

CFD analysis of shellfish aquaculture gear used in intertidal and subtidal locations

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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



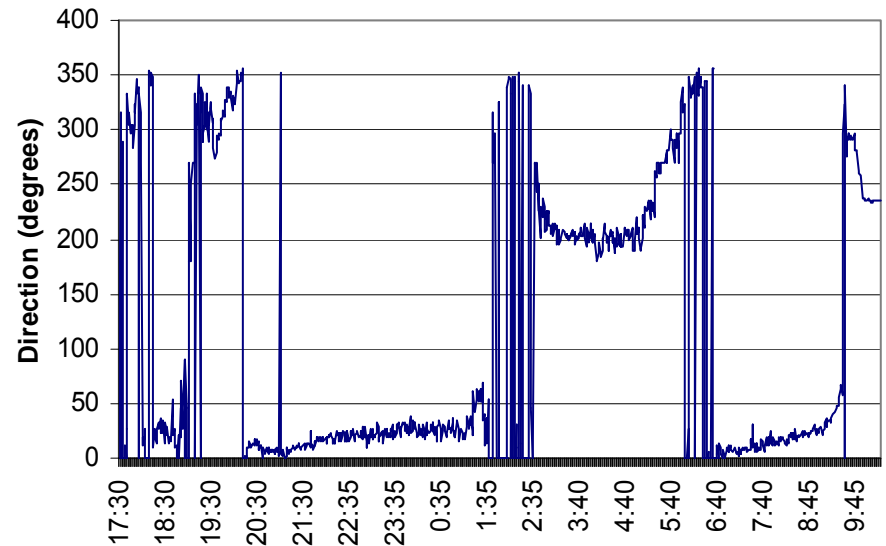
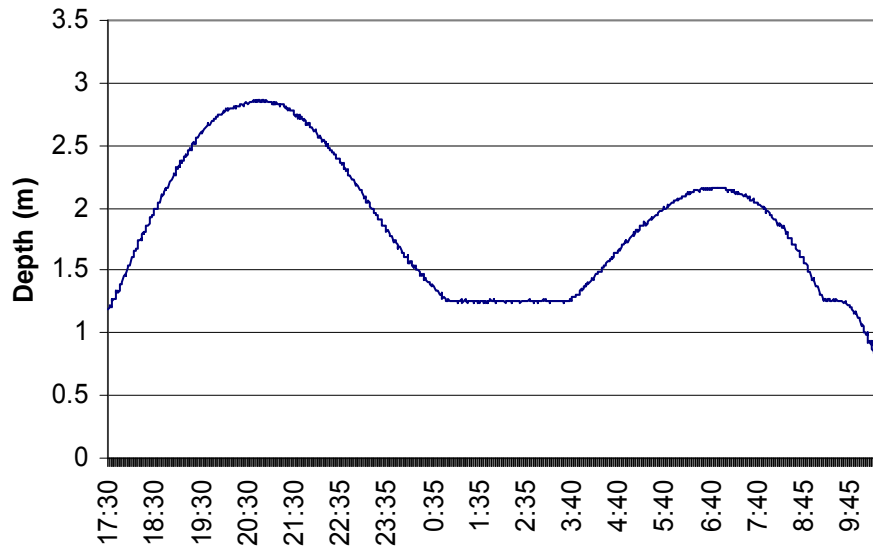
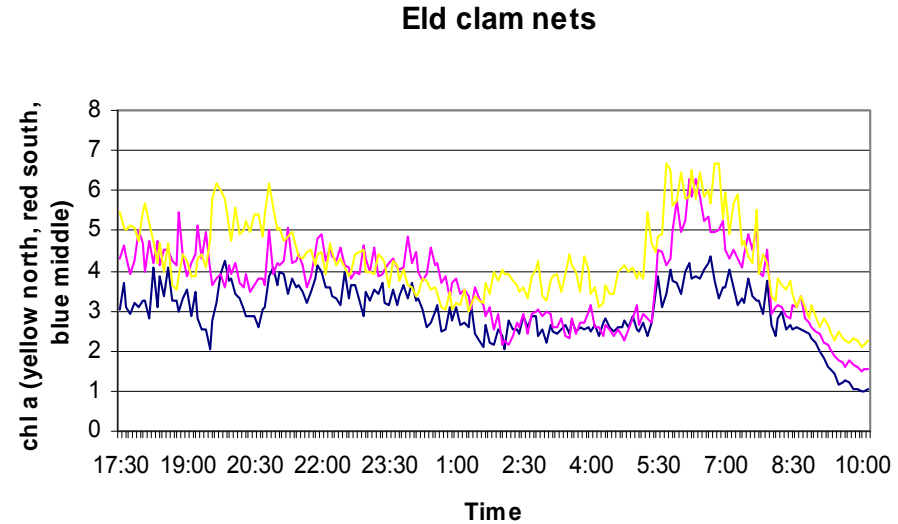
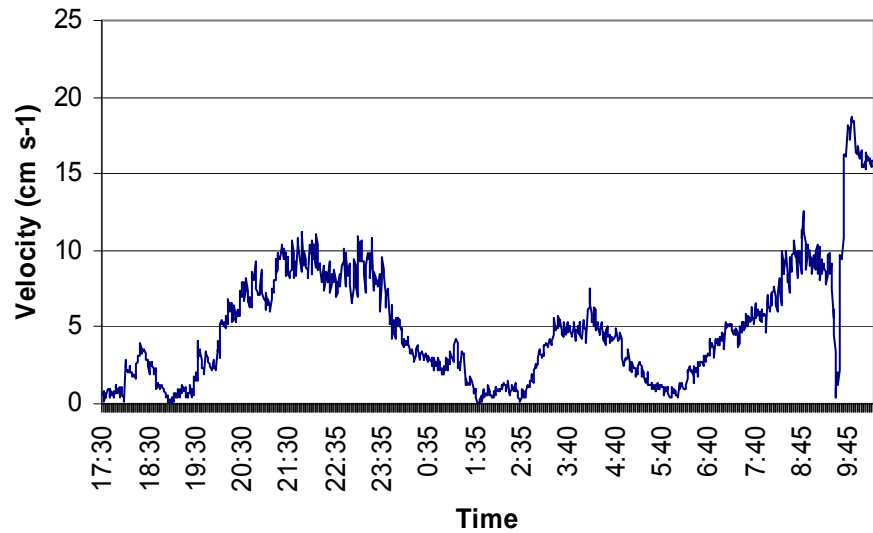
Approach

- 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

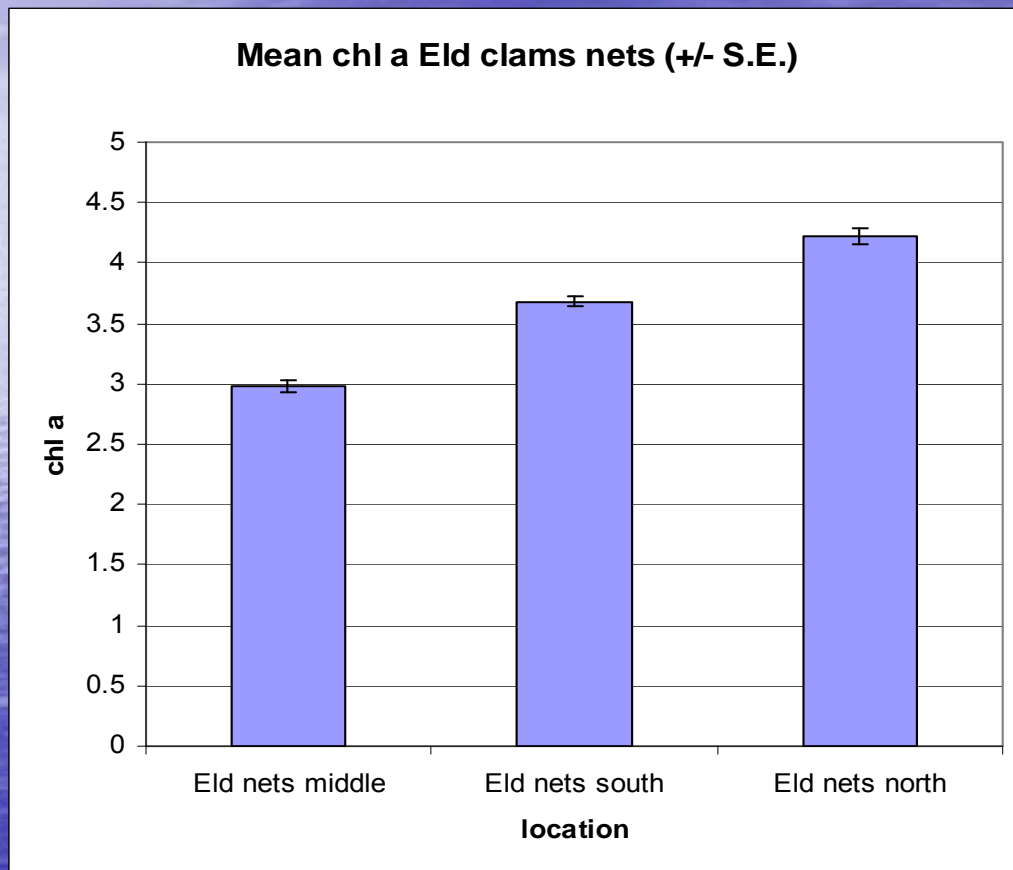


Hydrodynamics and CTD moorings: Eld clam nets

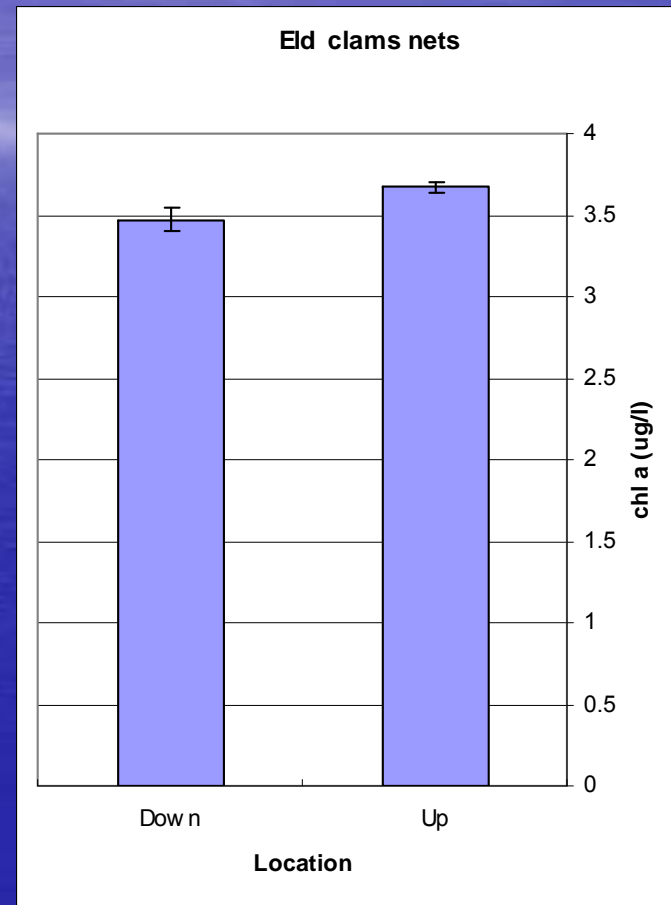
nets June 8-9, 2005



CTD moorings

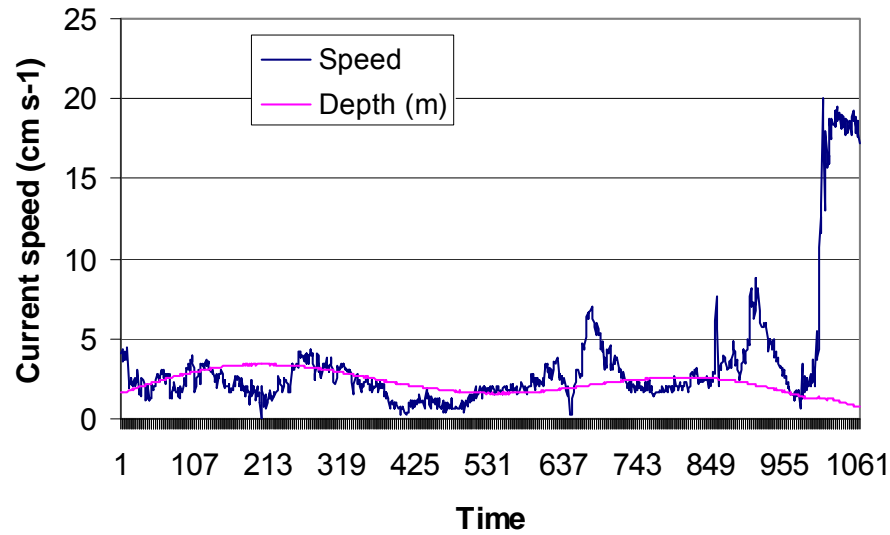


Diver samples

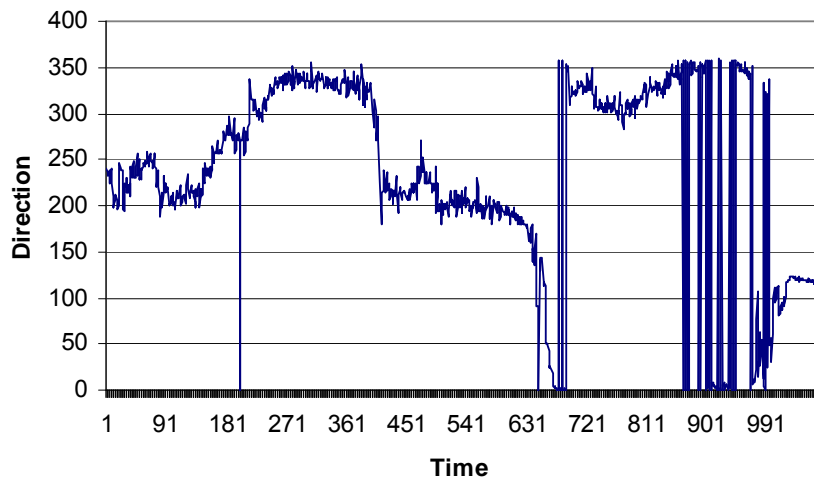
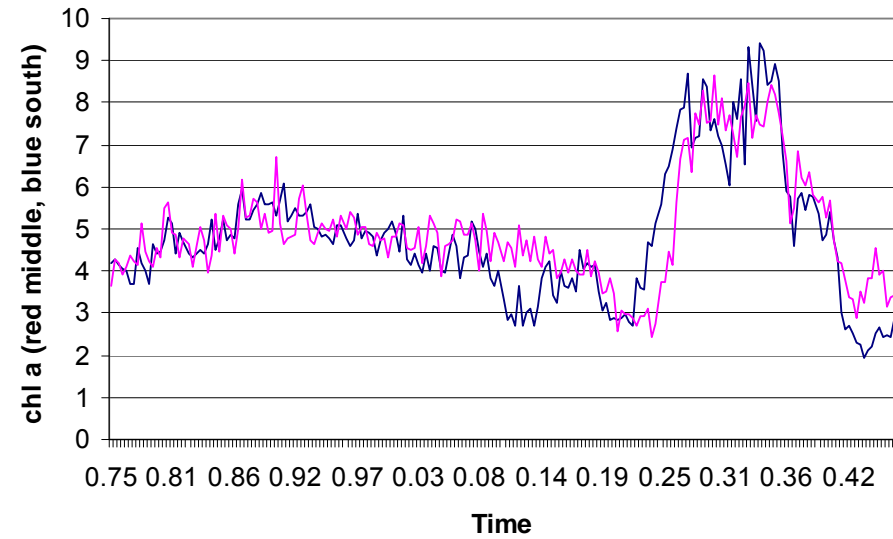


Hydrodynamics and CTD moorings: Eld clams bags June 10-11, 2005

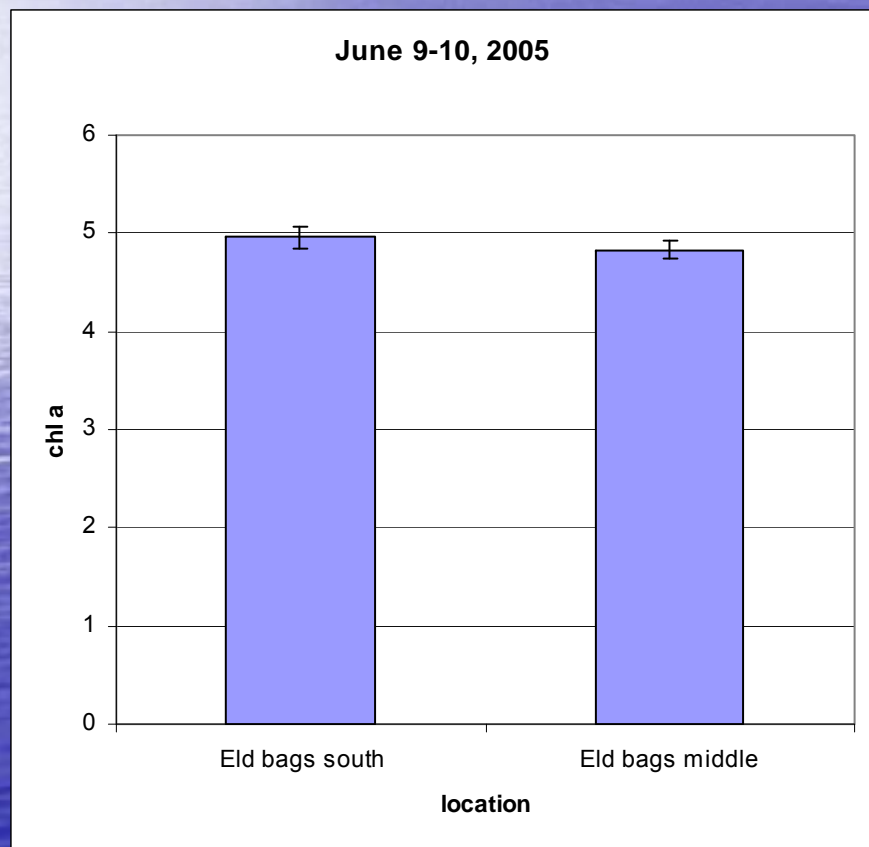
Eld clams bags



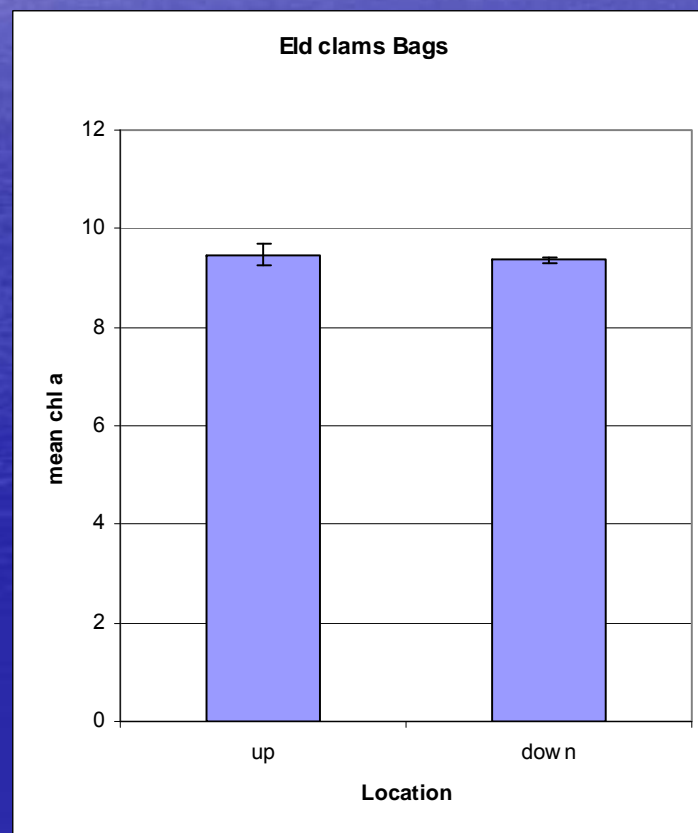
Eld clam bags



CTD moorings

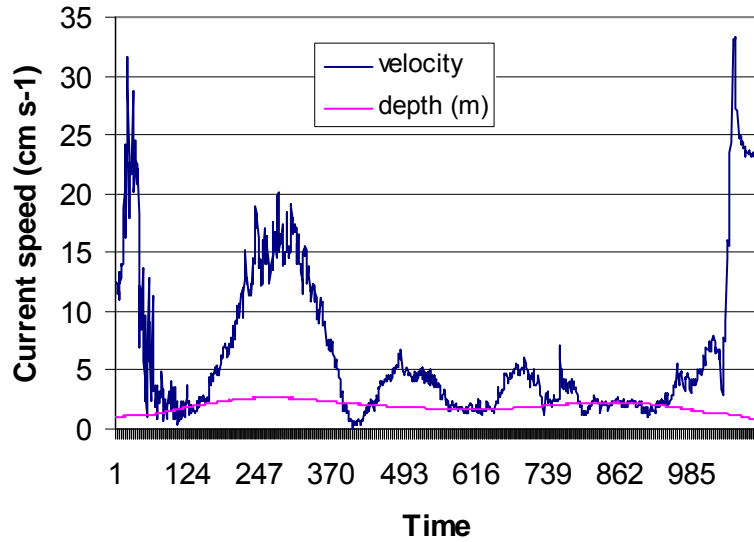


Diver samples

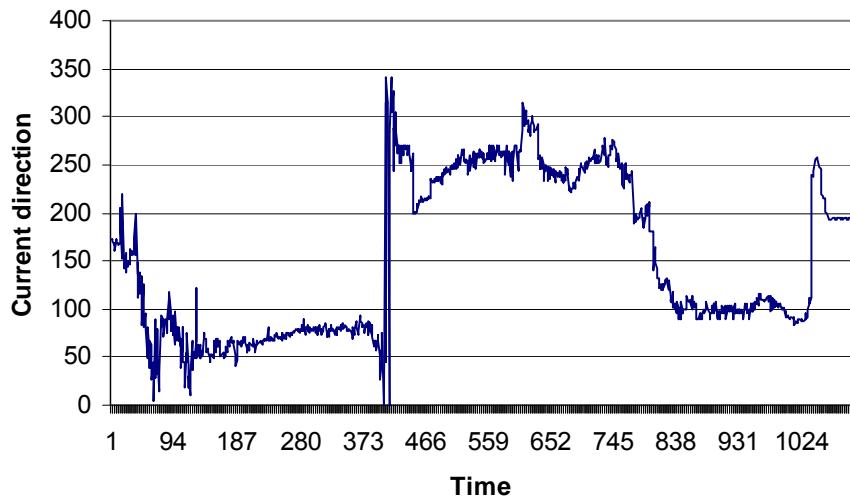
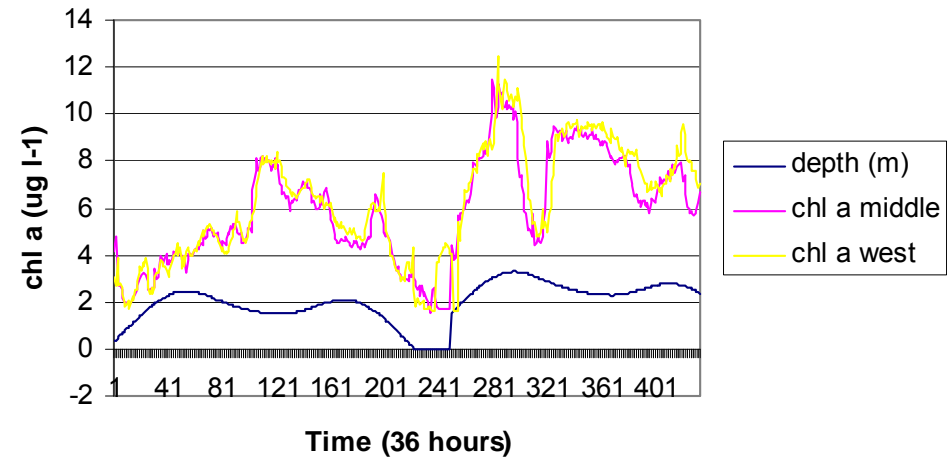


Hydrodynamics and CTD moorings: Thorndyke clams bags June 6-7, 2005

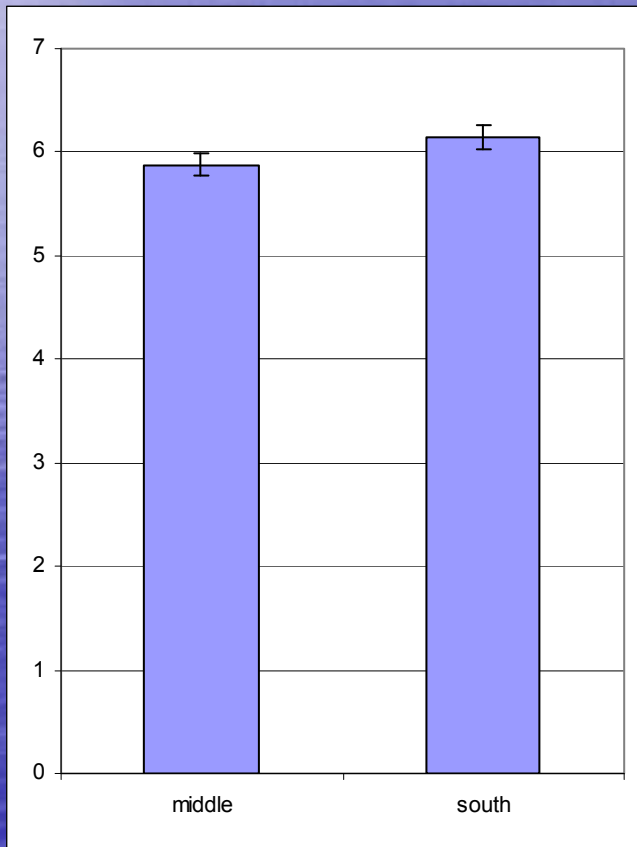
Thorndyke clams velocity



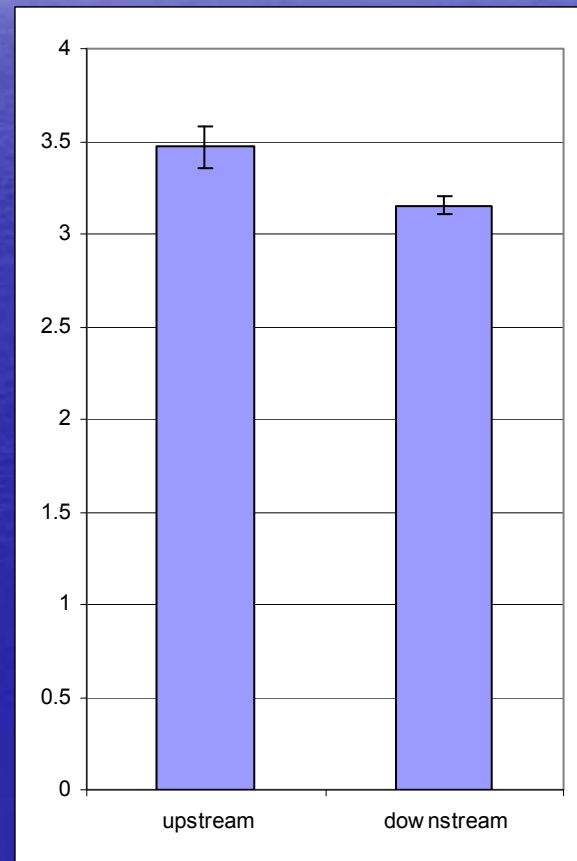
Thorndyke clams bags June 6, 2005 12:30



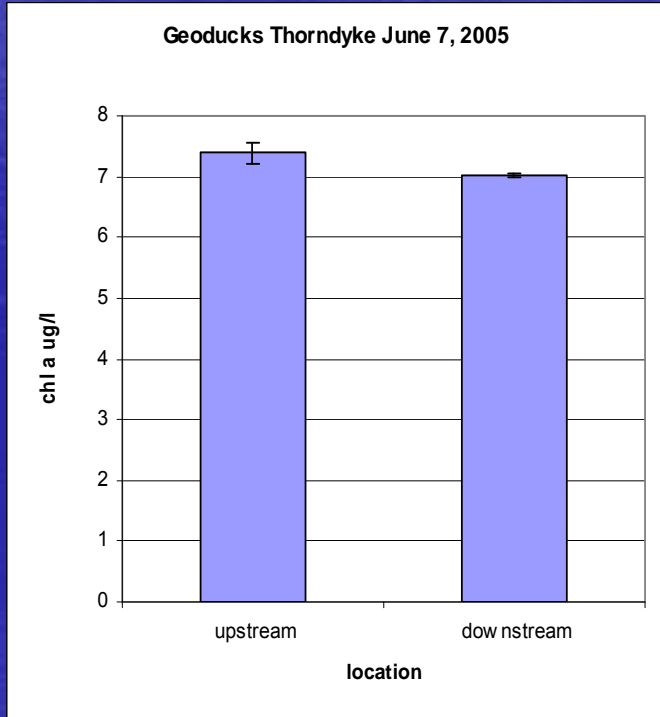
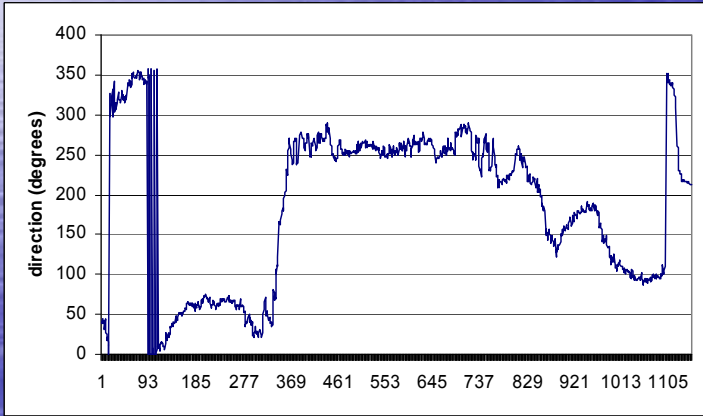
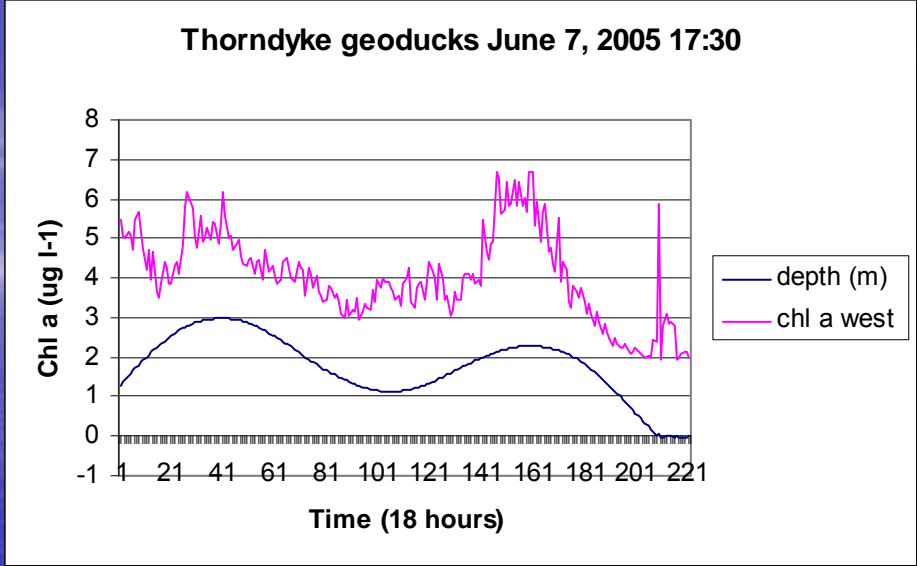
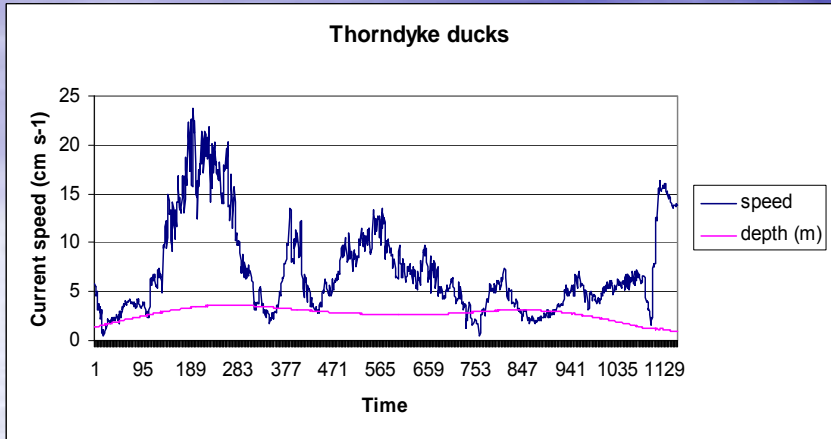
CTD moorings



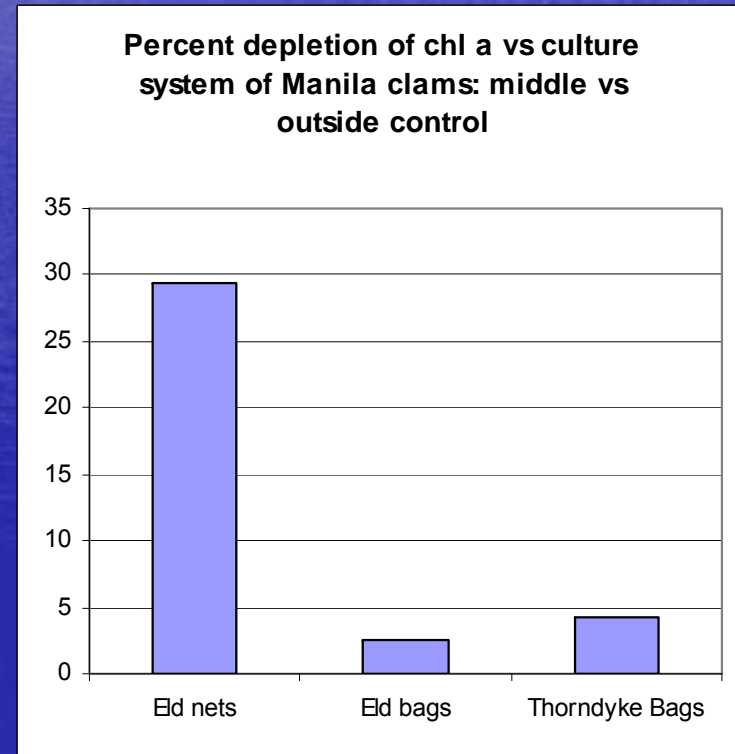
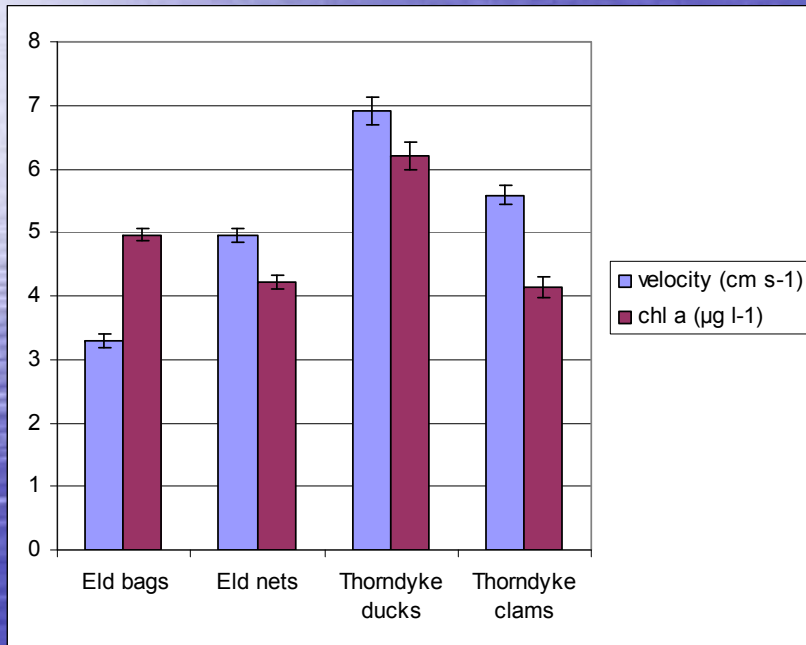
Diver samples



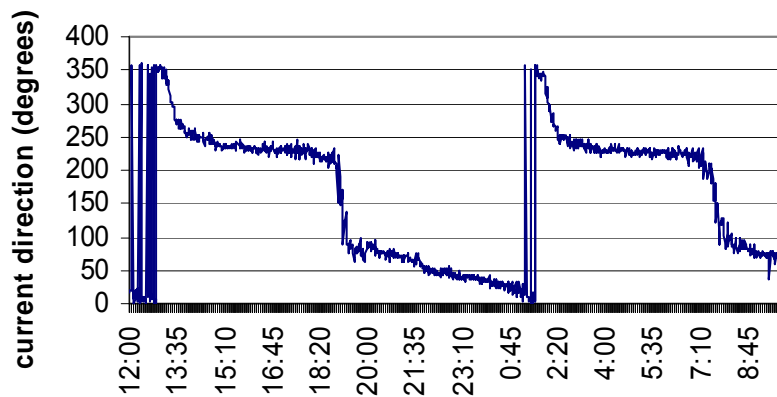
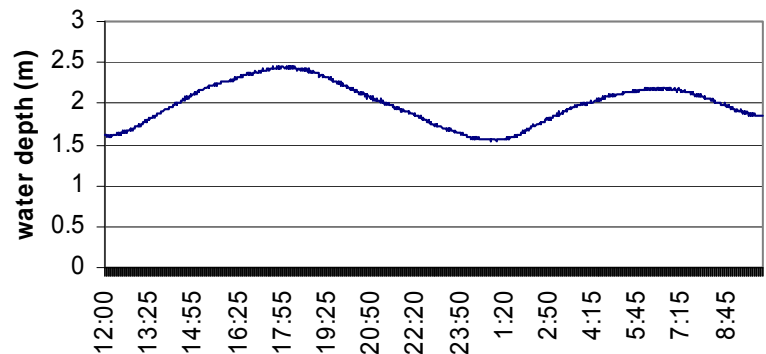
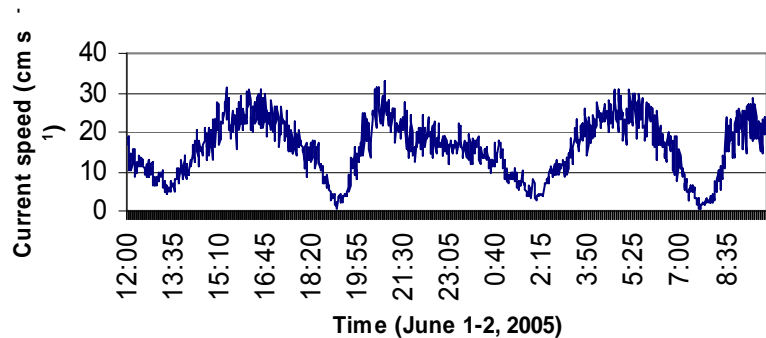
Hydrodynamics, CTD moorings and diver samples, Thorndyke geoducks June 7-8, 2005



Washington State: site comparisons

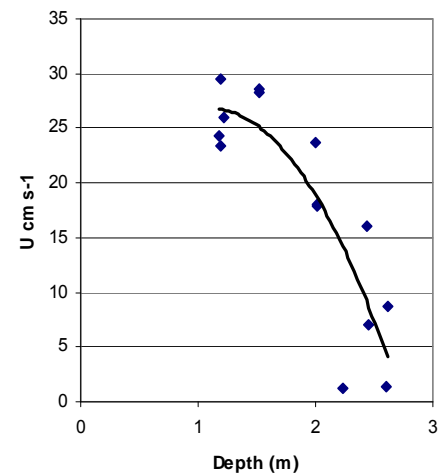


Connecticut relay site

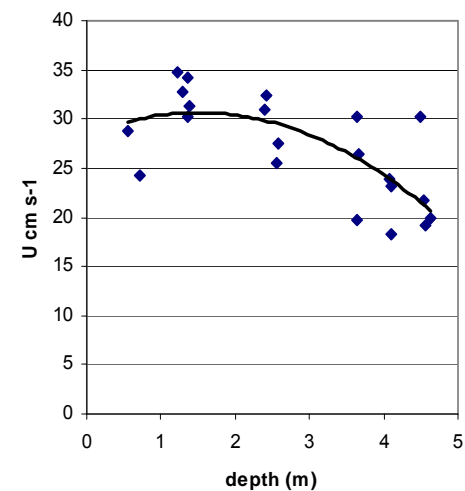


Eelgrass

profile 1a



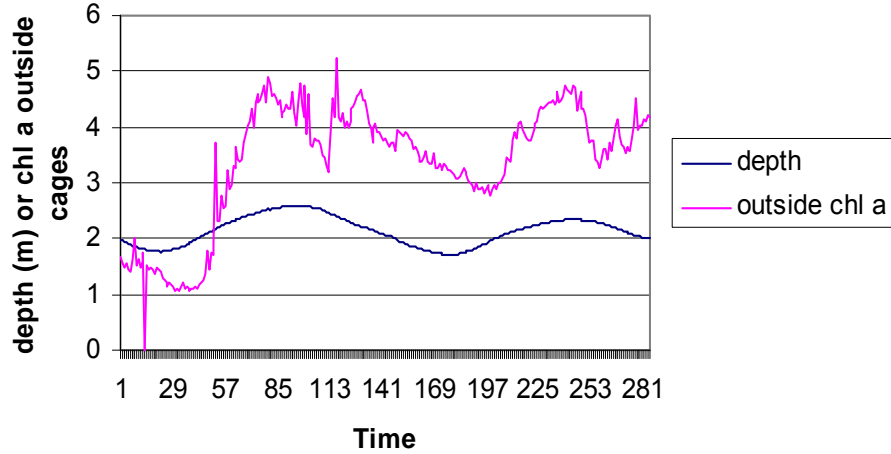
profile 2 (no eelgrass)



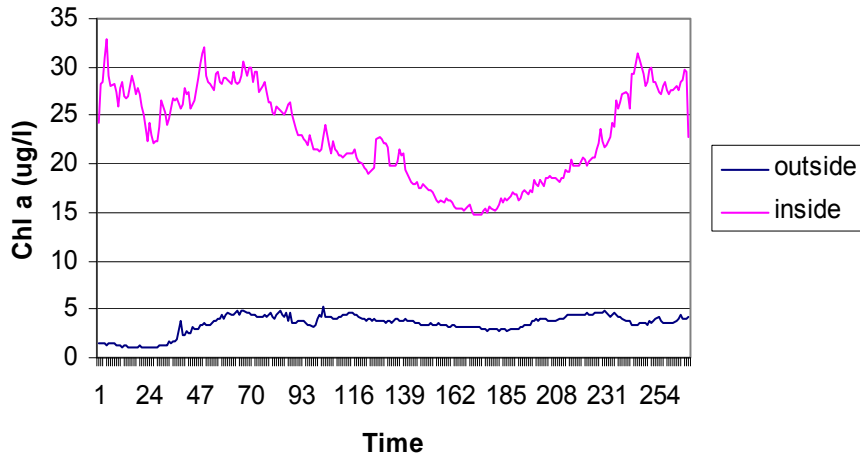
No eelgrass

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

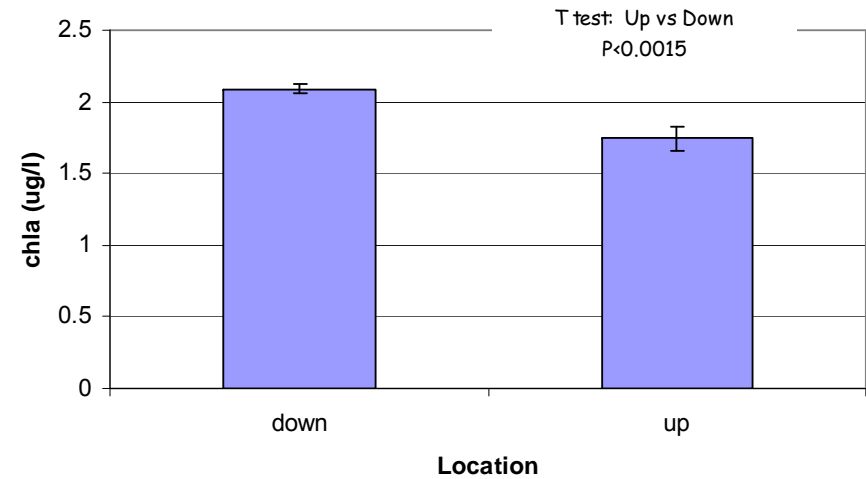
Connecticut relay site



Mouse Island Connecticut



Ram Island cages in eelgrass bed



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

Clam bags, Washington State



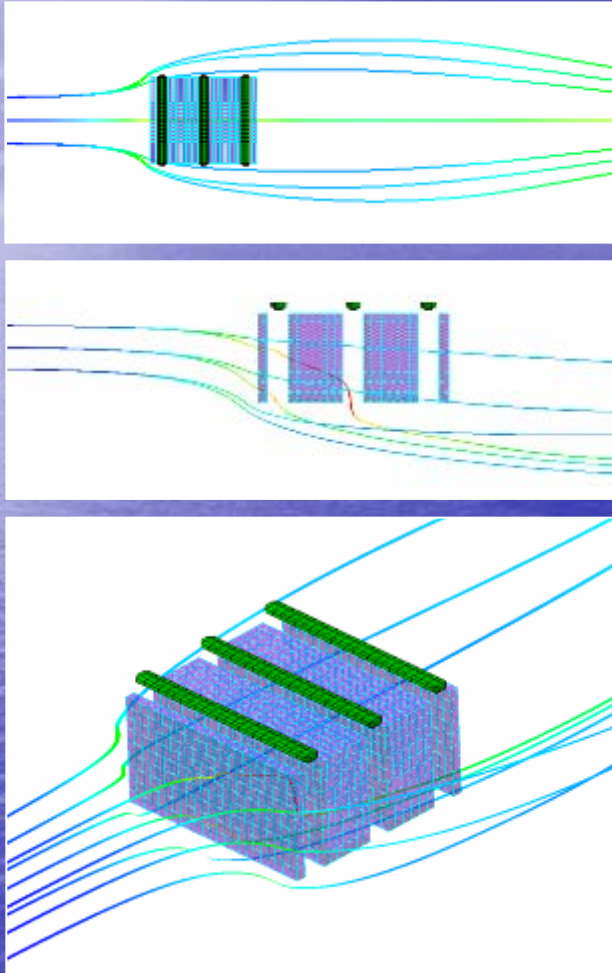
Clam nets, Virginia





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.



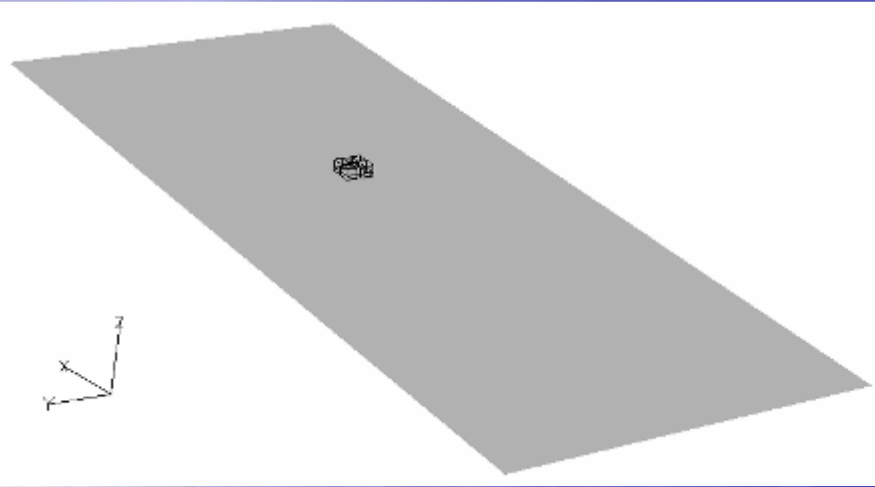
Modeling Approach

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

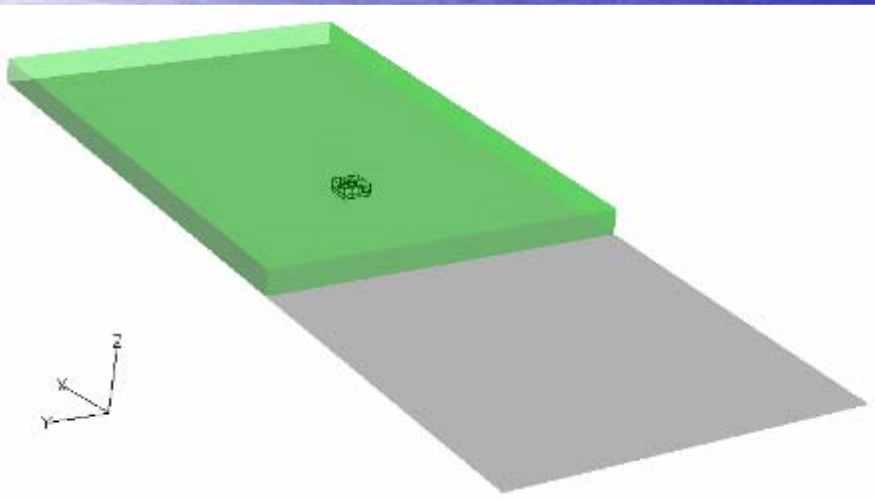
The Volume-of-Fluid (VOF) is capable of simulating flooding and drying.

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

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



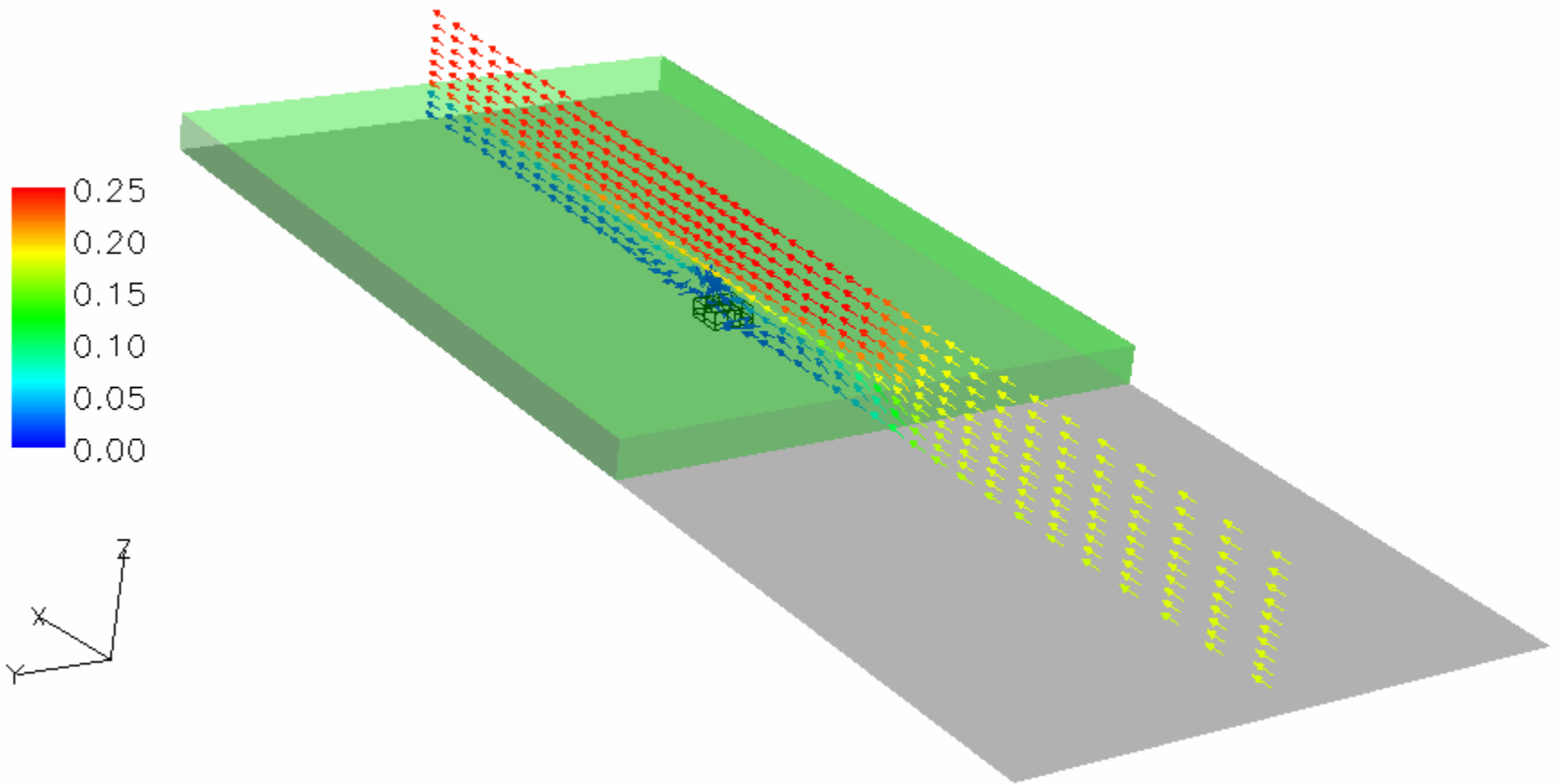
Model Domain and Depuration Cage



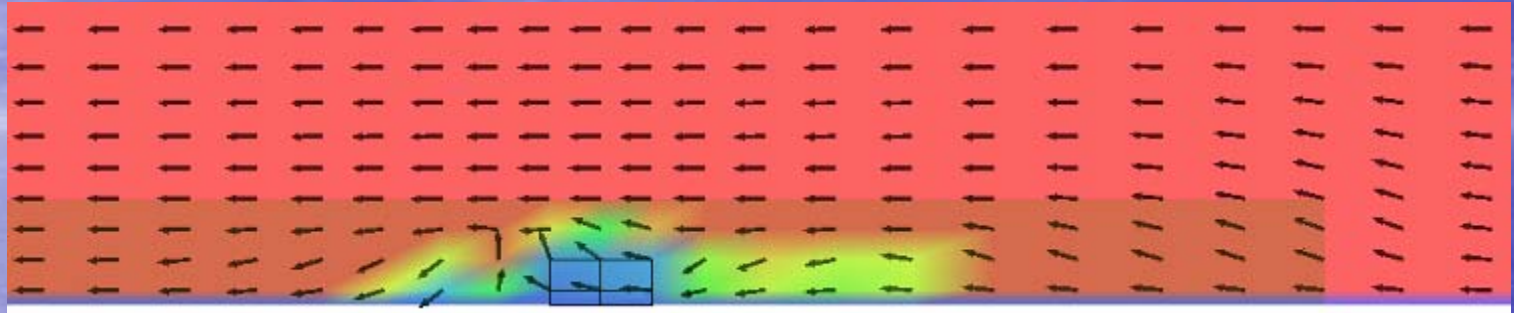
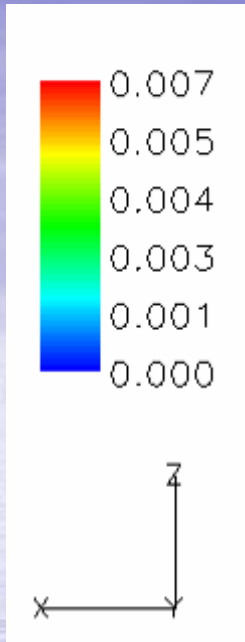
Depuration Cage and Eelgrass Bed

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

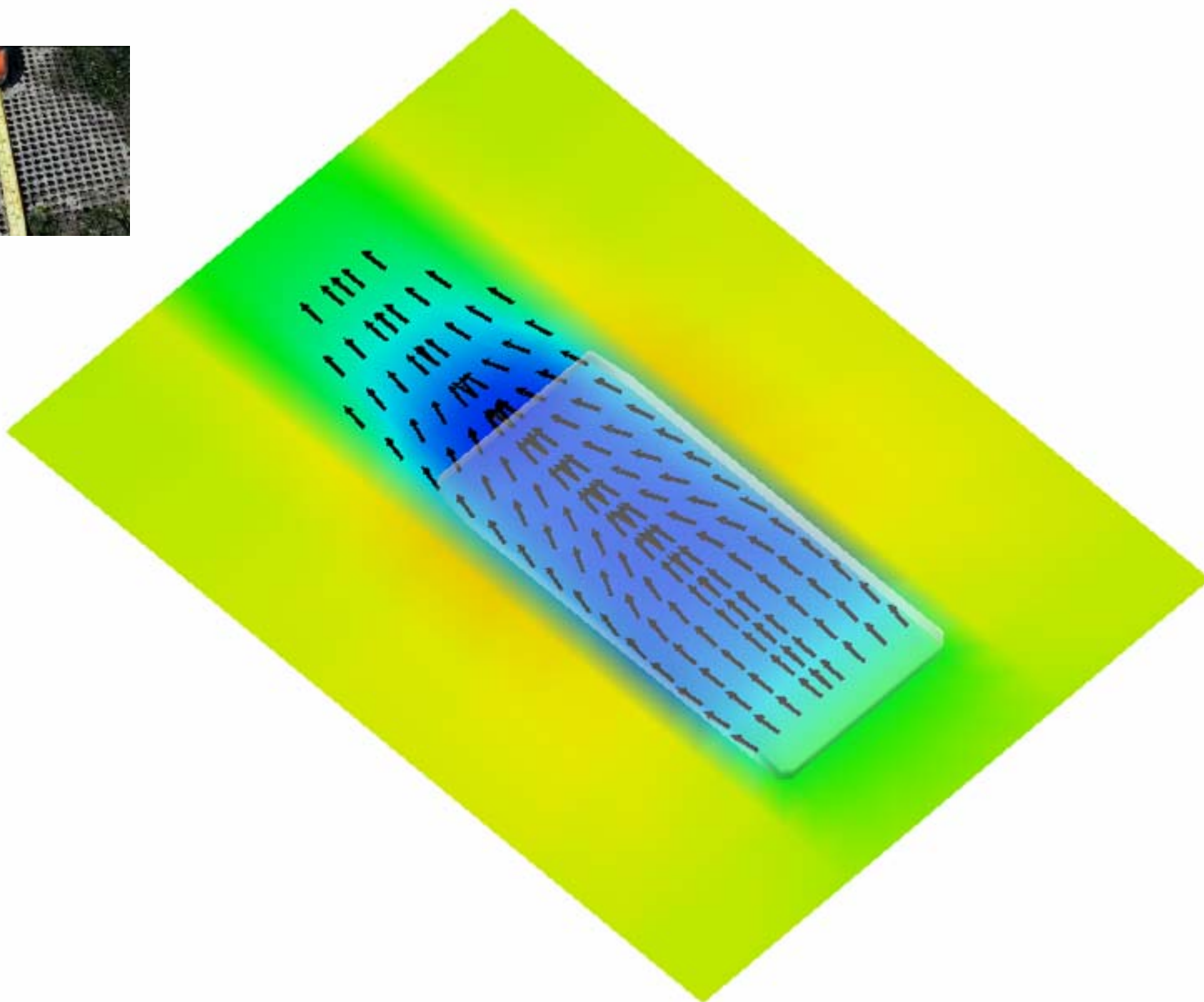
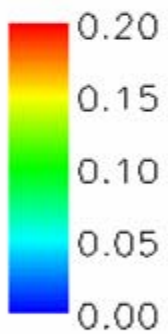


Calculated Flow Pattern
(colored by speed, m/s)

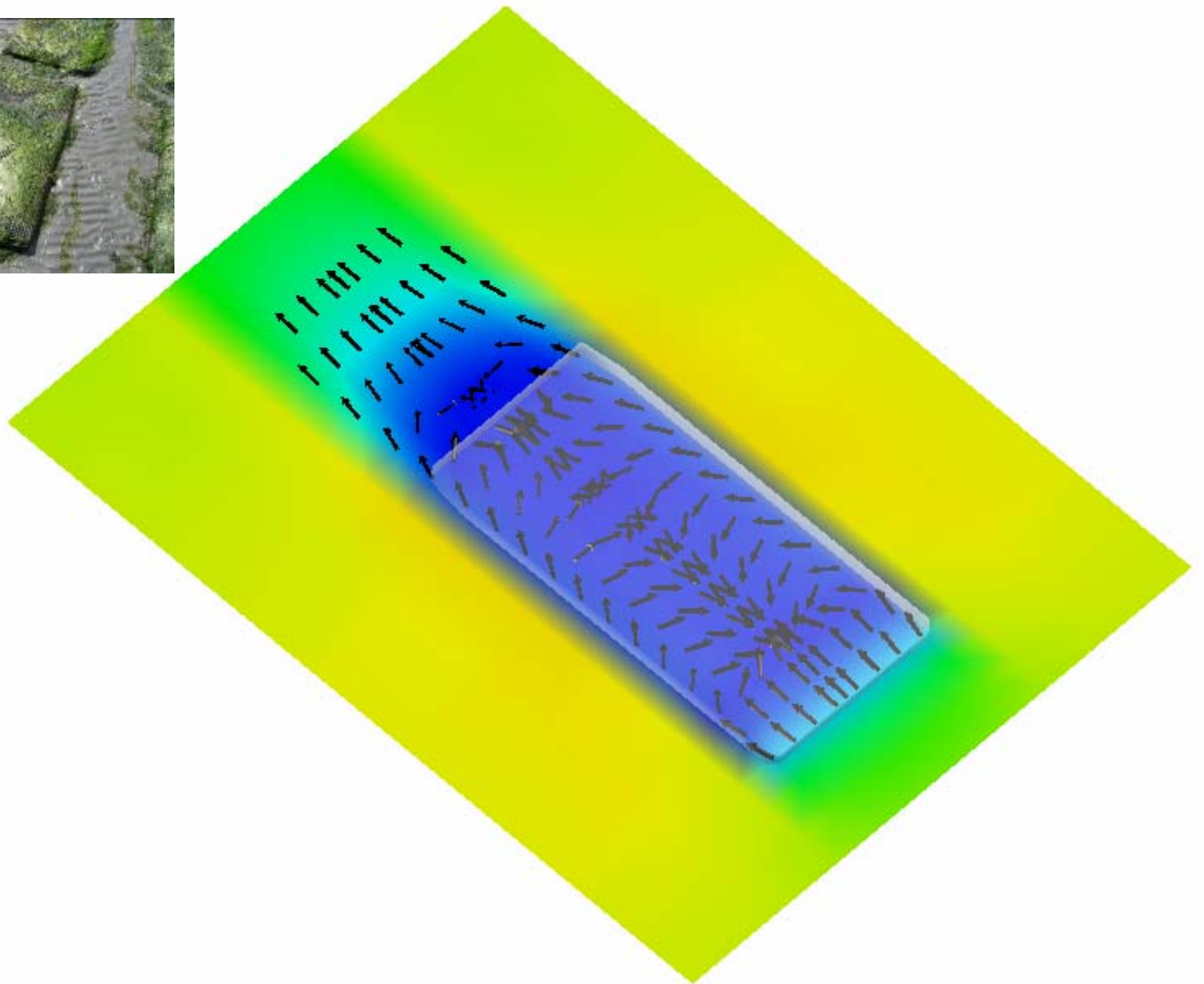
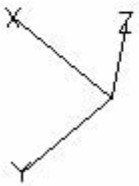
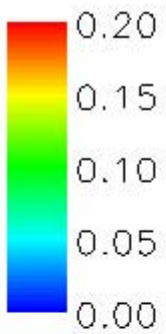


Calculated Flow Pattern
(colored by speed, m/s)

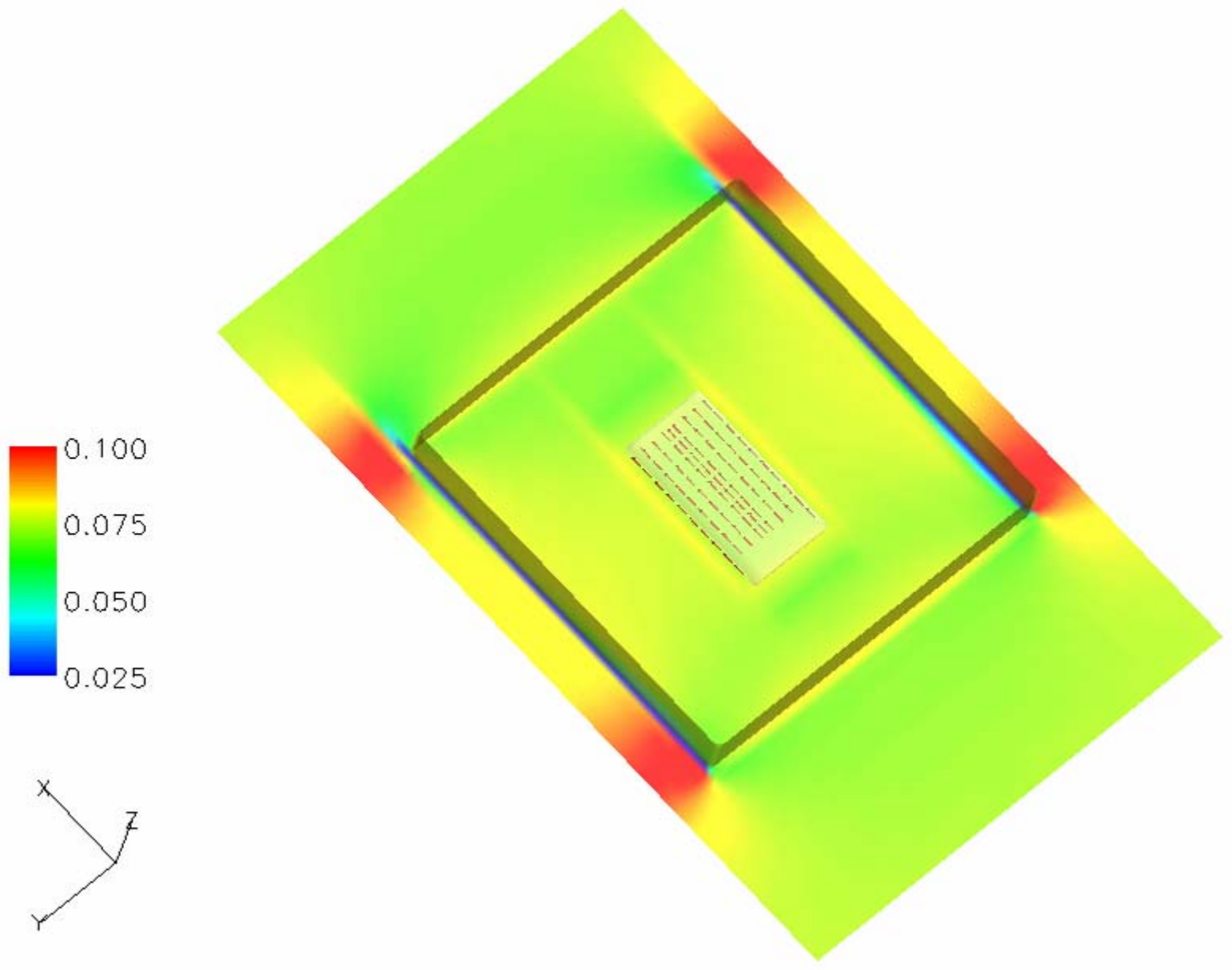
Consumption of food and transport of feces are calculated based on flow patterns surrounding the deputation cage (note: flow speeds in deputation cage are about 100 time less than flow speeds above the eelgrass bed).



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 $\frac{1}{2}$ 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

