Shellfish Restoration and Aquaculture Projects as a Means to Mitigate Coastal Nutrient Pollution

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Oyster Aquaculture Leases and Fish Traps in Narragansett Bay 1910

- 21,000 acres under lease
- Predominately seed plant and growout operations
- Harvest weight 57,828 mt live wt = 19,275 mt oyster meats

Source: 1911 Report of RI Shellfisheries Commission

Oyster Shucking House ca. 1910

RI Oyster Aquaculture 2006

- 99 acres under lease
- 2,357,000 oysters produced or about 47 mt oyster meats.
- 560 times less than 1910 production

Source: D. Alves 2006
RI-CRMC Aquaculture Report

Can Water Filtering by Bivalves Clean Up Degraded Coastal Waters?

The Problem: Eutrophication of Coastal Estuaries

- Popularity of Coastal Areas for Homes & Tourism
- Waste Disposal Problems – ISDS & treatment plants
- Nutrient Leaching from ISDS
- Degradation of Coastal Waters (Agriculture? Aquaculture? Others?)

Degradation of Coastal Waters

- Nitrogen as limiting factor in coastal productivity --- general consensus (e.g. Nixon 1995 Ophelia 41:199-219)
- Increased phytoplankton blooms (e.g. Cloern 2001)
- Light attenuation & loss of SAV (e.g. Heck et al. 2000: L&O)
- Changes in benthos from aerobic sands to anaerobic organic muds (e.g. Nixon, 1995)

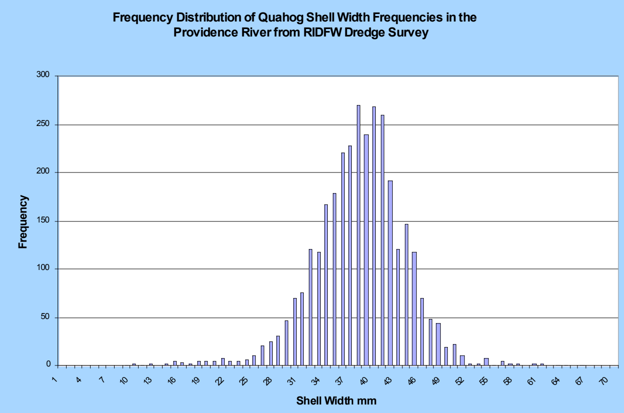
Evidence Aquaculture of Bivalves Can Filter Phytoplankton, Clear Water and Remove Nitrogen

- Documentation of phytoplankton removal by field populations of bivalves (e.g. Cloern, 1982; Ulanowicz & Tuttle 1992))
- MERL Experiments, increased sedimentation & mineral cycling (Doering & Oviatt, 1986; Pietros & Rice 2003)
- Turnover of water in Chesapeake from 3 days (1890s) to present 350 days (Newell, 1988)
- Programs to establish bivalve culture for remediation (e.g. O'Beirn, 1997)
- Promotion of sediment denitrification (Newell et al. 2002)

RIDEM-F&W Providence River Quahog Survey Results (1998)

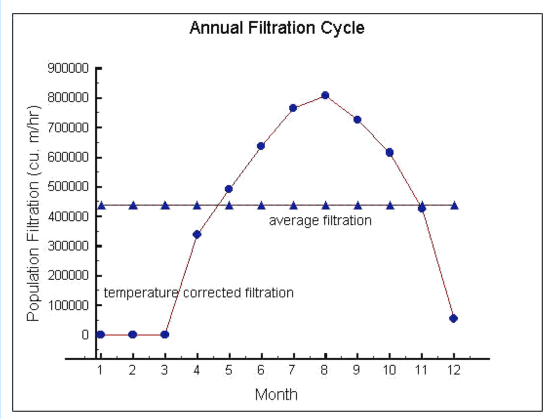
- Standing crop averages 9.1 clams/m^2 or about 26,400 metric tons
- MSY of quahogs 2,721 mt or 10.3% of standing crop biomass
- Quahogs w/ unusually thick shells (meat:whole body weight ratio = 0.18)

Data: N. Lazar & A. Ganz, RIDEM



Filtration Rate Modeling

- FR = $0.307L^{0.967}$ (FR in mL/min; L in cm) Source: Doering & Oviatt (1986)
- FR = $1.55T^{0.982}$ (FR in mL/min; T in ^{o}C above 10^{o}C) Modified from Doering & Oviatt (1986)

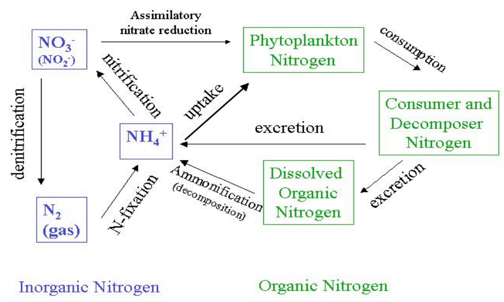


Filtration Volume Comparisons Providence River

- Hydrographic data: semi-diurnal tides w/ 12.5 h period; mean tidal excursion = 1.22 m; area = 2,119.8 ha; so, mean tidal prism = 25.8 million m^3
- mean population filtration per tide cycle = 5.5 million m^3 or 21% of tidal prism
- maximum August population filtration per tide cycle = 10.1 million m^3 or 39% of the tidal prism

Bivalves as promoting aquatic nitrogen cycling

Aquatic Nitrogen Cycle



How much protein nitrogen does an oyster have?

- Analysis of shells = <1% protein
- Analysis of soft tissues = 30% dry wt, or 6% wet wt protein (USDA Food Tables)
- Variable due to seasonal CI changes
- Protein ~14% nitrogen, so for each kg oyster meats harvested, 8.4 g-N is removed from estuary.

Well, send in the maids. How many oysters does it take to clean up after a tourist?

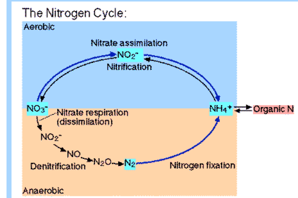
- People produce 5 kg-N/yr (range 2-8kg/yr; EPA septic system data)
- Attenuation by soils variable, (range 10-90%) So, assume 50% attenuation before reaching water
- Amount N reaching estuary per person per year = 5 kg/person/yr X 0.5 = 2.5 kg-N/person/yr
- 2.5 kg-N/yr ÷ 0.084 kg-N/kg-meats = 29.7 kg-meat/yr
- 29.7 kg-meat/yr ÷ 0.020 kg-meat/oyster = 1,485 oysters/yr per tourist

Comparative levels of nitrogen removal by RI's oyster farmers

- In 1910, 26.3M kg oyster meats harvested. So, 26.3M kg X 0.084 kg-N/kg-meat = 2.2M kg-N/yr or the equivalent of about 440k people's nitrogen waste.
- In 2006, 47,149 kg of oyster meats harvested (2,357,000 oysters x 0.020 kg-meat/oyster). So, 3,960 kg-N is removed, equivalent to 792 FTEs. (FTE = full tourist equivalents)

Nitrogen removal by sediment denitrification

- First demonstration New Zealand mussel farms (Kaspar et al., 1985)
- Delivery of feces & pseudofeces to sediments promote denitrification
- Experiments show 20% N-removal by denitrification (Newell et al 2002)



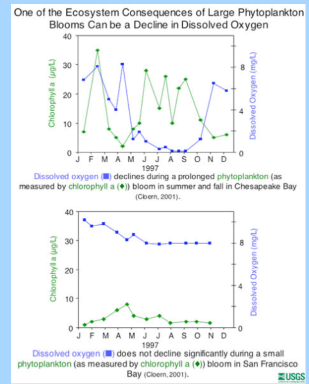
Nitrogen recycling in water column & phytoplankton regeneration

- Oysters excrete NH_3 at a rate dependent on meat weight $E = 50.65w^{0.7}$
- In mesocosms w/o sediments stocked with oysters approximating 1910 oyster pop. levels in NB, excretion 22.4 µg-N/L/day ≈ estimated phytoplankton requirements 20µg-N/L/day.
- $[NH_3]$ and $[chl_a]$ stable in tanks w/ & w/o oysters

Data from Pietros & Rice 2003

Implications of Nitrogen Cycling in Water Column

- Attenuation of phytoplankton boom & bust cycles
- Increasing ecosystem diversity & stability



So, What's the Bottom Line?

- Bivalve populations should be viewed as important in water quality maintenance & remediation
- Developing public policy of increasing bivalve biomass in coastal and estuarine waters (aquaculture & management)
- Harvest and aquaculture of rapidly growing stocks removes N by virtue of tissue growth and removal from estuary and stimulating sediment & water column processes
- Room for ***much*** industry growth; and alliances with those with environmental concerns.