Potential Influence of Multiple Anthropogenic Stressors on Restoration and Recovery of Native Olympia Oysters (*Ostrea lurida*) in the Coos Bay estuary, Oregon, USA

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Coos Bay: A Drowned River-Mouth Estuary (54 sq. km)

Olympia Oyster:

Ostrea lurida

Coos Bay, OR: Locally extinct / slow recovery 1985 - present

Ostrea lurida:

A. Clusters of oysters on rocks, shells, and other hard substrata

B. Individual oysters on mud, sand, and unconsolidated substrata

Mixed Life-history of Olympia Oysters (*Ostrea lurida*):

Brooding and Dispersive Larvae

B

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

Female oysters brood larvae about 10-12 days

A

Larvae settle and attach to shells and rock as surface for growth

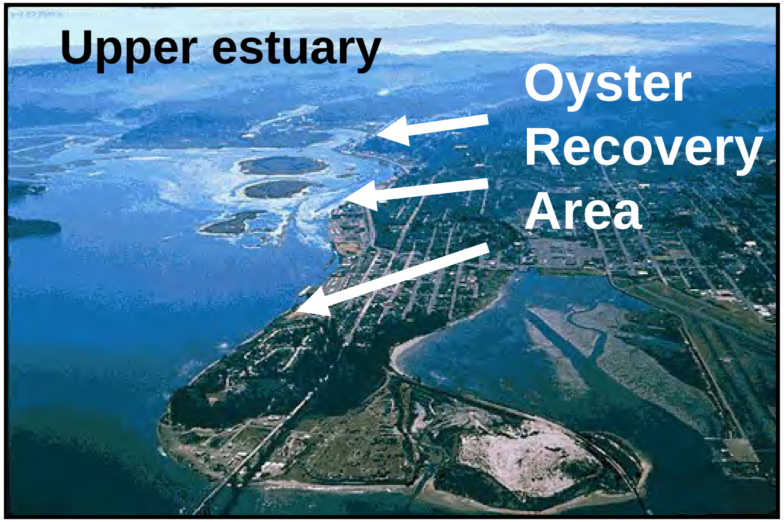
C

HISTORICAL DISTRIBUTION OF OLYMPIA OYSTERS IN OREGON

Dense beds of Olympia oysters restricted to three Oregon estuaries

Multiple Stressors that Influence Population Recovery of Olympia Oysters (*Ostrea lurida*)

1. Shoreline Alteration and Habitat Loss
2. Dredging of Sub-tidal Channels
3. Commercial Mariculture of Non-native Oysters
4. Poor Water Quality, Eutrophication, & Sedimentation
5. Predation and Competition with Non-native Invertebrates
6. Acidification of Nearshore Ocean Waters
7. Loss of Genetic Diversity

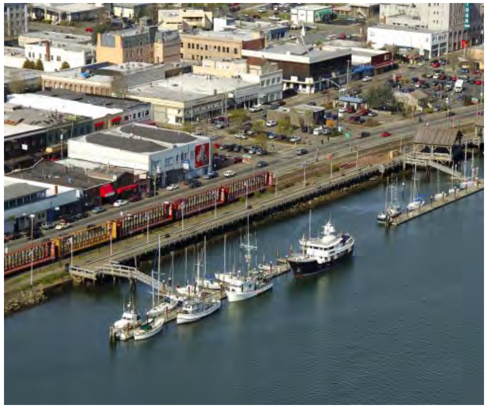


Multiple Stressors that Influence Population Recovery of Olympia Oysters (*Ostrea lurida*)

1. Habitat Alteration and Loss

Coos Bay (1896-1996): ca. 25% loss of wet surface area and 80% loss of historic tidal wetlands

- Marine Dominated
- Mesohaline
- Riverine



Multiple Stressors that Influence Population Recovery of Olympia Oysters (*Ostrea lurida*)

2. Dredging of Sub-tidal Channels

Navigational channel dredged and maintained at -45 ft MLLW

Olympia oyster shells in dredge spoils

Commercial cargo vessels transport logs and wood products to ports throughout the Pacific Rim

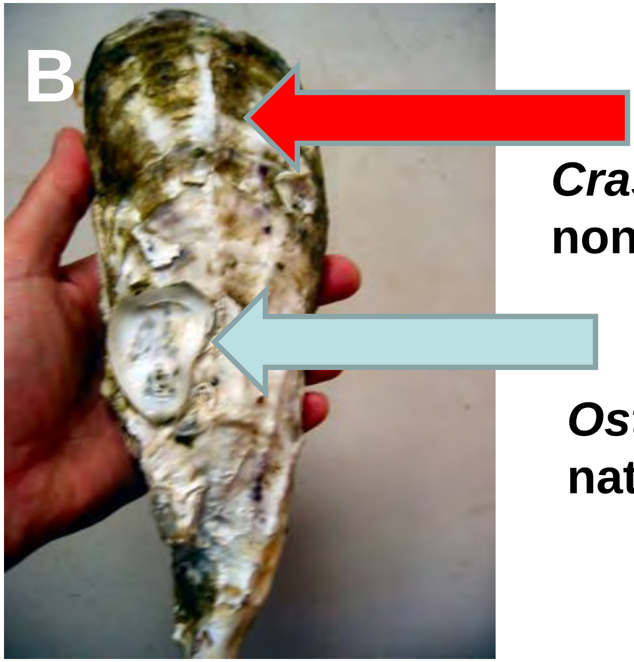
Multiple Stressors that Influence Population Recovery of Olympia Oysters (*Ostrea lurida*)

3. Commercial mariculture of non-native Pacific oysters

Larval settlement on adult Olympia oysters / *Ostrea lurida*

Outcome: Good / Successive Generation

Larval settlement on adult Pacific oysters / *Crassostrea gigas*



Outcome: Good / Available Substrate

Bad / Harvested and Removed from Population

COOS ESTUARY, OR Hydrologic Regions and Oyster Mariculture Operations

Pacific oysters: Coos Bay

Source – Sink Hypothesis

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

Ho: shells of commercial Pacific oysters provide a settlement site in the mid intertidal zone that is initially helpful but prematurely fatal for Olympia oysters

About 3 - 4% of Pacific oyster shells have attached Olympia oysters.
What % of the local Olympia oyster population is lost due to mariculture harvests?

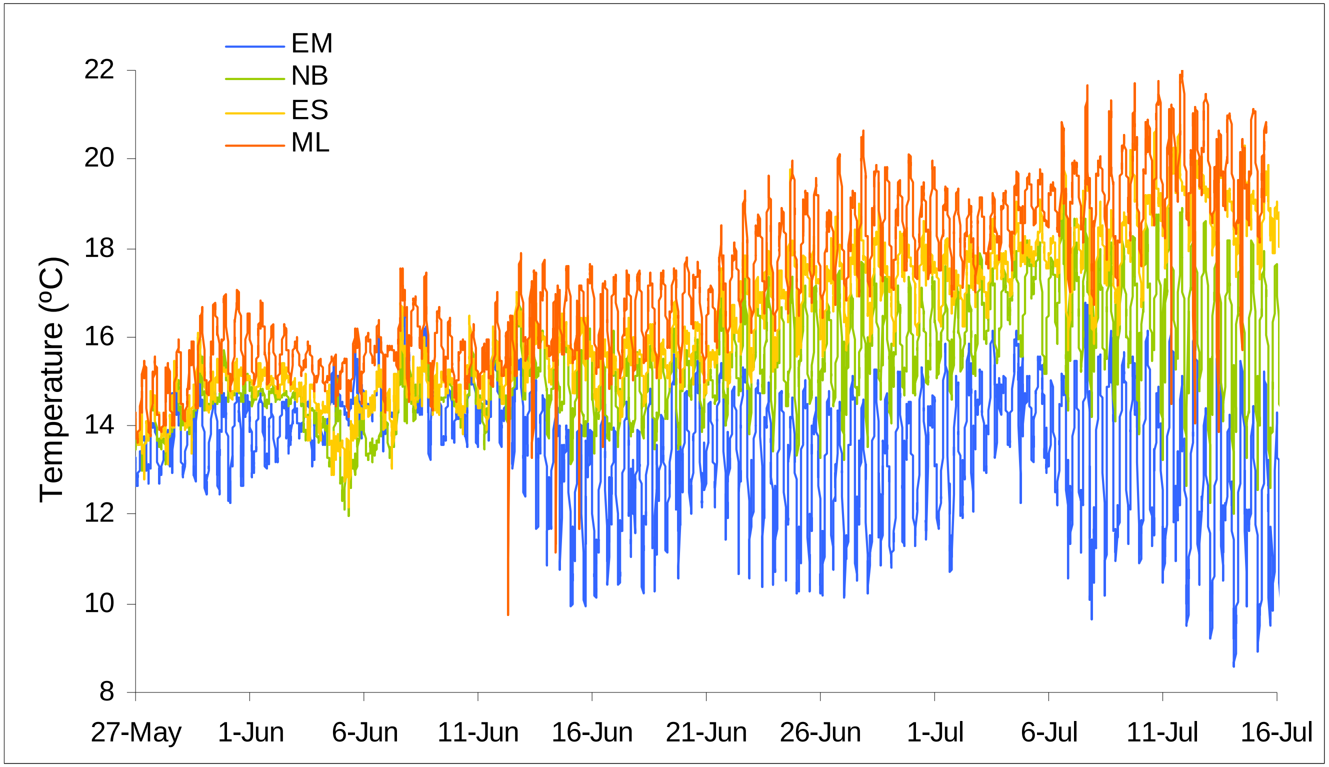
Shell Type	Number Examined
Pacific *Crassostrea gigas*: adult	Pile A: 386 shells Pile B: 525 shells
Attached Olympia *Ostrea lurida*: adult & juvenile	Pile A: 15 shells (4%) Pile B: 18 shells (3%)

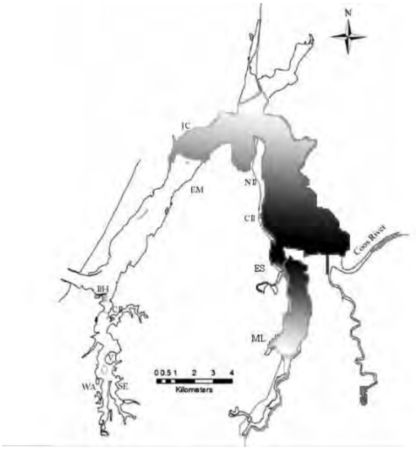
Multiple Stressors that Influence Population Recovery of Olympia Oysters (*Ostrea lurida*)

4. Poor Water Quality, Eutrophication, & Sedimentation

Elevated Temperatures & Low Dissolved Oxygen

(Nutrient Loading, High Turbidity, Sediment Deposition, High Productivity)





Water temperatures elevated in summer and may reach critical value to inhibit oyster reproduction

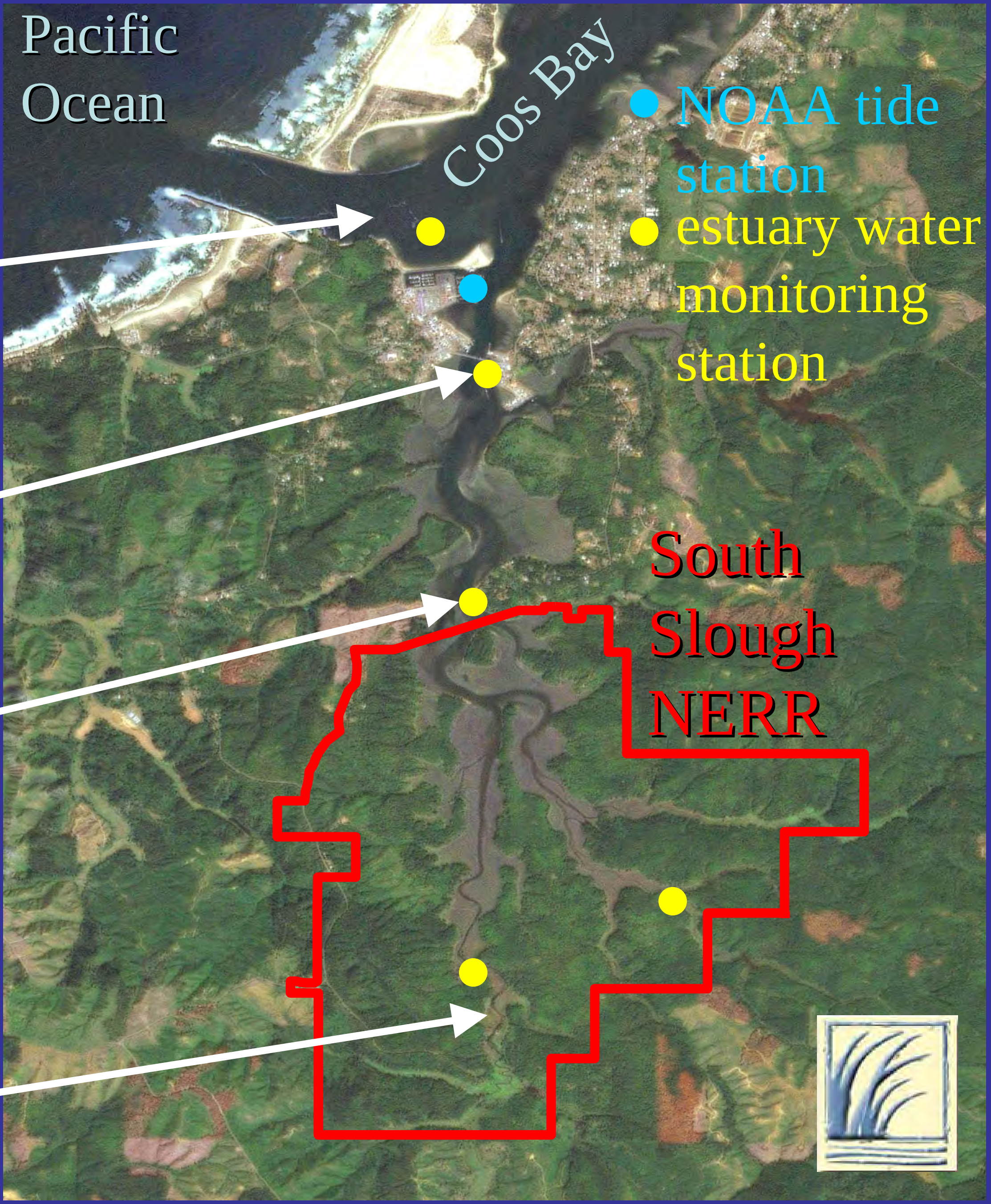
South Slough Estuarine Gradient

MARINE / BAY
Boathouse

MARINE DOMINATED
Charleston

MESOHALINE
Valino Island

RIVERINE
Winchester Creek



National Estuarine Research Reserve System-Wide Monitoring Program

Continuous near real-time measurements of water parameters:

- •Temperature
- •Salinity/Conductivity
- •Dissolved Oxygen
- •pH
- •Turbidity
- •Chlorophyll/fluorescence
- •Water level

YSI-6600 EDS Datasonde Probe array SatLink / GOES

YSI 605091 pH/ORP sealed gel probe

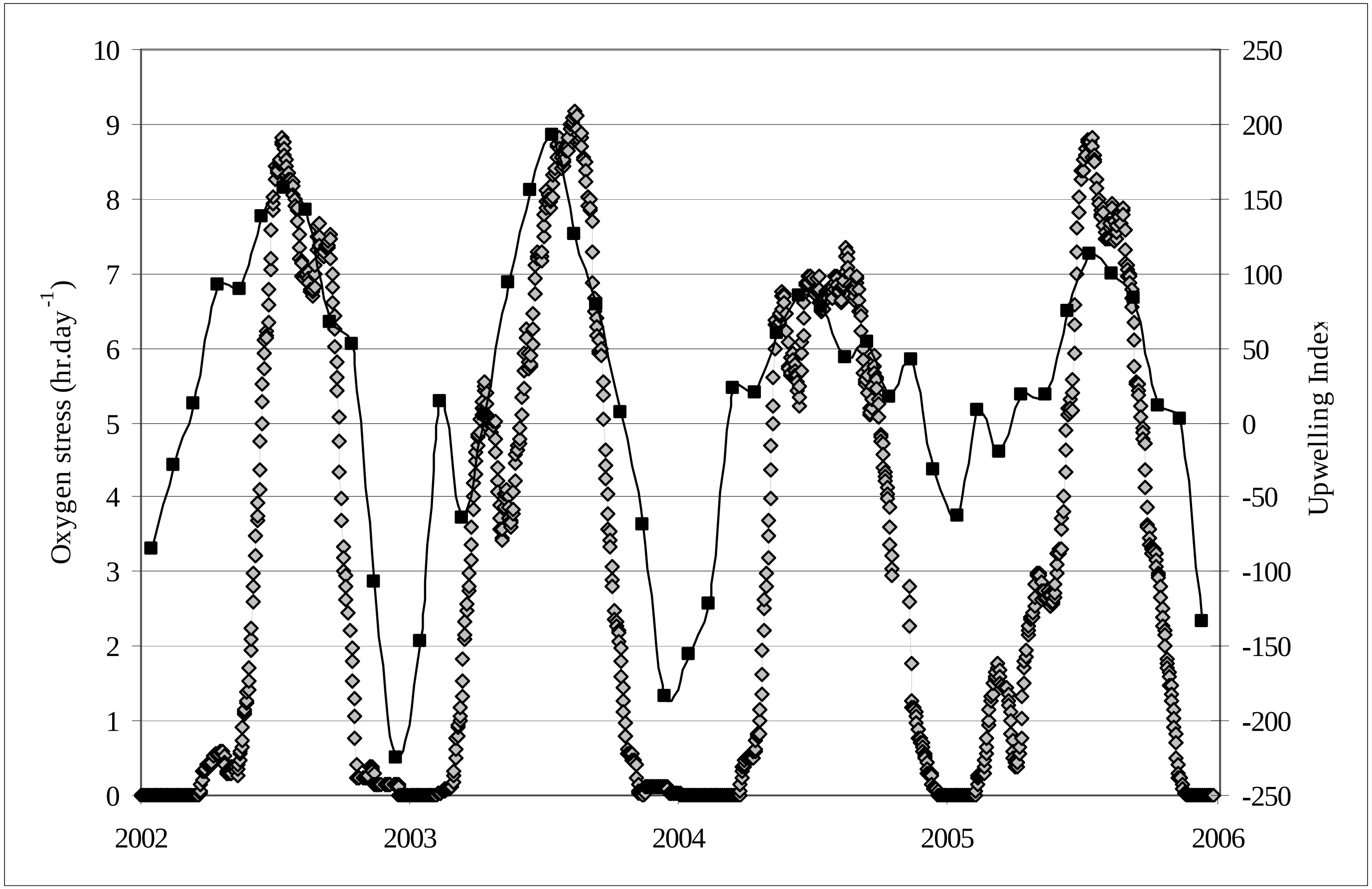
Res = 0.01 pH unit

Nutrients-HT & LT discrete grabs & diel tidal sampling (2 hr X 25 hr)

Monthly measurements of dissolved inorganic nutrients & plant pigments

- •Nitrogen: NO_2, NO_3, NH_4, DIN
- •Phosphorus: PO_4 (ortho-phosphate)
- •Plant Pigments: Chl *a,* phaeophytin
- •Bacteria (total coliforms)

COOS BAY / SOUTH SLOUGH, OR: Relationship between Oxygen Stress, Temperature, and Pacific Ocean Upwelling



3-5 day time lag between upwelling, low dissolved oxygen, and oxygen stress

Evidence of localized plankton blooms and primary production?

◇ **Oxygen stress = < 5 mg/L**

■ **Upwelling Index**

O2 stress with temperature r = 0.855

O2 stress with upwelling r = 0.711

O2 stress with lag upwelling r = 0.742

Multiple Stressors that Influence Population Recovery of Olympia Oysters (*Ostrea lurida*)

5. Predation & Competitive Interactions with Non-Indigenous Invertebrates

Coos Bay: ca. 110 species of non-indigenous invertebrates

Predation by European green crab

Carcinus maenas

Potential importance in upper intertidal zone

Oyster shell fragments after predation experiment

Overgrowth competition by epifouling invertebrates

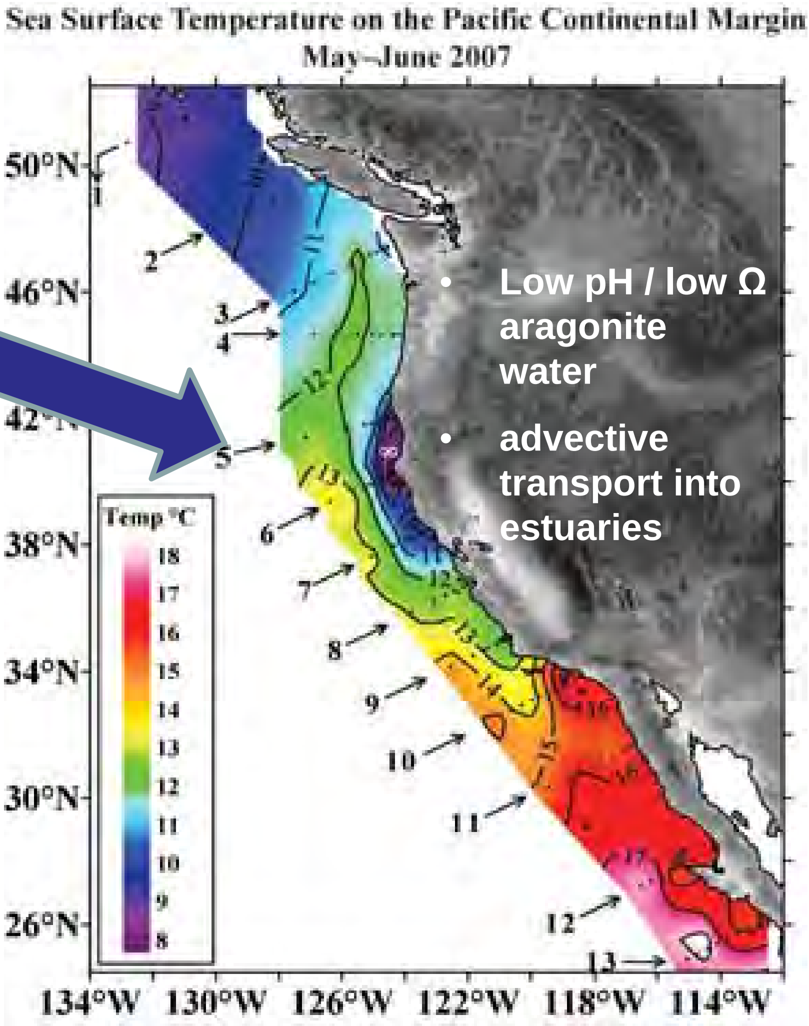
tunicates	**sponges**
bryozoans	**hydroids**
barnacles	**mussels**

Multiple Stressors that Influence Population Recovery of Olympia Oysters (*Ostrea lurida*)

6. Elevated pCO2 and Acidification of Nearshore Ocean Waters

Intense upwelling in S. Oregon / N. California brings deep cold water to the surface nearshore:

- **Low dissolved oxygen**
- **High nutrients**
- **Low pH**
- **Low aragonite saturation state**
- **Corrosive to oyster larvae**

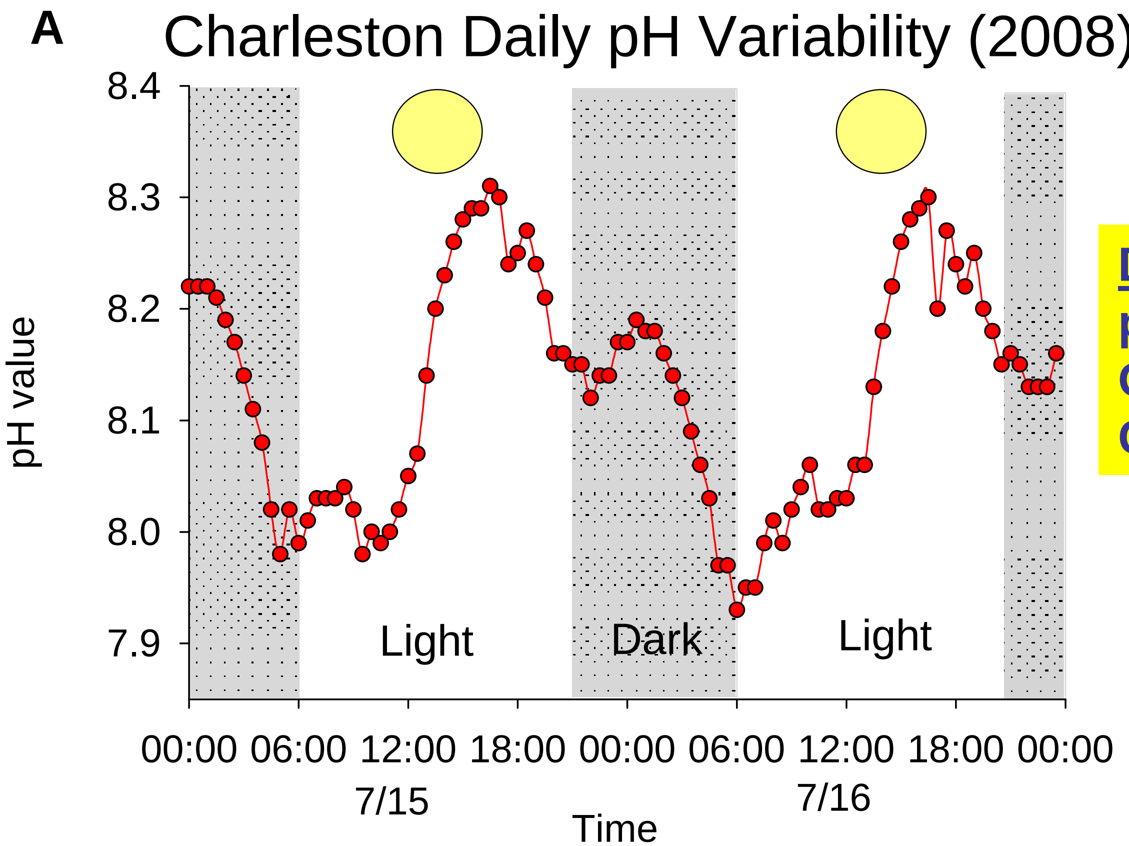


How is the carbonate chemistry of nearshore ocean waters modified by processes within PNW estuaries?

See B. Hales *et al*.; PICES S12-6538 / 1600 hrs

Daily Cycle of pH Changes within the South Slough Estuary:

Charleston Bridge / 15-17 July 2008



Estuary pH values fluctuate on a daily cycle:

<u>Daylight</u>: produce O2 / utilize CO2

highest pH in light (early afternoon)

lowest pH at dark (pre-dawn)

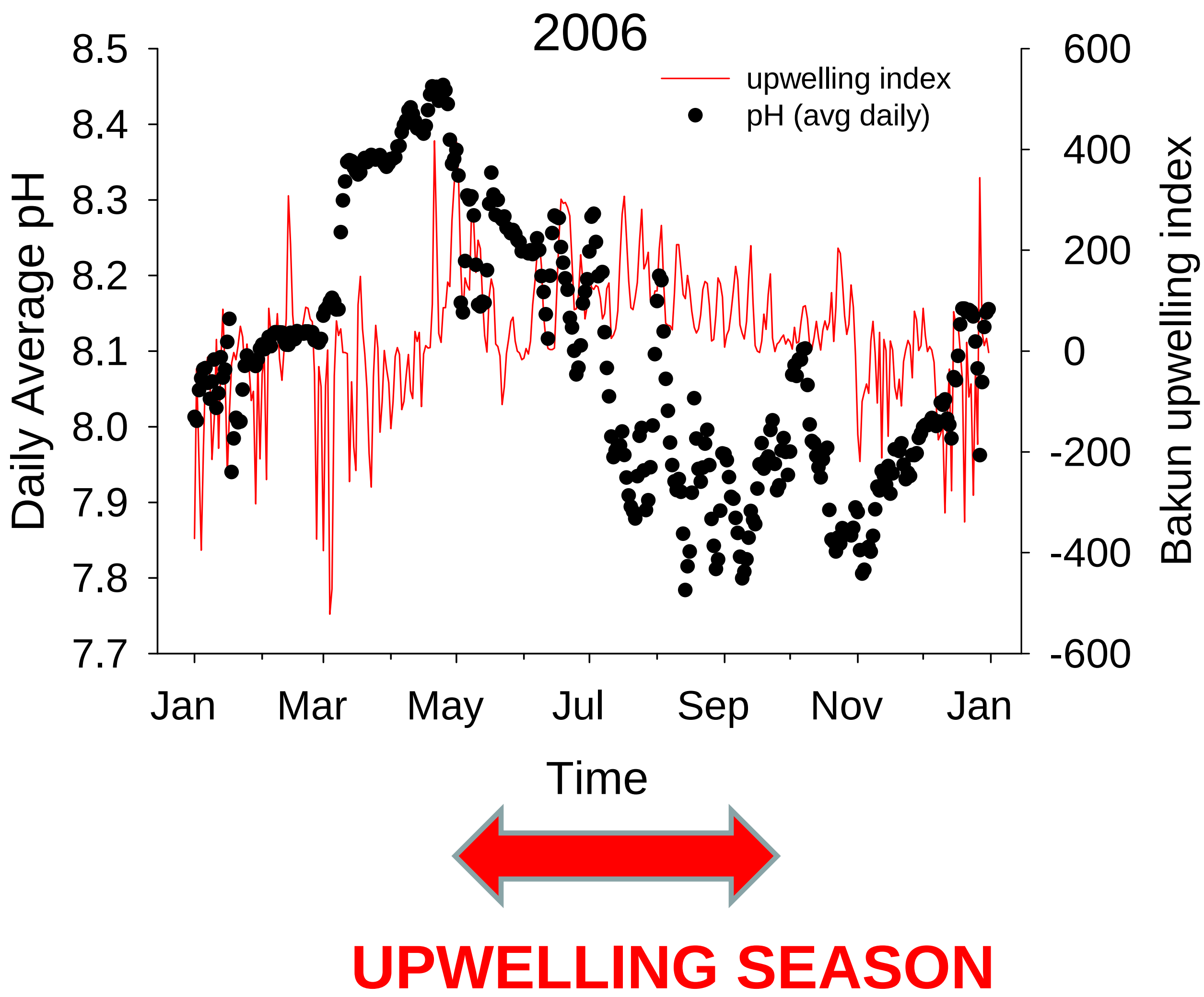
Daily pH cycle is driven by photosynthesis and respiration by estuarine phytoplankton, macroalgae, benthic diatoms, and eelgrass beds

Eelgrass: *Zostera marina*

Seasonal Variability in Upwelling and pH values in Coos Bay/South Slough

Elevated pH values in late spring / early summer (increasing photosynthesis & productivity of phytoplankton, benthic algae, seagrasses, marsh plants, etc.)

Low pH values in late summer (upwelling, decreased productivity, & breakdown of estuarine plants and algae)

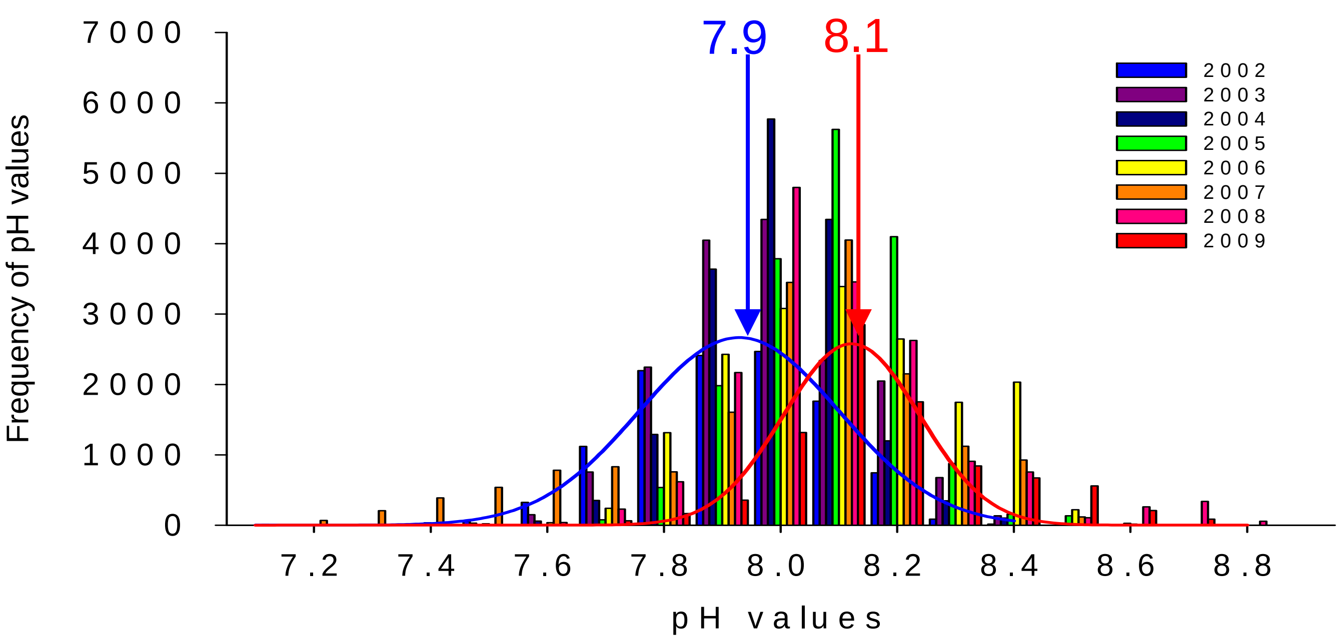


Time-series data reveal a long-term shift toward increased pH values within the marine-dominated region of the South Slough

<u>Annual averages</u>:

2002 / pH 7.9

2009 / pH 8.1



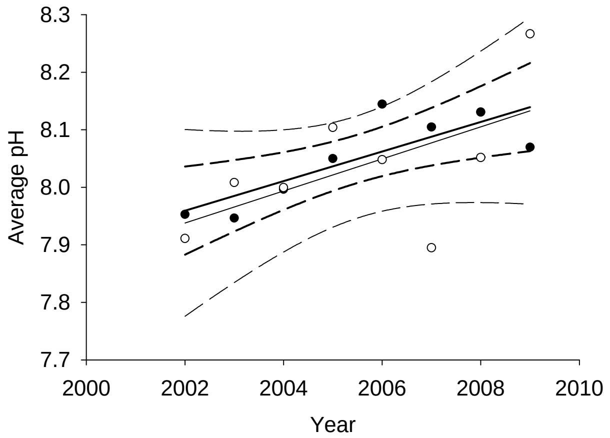
YSI-6600 EDS Datalogger

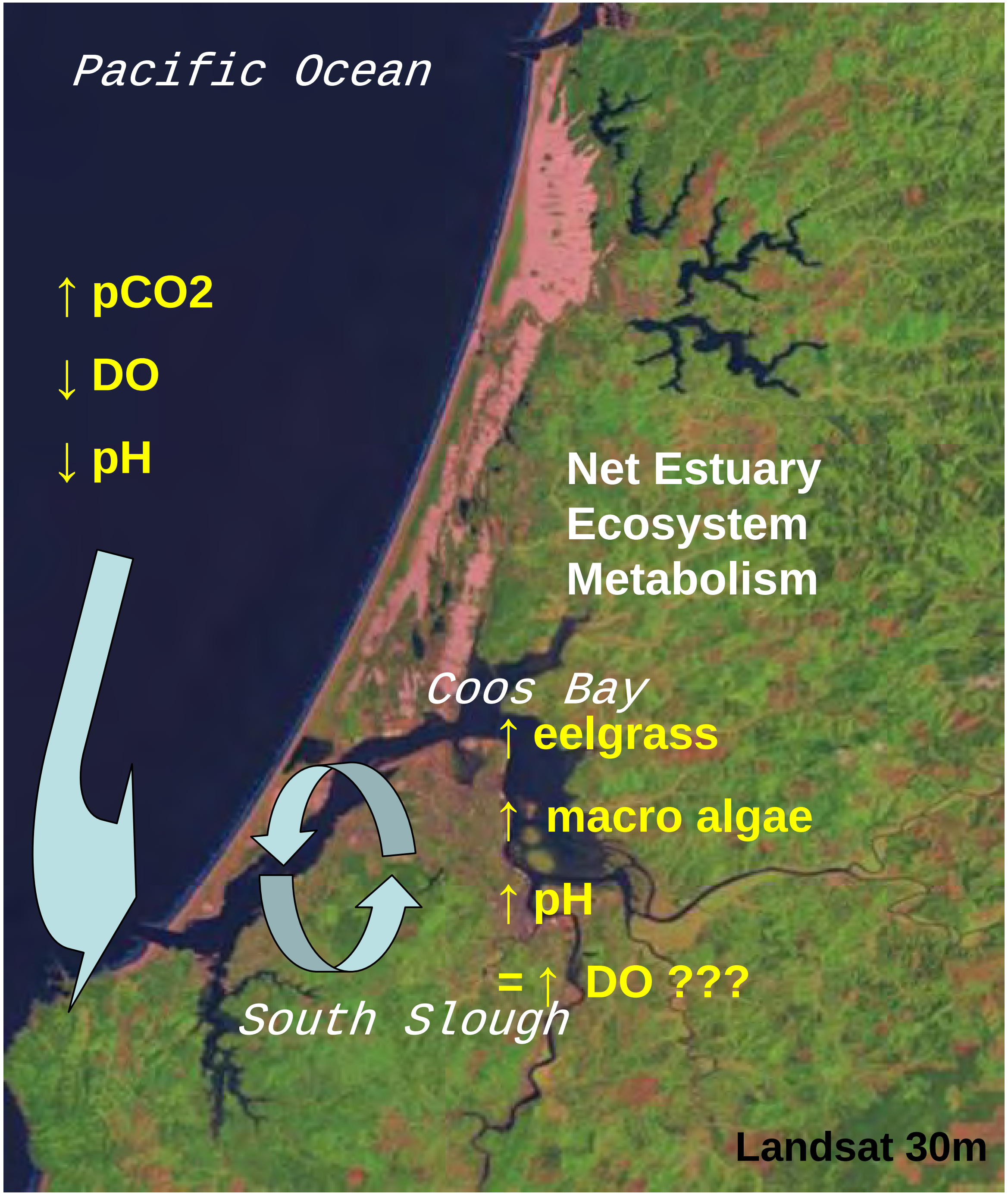
Total n = 208,400 pH measurements

Coos Bay / South Slough Estuary

Working Hypothesis:

Observed long-term (8 yr) trend toward increased pH values is due to localized increases in biotic production (*i.e.,* eelgrass and macrobenthic algae) coupled with decreases in DO values of upwelling source waters and ocean delivery of nutrients



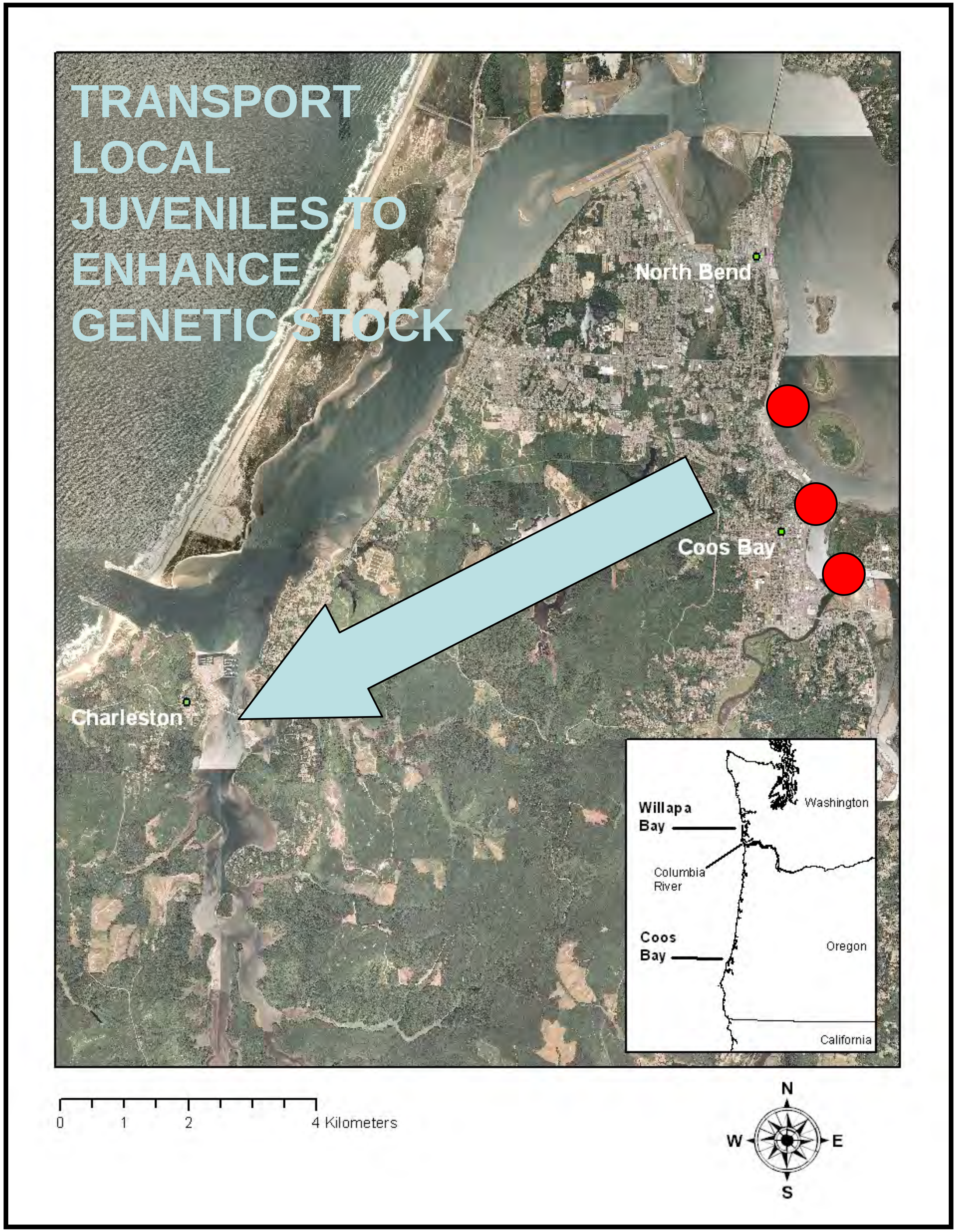


Larval Settlement in Coos Bay / Isthmus Slough: Deployment of Oyster Settlement Collector Bags (July 2010)

Juvenile Olympia Oyster Recruitment on Pacific Oyster Shell in Collector Bags (July 2010)

<u>Natural Recruits</u>:
Settlement Collector Bags (80 bags / yr) deployed at 3 locations in Coos Bay to provide substratum for larvae produced by locally-adapted adult Olympia oysters

Settlement Collector Bags




South Slough / Younker Point:
Olympia Oyster Grow-out Site
(Aug 2010)
DATALOGGER
1 MO / 200 bags
2 YR / 40 bags
1 YR / 300 bags
2 YR / 20 bags

National Estuarine Research Reserve System – Science Collaborative

New Project: A Collaborative Approach to Address Larval Supplies and Settlement as Critical Early-Life History Issues during Restoration of Olympia Oysters in Coos Bay and the South Slough Estuary, OR

Timeframe: 2011 – 2013

A. **Population Size Structure & Density, Gonad Development, Location of Breeding Adults, Fecundity, Brood Release, Estimate of Total Population Reproductive Output**

B. **Larval Behavior, Dispersal, Feeding, Susceptibility to Predation during Larval Life, Interactions with Estuarine Water Masses, Export & Retention**

C. **Larval Settlement, Delay of Metamorphosis, Post-larval Survival, Early Cluster Formation, Growth to Maturity**

D. **Olympia Oyster Restoration Advisory Committee – Stakeholders**

E. **Olympia Oyster Conservation and Restoration Plan for Coos Bay**

Summary:

1. Olympia oysters were historically abundant within Pacific coast estuaries. Oyster populations are making a slow recovery in parts of Coos Bay, but they are virtually absent from some regions.

2. Olympia oysters are exposed to multiple anthropogenic stressors including habitat loss, dredging, mariculture operations, poor water quality, interactions with non-native species, ocean acidification, and loss of genetic diversity.

3. Recovery of Olympia oyster populations in Coos Bay appears to be limited primarily by inadequate sites for larval settlement and recruitment.

4. Hard substrata is limited, and settlement of Olympia oyster larvae occurs on Pacific Oyster shells where they can mature, but are subject to incidental mortality when the commercial plots are routinely harvested every 2-3 years.

5. Local restoration activities have begun, and genetic enhancement in small-scale experimental oyster restoration plots will be used to guide larger-scale restoration efforts in South Slough and Coos Bay in the future.

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