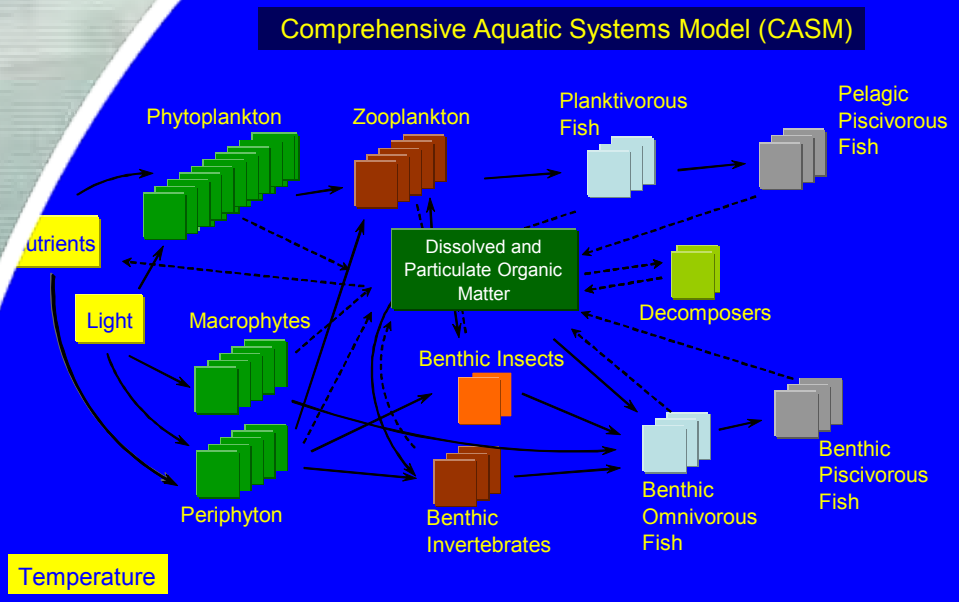
Dynamic Coupling of Hydrodynamic and Ecological Models

Todd M. Swannack, Ph.D.
Integrated Ecological Modeling
Environmental Laboratory
USACE-ERDC
Vicksburg, MS



Environmental Issues in the 21st Century

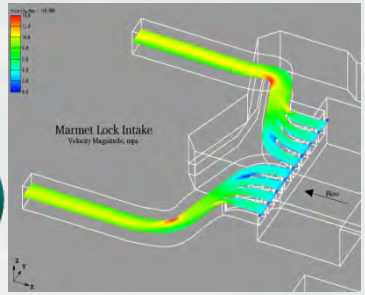
- Environmental/Water resource issues becoming more complex
- Require holistic approaches to understand system
- Coupled hydrodynamic-ecological models
  - ► Links fine scale hydrodynamics to ecological systems (e.g., food webs, fish behaviors, etc.)

Benefits of coupled Eco-Hydro approaches

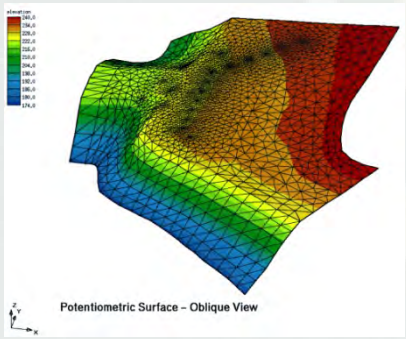
- Dynamic feedback between constituent transport and biota (uptake and nutrient cycling)
- Spatially-explicit
- Embraces temporal variability of flow, water quality and ecosystem dynamics

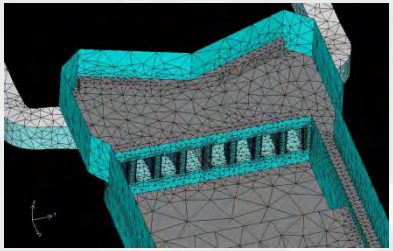
Adaptive Hydraulics Overview

Navier-Stokes Equations

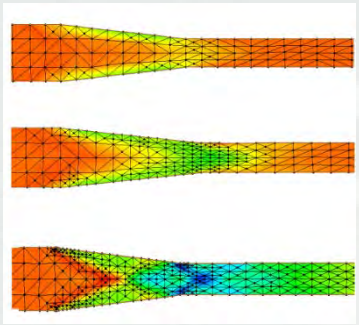


Unsaturated Groundwater Equations

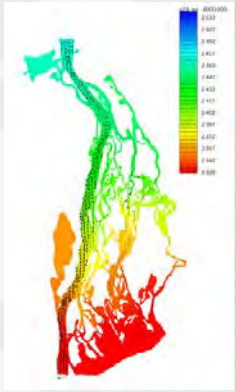




Computational Engine (FE utilities, preconditioners, solvers, I/O to xMS GUIs)

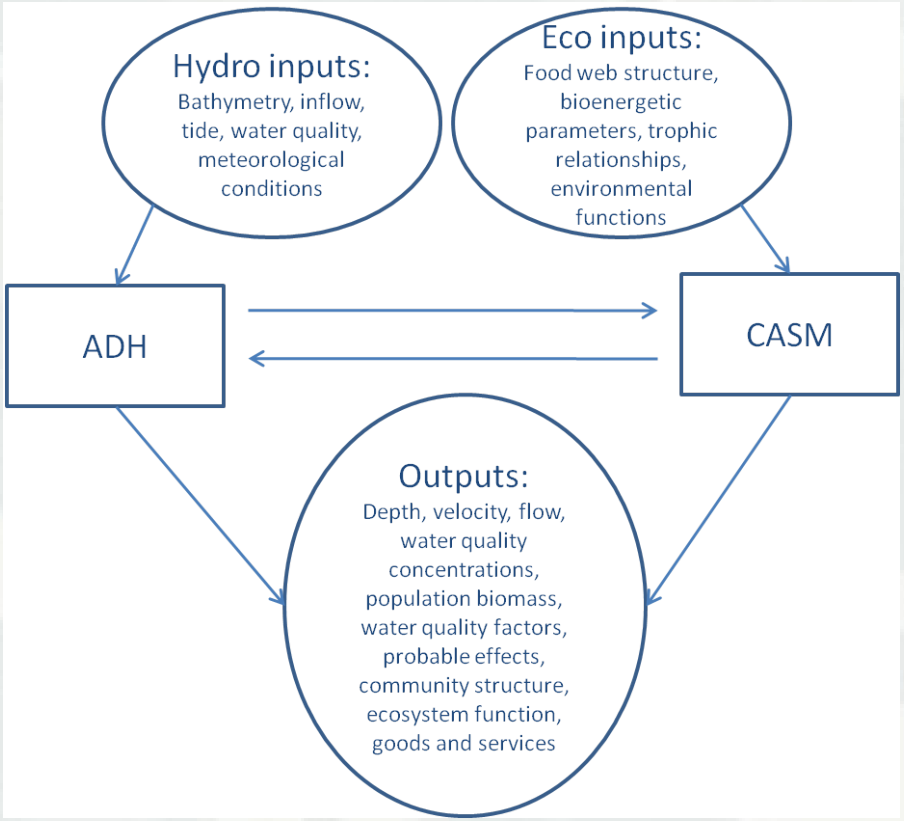


Shallow Water Equations



Gaurav Savant – USACE-CHL

ADH-CASM Linkage



ADH-CASM Outputs

Hydrology
- velocity
- depth, elevation
- salinity

Geomorphology
- sediment transport, deposition
- substrate variability
- channel structure

Biogeochemistry
- dissolved oxygen
- DIN, DIP, DOC
- particulate carbon, TSS
- water clarity

Habitat
- physical-chemical characteristics
- biological (e.g., SAV, emergents)

Biota
- phytoplankton
- periphyton
- SAV
- emergent aquatic plants
- zooplankton
- benthic invertebrates
- omnivorous fish
- piscivorous fish

Chesapeake Bay Oysters

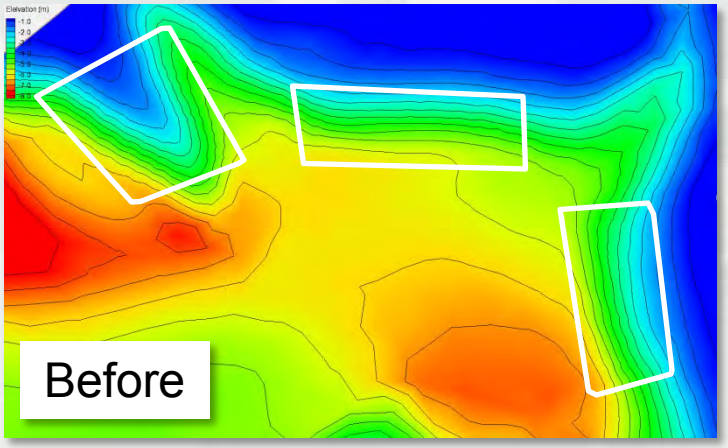
- Oyster populations at 1% of historic levels
- Oyster fishery is $100+ million/annually
- Oyster reefs provide tremendous environmental benefits (water quality, biodiversity, storm protection, etc)
- Different viewpoints on how to restore oysters and maintain fishery

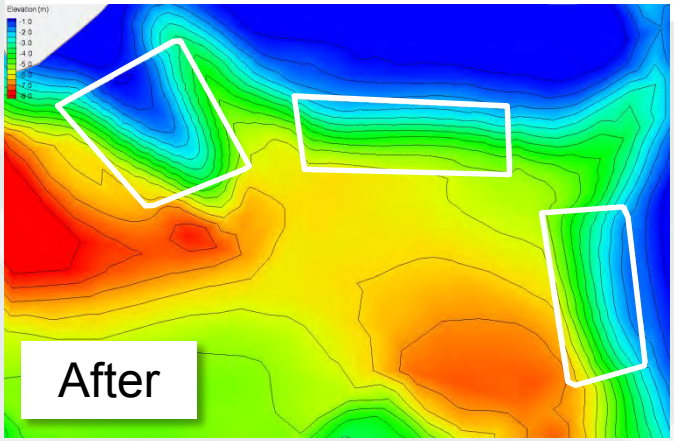
Brief History of the Great Wicomico River Oyster Restoration

- 2004: 9 reefs were restored with additions of shell and spat-on-shell
- Reefs were restored as low- and high-relief reefs
- Subtle changes in bathymetry, even with high-relief reefs (see below)
- Oysters density was ~5x greater on high-relief reefs

Susan Conner and Dave Schulte – USACE-Norfolk

Science Magazine 31 July 2009

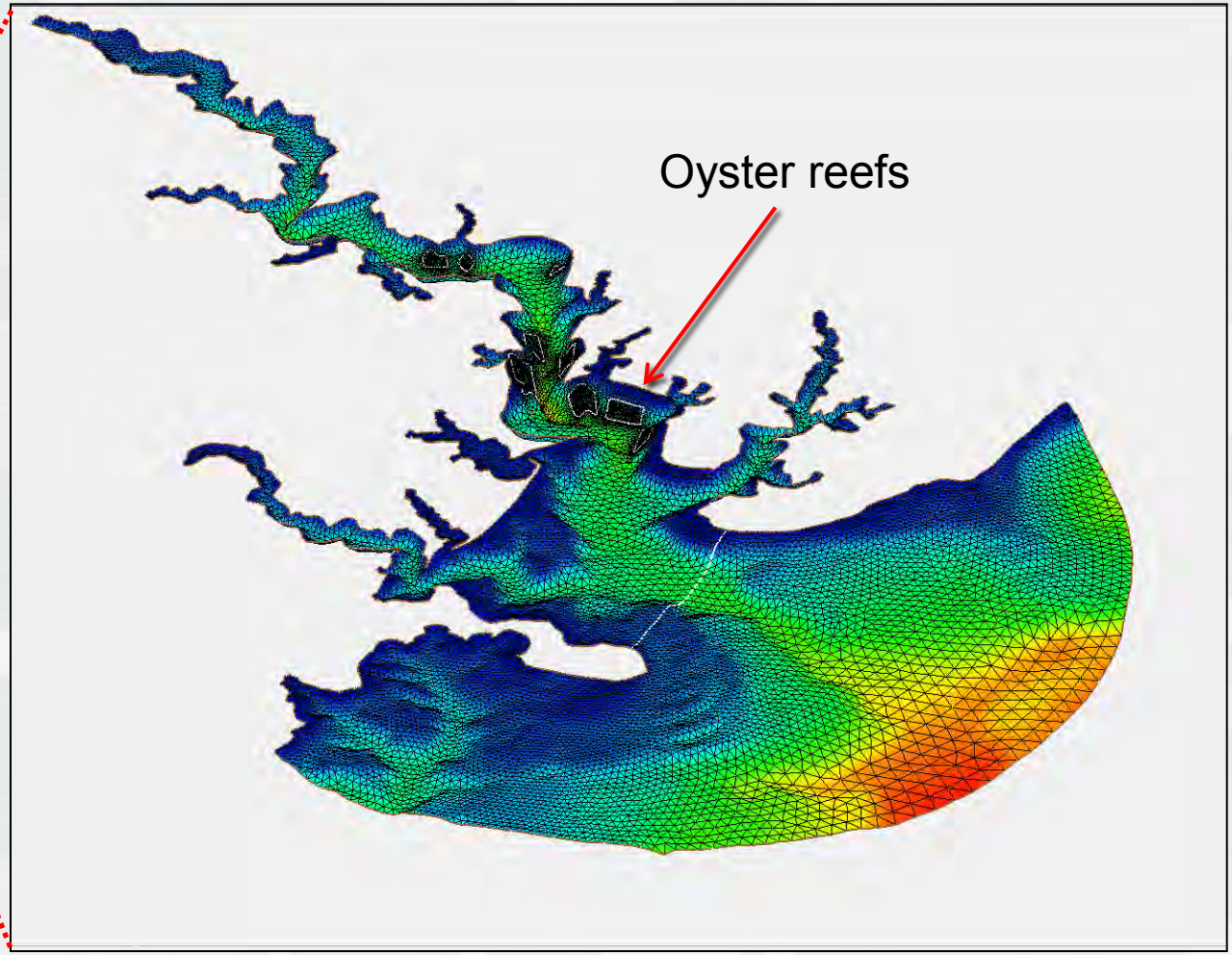




What effect do oysters have on the water quality in the vicinity of the reef?

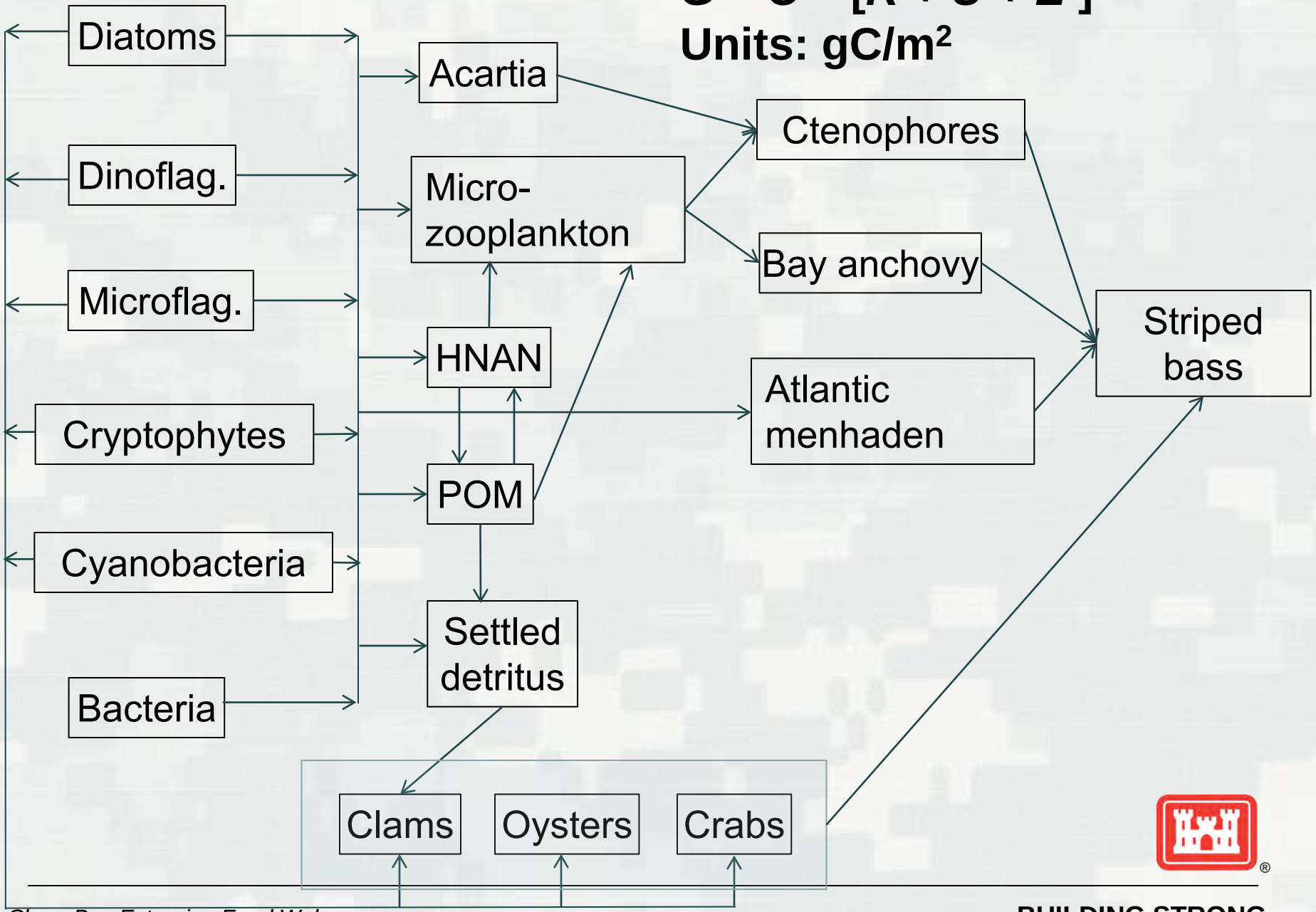
- Modeling scenarios
  - pre-construction (no structure + no function)
  - reefs (structure + no function)
  - reefs + CASM (structure + function)

Great Wicomico River ADH mesh



$G = C - [R + U + E]$

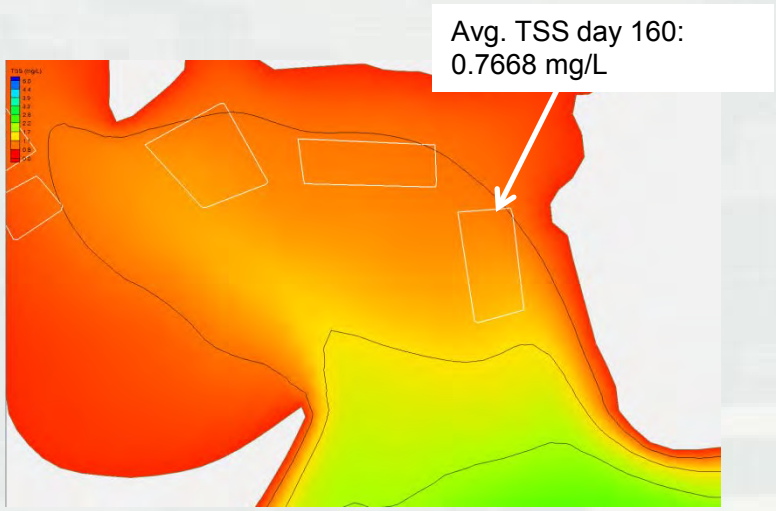
Units: gC/m²



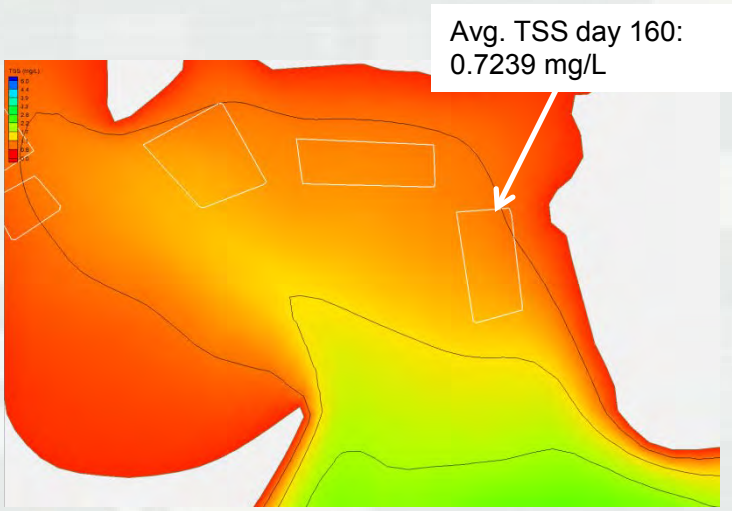
Ches. Bay Estuarine Food Web
Bartell et al 2003

TSS Reduction - filtration

- No CASM

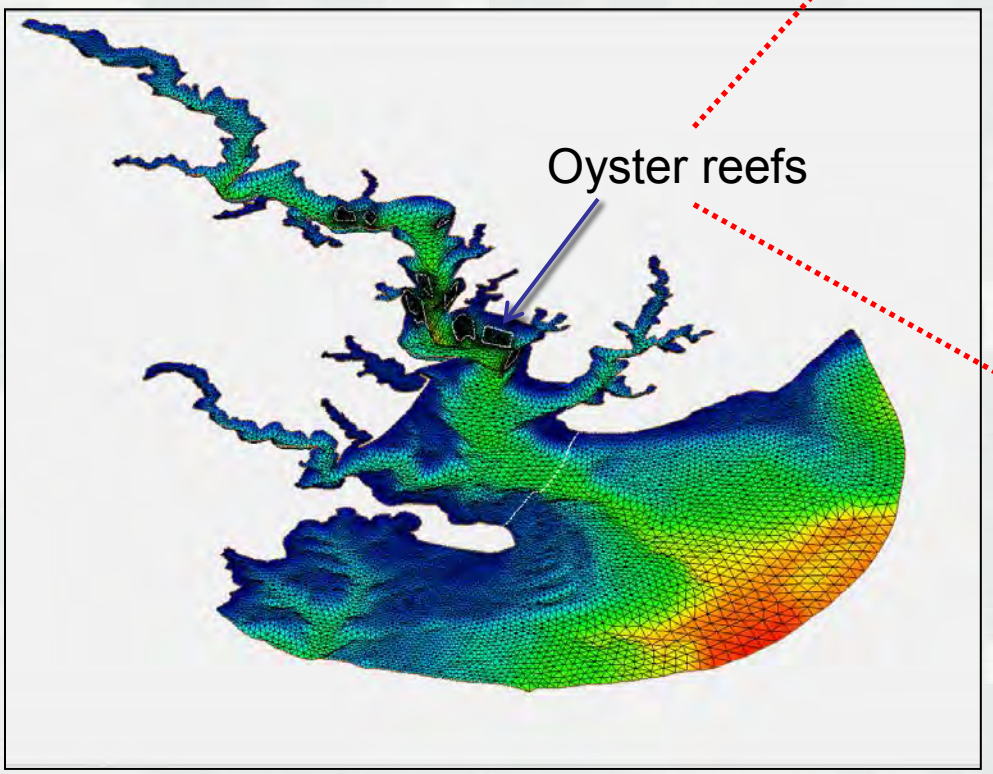


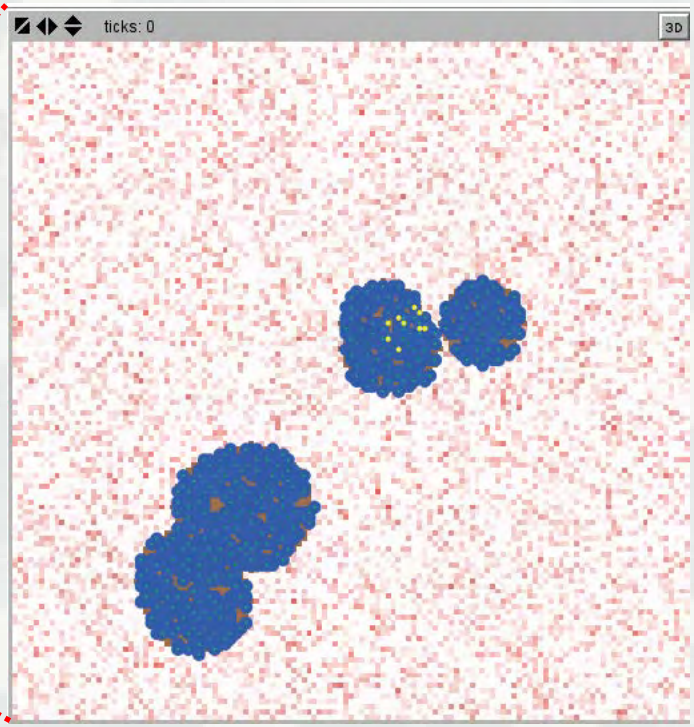
- With CASM



~5.6% reduction in TSS

Linking Population Dynamics





Oyster population model (prototype)

Discussion

- Coupling models result in direct benefits out (e.g., TSS reductions and nutrient uptake)

- Captures critically system processes, such as feedback loops and interspecies dynamics

Other uses for coupled modeling

- Ecosystem services
- How management affects multiple levels of trophic structure (e.g., salmonids to plankton)
- Examine future conditions (SLC, ocean acidification)
- Addresses issues across scales

Benefits

- Holistic approach
  - System dynamics for ecosystem restoration, sea level change, water chemistry
- Food web can be developed for any system
  - Data intensive, but can use surrogates to identify future research needs

Management implications

- Scenario analysis for multiple management strategies (rotational harvest, sanctuary, etc), hydrologic scenarios and/or climatic regimes
- Can develop system-level risk assessments
- Provides mechanism for visualizing dynamic feedback loops

Contacts

- Todd Swannack (Ecological Modeling/Coastal Ecology)
  - todd.m.swannack@usace.army.mil
  - 601-634-2068
- Candice Piercy (Hydrodynamic modeling/coupled approaches)
  - candice.d.piercy@usace.army.mil
- Mike Kjelland (Population modeling)
  - michael.e.kjelland@usace.army.mil