Initial Conditions Drive Threshold Dynamics on Restored Oyster Reefs

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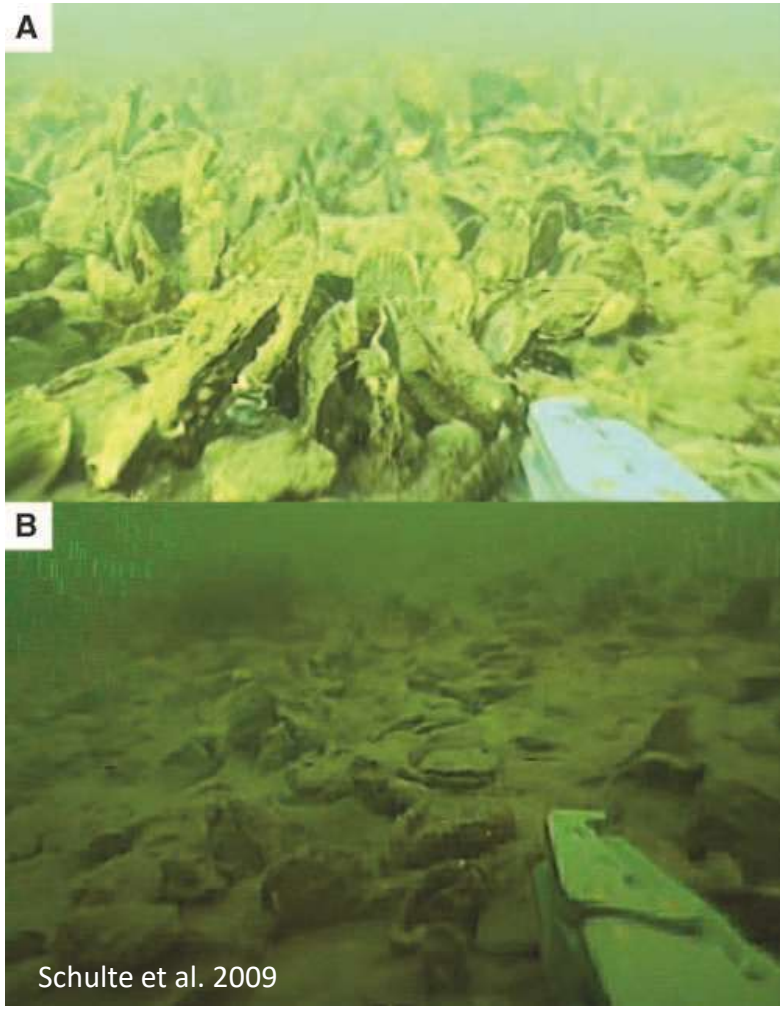
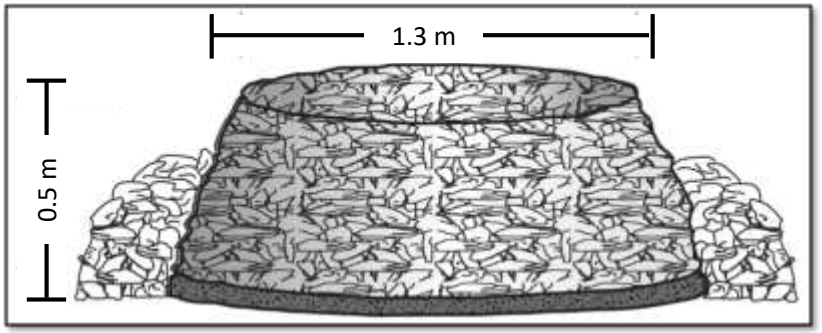
Oyster Reef Height

- Reef height impacts oyster survival, recruitment, and growth (Lenihan 1999, Schulte et al. 2009)
- Studies suggest divergent responses to reef height
- Do thresholds exist that drive reefs to persistence vs. degradation?



Reef Height Field Experiment

- Lynnhaven and Great Wicomico Rivers in Virginia
- 4 sites
- Reef heights: 0.05 m - 0.5 m
- Sampled 8 and 22 months after construction



Reef Sampling

Response Variables

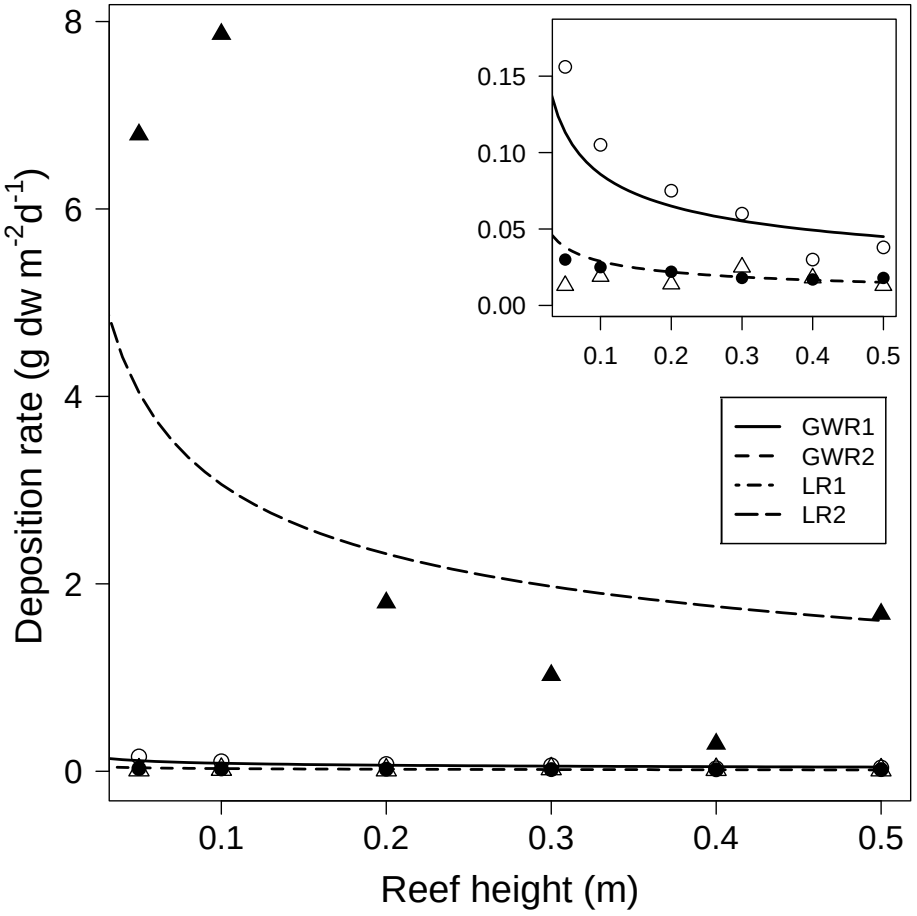
- Sediment Deposition
- Oyster Density

Analysis

- Fit a suite of models with and without a change point
- Akaike's Information Criterion (AIC) to select best model

Candidate Models	Function	Change Point
Linear	$y = ax + b$	No
Power	$y = ax^{b}$	No
Logistic	$y = c + \frac{d - c}{1 + e^{-a(x-b)}}$	Yes
Gompertz	$y = a + (b - a)e^{-e^{-c(x-d)}}$	Yes

Sediment Deposition

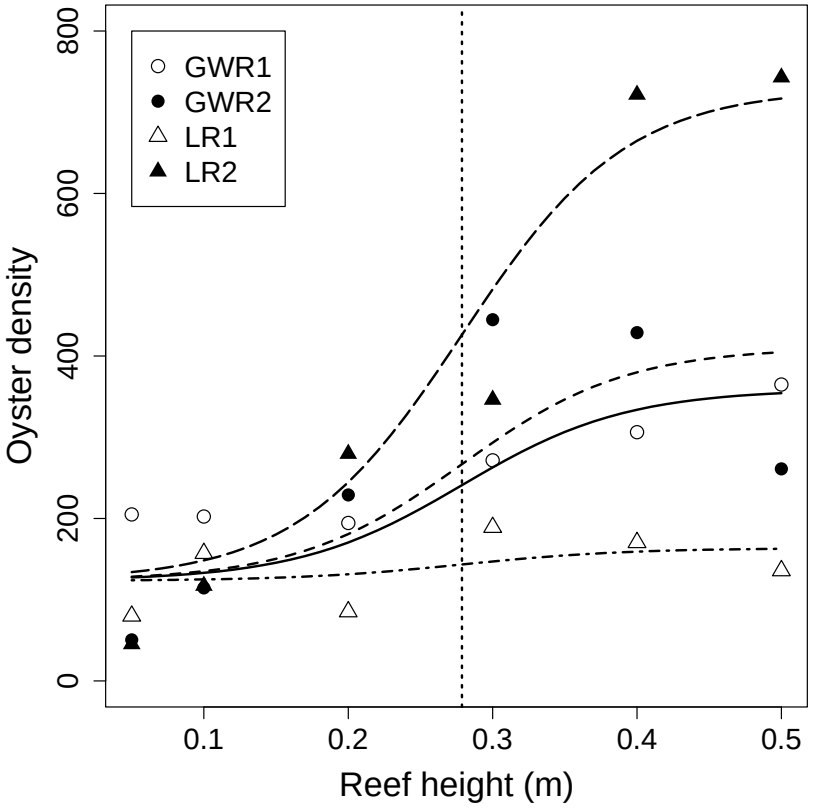


LR 2 Site: 0.1 m reef

GWR 2 Site: 0.4 m reef

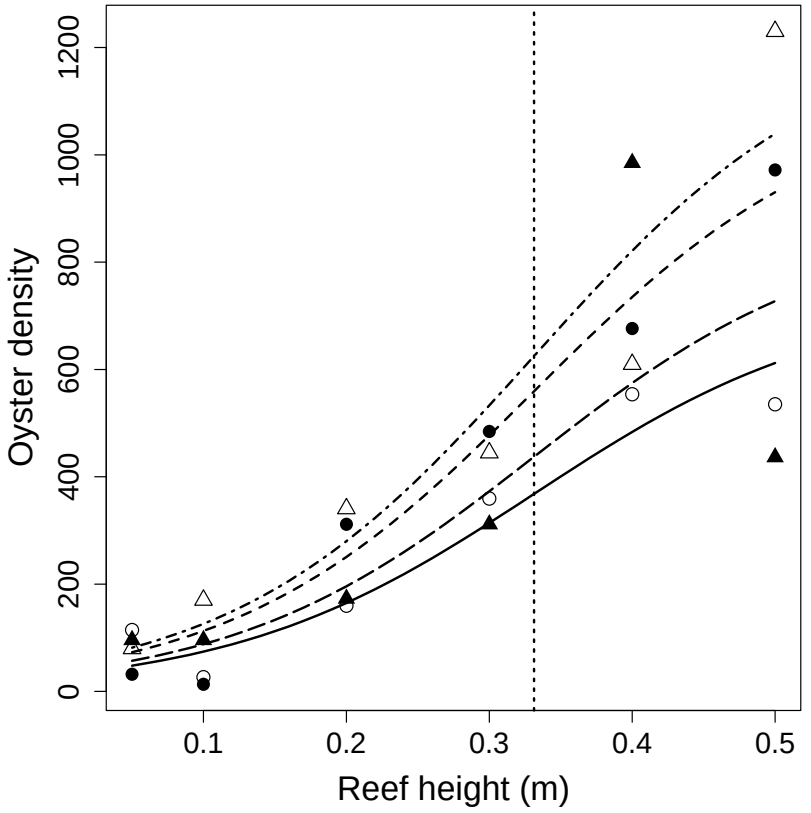
Oyster Density

2010

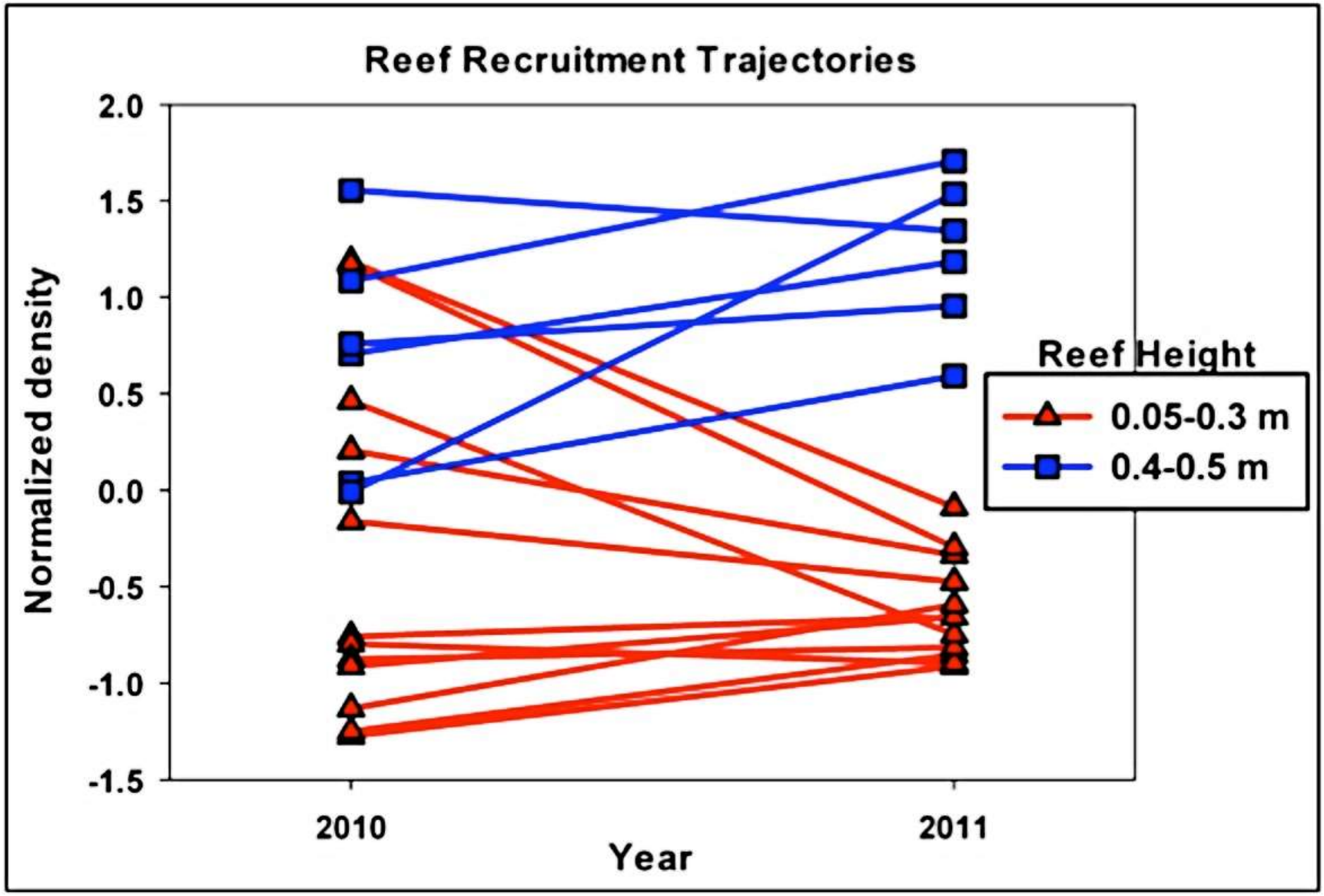


Estimated threshold: 0.27 m

2011

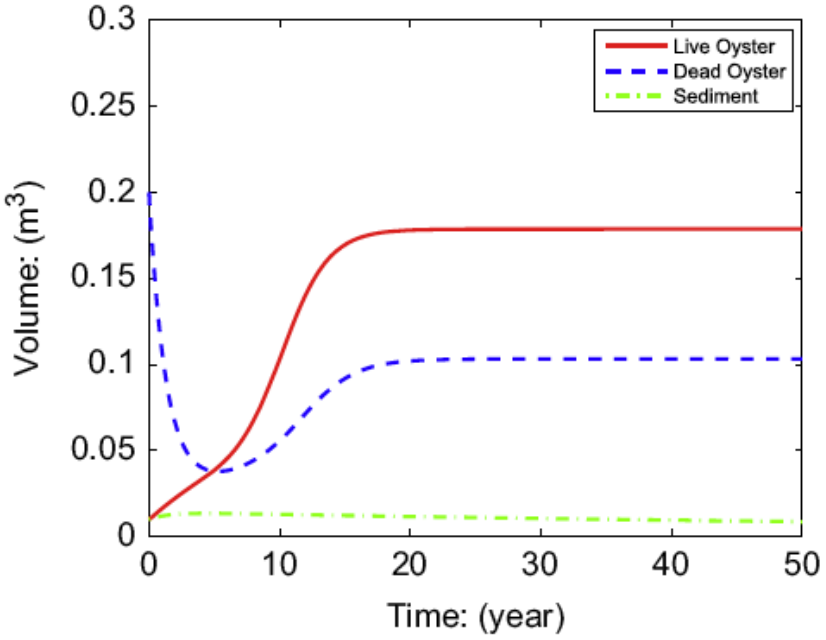


Estimated threshold: 0.33 m

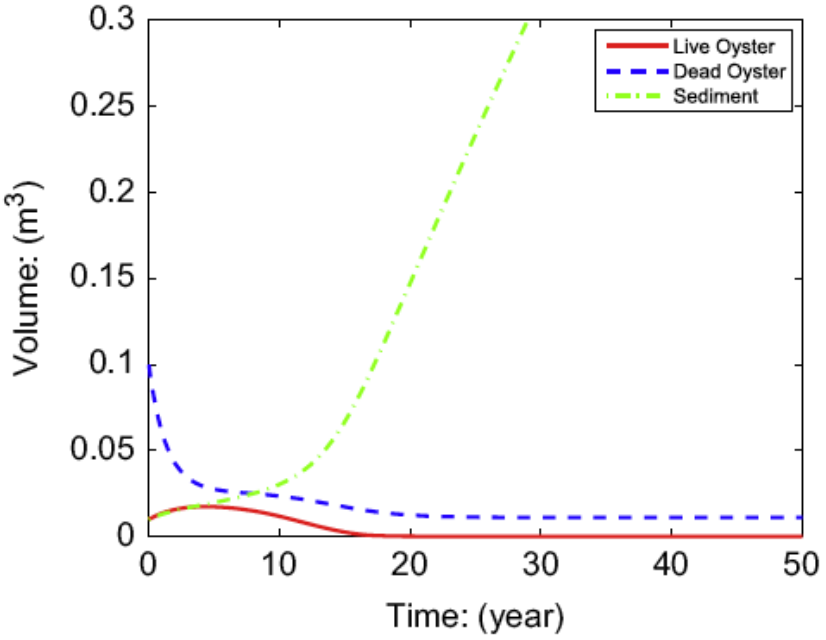

Reef Recruitment Trajectories
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
Normalized density
2010
2011
Year
Reef Height
0.05-0.3 m
0.4-0.5 m

Oyster Numerical Model

Initial Height: 0.2 m



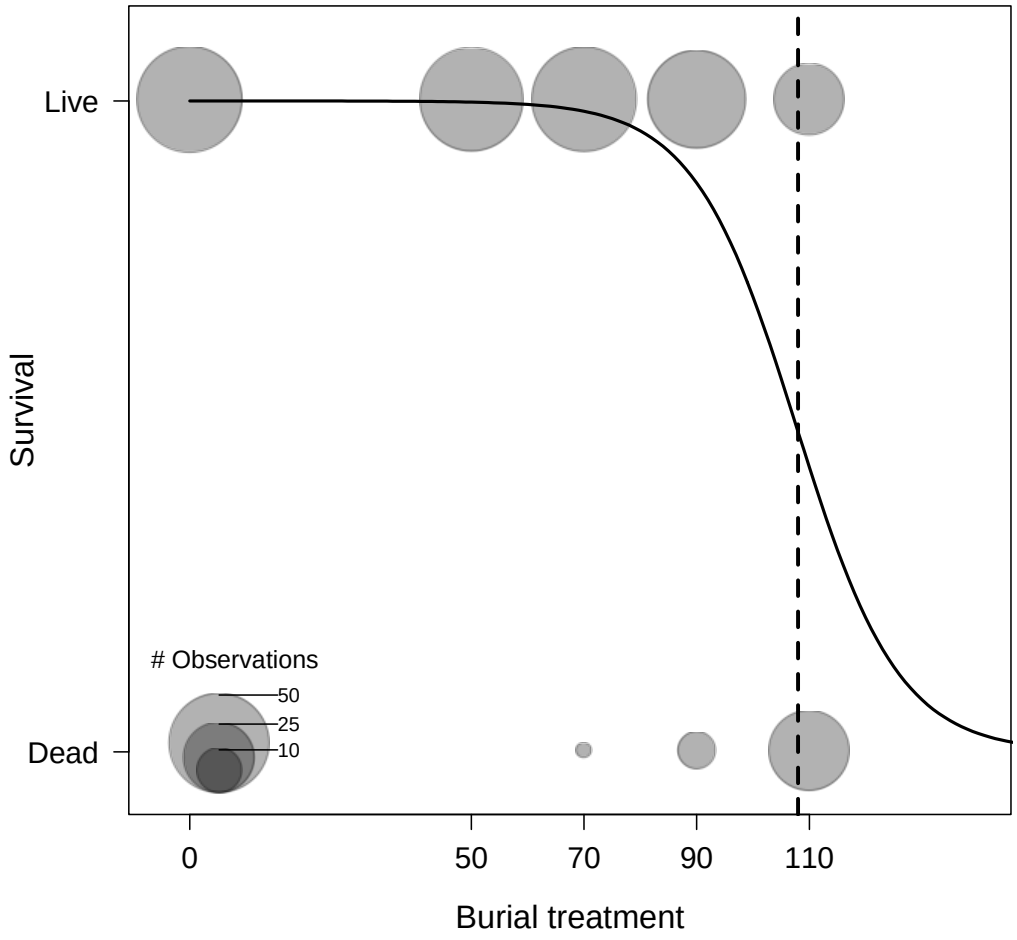
Initial Height: 0.1 m



Jordan-Cooley *et al.* 2011

Sediment Dynamics

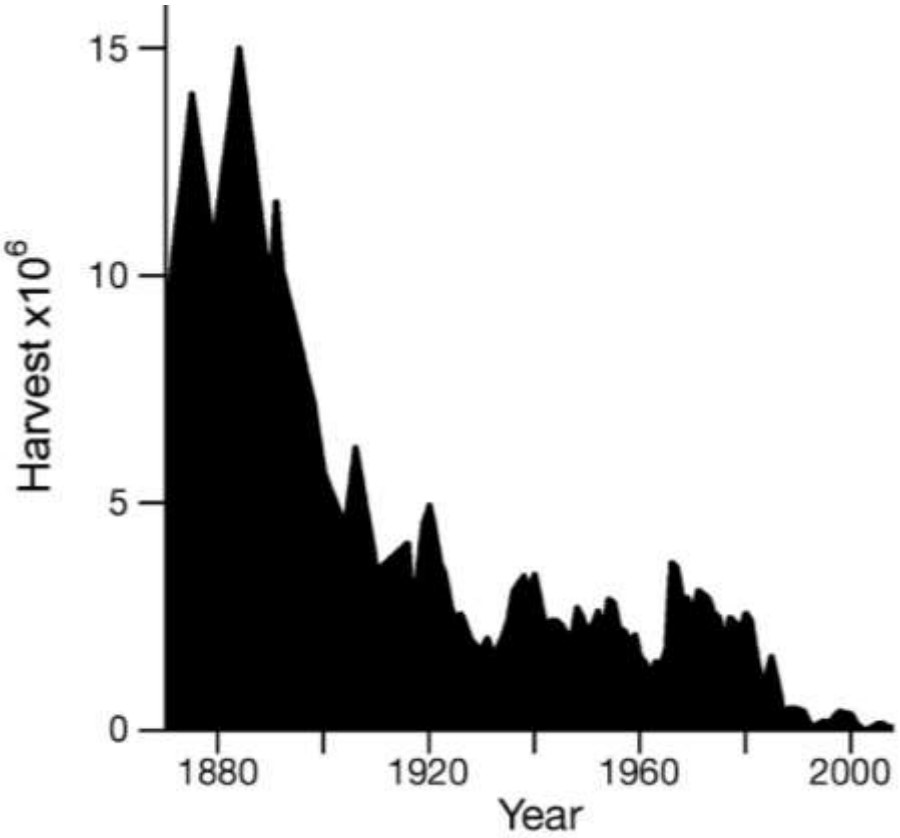
- Sedimentation has both lethal and sublethal effects
  - Survival
  - Biodeposition
  - Oyster condition
- Sublethal effects impact reef-building



Colden and Lipcius 2015

Restoration Implications

- Harvest reduces reef height disrupting self-sustaining feedbacks
- Reinforcing factor for observed declines
- Understanding thresholds can help best utilize limited resources



Wilberg et al. 2011

Acknowledgements

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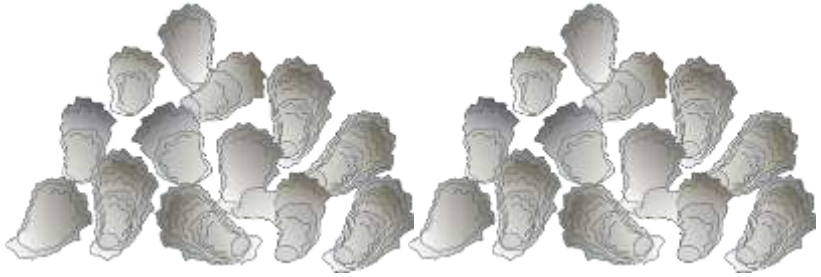
Application to Restoration

- Build reefs > 0.3 m in areas with similar deposition
- Use plateau shape to maximize high relief
- Close reefs to harvest

Oyster shell “pavements”
0.02-0.03 m vertical relief

“Egg-carton” style reefs
0.5-2m vertical relief



Numerical Model

Live Oysters:

$$\frac{dO}{dt} = rOf(d)\left(1 - \frac{O}{k}\right) - mf(d)O - e(1 - f(d))O$$

Oyster Shell:

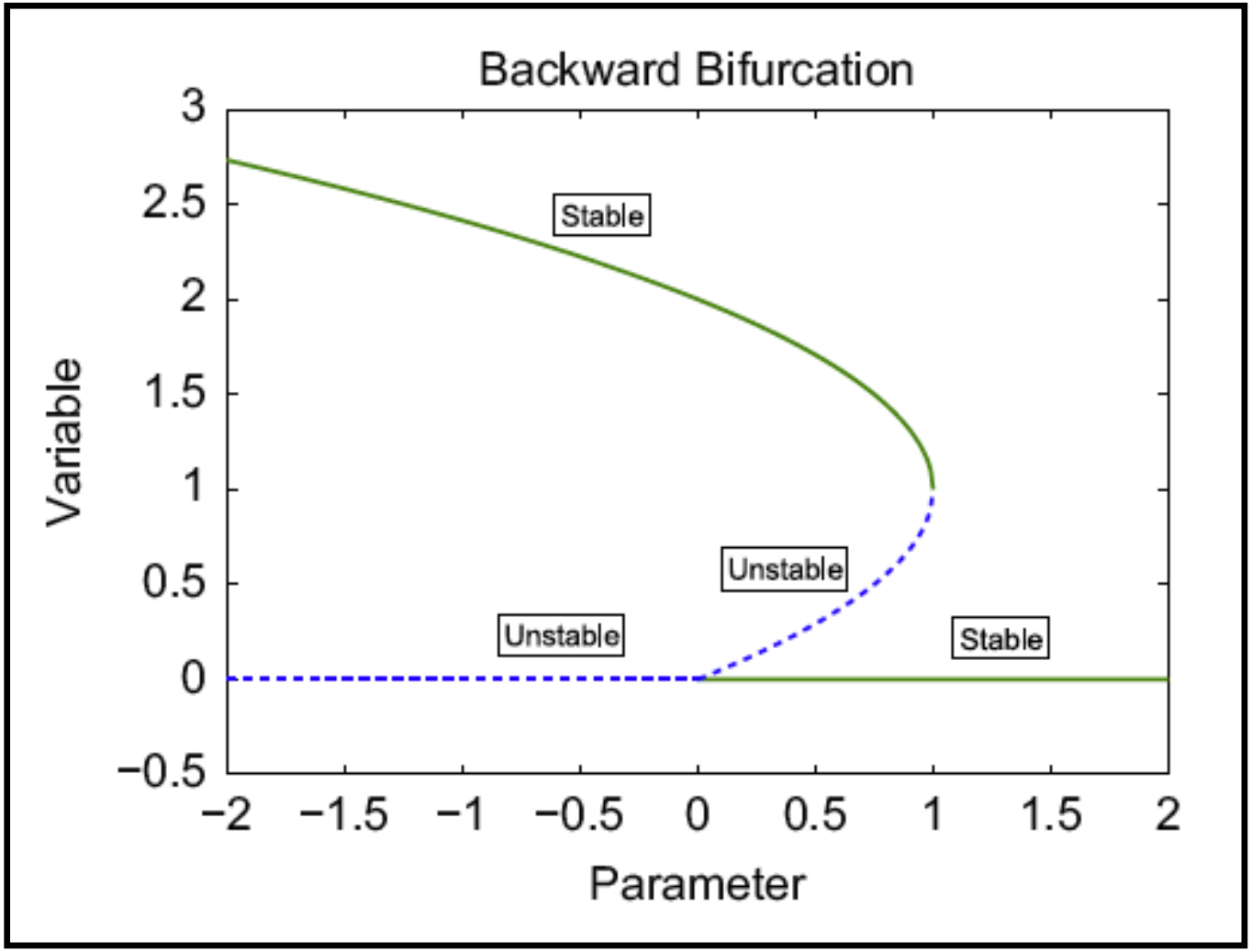
$$\frac{dB}{dt} = mf(d)O + e(1 - f(d))O - gB$$

Sediment:

$$\frac{dS}{dt} = -bS + Cge^{-FO/Cg}$$

Jordan-Cooley *et al.* 2011

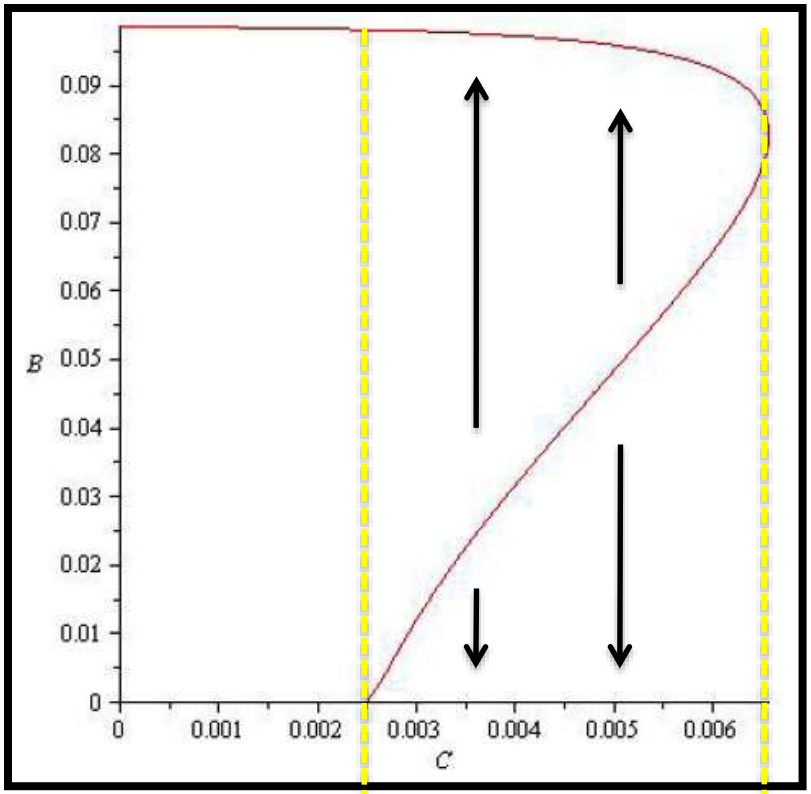
Oyster Numerical Model



Jordan-Cooley *et al.* 2011

Example of Bifurcation analysis

B vs Sediment in water column (C)



Stable Reef | **Alternative States** | **Degraded Reef**