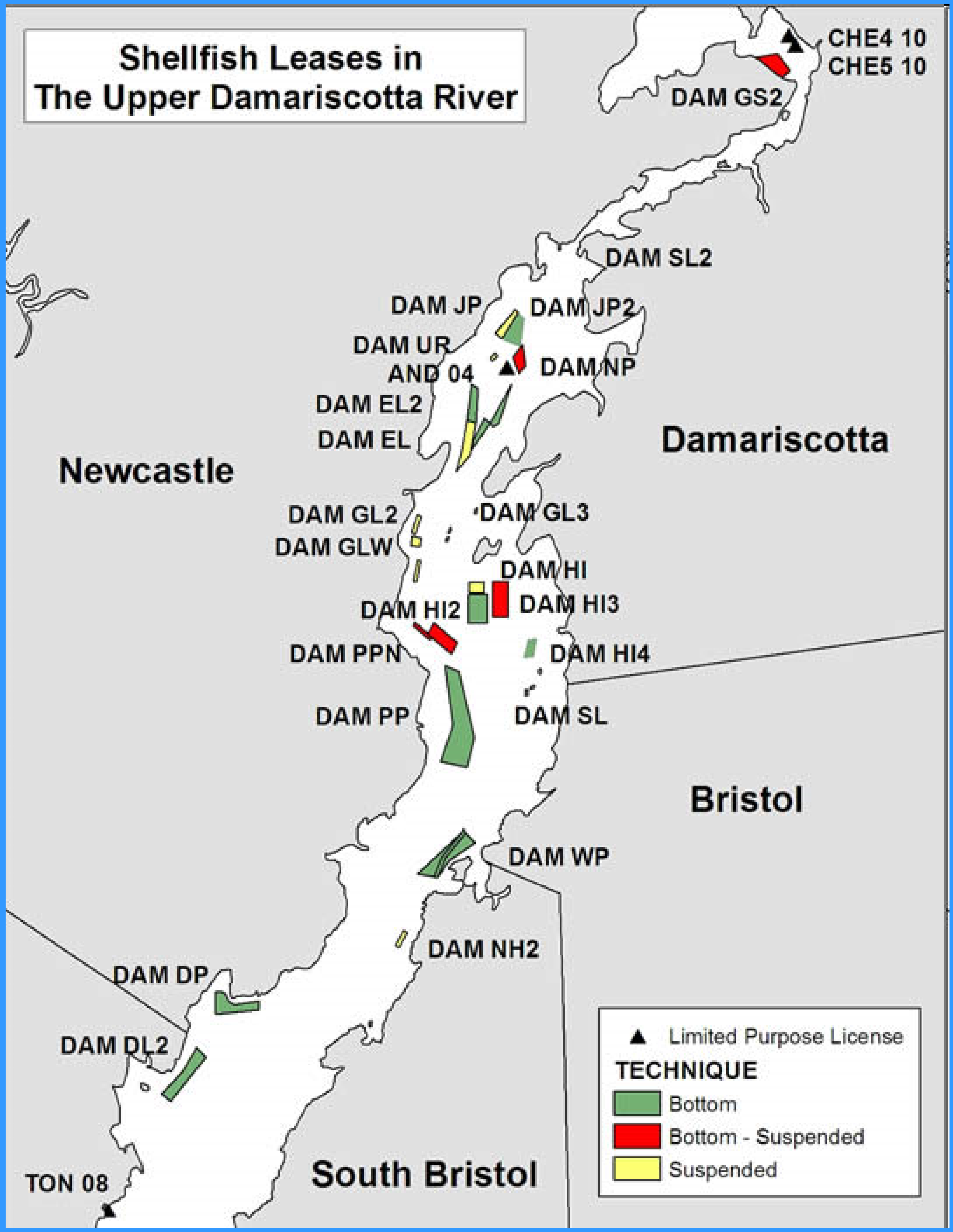
Total 118 acres

Annual sales about 2-4 million oysters

Value about $2 million

Native American Oysters

Crassotrea virginica

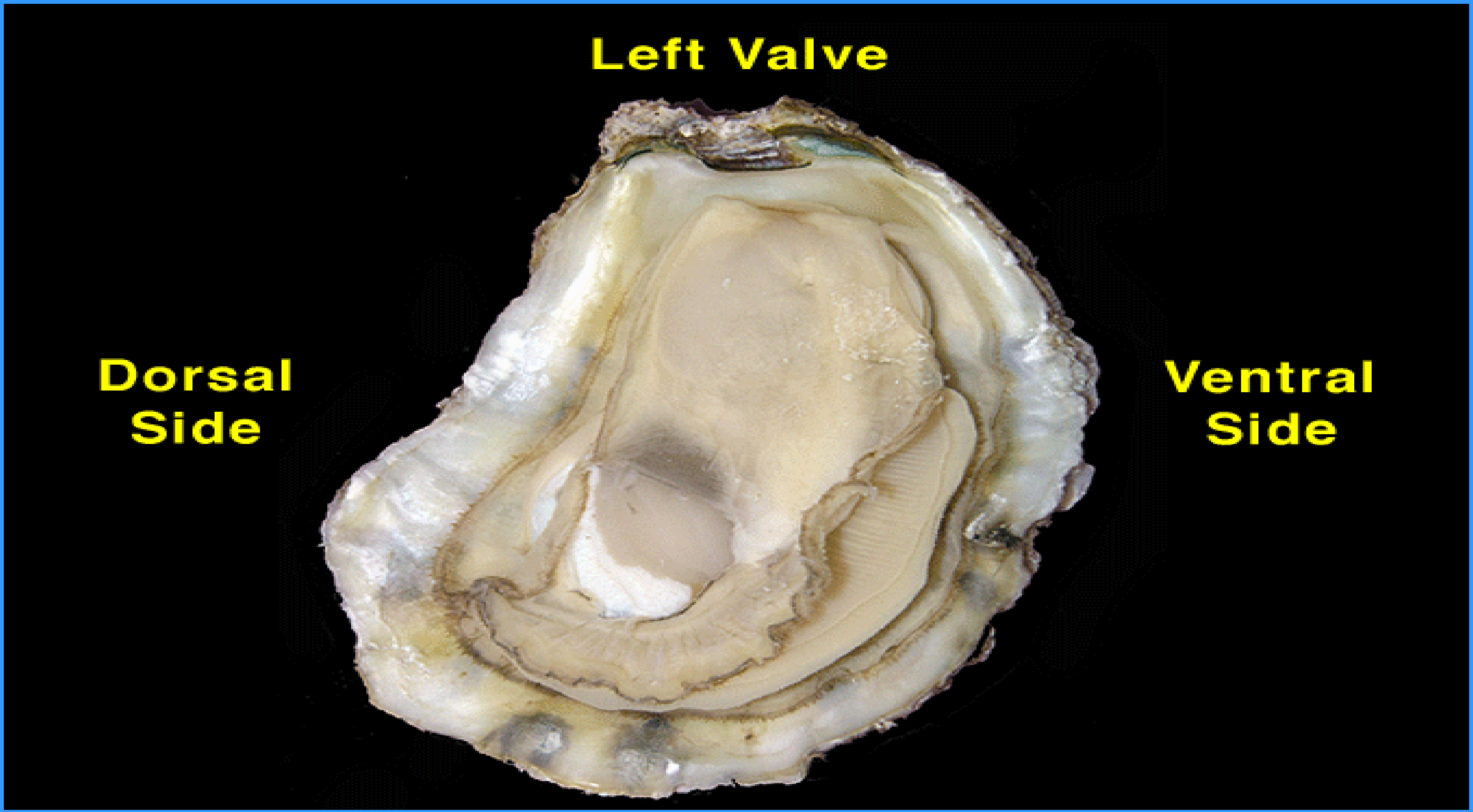


Upper river sites get above 20 C in the summer

Promotes rapid shell growth

Maine is northern range of this species which spreads to the Gulf of Mexico

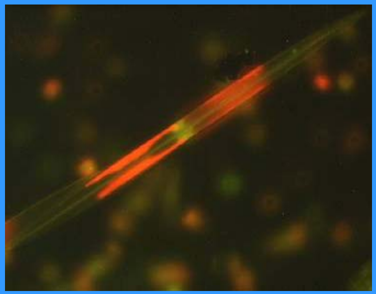
American oyster bivalve filter feeder, filters particles above about 2 µm at about 3 liters per hour per gram dry weight, filters out live phytoplankton and detritus

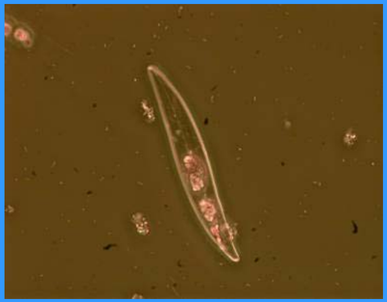


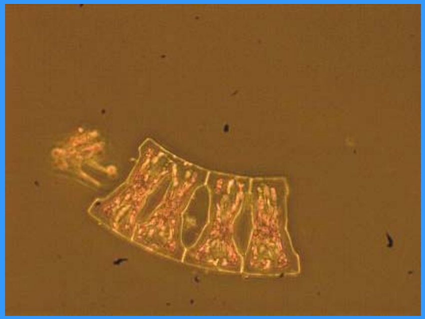
Oysters from a hatchery are grown from 1-10 mm in upwellers, transferred to floating trays, and seeded onto the bottom for growth to market size

Factors Affecting Shellfish Growth

- **Food concentration** and quality (phytoplankton, detritus, dissolved organic matter, particulate inorganic matter)
- **Shellfish density and biomass**
- **Hydrodynamics** of the culture system (tidal and wind-driven current speed and direction, waves)
- **Water temperature**







Production and ecological carrying capacity

- How many oysters can be grown on a lease site? We currently seed about 10 per square foot, or about 400,000 per acre. We limit the suspended oyster bags to 4,000 small or 1,000 larger seed oysters.
- Takes a 1-2 years to grow to market size (3 inches).
- How many oysters could be grown in the river before it has an impact on the phytoplankton, affecting other species such as clams or nearby farms?
- Is the river reaching is production potential?
- What controls the productivity of the oyster farms, year to year and in comparison with other potential sites in Maine?

Particle Flux and Consumption in Intertidal and Subtidal Shellfish Culture

Carter Newell and John Richardson
Blue Hill Hydraulics Incorporated

2008 paper presented at NSA in R.I.

Team: marine biologist and hydraulics engineer

Why?

Because the physics force the biology!

Filter feeder food availability is a function of food supply (flow) and demand (filter feeder biomass), as well as the type of culture system in any environment.

All results are site specific, due to the physical oceanography, as well as growth requirements of the species (temperature, salinity, food)

Primary Objectives of Studies

Oyster Bags on Double Row Trestles (Dungarvan Harbour, Ireland)

- determine food availability (what do they eat, how does it get there?)
- improve site layout (optimal placement of biomass to get the best bang for the buck)
- evaluate environmental impacts (water column effects)
- MOM approach: Modelling, On-growing shellfish farms, Monitoring (field data)

Development Timeline: develop the basic relationships in Maine, apply them elsewhere C. Newell and J. Richardson

NMAI Thorndyke Bay Study Site
(Hood Canal, Washington State)

Basic Research and Development (1990 – 2005)

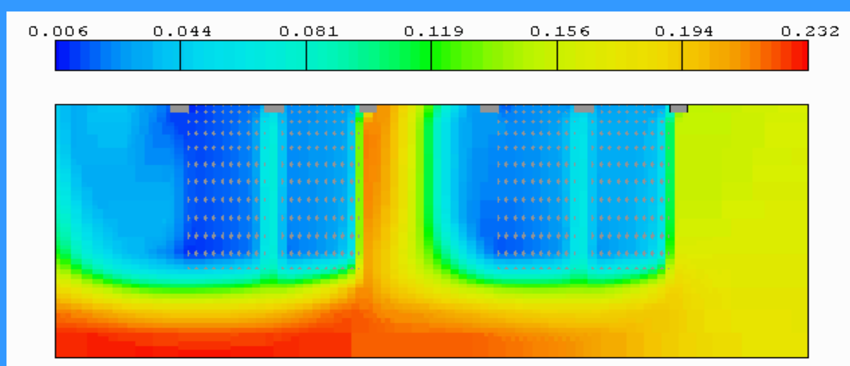
- **NSF SBIR: MUSMOD (Maine, Mussel Bottom Culture)**
- **USDA SBIR (Maine, Mussel Rafts, expert system)**
- **PSI (Totten Inlet, Puget Sound, Mussel Rafts)**
- **BC Fisheries, BCSGA (British Columbia, Oyster Rafts)**
- **USDA SARE (Maine, Oyster bottom culture)**
- **C-MAR (Carlingford Lough, N.I.,Mussel Bottom Culture)**

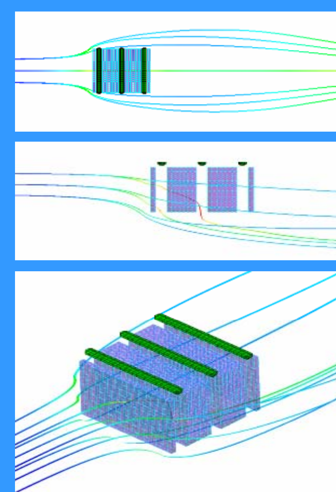
Current Studies (2005 – Present)

- **NMAI 1 (Intertidal - analysis of alternative shellfish culture systems Manila clams, prelim. geoducks)**
- **NMAI 2 (Intertidal – include geoducks, sediment transport)**
- **MAIC Aquaculture GIS (STEM-GIS, Stonington and Damariscotta, Maine)**
- **UISCE (Understanding Irish Shellfish Culture Environments). Site optimization of intertidal and subtidal aquaculture, (intertidal trestle Crassostrea gigas, subtidal bottom and longline Mytilus edulis).**
- **NRAC Oyster GIS**

Basic Analysis Procedure

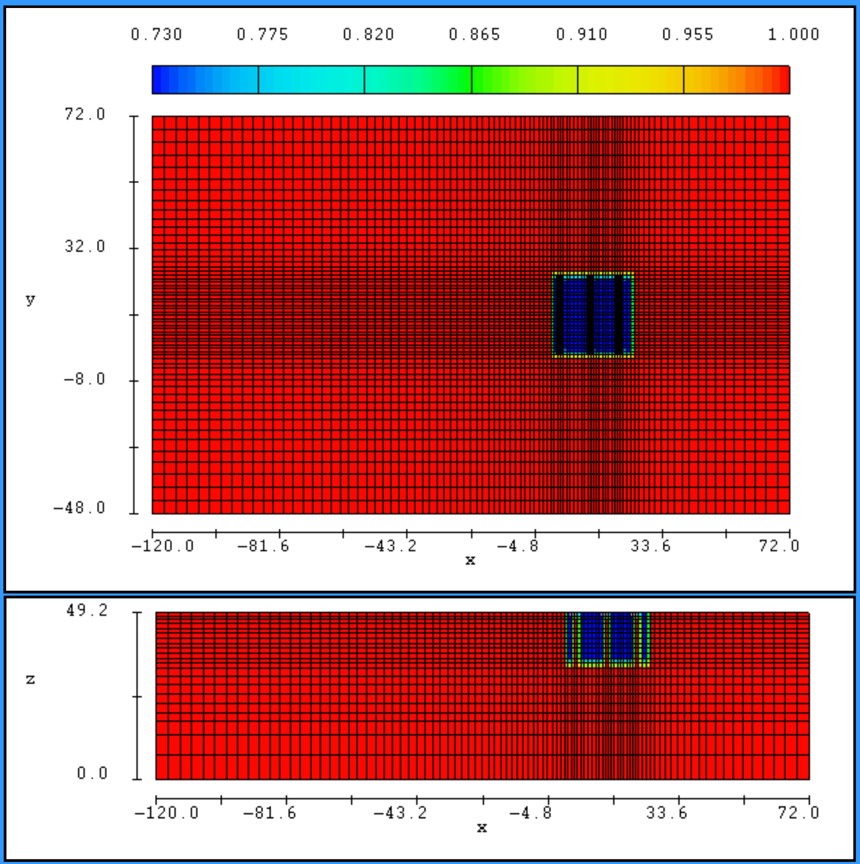
- Simulate 3-D Flow through Gear, Calibrate Model With Field Data
- Implement Field Sampling Program (based on model results)
- Calculate Particle Flux/Consumption
- Complete What-if (?) Scenarios





Calculated Streamlines of Flow through Aquaculture Raft (colored by speed, plan-view / side-view / oblique-view)

Model Development: mussel rafts



Computational Mesh
(colored by volume-fraction)

Model Setup

1. **Obtain design drawings**
2. **Construct – structured, rectangular mesh (190,000 cells)**
3. **Add geometry**
4. **Specify boundary conditions**

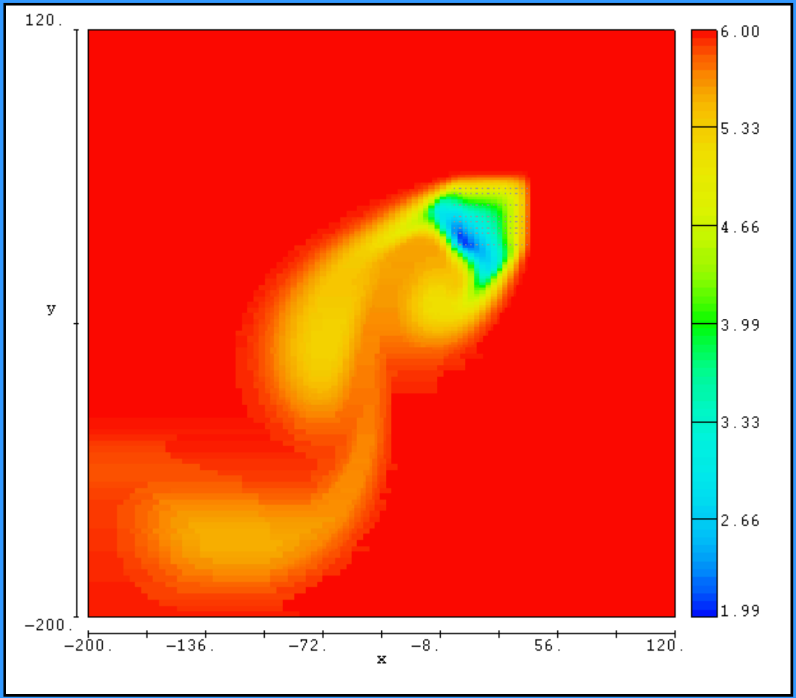
Basic Analysis Procedure

Totten Inlet
(Puget Sound, Washington State)

- Scalar advection routines are used to simulate the movement of dispersed constituents.
- Kinetics equations are used to characterize food consumption.

Applications: consumption modeling of mussel rafts. Chl a uptake is a function of current velocity and raft biomass.

Scale is chl a ug l^{-1}

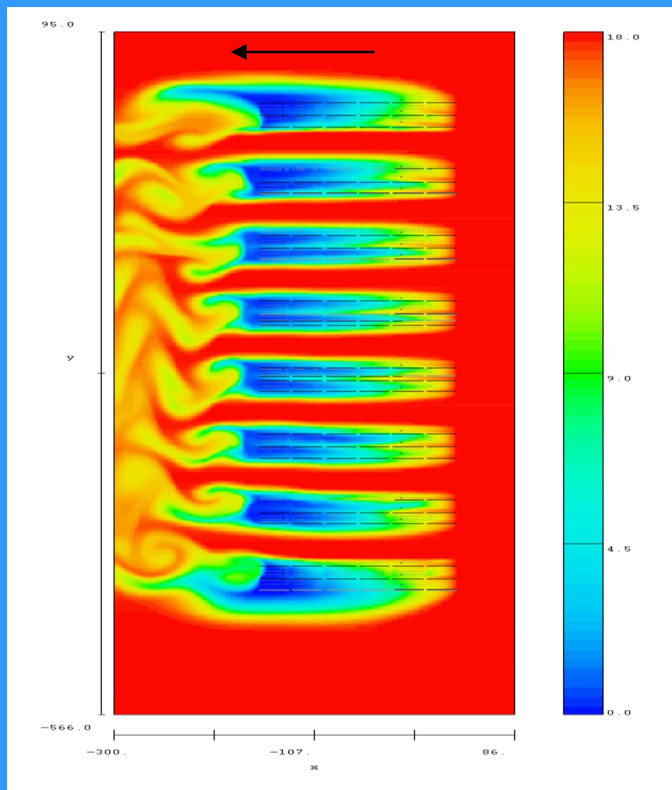


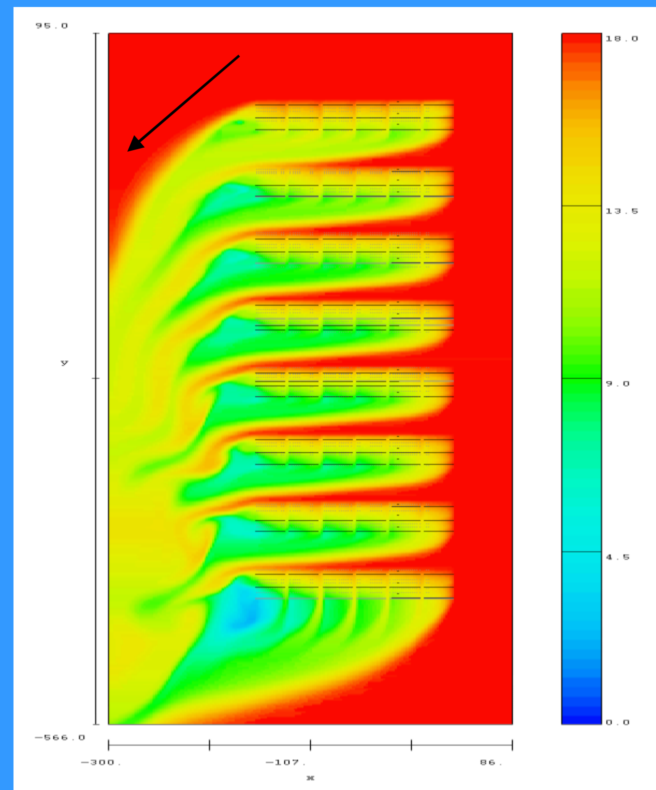
Model simulation for 15 cm s^{-1} approach velocity and 30 cm diameter ropes

30 cm diameter

Approach Velocity (cm/s)	U. Right	Center	U. Left	L. Right
3	4.97	**0.65**	4.54	4.54
6	5.44	**1.87**	5.16	5.16
9	5.62	**2.71**	5.40	5.40
12	5.71	**3.29**	5.54	5.54
15	5.76	**3.70**	5.63	5.63

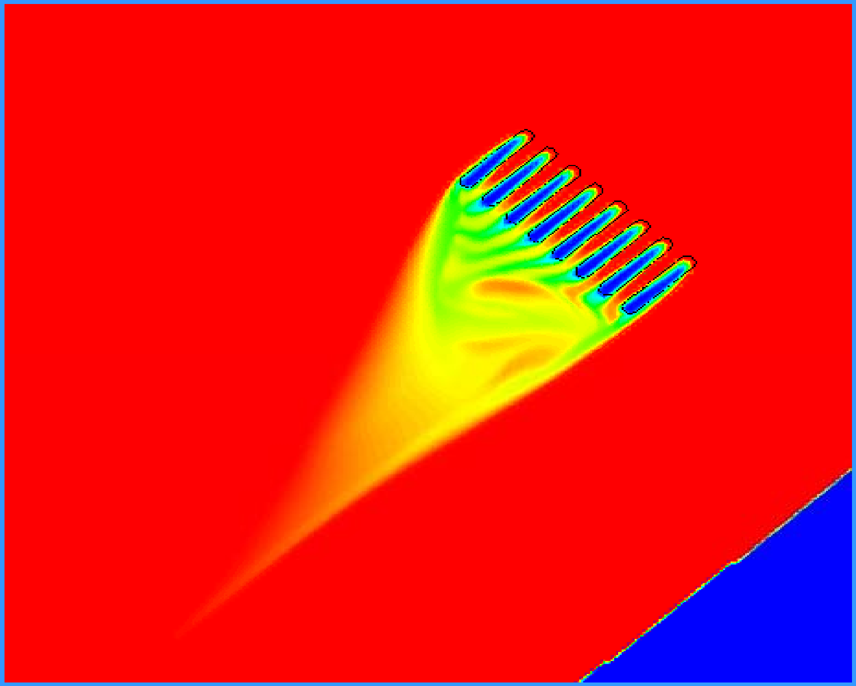
What-if Scenarios: Totten Inlet Mussel Rafts (existing and potential if orientation to flow was modified)



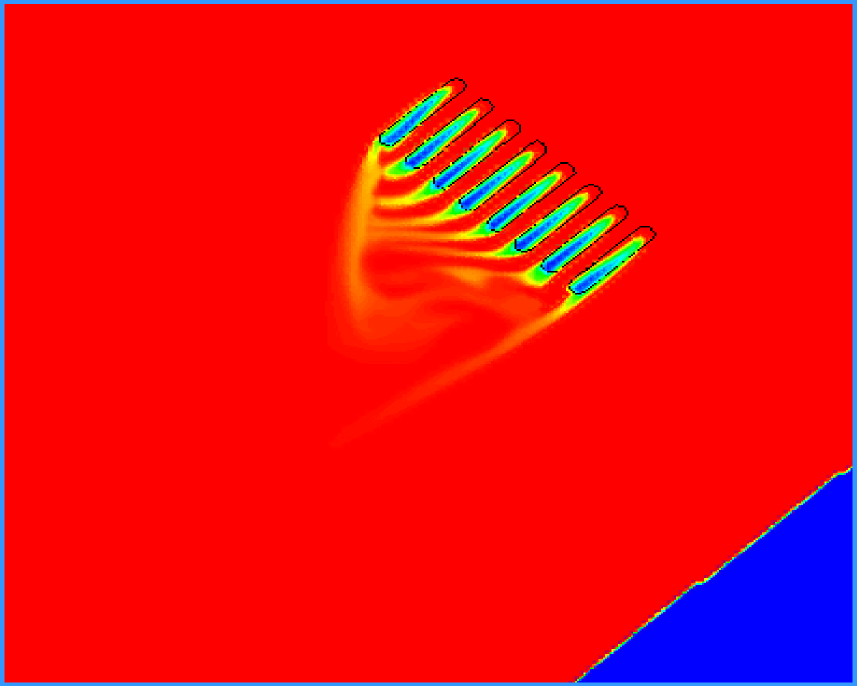


Calculated Food Availability
(colored by concentration, red – 18.0 μg/l, arrows show direction of approach flow - 15 cm/s)

Downstream wake of chl a depletion for W. Coast mussel rafts at 2 velocities



5 cm s-1 approach velocity



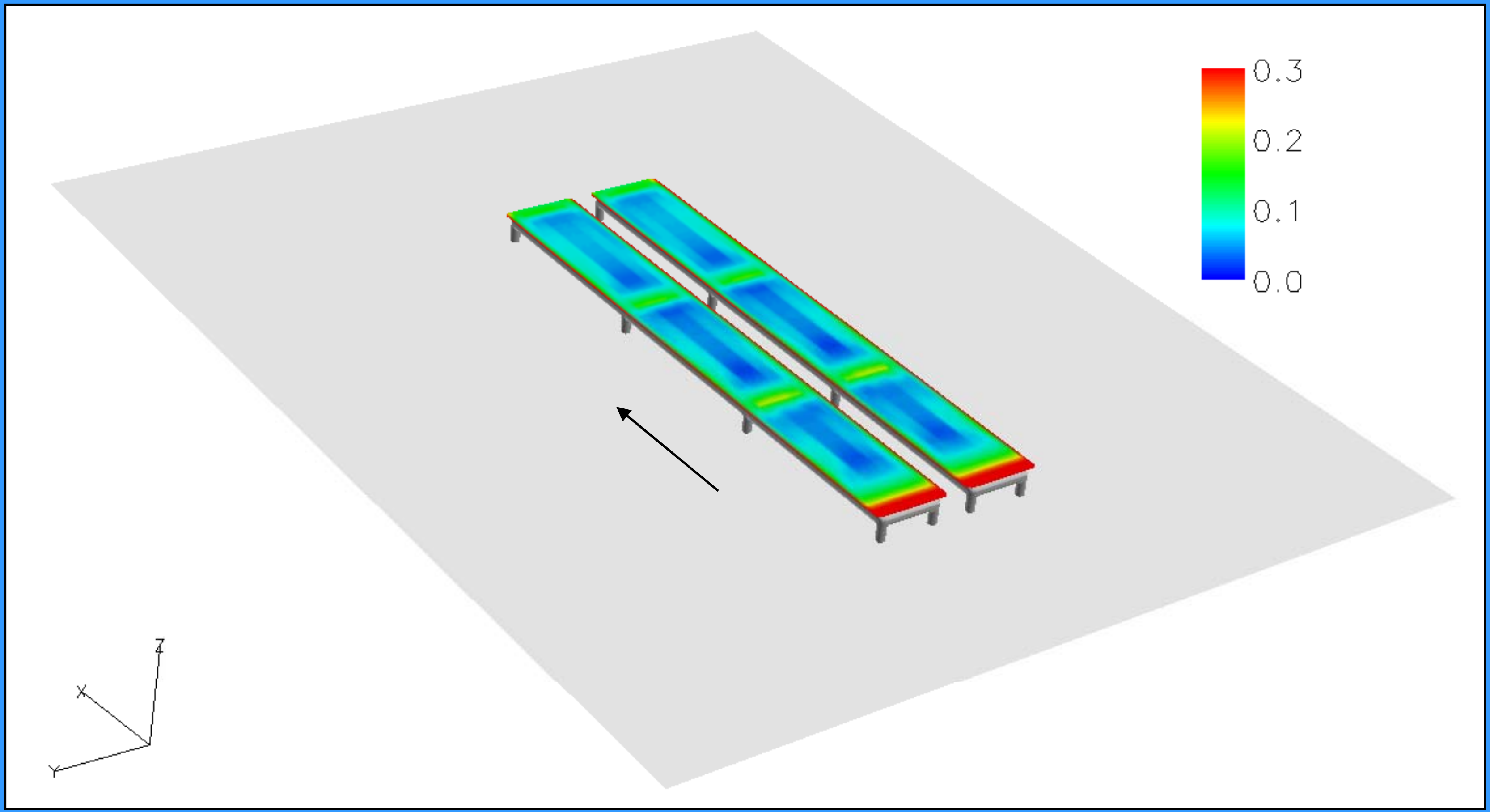
15 cm s-1 approach velocity

Analysis Procedure for Intertidal Culture

3-D flow models are modified to represent bottom culture structures and the same analysis procedures are followed (i.e., minimum change is required.

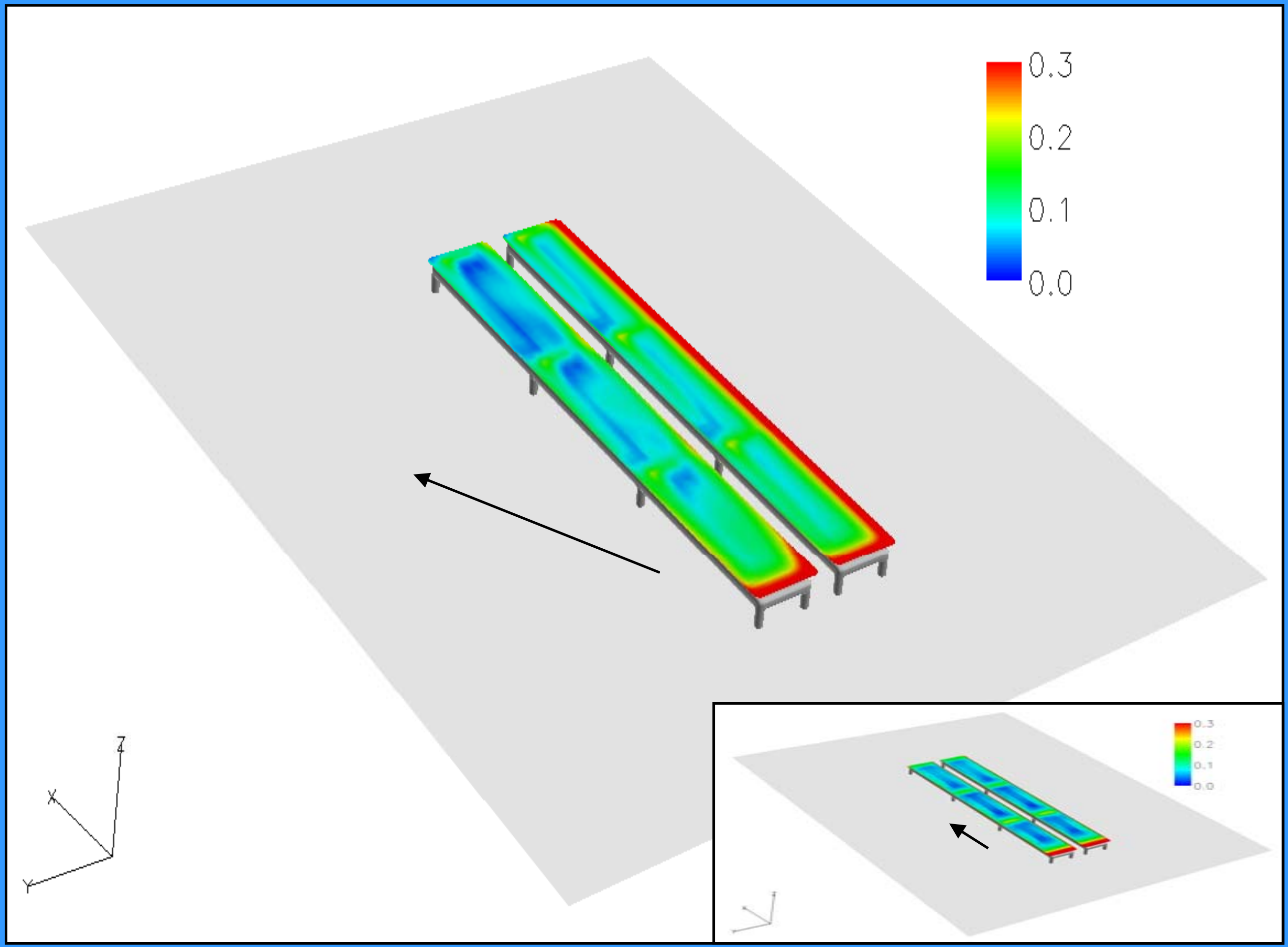
Oyster Trestles
(Dungarvan Ireland)

Sample Results



Average Velocities inside Oyster Bags
(arrow shows direction of flow, approach velocity equals 0.5, units are ft/s)

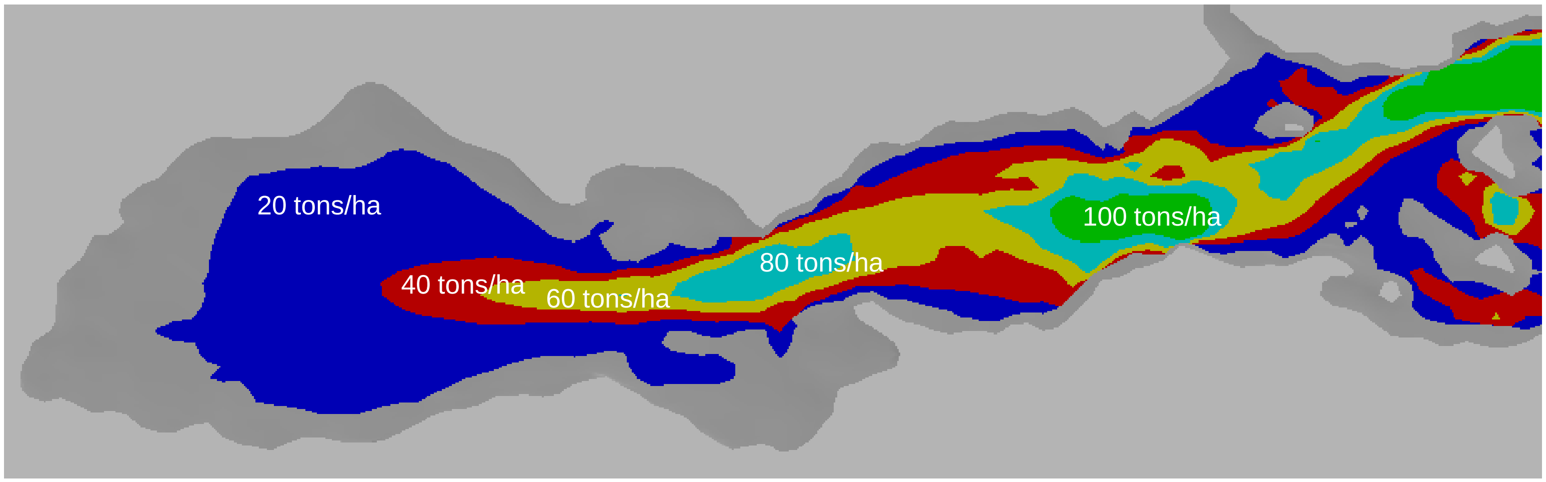
Sample Results

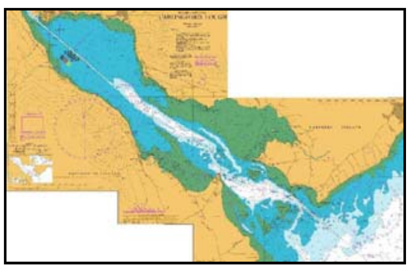


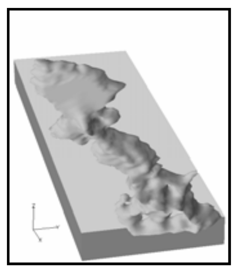
Average Velocities inside Oyster Bags
(arrow shows direction of flow, approach velocity equals 0.5, units are ft/s)

Carlingford Lough, Ireland

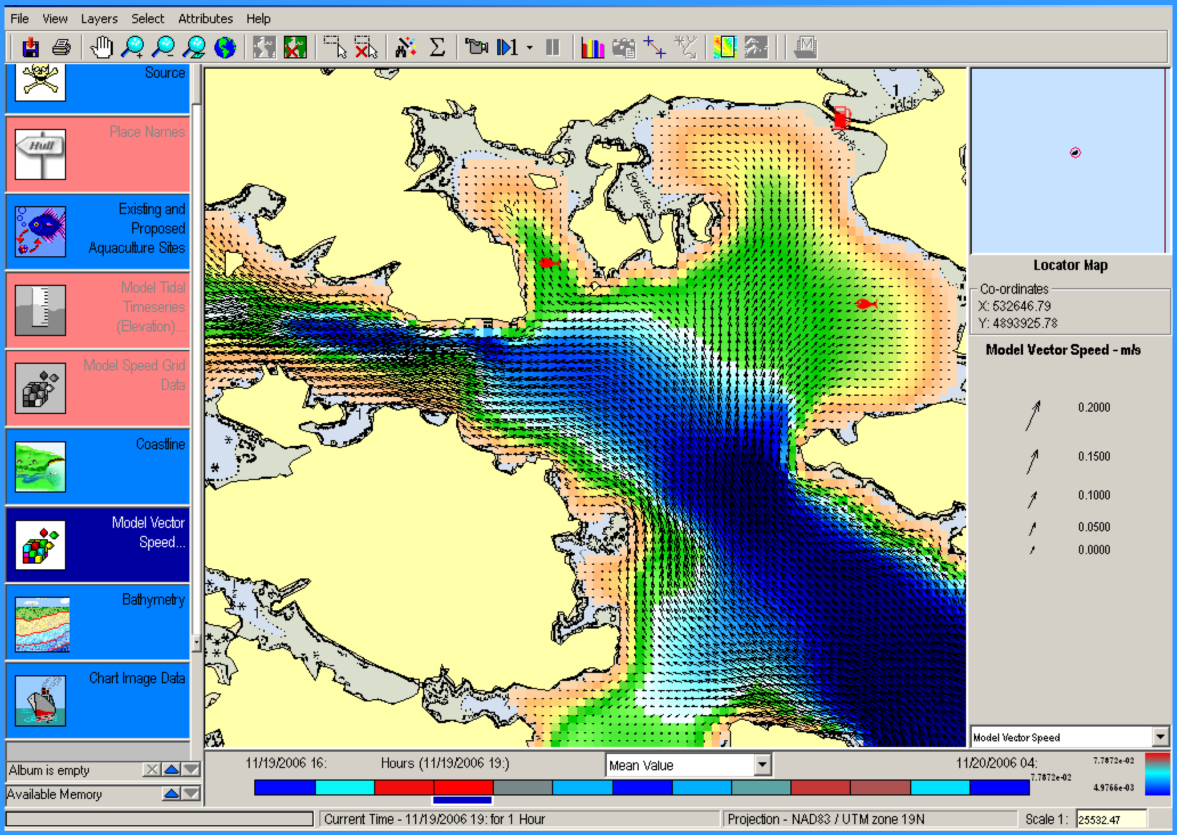
optimal seeding should be a function of flow velocity for mussel bottom culture







Where We are Headed…



- Aquaculture GIS – better siting of operations, predict growth as a function of site and seeding density, other tools for resource management, environmental impacts

WHAT ABOUT ALL THE OTHER CREATURES?

Table 2. Total numbers of individuals found at subtidal (S1 & S2), raft (R1 & R2) and intertidal (I1 & I2) sites (numbers of individuals per core).

Taxa						Subtidal		Raft			Intertidal
Crustacea											
Semibalanus balanoides (Linnaeus)		3				21			71		
Balanus crenatus (Bruguière)				4							
Balanus eburneus (Gould)	12			18				2			
Gammarus oceanicus (Segerstrale)									132		
Jaera marina (Fabricius)										3	
Leptocheirus pinguis (Stimpson)		1								1	
Echinodermata											
Asterias forbesi (Desor)						8					
Amphipholis squamata (Delle Chiaje)				3							
Ophiopholis aculeata (Linnaeus)						2					
Strongylocentrotus droebachiensis (Müller)				1							
Mollusca											
Acmaea testudinalis (Müller)	10						12				
Anomia aculeata (Müller)						23					
Buccinum undatum (Linnaeus)		3								1	
Clinocardium ciliatum (Fabricius)						1					
Littorina littorea (Linnaeus)		4							22		
Littorina saxatilis (Olivi)		4									
Macoma calcarea (Gmelin)		1				93				1	
Nucella lapillus (Linnaeus)										2	
Oligochaeta											
Tubificidae											130
Polychaeta											
Amphitrite sp. (Mueller)							218				
Arabella iricolor (Montagu)		1									
Capitella capitata (Fabricius)		6								1	
Cirratulidae (Ryckholdt)		3				7					
Glycera dibranchiata (Ehlers)		2									
Lepidonotus squamatus (Linnaeus)		1				20					
Lepidonotus variabilis (Webster)	46			23				2			
Marphysa sanguinea (Montagu)						5					
Nephtys sp. (Cuvier)			18								
Nereis pelagica (Linnaeus)		5				52			10		
Phyllodoce arenae (Webster)		3				14				1	
Sabella sp. (Linnaeus)								1			
Porifera											
Cliona sp.								2			
Total no. taxa			**19**			**17**			**15**		
Total no. individuals	**130**		**509**		**391**						