are:

1. *Designate EFH*. Councils are required to describe and identify EFH for each life stage of the species included in their FMPs.
2. *Minimize to the extent practicable the adverse effects of fishing on EFH*. Councils must assess fishing impacts to EFH, taking Habitat Areas of Particular Concern (HAPCs) into special consideration (i.e., habitat types that are especially sensitive, ecologically important, or rare), and minimize the impacts of fishing on EFH to the extent practicable.
3. *Consult on potential fishing and non-fishing impacts to EFH*. NOAA Fisheries and the Councils are required to comment on activities proposed by Federal action agencies (e.g., Army Corps of Engineers, Federal Energy Regulatory Commission, Department of the Navy) that may adversely impact areas designated as EFH.
4. *Further review of decisions inconsistent with NMFS or Council Recommendations*. If a Federal agency decision is inconsistent with a NOAA Fisheries conservation recommendation, the Assistant Administrator for Fisheries may request a meeting with the head of the Federal action agency to review and discuss the issue.

National Environmental Policy Act

The National Environmental Policy Act (NEPA) (42 *U.S.C.* 4321-4347) requires Federal agencies to analyze the potential effects of a proposed Federal action which would significantly affect the human environment. It specifically requires agencies to use a systematic, interdisciplinary approach in planning and decision-making, to insure that presently unquantified environmental values may be given appropriate consideration, and to provide detailed statements on the environmental impacts of proposed actions including: (1) any adverse impacts; (2) alternatives to the proposed action; and (3) the relationship between short-term uses and long-term productivity. The agencies use the results of this analysis in decision-making. Alternatives analysis allows other options to be considered. NOAA Fisheries plays a significant role in the implementation of NEPA through its consultative functions relating to conservation of marine resource habitats.

Rivers and Harbors Act of 1899

The Rivers and Harbors Act of 1899, Section 10 (33 *U.S.C.* 403) authorizes the USACE to regulate activities that affect waters of the United States. These activities include construction of wharves, piers, jetties, and excavating or altering stream channels of navigable waters. NOAA Fisheries may comment on proposed activities (usually via the FWCA); and the CWA 404(q) elevation process (see Clean Water Act, above) is available to NOAA Fisheries under the Rivers and Harbors Act. A Rivers and Harbors permit issued by the Corps constitutes a Federal action that could trigger consultation under ESA or the Magnuson Act.

Presentation (pdf)

Permitting for Olympia oyster restoration projects in Washington State

Russell Rogers
Washington Department of Fish and Wildlife, Brinnon, WA
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The major state permit involving projects in marine waters is a Hydraulic Project Approval (HPA). Recent direction from the State Attorney General's Office has reiterated that private commercial aquaculture is exempt from the HPA process. Some Olympia oyster restoration activities can fall under this umbrella; however, many cannot, especially for projects involving public tidelands or public entities such as county Marine Resource Councils (MRC).

To be exempt from a HPA the restorationist must be a Registered Aquatic Farmer with WDFW and the project must fall on private tidelands. This exemption would not apply to any Federal or county permits. County Shoreline Development Permits vary from county to county.

To place oyster seed on a tideland, public or private, requires a Shellfish Transfer Permit or a Shellfish Import Permit from WDFW. These permits are specifically for disease, pest, and predator control.

For more information about HPA's consult the department web page for these permits:
http://wdfw.wa.gov/hab/hpapage.htm

For Shellfish transfer or import permits contact:
Russell Rogers
Fish and Wildlife Biologist
Washington Department of Fish and Wildlife
Point Whitney Shellfish Laboratory
1000 Point Whitney Road
Brinnon, WA 98320
Office (360) 586-1498 ex 221
Cell (360) 460-4923
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Presentation (pdf)

Native oyster restoration permitting in the State of Oregon

Matthew Hunter
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The state of Oregon has 22 bays and estuaries of which three, possibly more, had native oyster populations large enough to support commercial or subsistence fisheries. Significant harvest and habitat destruction from development and industrialization caused the collapse of the native oyster from historic levels. Currently there are remnant populations in three of those estuaries (Netarts, Yaquina, and Coos Bay). There have been limited restoration projects in two estuaries, Netarts and Yaquina. More recently, three independent projects have been proposed in Netarts, Yaquina, and Coos Bay.

Land use laws in the state of Oregon for estuary use are somewhat complex. They are multi-jurisdictional and are ultimately issued by the county in which the estuary is located. There are four main entities that have jurisdiction over oyster cultivation and restoration in one form or another in estuary state lands. The Oregon Department of Agriculture has legislative jurisdiction over all cultivated oyster lands with some exceptions. Those exceptions are then either covered by the Oregon Department of State Lands, or by individual counties and/or ports. These last two were given jurisdiction of the estuary back at statehood. Some estuaries are solely covered by one entity, while others may be controlled by all four in any mishmash of ways. This can and does cause for a very convoluted permitting process for restoration projects.

The basic process is as follows;

1. Determine jurisdiction for the estuary the restoration project is planned for.
2. Submit proper permit applications depending upon agency.
3. Applications are then sent out to concerned agencies (ODFW, USFW, NOAA, and etc.) and parties (watershed groups, conservation groups, and the general public via website) for comment.
4. When the comment period has ended the permitting agency makes its ruling whether or not the permit has been granted depending upon what comments were submitted.
5. Upon permit issuance, if from a state agency, then the final permit needed is a county land use permit. If the initial permit is from a county then there is no need for a land use permit.
6. If broodstock needs to be collected then a scientific take permit from the Oregon Department of Fish and Wildlife (ODFW) is needed.
7. If broodstock or seedstock needs to be imported into the state of Oregon then an ODFW transportation permit needs to be applied for.

Contacts

- Oregon Department of Agriculture - 503-986-4718
- Oregon Division of State Lands - 503-378-3805 ext. 259
- Oregon Department of Fish and Wildlife - 503-325-2462
- Counties (seven on coast) - http://bluebook.state.or.us/local/counties/counties.htm
- Oregon Ports - 503-585-1250

Presentation (pdf)

California Department of Fish and Game regulations and guidelines relating to outplanting activities

Tom Moore
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Outplanting is defined here to mean the release of captive marine plants, invertebrates, or vertebrates into state waters outside of state-water-bottom lease areas. The intent in producing these guidelines is to support consistent evaluation of proposals to release cultured species or wild broodstock into the marine environment.

The goal in producing these guidelines is to guide the evaluation of these specific external and internal outplanting activities to ensure, to the extent possible, that the activity avoids negative environmental impacts. The guidelines are general in nature. Specific terms or conditions that may be appropriate for individual project approval will be considered on a case by case basis and are not an element of this document

Permitting Process

Cultured species may be placed in waters of the state by non-departmental entities under two authorities (Sections 6400 and Section 15200 of the Fish and Game Code). Section 6400 controls the placement of live plants or animals into state waters for all activities other than those governed by aquaculture law (Division 12 commencing with Section 15000). The authority to approve these outplanting activities rests with the Department of Fish and Game and the authorizing Section specifically requires inspection and securing written permission from the Department. That permission generally takes the form of a Private Stocking Permit (FG 749)(Section 238.5, Title 14 CCR), which requires the signature of the Regional Manager.

Section 15200 controls the placement of live plants and animals into state waters for aquaculture activities. That Section conveys authority to the Fish and Game Commission to regulate placement of product into state waters and specifically exempts the aquaculture industry from having to have a permit to transfer between and place animals within aquaculture lease sites or privately held subtidal lands. Title 14 makes it clear that once stocked in the wild (under terms of a Private Stocking Permit) aquaculture products are considered wild (Section 238.5, Title 14).

Cultured species may be placed in waters of the state by the Department under multiple authorities (most notably Sections 6590 and 2061). The focus of these activities is either enhancement of wild stocks that have experienced declines or the recovery of stocks that are listed or being considered for listing under the ESA. The activities conducted under each of these authorities have distinct review processes involving separate advisory panels and may involve other agencies and outside private entities (aquaculture businesses). The Department may also place aquaculture stock into state waters for research purposes. None of the general research activities require specific permits or review beyond that provided by administrative/supervisory structure.

It is the intent of this document to provide guidelines and a structure oriented toward obtaining that consistency with the view that, if done correctly, outplanting is an activity that can have significant benefits to society. However, it must be recognized at the outset that risks associated with outplanting can only be minimized, they cannot be eliminated.

Guideline - Overview

Since there will always be attendant risk associated with outplanting, the activity needs to identify a demonstrable benefit to offset the risk. While a review with this type of focus will largely be subjective, it is appropriate given recognition that attendant risks can only be minimized. The types of benefit necessary would include potential to:

- Enhance depleted stocks using a technique that has already been demonstrated to be successful;
- Recover an ESA listed or candidate species using a technique that may be successful;
- Develop enhancement techniques that have the potential to succeed; or
- Meet research or educational goals that cannot be achieved using other approaches and that have potential management or societal benefit.

With positive attributes that suggest further review is warranted, the following guidelines should be followed to minimize risks to the greatest extent possible.

<u>Guidelines - Specific</u>

1. Health Information - allow outplanting if:
   - aquaculture product comes from a source where a two-year health history is available that identifies potential pathogens or morphological changes in the species and specific age class to be outplanted, AND/OR;
   - the specific age class and population (lot) being considered for outplanting has been subject to a recent health exam (within last 90 days) that identifies potential pathogens or morphological changes and includes consideration of all Title 14, CCR, Section 245 listed pathogens. Samples taken for the health exam must be sufficient to provide statistical assurances of detecting a pathogen at a 5% or higher rate of prevalence with 95% confidence;
   - all disease control policies have been adhered to;
   - all health exams have been conducted by Department or Department-approved pathologist; and
   - species from the source location has not experienced recent significant mortality or disease event of unknown origin (mortality of 1% per day for at least five days or indication of new pathogen) and stock to be outplanted has remained isolated from the date of last exam.

2. Location Choice - allow outplanting only if:
    - there are no significant potential adverse interactions (e.g., health issues, competition concerns, genetic issues) with wild stocks of economic significance in the vicinity of the proposed outplant;
    - there are no related wild stocks that are ESA listed or candidate species in the vicinity of the proposed outplant unless there are over-riding recovery considerations;
    - the location of the release site is determined using GPS for benthic forms and provided to a central data repository for long-term archiving, and
    - the outplanting is compatible with other management processes affecting the outplant location (MLPA, MLMA, etc.).

3. Biological Considerations - allow outplanting only after consideration of potential:
    - effects of predation and competition;
    - effects on ESA listed species; and
    - genetic implications, including changes in survival characteristics of wild stock through breeding with hatchery stock; and
    - use of alternative closely related species; and
    - effect associated with use of hybrids or exotic species (requires Commission approval).

4. Information Considerations - allow outplanting only if:
    - activity is structured to provide useful information or measure of efficacy (e.g., marking);
    - monitoring and reporting requirements are established through identified control measures to facilitate rapid response in the case of suspected disease outbreak; and
    - location and timing options have been considered to optimize success.

Control Measures

In order to provide reasonable administrative oversight over widely disparate internal and external activities, approval of all outplanting activities should come under signature authority of the Marine Region Regional Manager.

Presentation (pdf)

Obtaining a permit from BCDC for oyster restoration projects

Jenn Feinberg
San Francisco Bay Conservation and Development Commission (BCDC)
jenniferf@bcdc.ca.gov

The placement of fill, extraction of materials, and substantial changes in use in the Bay are all activities that require authorization through a BCDC permit. Obtaining a BCDC permit is necessary prior to the placement of materials, such as palettes and oyster shells, for oyster restoration/recruitment studies. Oyster restoration projects can be authorized through either an administrative or a major permit. Those projects that involve the placement of less than 10,000 square feet of fill can be authorized at the administrative level. Those projects involving the placement of more than 10,000 square feet of fill would be authorized through a major permit, which requires approval from the Commission.

Permitting Process

Once a permit application has been submitted, BCDC has thirty days to respond to the submittal to indicate if any additional material is needed to file the application as complete. A complete permit application includes, but is not limited to, the following items: (1) a detailed project description; (2) an application processing fee (based on the total project cost); (3) proof of legal property interest; (4) local discretionary approvals, if any are needed; (4) some form of CEQA analysis; and (5) project plans. Additionally, we would like the applicant to provide documentation from Fish and Game, U.S. Fish and Wildlife Service and NOAA Fisheries that indicates that the proposed project will not have an adverse impact on any special-status species or critical habitats. Finally, a detailed monitoring plan should also be included in the permit application. It is important for the applicant to realize that his/her project must be consistent with the Commission's policies on subtidal habitats in order to receive authorization for any restoration project.

Once an application is filed complete, BCDC has ninety days to issue the permit. Generally, the process for obtaining an administrative permit is shorter than if the project qualifies for a major permit. A public hearing and vote on the project by the Commission is necessary for all major permit applications.

Application Fees

Abbreviated Regionwide Permit	$220
Regionwide Permit	$450
First Time Extension for any permit	$220

Non-material Amendment to permit, including Subsequent Time Extension	$450
Material Amendment to permit	Same as for first time application
Material Amendment to application	Seventy-five percent (75%) of original application fee
Emergency Permit	Same as for project as if not an emergency

Minor Permit with a total project cost (TPC) of:

(1) less than $300,000	$670
(2) $300,000 to $10 million	0.22% of TPC*
(3) more than $10 million	$22,400

Major Permit with a total project cost (TPC) of:

(1) less than $250,000	$1,100
(2) $250,000 to $10 million	0.45% of TPC*
(3) more than $10 million	$44,800

Application Information

BCDC's application and application instructions can be found at www.bcdc.ca.gov. Click on the "Applying for a Permit" link on the left-hand side to download this information. The policies on subtidal habitat can be found by clicking on "Laws, Regulations, and Plans" on the left-hand side and then clicking on "San Francisco Bay Plan."

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No presentation is available

Session: The Community's Role in Restoration

The Community's Role in Restoration – Session Summary

Panel members:
Megan Callahan-Grant (NOAA Restoration Center)
Loren Coen (South Carolina Department of Natural Resources)
Marilyn Latta (Save San Francisco Bay Association)
Betsy Peabody (Puget Sound Restoration Fund)
Dick Vander Schaaf (The Nature Conservancy, Oregon)

One of the tenets of the NOAA Community-based Restoration Program is the importance of hands-on citizen engagement in restoration projects. Citizen participation provides educational opportunities, builds coalitions, and fosters long-term stewardship of the nation's coastal and marine resources. In addition to encouraging multiple constituent partnerships for projects, volunteers are also critical to the success of many ecological restoration activities. No agency, nonprofit organization, or coalition of organizations could carry out habitat restoration through paid labor alone, and volunteers also serve as vital conduits for environmental messages.

Oyster restoration, like most restoration activities, is labor-intensive and requires the involvement of people with a diverse array of skill sets and resources. This session discussed lessons learned and strategies for the most effective methods to further engage various members of the community in oyster restoration.

Participants agreed on the importance of the community's role in oyster restoration. Some of the reasons noted, in addition to those listed above, included the need to supplement available funding, build constituencies, and add voices to lobby for more restoration and science. Fortunately, oysters are a compelling species, and people are intrigued by the historical and cultural ties (e.g., gold rush, tribal uses). Citizens also become engaged to improve the system as a whole, and to enjoy more fishable and swimmable waters, as well as to improve future oyster harvests. The following additional recommendations and comments were provided during the session. Although discussions focused on oyster restoration in particular, many of these recommendations may be applied to other types of restoration activities.

<u>Recommendations and comments</u>
Engaging the community

- Tell the story of oyster restoration (i.e., talk about the history, industry, tribes, future restoration vision, connections with ecosystem health, etc.), and make it "our" story, not "my" story
    - Be honest and encourage open dialogues with constituents and the public—build common restoration visions and convey gaps in knowledge
    - Transmit messages in lay terms to effectively convey basic information
- Confer that the needs are so great the community must become engaged
- Reach out to broad sectors of the community for not only general labor (e.g., bagging and moving shell), but additional resources (e.g., boats, barges), specific skill sets (e.g., GPS/GIS, species identification), and general support

    - Consider commercial growers, oystermen/fishermen, tribes, volunteer groups (e.g., Americorps, high schools, river/creek organizations), retirees, tideland owners, scientific groups (e.g., universities, research centers)
        - Need to address distinct but incredibly valuable constituencies
    - Try to partner with groups (as opposed to soliciting only individuals) to leverage their organization, commitment, and network
    - Do not underestimate the power of the media—keep them involved
    - Initiate dialogues with tribes regarding common visions for restoration versus harvest areas
    - Involve partnership board members in hands-on activities
- Websites are not only valuable for communicating your message, but also specifically for recruiting and keeping people engaged (i.e., share information and updates on restoration activities; post monitoring information; compare with other oyster restoration activities)

Maintaining/maximizing participation

- Attempt to nurture a core group of constituents/volunteers who can assist with training other volunteers, and support monitoring efforts
- Discover and tap into people's technical skills
- Use a volunteer coordinator whenever possible
- Have someone with project knowledge on the site during all events; be prepared to give an initial briefing and answer questions throughout
- Be flexible and open—a volunteer who participates only once may still become an advocate
- If possible, bring volunteers back to the same site; many people want to see progress and change
- Recognize and award participation

Challenges and hurdles

- Telling the right story
- Public interpretation/perception of restoration results
- Increasing involvement from the scientific community
- Difficult working environment (e.g., waist-deep water, visibility, safety, etc.)
- Staff time to work with volunteers
- Consistent funding
- Maintaining volunteer interest, especially out of season or dealing with volunteer fatigue

Session: Short And Long-term Goals and Priorities

Short-term and Long-term Goals (restoration, research, monitoring) – Session Summary

The last session of the workshop centered on the global and regional status of the Olympia oyster and actions needed to restore and protect this species and habitat. Mike Beck (The Nature Conservancy) presented "Shellfish at risk: putting the scale of habitat loss and strategic needs in perspective," an overview of the worldwide threat to shellfish. Beck stated that shellfish beds may be one of most functionally degraded habitats in the world and that concerns over their decline date back to the 1300s. He noted that most of the shellfish restoration work is localized, and rarely have we addressed the problem of shellfish ecosystems on a national or global scale. Beck proposed that, along with restoring these habitats, we need to develop protection strategies to insure our restoration investments. Some of these strategies include conservation-minded, venture capital funding, as well as leasing and owning submerged lands for conservation and restoration. We also need to investigate new approaches for reaching sustainable populations and develop a projected timeline and path for scaling up restoration efforts. A compelling case for action must be made, as was made with coral reefs, to bring a global perspective to the loss of oysters and the resultant implications to the natural world and to humans.

The second part of this session gave participants an opportunity to discuss the most important short-term (1–5 years), medium-term (5–10 years), and long-term goals (20+ years) for native oyster restoration, research, and administrative activities in their own states (Washington, Oregon and California). The states share some common needs, including the need to standardize monitoring protocols, document fish utilization and ecosystem function of the oyster beds, and improve our understanding of genetics and population structure. Below is a list of prioritized items under each category for each state. Due to time constraints not all of the goals or time lines were addressed. However, the intention is to revisit these discussions in future workshops and working groups.

Washington

<u>Research Goals</u>

Short

1. Research basic population and community ecology
    a. Investigate site selection by placing outplants at various sites
    b. Quantify fish utilization of beds (function)
2. Monitoring
    a. Monitor recruitment success
    b. Population growth and decreases
    c. Ambient monitoring especially at enhancement sites
3. Population genetics
    a. Population structure
    b. Age structure of populations

Medium

1. Develop a standardized coast-wide spat monitoring protocol
    a. Effort will help to identify sources and sinks of oyster larvae

Restoration Goals

Short

1. Refer to oyster reef as oyster beds
2. Give protection status to bed in North Bay
3. Comprehensive survey of intertidal and subtidal and place into GIS format
    a. Will require multibeam/sidescan equipment dedicated to effort

Oregon

Research Goals

Short

1. Conduct comprehensive surveys of the intertidal and subtidal
2. Continue lab experiments addressing genetics/age structure
3. Standardize monitoring to understand sources, sinks, population, ambient conditions, and habitat services
4. Investigate disease and mortality
5. Global literature review

Restoration Goals

Short

1. Test various substrates for recruitment
2. Tell the 'story' of the fishery and its impact to society

Administrative Goals

Short

1. Global literature review

California

Research Goals

Short

1. Identify and describe the historic and current physical and genetic structure of intertidal and subtidal beds
2. Quantify fish utilization of beds (function)
3. Review grey literature—especially similarities with small European bivalves
4. Conduct controlled lab experiments on water quality
5. Maintain current projects
6. Develop long-term monitoring goals
7. Investigate disease and mortality

Medium

1. Investigate the role of sedimentation in recruitment success and sustainability of beds
2. Investigate mortality and disease

Restoration Goals

Short

1. Standardize monitoring techniques to compare within and among estuaries along the coast of California
2. Maintain current restoration projects
3. Better define the restoration projects (target restoration projects to answer research questions)
4. Develop techniques that can be scaled up in size

Administrative

Short

1. Regional and coast-wide website for detail on restoration and monitoring
2. Develop contact list of oyster restoration practitioners

Shellfish at risk: putting the scale of habitat loss and strategic needs in perspective

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Global Marine Initiative, The Nature Conservancy
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Temperate bays and estuaries around the world are some of the most productive and degraded ecosystems on earth. Populations of many commercially important species of bivalves have declined dramatically during the past century in temperate marine and estuarine systems throughout the United States, Europe, China, and Australia among others. In many regions, including the U.S. West Coast, many coastal habitats were already severely degraded or driven to virtual extinction well before 1900. Many native oyster reefs were ecologically extinct by the early 1900s along much of the coast and in many bays before that. These shellfish reefs are one of the most endangered coastal habitats.

Unfortunately, most shellfish restoration work is localized, and few scientists, public agencies, or conservation organizations address the problems of shellfish ecosystems on a regional, national, or global scale. Scientists and natural resource managers almost always look at shellfish on a bay-by-bay basis and rarely attempt to synthesize a general view of their alarming decline. As a result, we are ill informed about the general status of temperate coastal and marine ecosystems, and efforts to restore habitats such as shellfish beds and reefs tend to be conducted piecemeal rather than as parts of a broader strategy.

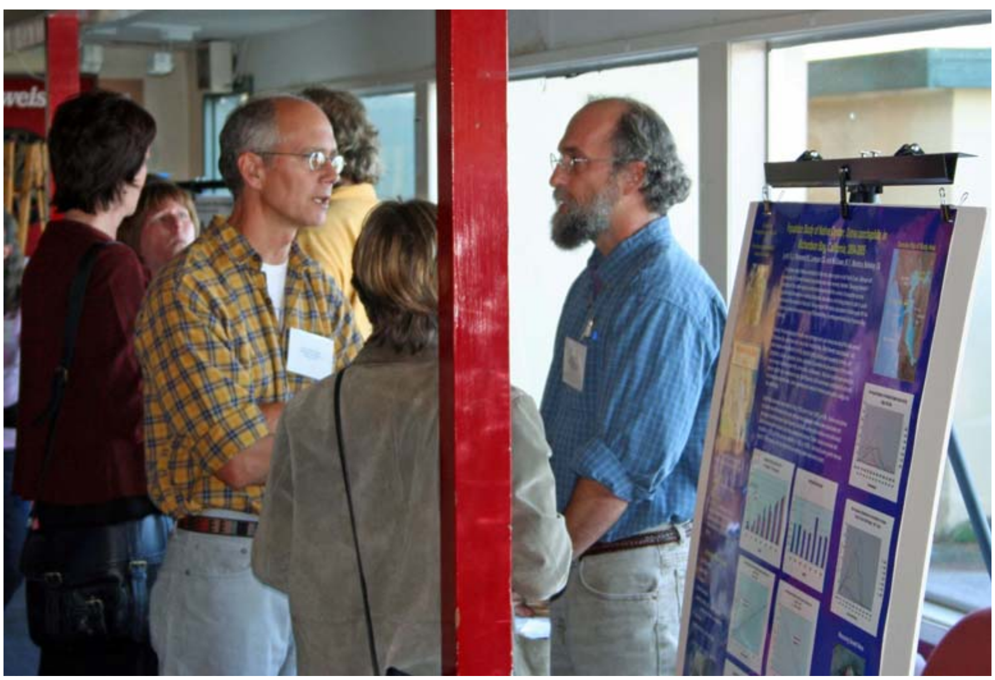
But there is hope, because there are many lessons to be learned from habitat conservation and restoration in shellfish and other reef ecosystems and opportunities to help fund that work. For example, we can learn from global efforts to galvanize support for coral reefs. A 1998 global study of tropical coral reefs, Reefs at Risk, analyzed the condition of coral reefs and threats to their survival and it has been very effective in galvanizing support for further research and improved conservation and management of tropical reefs around the world. Similar efforts are needed for shellfish reefs and beds that enrich coastal habitats.

The growing interest in ecological services also bodes well for expanding shellfish restoration efforts. Potential services are more transparent and measurable for shellfish restoration than for most coastal ecosystems in terms of water filtration, hazard reduction, habitat provision, and recreational and commercial fishing opportunities.

There are opportunities to increase investments in restoration. One example is through conservation-minded venture capital funding. There is a growing interest in funding projects that can yield both investment income as well as conservation returns. There are also opportunities to protect these investments in restoration as well, for example by leasing and owning submerged lands for conservation and restoration. The Nature Conservancy working with the NOAA Community-based Restoration Program and many others has also developed a network of shellfish restoration projects and practitioners to help foster better communication and coordination, and to help envision the scales of restoration needed and identify opportunities to realize them.

Presentation (pdf)

Poster Session



San Francisco Bay native oyster recruitment study – A collaborative effort to research population dynamics and restoration opportunities for *Ostrea conchaphila* in San Francisco Bay

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The native Olympia oyster, *Ostrea conchaphila*, was once abundant in many estuaries along the West Coast of North America. Loss of habitat, over-harvesting, and degraded water quality have severely depleted the native oyster population in San Francisco Bay, reducing a once dominant local fishery resource to a few scattered populations. In 2002, Save The Bay spearheaded a project to monitor oyster populations and water quality at five sites located throughout the bay. Our project this year is a continuation and expansion of this initial effort.

Save The Bay, San Jose State University, the National Oceanic and Atmospheric Association (NOAA) Fisheries Restoration Center, the Smithsonian Environmental Research Center, Restore America's Estuaries, and other agencies and partners have come together for the second phase of the San Francisco Bay Native Oyster Recruitment Study. Bringing together academic professionals, non-profit restoration focused groups, and government agencies has resulted in a project dedicated to researching factors affecting the variability of oyster populations at locations throughout San Francisco Bay, with valuable dedicated volunteer support to help accomplish this goal. The results of this research are intended to better inform future large-scale restoration efforts and to ensure the survival and success of this valuable species.

Project Design

Currently Save the Bay and San Jose State University are leading an effort to monitor oyster populations at seven different sites, with the potential to increase our study method to more sites throughout the coming year. The sites are broken into two groups, with four sites located in the central and northern parts of the bay and three sites located within the boundaries of the South Bay Salt Pond Restoration Project, the largest tidal wetland restoration project on the West Coast of the United States. Dr. Lynne Trulio, lead scientist for this 15,000 acre restoration project, Dr. Chela Zabin, ecologist with the Smithsonian Environmental Research Center, and Natalie Cosentino-Manning, Marine Ecologist with the NOAA Restoration Center, are all advising the project design and implementation.

All sites are being chosen based on the natural occurrence of *Ostrea conchaphila* at the site or within the vicinity, and for ease of access. Four different configurations will be examined for this project:

1. Natural substrate: hard surfaces found at each site including rocks, pier pilings, cement, riprap, etc. will be monitored to understand how the existing habitat is being used by *Ostrea conchaphila*.
2. Shell strings: Pacific oyster shells with holes bored through are strung along a rope and will be hung in the water column. This method is commonly used by oyster researchers and restorationists because the shells support the attachment and growth of new oyster spat.
3. PVC settling plates: PVC settling plates (with attached brick to provide weight) are hung, PVC plate surface facing down. The settling plates are a standard material used by marine scientists to study species recruitment.
4. Oyster shell bags: Pacific oyster shells in a small mesh bag are hung to mimic a complex pile of shells, as natural oyster reefs would have been. Similar larger mesh bags of shells are currently being used in concurrently occurring oyster restoration projects in San Francisco Bay.

Project Research Questions

This study will provide a snapshot of oyster recruitment at the six sites throughout the bay, and will allow for analysis of recruitment rates as they may differ throughout the year and throughout the sites, and between substrate types, both naturally occurring and introduced by this project. The objectives of this research are to answer the following research questions:

At Each Site and Across Sites:

1. What is the rate of new oyster spat recruitment per month (or bi-monthly if each month proves to be too short of a time span in which to observe new recruits)?
2. What is the difference in recruitment rates between the four different substrate treatments: oyster shell suspended in water column, oyster shell in a simulated reef structure suspended in the water column, PVC settling plates suspended in the water column, cleared existing substrate on a monthly (or bi-monthly) basis (for one year, possibly two years)?
3. Is recruitment to introduced substrates correlated/indicative of recruitment to intertidal naturally existing substrate?
4. What is the diversity of the other species (fouling organisms) found on the introduced substrates on a monthly (or bi-monthly basis) and on a yearly (possibly quarterly) basis?
5. Can a difference be determined in recruitment rates of *Ostrea conchaphila* due to presence of fouling organisms?

Between Site Groups:

1. Is there a difference in recruitment rates between the three south San Francisco bay sites located within the boundaries of the Salt Pond Restoration Project, with the three sites located in the central and northern shores of San Francisco Bay?
2. Is there a difference in the fouling organisms found on introduced substrates between the South Bay sites and other sites?

Presentation (pdf)

Population study of native oyster, *Ostrea conchaphila*, in Richardson Bay, California, 2004-2005

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The Olympia oyster (*Ostrea conchaphila*) is the only native oyster on the Pacific Coast. Although still widespread, the formerly abundant populations have been severely depleted. Emerging interest in restoration of the native oyster as habitat enhancement and for a variety of ecosystem services requires basic information on existing distribution, abundance, and limiting factors in order to guide and measure the success of restoration. Here we report the relative abundance of native oyster for two consecutive years at seven sites in or near Richardson Bay, an embayment within San Francisco Bay, California.

Seventy ten-minute ecological transects were performed each year during low tide at five sites around Richardson Bay, and at two other sites on San Francisco Bay. Shell diameter was measured, and water samples were collected to monitor potential limiting factors such as salinity, turbidity, pH, temperature, calcium, phosphate, silicate, and nitrate. Occurrence of main predators of the oysters was recorded, including oyster drills, shore crabs, and flatworms. Individual oysters were marked to measure growth rate in subsequent years. Size frequency catch curves were constructed to estimate recruitment and survival rates. Linear regression and analysis of variance were used to analyze the data statistically.

Oyster total abundance was similar in Year 2 (1353) and in Year 1 (1438, $p = 0.54$). Relative abundance by location ranked the same both years, with one exception, and predators were associated with decreased counts at two sites. Size-frequency distribution curves show variation and multi-modal peaks consistent with constant population renewal and turnover. Oyster counts correlated with phosphate ($r = 0.73$, $p < 0.05$) and with calcium ($r = -0.80$, $p < 0.005$). Individual oyster growth rate was highest (1.26 mm/week) at the site adjacent to an ongoing oyster restoration project.

The Olympia oyster once thrived in a healthy San Francisco Bay ecosystem. The first step in successful restoration is acquiring detailed knowledge of the population distribution, abundance, and factors limiting survival. In this study, population abundance and size composition as well as statistical relationships with environmental factors were determined for seven sites in Richardson Bay and northern San Francisco. Total counts during both years of the study remained statistically unchanged while size-frequency distributions varied widely, reflecting the variation inherent in larval release and settlement, as well as differential survival at varied sites. Abundance was positively correlated with dissolved phosphate and negatively correlated with dissolved calcium and the presence of oyster predators.

This study provides a detailed baseline population assessment for *Ostrea conchaphila* and its environment in a sub region of San Francisco Bay to complement the more general bay-wide assessments that have been done to date.

Presentation (pdf)

Oyster restoration at Woodard Bay, Henderson Inlet, WA

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The Olympia oyster (*Ostreola conchaphila),* the only oyster species native to the West Coast, was once prolific throughout the Puget Sound and in Willapa Bay, WA. Over the past century, the Olympia oyster has suffered significant declines due to a combination of over harvest, pollution, and habitat loss. The current population of native oysters is estimated around 10% of historic levels. There are still natural sets in both the South Puget Sound and in Willapa Bay, but the juvenile mortality rate has remained high and natural recovery appears to be slow. We now have the opportunity to restore this culturally and ecologically important species and to improve the diversity and health of the larger benthic community.

Here we describe efforts to enhance habitat for a breeding population of native oysters at a conserved site with a small remnant stock of native oysters nearby.

Project goals are to: 1) pilot the use of a new Conservation Leasing Program developed in Washington State, 2) identify the best locations in Woodard Bay for native oyster restoration and 3) test restoration methodology and 4) restore habitat for natural recruitment by Olympia oysters.

The project is being implemented in phases:
Phase I (completed 2005) – Baseline ecological assessment and research on larval availability, recruitment potential and survival.
Phase II (started in 2006 and ongoing) – Pilot habitat enhancement and monitoring to test proposed methodology and design.
Phase III (planned for 2007) - Expand habitat enhancement up to 5 acres in 2007.

Presentation (pdf)

Native oyster, *Ostrea conchaphila*, restoration experiments in Richardson Bay, California, using palettes of Pacific oyster shells

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An experimental community-based native oyster, *Ostrea conchaphila*, restoration project in Richardson Bay, California (northern San Francisco Bay) successfully demonstrated that reefs made of clean oyster shells would be colonized by oyster larvae produced by existing wild native oyster spawners. Native oysters were previously widespread and abundant intertidally and subtidally in San Francisco Bay. Presently they are sparse and restricted in distribution subsequent to a variety of impacts: overharvesting, pollution, sedimentation, and non-native predators. A previous study demonstrated that larvae are widespread in the plankton of San Francisco Bay, so the hypothesis that shell substrate for settlement was limiting was tested by a pilot-scale placement of shell reef modules in northern Richardson Bay in May-June 2004. Monitoring consisted of monthly inspection of PVC settling plates, fish sampling, and water quality (temperature, salinity, secchi depth) measurements. Ongoing observations of bird species richness and abundance were summarized to include in the baseline characterization of the intertidal and shallow subtidal ecosystem. The PVC settling plates were not settled on by oysters during this study. Bags of oyster shells from four of the twelve reef modules were inspected in September 2004. Native oyster recruits were found at all four sites with up to 13 oysters on 50 shells sampled at one near shore intertidal site. This site was sampled again in February 2005 when 23 native oysters were found on a sample of 100 shells. The mean diameter of native oysters increased more than 60% at this site from 19 mm in September to 31 mm in February proving recruitment, growth, and survival of native oysters on the shell substrate.

A second set of shell on palette reefs was deployed in autumn 2005 in marina areas with restricted tidal exchange and near eelgrass beds in Richardson Bay farther from shore than the initial set of intertidal and subtidal reefs. The new areas were selected to investigate the hypotheses that reduced larval dispersal in marinas and a synergistic effect with eelgrass would enhance recruitment. Both areas were too deep for convenient monitoring for oyster settlement, so small mesh bags of 10-12 shells were attached to the buoys and anchors marking the locations of the oyster shell reefs. No oysters had recruited to the experimental bags of 10-12 shells through July 2006. The large bags of shells on the reef palettes from these new sites and from the intertidal and subtidal sites will be examined in early September. Fish were sampled by fish traps placed adjacent to the marina and seagrass palettes of shells. Native mud crabs and non-native green crabs were collected in the traps along with three species of goby that had not previously been collected during the monitoring.

An unusual thornback fish (*Platyrhinoidis triseriata*) was collected during the monitoring. This is only the second known record of this fish from within San Francisco Bay. Two of the five most abundant bird species observed, scaup and surf scoter, are reported to eat native oysters.

Presentation (pdf)

Seasonal settlement of native West Coast (*Ostrea conchaphila*) larvae in two California estuaries

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Declines in populations of the native oyster, *Ostrea conchaphila*, have piqued recent interest in restoring its populations. Since local population persistence is influenced by larval settlement, information about the magnitude and timing of settlement will provide valuable contributions to restoration efforts. Thus, we examined settlement as a function of season and simultaneously measured temperature, which is reported to influence settlement timing by cueing synchronized male spawning and subsequent larval settlement. Previous literature based on anomalous open coast populations found that settlement of *O. conchaphila* peaked in June and July in San Diego, CA, and that settlement occurred once seawater reached a critical temperature of 16° C. To observe variation over seasons in larval settlement density within the more common estuarine habitat in southern California, we placed artificial substrate tiles in two separate locations within Newport Bay, CA and in two locations within Aqua Hedionda Lagoon, Carlsbad, CA. Temperature was monitored at each site every 15 minutes using Tidbit™ loggers. Tiles were collected and oyster settlers counted every two weeks during spring tides to pinpoint pulses in settlement. Preliminary results indicate overall settlement in Aqua Hedionda occurred from June until February and ranged from 5 $\pm$ 4.39 oysters/m^2 to 223 $\pm$ 48.9 oysters/m^2 with peak settlement in June. For Newport Bay, overall settlement occurred from May until November and ranged from 16 $\pm$ 9.3 oysters/m^2 to 845 $\pm$ 247 oysters/m^2 with peak settlement in June of 845 $\pm$ 48.9 oysters/m^2. Further, settlement is significantly higher in Newport Bay than in Aqua Hedionda, but only during June when settlement peaks. Contrary to information from published literature describing timing of *O. conchaphila* settlement, populations within these estuaries show settlement occurring shortly after the water temperatures reached 20° C in May, as opposed to previously recorded temperatures of 16° C in April.

Presentation (pdf)

Native oyster restoration on the North Richmond shoreline of San Pablo Bay

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In 2007, the Natural Heritage Institute and its partners will initiate a pilot native oyster restoration project on the North Richmond shoreline with funds provided by the CALFED Watershed Program. The project will be modeled after other similar pilot projects in the San Francisco Estuary. The specific location has not been determined yet, but the most likely site will be near the fishing pier at Point Pinole Regional Shoreline. The native oyster restoration project will be implemented as part of a larger North Richmond Shoreline project that includes a year-long bird census, an assessment of subtidal, tidal, and adjacent upland habitats, and the creation of the North Richmond Shoreline Academy. The Academy will provide classes and training to increase the capacity of the local communities to understand, appreciate, and manage the North Richmond Shoreline. Project partners include the Community Health Initiative, the Golden Gate Audubon Society, the Parchester Village Neighborhood Council, the Urban Creeks Council, and the West County Toxics Coalition.

Presentation (pdf)

Appendices

West Coast Native Oyster Restoration Workshop Agenda

September 6-8, 2006
San Rafael, CA

Images: Couch and Hassler, 1989

Purpose:
1) To share the current state of knowledge regarding native oyster restoration efforts; 2) To bring together the best available science and identify research needs that will help to guide future restoration efforts, and 3) To develop guidelines and methods for future oyster restoration efforts.

WEDNESDAY		
Presenter	**Time**	**Title**
Natalie Cosentino-Manning *NOAA Restoration Center* and Mary Selkirk *Center for Collaborative Policy*	12:00 – 12:20	Opening remarks
David Lewis *Save the Bay*	12:20 – 12:40	Welcome to San Francisco Bay
Joth Davis *Baywater, Inc.*	12:40 – 1:00	Restoration of West Coast native oysters - a perspective on the history of exploitation and recent restoration efforts
Olympia Oyster Distribution		
Maria Polson *CA State University, Fullerton*	1:00 – 1:20	Current geographic distribution and intertidal population status for the native west coast oyster, *Ostrea conchaphila*, from Alaska to Baja
Mike McGowan *Maristics*	1:20 – 1:40	Survey of native oyster, *Ostrea conchaphila*, distribution in San Francisco Bay in 2001-2003 with observations on population-limiting factors
Scott Groth *OR Dept. of Fish and Wildlife*	1:40 – 2:00	Historic and present distribution/abundance of Olympia oysters in Oregon
Betsy Peabody *Puget Sound Restoration Fund*	2:00 – 2:20	Historic and current distribution of Olympia oysters in Puget Sound
	2:20 – 2:50	**Panel Discussion**
	2:50 – 3:00	**Break**

		Biology, Genetics, and Dispersal
Ted Grosholz *University of California, Davis*	3:00 – 3:20	The life and times of the Olympia oyster
Brent Vadopalas *University of Washington*	3:20 – 3:40	Using quantitative PCR to understand Olympia oyster larval dispersal
Danielle Zacherl *CA State University, Fullerton*	3:40 – 4:00	A shell of its former self. Can *Ostrea conchaphila* larval shells reveal information about a recruit's birth location?
Mark Camara *USDA-Agricult. Research Serv.*	4:00 – 4:20	Genetic considerations for hatchery-based enhancement of native oyster populations. Are good intentions enough?
	4:20 – 5:00	**Panel Discussion**
	5:00 – 7:00	**Poster Session**
		THURSDAY
	6:30 – 8:00	**Field Tour** - Marin Rod and Gun Club
	8:00 – 8:15	**Refreshments**
		Limitations to Restoration and Recovery
Alan Trimble *University of Washington*	8:15 – 8:30	Factors preventing the recovery of a historically overexploited shellfish species - *Ostreola conchaphila*, the native oyster of the Pacific Coast of N.A.
Carolyn Friedman *University of Washington*	8:30 – 8:45	Restoration and diseases of Olympia oysters in San Francisco Bay
Jim Moore *CA Dept. Fish and Game*	8:45 – 9:00	Dissemated neoplasia in *Ostrea conchaphila*
	9:00 – 9:10	**Break**
Eric Buhle *University of Washington*	9:10 – 9:25	Impacts of invasive drills on Olympia oysters in Puget Sound: implications for restoration
Ted Grosholz *University of California, Davis*	9:25 – 9:40	Top down obstacles to native oyster recovery and restoration in California
Andy Cohen *San Francisco Estuary Institute*	9:40 – 9:55	Preventing the introduction of non-native species with imported oyster shell used for cultch in restoration projects: an inspection, and consideration of future protocols
	9:55 – 10:40	**Panel Discussion**
	10:40 –10:50	**Break**

Ecological Interactions – Ecosystem Services		
Jonathan Grabowski *Gulf of Maine Research Institute*	10:50 – 11:10	Habitat restoration to recover ecosystem function in the southeastern U.S.
Hunter Lenihan *University of CA, Santa Barbara*	11:10 – 11:30	Eastern oysters, restored reefs, and food web interactions: the role of habitat structure in modifying effects of disturbance
David Kimbro *University of California, Davis*	11:30 – 11:50	Maintenance of biodiversity in a native California oyster community: the relative importance of disturbance, competition, and facilitation
	11:50 – 12:15	**Panel Discussion**
	12:15 – 1:00	**Lunch**
Restoration: Past, Present and Future		
Jennifer Ruesink *University of Washington*	1:00 – 1:15	Evaluation of native oyster (*Ostreola conchaphila*) status and restoration techniques in Puget Sound, Washington, U.S.A.
Betsy Peabody *Puget Sound Restoration Fund*	1:15 – 1:30	Native oyster restoration in Puget Sound - Where we've been, where we're going
Dick Vander Schaaf *The Nature Conservancy*	1:30 – 1:45	Native oyster restoration in Netarts Bay, Oregon: ecological and management challenges
Steve Rumrill *South Slough NERR*	1:45 – 2:00	Restoration of Olympia oysters in the South Slough estuary, OR: planning as a precursor to population recovery
	2:00 – 2:10	**Break**
Dave Couch *City of Arcata*	2:10 – 2:25	Native oysters in Humboldt Bay and Arcata's native oyster project
Bud Abbott *MACTEC Eng. and Consul., Inc.*	2:25 – 2:40	Limiting factors at three habitat restoration sites in San Francisco Bay
Loren Coen *South Carolina DNR*	2:40 – 3:00	Lessons from the study of the Eastern oyster, *Crassostrea virginica* Gmelin restoration efforts: some learned and some forgotten
	3:00 – 4:00	**Panel Discussion**

FRIDAY		
	8:00 – 8:30	**Refreshments**
Permitting		
Kerry Griffin *NOAA Restoration Center*	8:30 – 8:40	This session will cover permitting for native oyster restoration and research/monitoring.
Russell Rogers *WA Dept. of Fish and Wildlife*	8:40 – 8:50	
Matt Hunter *OR Dept. of Fish and Wildlife*	8:50 – 9:00	
Tom Moore and Jennifer Feinberg *CA Dept. Fish and Game and SF Bay Cons. & Dev. Comm.*	9:00 – 9:10	
The Community's Role in Restoration		
Megan Callahan-Grant *NOAA Restoration Center* Betsy Peabody *Puget Sound Restoration Fund* Dick Vander Schaaf *The Nature Conservancy* Marilyn Latta *Save the Bay* Loren Coen *South Carolina DNR*	9:10 – 10:00	This session will be a panel-led discussion on engaging the community in restoration and research/monitoring.
	10:00 – 10:10	**Break**
Short-term and Long-term Goals and Priorities		
Mike Beck *The Nature Conservancy*	10:10 – 10:30	Shellfish at risk: putting the scale of habitat loss and strategic needs in perspective
All	10:30 – 12:00	Small group discussions by state. Questions are provided to guide discussions.
Summer Morlock *NOAA Restoration Center*	12:00 – 12:15	Next steps Closing and Thank yous
Adjourn		

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