AquaModel:
Mariculture model development and testing

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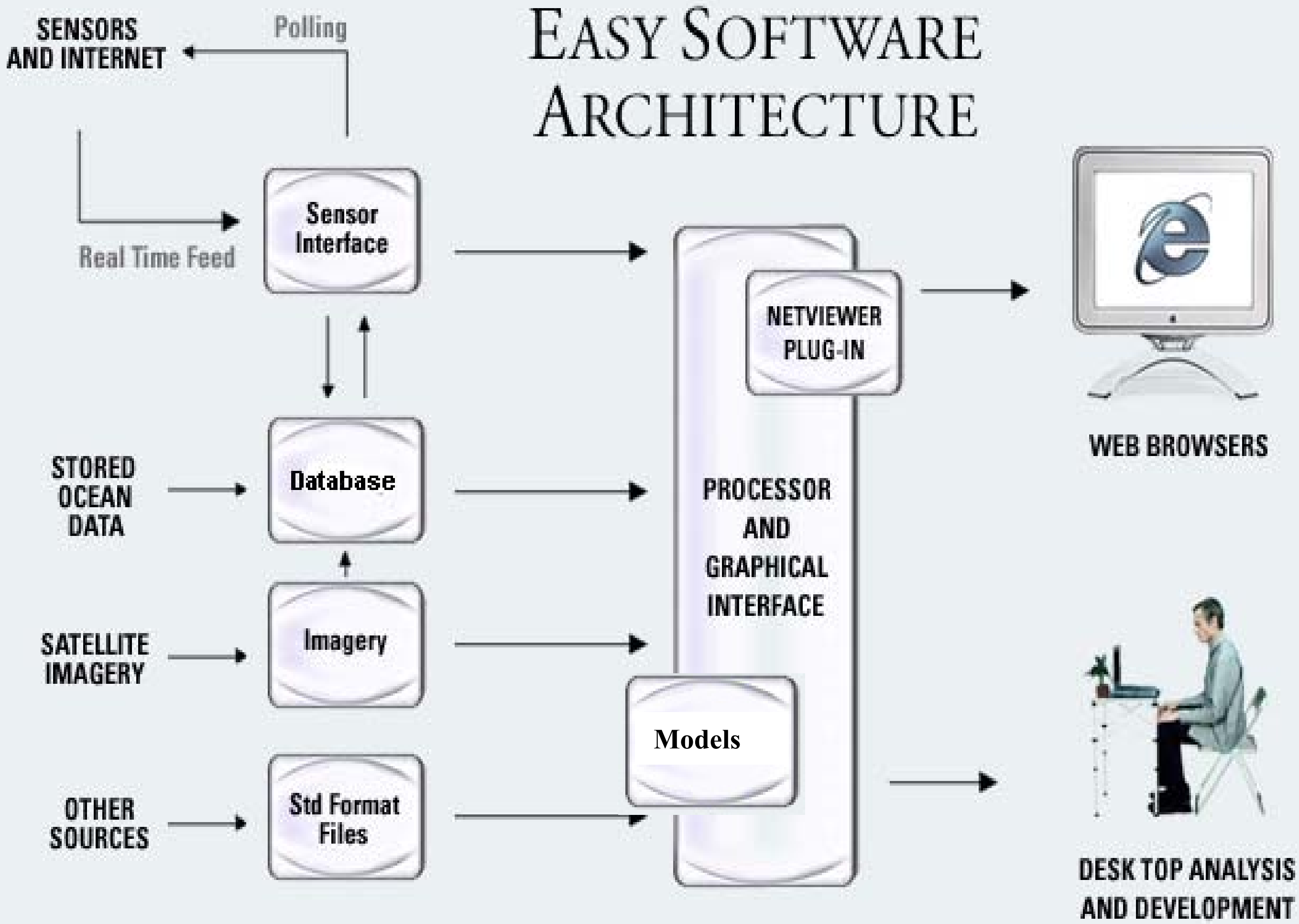
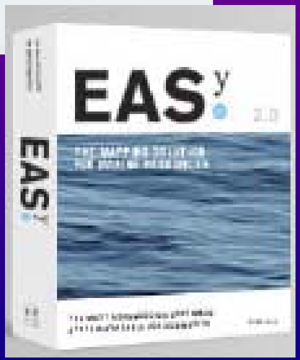
Overview of Talk

- GIS known as EASy: Environmental Assessment System
- Examples of GIS use
- AquaModel within a Geographic Information System (GIS)
- General architecture of AquaModel & its origins
- Output features and application in two different ecoregions
- Short clips of model running real time



- Three dimensional system for marine applications
- Compatible with ESRI (arc-info) GIS
- Interfaces for models, spreadsheets, databases, and Internet



EASy Graphical Environment

Species richness relative to bathymetry, water density differentials & bottom temperature

Time Series plots

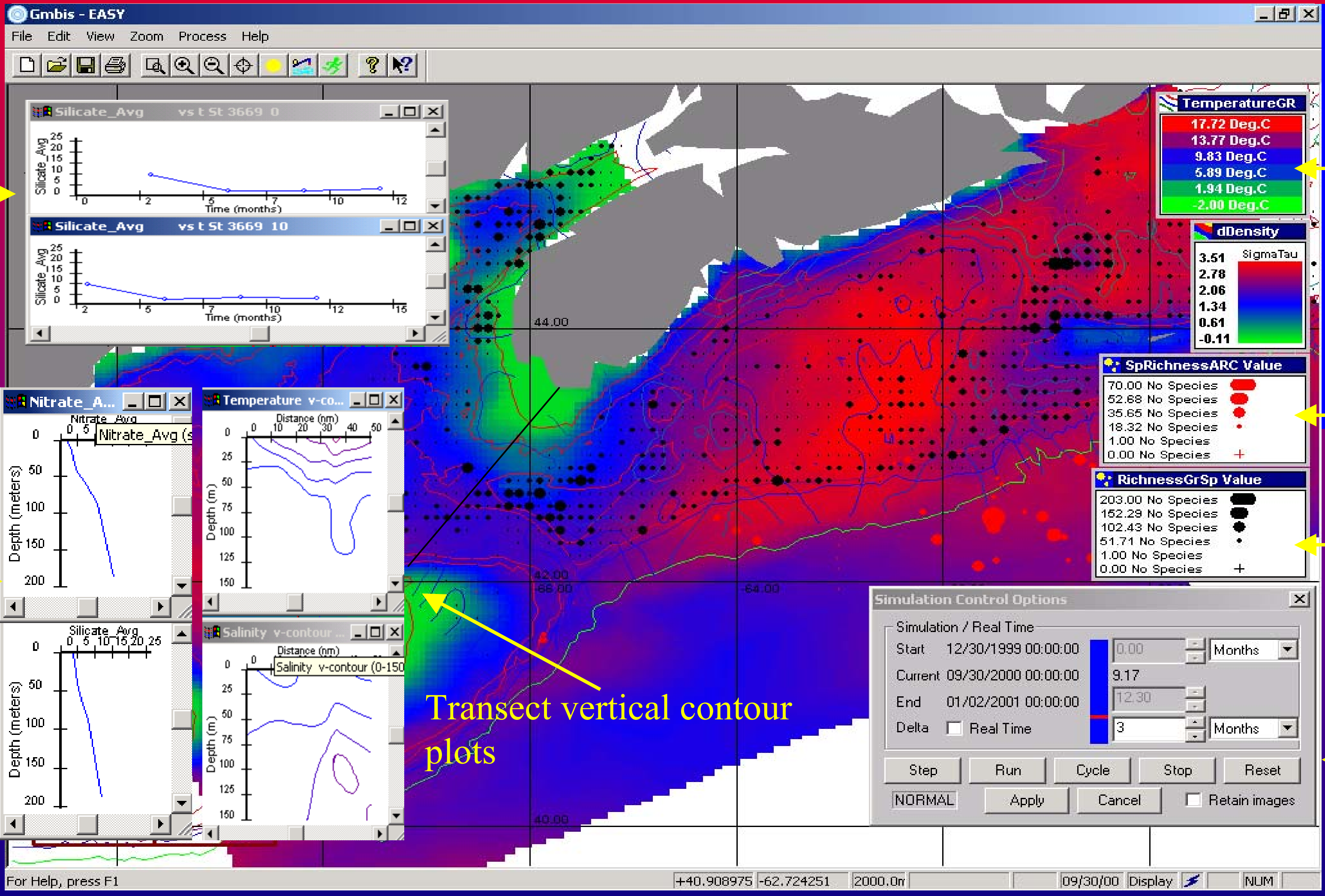
Depth profile plots

Contour plot

False colour plot

Bubble Plots

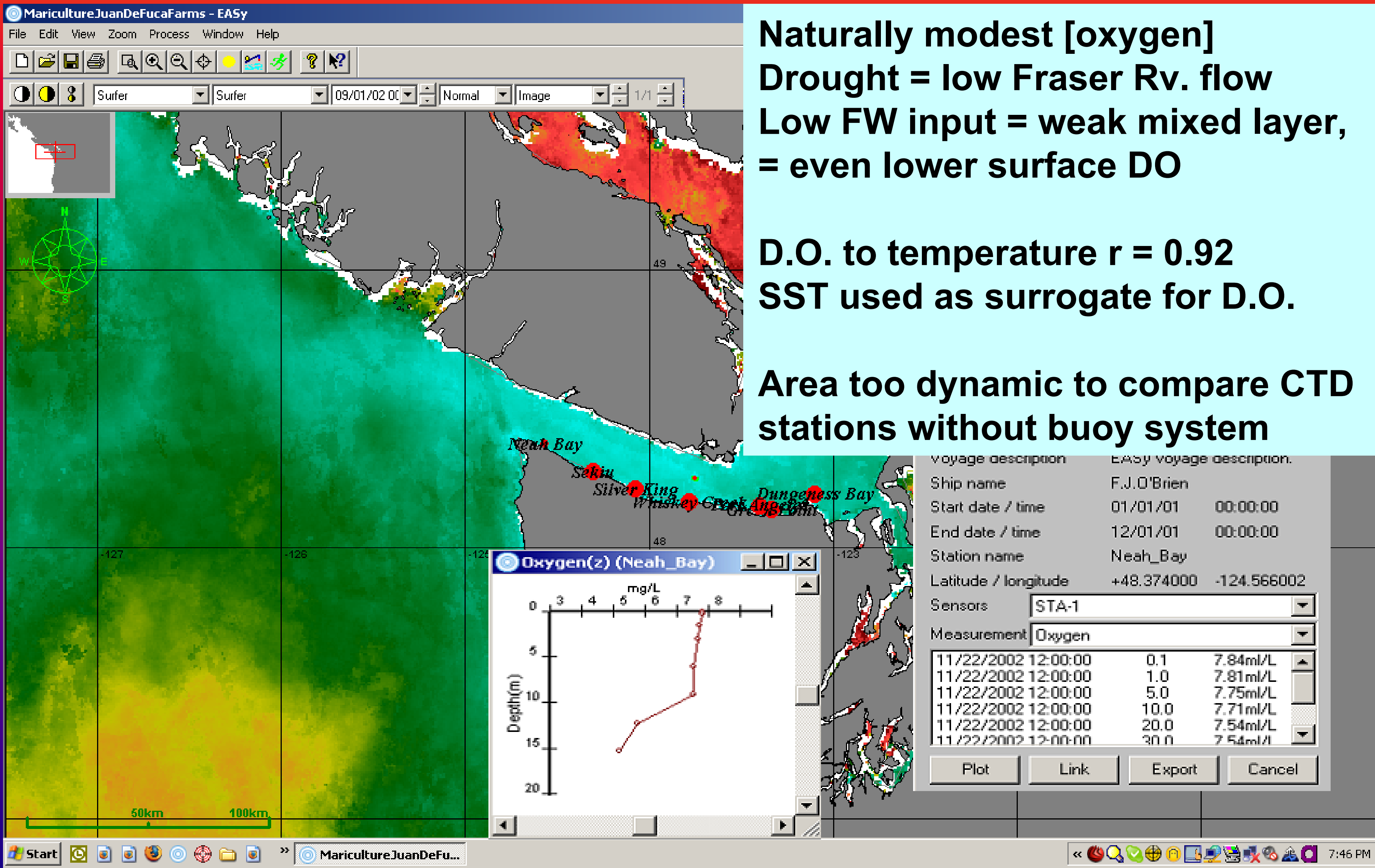
Simulation control panel



Transect vertical contour plots

Tsontos, V. M. and D. A. Kiefer. 2000. Oceanography 13(3): 25-30.

Physicochemical Characterization: Strait of Juan de Fuca 30 - 50 m Zone
Possible mariculture site with strong currents & HNLC conditions

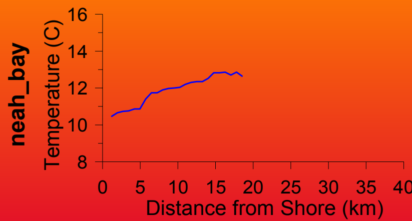


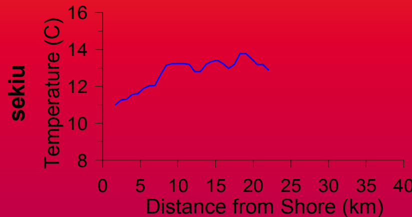
Naturally modest [oxygen]
Drought = low Fraser Rv. flow
Low FW input = weak mixed layer,
= even lower surface DO

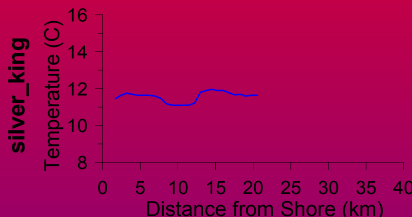
D.O. to temperature r = 0.92
SST used as surrogate for D.O.

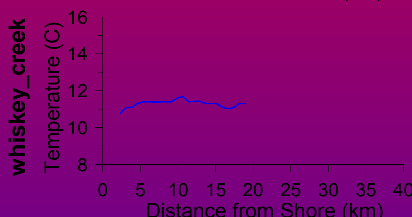
Area too dynamic to compare CTD stations without buoy system

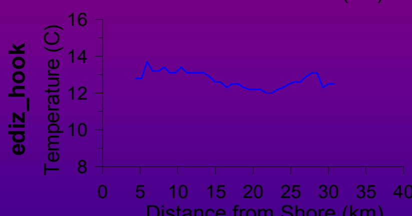
Longitudinal and cross channel transects

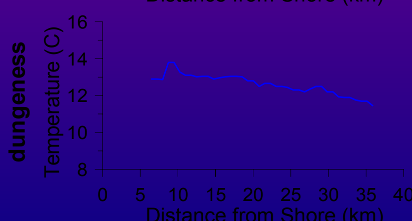












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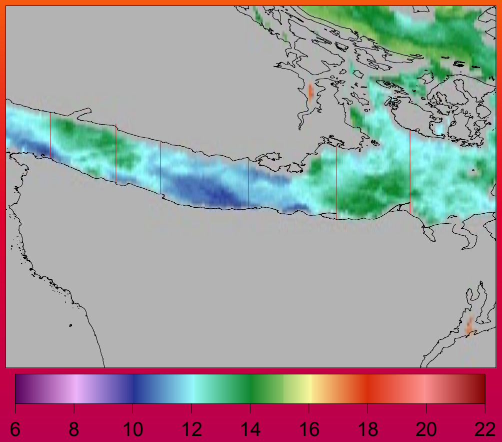
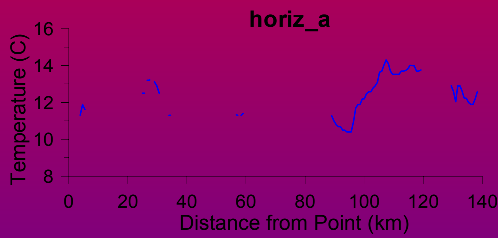
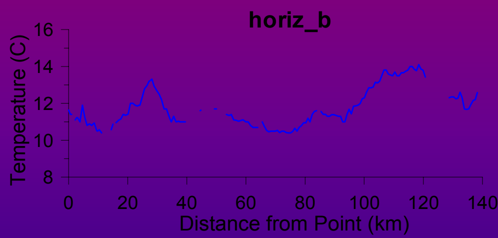
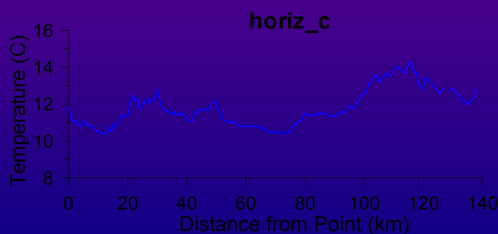
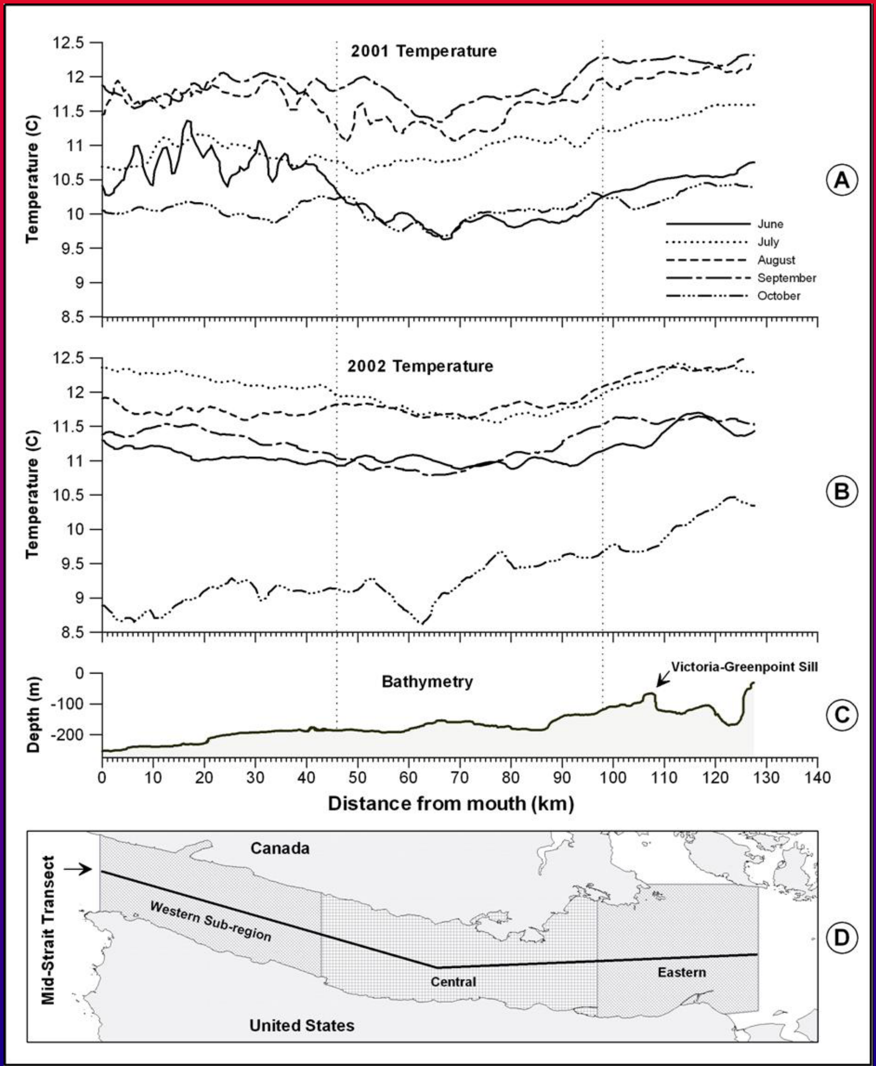
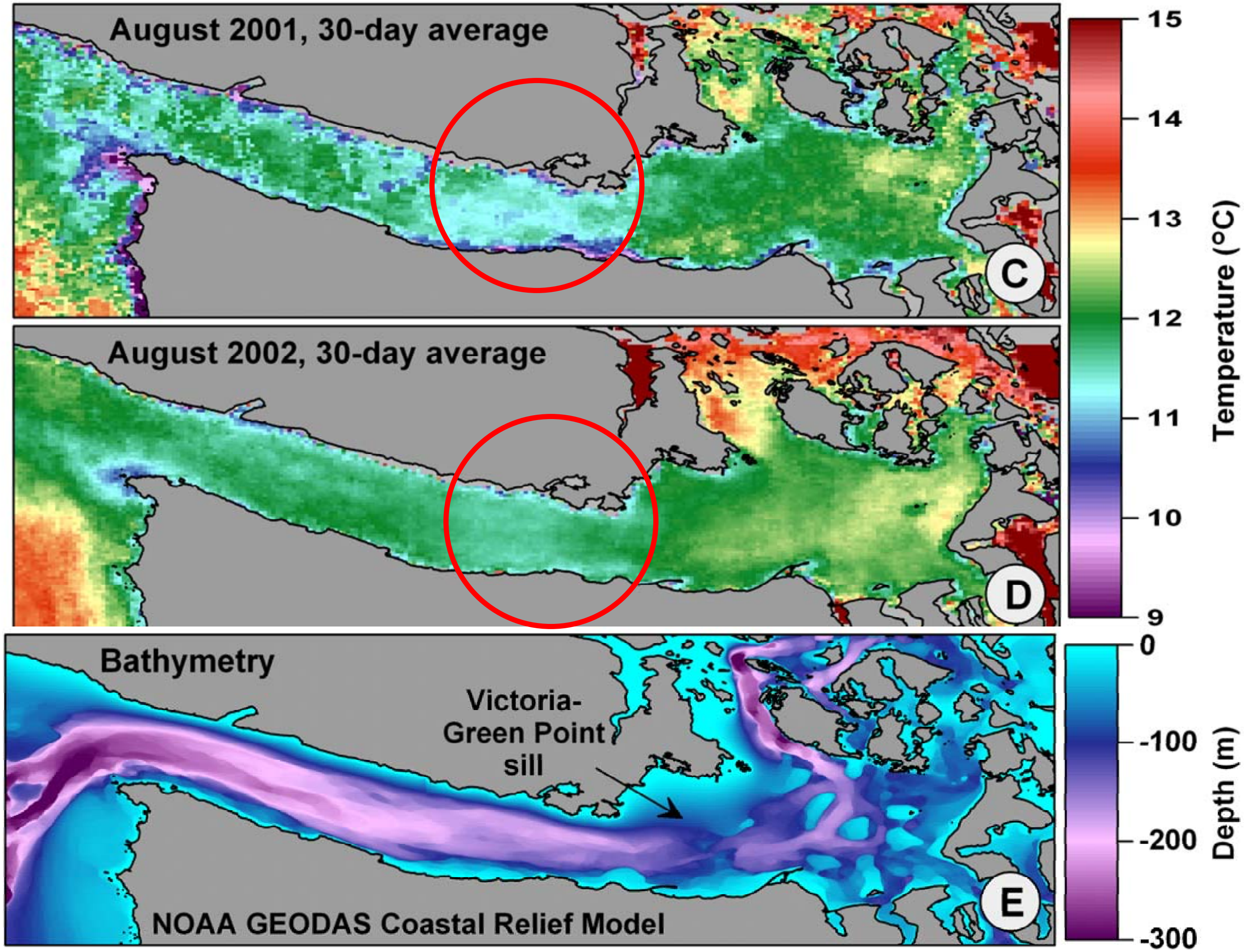












- **Significantly lower temperature,**
- **Therefore dissolved oxygen lower too**
- **Implications for farm siting**

Rensel et al. submitted

Primary AquaModel simulation variables

Near field use:

1) carbon flux ➔ Benthic footprint of organic carbon deposition
resuspension, transport and respiration

2) Oxygen flux ➔ Fish Respiration limits pen loading
TOC drives sediment oxygen demand

Meso-field use:

1) Nitrogen flux ➔ Pelagic footprint
Simulates excretion of NH4, Phytoplankton growth
& Zooplankton grazing

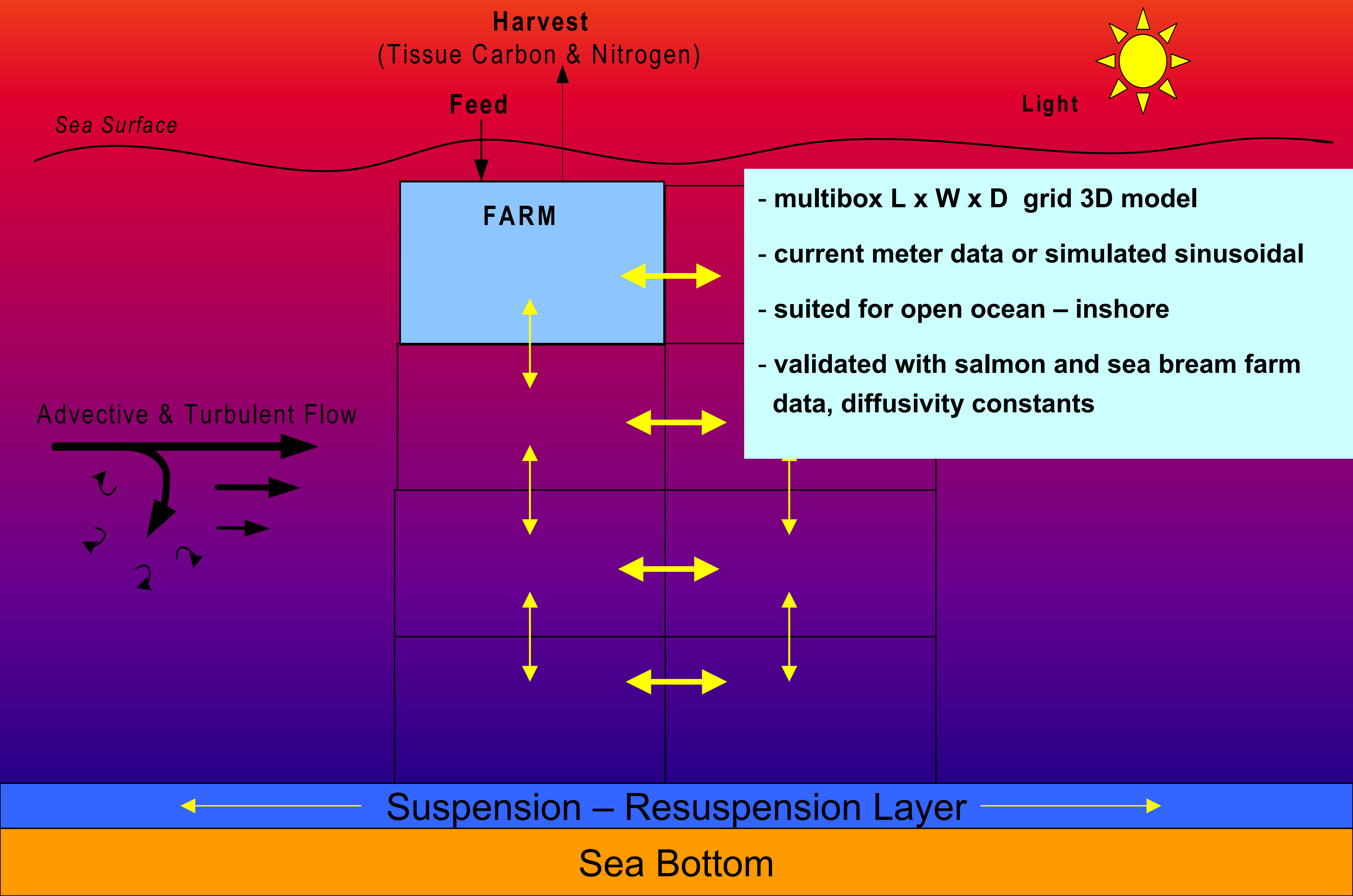
Other simulated outputs including profiles & transects:

- Instantaneous fish growth rate
- Fish biomass
- Optimal feed requirement
- Fecal carbon distribution
- Waste feed carbon distribution
- Sediment anaerobic and aerobic profiles
- Sediment deposition by component: fecal, feed, combined
- Near bottom suspended layer DO: fecal, feed, combined

All outputs from vertical profiles recorded to spreadsheet file if desired from several locations

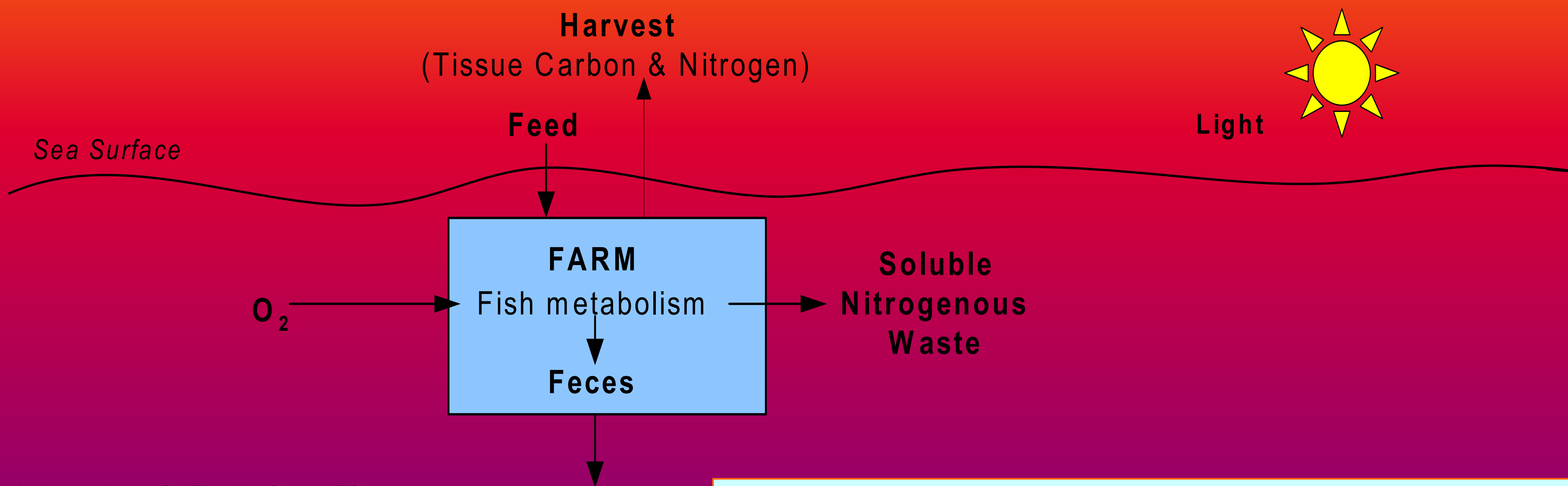
20+ pens or farms modeled simultaneously

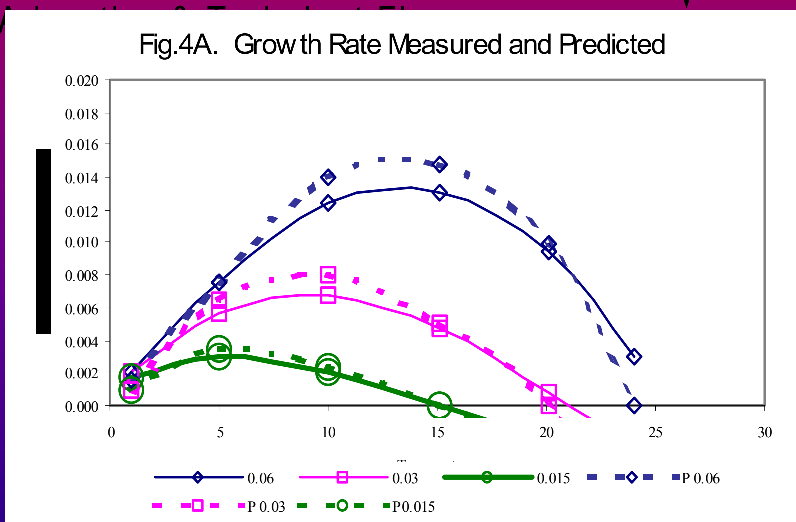
Hydrodynamic Module



- multibox L x W x D grid 3D model
- current meter data or simulated sinusoidal
- suited for open ocean – inshore
- validated with salmon and sea bream farm data, diffusivity constants

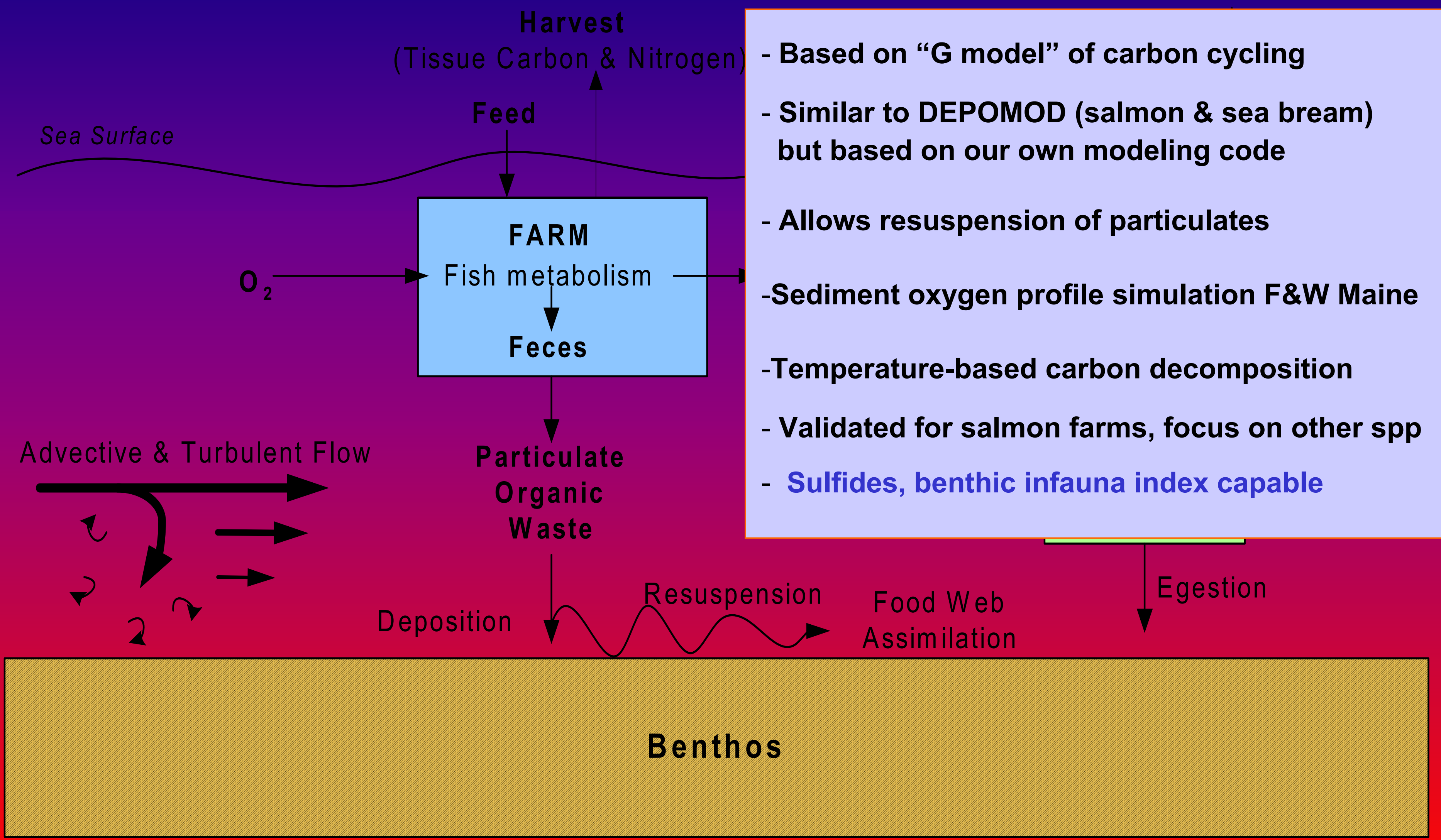
Fish Physiology Module





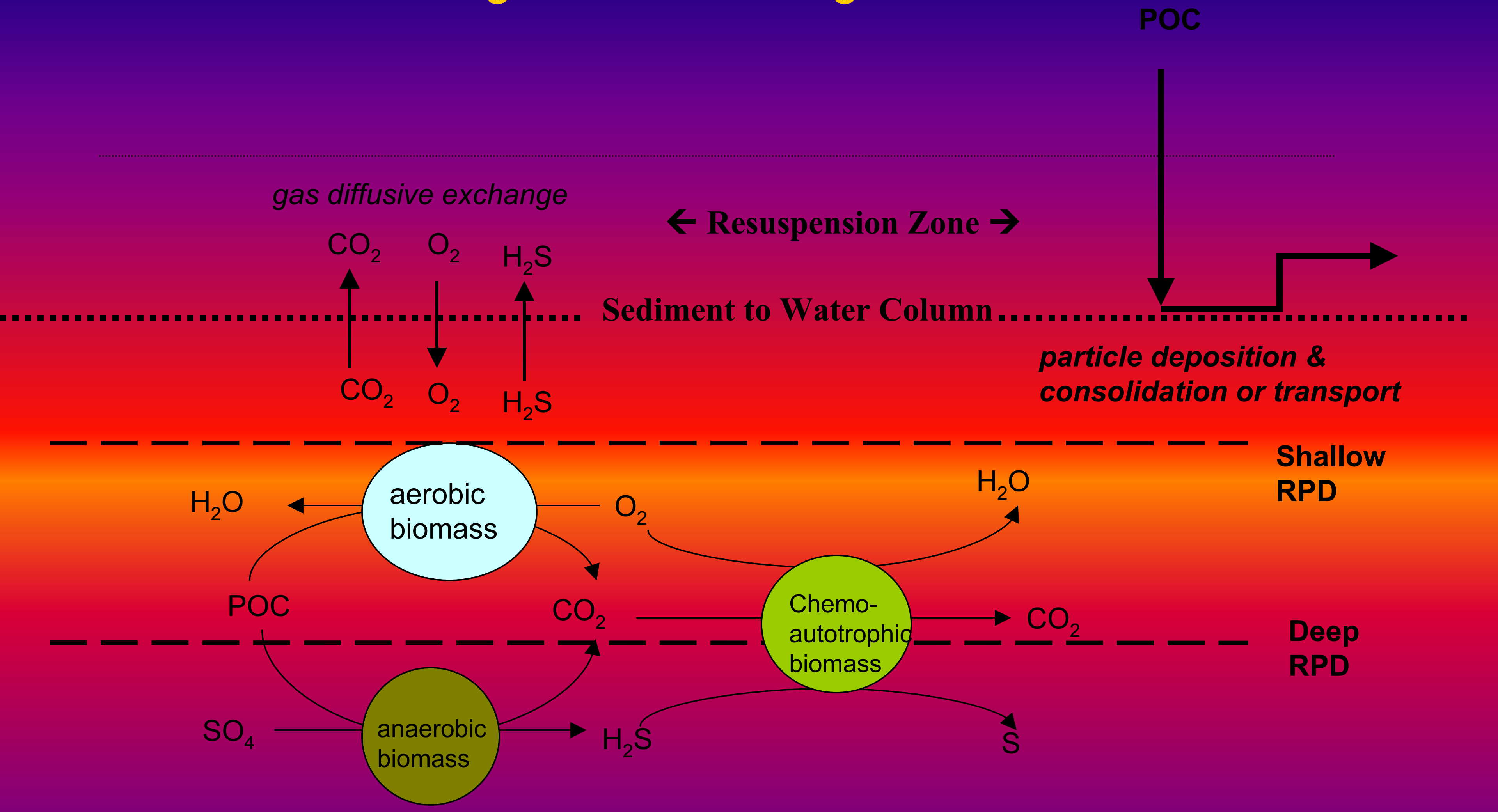
- Carbon – Oxygen – Nitrogen based
- Growth and metabolism simulation (parameterized the literature data of Brett, Fry and others)
- Varies with activity level, temperature, ration, etc.
- Spp. specific respiration, N excretion & settling rates
- Validation salmon physiology lab data, field data

Benthic Module

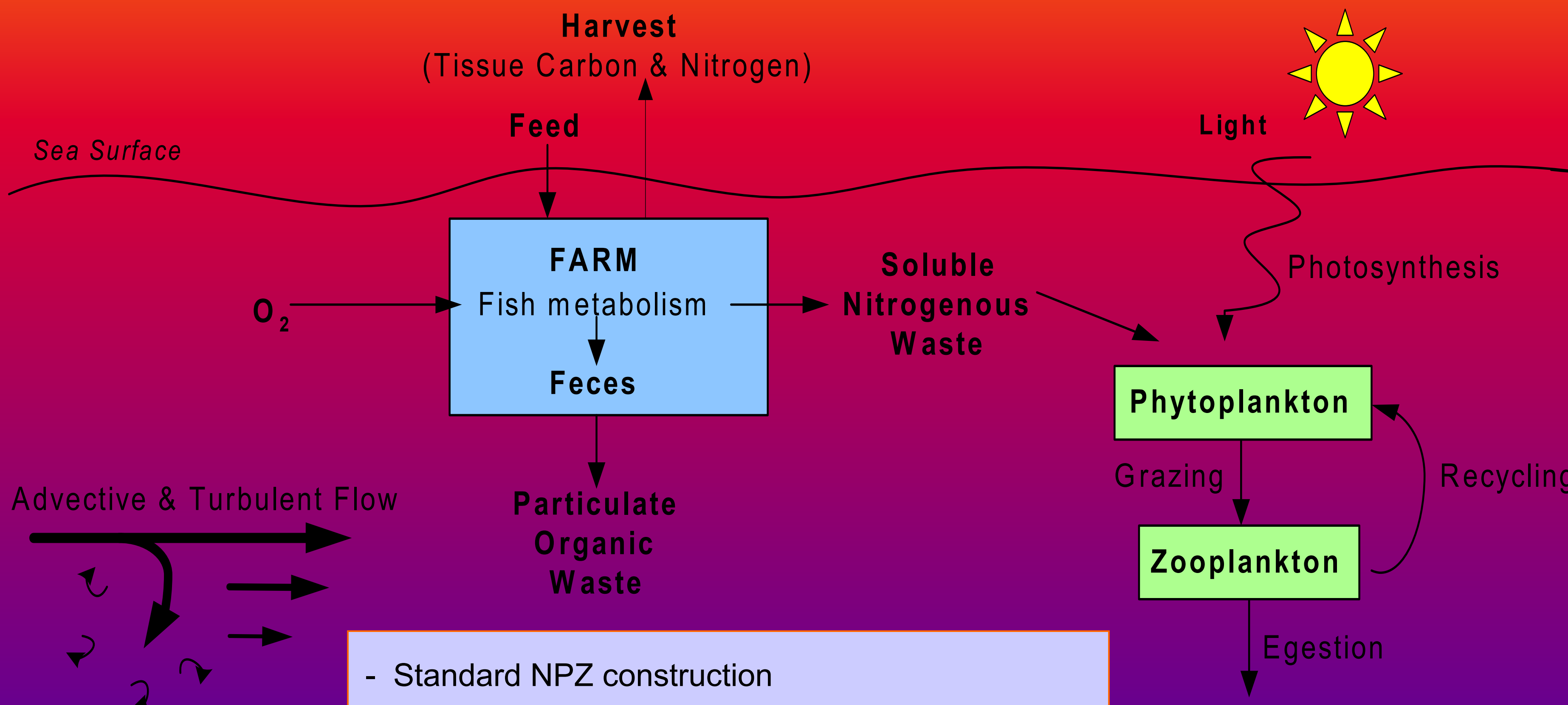


- Based on “G model” of carbon cycling
- Similar to DEPOMOD (salmon & sea bream) but based on our own modeling code
- Allows resuspension of particulates
- Sediment oxygen profile simulation F&W Maine
- Temperature-based carbon decomposition
- Validated for salmon farms, focus on other spp
- Sulfides, benthic infauna index capable

Benthic - Pelagic Model Linkages



Nutrients – Algae - Zooplankton

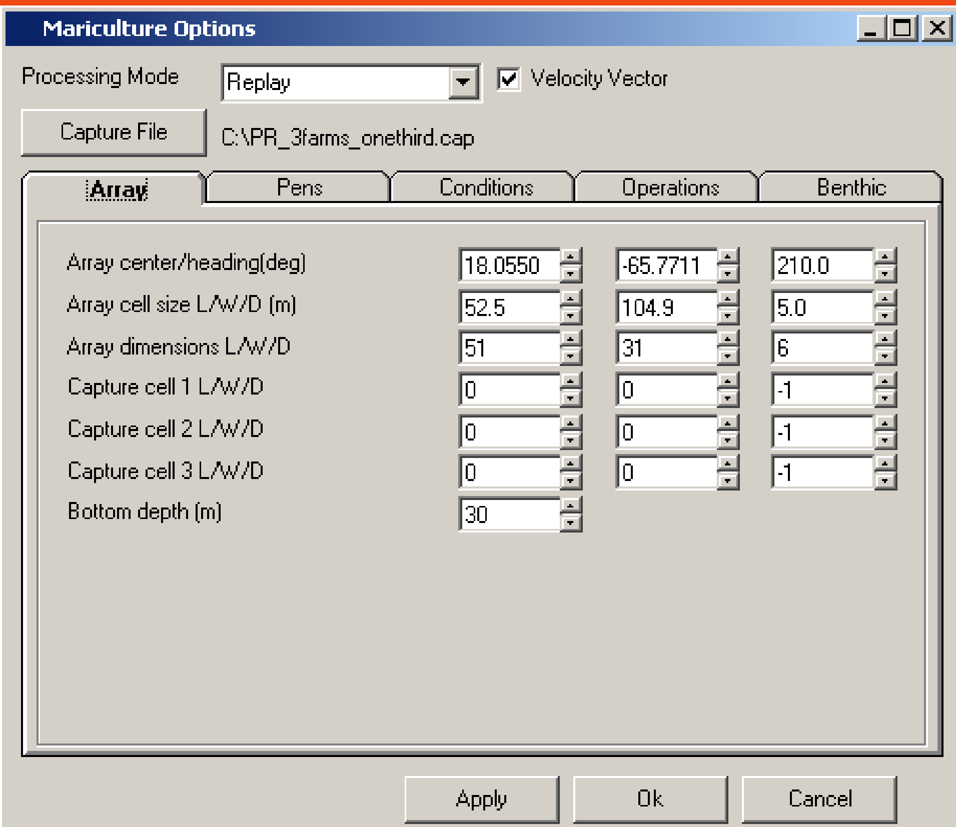


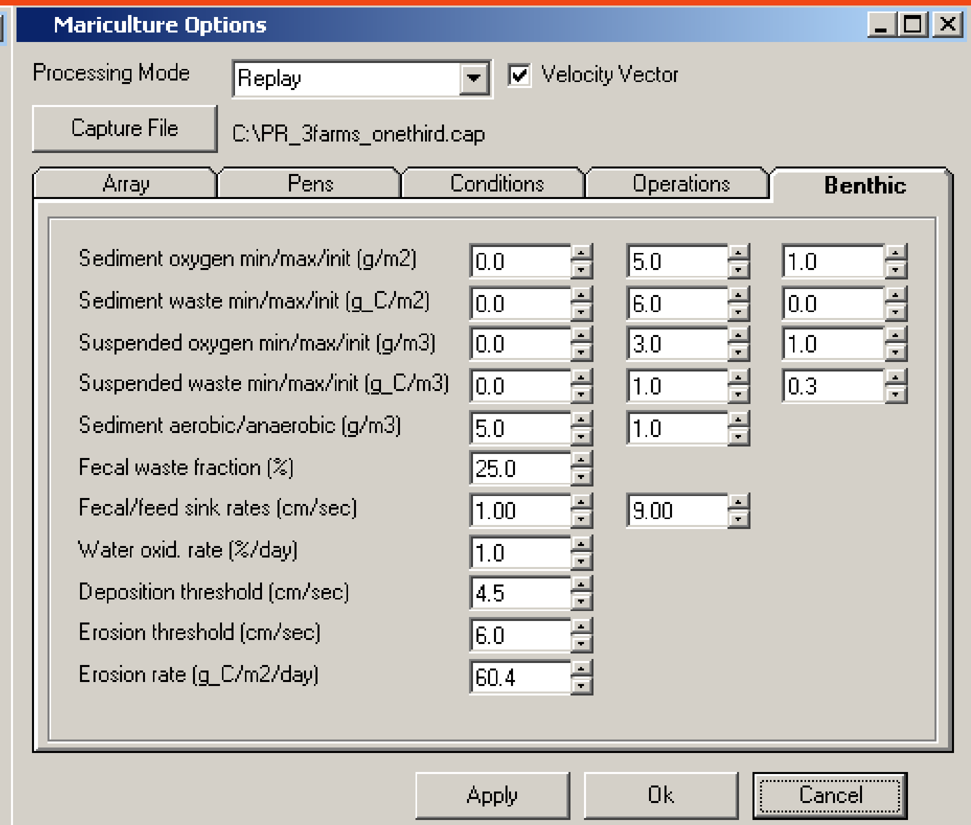
- Standard NPZ construction
- Nitrogen to phytoplankton & zooplankton growth
- Recycling and losses such as grazing
- Validated with published research including DAK

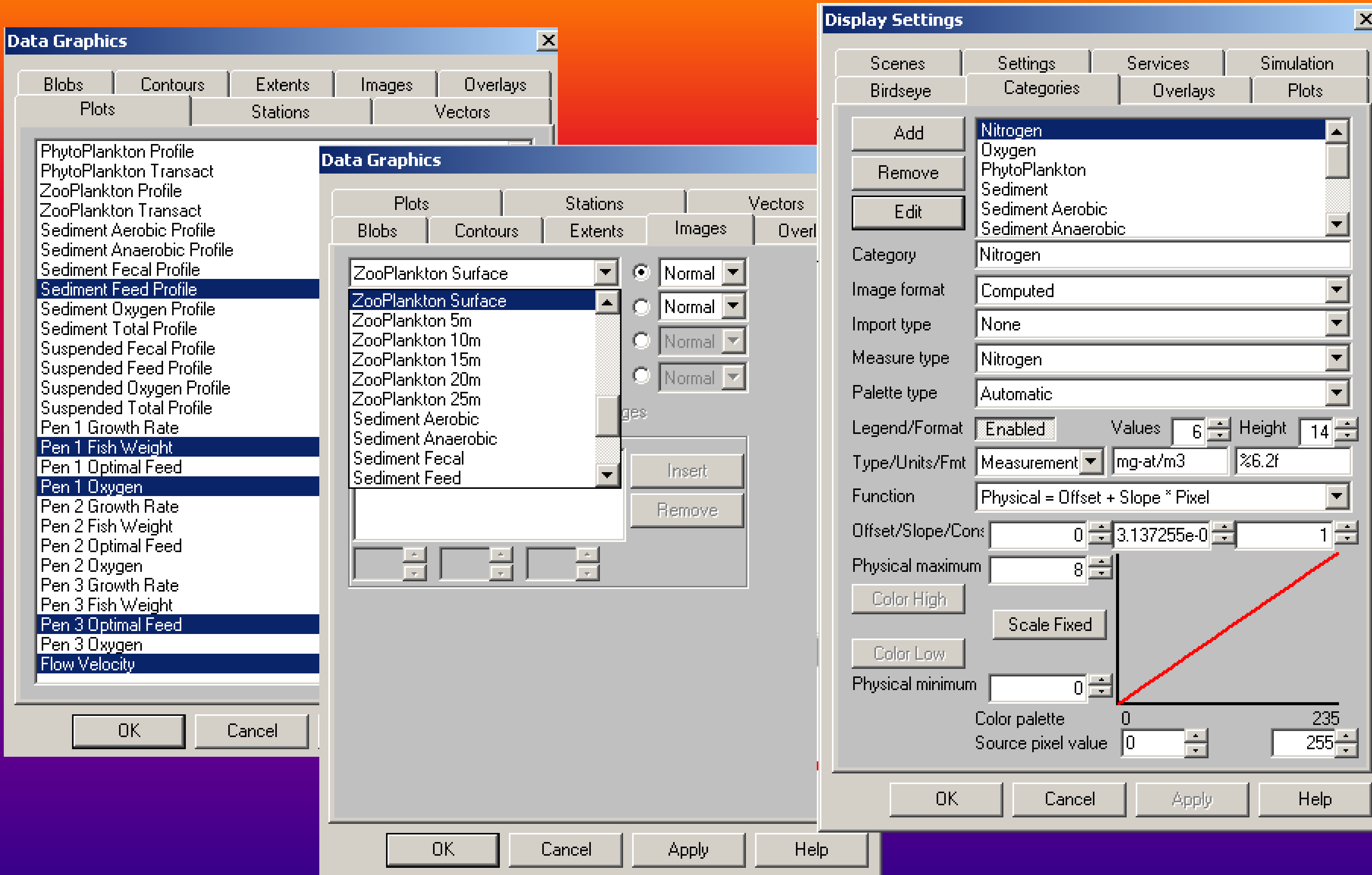
Model Construction: Teamwork

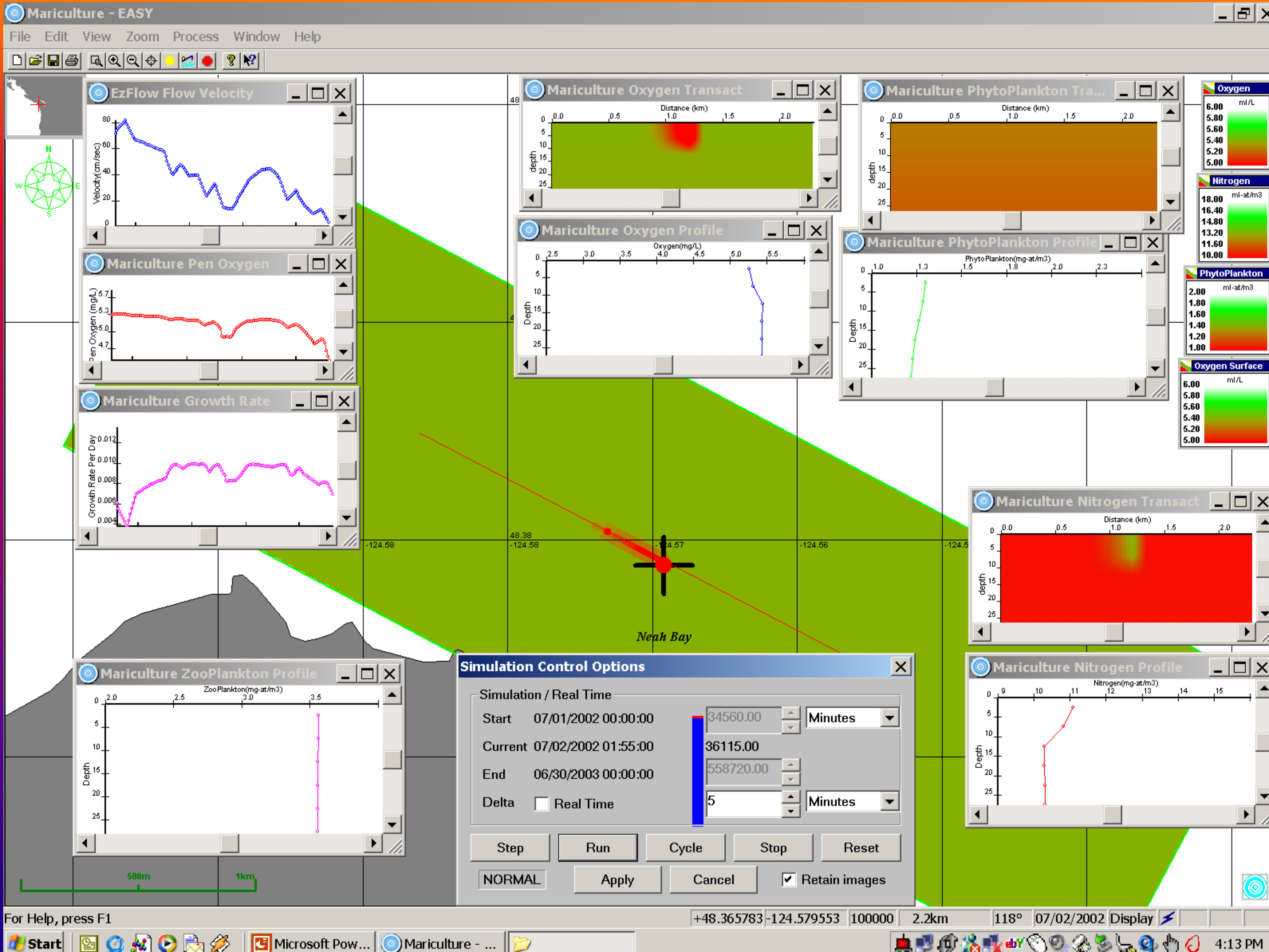
- Develop a conceptual model
- Collect or obtain quality process data & linkages
- Conceive, write and link equations (Mathmatica)
- Write code (visual basic)
- Debug code
- Enter data, images, polling sources
- Run and compare to validation data
- Revise equations and code, run again & again
- Sensitivity analysis (vary range of less known f)
- Validate, validate, validate…..

Accessible User Controls

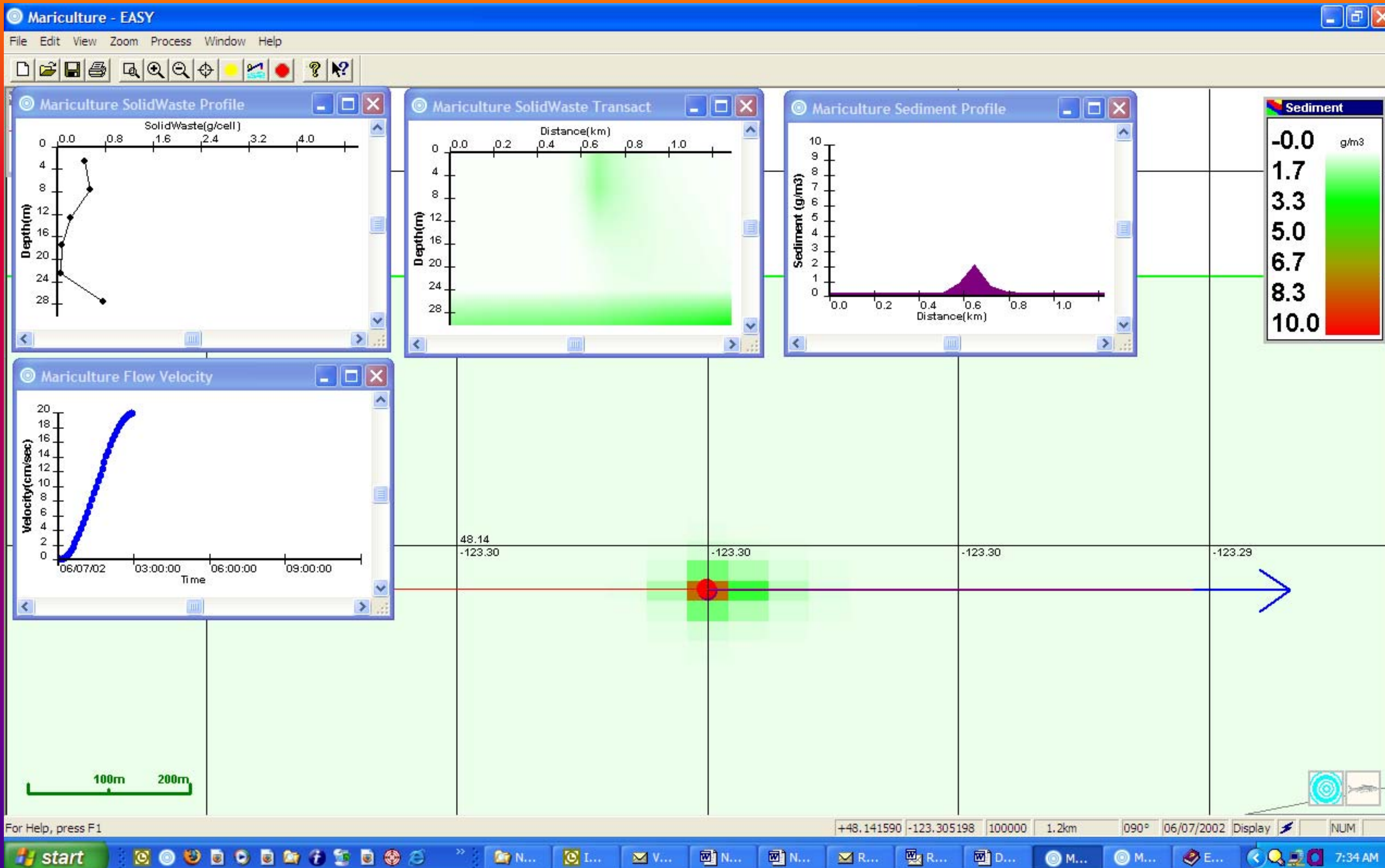





Data Graphics
Blobs
Contours
Extents
Images
Overlays
Plots
Stations
Vectors
PhytoPlankton Profile
PhytoPlankton Transact
ZooPlankton Profile
ZooPlankton Transact
Sediment Aerobic Profile
Sediment Anaerobic Profile
Sediment Fecal Profile
Sediment Feed Profile
Sediment Oxygen Profile
Sediment Total Profile
Suspended Fecal Profile
Suspended Feed Profile
Suspended Oxygen Profile
Suspended Total Profile
Pen 1 Growth Rate
Pen 1 Fish Weight
Pen 1 Optimal Feed
Pen 1 Oxygen
Pen 2 Growth Rate
Pen 2 Fish Weight
Pen 2 Optimal Feed
Pen 2 Oxygen
Pen 3 Growth Rate
Pen 3 Fish Weight
Pen 3 Optimal Feed
Pen 3 Oxygen
Flow Velocity
OK
Cancel
Data Graphics
Plots
Stations
Vectors
Blobs
Contours
Extents
Images
Overl
ZooPlankton Surface
ZooPlankton Surface
ZooPlankton 5m
ZooPlankton 10m
ZooPlankton 15m
ZooPlankton 20m
ZooPlankton 25m
Sediment Aerobic
Sediment Anaerobic
Sediment Fecal
Sediment Feed
Normal
Normal
Normal
Normal
Insert
Remove
OK
Cancel
Apply
Help
Display Settings
Scenes
Settings
Services
Simulation
Birdseye
Categories
Overlays
Plots
Add
Remove
Edit
Nitrogen
Oxygen
PhytoPlankton
Sediment
Sediment Aerobic
Sediment Anaerobic
Category
Nitrogen
Image format
Computed
Import type
None
Measure type
Nitrogen
Palette type
Automatic
Legend/Format
Enabled
Values
6
Height
14
Type/Units/Fmt
Measurement
mg-at/m3
%6.2f
Function
Physical = Offset + Slope * Pixel
Offset/Slope/Cons
0
3.137255e-0
1
Physical maximum
8
Color High
Scale Fixed
Color Low
Physical minimum
0
Color palette
0
235
Source pixel value
0
255
OK
Cancel
Apply
Help



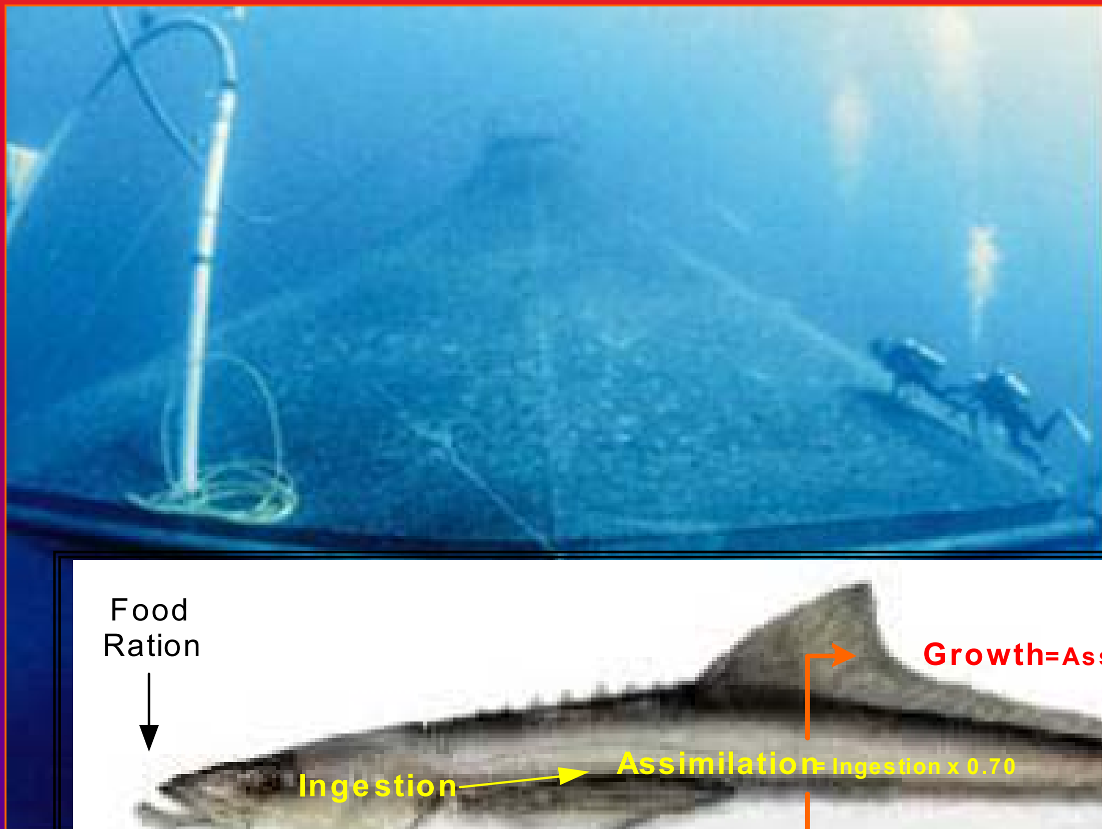
Mariculture - EASY
File Edit View Zoom Process Window Help
EzFlow Flow Velocity
Velocity(cm/sec)
Mariculture Pen Oxygen
Pen Oxygen (mg/L)
Mariculture Growth Rate
Growth Rate Per Day
Mariculture Oxygen Transact
Distance (km)
depth
Mariculture PhytoPlankton Tra...
Mariculture Oxygen Profile
Oxygen(mg/L)
Depth
Mariculture PhytoPlankton Profile
PhytoPlankton(mg-at/m3)
Oxygen
ml/L
Nitrogen
ml-at/m3
PhytoPlankton
Oxygen Surface
Mariculture Nitrogen Transact
Mariculture Nitrogen Profile
Nitrogen(mg-at/m3)
Mariculture ZooPlankton Profile
ZooPlankton(mg-at/m3)
Neah Bay
500m
1km
Simulation Control Options
Simulation / Real Time
Start 07/01/2002 00:00:00
Current 07/02/2002 01:55:00
End 06/30/2003 00:00:00
Delta
Real Time
34560.00
36115.00
558720.00
5
Minutes
Step
Run
Cycle
Stop
Reset
NORMAL
Apply
Cancel
Retain images
For Help, press F1
+48.365783 -124.579553 100000 2.2km 118° 07/02/2002 Display
Start
Microsoft Pow...
Mariculture - ...
4:13 PM

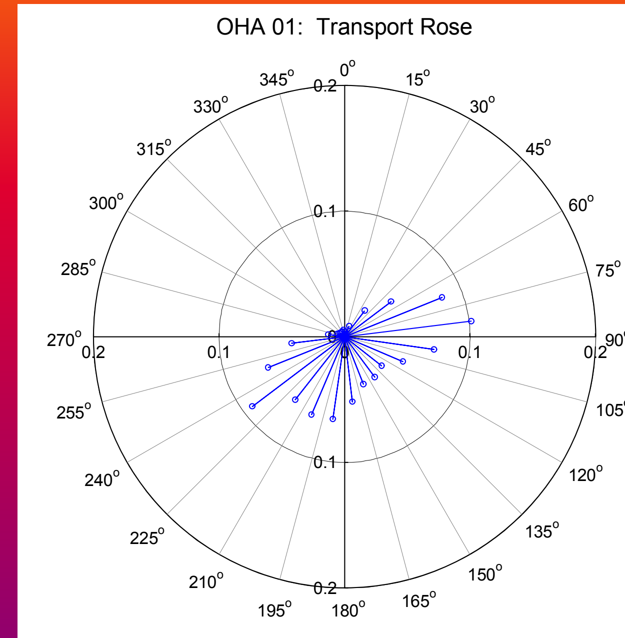


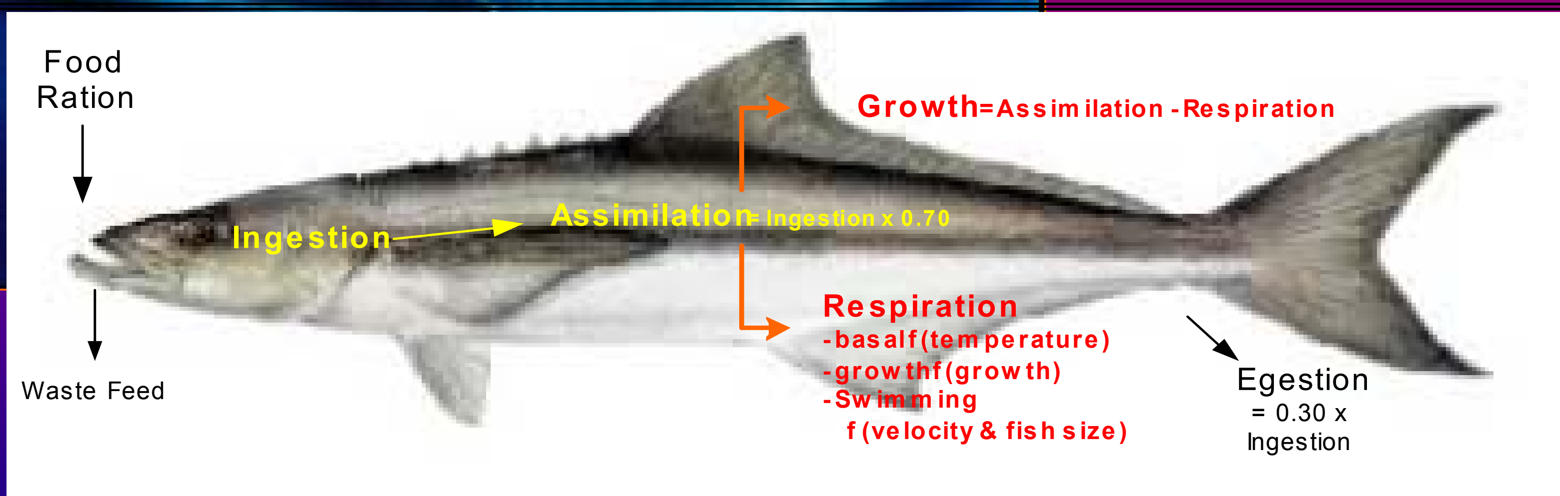
Mariculture - EASY
File Edit View Zoom Process Window Help
Mariculture SolidWaste Profile
SolidWaste(g/cell)
Depth(m)
Mariculture SolidWaste Transact
Distance(km)
Depth(m)
Mariculture Sediment Profile
Sediment (g/m3)
Distance(km)
Sediment
g/m3
-0.0
1.7
3.3
5.0
6.7
8.3
10.0
Mariculture Flow Velocity
Velocity(cm/sec)
Time
06/07/02
03:00:00
06:00:00
09:00:00
48.14
-123.30
-123.30
-123.30
-123.29
100m
200m
For Help, press F1
+48.141590 -123.305198 100000 1.2km 090° 06/07/2002 Display NUM
start
7:34 AM

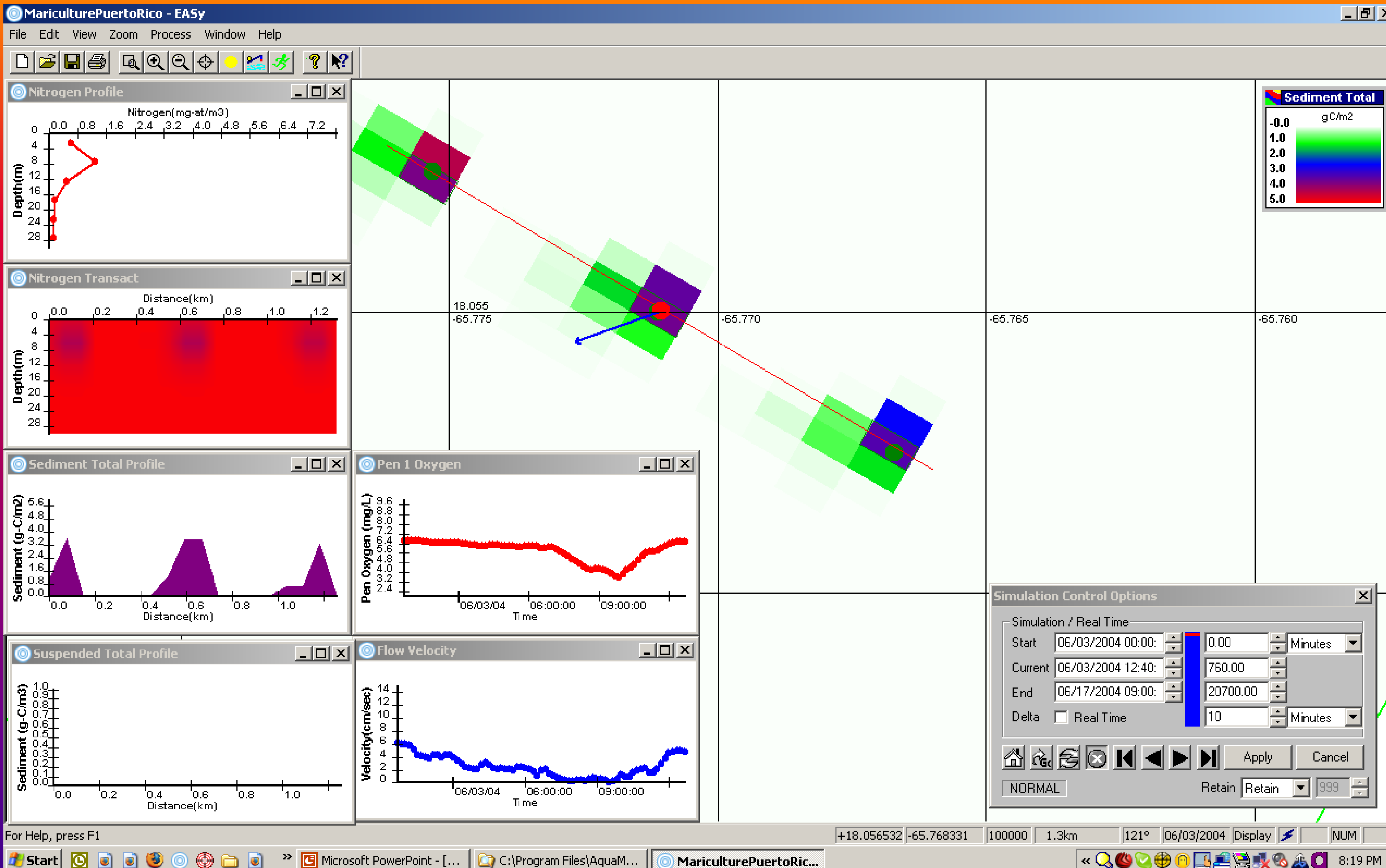
Cobia Cages Offshore of Puerto Rico

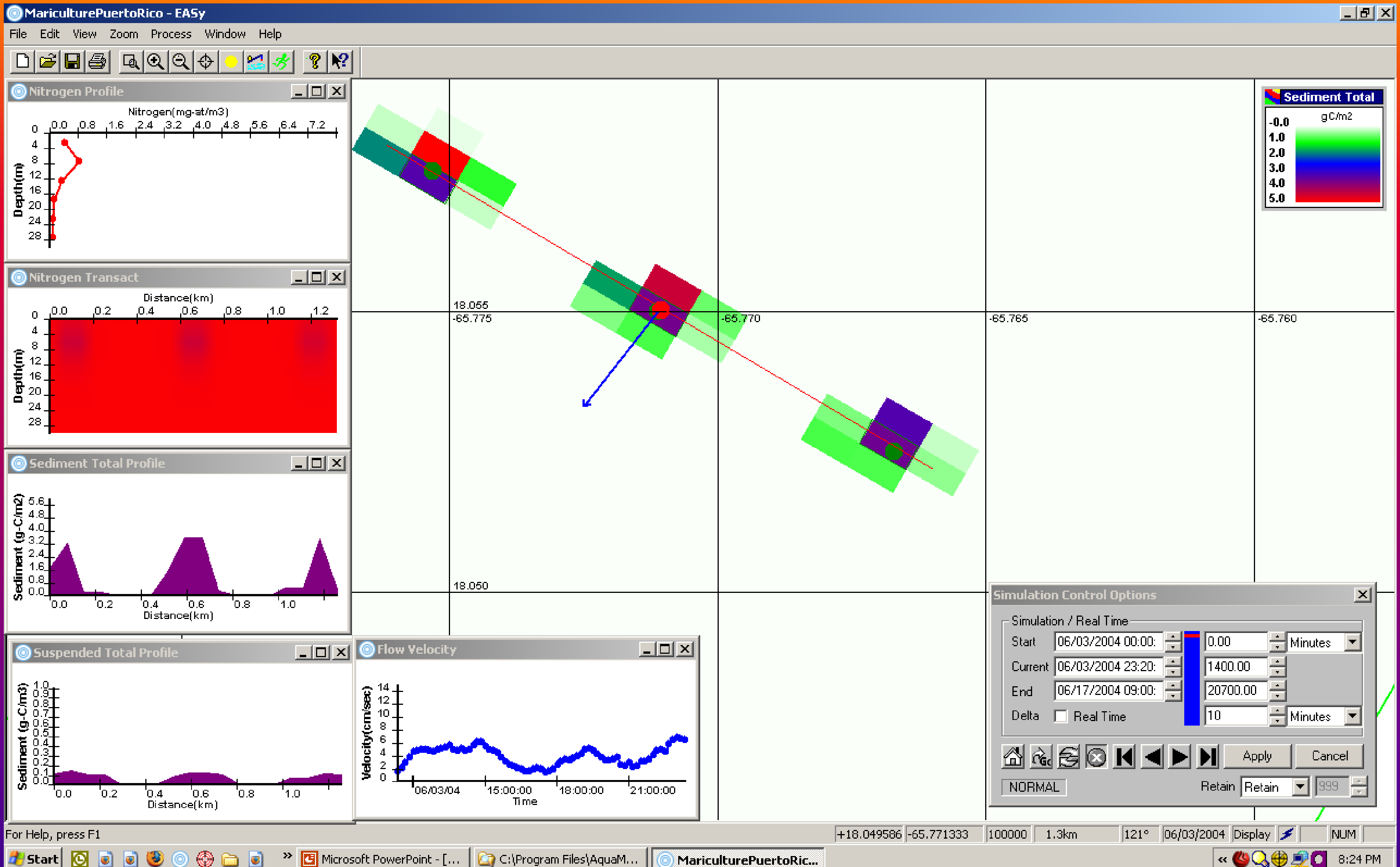
Rachycentron canadum







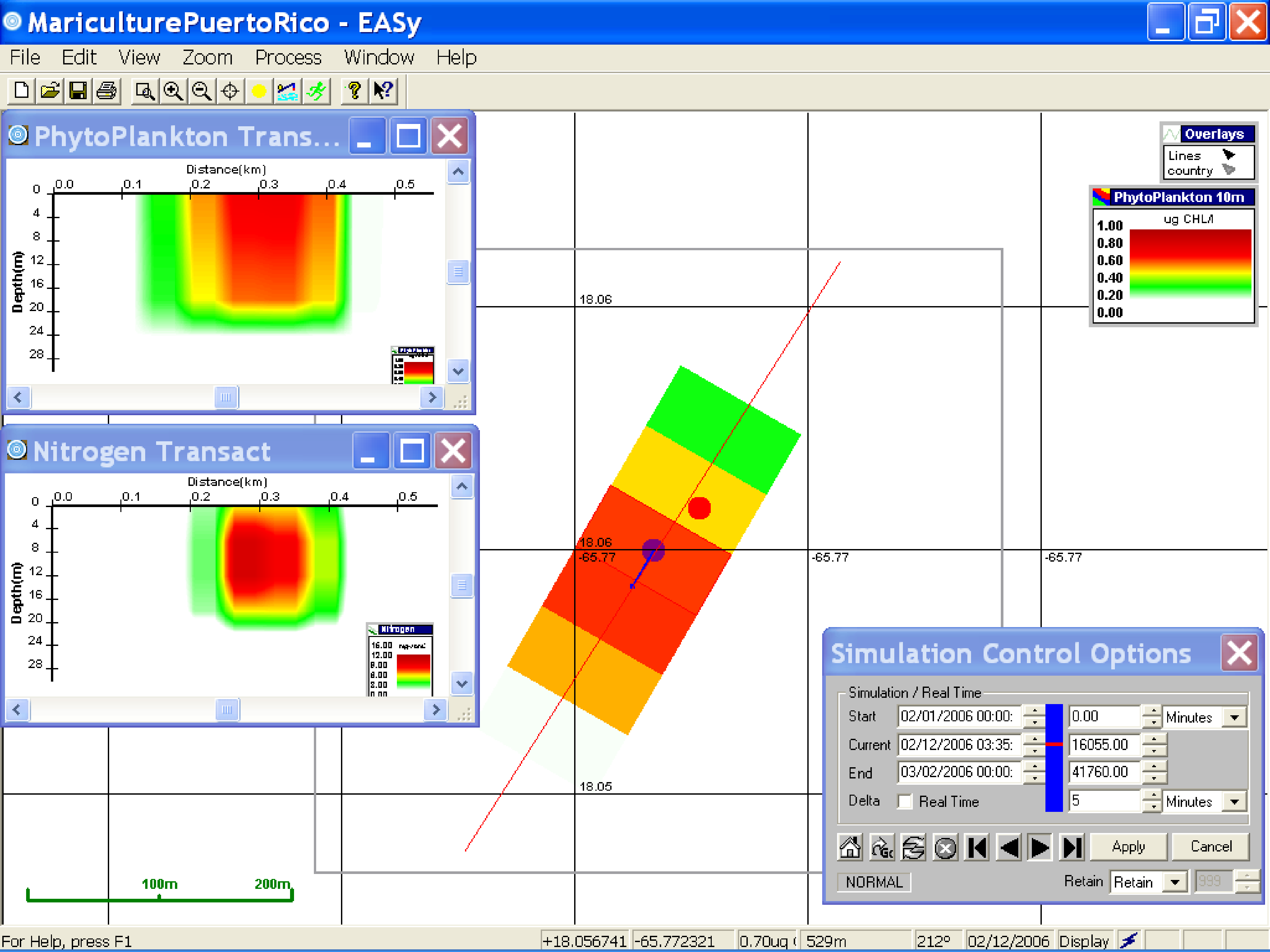

MariculturePuertoRico - EASy
File Edit View Zoom Process Window Help
Nitrogen Profile
Nitrogen(mg-at/m3)
Depth(m)
Nitrogen Transact
Distance(km)
Depth(m)
Sediment Total Profile
Sediment (g-C/m2)
Distance(km)
Suspended Total Profile
Sediment (g-C/m3)
Distance(km)
Pen 1 Oxygen
Pen Oxygen (mg/L)
06/03/04 06:00:00 09:00:00
Time
Flow Velocity
Velocity(cm/sec)
06/03/04 06:00:00 09:00:00
Time
18.055
-65.775
-65.770
-65.765
-65.760
Sediment Total
gC/m2
-0.0
1.0
2.0
3.0
4.0
5.0
Simulation Control Options
Simulation / Real Time
Start 06/03/2004 00:00: 0.00 Minutes
Current 06/03/2004 12:40: 760.00
End 06/17/2004 09:00: 20700.00
Delta Real Time 10 Minutes
Apply
Cancel
NORMAL
Retain Retain 999
For Help, press F1
+18.056532 -65.768331 100000 1.3km 121° 06/03/2004 Display NUM
Start
Microsoft PowerPoint - [...
C:\Program Files\AquaM...
MariculturePuertoRic...
8:19 PM


MariculturePuertoRico - EASy
File Edit View Zoom Process Window Help
Nitrogen Profile
Nitrogen(mg-at/m3)
Depth(m)
Nitrogen Transact
Distance(km)
Depth(m)
Sediment Total Profile
Sediment (g-C/m2)
Distance(km)
Suspended Total Profile
Sediment (g-C/m3)
Distance(km)
Flow Velocity
Velocity(cm/sec)
Time
Sediment Total
gC/m2
18.055
-65.775
-65.770
-65.765
-65.760
18.050
Simulation Control Options
Simulation / Real Time
Start 06/03/2004 00:00: 0.00 Minutes
Current 06/03/2004 23:20: 1400.00
End 06/17/2004 09:00: 20700.00
Delta Real Time 10 Minutes
Apply
Cancel
NORMAL
Retain Retain 999
For Help, press F1
+18.049586 -65.771333 100000 1.3km 121° 06/03/2004 Display NUM
Start
Microsoft PowerPoint - [...
C:\Program Files\AquaM...
MariculturePuertoRic...
8:24 PM

Tabular Output Results Example:

Under cages or other selectable locations & depths

Within or Under Cage	Flow Velocity	Growth Rate	Fish Biomass	Dissolved Oxygen	Nitrogen	Phytoplankton	Zooplankton	Fecal Carbon	Feed Carbon	Sediment Carbon
Units→	cm s^{-1}	1/d	MT	mg L^{-1}	µM	µg L^{-1}	µg L^{-1}	g m^{-3}	g m^{-3}	g m^{-2}
Mean	8.4	0.01	483.9	5.47	1.06	0.06	0.09	0.02	0.06	0.75
SD	5.2	0.00	421.7	0.18	0.71	0.03	0.02	0.04	0.03	1.51
Change	na	na	na	-0.23	+0.91	-0.04	+0.04	+0.02	+0.06	+0.75
90th %	15.9	0.01	543.4	5.63	1.96	0.10	0.13	0.03	0.10	2.82
10th %	2.9	0.01	426.5	5.24	0.42	0.03	0.06	0.01	0.03	0.00


MariculturePuertoRico - EASy
File Edit View Zoom Process Window Help
PhytoPlankton Trans...
Distance(km)
0.0 0.1 0.2 0.3 0.4 0.5
Depth(m)
0 4 8 12 16 20 24 28
Nitrogen Transact
Distance(km)
0.0 0.1 0.2 0.3 0.4 0.5
Depth(m)
0 4 8 12 16 20 24 28
Nitrogen
16.00 12.00 8.00 6.00 2.00
Overlays
Lines
country
PhytoPlankton 10m
ug CHL/l
1.00 0.80 0.60 0.40 0.20 0.00
18.06
18.06
-65.77
-65.77
-65.77
18.05
100m 200m
Simulation Control Options
Simulation / Real Time
Start 02/01/2006 00:00: 0.00 Minutes
Current 02/12/2006 03:35: 16055.00
End 03/02/2006 00:00: 41760.00
Delta Real Time 5 Minutes
Apply Cancel
NORMAL
Retain Retain 999
For Help, press F1
+18.056741 -65.772321 0.70ug 529m 212° 02/12/2006 Display

So what is new ? (Why not use existing models?)

1) The only combined water column – benthic simulation model for aquaculture
2) Fish physiology submodel that will accept constants and functions from different fish species
3) Only real time visualization model with useful GUI
4) First windows-based package that couples to a parent GIS system (EASy)
5) Relatively easy for coastal managers to use
6) “Raises the bar” for those seeking permits to compare sites, improve and defend their choices

Potential Users of AquaModel

- **Government regulators or coastal managers** to assess impacts and effects

  Is a proposed operational sustainable in terms of achieving limited impact in a steady state basis?

- **Mariculturists** to evaluate potential sites and plan operations

  Will a candidate site be economically viable as well as environmentally acceptable?

- **Researchers** to provide a home for their data and means to test and visualize their submodels using the modeling within GIS features

  Cooperative efforts underway

Future Directions

Extensive additional validation : Puget Sound and S. latitudes

New culture species models, physiological characterization

Shellfish rafting effects module

Integrated Aquaculture (IMTA)

Far field hydrodynamic submodel allowing lagrangian flow field

Long term time series using several hour time steps

Looking for additional collaborations with agencies & researchers around the world

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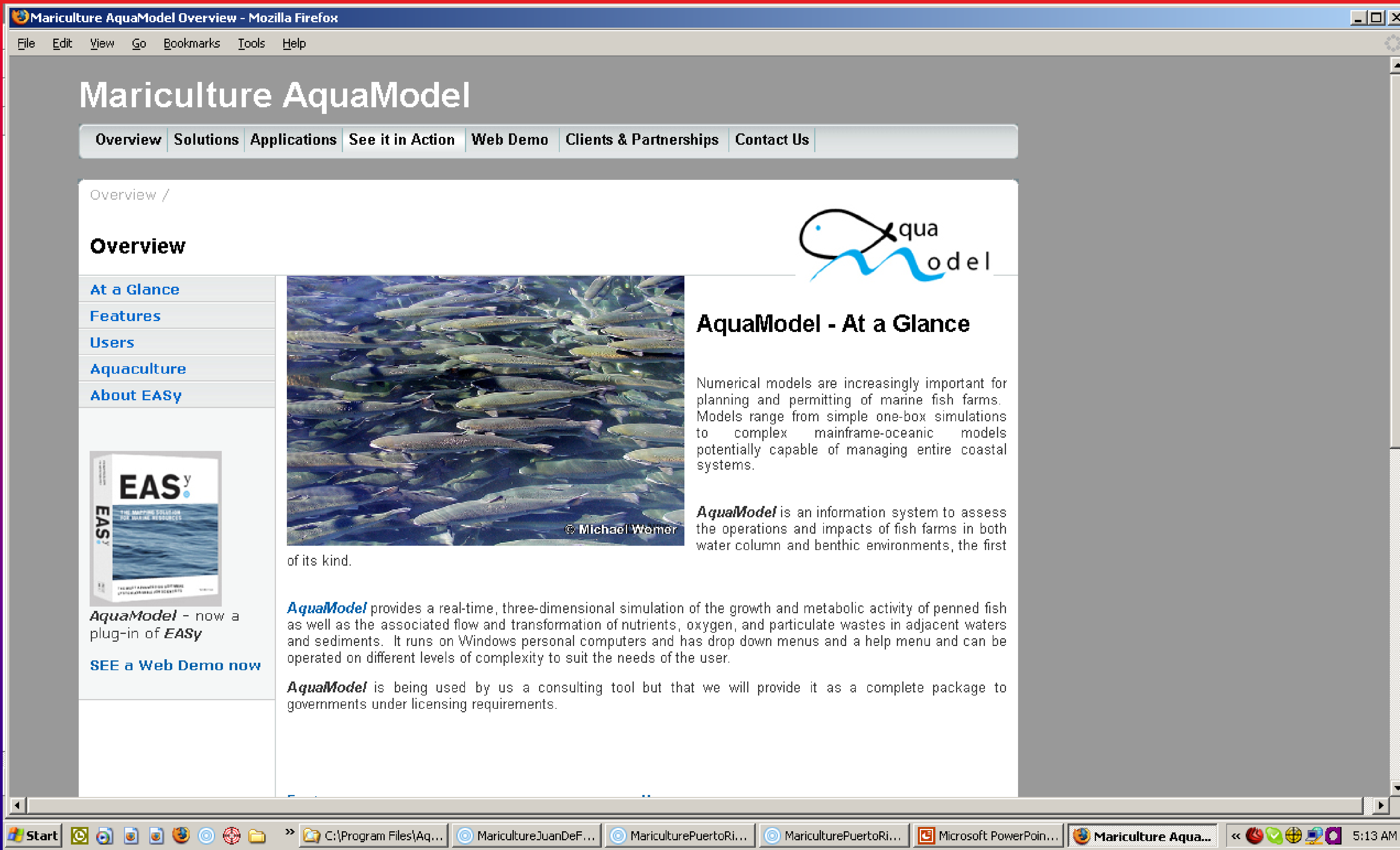
More Information: Google "AquaModel"

or http://netviewer.usc.edu/aquamodel/index.html



Model Run Demo

Funding

NOAA Office of Oceanic & Atmospheric Research

NOAA SBIR Program

USDA SBIR Program

Collaborators

Dr. Dale Kiefer, University of Southern California, Los Angeles

Dr. Frank O'Brien, Systems Science Applications

Dr. Katsyuki Abo, National Research Institute of Aquaculture, Japan

Dr. Vardis Tsontos and Tim Lam, SSA, Los Angeles

Hubbs Seaworld Research Institute, San Diego

Troutlodge Inc. Western Washington

AGS Fish Farms, Inc. Puget Sound

Ocean Spar Technologies Puget Sound