Oysters' Contribution to Water Column Filtration

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NOAA Brown Bag Seminar Series

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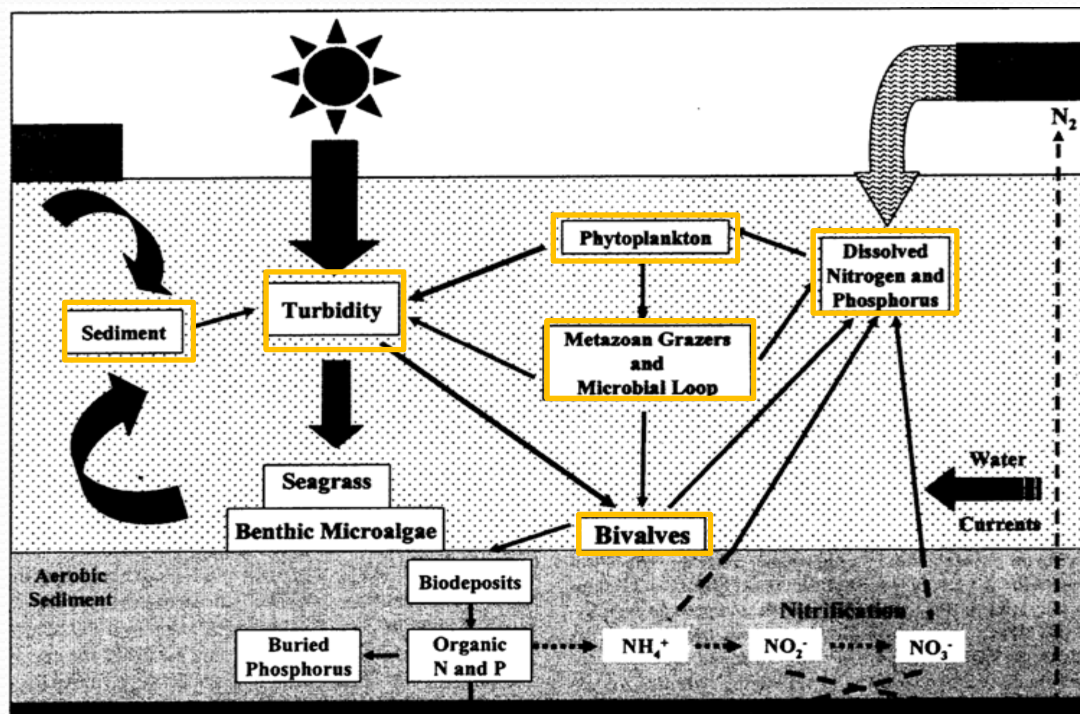
http://www.asknature.org

www.sms.si.edu/irlspec/Ostreola_equestris.htm

Benthic Suspension Feeders

- Passive v. active
- How does their particle removal affect the ecosystem?
  - Benthic-Pelagic Coupling
  - Water clarity

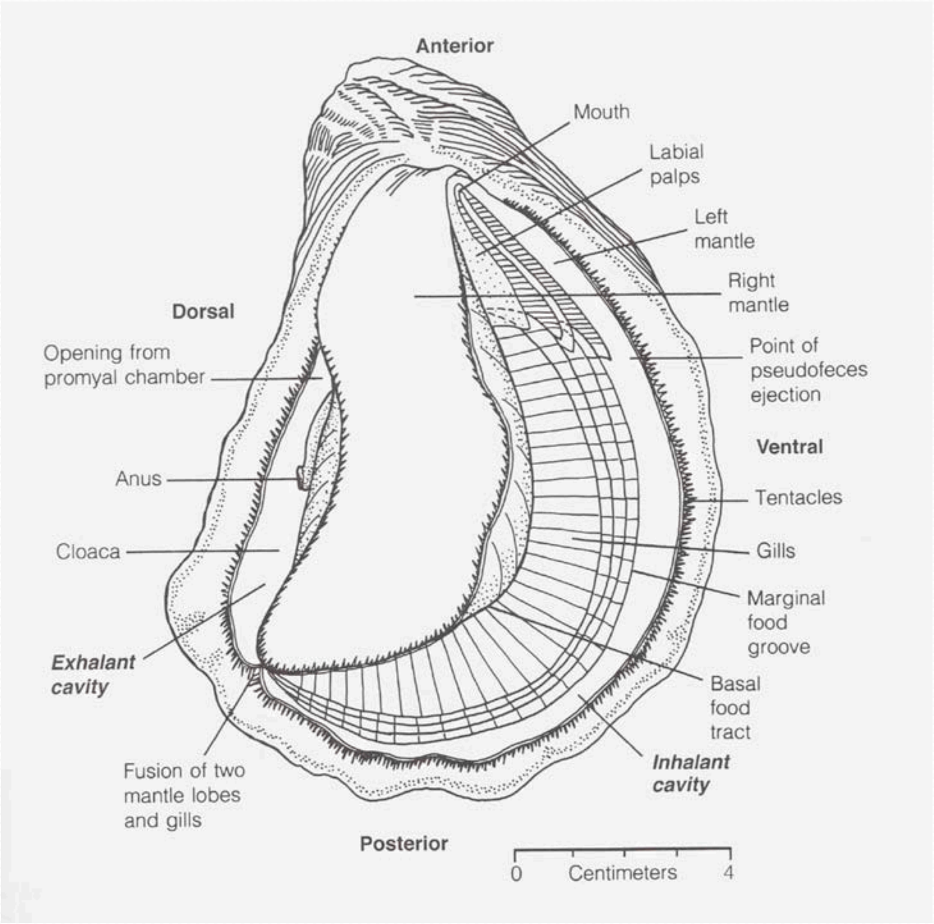


(Newell 2004)

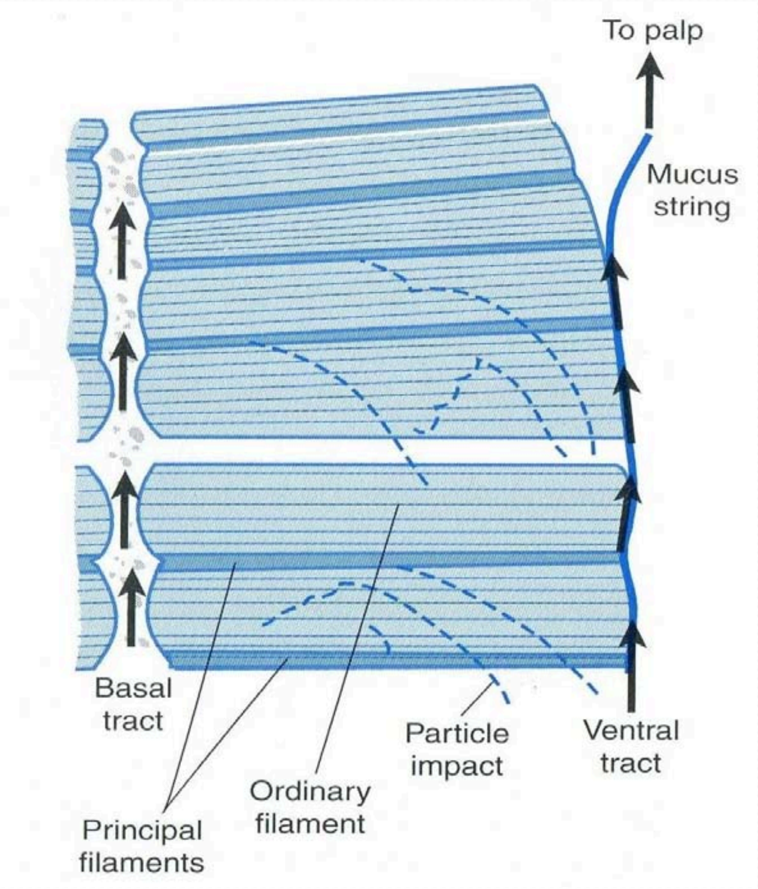
Outline

- Background
  - Oyster filtration biology
  - Significance of *Crassostrea virginica* and the Chesapeake Bay
- Introduction to *Ostrea equestris* and its co-occurrence with *C. virginica* in NC
- Filtration study on *O. equestris*
- Future directions for research

Diagram of oyster gills/palps



From Newell and Langdon 1996



From Levinton 2001

Crassostrea virginica (Gmelin)

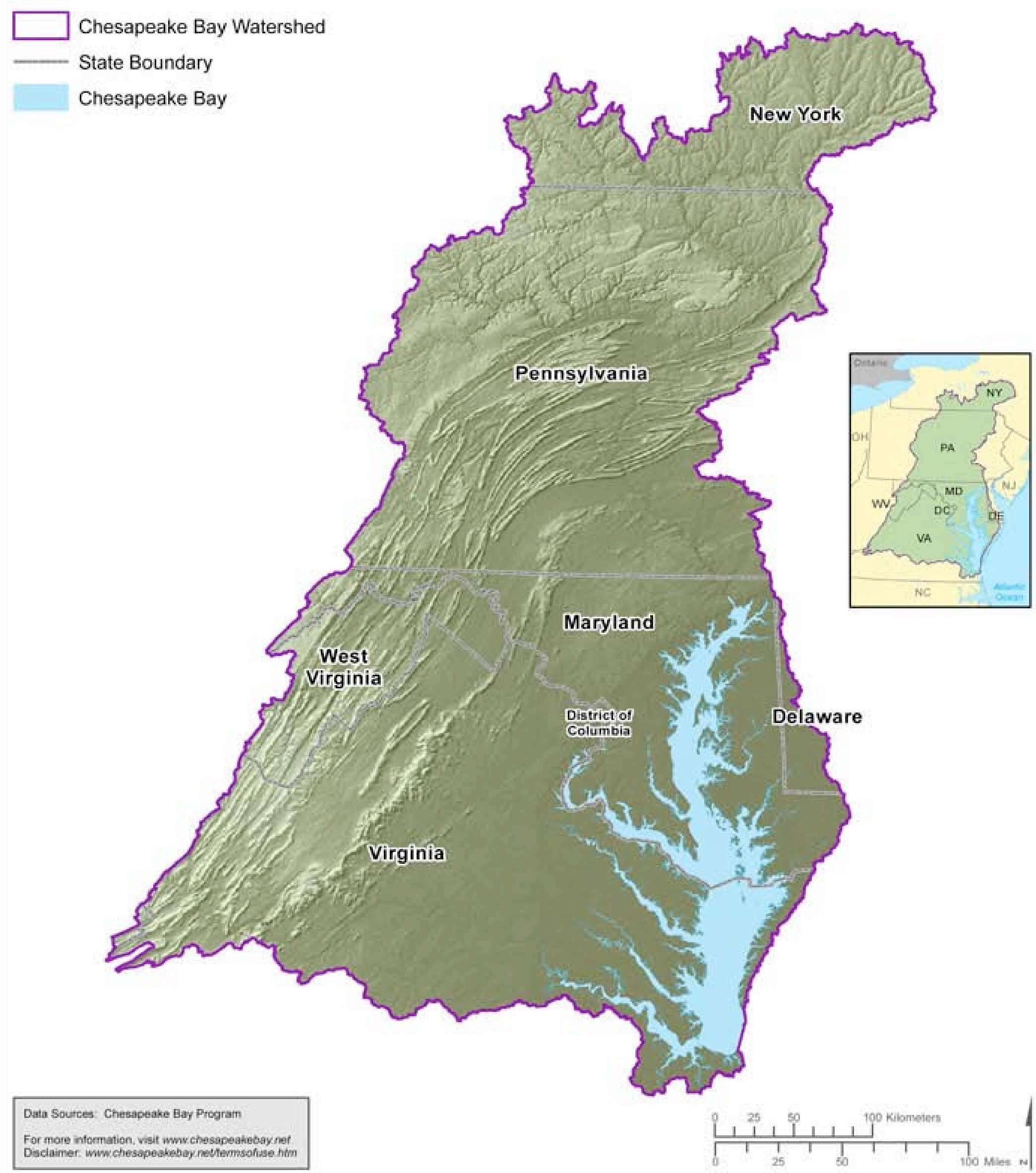
- Commercial species
  - $88 mil. industry in the US
- Reef-building
- Primary sink for phytoplankton production in estuaries (e.g. Banas et al 2007)
- Top-down control of phytoplankton through filtration of the water column (Newell 2005)
- Commonly used in restoration projects
- Optimum salinity range

  14 to 28‰
- Filter particles >3µm with high efficiency

  (Haven and Morales-Alamo 1970)

Chesapeake Bay Watershed

Chesapeake Bay Program
A Watershed Partnership



Data Sources: Chesapeake Bay Program

For more information, visit *www.chesapeakebay.net*
Disclaimer: *www.chesapeakebay.net/termsofuse.htm*

Created by EA, 1/24/08

UTM Zone 18N, NAD 83

Land Cover

Chesapeake Bay Watershed

Chesapeake Bay Program
A Watershed Partnership

Land Cover Classes

- Low/Medium intensity developed
- High intensity developed
- Wetlands
- Forest
- Agriculture
- Barren
- Chesapeake Bay Watershed
- Chesapeake Bay
- State Boundary

Data Sources: Chesapeake Bay Program, National Land Cover Data 2001

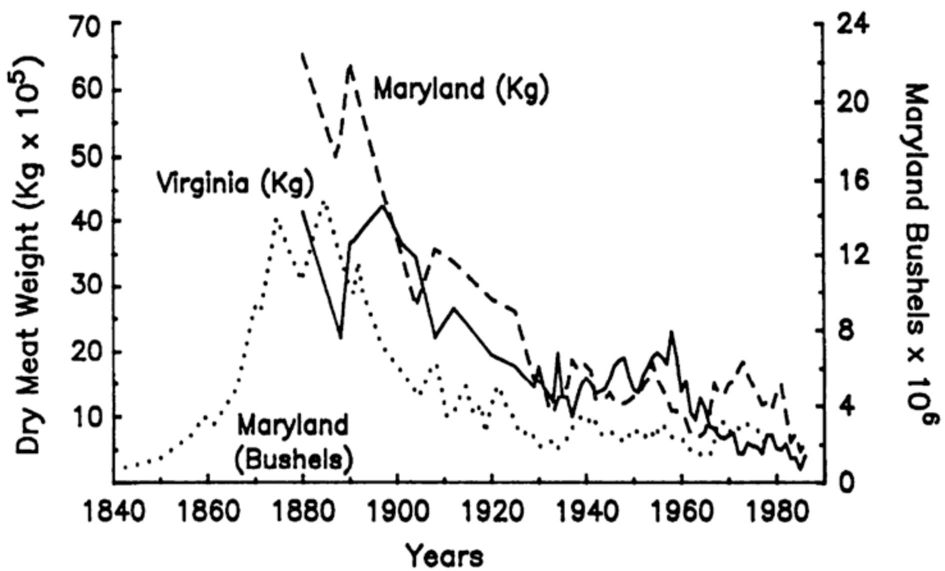
For more information, visit *www.chesapeakebay.net*

Created by EA, 1/23/08

UTM Zone 18N, NAD 83

Oysters and the Chesapeake Bay : Background

- Newell 1988
  - Prior to harvesting, oysters filtered volume of Bay every 3-6 days
  - Oyster populations reduced by >90%, turnover time increased to ~325 days
  - Reduction in phytoplankton consumption from 23-41% to 0.4% in 1988 (Newell 1988)
- Pomeroy et al. 2006
  - Oysters at pre-harvest levels likely did not control phytoplankton blooms and hypoxia
  - Actual filtration potential lower than Newell estimated, oysters not a magic bullet



From Newell 1988. Oyster landings for Maryland and Virginia from NMFS statistics converted to dry weight.

Realistic Expectations for Oyster Filtration

- Difficult to measure effects of oyster filtration on large bodies of water due to practicality and current lack of restoration projects at that scale
- Localized effects of oyster filtration on water quality and nutrient concentrations have been well documented
  - Nelson et. al 2004
- Cerco & Noel modeling study: most direct benefit from 10% increase in oyster biomass would be increased water clarity and a 20% increase in summer SAV biomass

Oyster Restoration in Action

NOAA Oyster Work Day 2012

Ostrea equestris (Say 1834)

- Subtidal, stenohaline (Galtsoff & Merrill 1962)
  - Salinities above 25‰
- Noncommercial
- More common than previously thought (Markwith 2010)
- Formerly *Ostreola equestris*
- Size: 35-55 mm

(Markwith 2010, Lapegue et al, 2006, Shilts et al, 2007)

C. virginica

- Denticles absent
- Higher length-to-height ratio
- Crenulated margin absent
- Centered adductor muscle scar
- 100 - 115 mm
- Reef-building
- Broadcast spawners

http://www.jaxshells.org/crassost.htm

O.equestris

- Denticles present along the lateral margin of right valve
- Lower length-to-height ratio
- Crenulated margin on left valve
- Off-center adductor muscle scar
- 35-55 mm
- Non reef-building
- Brooders

http://www.nmr-pics.nl/Ostreidae_new/album/

(Coe 1943; Galtsoff & Merrill 1962; Menzel 1955)

Prevalence of *O. equestris* in NC

- 100% of the live oyster population within low intertidal shell hash habitats and on floating docks
- 10% of the oyster population in the interior of oyster reefs
- 20% of the oyster population at the edge of reefs
- Equally common in northern and southern NC sites
- Patch density from <5 to >125 oysters/0.25m^2(Markwith 2010)
- Bowen's Island, SC - densities of up to 139 oysters/0.25m^2 (Warren & Hadley, unpublished data)
- Recent range expansion?

Ecological Implications

- Little known about this oyster's role in the environment
- How does it compare with *Crassostrea virginica* in terms of filtration?
- Possible competitor of *C. virginica*?

Research Questions

Q #1.) What is the relationship between clearance rate and biomass for this oyster? How does it compare to *C. virginica* and other bivalves?

Q #2.) How does flow speed affect clearance rate?

Q #3.) How does concentration of algae affect clearance rate?

Methods

- Collection
  - UNCW Research Lease, Masonboro NC
  - Epibionts removed
  - Experiment performed between 12 and 48 hrs of collection
- Experiments
  - Measure decline in particles
    - Liquid phytoplankton suspension
    - Four flow speeds: 0, 3, 10 and 20 cms^{-1}
  - 2 different concentrations
    - 1×10^5 algal cells mL^{-1} and
      1×10^6 algal cells mL^{-1}
- Sequoia LSST Portable Laser diffraction particle size analyzer
- Normalize data for ash free dry weight
- Clearance rates calculated for particles 1µm-10 µm in diameter

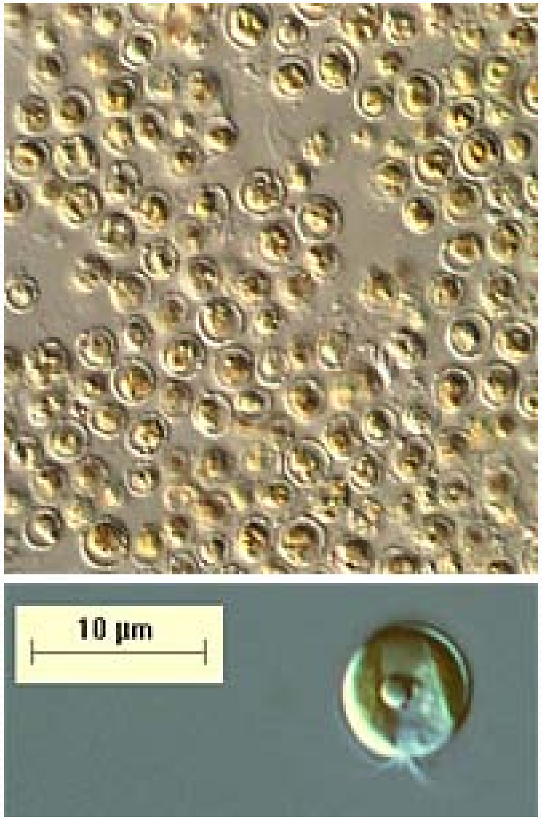
Clearance rate

$$CR = \frac{V}{t}\left(\ln\frac{C_{BO}}{C_{Bt}} - \ln\frac{C_{CO}}{C_{Ct}}\right)$$

CR	Clearance Rate
V	Volume of Suspension
t	Time
C_{BO}	Initial concentration
C_{Bt}	Final concentration
C_{CO}	Initial concentration (control)
C_{Ct}	Final concentration (control)

(Coughlan 1969)

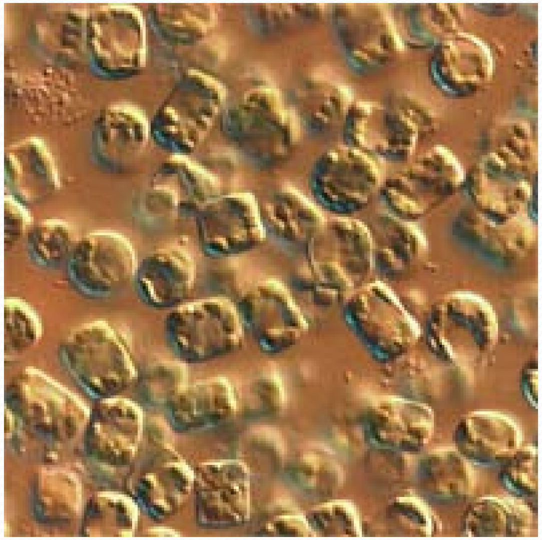
Oyster Diet



Pavlova sp.

Isochrysis sp.

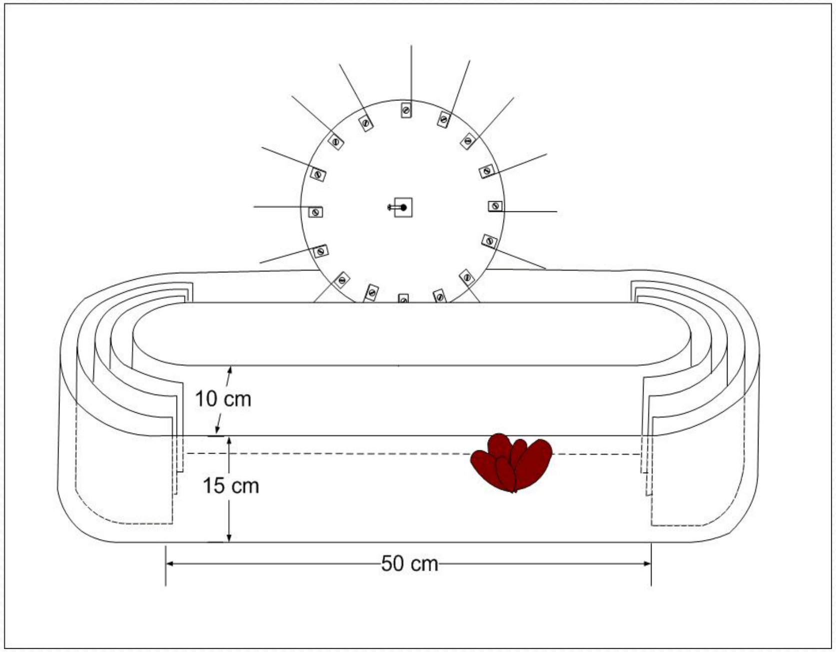
Tetraselmis sp.

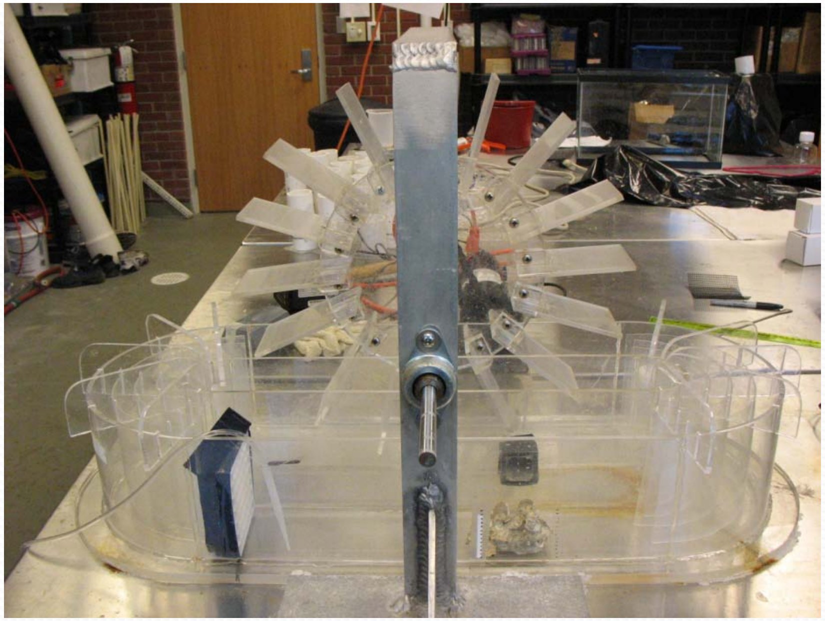


Thalassiosira weissflogii

http://www.reedmariculture.com/product_instant_algae_shellfish_diet.html

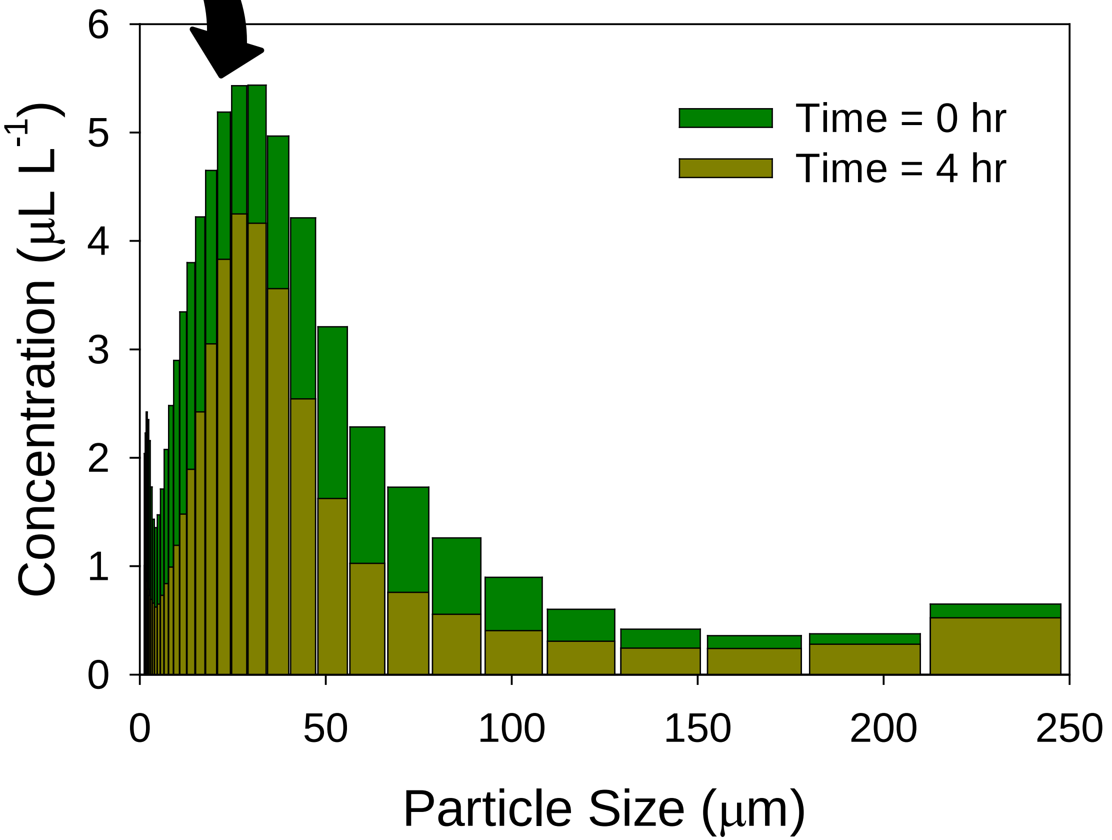
Paddle Flume Tank





16.4 L laboratory paddle-flume tank

Particle Analysis



Q #1 Results

$CR = aW^b$

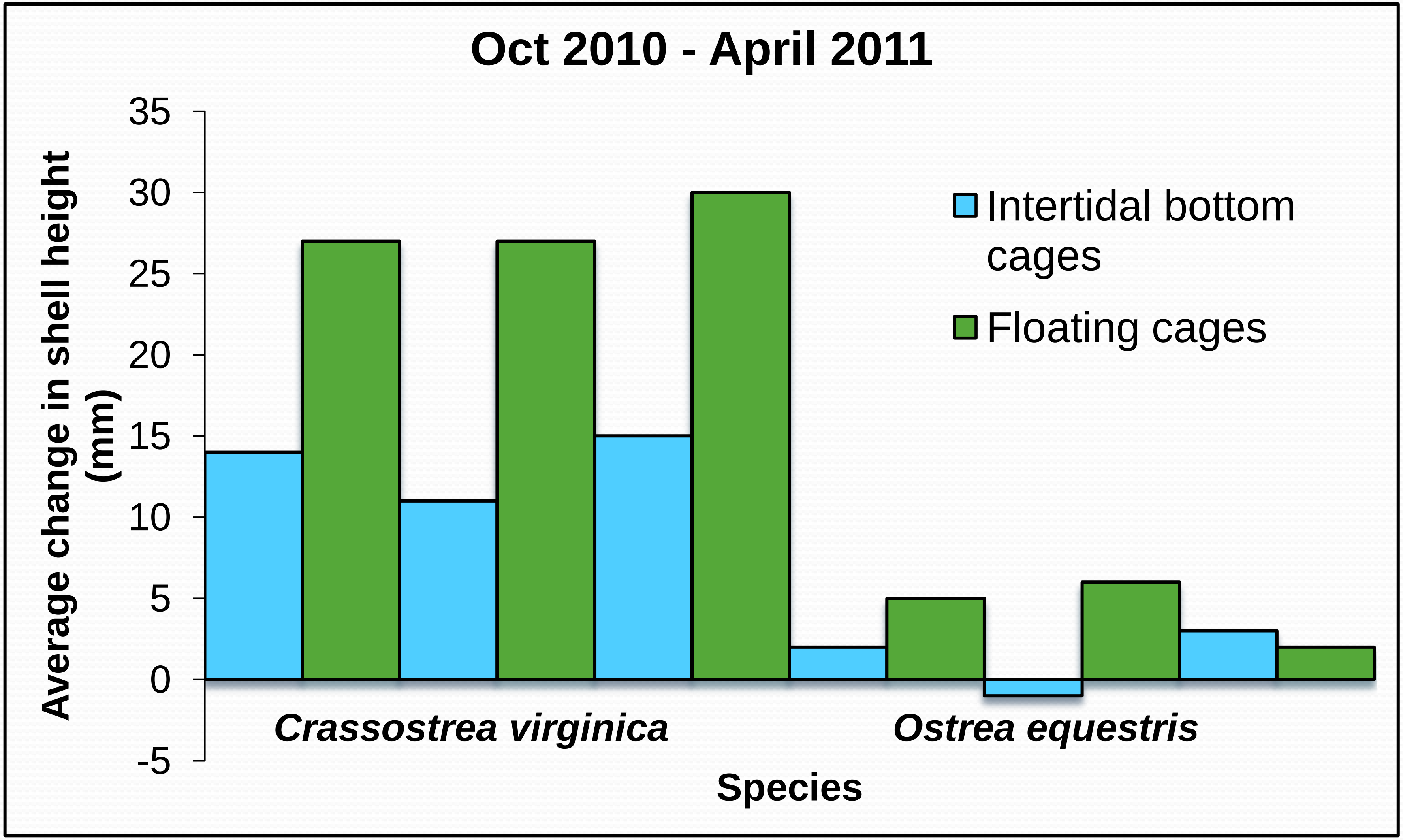
What is the relationship between clearance rate and biomass for this oyster? How does it compare to *C. virginica* and other bivalves?

Species	***n***	***W***	***a* ± SE**	***b* ± SE**
Ostrea equestris	85	0.096-1.200	0.20±0.018	0.58±0.15
Crassostrea virginica	10	0.063-0.994	6.79±1.41	0.73±0.22
Geukensia demissa	18	0.009-1.039	6.15±1.19	0.83±0.07
Mercenaria mercenaria	6	0.017-2.387	1.24±1.21	0.80±0.09

(Riisgard, 1988)

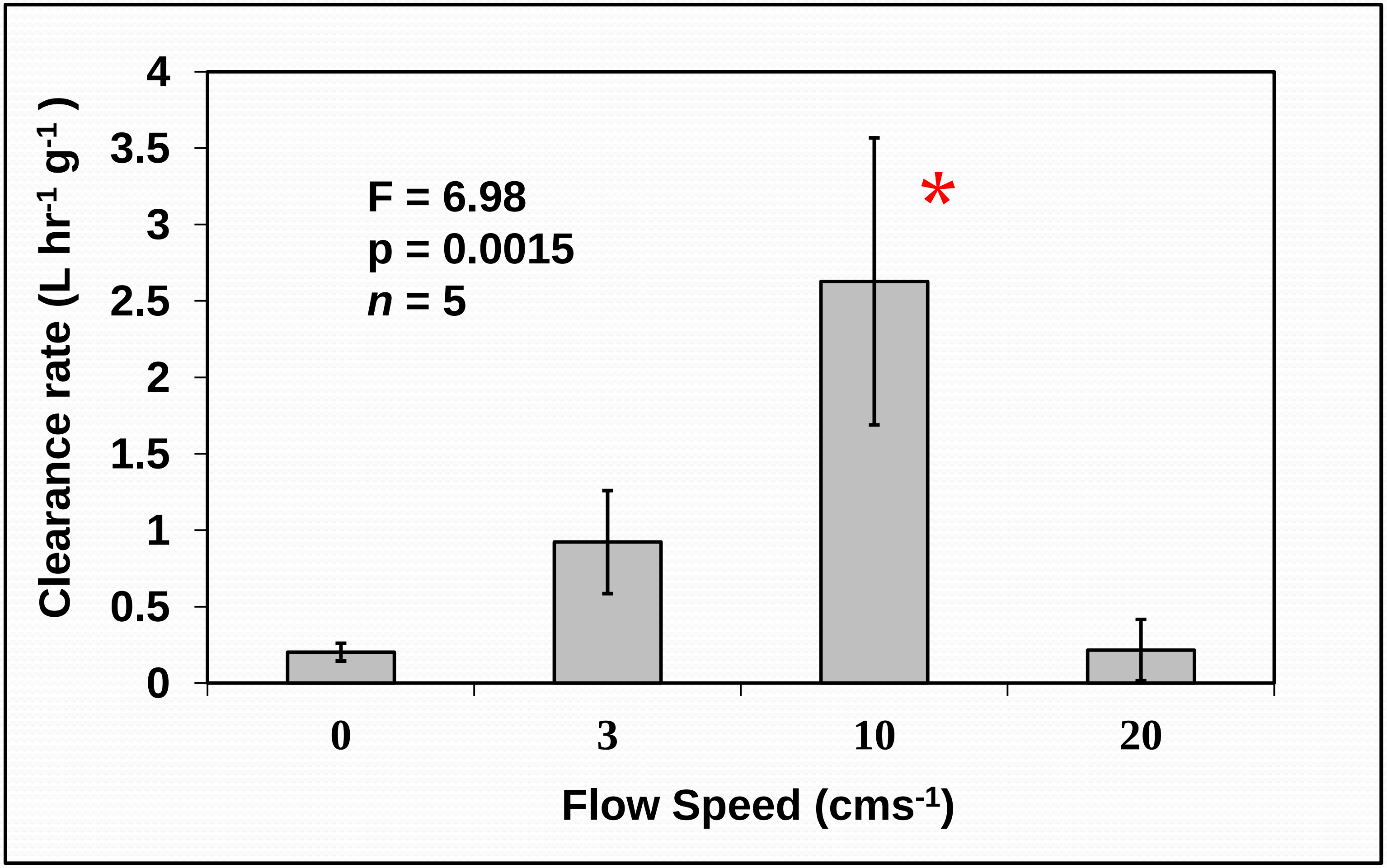
- Scaling relationship is similar to those reported for other species, but the magnitude (*a*) is much lower
- ***C. virginica* filters about thirty times as much water per unit biomass as *O. equestris*!**

Growth Comparison



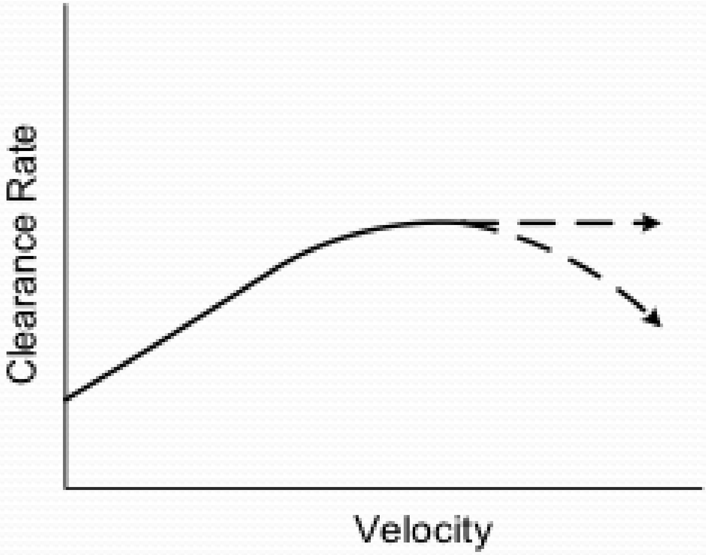
Q #2 Results

How does flow speed affect clearance rate?



Q #2 Discussion

How does flow speed affect clearance rate?

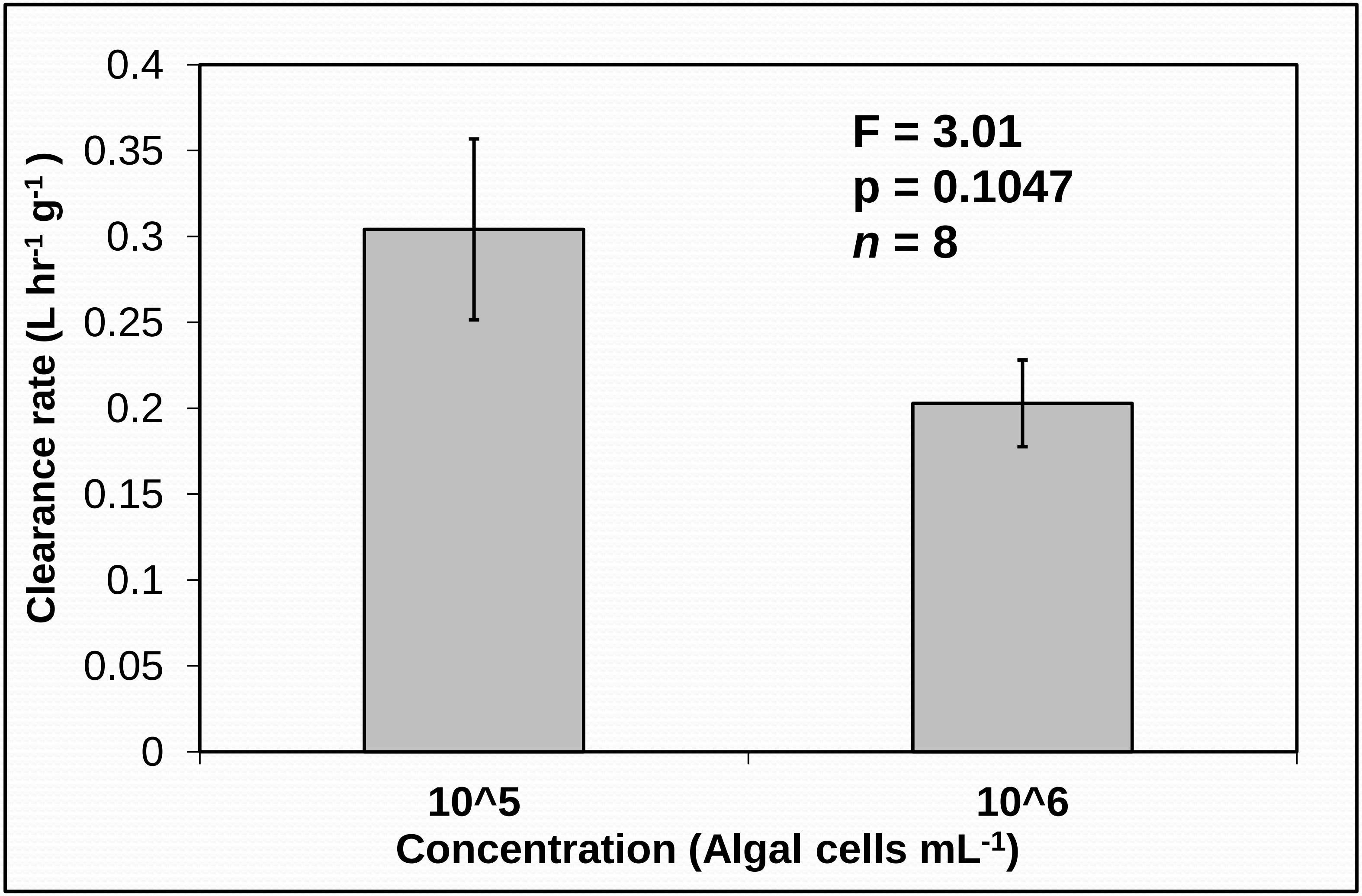


Hypothetical relationship between flow and clearance rate for an active suspension feeder. (after Wildish and Kristmanson 1997).

- **10 cm s^{-1} treatment had significantly higher clearance rate**
- Solitary ascidian- max. filtration at moderate flow speeds of ~12 cm/s (Sumerel 2009)
- Bay scallop- unimodal response in both filtration rate and growth with flow speed (Wildish and Saulnier 1993)
- *C. virginica*- positive monotonic relationship between growth and flow speed up to 7 cm s^{-1} (Lenihan et al 1996)
- ***O. equestris*** **exhibits optimum filtration at a higher flow speed than** ***C. virginica***

Q #3 Results

How does concentration of algae affect clearance rate?



Q #3 Discussion

How does concentration of algae affect clearance rate?

- *O. equestris*: no difference in clearance rate based on concentration
- *Mytilus edulis*: clearance rate increases with concentration to an asymptotic value (Bayne et al 1989)
- *C. virginica*: clearance rate increases with concentration up to 10 mg L^{-1} (Newell and Langdon 1996)
- *C. virginica*: as concentration increases, oysters are less efficient at retaining small particles (Palmer & Williams 1980)
- **Both concentrations might be within the range where sorting/ingestion is the limiting factor**

Future Research Directions

- Investigate filtration of *O. equestris* in the field
- Examine particle size selectivity in *O. equestris*
  - What is actually being ingested?
  - What does the oyster reject as pseudofeces?
  - How does this compare with *C. virginica?*
- Compare growth of *C. virginica* and *O. equestris* together and separately- competition for food?
- Compare the larval settlement preferences of *C. virginica* and *O. equestris*- competition for substrate?
- **Investigate the potential interaction between species**

Acknowledgements

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- Funding sources: UNCW & NC Sea Grant
- Hurst family (UNCW Clam lease)

Pomeroy et al. 2006: Reconsidering Oysters as the Solution

- Oysters even at pre-harvest levels likely did not control phytoplankton blooms and hypoxia
  - Summer clearance rates overestimate spring filtration
  - Spatial limits to control: stratification, large Bay, small tidal amplitude
  - Existing suspension-feeding guild not controlling bloom
- Actual filtration potential lower than Newell estimated, oyster restoration cannot control bloom and hypoxia