Impacts of management strategies on the population dynamics of the eastern oyster in the Great Wicomico River

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Eastern Oyster Fishery

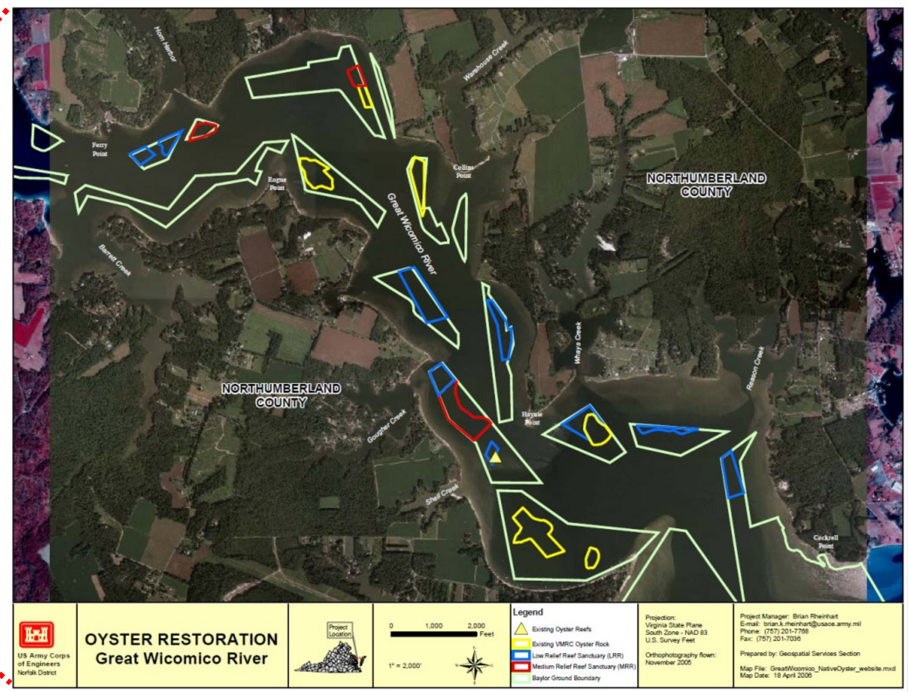
- Oyster abundance has changed
- Oyster reefs provide tremendous environmental and economic benefits
- Different viewpoints on how to restore oysters and maintain fishery

Oyster Management

- **Two management strategies**
  1. Permanent Sanctuaries
     - Never harvested (no fishery)
     - Maximize environmental benefits
  2. Rotationally Harvest
     - Harvest reefs on 3 year cycle
     - Maintains fishery
- **Long-term impacts of both not well understood**

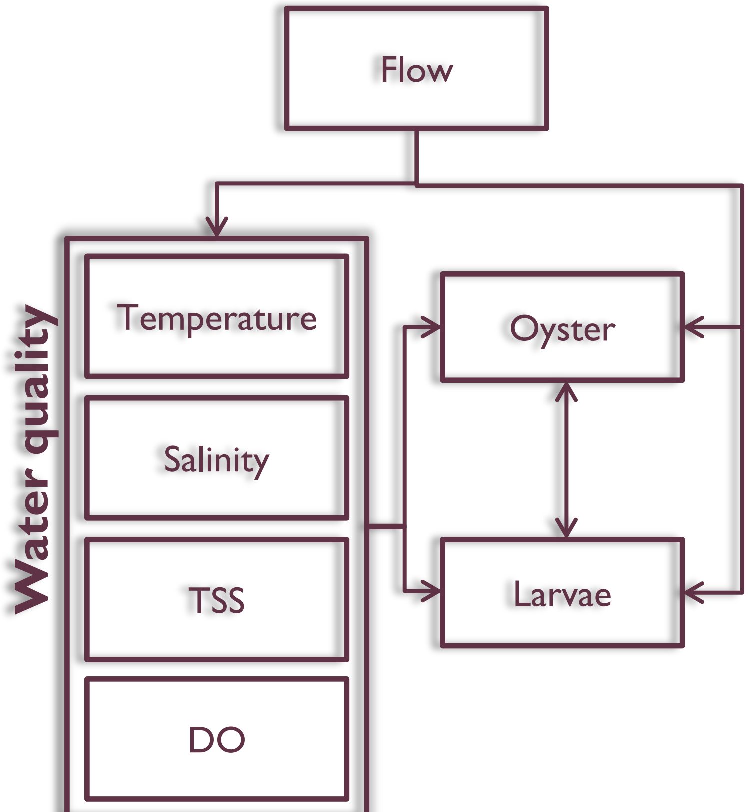
Research Questions

- How do different management strategies affect the oyster fishery in the Great Wicomico River of Chesapeake Bay? Do sanctuaries matter?

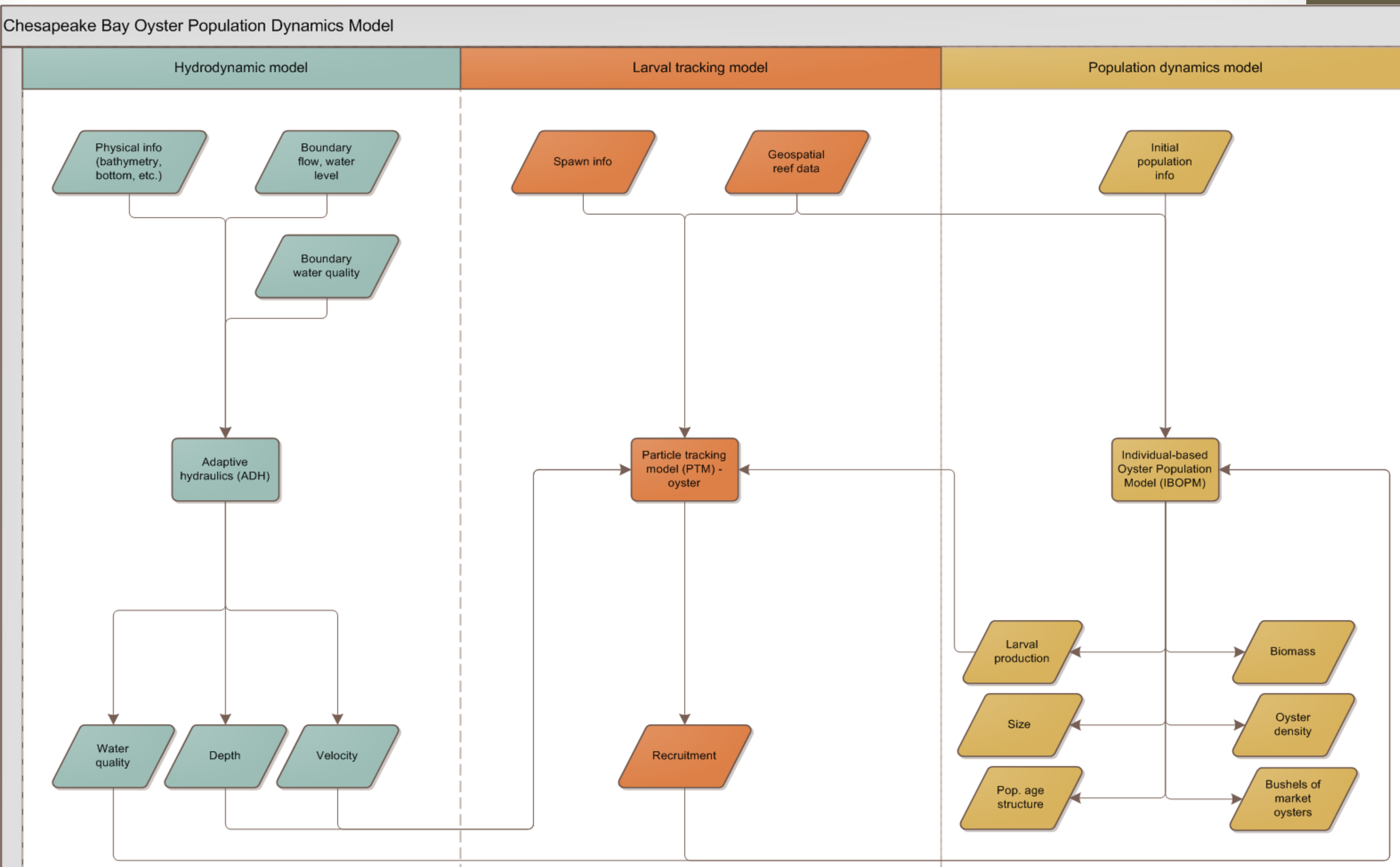


Linking oyster population to environmental processes

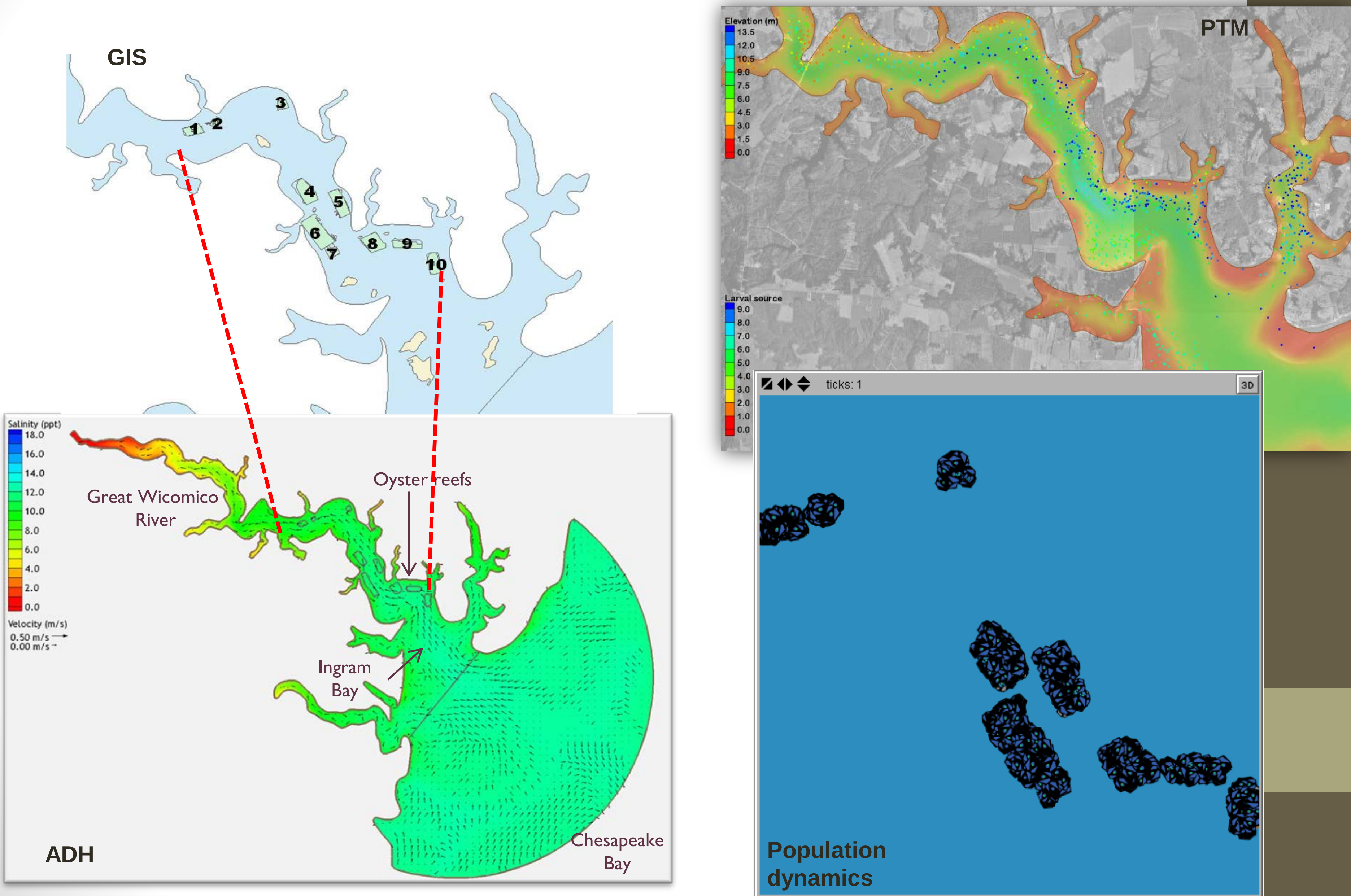
Population dynamics conceptual model



Integrated Conceptual Model



Integrated Model



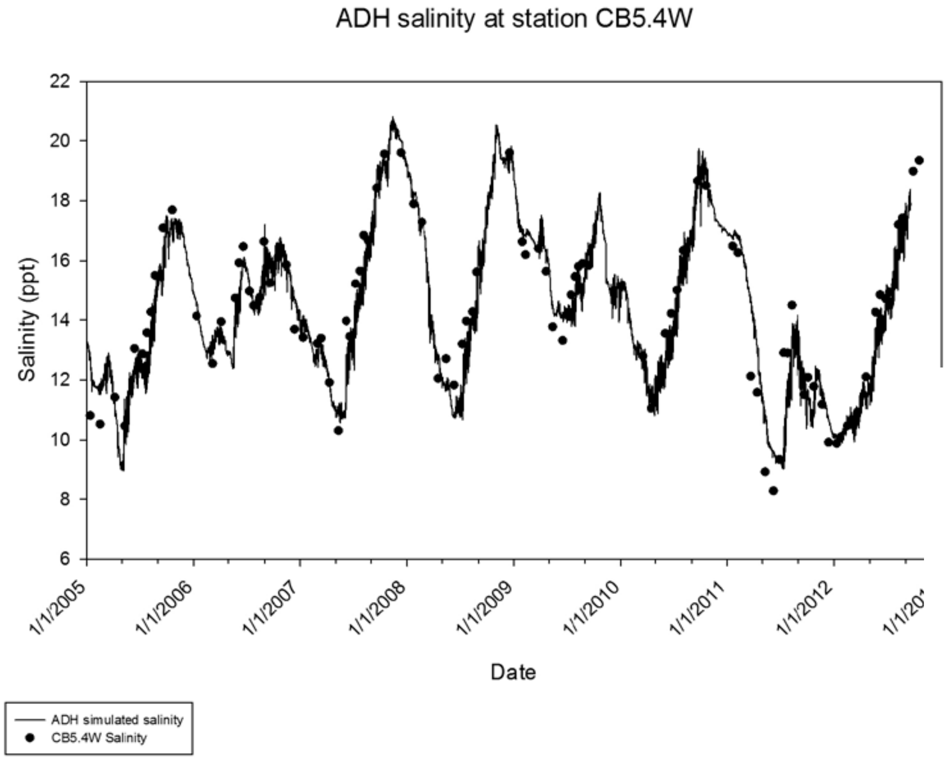
- **Adaptive Hydraulics**

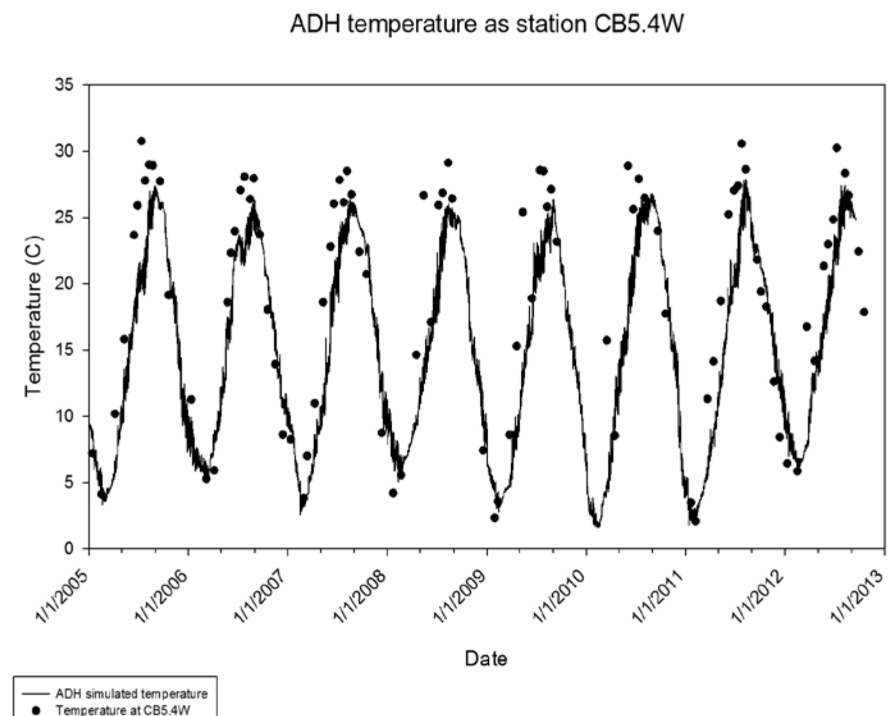
- **Spatial Scale**
  - Improved over previous model
  - 14000 nodes
    - 25000 Elements
    - 40 m – 335 m
    - Finer resolution on oyster reefs

- **Mesh can adapt as needed during simulation**

Model Evaluation

ADH Salinity & Temp

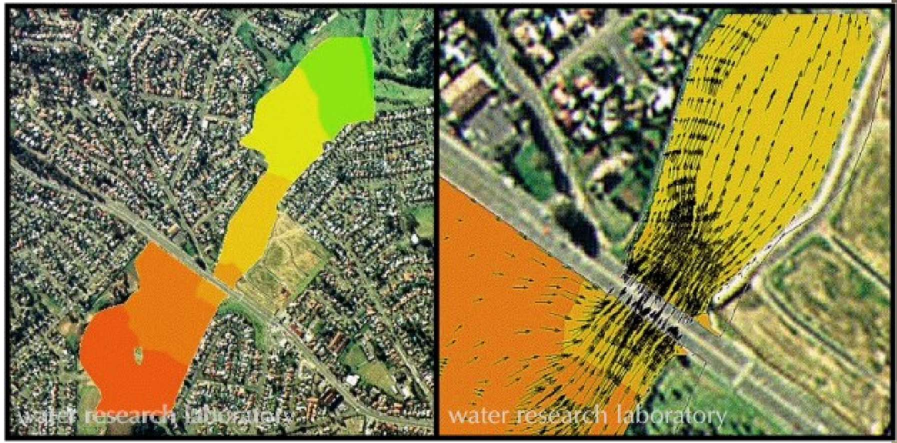




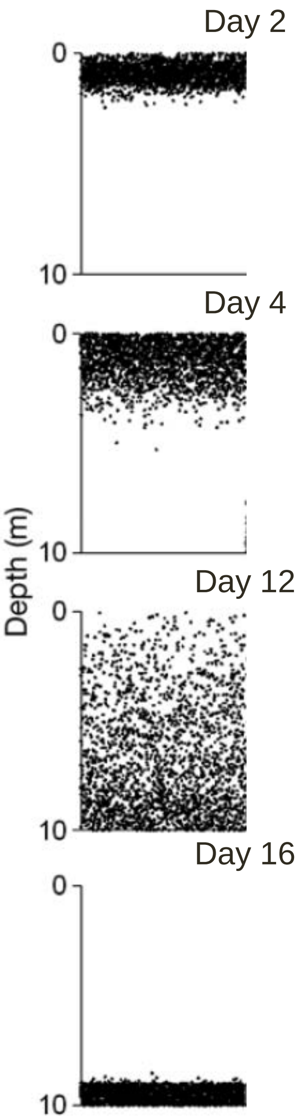
Larval Dispersal

- Larval dispersal poorly understood, yet critical for connectivity & recruitment among reefs

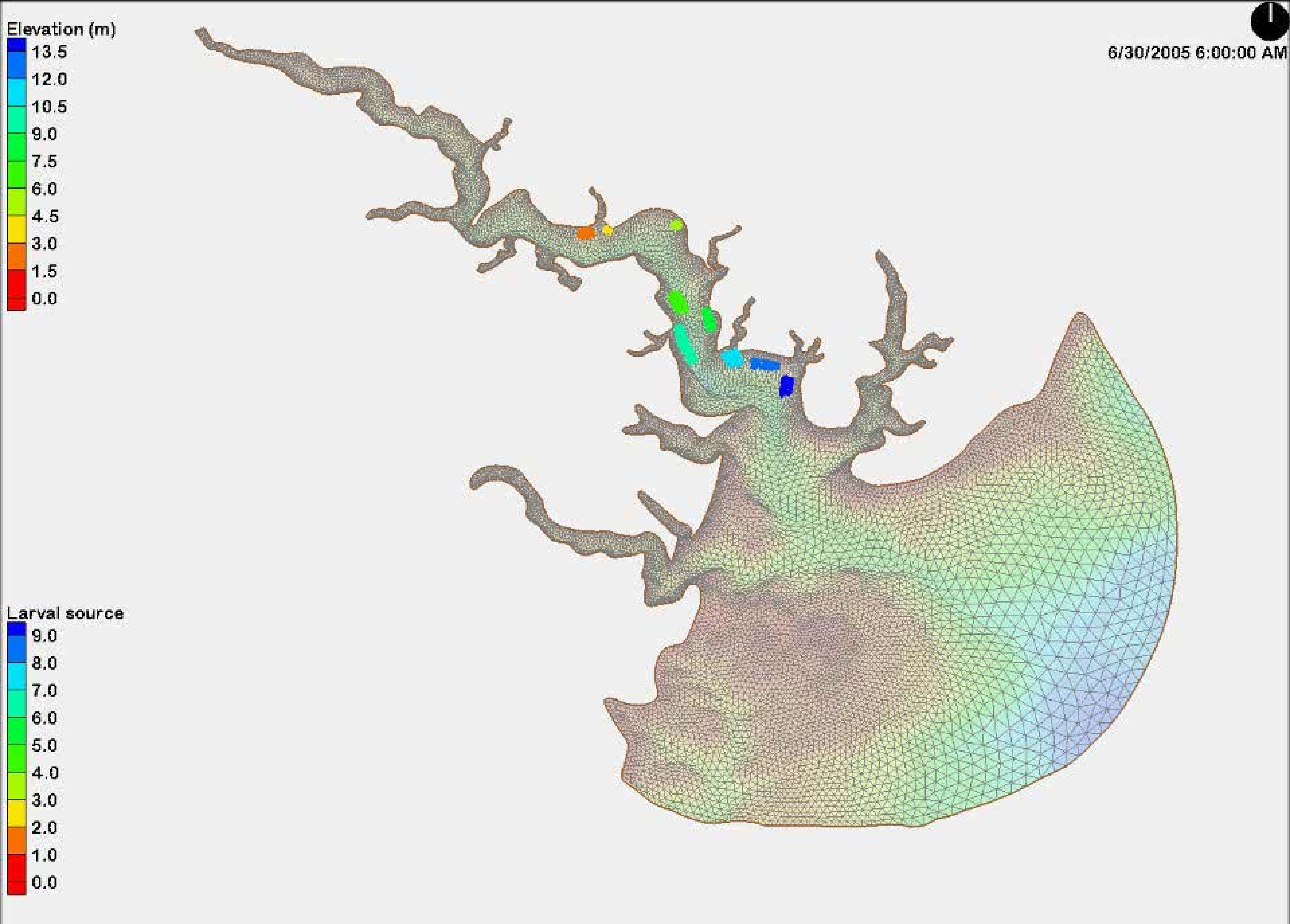
- Langrangian particle tracking model (PTM)
- Uses H_2O level and current estimates from ADH to predict where discrete constituents are transported (used for sediment)



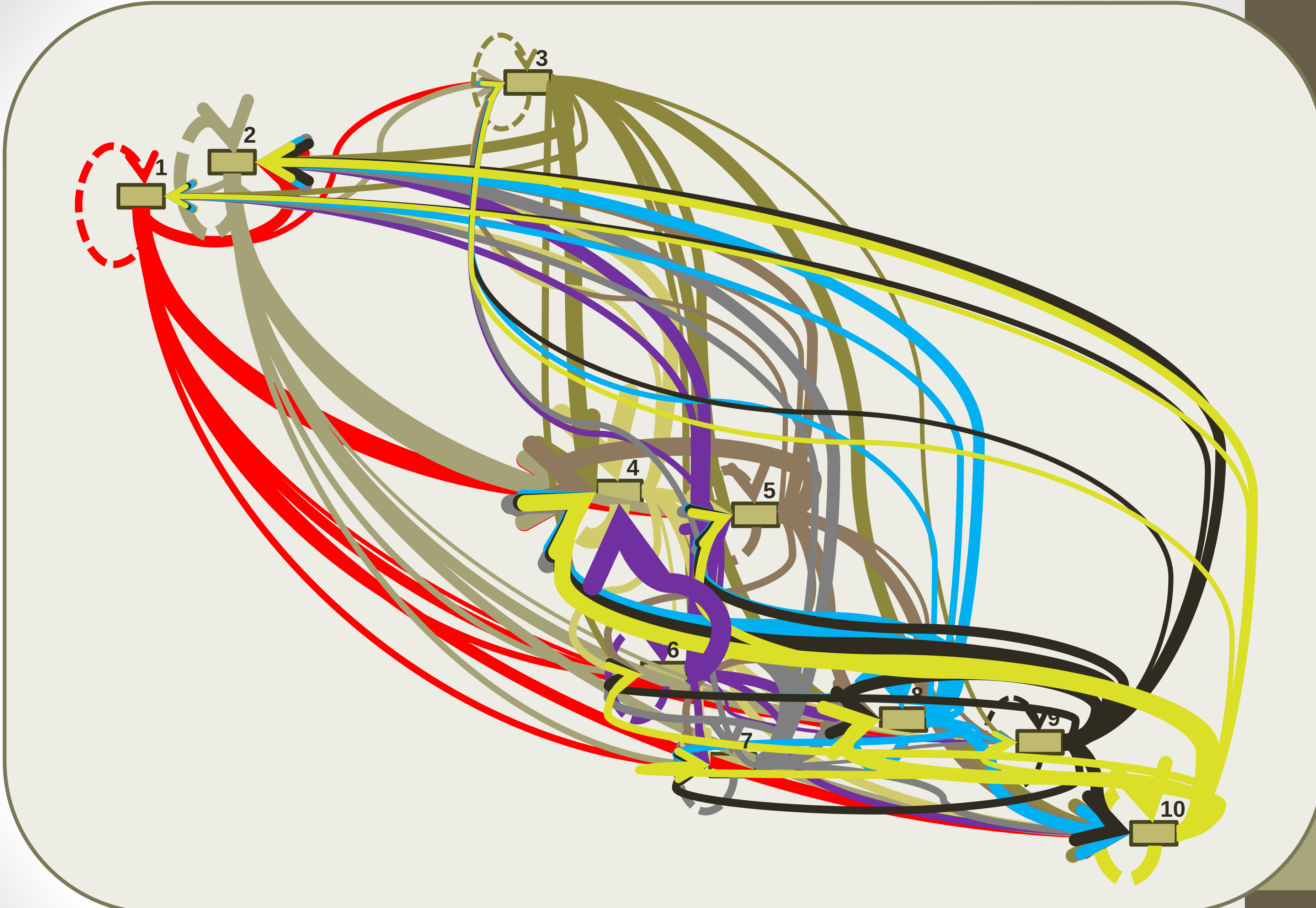
Larval Tracking Model



- **Larval Tracking Model**
  - Modified PTM with oyster larvae behaviors (Based on North et al. 2008)
  - Neutrally buoyant
  - Advection-distributed
  - After 14 days, migrated downward
    - If they found suitable substrate, the settled
    - If not, they died



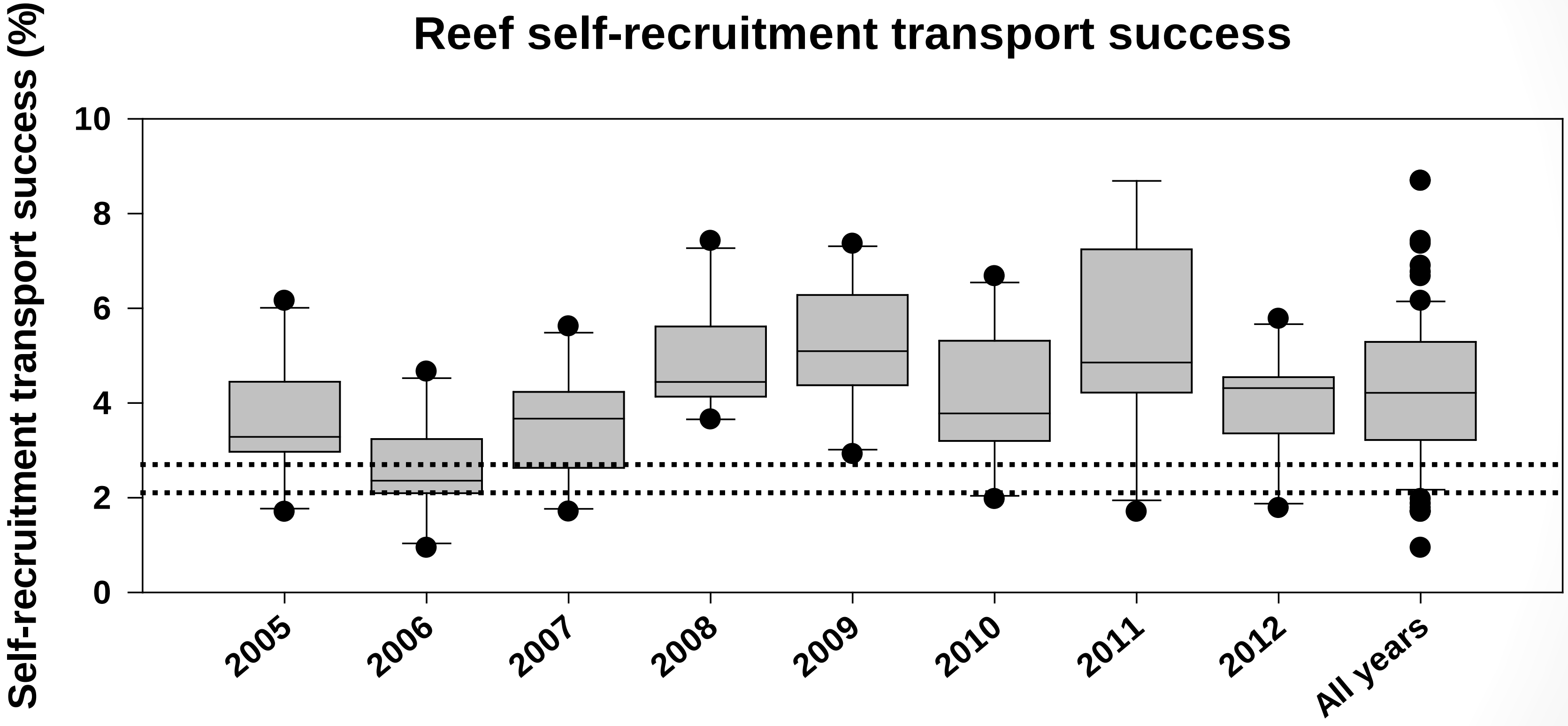
Elevation (m)
13.5
12.0
10.5
9.0
7.5
6.0
4.5
3.0
1.5
0.0
6/30/2005 6:00:00 AM
Larval source
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0



= Oyster Reef

Model evaluation

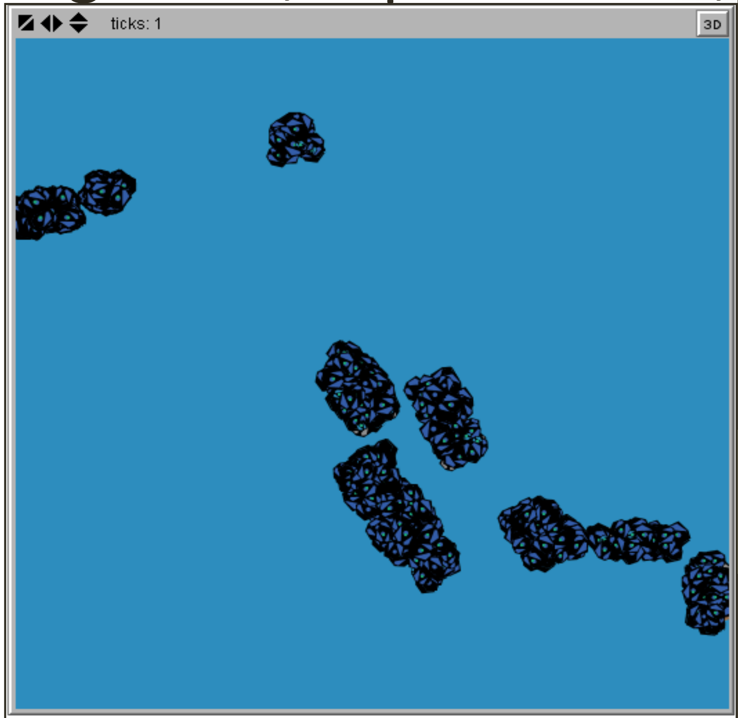
LTM results for Great Wicomico



Self-recruitment rates from North et al. 2008

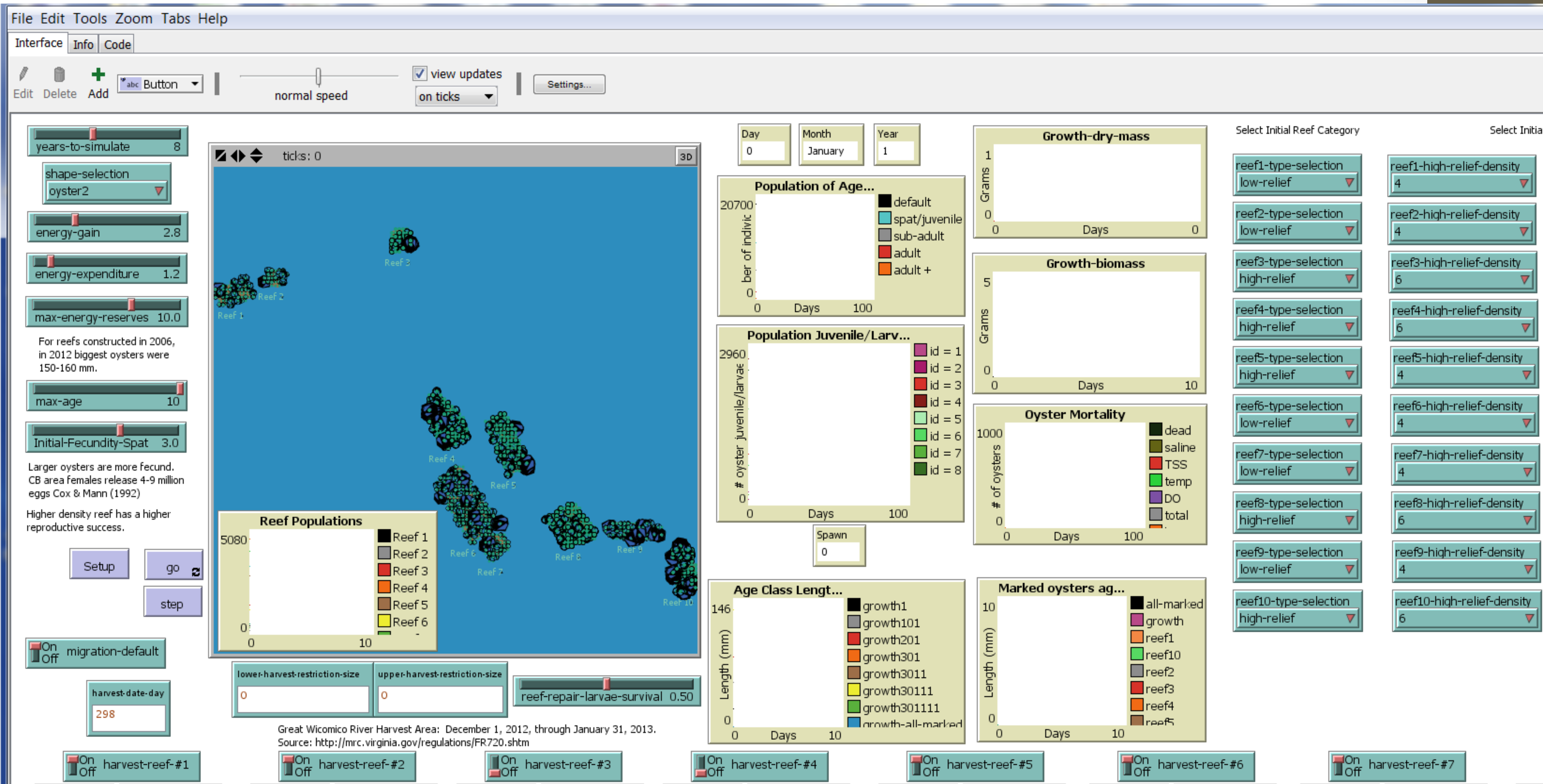
Population Dynamics Model

- Spatially-explicit, agent-based model
  - Agents were aggregated oyster cohorts
  - Bioenergetics-based growth
  - Stage-specific reproduction and mortalities
  - Environmental conditions affect growth, reproduction, & mortality
  - 10 geo-referenced reefs
  - Daily time step
- Programmed in Netlogo



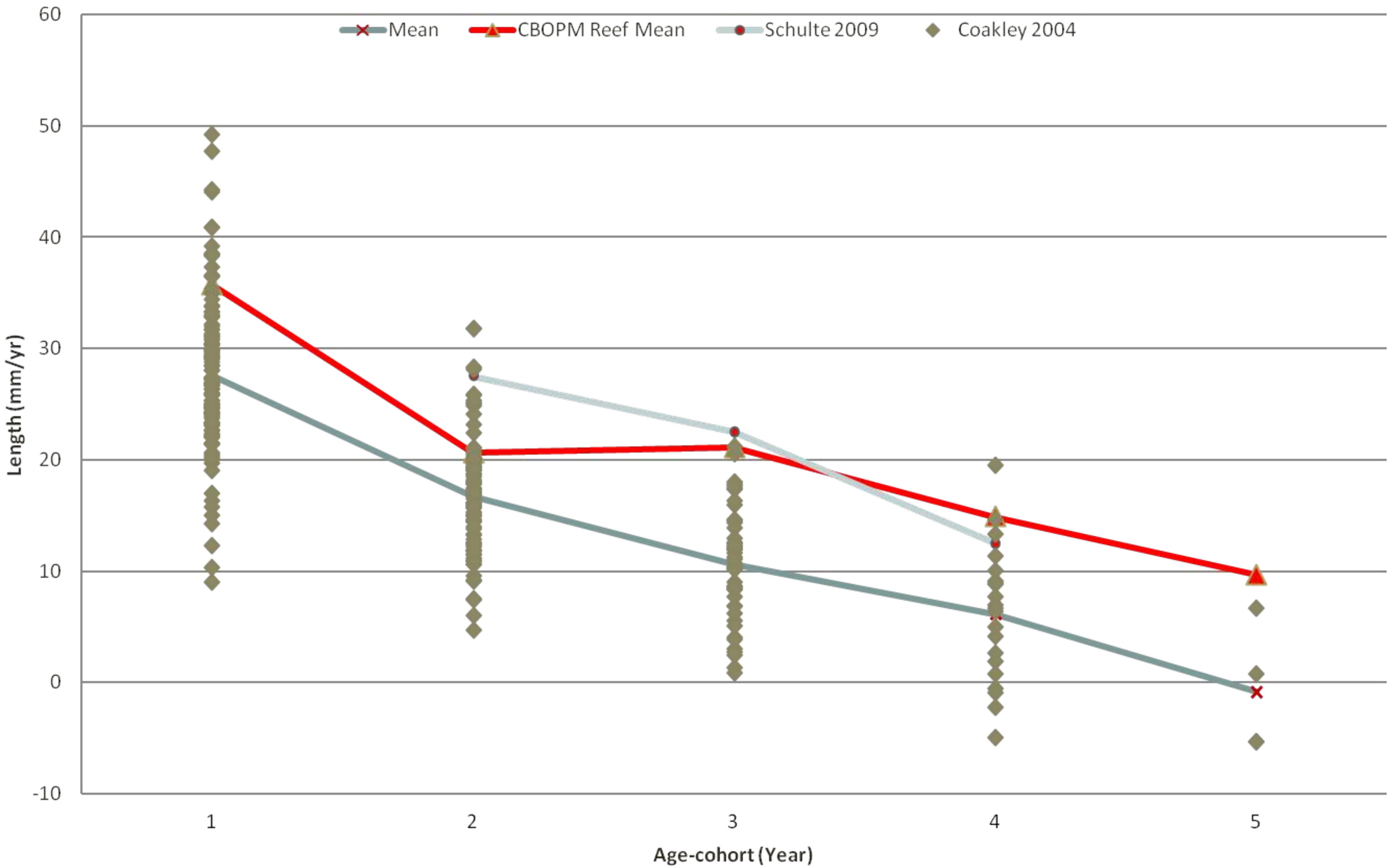
Population Dynamics Model

- ADH and Larval tracking model provide inputs
- User defines management strategies and reef attributes



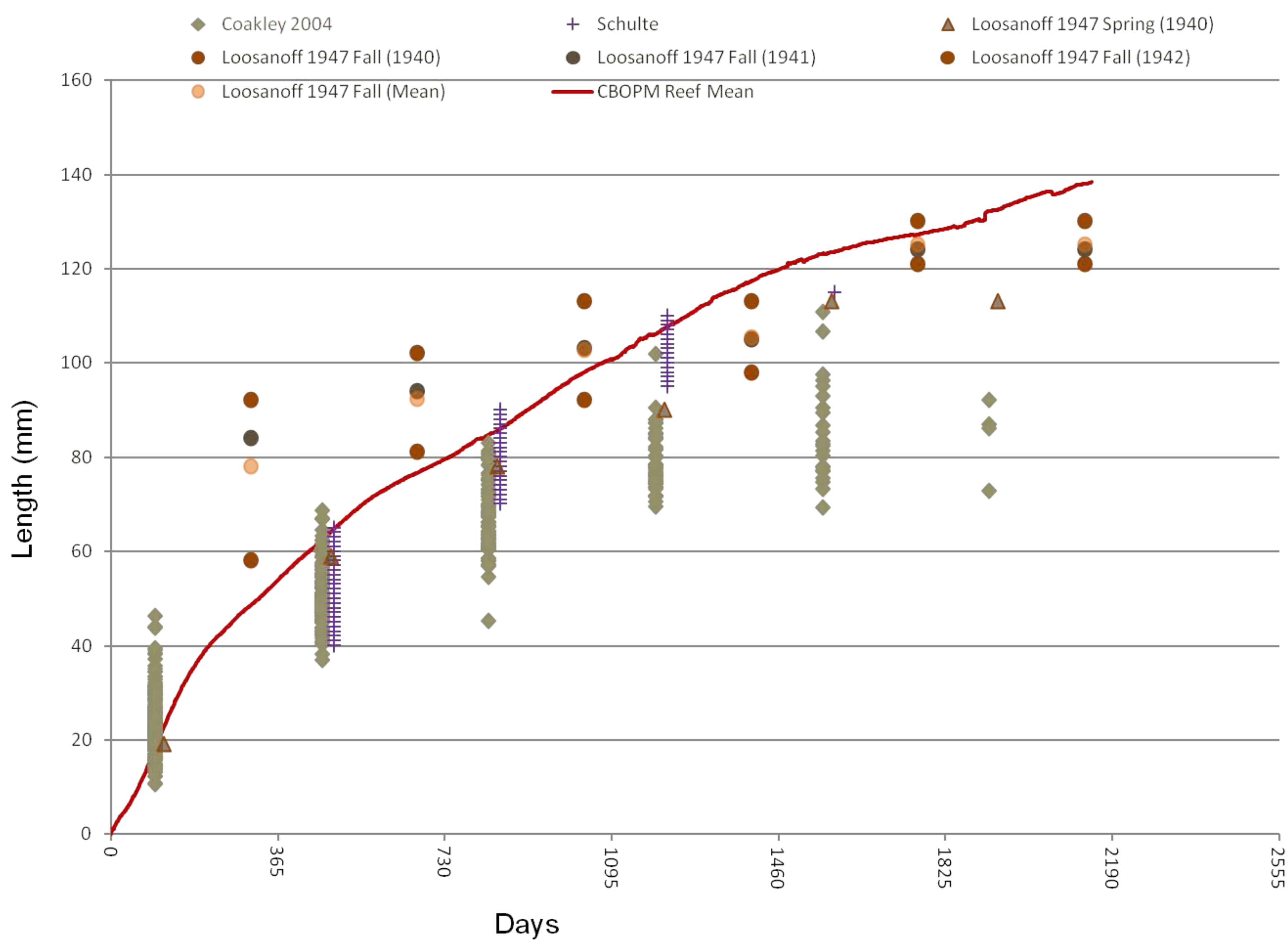
Model Evaluation

Oyster growth rates & lengths



Model Evaluation

Oyster growth rates & lengths



Model Application

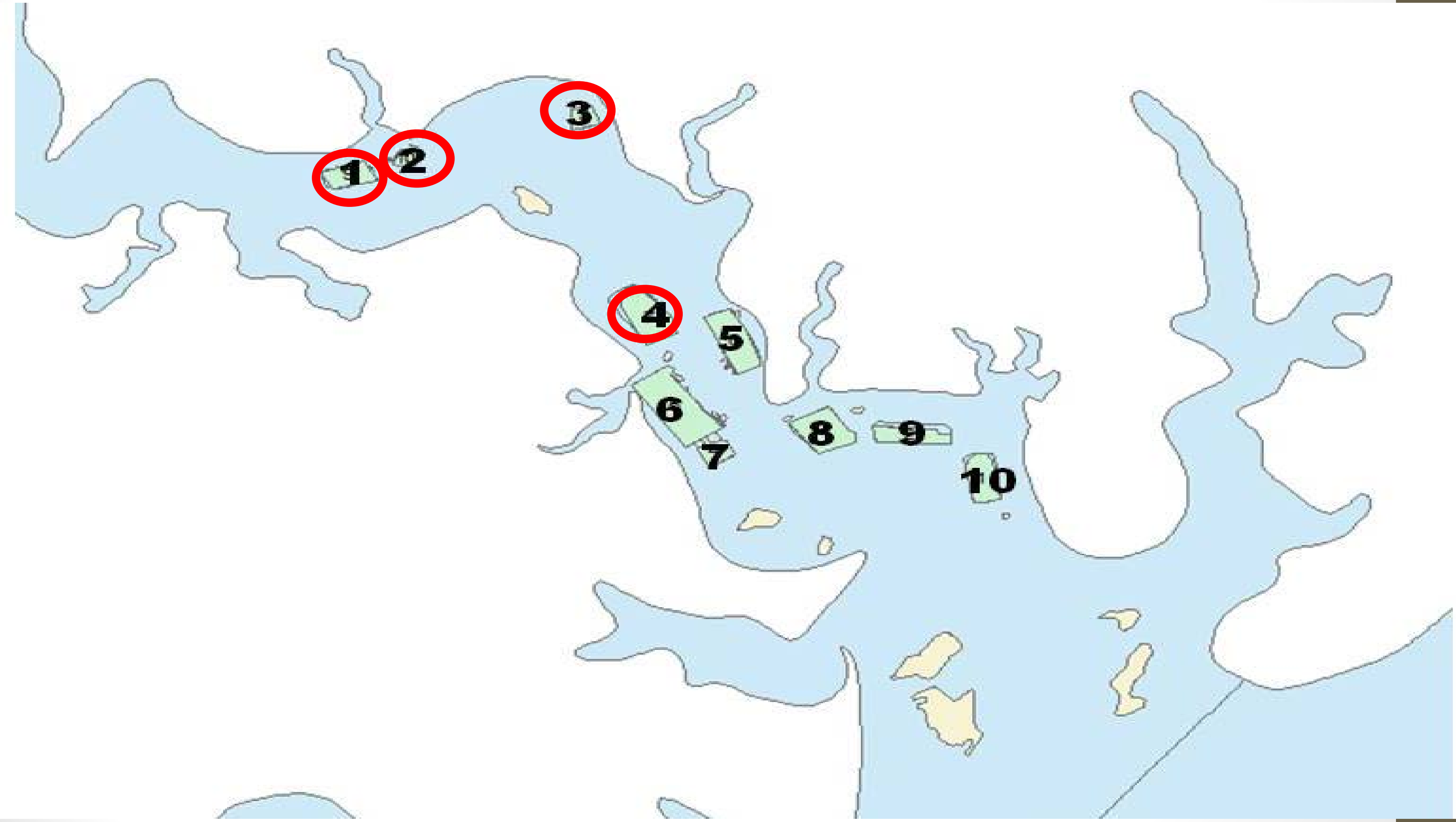
Sanctuaries vs Harvesting

- Ran six scenarios (8 yr. simulations, 25 reps each)

- **Sanctuaries**
  1. Sanctuary only (Higher densities)
  2. Traditional reefs w/o harvesting (*low-relief*)
- **Harvesting**
  3. Harvest every reef annually
  4. Rotational harvest of every reef (each reef harvested once every three years. 3, 4, 3 pattern)
  5. 6 rotational reefs (2, 2, 2), 4 sanctuaries (randomly chosen)
  6. 6 rotational reefs (2, 2, 2), 4 sanctuaries (upstream)

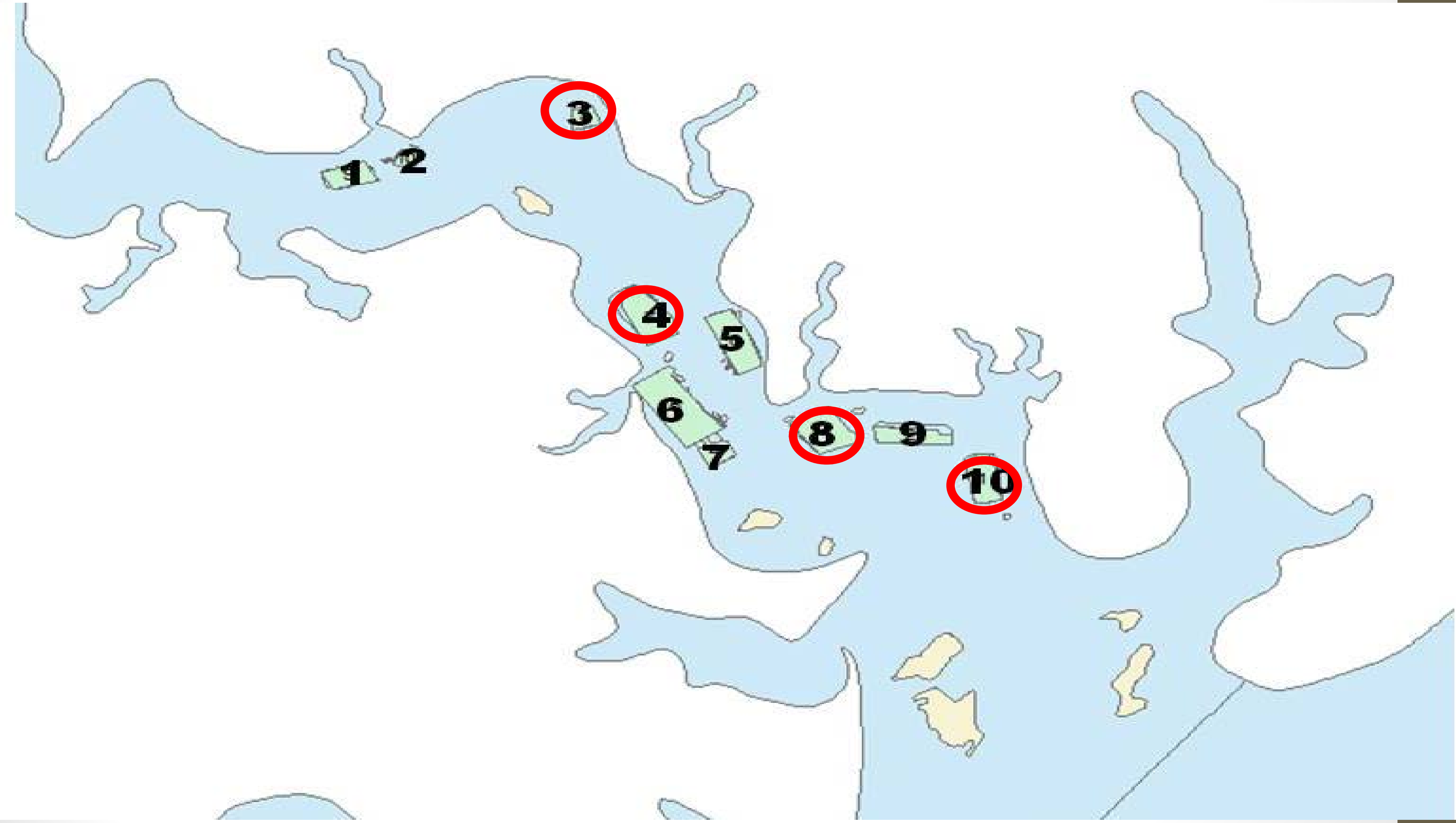
Sanctuary design

Upstream

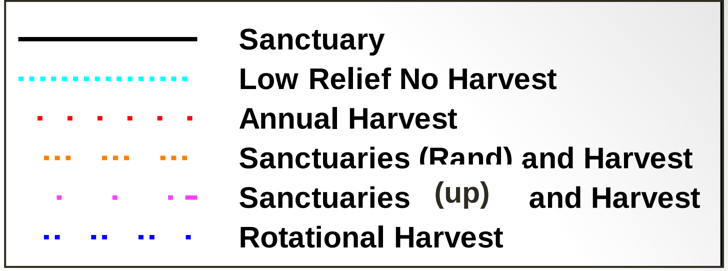


Sanctuary design

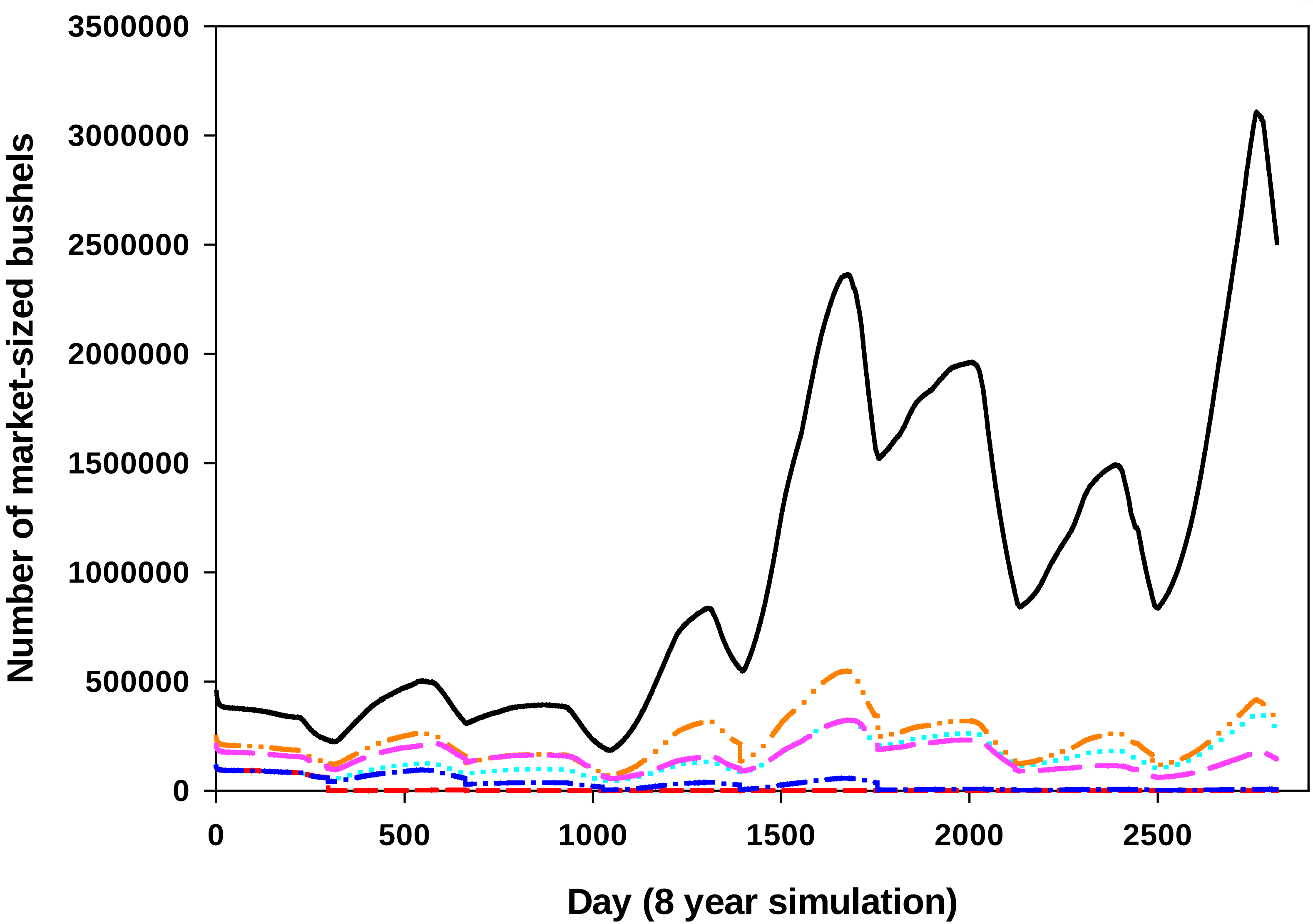
Random



Results

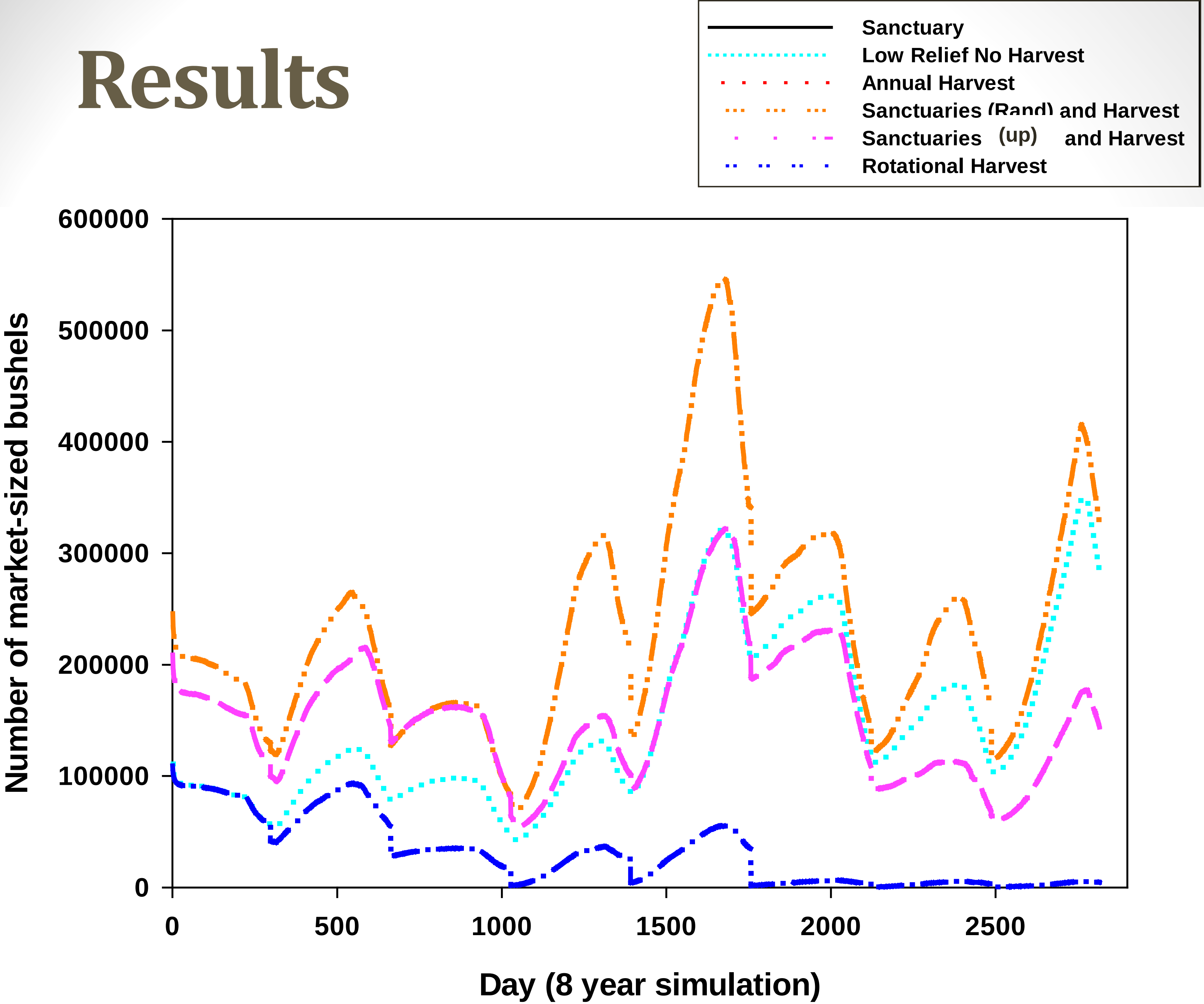


Sanctuary
Low Relief No Harvest
Annual Harvest
Sanctuaries (Rand) and Harvest
Sanctuaries (up) and Harvest
Rotational Harvest



Number of market-sized bushels
3500000
3000000
2500000
2000000
1500000
1000000
500000
0
0
500
1000
1500
2000
2500
Day (8 year simulation)

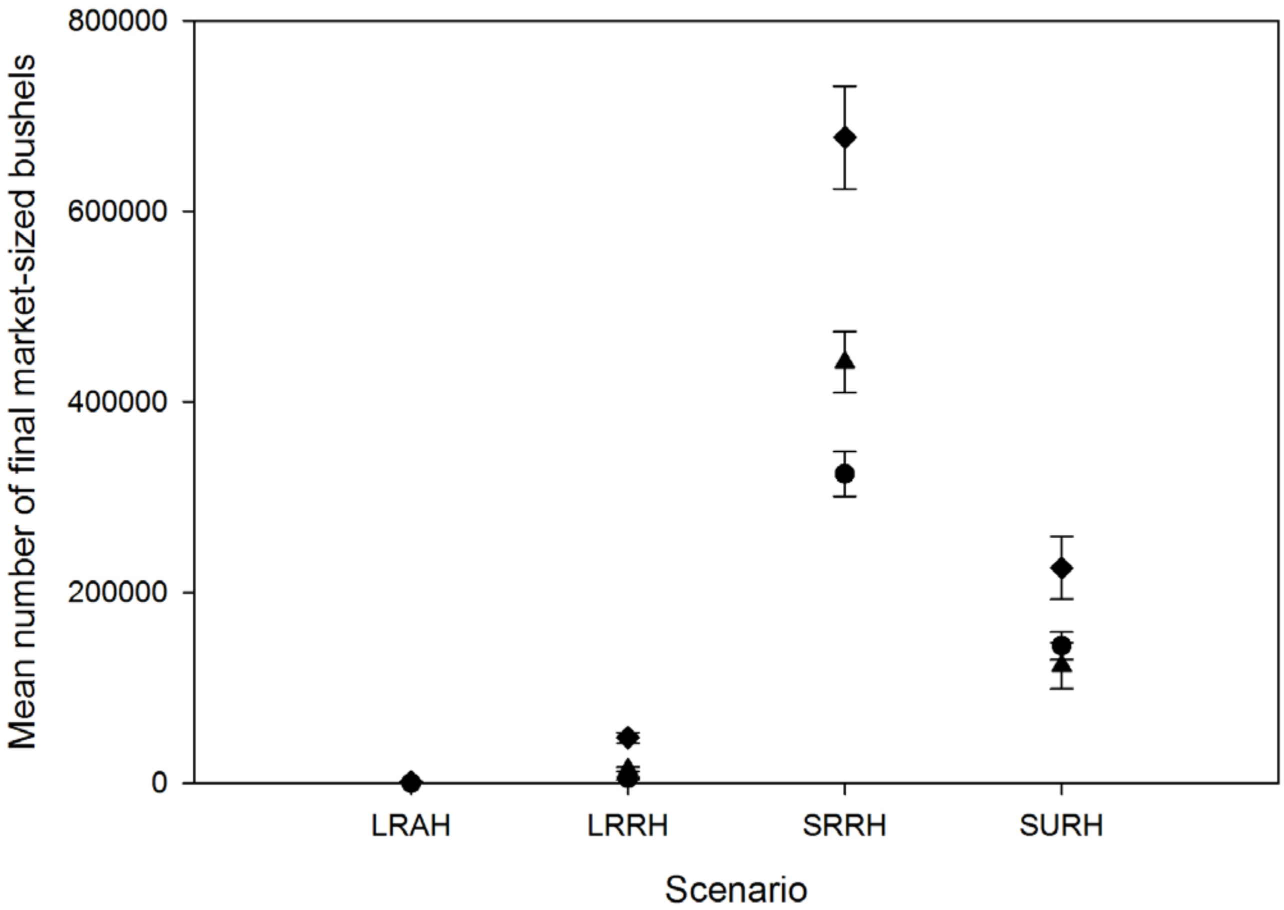
Results



Sanctuary
Low Relief No Harvest
Annual Harvest
Sanctuaries (Rand) and Harvest
Sanctuaries (up) and Harvest
Rotational Harvest
600000
500000
400000
300000
200000
100000
0
Number of market-sized bushels
0
500
1000
1500
2000
2500
Day (8 year simulation)

Results con't.

Abundance after harvest



10% spat remain

50% spat remain

50% all remain

Implications for Management

- Recruitment is critical process to consider when managing reefs

- Spatial position and density of sanctuaries matters
    - Grouping sanctuaries doesn’t produce as many recruits
        - E.g., our upstream sanctuary scenario produced fewer oysters

    - Placing sanctuaries strategically produces more oysters, even with harvest, produced more oysters than low density sanctuaries

Implications for Management

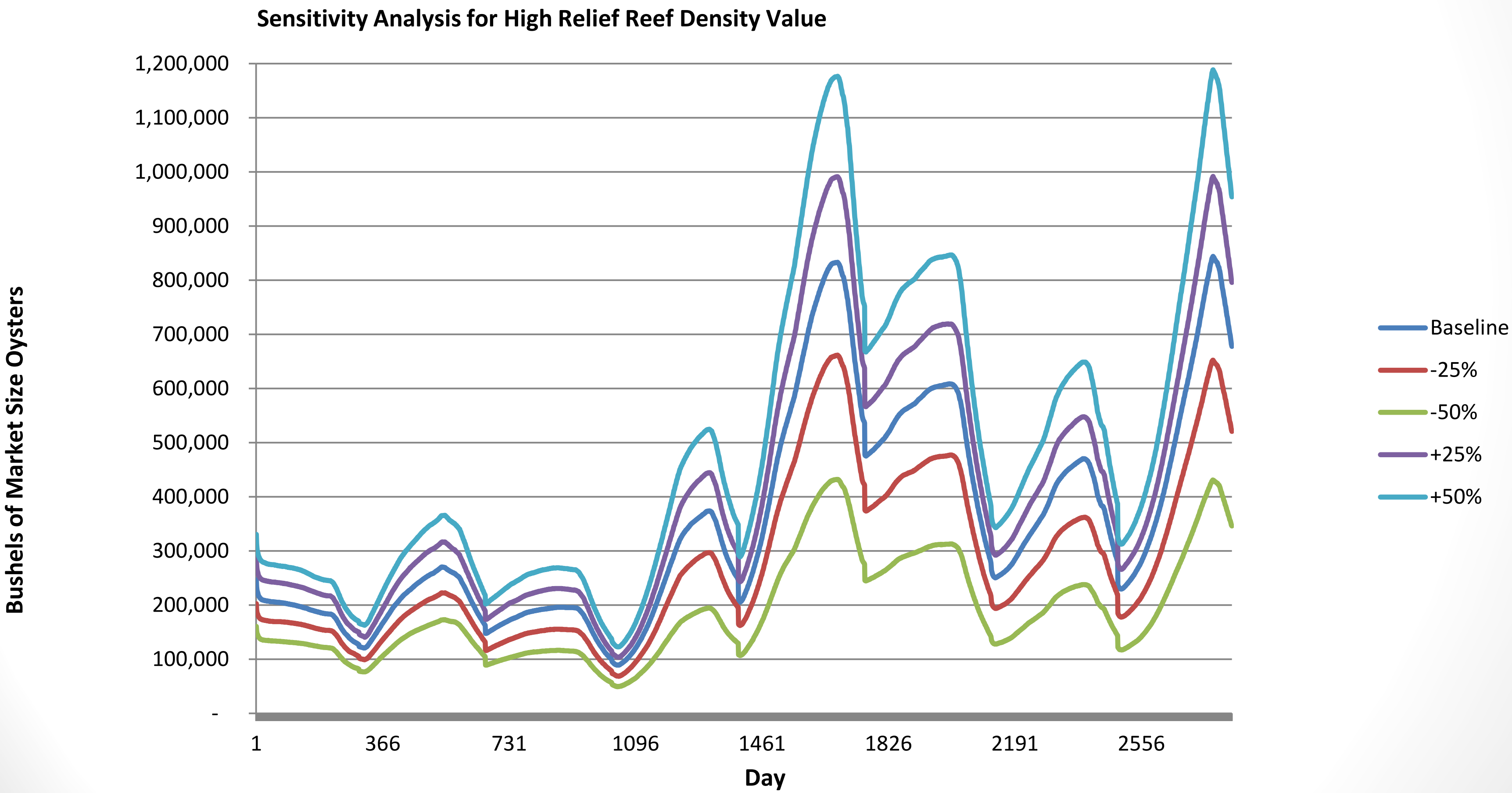
- Sanctuary density matters
  - Lower densities do not do as well
  - There is evidence that higher density sanctuaries have higher survival, however, this was not in the model.

- Harvest limits do increase oyster abundance, do not compensate for loss of sanctuaries.

Future research

- Apply model to Rappahannock River (20-reef system)
- Frequency of harvesting
- Determine optimal number of sanctuaries
- Determine optimal spatial configuration
- Explore recruitment networks for source-sink dynamics

Questions?



Sensitivity Analysis for High Relief Reef Density Value
1,200,000
1,100,000
1,000,000
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
-
1
366
731
1096
1461
1826
2191
2556
Day
Bushels of Market Size Oysters
Baseline
-25%
-50%
+25%
+50%