CFD analysis of shellfish aquaculture gear used in intertidal and subtidal locations
Drs. John Richardson, Carter Newell

NMAI Objectives

- Investigate effects of alternative shellfish culture methods on flow, food availability and environmental effects.
- Combination of field data collection and computer modeling using computational fluid dynamics (CFD).

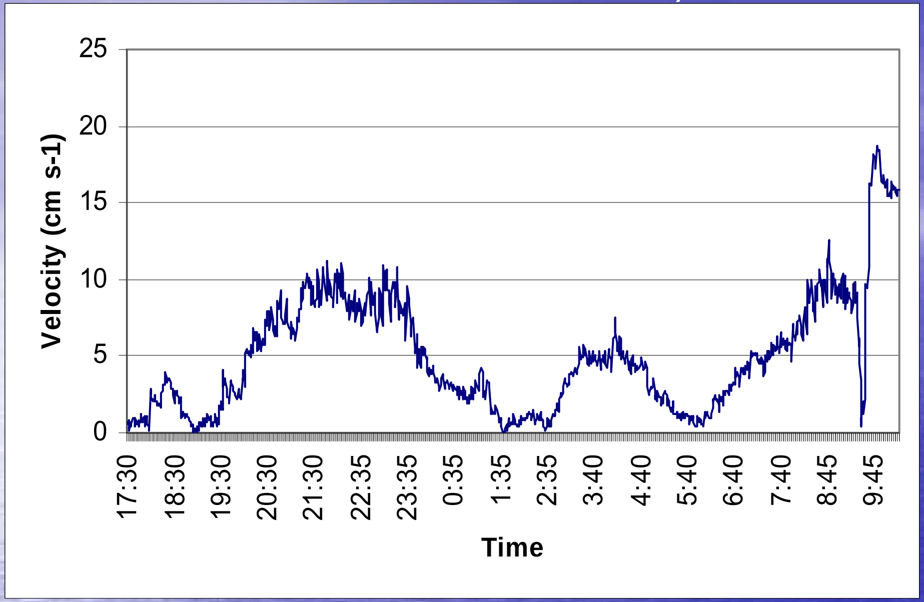
Sites investigated

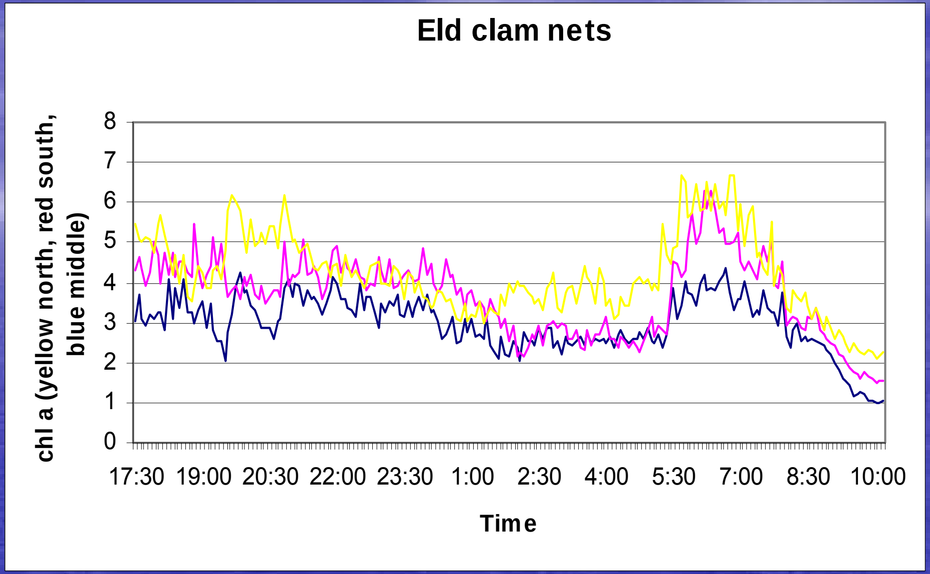
- Thorndyke, Hood Canal, Washington State
- Eld Inlet, Washington State
- Long Island Sound, Connecticut
- Cherrystone Creek, Virginia

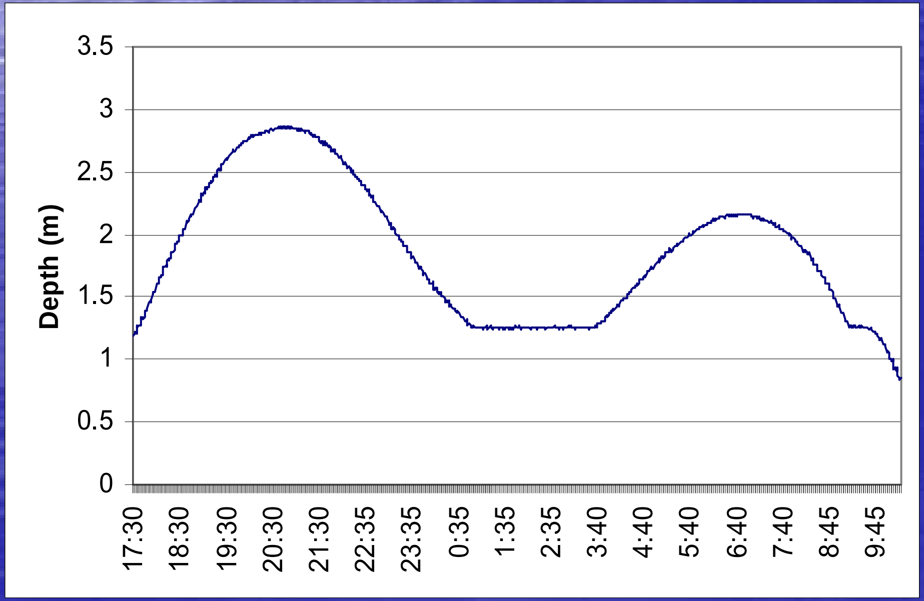
Approach

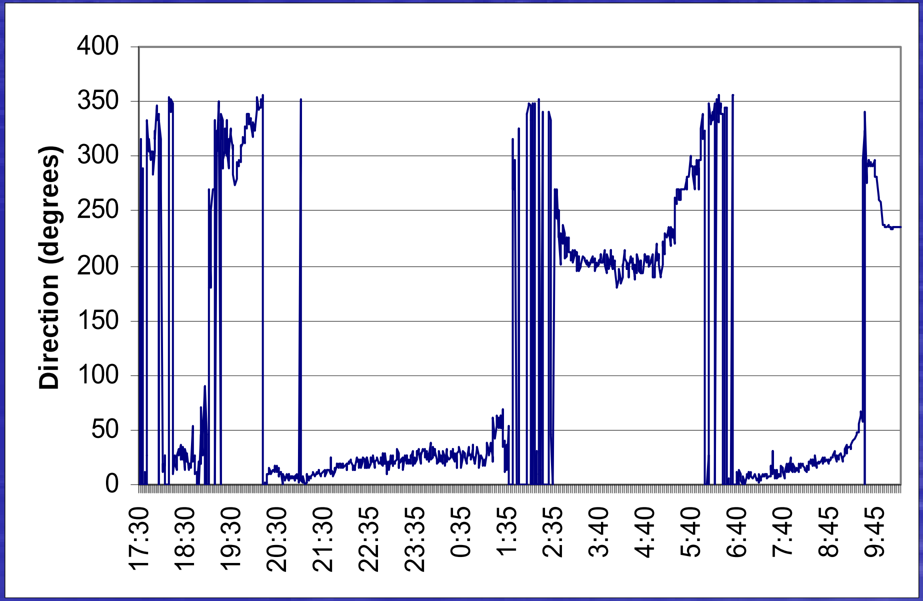
- Site layout: bathymetry, location of culture plots, eelgrass
- Alternative methods for shellfish aquaculture:
  - Clams under nets: Virginia
  - Oysters in bottom cages: Connecticut
  - Clams in bags and geoducks in tubes: Thorndyke
  - Clams in bags and under nets: Eld Inlet
- Site hydrodynamics: current meter
- Culture system hydrodynamics: structure dimensions, mesh size, fouling
- Uptake of phytoplankton: CTD moorings, SCUBA sampling of upstream and downstream
- Feces settling rates
- Models

Hydrodynamics and CTD moorings: Eld clams nets June 8-9, 2005

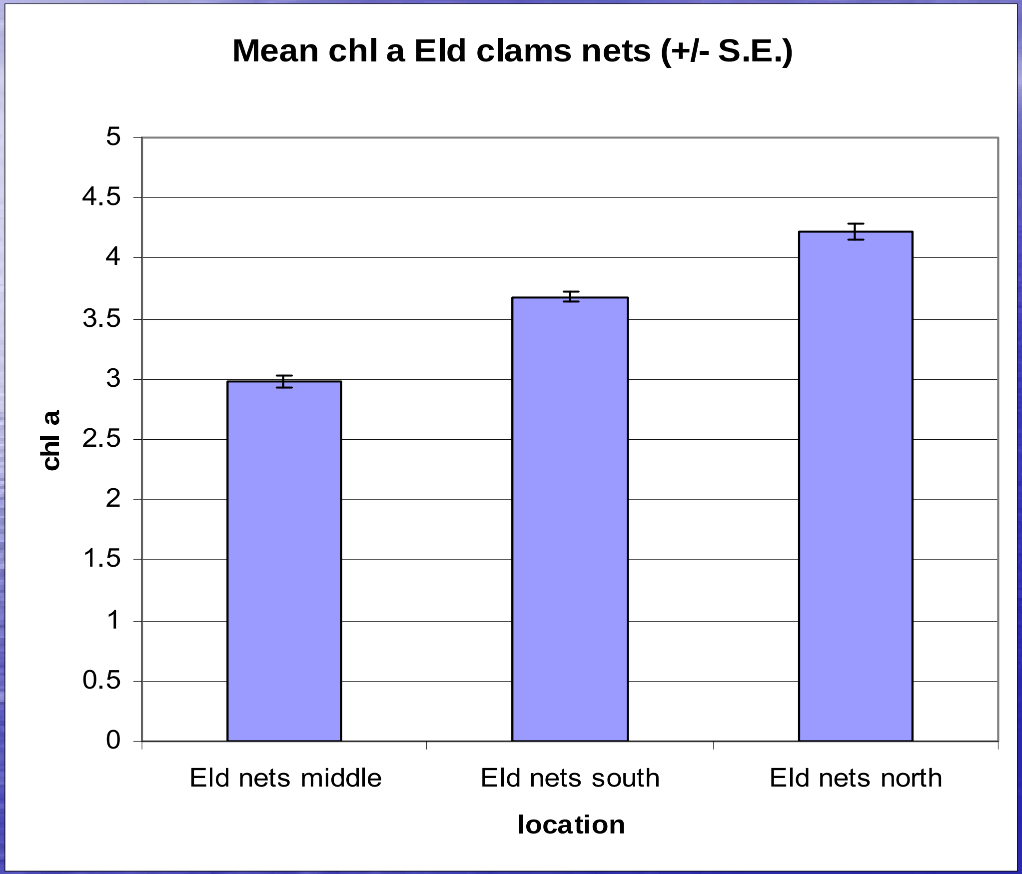




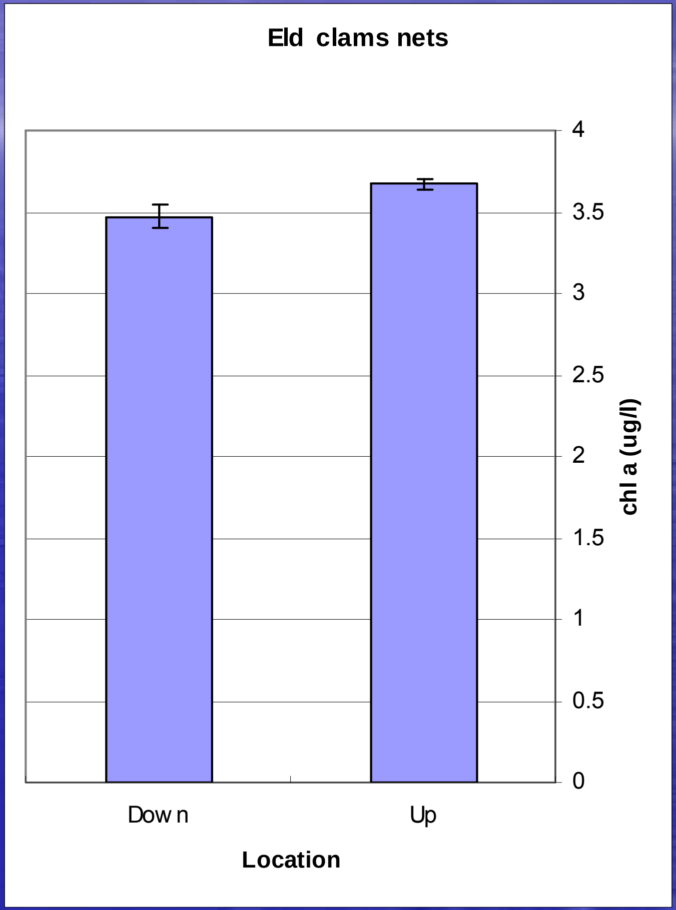




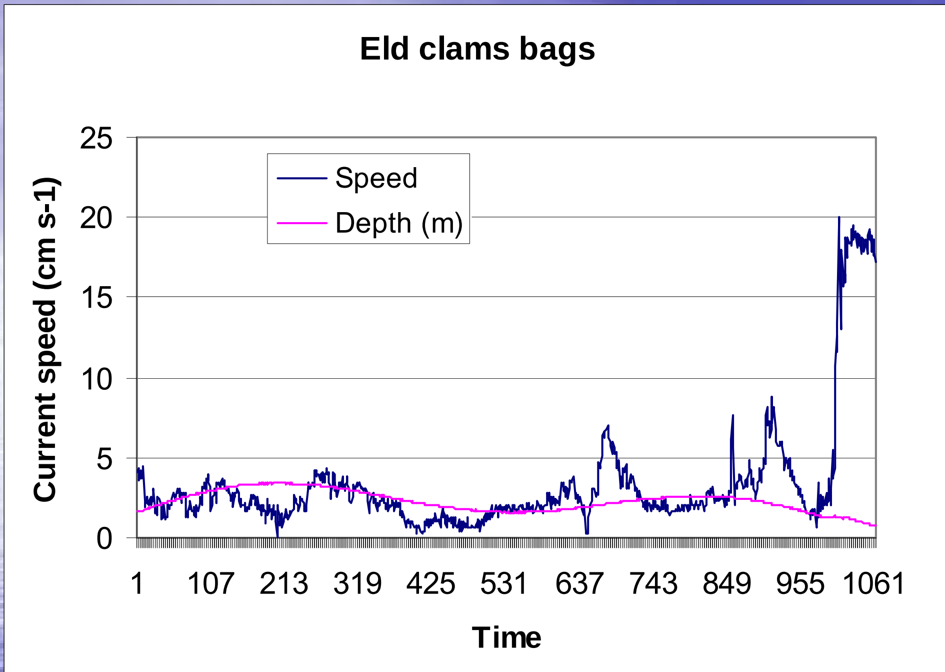
CTD moorings

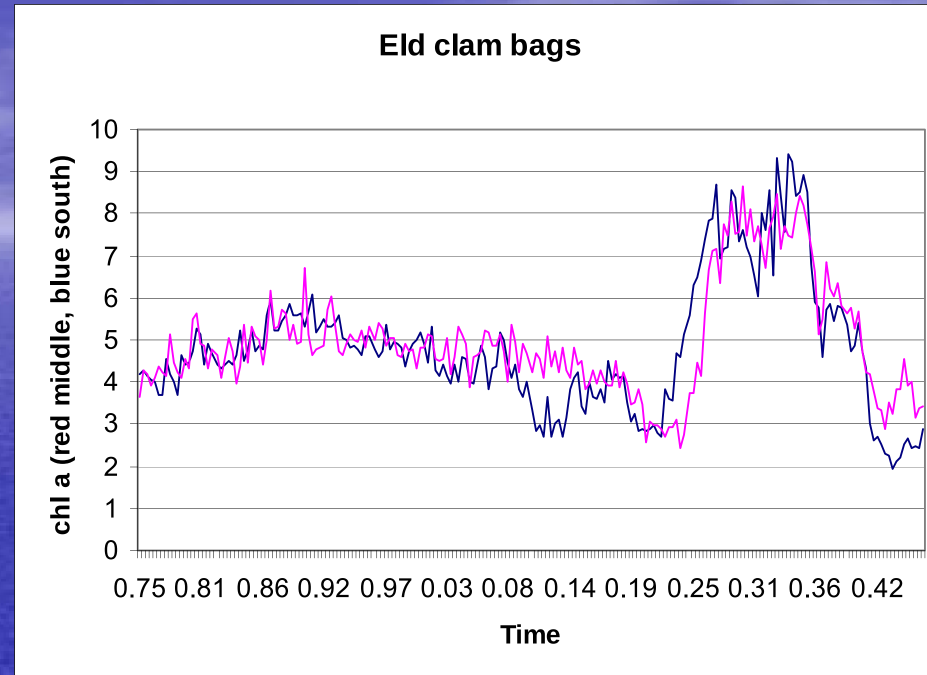


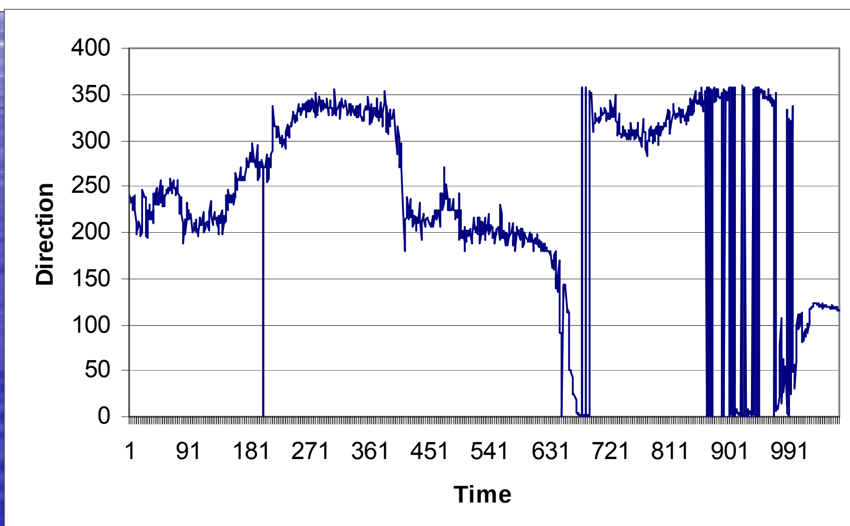
Diver samples



Hydrodynamics and CTD moorings: Eld clams bags June 10-11, 2005

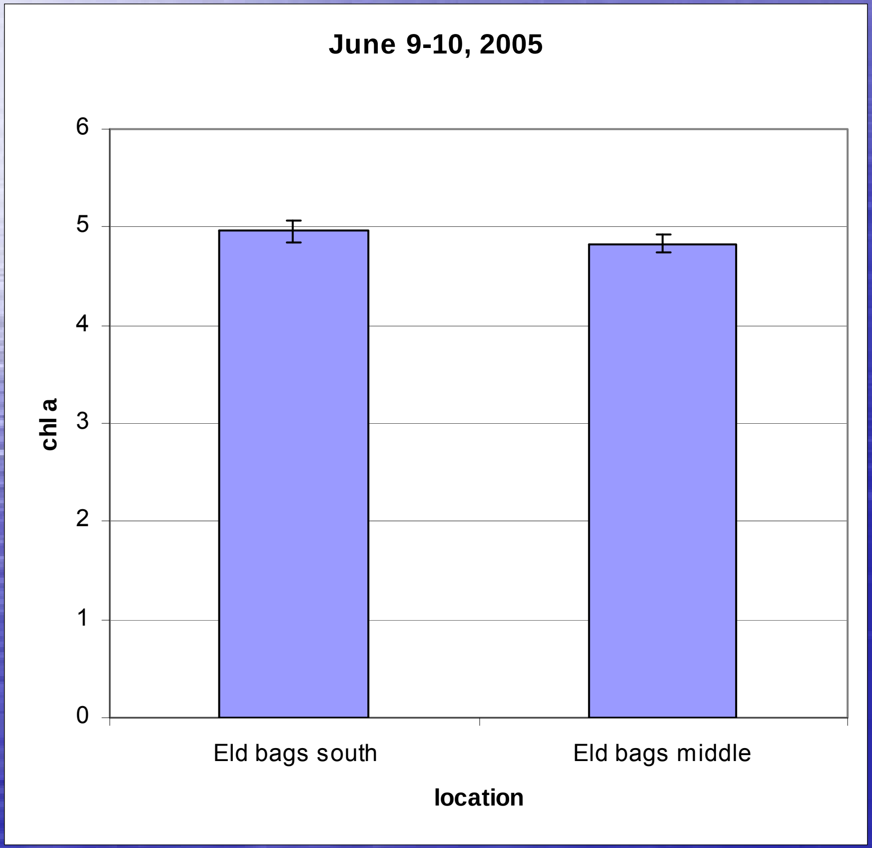


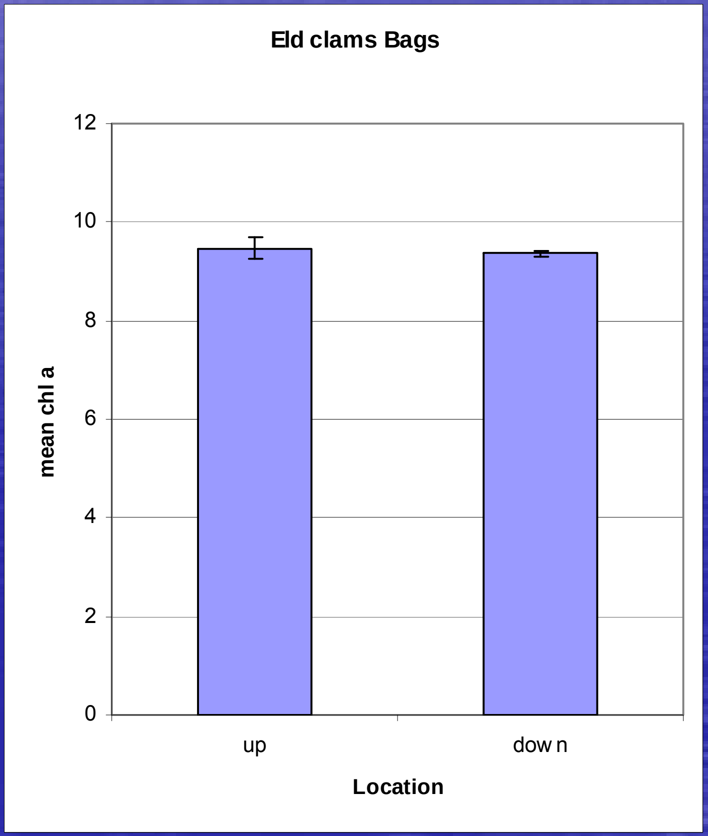




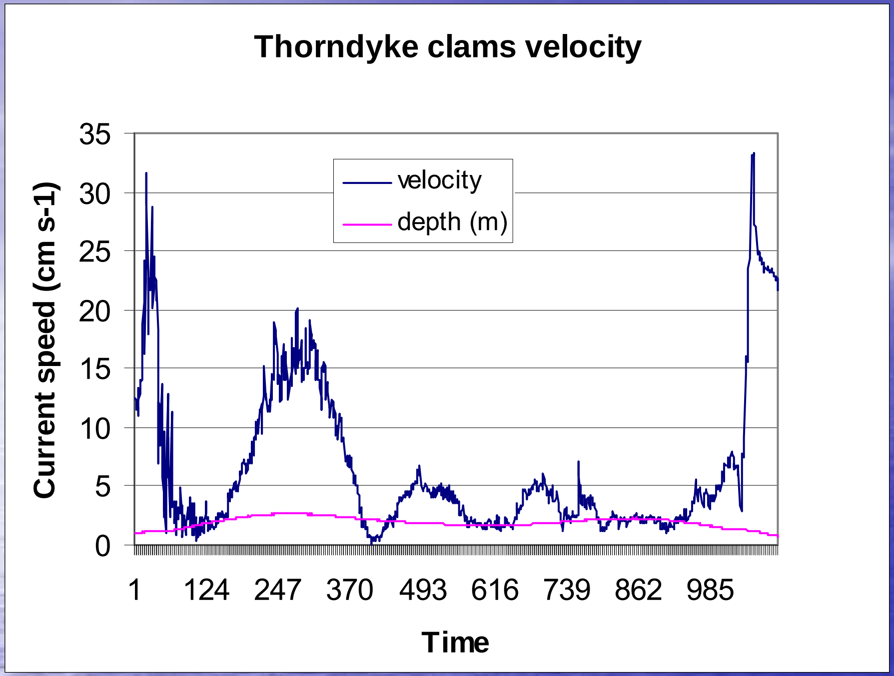
CTD moorings

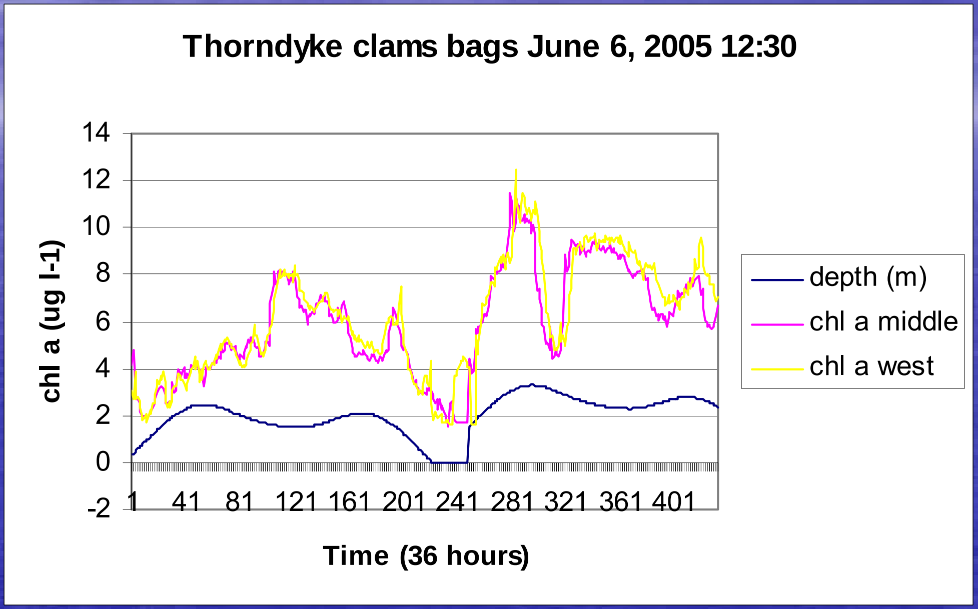
Diver samples

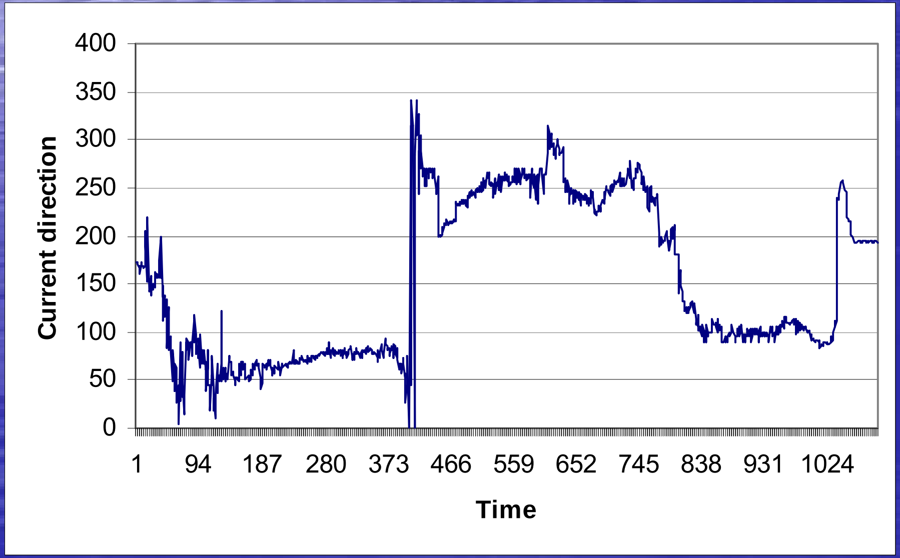




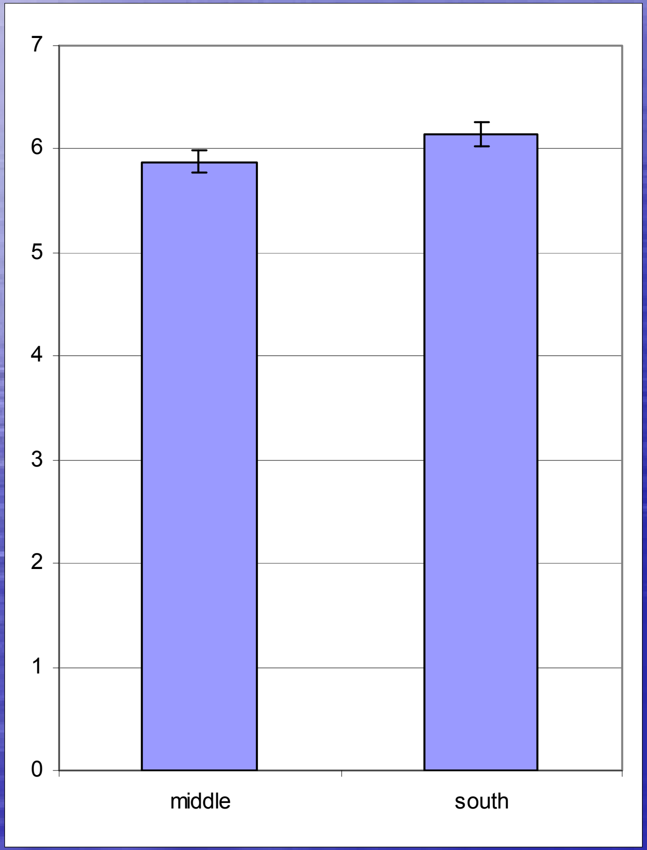
Hydrodynamics and CTD moorings: Thorndyke clams bags June 6-7, 2005



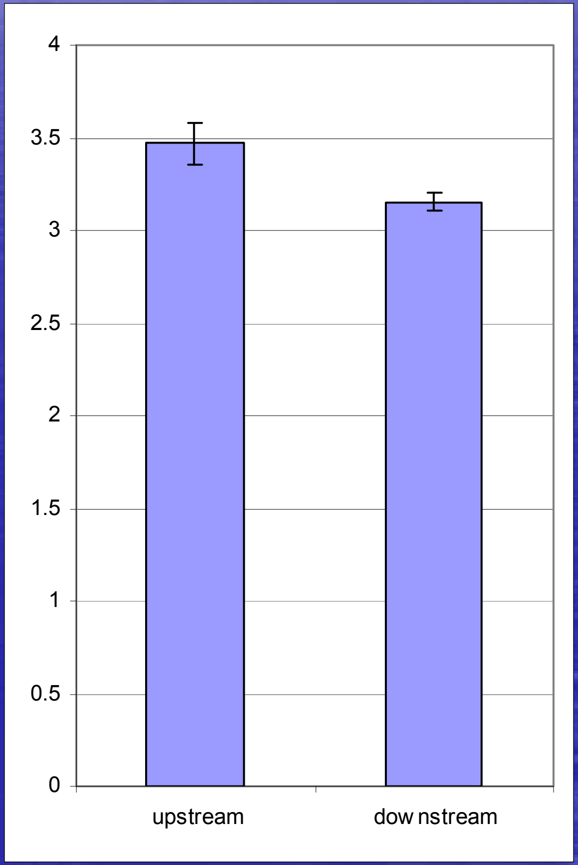




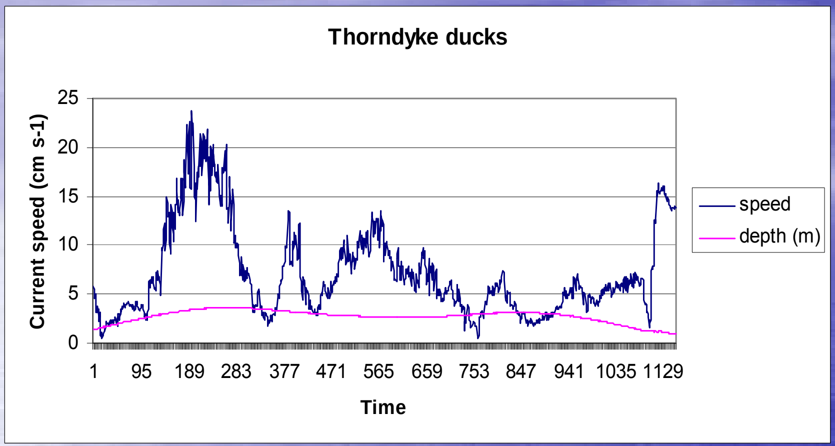
CTD moorings

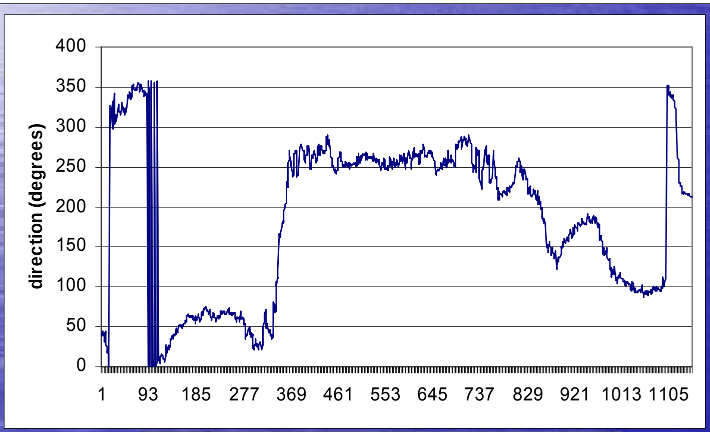


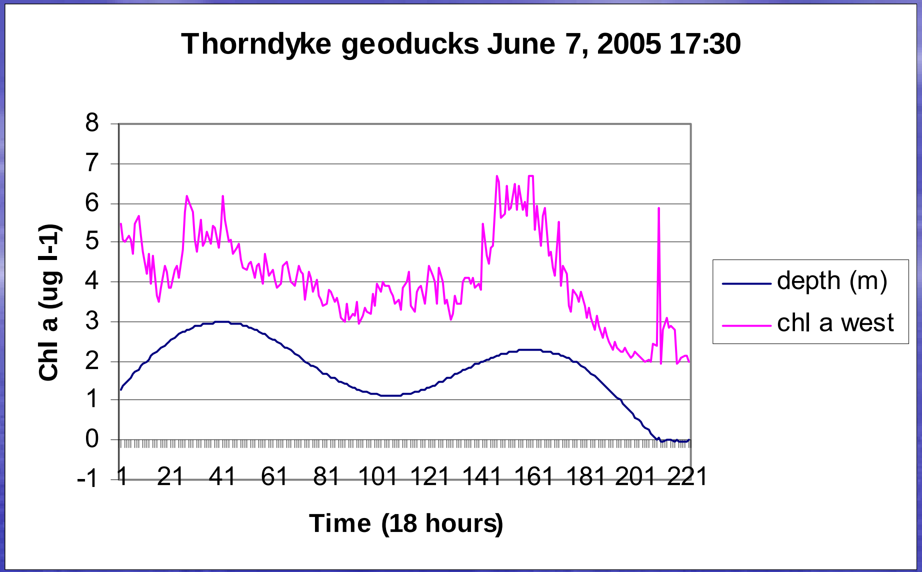
Diver samples

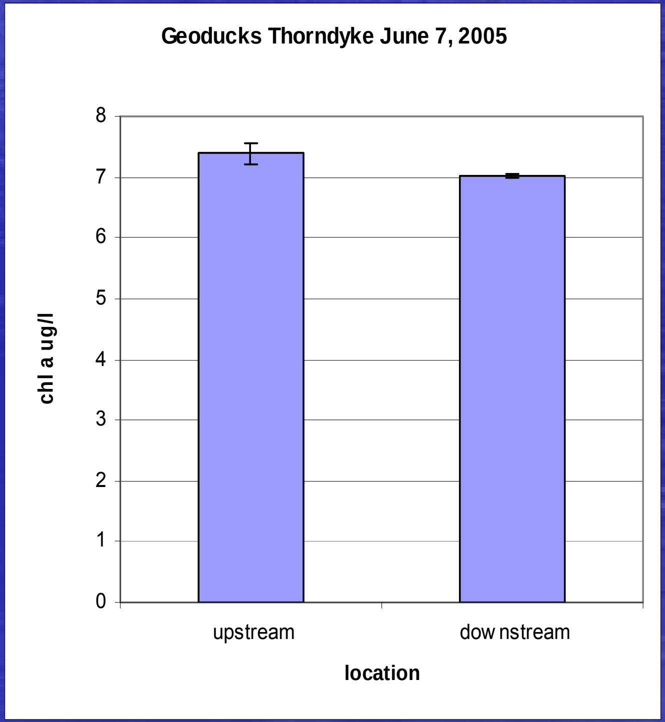


Hydrodynamics, CTD moorings and diver samples, Thorndyke geoducks June 7-8, 2005

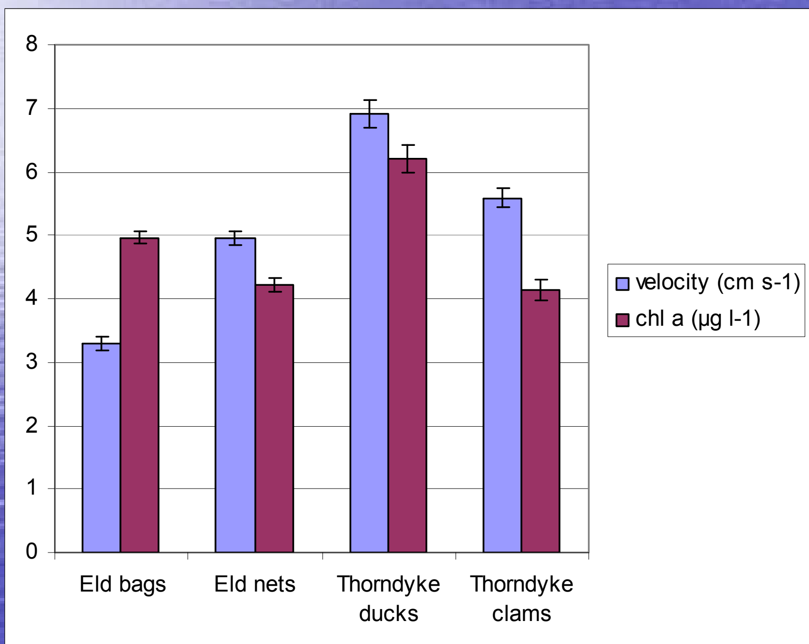


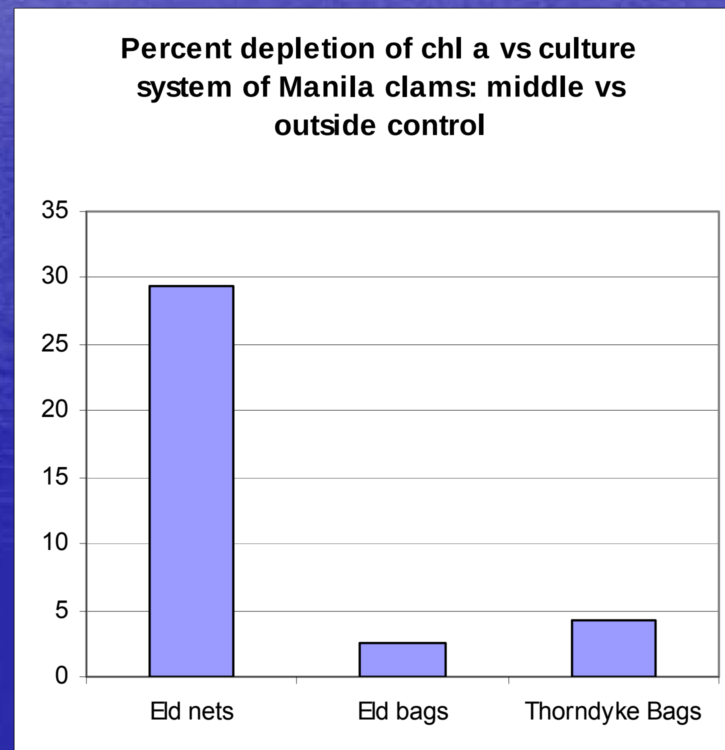


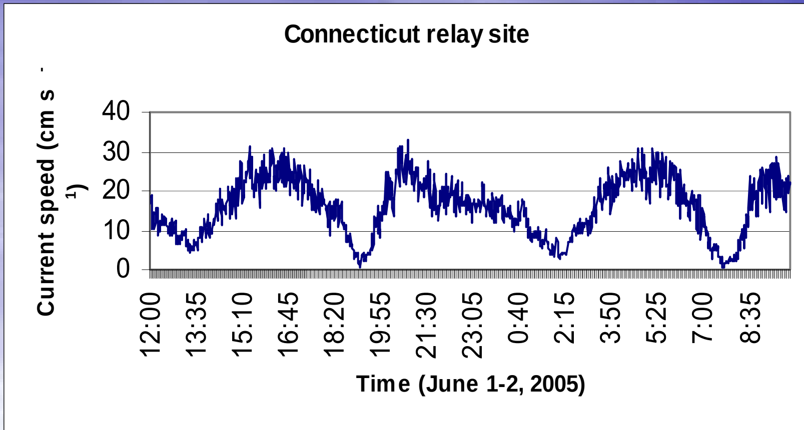


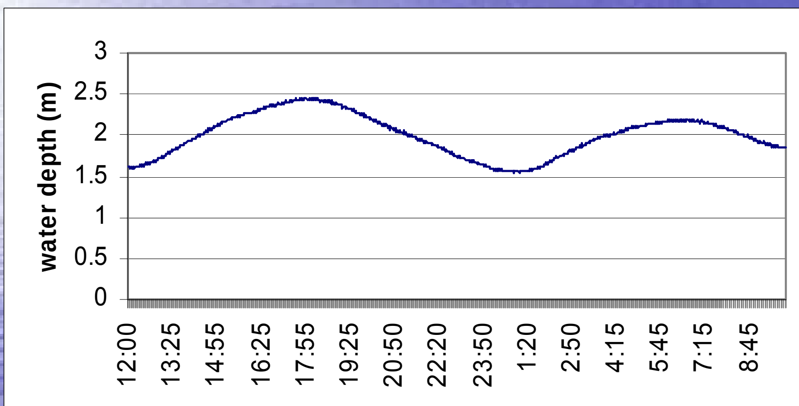


Washington State: site comparisons

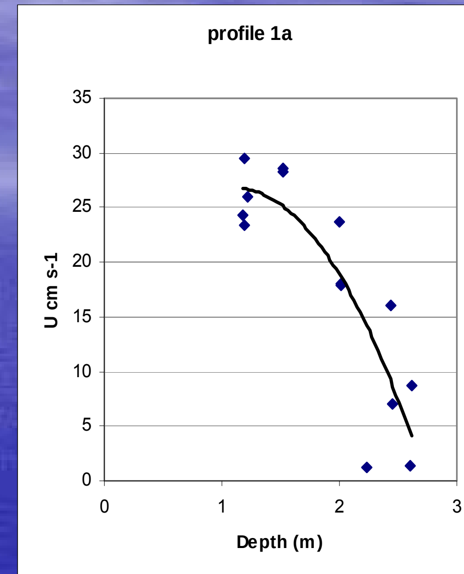




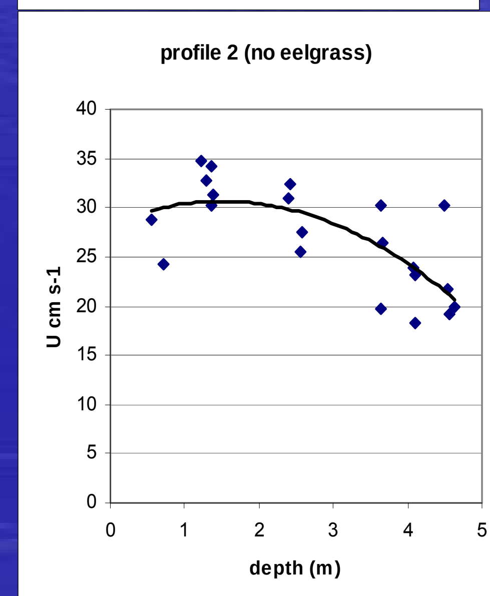




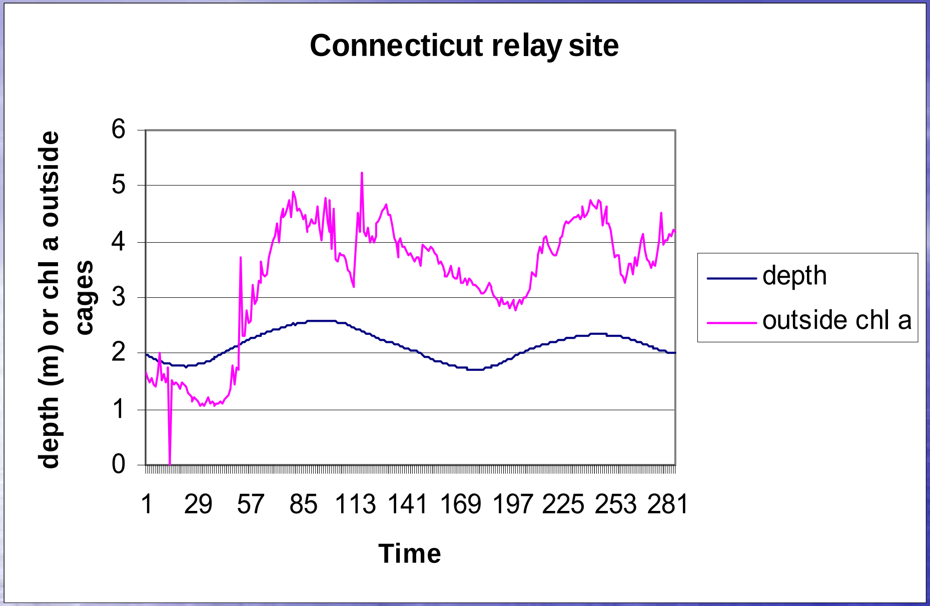
Eelgrass

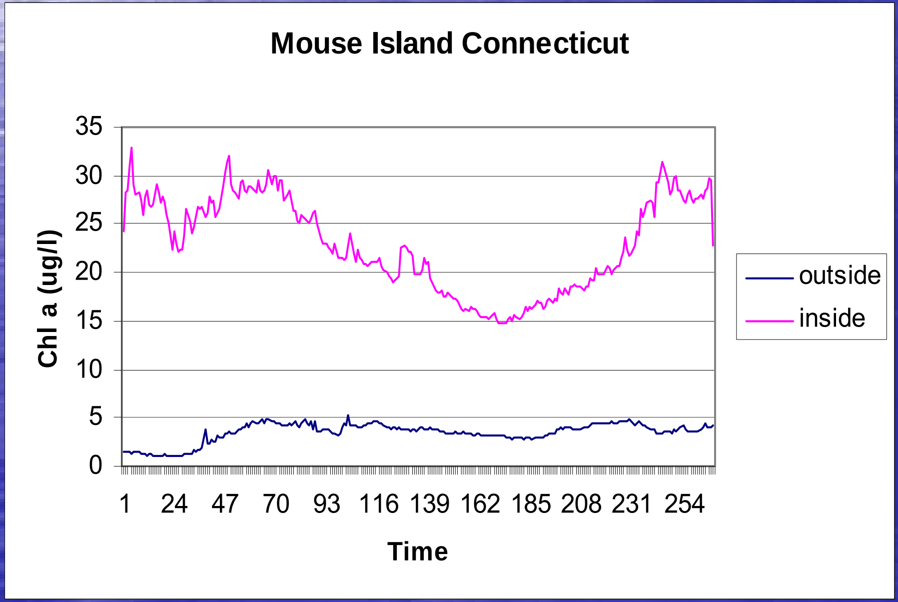


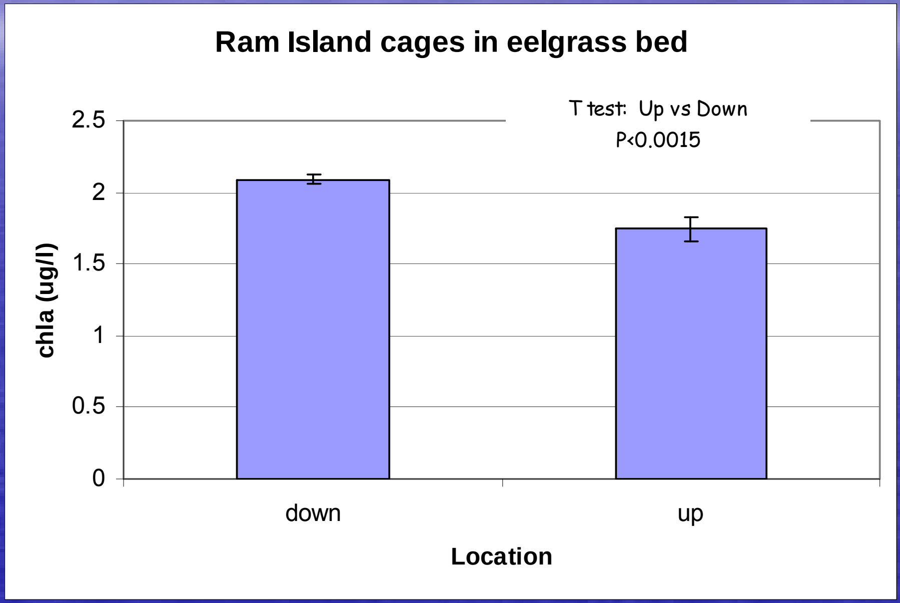
No eelgrass



CTD moorings and diver samples: more food inside (and downstream) of oyster cages







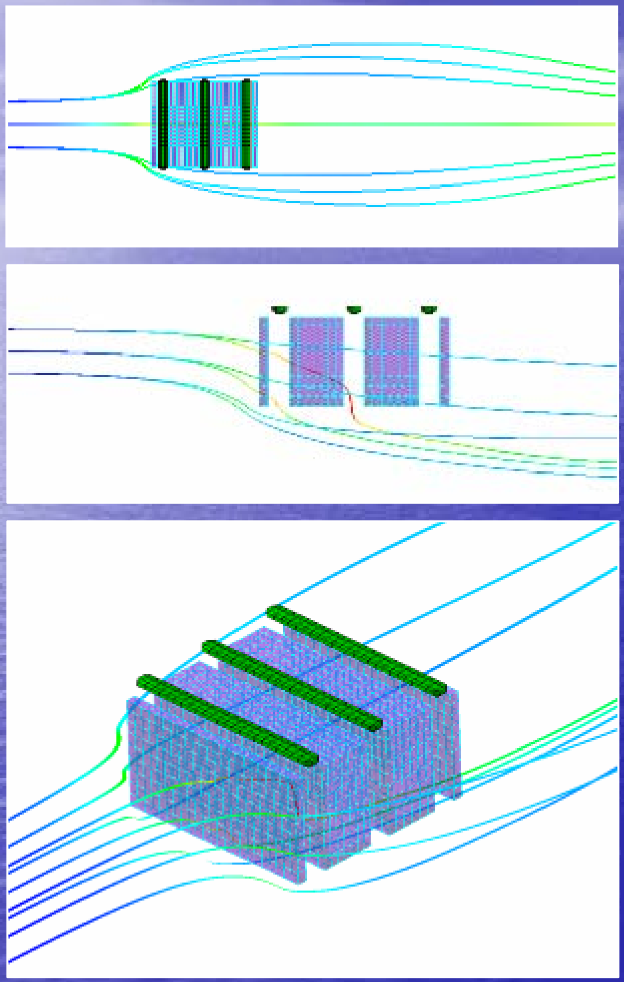
Macroalgal fouling of nets and bags a major factor in reducing flow through porous media

Clam bags, Washington State

Clam nets, Virginia

Analytic models of all sites must be able to account for the hydraulic effects of:

- the tide (flooding and drying),
- bio-fouling,
- sub-aquatic vegetation (eel grass), and
- the aquaculture gear itself.



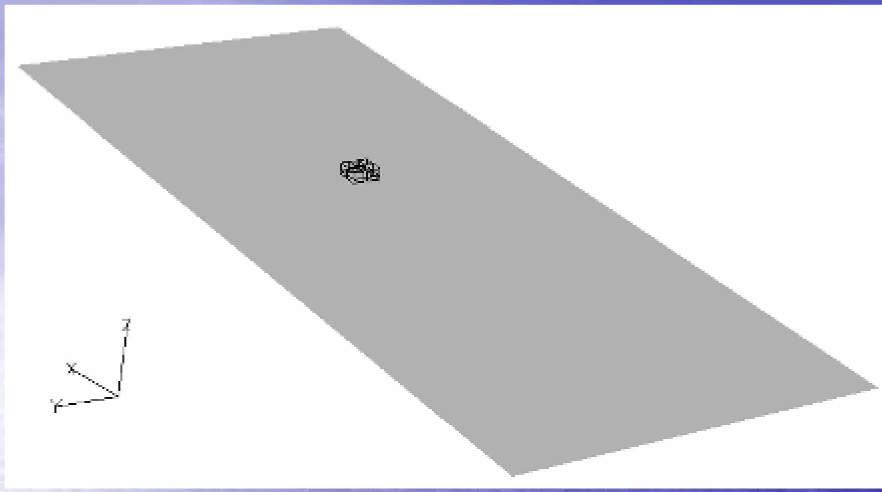
Calculated Streamlines of Flow through Aquaculture Raft, Colored by Speed
Plan-view / Side-view / Oblique-view

Modeling Approach

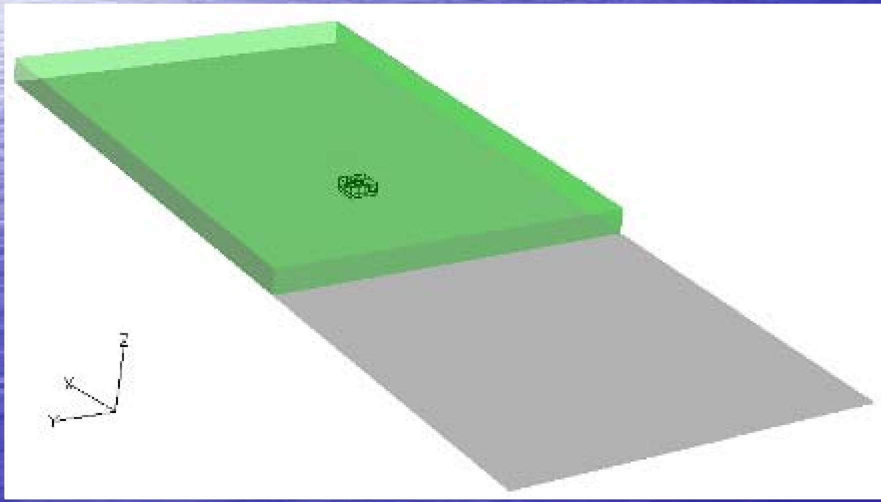
The modeling approached was based on the application of partial volume techniques known as VOF and FAVOR.

The Volume-of-Fluid (VOF) is capable of simulating flooding and drying.

Fractional Area/Volume Obstacle Representation (FAVOR) enables the simulation of flow around solid obstacles and through porous and open regions.



Model Domain and Depuration Cage



Depuration Cage and Eelgrass Bed

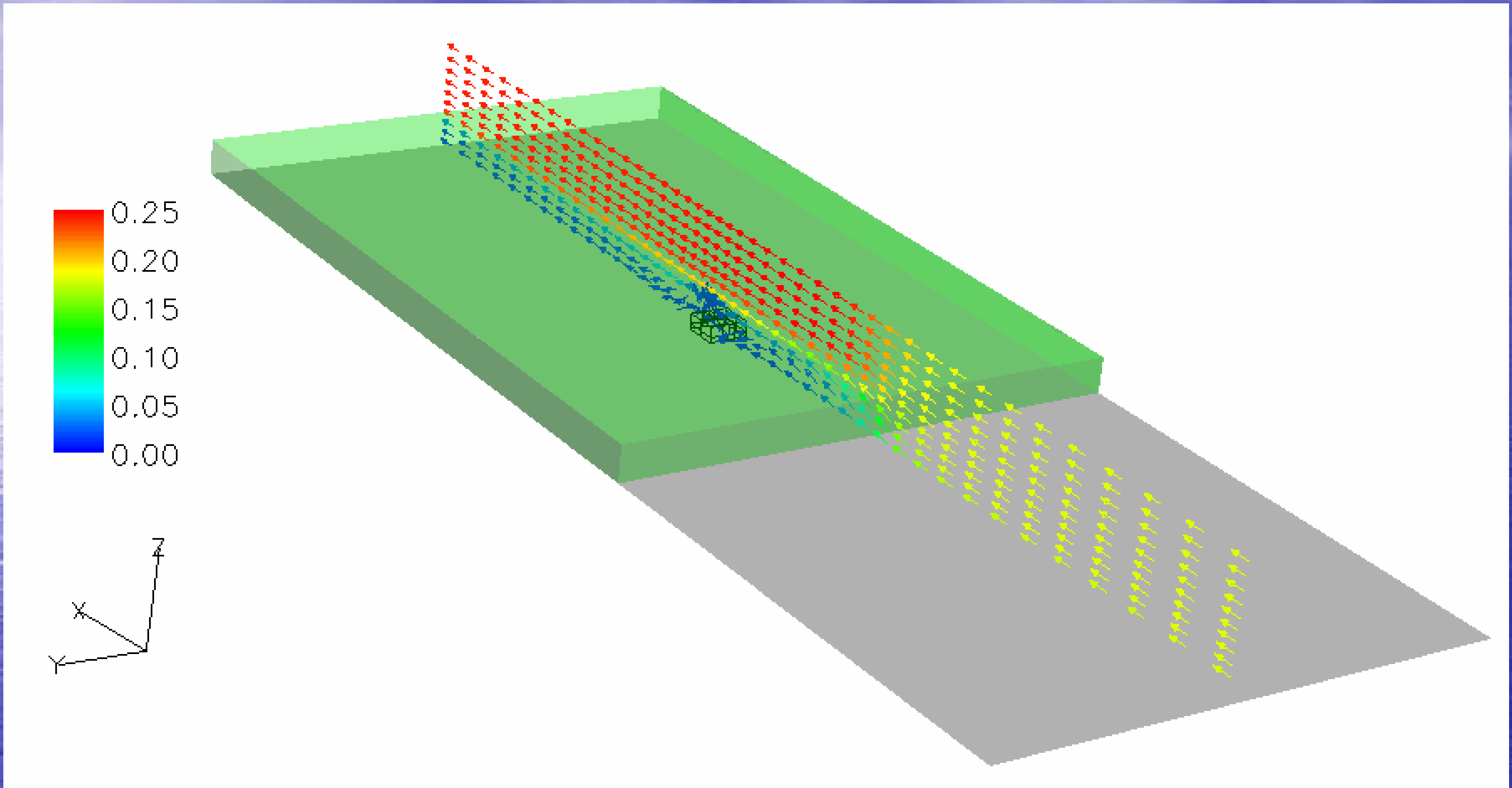
Modeling Depuration Cages (CT)

Step 1: Define Modeling Region,

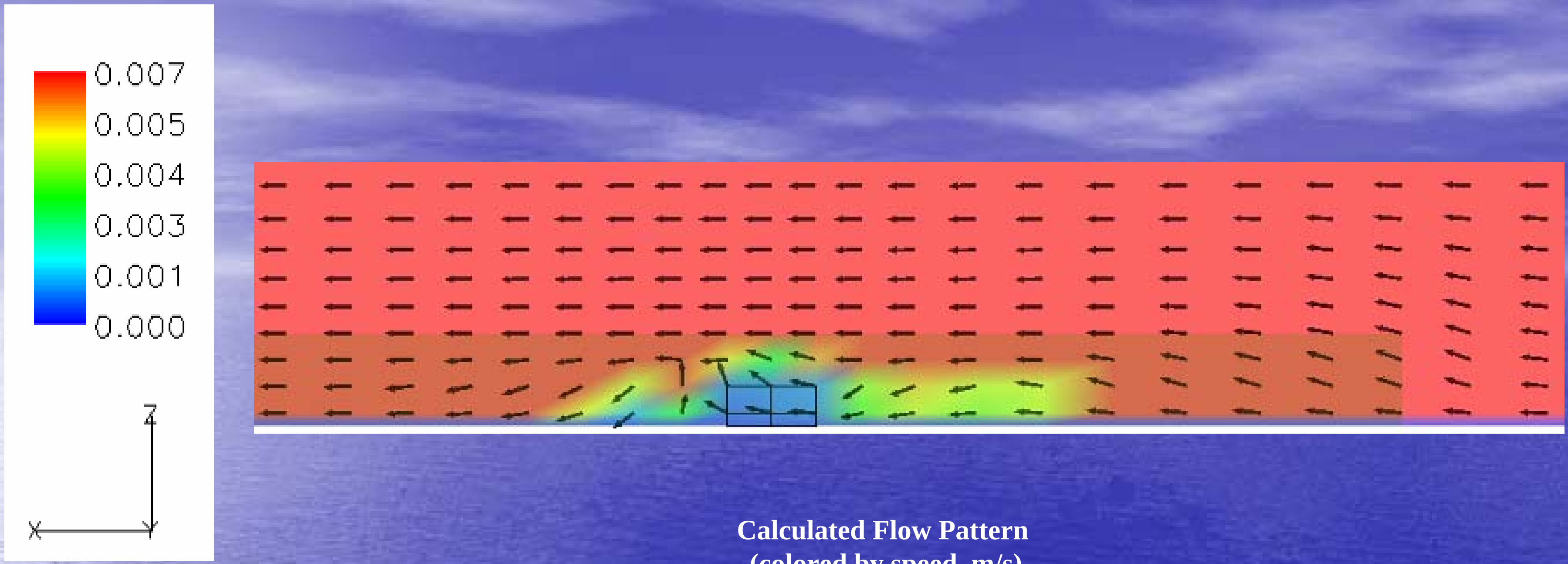
Step 2: Set Porosity of Cages based on Measurements of Screen Size and amount of fouling,

Step 3: Model Eelgrass Bed as Porous Region surrounding Cages (set porosity according to measurements of plant density), and

Step 4: Calculate Resulting Flows

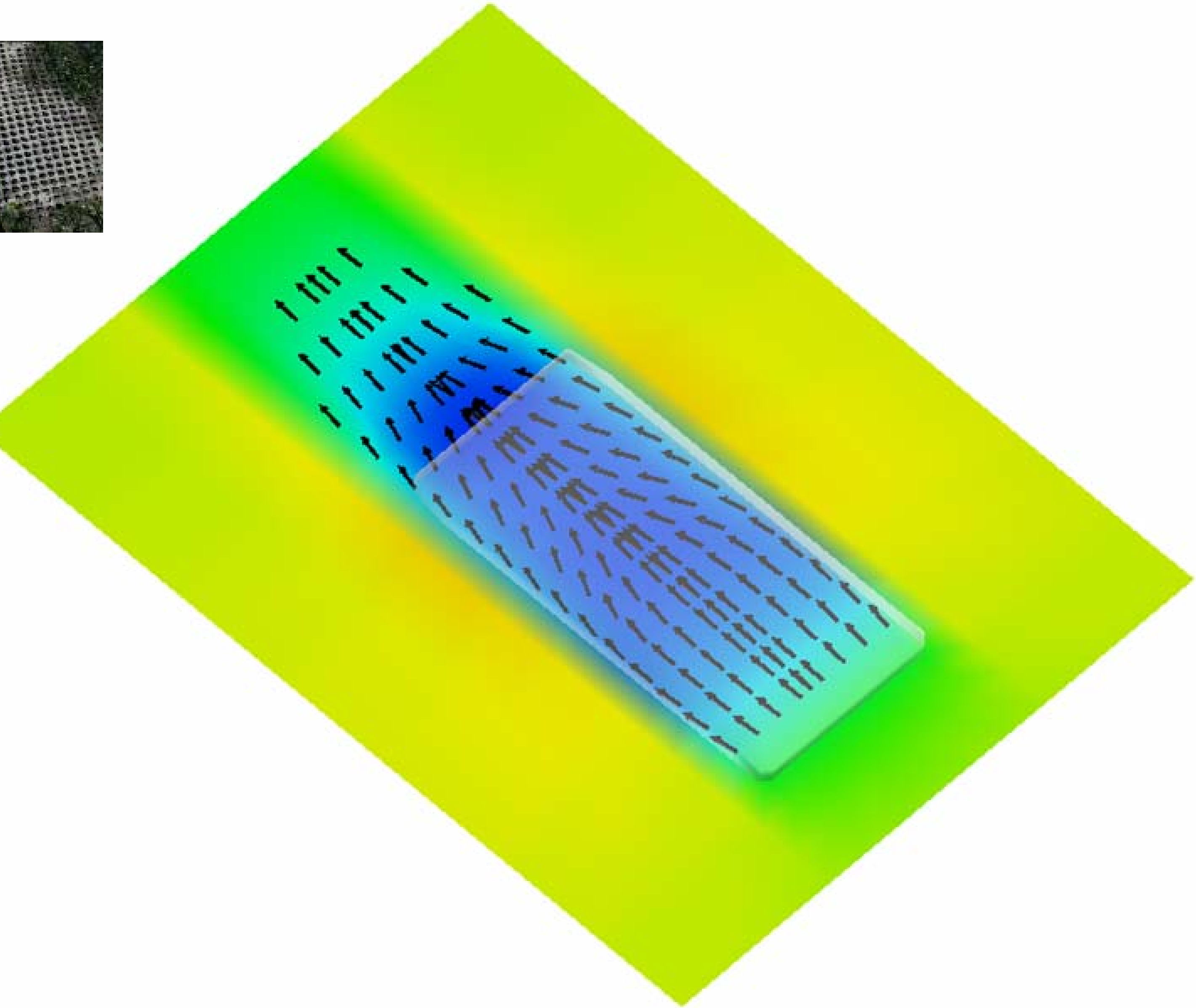


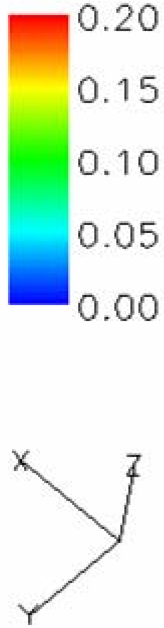
Calculated Flow Pattern
(colored by speed, m/s)



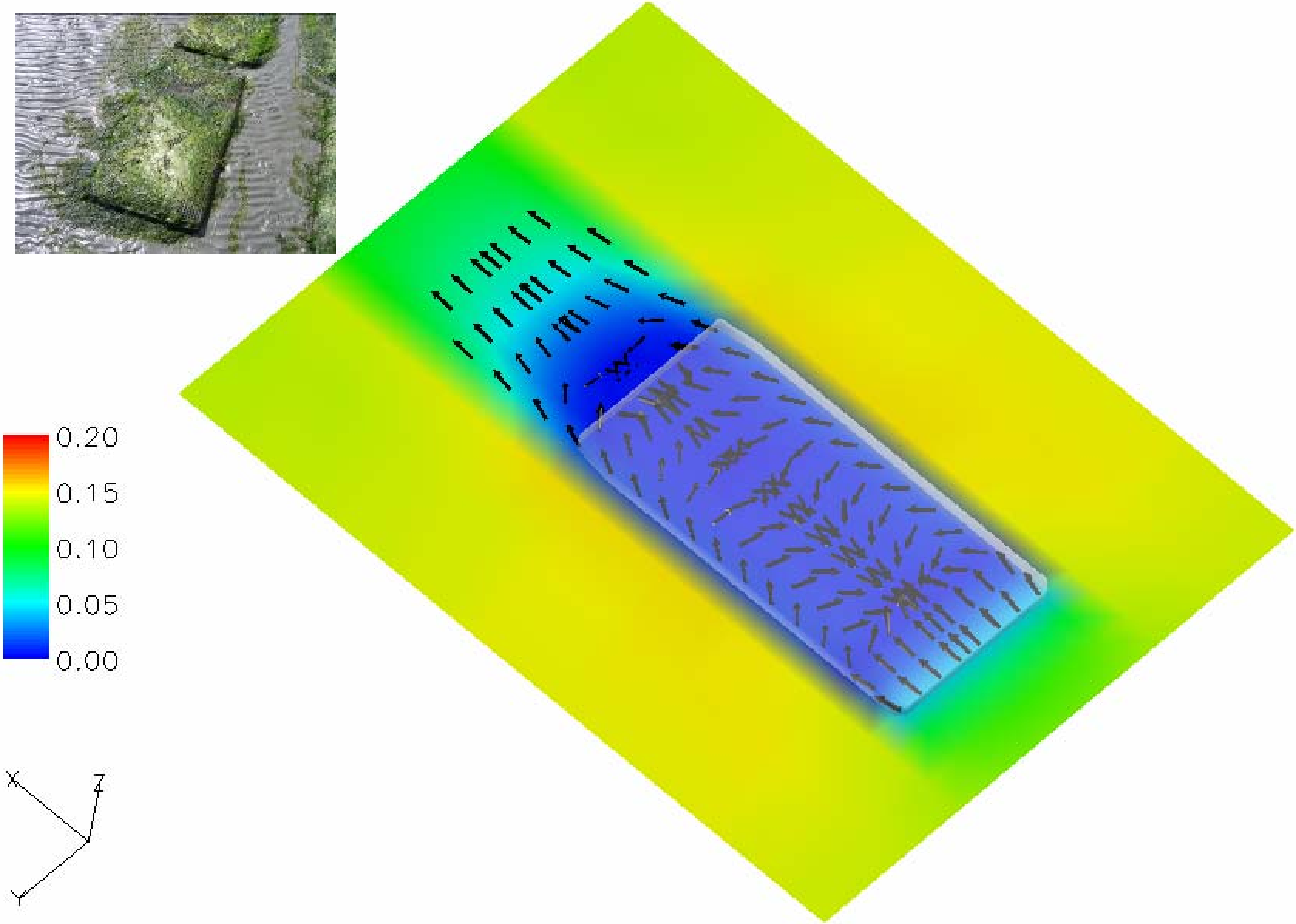
Calculated Flow Pattern
(colored by speed, m/s)

Consumption of food and transport of feces are calculated based on flow patterns surrounding the depuration cage (note: flow speeds in depuration cage are about 100 time less than flow speeds above the eelgrass bed).

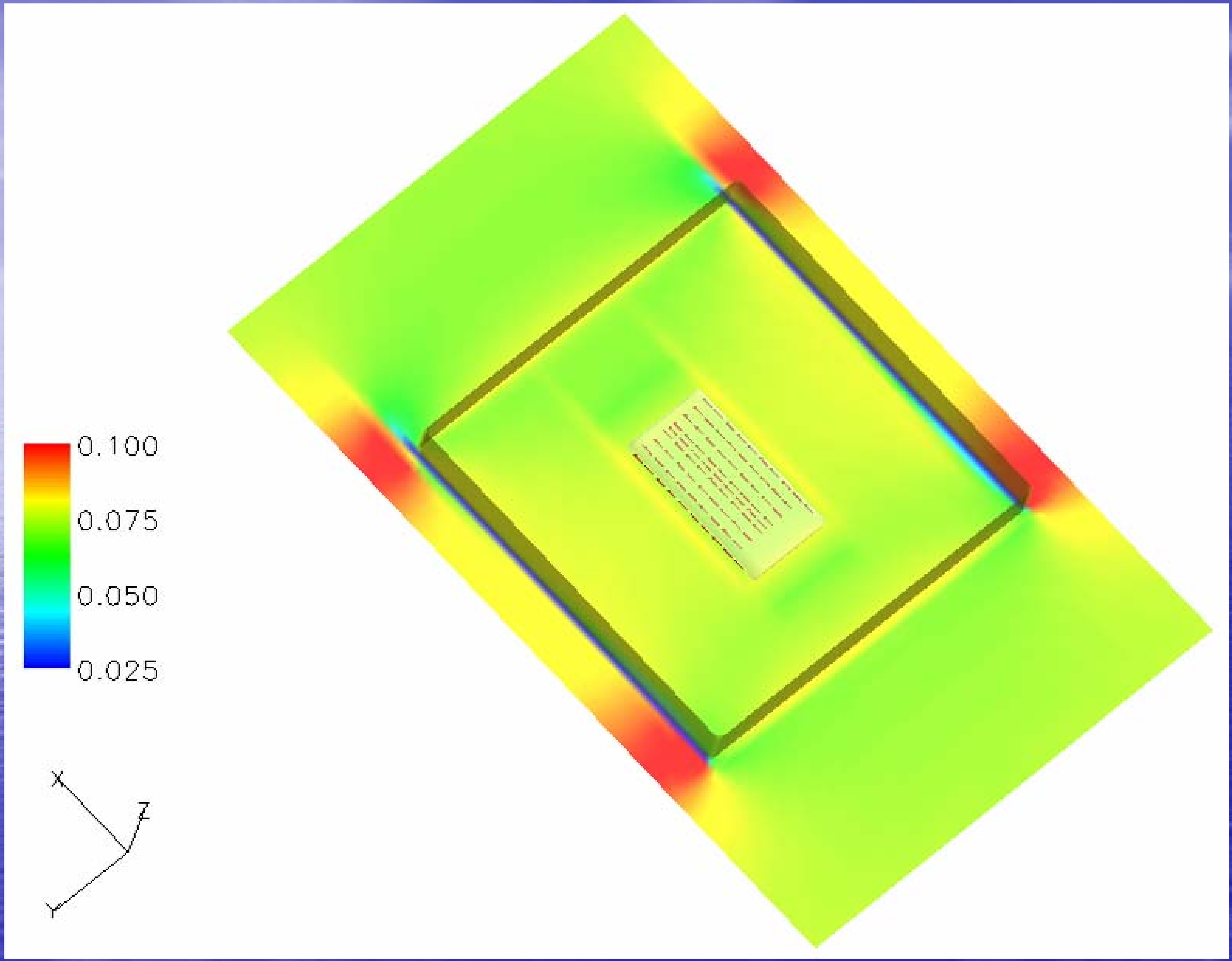




Velocities in the middle of the bag are about 10 times less than the mean flow speed.



Velocities in the middle of the bag are 100 times less than mean flow speeds when the bag is fouled.



Velocities beneath the buoyed net in the clam bed are about ½ of the mean flow speed (note: the amount of biofouling modeled is the same as that modeled for the dirty bag).

Dye studies: clam bags (Eld Inlet)

Mean flow

Injected in front of clam bags: most flow goes outside and over the bag

Future Research

- Continue dye studies of alternative methods to calibrate flow models
- Include particle tracking of organic deposition and effects of waves on resuspension
- Further investigate effects of macroalgae and control methods (harvest and sale?)
- Hydrodynamics of geoduck tubes and bags on racks

Acknowledgements

- Dan Cheney, Andy Suhrbier, Dror Angel, Joth Davis, Tessa Getchis, Mark Luckenbach, NOAA Sea Grant