INTERACTIONS WITH NON-INDIGENOUS SPECIES POSE AN IMPEDIMENT TO RECOVERY OF NATIVE OLYMPIA OYSTERS

(Ostrea conchaphila)

WITHIN COOS BAY, OREGON, USA

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PICES XVII / Dalian  MEQ S8-5234
Outline:

1. Olympia Oysters (*Ostrea conchaphila*) in Oregon Estuaries
2. Local Extinction & Slow Recovery in Coos Bay
3. Restoration Program for Olympia Oysters in Coos Bay & South Slough
4. Potential Limiting Factors
5. Non-Indigenous Species as an Impediment to Population Recovery
6. Summary & Next Steps
LOCATION OF STUDY AREA: COOS BAY, OREGON, USA
Coos Bay: A Drowned River-Mouth Estuary

Coos Bay – North Bend

North Spit

Coos Bay

South Slough

Charleston

Oregon Institute of Marine Biology
Olympia oysters
Ostrea conchaphila
- Native from Alaska to Baja California
- Historically extensive in Coos Bay / dredge spoils
- Local extinction due to sedimentation & tsunami / 1700-1800s
- Reintroduced from outside source / 1940-50s

Pacific oysters
Crassostrea gigas
- Native from Russia to China
- Imported to North America from Japan / 1903
- Cultured in Coos Bay 1910s - present
- Mariculture operations include bottom, stake, and rack culture
Olympia oysters (*Ostrea conchaphila*):

**Appearance**: Small (4-7 cm) epibenthic bivalves, non-motile with left valve typically cemented to shell or other hard substrata.

**Reproduction & Growth**: Protandric hermaphrodite, multiple spawning in spring and summer, internal fertilization with brooded embryos, release of planktonic veliger larvae.

**Habitat**: Lower intertidal to shallow subtidal, attachment to hard surfaces in sheltered waters, often on adult shells. Forms sparse to dense clusters or beds on bottom.

**Feeding**: Filter-feeder / suspension-feeder, consumes phytoplankton and protists.

**Predators**: Seastars, crabs, boring gastropods, polychaetes, fish, birds, humans.
History of Olympia Oysters in Oregon Estuaries

Netarts Bay:
- Extensive commercial fishery 1860’s
- Low numbers by 1930’s
- Exotic snail predator 1957 (*Ocenebra*)
- Absent in 1992
- Restoration work in 2006-08

Yaquina Bay:
- Extensive commercial fishery 1860’s to 1890’s
- Commercial harvest ended by 1940’s
- Slow recovery of natural populations 2006-08

Coos Bay:
- Extensive historic populations and shell deposits
- Local extinction prior to European settlement
- Reintroduction with Pacific oysters from Willapa Bay 1950’s
- Slow recovery of natural populations 1987-2008
- Restoration work initiated in 2008
Recent Shell Deposits of *Ostrea conchaphila* in Coos Bay, OR

Extensive Olympia oyster shells in islands formed by dredge spoils in Coos Bay
Coos Bay, OR:

**Ostrea conchaphila**: Size distribution of adult oysters for Coos Bay surveys conducted in 1997 and 2006.

Recruitment of small oysters observed in 2006

South Slough Olympia Oyster Restoration Project: 2006-2015

Components:

History of Native Oysters in Oregon Estuaries (2006-07)

Genetic Identity of Broodstock Oysters (2006-07)


Recruitment of Olympia Oysters to Fouling Panels and Shells (2004-05)


Culture, Settlement, and Out-planting of Juvenile Oysters (2008-12)
South Slough Olympia Oyster Restoration Project: 2006-2015

Components (continued):

Common-Garden Experiment to Investigate Local Adaptation (2009-2014)


Ecological Interactions with Predators and Competitors (2008-2010)

Alteration of Hydrodynamics by Oyster Clusters (2008-09)


Initiation of Larger-scale Oyster Restoration Study Areas (2012-15)
What factors may limit the recovery of Olympia oysters in Coos Bay and the South Slough?

- Ambient physical conditions (temperature / salinity)
- Larval supplies (growth, survival, retention)
- Availability of appropriate substratum for larval settlement
- Recruitment of post-larvae into established populations
- Survival and growth of adult oysters
- Predation by crabs and snails
- Overgrowth by native and non-indigenous tunicates
Broad-Scale Assessment of Estuarine Invasive Species in Coos Bay

Fouling panel deployment from docks, piers, and on soft-sediment frames throughout estuarine habitats (2004)

Recovery of panels after 90-100 days, followed by digital photos, preservation, and taxonomic identification
What region of the estuary is conducive to the settlement and recruitment of Ostrea conchaphila?
Coos Bay, OR: Juvenile Native Oysters Recruited to PVC Fouling Panels Deployed off the Port of Coos Bay – Citrus Dock in the Mesohaline Region of the Estuary

PVC plate deployed in Coos Bay for 90-100 days in 2004

Juvenile *Ostrea conchaphila* attached to PVC plate
Which species of crabs prey upon adult Olympia oysters?

A. Cancer magister  
Native: NO

B. Cancer antennarius  
Native: NO

C. Cancer productus  
Native: YES

D. Carcinus maenas  
Non-native: YES
Overgrowth Competition by Epifouling Organisms

- Tunicates
- Bryozoans
- Sponges
- Hydroids
- Barnacles
- Mussels
- Anemones

Oyster Epifouling Plates:
- Living Adult Oysters
- Gorilla Glue Adhesive
- Deployed at 11 Locations in Coos Bay and South Slough
- Seasonal monitoring of Epifouling Organisms

Ostrea & fouling community

Ostrea conchaphila / Settlement Plate
Ostrea conchaphila: Overgrowth Competition by Non-indigenous Tunicates

Colonial:  Didemnum spp.
          Botryllus schlosseri
          Botrylloides violaceus

Solitary:  Styela clava
          Molgula manhattenensis
          Ciona intestinalis
          Ciona savignyi
Deployment of Oyster Plates and Common-Garden Bags in Coos Bay and South Slough, OR
COOS ESTUARY, OR  Hydrologic Regions and Distribution of Olympia Oysters

- Marine Dominated
- Mesohaline
- Riverine

Pacific oyster:
Commercial mariculture

Olympia oysters
Production of native Olympia oyster larvae occurs from recovering populations in Coos Bay.

Do the shells of commercial Pacific oysters provide a settlement site in the mid intertidal zone that is ultimately fatal for juvenile Olympia oysters?
Larval Settlement and Recruitment of Olympia Oysters to Shells

Female oysters brood larvae about 10-12 days

Planktonic veliger larva swims and feeds for about 8-10 days

Larvae settle and attach to shells as surface for growth
**Ostrea conchaphila**: Larval Settlement and Recruitment on Shells of Living Pacific Oysters (*Crassostrea gigas*)

**Juvenile recruitment on adult Olympia oysters / Ostrea**

**Outcome**: Good / Successive Generation

**Juvenile recruitment on adult Pacific oysters / Crassostrea**

**Outcome**: Good / Available Substrate

**Bad / Harvested and Removed from Population**
Examination of Pacific oyster (*Crassostrea gigas*) shells from mariculture facility for attached Olympia oysters (*Ostrea conchaphila*) / Aug 2008
About 3 - 4% of Pacific oyster shells have attached Olympia oysters. What % of the local Olympia oyster population is lost due to mariculture harvests?

<table>
<thead>
<tr>
<th>Shell Type</th>
<th>Number Examined</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pacific <em>Crassostrea gigas</em>: adult</td>
<td>Pile A: 386 shells</td>
</tr>
<tr>
<td></td>
<td>Pile B: 525 shells</td>
</tr>
<tr>
<td>Attached Olympia <em>Ostrea conchaphila</em>: adult &amp; juvenile</td>
<td>Pile A: 15 shells (4%)</td>
</tr>
<tr>
<td></td>
<td>Pile B: 18 shells (3%)</td>
</tr>
</tbody>
</table>
SOUTH SLOUGH ESTUARY, OR

Location and spatial extent of three distinct hydrographic regions located along the estuarine gradient of the South Slough tidal basin

- **Marine-Dominated**
  - 31-20 psu
- **Mesohaline**
  - 28-15 psu
- **Riverine**
  - 21-0 psu

IRS 5 m color mosaic / APR 2002

Olympia oysters in shell middens
Project Area: Restoration of Native Olympia Oysters Within The South Slough Estuary, Oregon
Location of Olympia oyster out-planting sites in the South Slough estuary 2008

Natural Substrata:
- Sand / mud
- Mudstone cobble

Substratum Enhancements:
- Pacific oyster shell rubble
- Shell bag mini-reefs
Re-establishment of Olympia Oysters in the South Slough Estuary: Common Garden Experiment

Evidence for local adaptation?

Broodstock Source

A. Willapa Bay, WA

B. Coos Bay, OR

Oyster Cultch (shell with juveniles)

Ecological Performance
- Survival
- Growth
- Onset of Reproduction
- Reproductive Output
- Susceptibility to:
  - predation
  - overgrowth
  - competition
  - sedimentation

22 Oyster Bags Outplanted into the South Slough Estuary in 2008
Summary:

1. Native Olympia oysters were historically abundant in some Oregon estuaries, but not all estuaries

2. Populations of Olympia oysters are making a slow recovery in parts of Coos Bay, but they are virtually absent from some regions

3. The genetic signature and shell morphology of Coos Bay oysters is nearly identical to oysters from Willapa Bay, WA, and a common-garden field experiment has been initiated to investigate local adaptation

4. Interactions with non-native crabs, tunicates, and sponges pose an impediment to survival and growth of Olympia oysters in Coos Bay

5. Hard substrata is limited, and settlement of Olympia oyster larvae on Pacific Oyster shells is a potentially important source of incidental mortality when the commercial oyster plots are routinely harvested every 2-3 years *

6. Results generated by small-scale experimental oyster restoration plots will be used to guide larger-scale oyster restoration efforts in South Slough and Coos Bay in the future
**Additional Thoughts and Considerations:**

1. Do Pacific oysters have a net positive or negative impact on recruitment and reproductive success of Olympia oysters?

2. The “death assemblage” of shell piles suggests that 3-4 Olympia oysters are killed / 100 Pacific oysters harvested. How many Pacific oysters are harvested per year from Coos Bay? How many Olympia oysters are inadvertently removed as by-catch?

3. The “death assemblage” of shells also suggests that 3-4 Olympia oysters successfully settled and grew (some to maturity) per 100 Pacific oysters harvested. Would these attached Olympia oysters have been lost without the shell as substratum?

4. Living Pacific oysters are the primary hard substratum available in Coos Bay and may be an important factor in the recovery of Olympia oysters along the shoreline.

5. What % of the reproductive population of Olympia oysters resides on Pacific oyster shells versus rocks, rip-rap, and pilings?
Acknowledgements:

• NOAA Community-Based Restoration Program
• Murdock Charitable Trust
• COSEE – Pacific

Field and Lab Work: Scott Groth, Kevin Cellura, Rheannon Arvidson, Hans Klausner, Alicia Helms, Adam DeMarzo
Where did the Olympia oysters that currently inhabit Coos Bay come from?

Genetic Identity of Broodstock Oysters:

Sample Collections from Coos Bay Populations
North Bend, Coos Bay, Isthmus Slough, Shinglehouse Slough / (D. Stick, S. Rumrill, S. Groth, D. Sowers / 2005)

Genetic Analysis / DNA Microsatellites
M. Camara, C. Langdon, D. Stick / 2006-07

Preliminary findings so far (2007) …
Genetic identity (DNA microsatellite variability) and phenotypic evidence (oyster body size and shape) indicate that specimens from Coos Bay are not distinctly different from populations in Willapa Bay, WA and Tomales Bay, CA.

Recommendation: Use local adults from Coos Bay and distant adults from Willapa Bay as broodstock for larval cultures and outplanting. Conduct a “common garden experiment” to assess importance of local adaptation.
Measurements of Oyster shell dimensions and variability

Variation due to:
• Location / estuaries
• Substratum
• Hydrodynamic environment
• Broodstock source
Are *Ostrea* larvae retained or exported from Coos Bay and the South Slough estuary?

Laboratory and field behavior of pediveliger larvae

Hydrodynamic model to estimate retention time

Dispersion and tidal current studies with Rhodamine WT dye and ADCP deployment

Drifter studies with drogues & oranges

ABS drogue

Numbered orange
Populations of Native Olympia Oysters are Making a Slow Recovery in the Middle and Upper Regions of Coos Bay

Salinity range 10 to 30 psu (mesohaline to polyhaline hydrographic region)

Availability of Suitable Surfaces for Settlement and Growth Appears to be an Important Limiting Factor

Suitable Hard Surfaces include Shell Rubble, Rocks, Gravel, Pilings, Rip-Rap, and Living Pacific Oysters (Crassostrea gigas)
Observations of Olympia Oysters in Their “Natural” Environment
Questions
Coos Bay: A Drowned River-Mouth Estuary (21 sq. miles)
South Slough National Estuarine Research Reserve

Designated 1974
4,800 ac research natural area

Habitats:
- estuary
- wetlands / riparian
- coastal forest

Land-Margin Ecosystem

Ocean

↑ Estuary

Lower River
Commercial Mariculture of Pacific Oysters in South Slough NERR, OR

A. Bottom culture

B. Stake culture

C. Rack culture

South Slough Estuary
Restoration of Olympia oysters in the South Slough Estuary

Vision: Successful establishment of self-sustaining populations of Ostrea conchaphila throughout the South Slough and Coos Bay, to the extent that native oysters can provide habitat and contribute to improved ecological functions

Project Goal: Increased understanding of intrinsic and ecological factors to facilitate and encourage recovery of self-sustaining populations in the estuarine tidal channels and tideflats

Objectives:

1. Determine the genetic identity of existing oyster populations in Coos Bay and identify appropriate broodstock sources (2006)

2. Establish an experimental population and conduct an on-site assessment of oyster survivorship, growth, and reproduction in South Slough (2007-09)
Conclusions:

1. New project to initiate restoration and recovery of *Ostrea conchaphila* populations in the South Slough estuary

2. Genetic identification of an appropriate source of broodstock in 2006-07

3. Culture, settlement, and out-planting of 15,000 to 22,000 oysters will occur in summer 2008

4. Field assessments to determine survival, growth, and reproduction in 2008-2010

5. Future work to determine larval export, retention, and interactions with predators, competitors, and eelgrass
LARGE-SCALE RESTORATION OF OLYMPIA OYSTERS IN PUGET SOUND, WA

Over 7 million oysters spread out at 80 sites (1999-2006)
Survivorship rate at 29-95%
Re-establishment of naturally spawning populations at 8 sites
Harvest and Culture of Native Olympic Oysters (1850s-1920s)

- Oyster Barge
- Diked Culture Plots
- Tong Harvest
South Slough Estuarine Gradient

MARINE / BAY
Boathouse

MARINE
DOMINATED
Charleston

MESOHALINE
Valino Island

RIVERINE
Winchester Creek
Marine Biogeographic Regions represented by the National Estuarine Research Reserve System

Gulf of Alaska
Puget Sound
Lower Columbia
Central California
Southern California
Gulf of Maine
Great Lakes
Mid Atlantic
Delaware / Chesapeake
South Atlantic
Caribbean
Gulf of Mexico

NERRS Biogeographic Regions are Sub-sets of NOAA Large Marine Ecosystems
Coos Bay: A Pacific Northwest Drowned River Mouth Estuary

Commercial oyster harvest since 1850s / Import of *C. gigas* 1920s

Coos Watershed
608 mi²

Coos Estuary
21 mi²
Coos Bay: A Drowned River-Mouth Estuary (21 sq. miles)

Oregon, USA:

Coos Bay
South Slough
Cape Arago
Oregon Institute of Marine Biology
Life History of Pacific Oysters: *Crassostrea gigas*

- Sperm
- Egg
- Embryo
- Trochophore larva
- Veliger larva
- D-shell larva
- "Cultch" juveniles on adult shell
- 20-28 days in plankton
- Settled juveniles
- Adult oyster
- Settled juveniles on adult shell
Ecology of oysters (*Crassostrea gigas*):

**Appearance**: Large (8-15 cm) epibenthic bivalves, non-motile with left valve typically cemented to substrata.

**Reproduction & Growth**: Protandric hermaphrodite, spawn in summer, external fertilization with planktonic veliger larvae. Post settlement growth about 25 mm per year.

**Habitat**: Mid intertidal to shallow subtidal, attachment to hard surfaces in sheltered waters, often on adult shells. Mariculture species.

**Feeding**: Filter-feeder / suspension-feeder, consumes phytoplankton and protists.

**Predators**: Seastars, crabs, boring gastropods, polychaetes, fish, birds, humans.
South Slough Estuary Olympia Oyster Restoration Project: 2006-2015

- History of Native Oysters in Oregon Estuaries

- Genetic Identity of Broodstock Oysters
  Oregon State University (M. Camara, C. Langdon, D. Stick / 2006-07)

- Distribution and Recovery of Olympia Oysters in Coos Bay
  Oregon Dept. Fish and Wildlife (S. Groth / 2005-06)

- Recruitment of Olympia Oysters to Fouling Panels and Shells
  SSNERR / SERC (C. deRivera, S. Rumrill / 2004-05)

- Characterization of Estuarine Water Quality Conditions

- Culture, Settlement, and Out-planting of Juvenile Oysters
  SSNERR / TNC (S. Rumrill, D. Vander Schaaf / 2008)

  SSNERR (2008-10)

- Ecological Interactions with Competitors, Predators, and Eelgrass (2008-2010)

Distribution and Recovery of Olympia Oysters in Coos Bay

Coos Bay, OR: Map indicates the location of local landmarks and five study sites examined in 2006 during quantitative surveys of *Ostrea conchaphila* populations.