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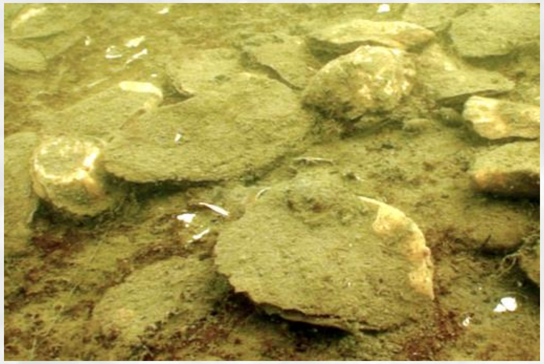
Oyster Environmental Interactions

Carter R. Newell
Pemaquid Oyster Company, musselsandoysters@gmail.com

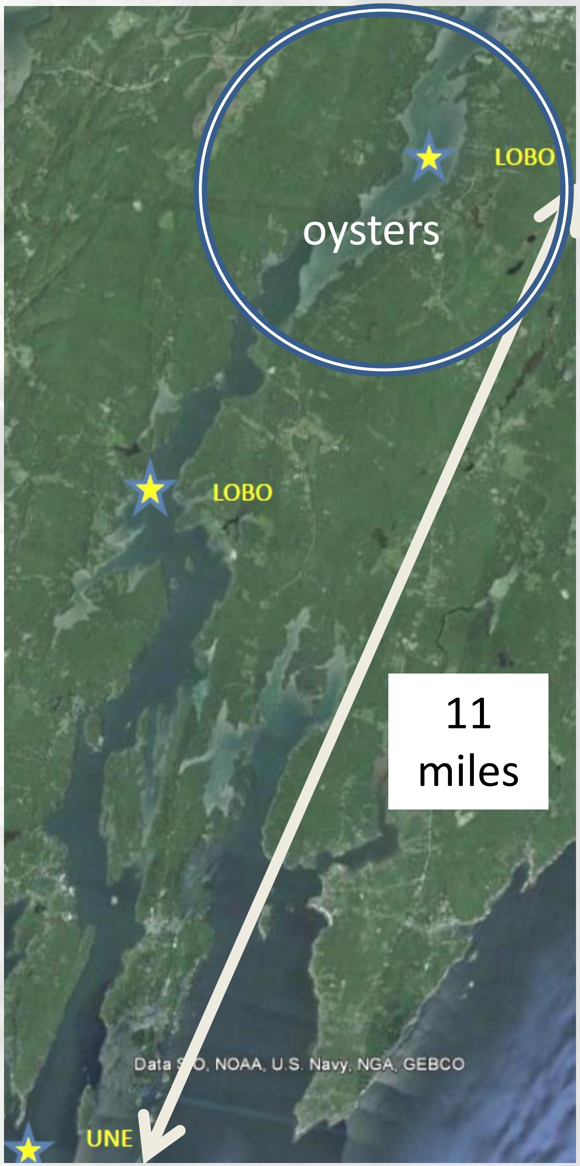
Oyster environmental interactions

Newell, C.R. Ph.D. Maine Shellfish R&D, Damariscotta, School of Marine Sciences, University of Maine, Pemaquid Oyster Company, Pemaquid Mussel Farms

How do coastal ecosystems affect the growth rates of *Crassostrea virginica* on seafarms? ⟷ **How do populations of *Crassostrea virginica* affect coastal ecosystems?**



Understanding the Productivity of the Damariscotta River April 1, 2016 DRA



The Damariscotta River Estuary and locations of monitoring buoys

Oyster farming processes

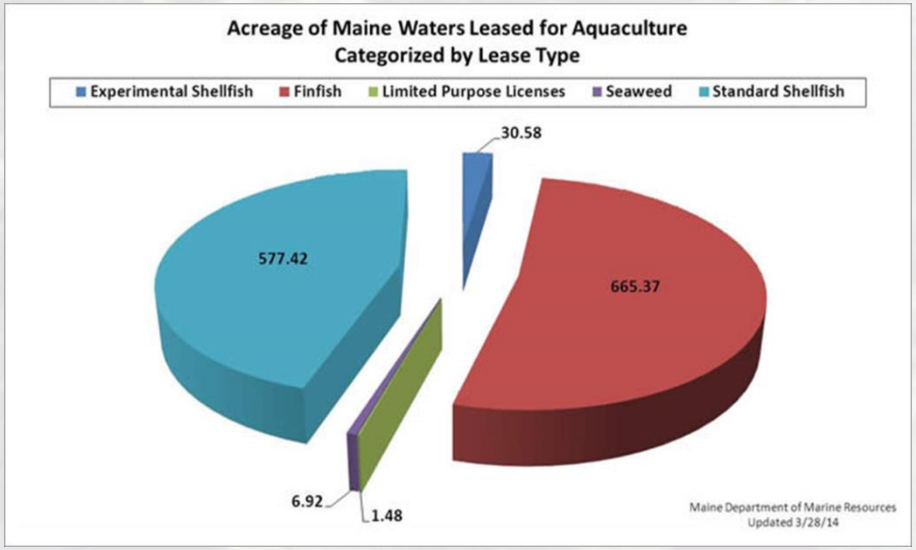
site selection, hatchery, upwellers, nursery, grow-out, processing, harvesting, sales.

What makes aquaculture successful?

- **RIGHT SPECIES**
- **RIGHT ENVIRONMENT**
- **RIGHT CULTURE TECHNOLOGY**
- **RIGHT MARKET PRICE**
- **ENVIRONMENTAL STEWARDSHIP**

What factors can threaten it?

- **EXPOSURE TO WAVES FROM BIG STORMS**
- **BACTERIAL POLLUTION (RAINFALL, NON-POINT SOURCE, POINT SOURCE)**
- **RED TIDES**
- **VIBRIO OUTBREAKS**
- **DISEASE AND MORTALITY**
- **PREDATION**



Maine currently leases about 600 acres to all shellfish farms in the state

Oysters $5 to $10 million and growing
Mussels $1 to $2 million and growing

Scales of Interactions

The estuary

- Geomorphology - water depth, PAR, water residence times, fresh water input, nutrient sources, exposure to waves, physical oceanography

The bay

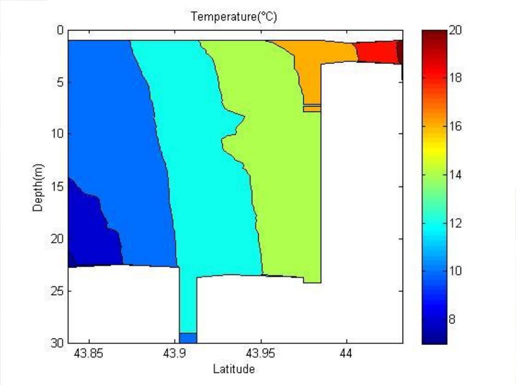
- Productivity – PAR and nutrients, seasonal and tidal effects, weather events, grazing, water flow patterns, resuspension

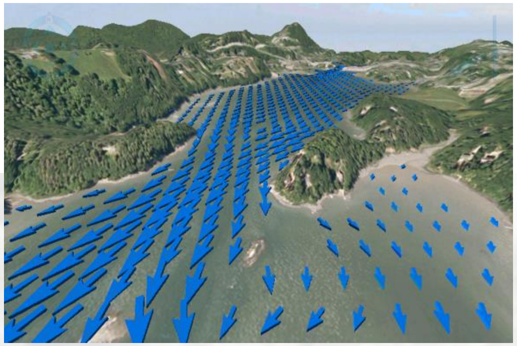
The farm

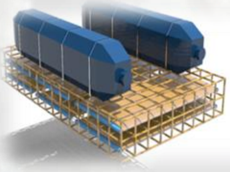
- Food supply and demand, oyster biomass, aquaculture structure (suspended, bottom), husbandry

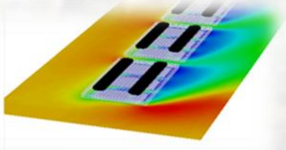
The oyster

- Local food availability as a function of stocking density, particle concentration and quality, hydrodynamics









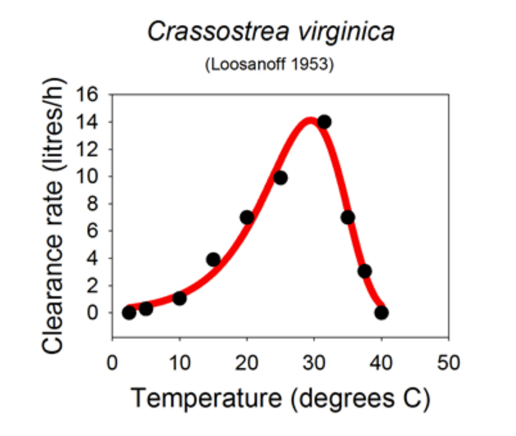
Environmental Growth Drivers and Ecosystem Interactions

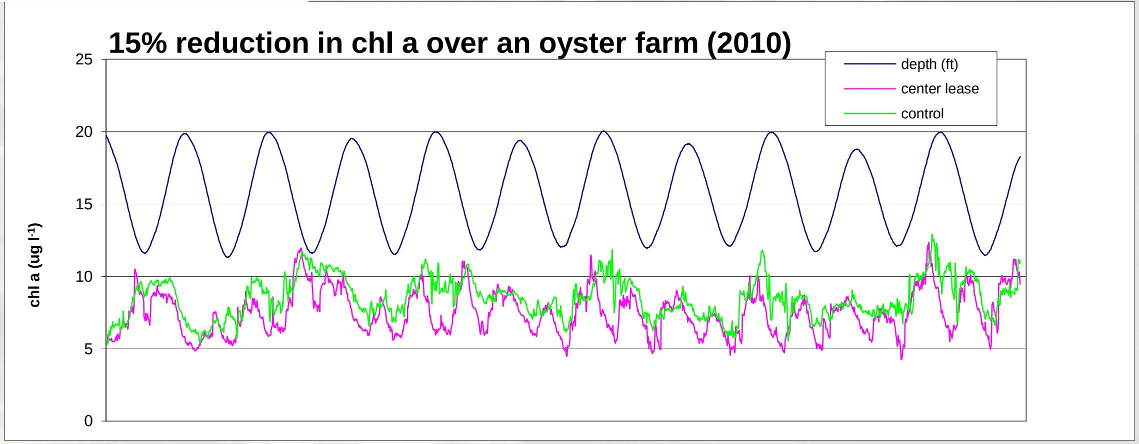
American oyster growth drivers

- **Water temperature**:⬆ filtration rate, food assimilation rate, rate of shell growth, reproduction (20-30° C)
- **Water salinity**:⬇ filtration rates (18-32 psu)
- **Particle size** (> 2 µm), **type** (**inorganic, organic**), **concentration**
- **Food quality**: **phytoplankton** (diatoms, dinoflagellates, ciliates, microflagellates); **detritus** (phytodetritus, macroalgal detritus) **detritus quality** (digestibility, N/C ratio)
- **Water velocity**: (⬆ for populations)

Ecosystem interactions

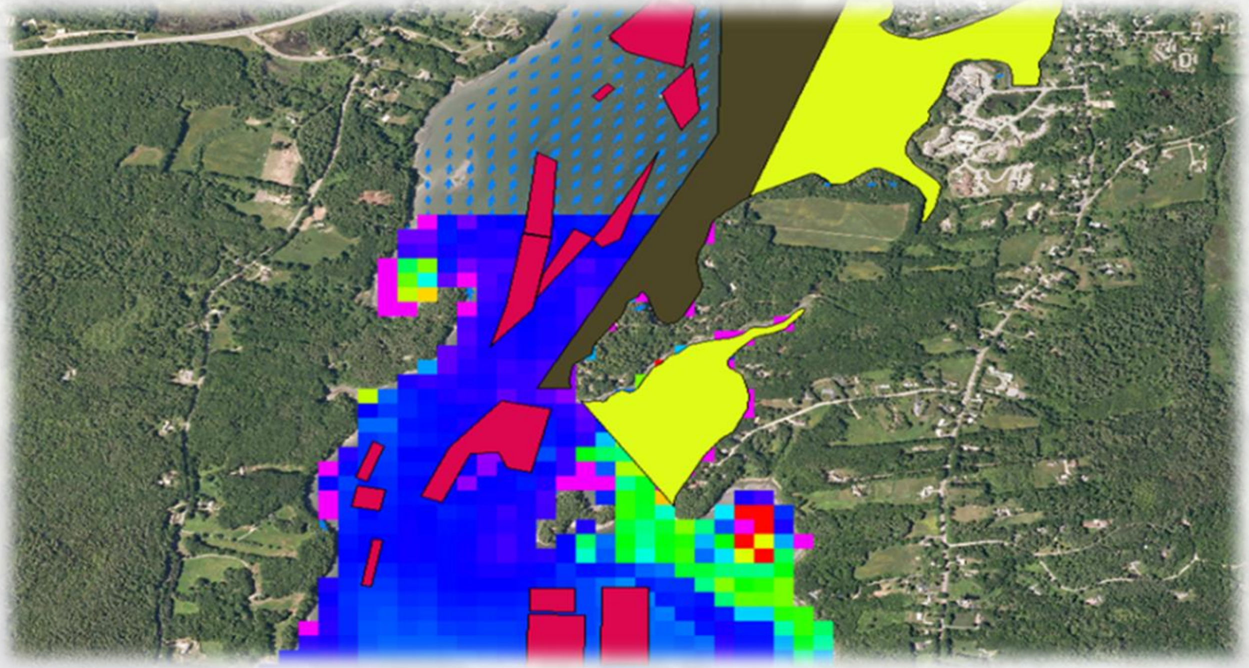
- ⬇ Phytoplankton biomass
- ⬆ Sedimentation of biodeposits
- ⬆ Light penetration
- ⬆ Nutrient regeneration and nutrient removal
- ⬆ Benthic and pelagic habitat for invertebrates, fish and birds
- ⬆ Benthic diatom populations
- Restoration of wild populations





With UDSA and MAIC funding we have developed an oyster GIS system

- **Site selection** for sustainable seafarms
- Improve **husbandry practices** and profitability (growth rate and yield)
- Understand **aquaculture/environment and human interactions**

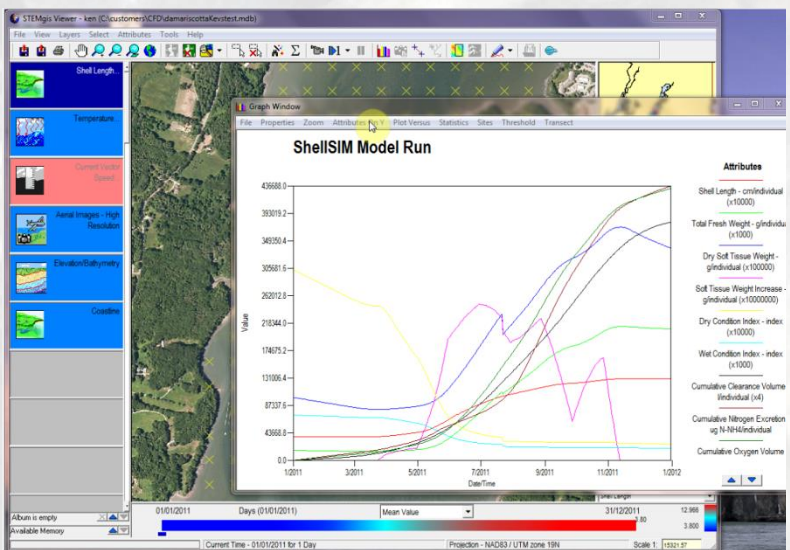


System architecture shellgis.com

Based on STEM-GIS platform developed by Discovery Software Ltd. UK
x, y, z, time dimensions

ShellGIS Workspace

- **Data layers (50 m grid)**
  - Flow model out put
  - Water quality data
  - Static layers
- **Models**
  - SHELLSIM growth model
  - Benthic boundary layer particle and nutrient exchange algorithms
  - Suspension culture particle and nutrient exchange algorithms
  - Hydraulic zone of influence
  - Economic models
  - Benthic biodeposition and nutrient regeneration (coming soon!)



ShellGIS
modelling & mapping shellfish growth

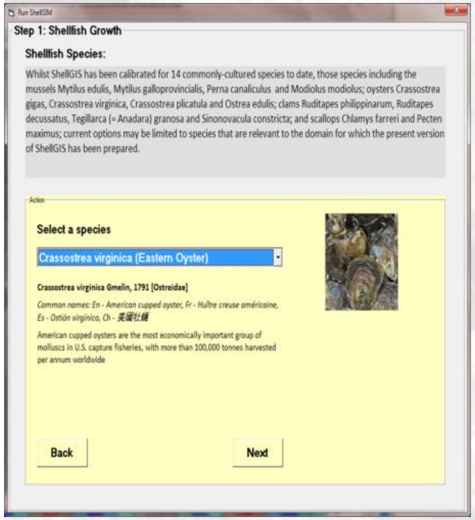
Factors affecting utility and functionality of GIS system

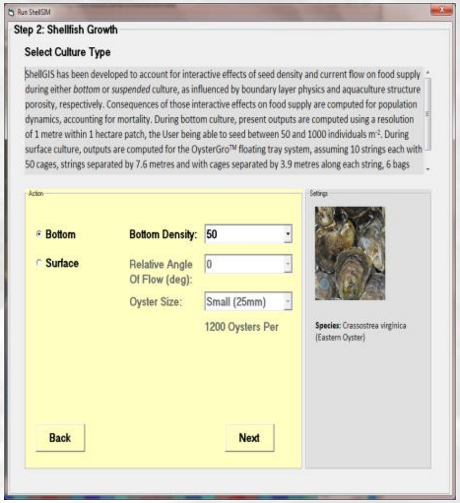
Data and models

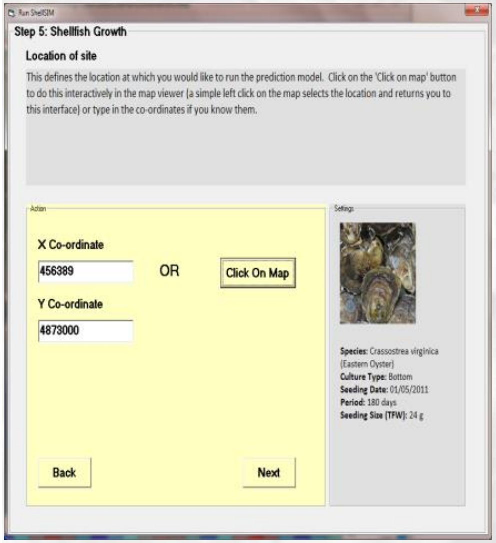
- Hydrodynamic flow model (Mike 21, FVCOM)
  Bathymetry, tide gauge and water velocity field measurements
- Shellfish growth model (ShellSIM)
  species calibration (ecophysiology) *in-situ*
- Water quality data: how it varies temporally and spatially within the bay and the farm

User interface

- For *growers*: what species, what type of culture, where, seed size, density, time of year: growth rates, yield, profit
- For *scientists*: how animals respond to changing environments, model functional responses such as clearance rates, oxygen consumption, ammonium excretion, biodeposition, growth, and reproduction
- For *regulators*: (coming soon) ecosystem services, benthic impacts and nutrient regeneration

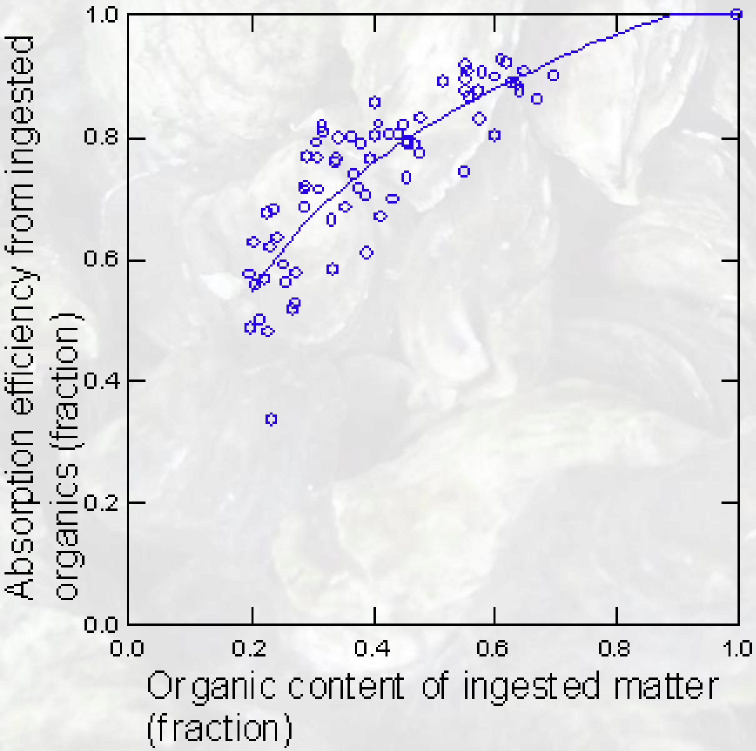




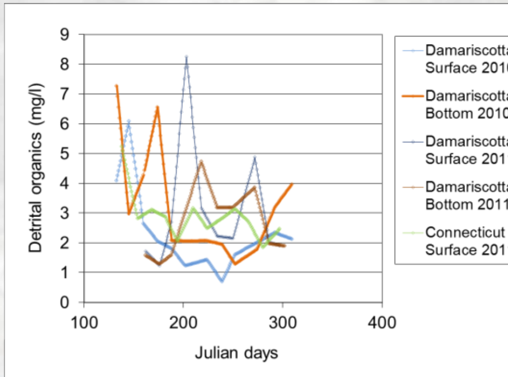


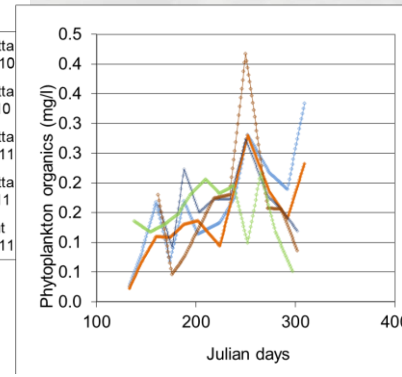
Measured and modeled oyster growth based on field measures of oyster responses to environmental conditions (food quality)

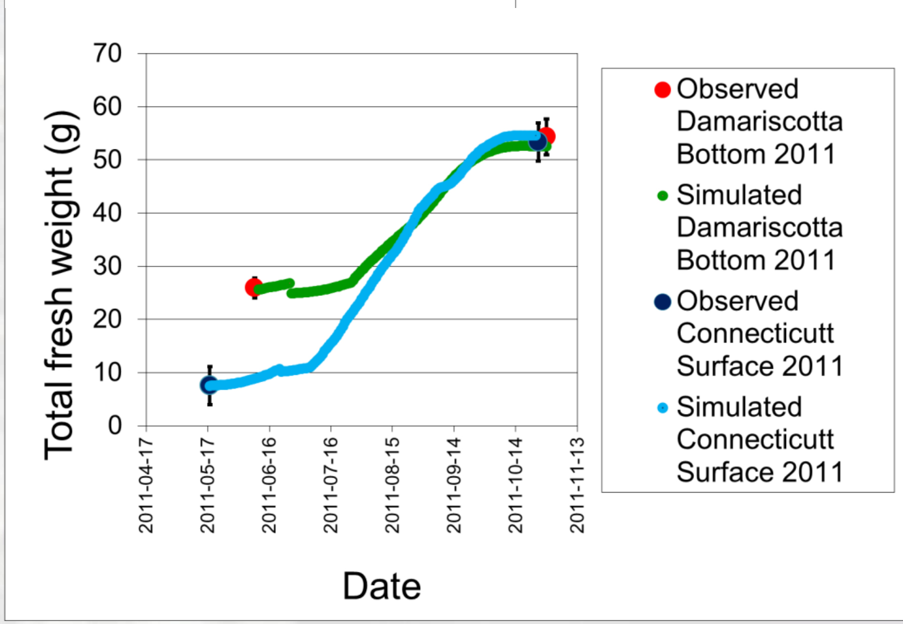
Absorption of food particles

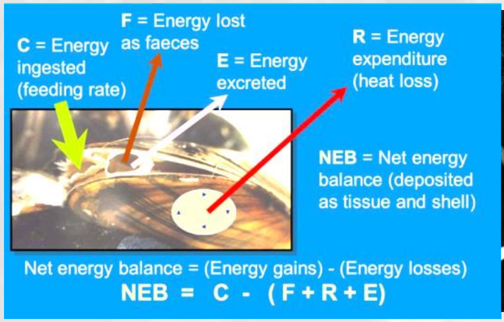


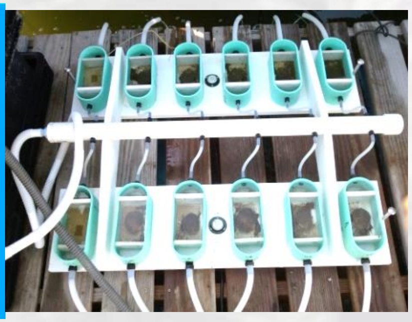
Food availability, measured and modeled growth using ShellSIM







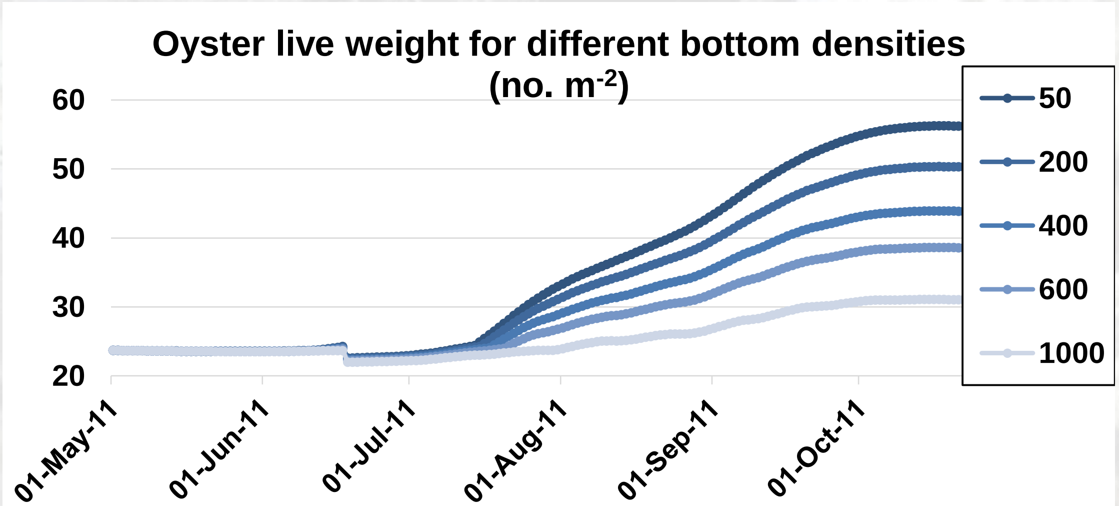




Model results: oysters grow faster in warmer water, in fast moving water, and each place has an optimal stocking density

At one location (click on map)

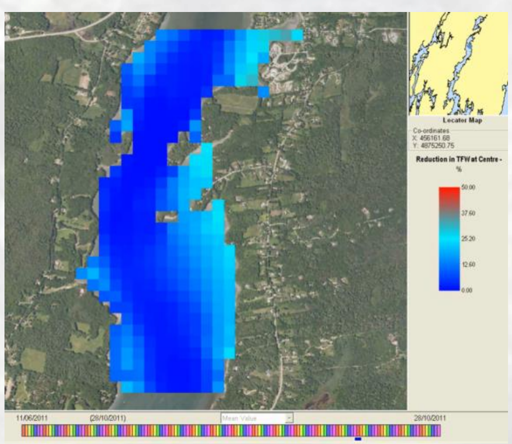
Effects of density (bottom culture)



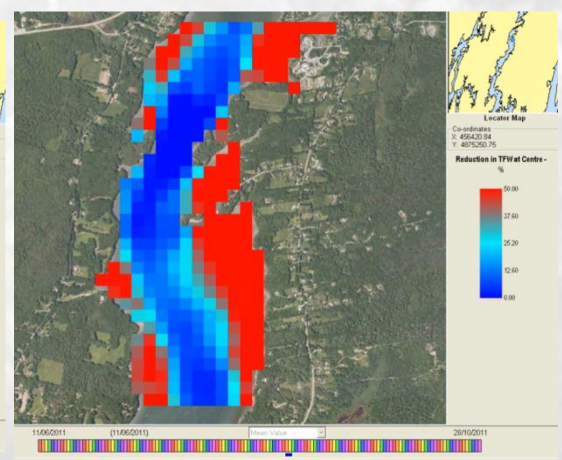
Effects of temperature (+/- 5ºC)

For whole bay (% reduction in growth) at 2 bottom densities

100 oysters m^{-2}

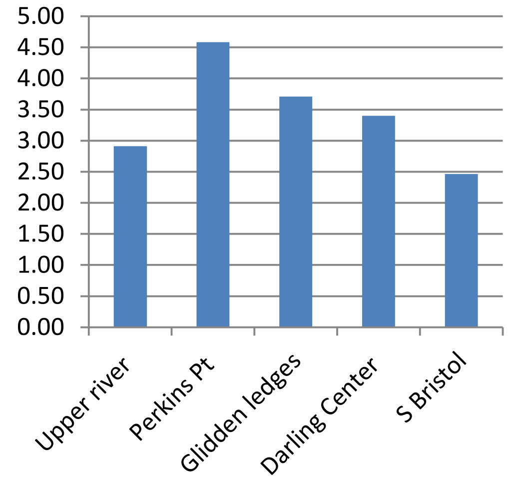


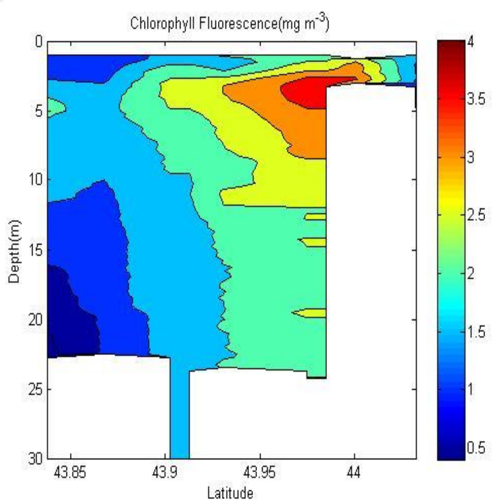
500 oysters m^{-2}



How can we improve our understanding of oyster/ecosystem interactions?
Better data on growth drivers : CTD transects and water samples

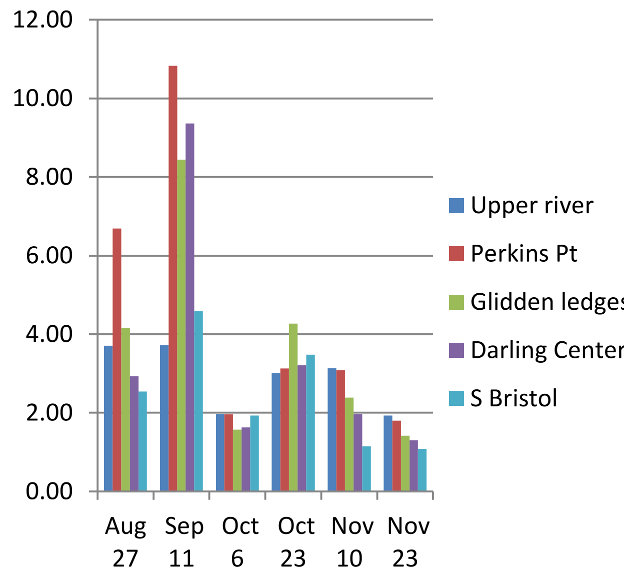
Mean chl a all profiles Aug - Nov, 2015



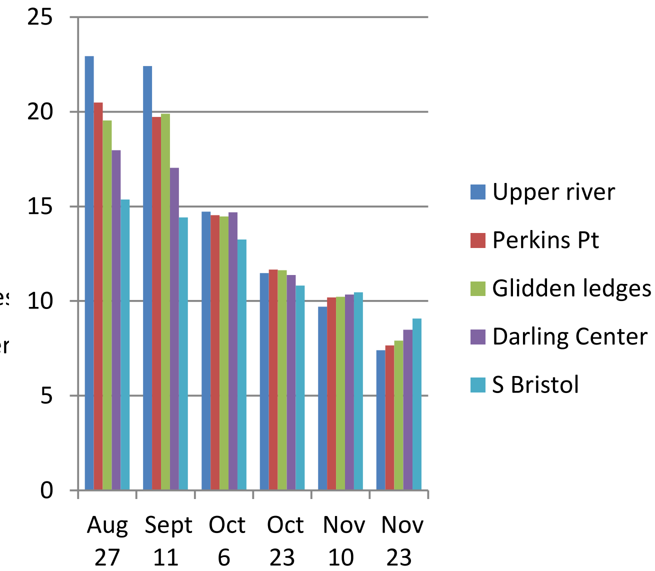


Student transects

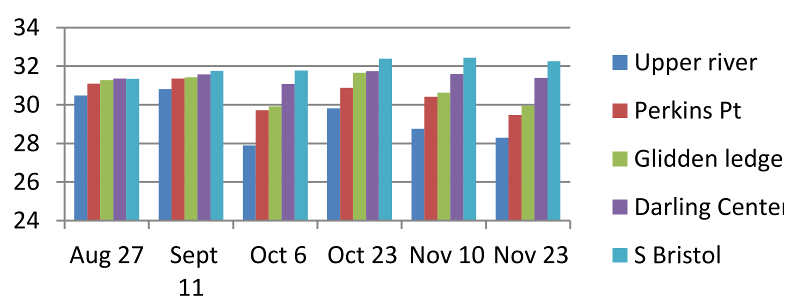
Mean Chl a from CTD casts Damariscotta River August - November, 2015



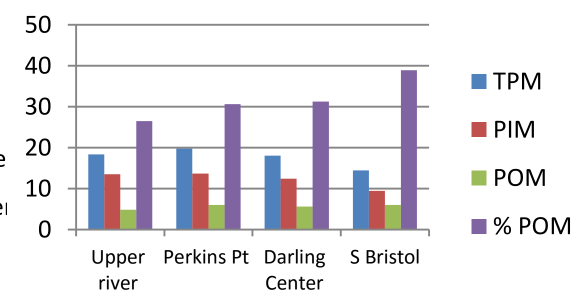
Mean temperature CTD profiles Damariscotta River Aug - Nov 2015



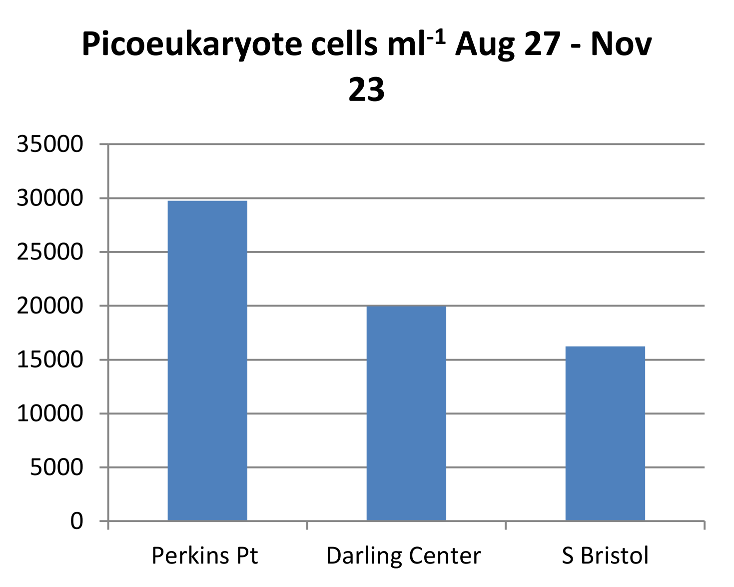
Salinity Aug - Nov 2015 Damariscotta

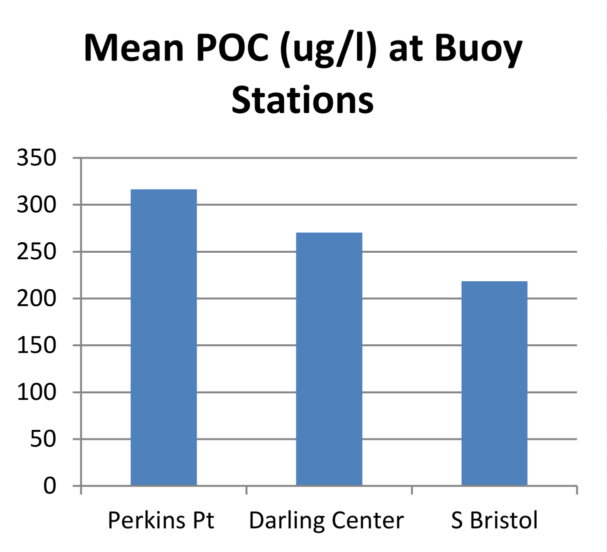


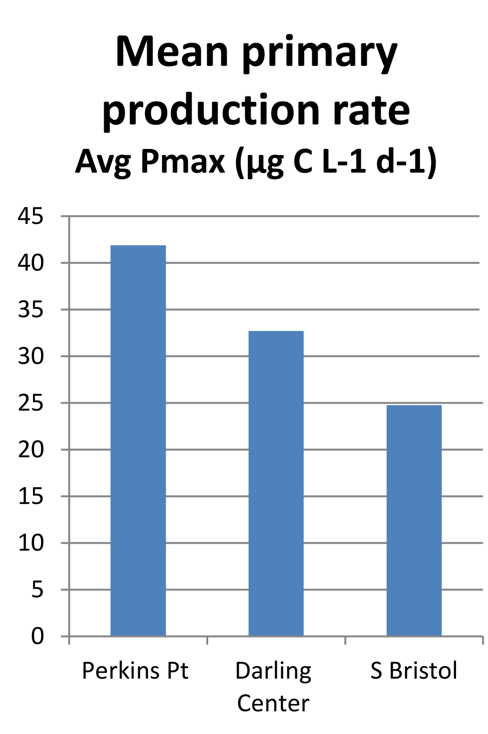
Suspended particulate matter mg l-1

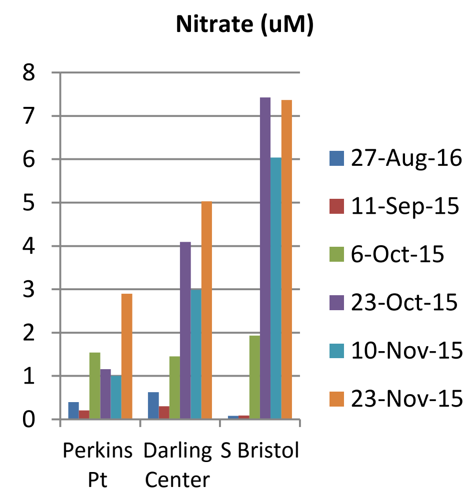


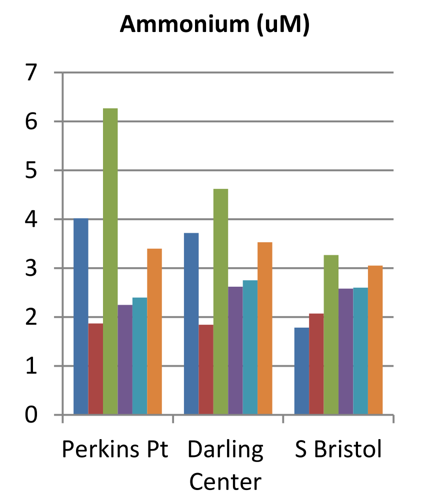
How can we improve our understanding of oyster/ecosystem interactions? Water samples

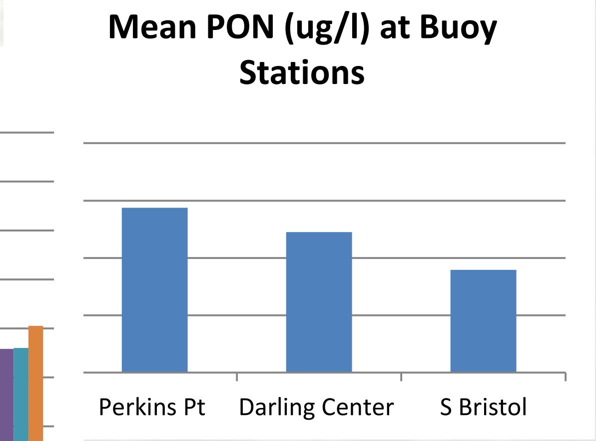








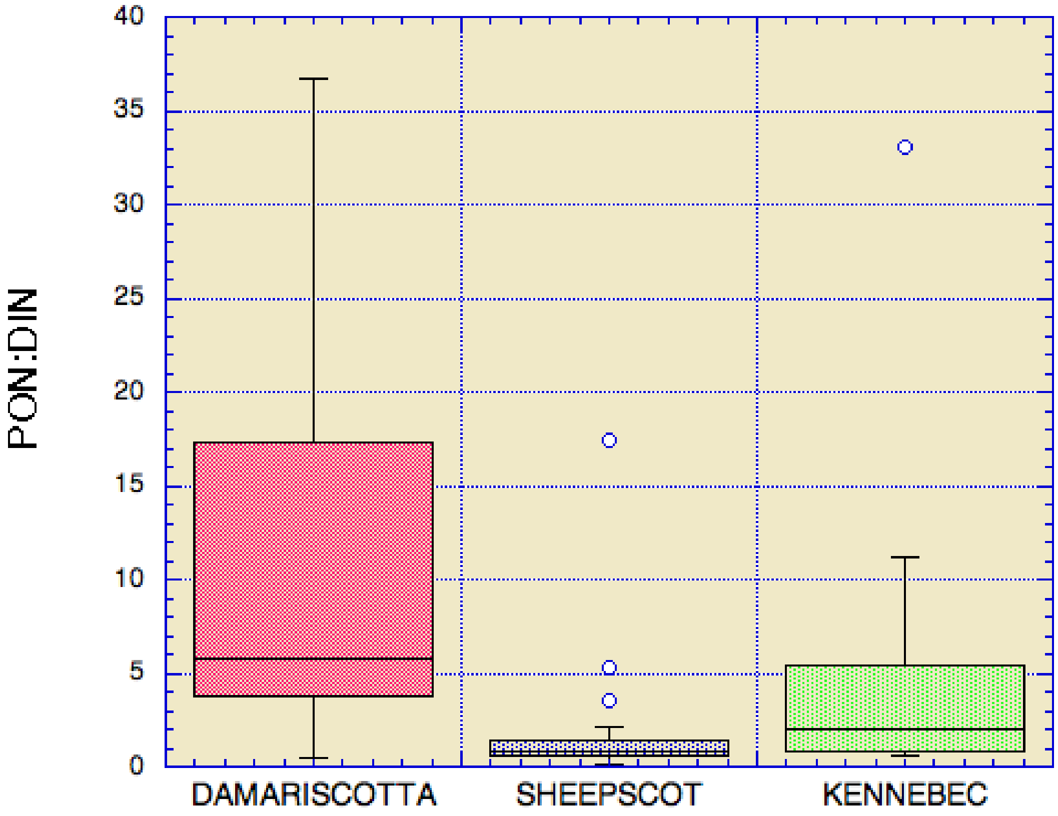




How does this compare with other places?

Three estuaries cruises in 1993-1994

The Damariscotta River is much more efficient at converting nutrients to phytoplankton than the Sheepscot and Kennebec (plot from Dr. Larry Mayer)



(DIN+PON) FOR EACH SYSTEM IS ABOUT 10-15μM

How can we improve our understanding of oyster/ecosystem interactions? Vertical zooplankton tows (they also feed on phytoplankton)

Copepod – *Eurytemora herdmani*

Mysid shrimp – *Neomysis americana*

Polychaete larvae

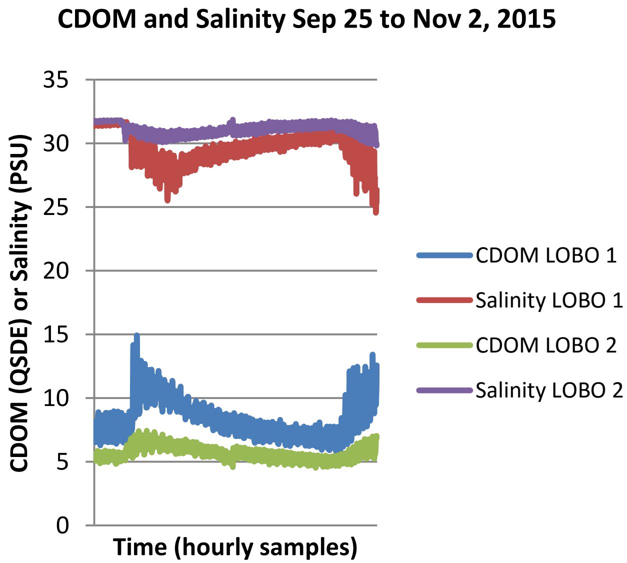
Copepod – *Acartia hudsonica*

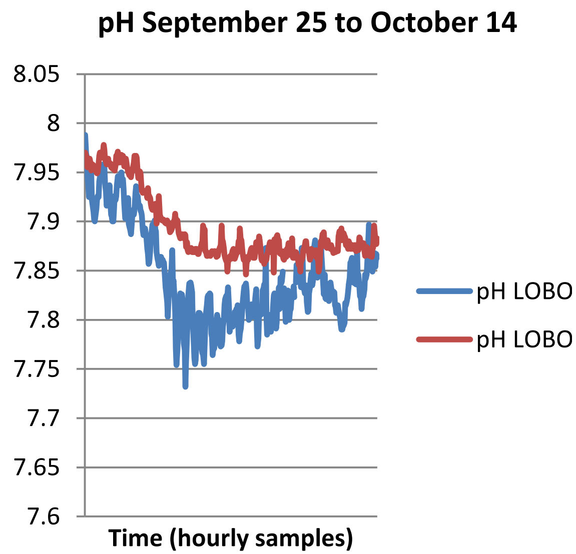
Barnacle and bivalve larvae

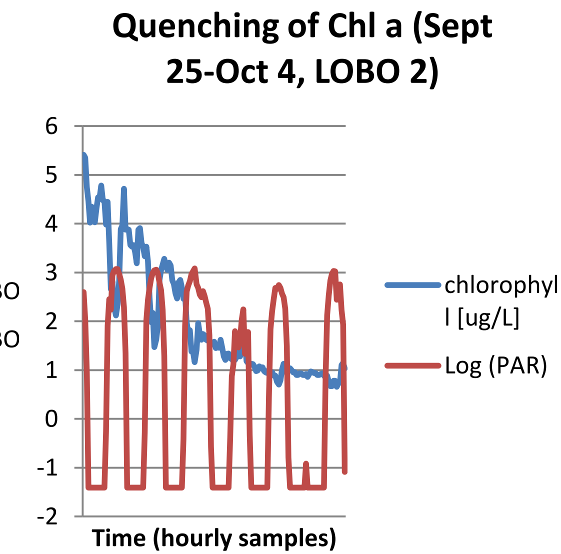
Cladoceran – *Evadne nordmanni*

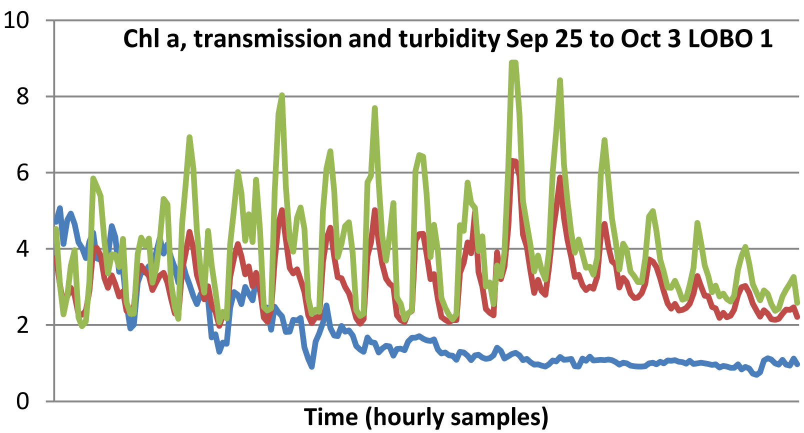
Copepod nauplii

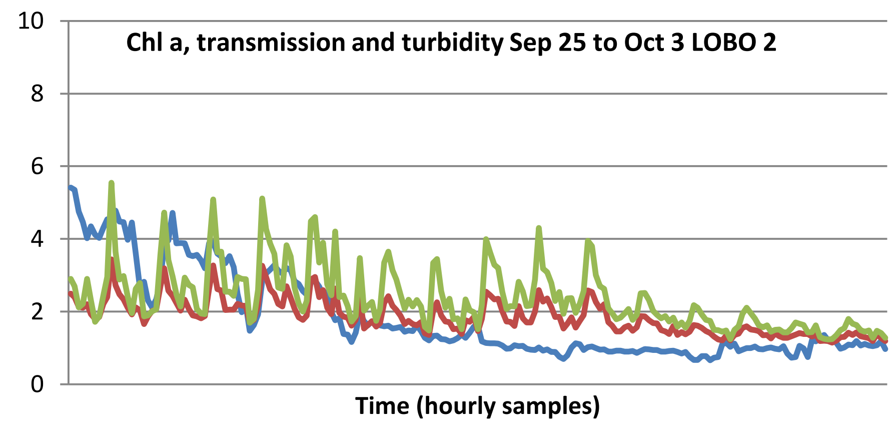
How can we improve our understanding of oyster/ecosystem interactions? LOBO buoys



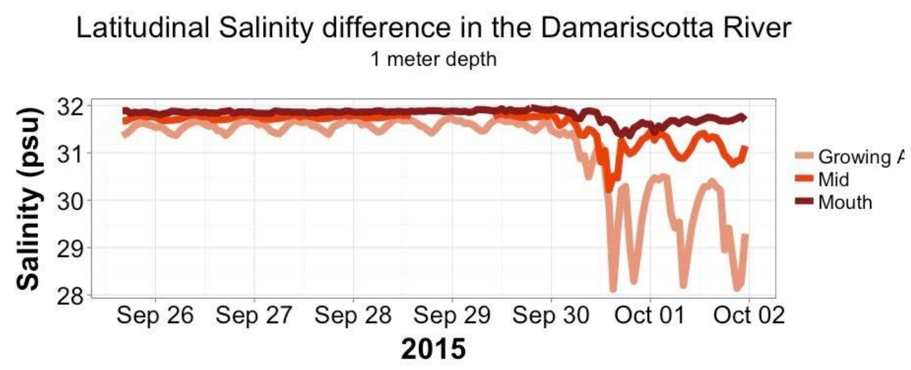


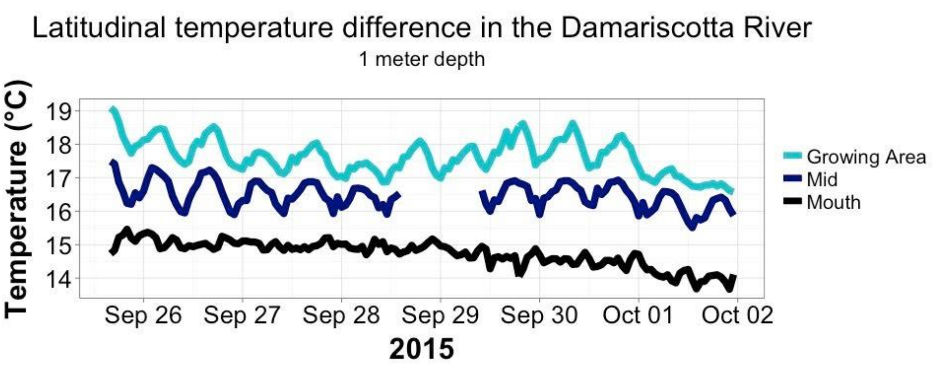


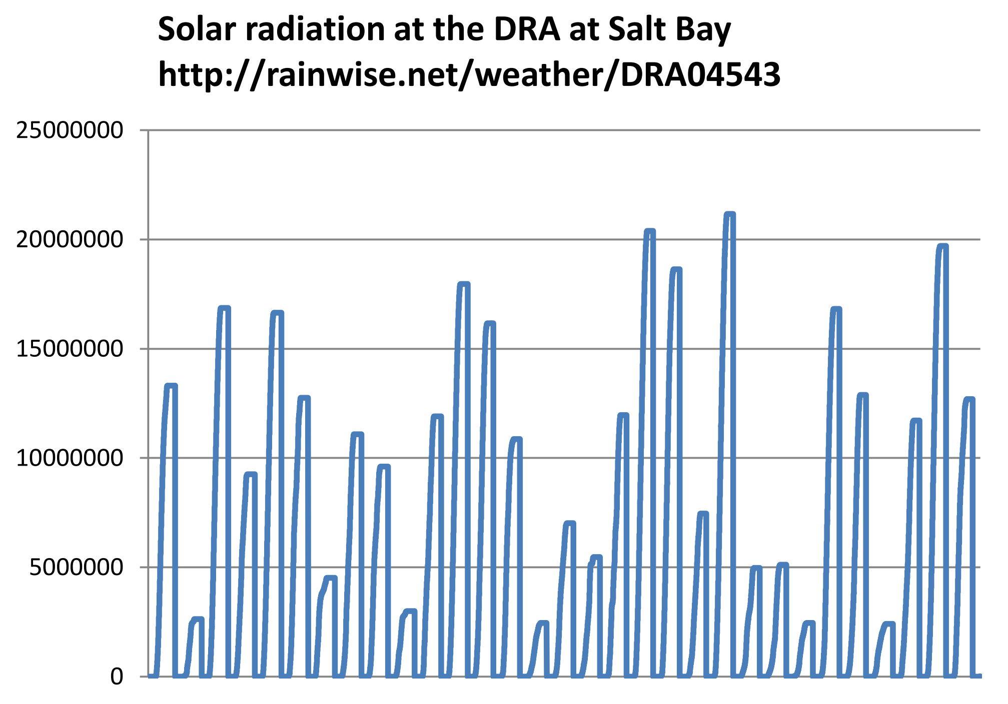


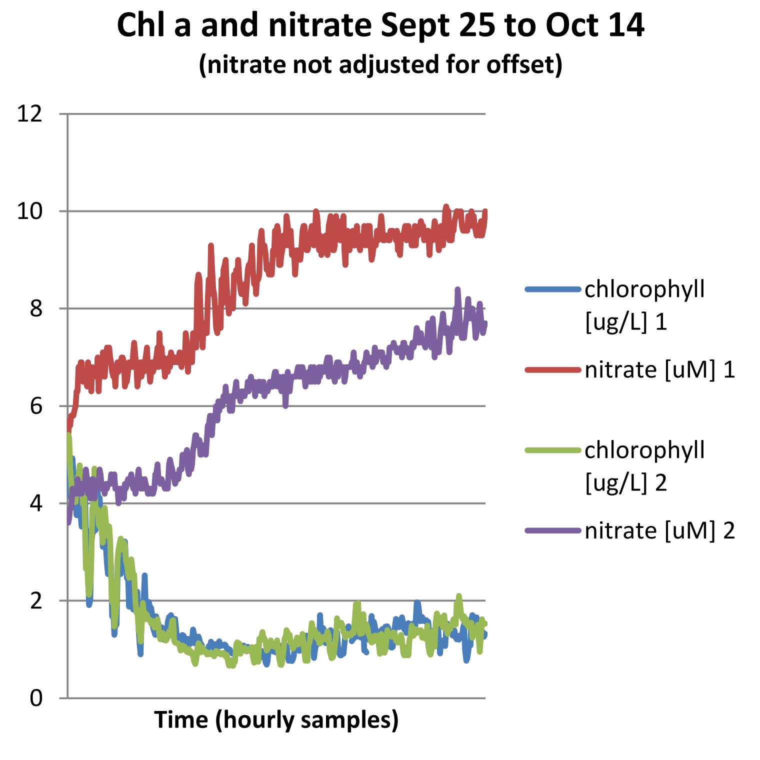


How can we improve our understanding of oyster/ecosystem interactions? Buoys and weather stations



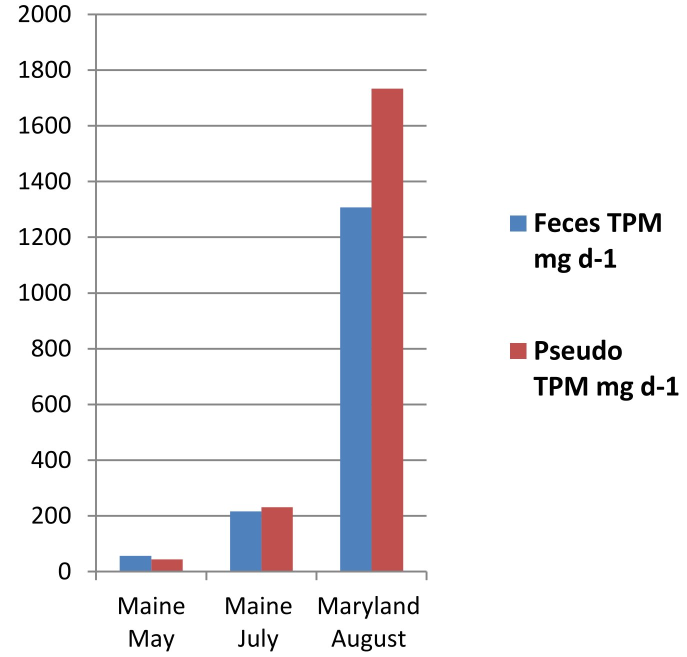


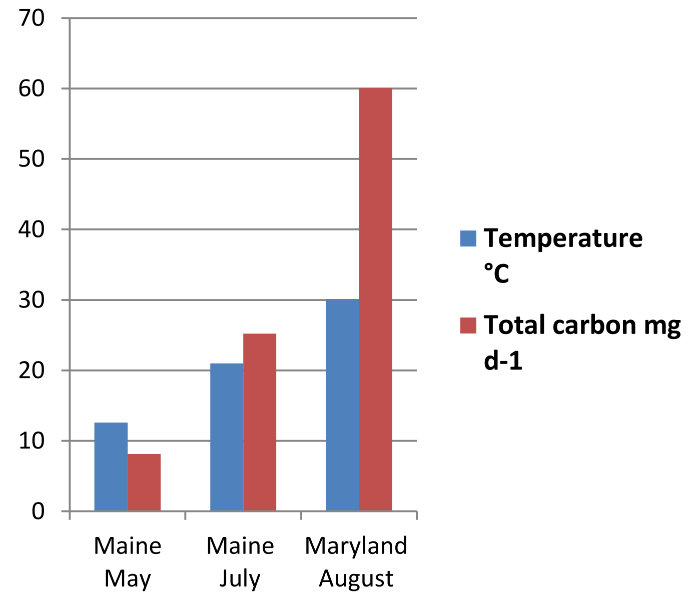




Model and field data: benthic biodeposition

In July in Maine, a million mature oysters removes 400 kg TPM per day and repackages it into biodeposits



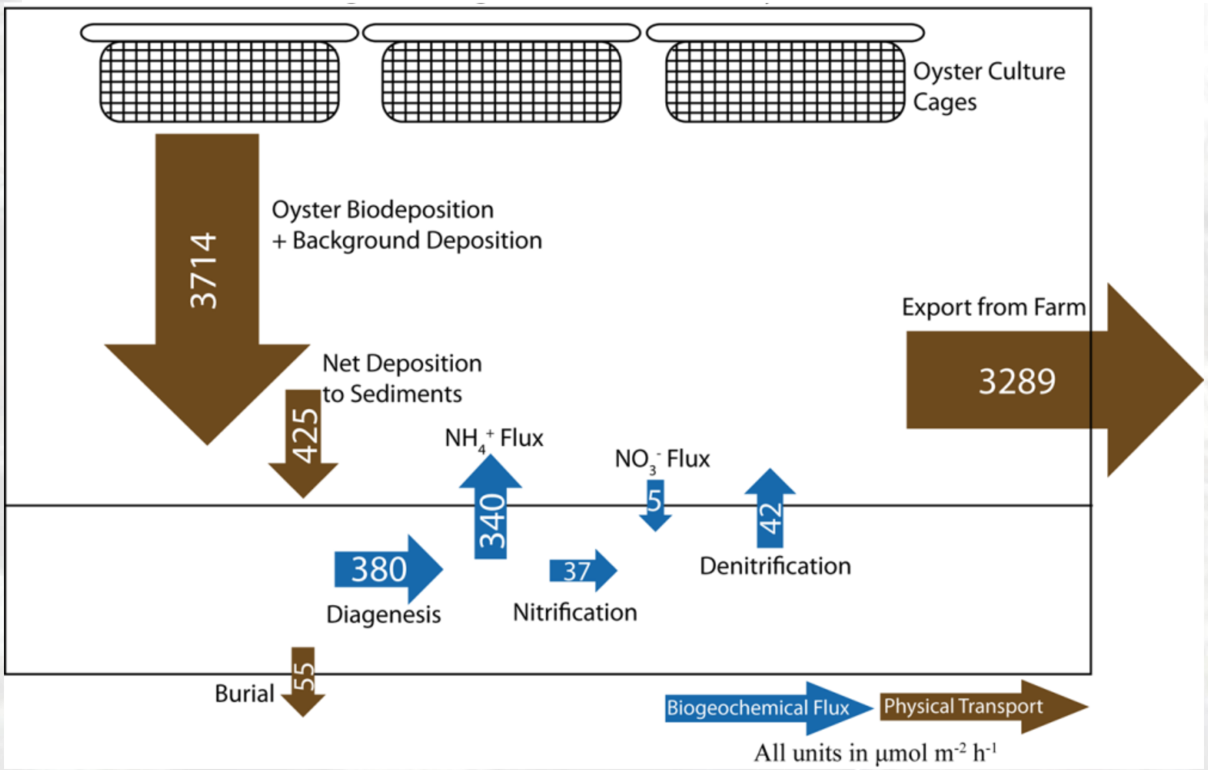


Maryland conditions in August

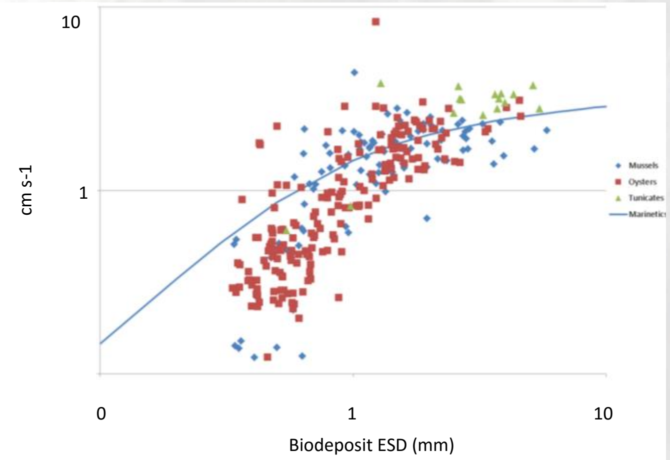
Chl a	SPM	POM	PIM	Temp	Sal	DO
ug l-1	mg l-1	mg l-1	mg l-1	C	ppt	mg l-1
31.39	37.38	5.91	31.37	30.12	9.30	7.12

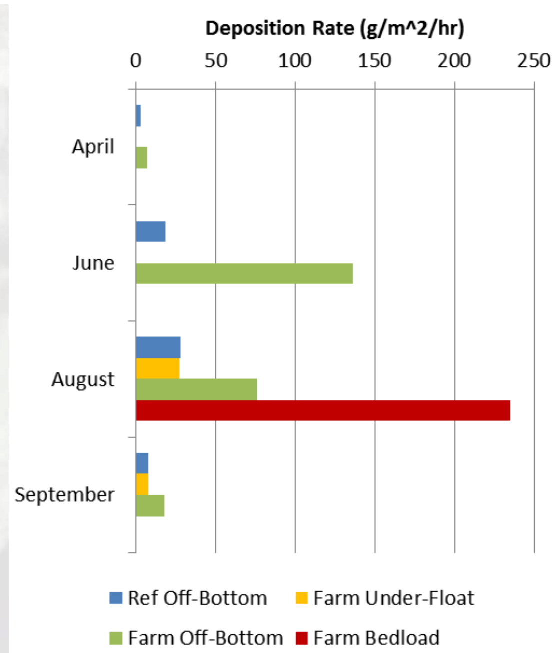
Biodeposition continued:What happens to it?*

In both Maine and Maryland, shellfish biodeposition is about 2x background deposition but at these sites with tidal flow > 35 cm s^{-1} most is moved off site and converted into ammonium within a couple of days (recycling)



Oyster, mussel and tunicate biodeposits settle at .2-2 cm s^{-1}





- Maryland farm **biodeposition settles quickly to bottom and mostly moved as bedload due to resuspension from tidal currents and waves**
- **Most of the nitrogen is converted back to ammonium** for the phytoplankton to use within days, affecting the Bay Scale nutrient budget for phytoplankton

*Testa, J.M, D.C. Brady, J.C. Cornwell, M.S. Owens, L.P. Sanford, M.S. Owens, L.P. Sanford, C.R. Newell, S.E. Suttles and R.I.E. Newell. 2015. Modeling the impact of floating oyster aquaculture on sediment-water nutrient and oxygen fluxes. Aquaculture Environment Interactions 7:205-222.

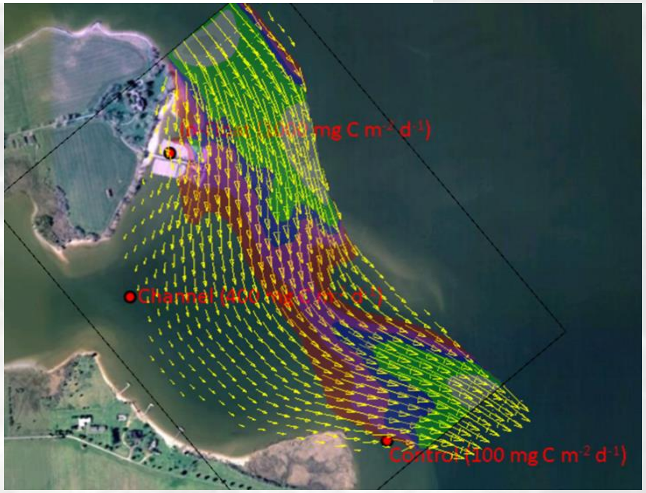
Biodeposition continued: the importance of erosion

Every site is different but in general, **higher water velocity** allows for **greater farm productivity** as well as better **nutrient recycling efficiency** and **minimal benthic impact**

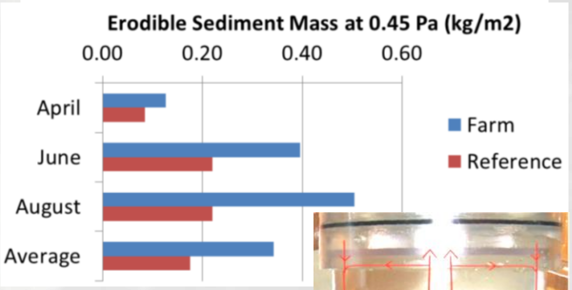
Maryland site: high loadings, shallow water but **tidal resuspension** and periodic **wave resuspension**

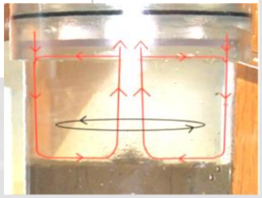
Green – Area where current induced erosion rate exceeds deposition rate

Yellow – Area with wave induced resuspension using SWAN wave model and water depth



The farm sediments are easily eroded





What have we learned?

- **Estuarine geomorphology** results in longer **residence times** in the upper estuary, where it is shallow and sufficient **light and nutrients for phytoplankton** to grow, increasing **primary productivity.** Fort Island Narrows and Glidden Ledges contribute significantly to the productivity in the Damariscotta River.
- The upper estuary also has **higher suspended particulate matter and detritus concentrations**
- **Water temperature is higher** in the upper estuary, allowing for higher filtration rates and rapid growth of oysters
- **Rainfall events** result in **lower salinity, higher CDOM, higher nutrients and lower pH** in the upper estuary.
- There are significant **seasonal and tidal variations** in all parameters
- **Nitrate** concentrations are lower in the upper estuary but **ammonium** concentrations remain high throughout the season
- **Oyster biodeposition** increases with water temperature, phytoplankton concentrations and suspended particulate matter but **hydrodynamic factors control its dispersion**
- Oyster farms act to **concentrate, remove and recycle nutrients** in the estuary and have beneficial ecosystem interactions
- The farms act as **biological reefs**, attracting seaweed, invertebrates, fish and birds
- A **Shellfish GIS system** may be used to quantify aquaculture/environment interactions and improve husbandry practices

Why is it worth it?

- Recognize and quantify the value of **estuaries as food growing areas**
- Understand **what makes estuaries productive** and how they change under different environments (i.e. increased temperatures and precipitation, pH)
- Quantify **ecosystem services of bivalves**
- Choose and manage sites based on their **suitability and sustainability**
- **Evolve from trial and error aquaculture** to sustainable economic development
- Improve engineering of aquaculture structures and placement in estuaries

They taste good!

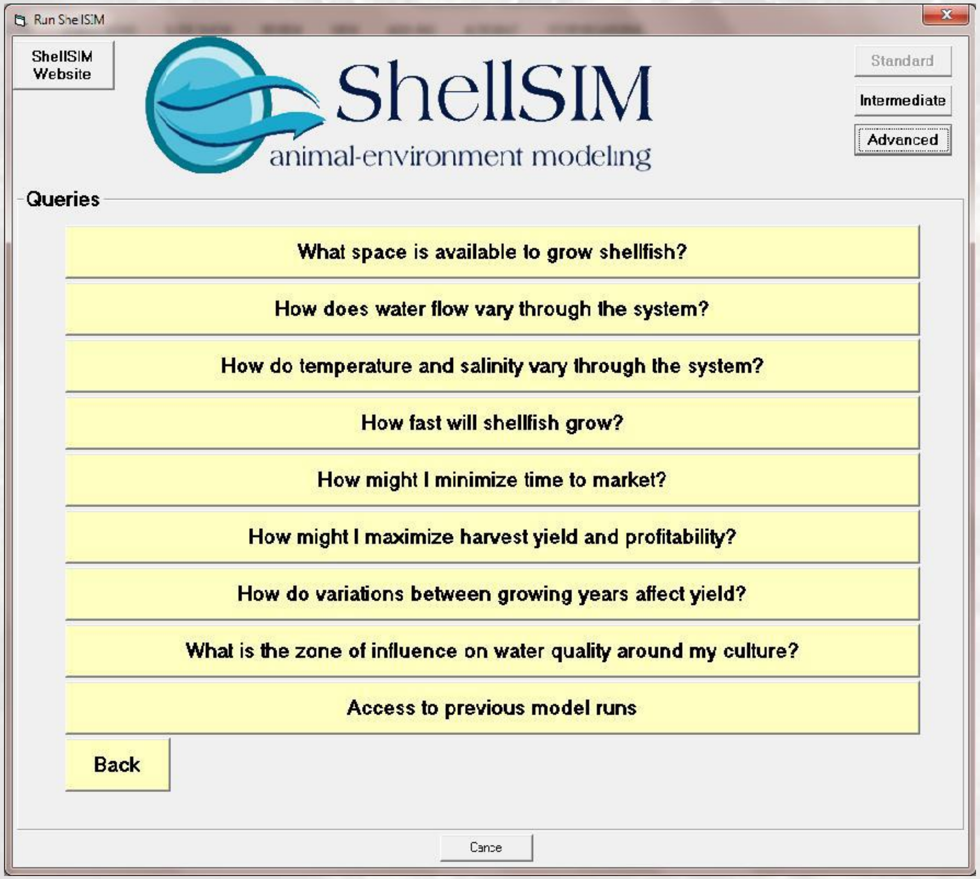
What else can we do?

Reduce cost of modeling and data collection , make it widely available for stakeholders (web based), and user friendly

Develop simple models of estuarine productivity

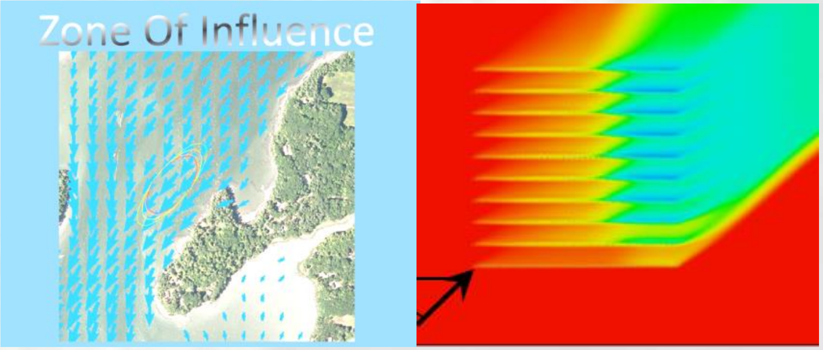
Advocate for and protect clean water

Frequently asked questions



Coastal Observation Buoy (COB)
Prescott, Newell, Davis 2016 $2500

Temp, sal, PAR, chl a shellfish growth basket, wifi



Water column effects of a small farm

Human interactions: Pemaquid Oyster Festival
Last Sunday in September – see you there!

- Shuck 15,000 oysters
- Raise $15,000 for Ed Myers marine conservation fund
- Over $100,000 to date
- Boat tours of oyster farms
- Shucking contest
- Live music all day
- Tent of education/information including land trusts, conservation groups, regulators, research, touch tank, children's activities

Acknowledgements

1865 The University of Maine

Maine Aquaculture Innovation Center

Pemaquid Oyster Company
Farming the Damariscotta River since 1986

Plymouth Marine Laboratory

University of Maryland 1856

Discovery Software

Pacific Shellfish Institute

Bigelow | Laboratory for Ocean Sciences

1865 The University of Maine Aquaculture Research Institute

Sea Grant

Maine EPSCoR

mti Maine Technology Institute

USDA

ShellGIS modelling & mapping shellfish growth
www.shellgis.com

Pemaquid Mussel Farms

Northeastern Regional Aquaculture Center

Damariscotta River Association · Since 1973 ·

Blue Hill Hydraulics Incorporated
1.207.374.3294 info@BlueHillHydraulics.com