



# The Role of Uncertainty in Limiting Demographic Model Application in Oyster Management in Chesapeake Bay

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# The Actual Modelers

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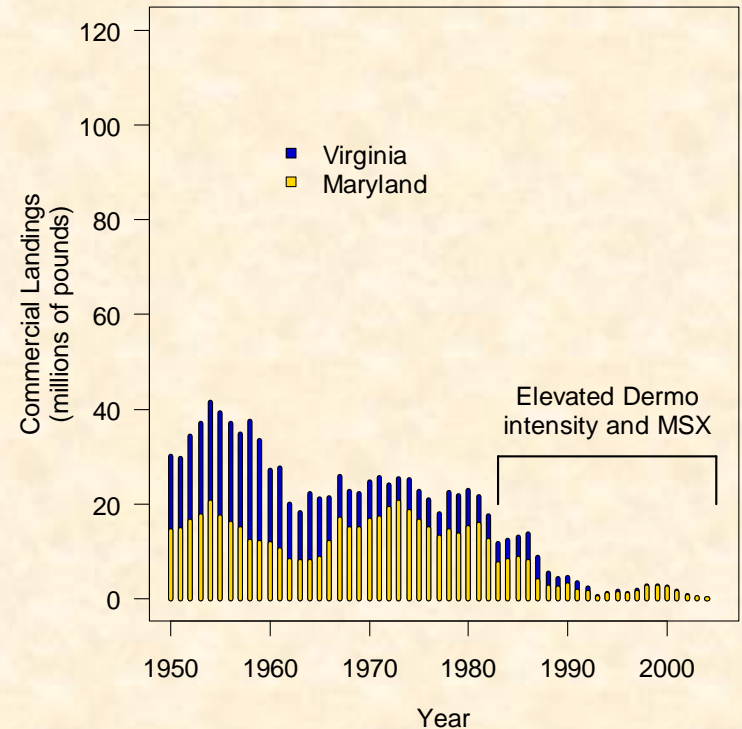
# Motivation for Model Development



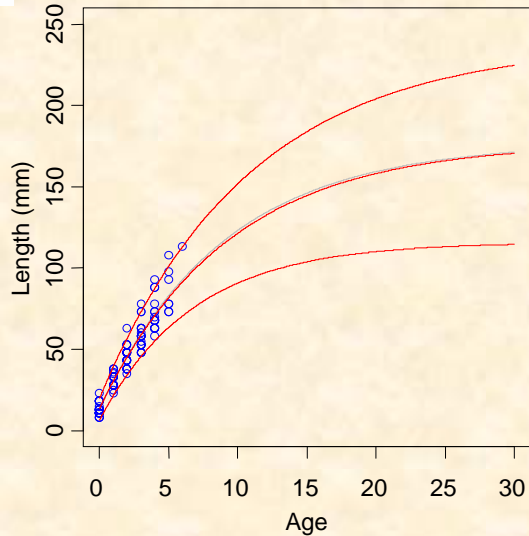
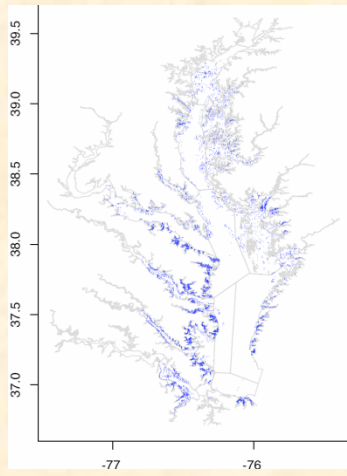
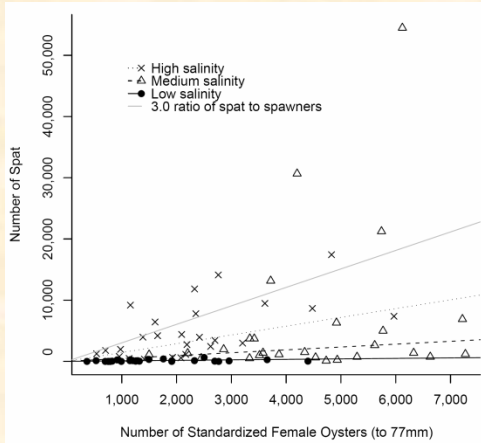
Oyster population in the Chesapeake Bay has declined – disease, harvest, habitat loss

Programmatic EIS for oyster restoration was prepared;  
Included alternatives for native restoration and introduction of Asian oyster

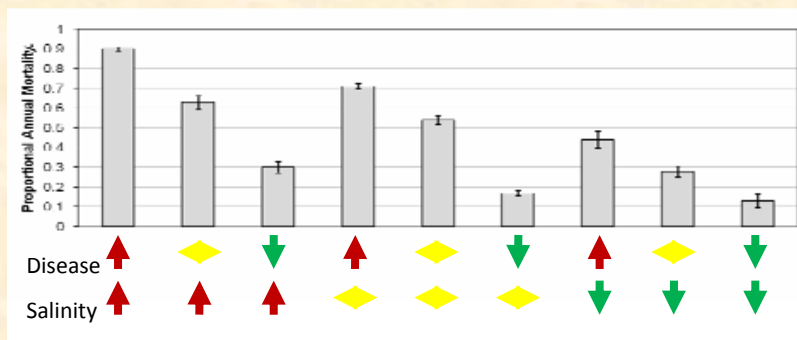
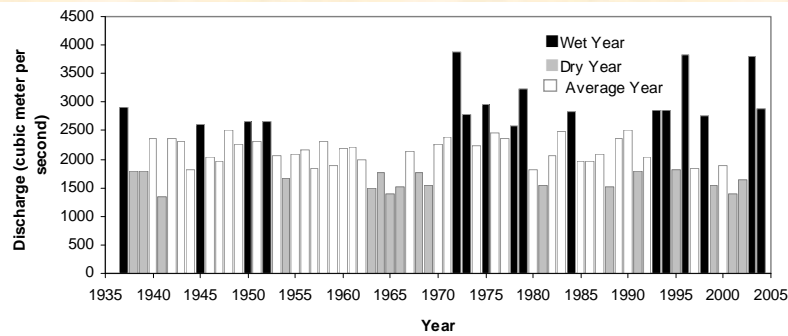
Oyster demographic model (ODM) was intended to integrate available data to predict population trends under various management scenarios



# Why Model?



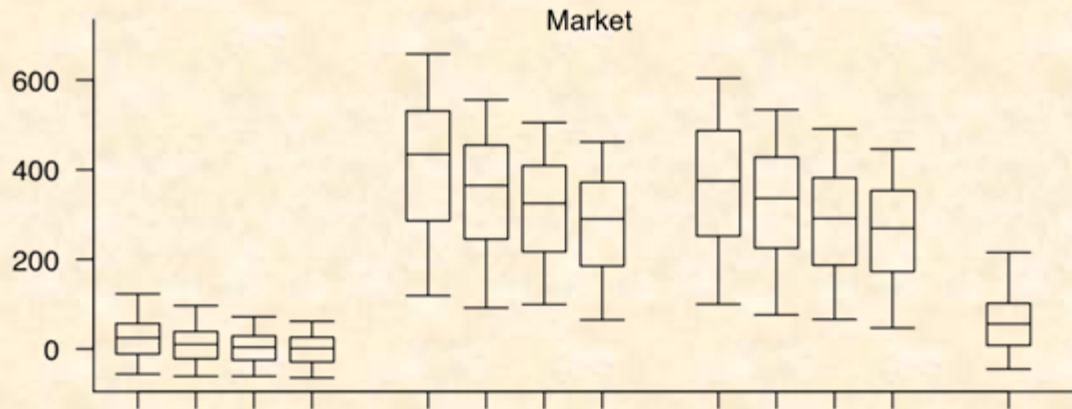
- Populations are controlled by their recruitment, growth, and survival rates
- These rates are affected by weather, salinity, harvest, disease...
- Can't perform calculations to predict how rates interact without a computer



# Why Model? (Cont.)

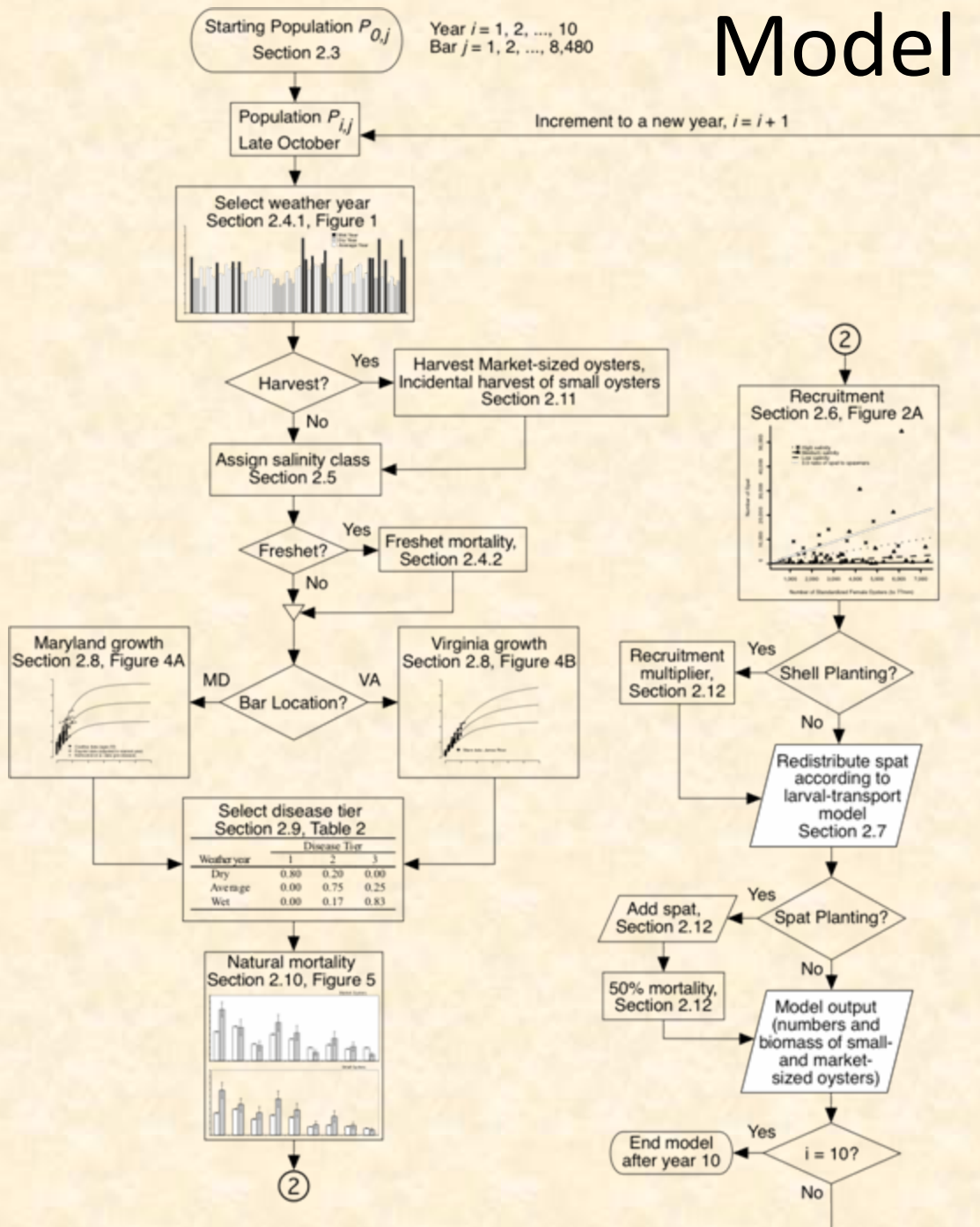


- Demographic model integrates data to predict likely outcomes and relative uncertainty
- Provides a weight-of-evidence approach to evaluating alternatives



- It's not a crystal ball

# Model Structure



- 1,000 simulations for each alternative
- Estimates and confidence limits based on median, 5<sup>th</sup> and 95<sup>th</sup> percentiles of all runs

# Model Evaluation

## James River Projections



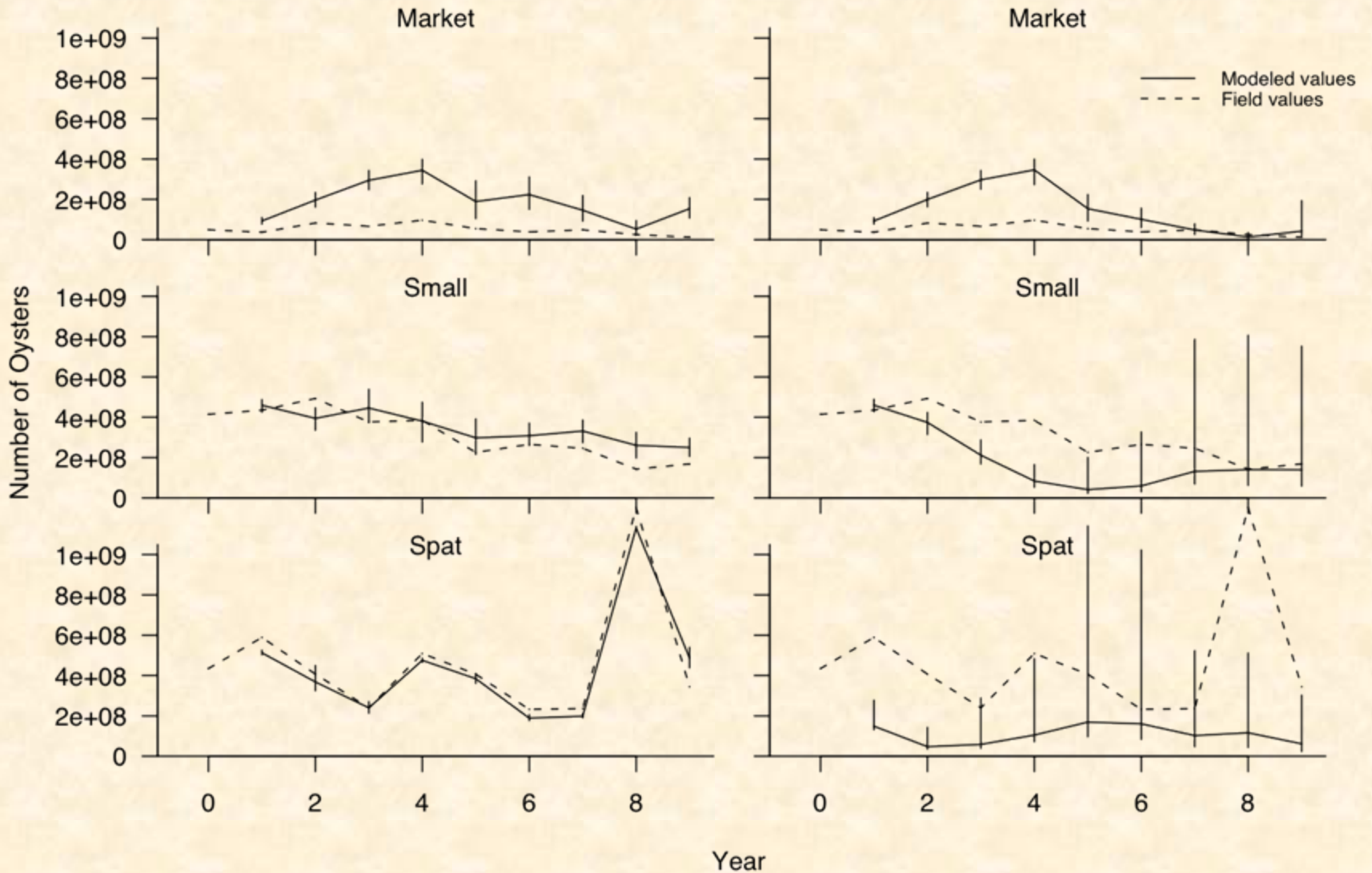
- Absolute abundance estimates by size (courtesy R. Mann, VIMS), 23 oyster bars, 1994-2004
- Used 1994 estimates to initiate model
- Projected oyster abundance by size from 1995-2004 using demographic model
  - General mortality and recruitment parameters
  - Specific growth function for James River

# James River



A. James River, Spat Not Modeled

B. James River, Spat Modeled



# Limitations of the “Validation”

- Model based on Bay-wide information, not-James River-specific
- James River data were detailed and specific, while many model inputs were averages, approximations and estimations
- Time frames differed (e.g., long-term climate averages vs. year-specific conditions)

# Rigorous ODM Peer Review

- Oyster Advisory Panel (OAP):
  - Dr. B. Rothschild, UMASS, Chair
  - Dr. Jim Anderson (URI)
  - Dr. Eric Powell (Rutgers)
  - Dr. Roger Mann (VIMS)
  - Dr. Mike Roman (UMD)
  - Mark Berrigan (FL DOA)
  - Maurice Héral (IFREMER)
- Responsible for peer review of ODM and Final PEIS

# Primary OAP ODM Review Issues



- Input data sets create unquantifiable uncertainty
- Model cannot be properly validated
- Estimation of recruitment is non-standard
- *C. ariakensis* should not be modeled because insufficient data exist to parameterize the model

# Consequence of OAP Review

- ODM outcomes could not serve as the basis for comparing outcomes of alternatives in the PEIS
- Quantitative ODM outcomes could be used to “inform” narrative assessments of native oyster alternatives
- Final management decision (implement a combination of native oyster alternatives) based substantially on concerns about “unknown unknowns”
- Modeling effort did contribute to a comprehensive identification, collection and integration of disparate oyster research and management data from throughout the Bay

# Issues/Challenges

- Adapting/integrating the only data available to parameterize a model makes for interesting science but introduces unquantifiable uncertainty unacceptable to decision makers
- Stationary processes are increasingly unlikely as modeled time span increases, making historical data decreasingly valuable as predictors
- Degree of acceptability of uncertainty is inversely proportional to the levels of controversy and reversibility associated with the management decision
- Attempting to model oyster populations throughout the Bay as a single stock was probably over-reaching due to high spatio-temporal variability in environments and life history characteristics
- While modelers know that projections are only potential outcomes with often large levels of uncertainty, non-scientists focus on the number and ignore the uncertainties (i.e., outcomes are taken out of context)

# Backup Model Detail Slides

# Starting Population and Habitat

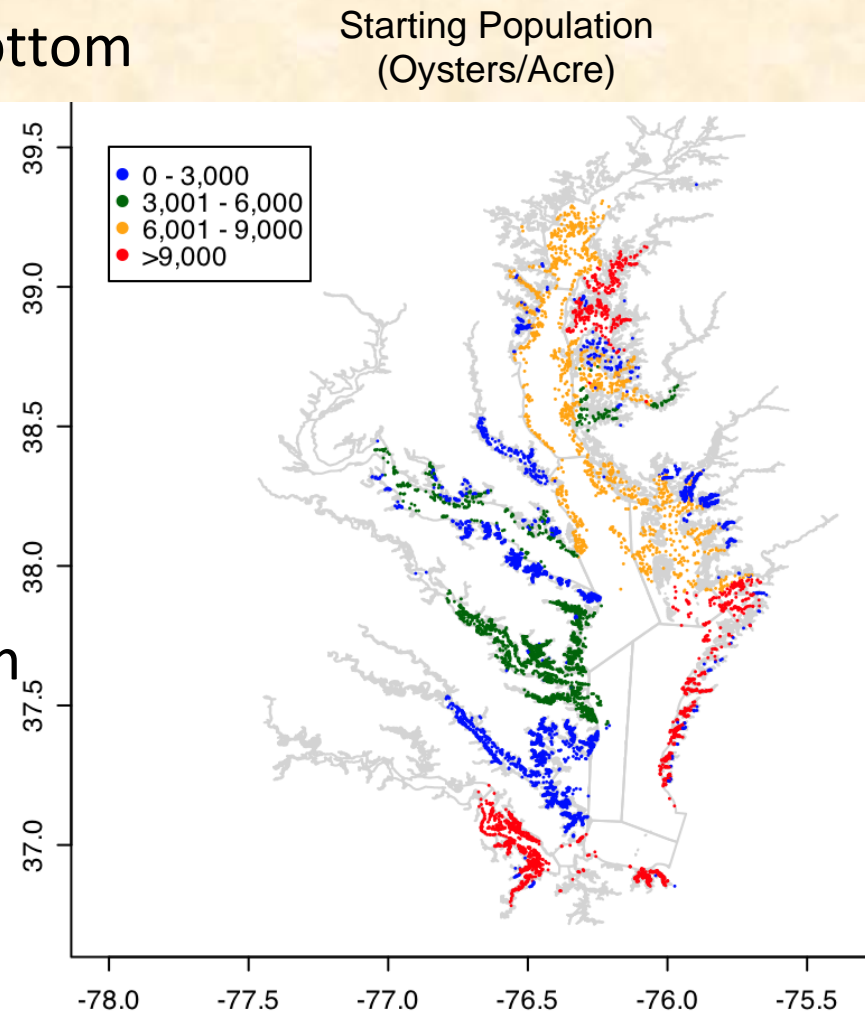


## Habitat :

- GIS of historical surveys, leased-bottom sites, and restoration sites
- Reduced to reflect sedimentation
- 8,480 “bars”  
(Greenhawk et al. 2005, MDDNR)

## Starting Population:

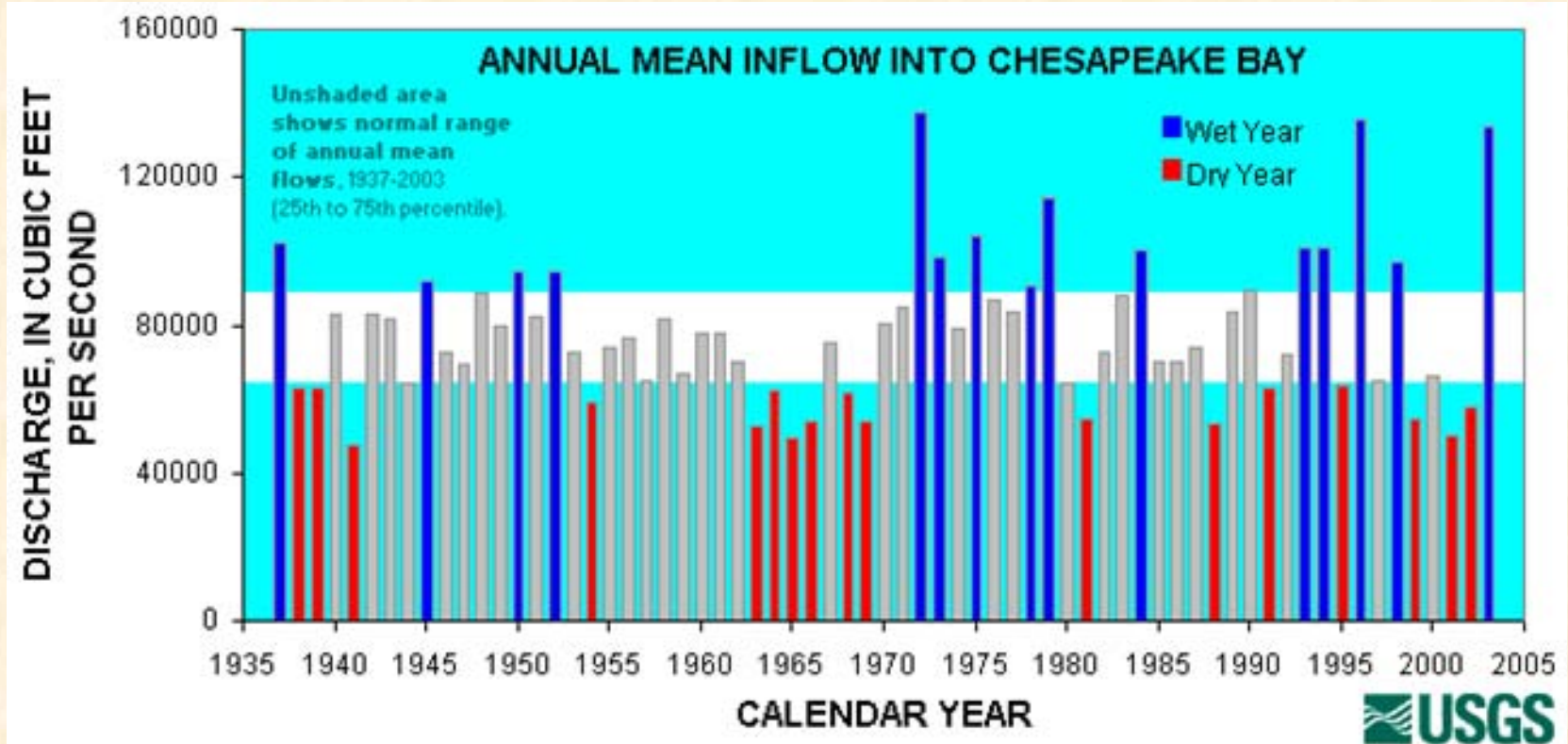
- Maryland – MDDNR fall survey
- Virginia – Chesapeake Bay Program  
(primarily VIMs surveys)
- **IMPORTANT LIMITATIONS**



# Weather



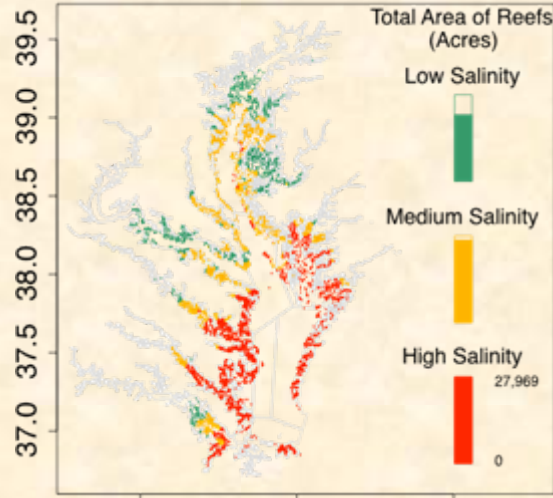
- Annual precipitation affects Disease Intensity, Recruitment, Freshets
- Randomly select ten-year blocks in model



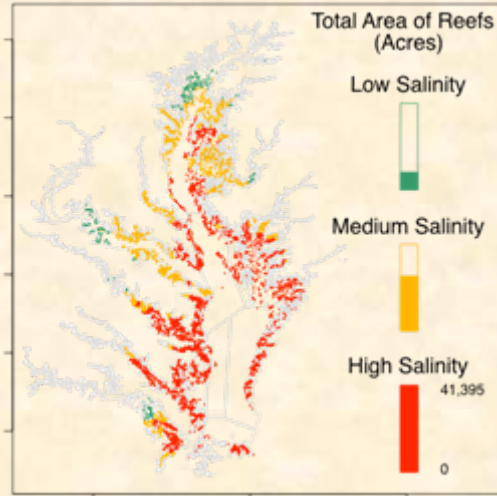
# Salinity



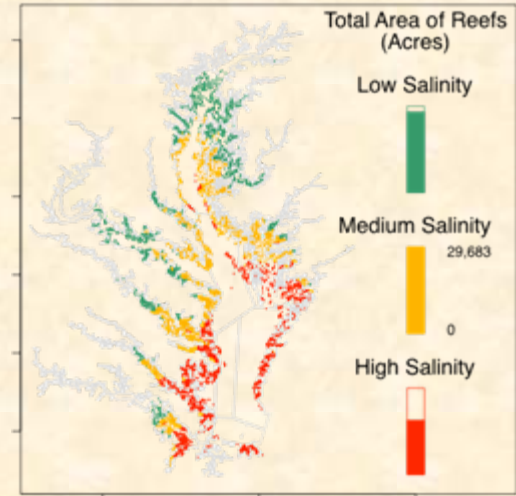
1995 - Dry Year



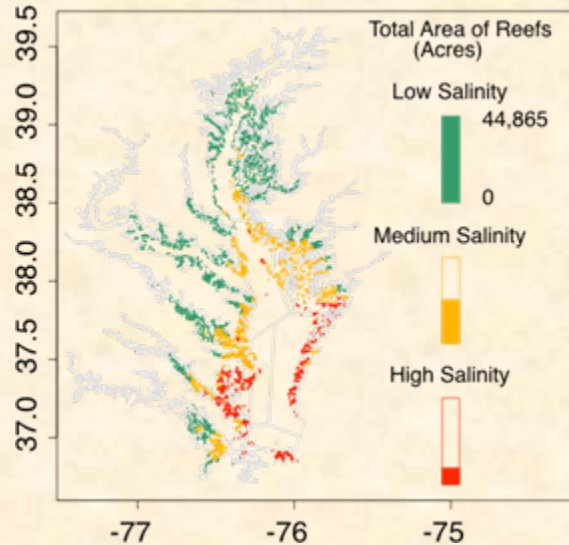
1999 - Dry Year



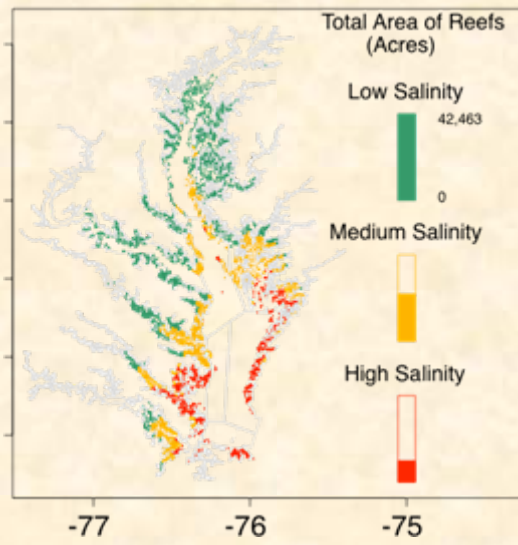
1997 - Average Year



1996 - Wet Year



1998 - Wet Year



Low < 11 ppt  
Medium 11-15 ppt  
High > 15 ppt

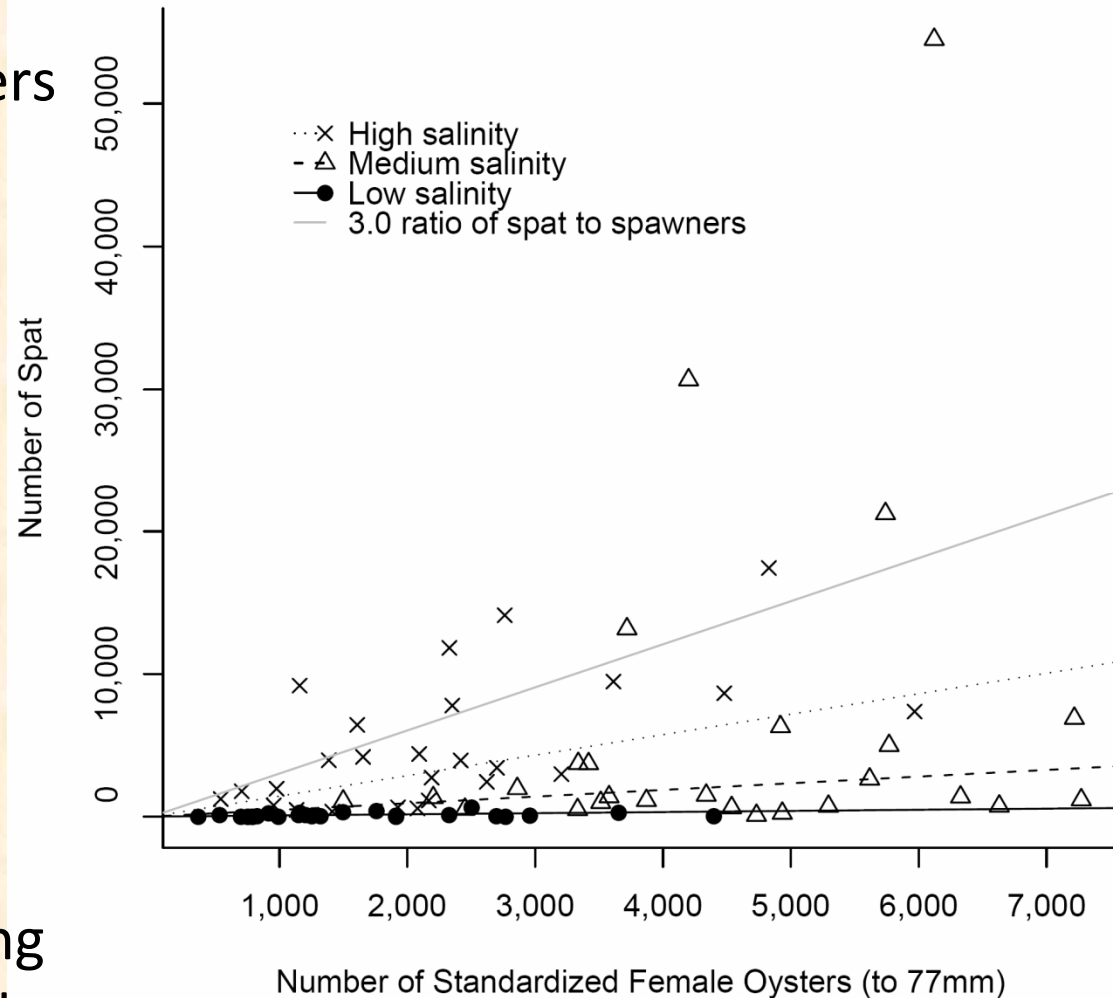
Latitude (degrees N)

Longitude (degrees W)

# Recruitment



- Based on relative numbers of adults and spat
- Function to estimate # spat produced
- Salinity and occasional large spat sets are important
- Spat distributed according to larval transport model



# Growth

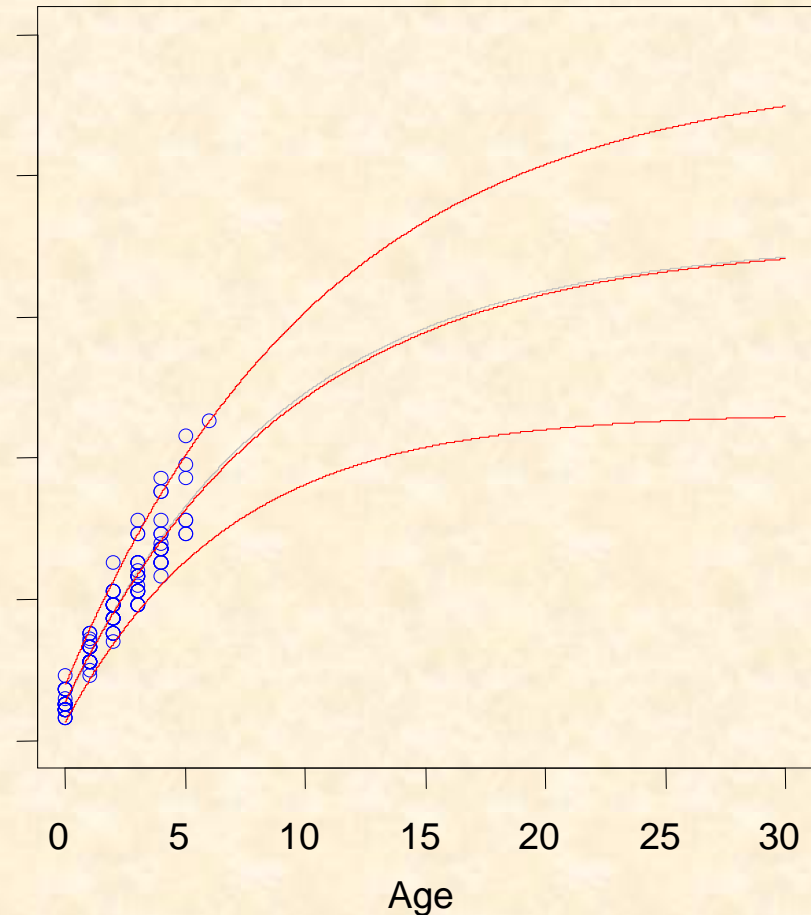
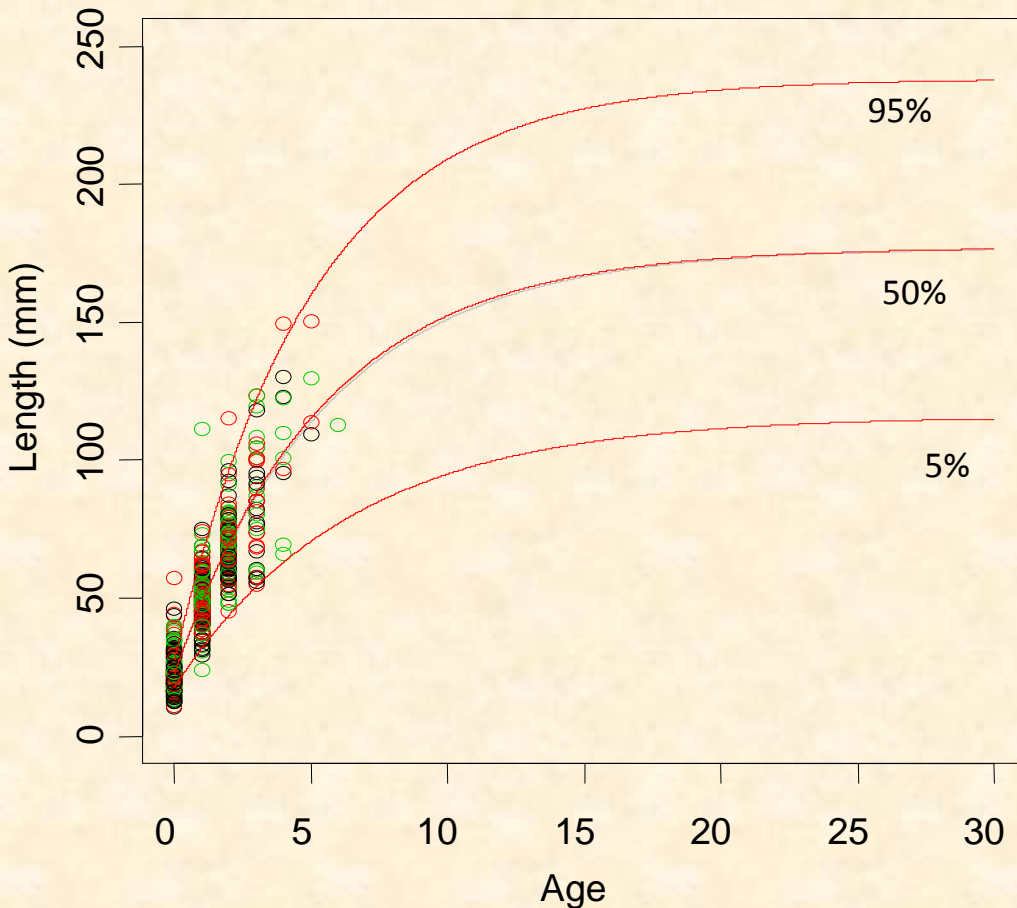


- von Bertalanffy function at size (not age)

$$L_2 = L_1 + (L_\infty - L_1)(1 - e^{-K})$$

Maryland

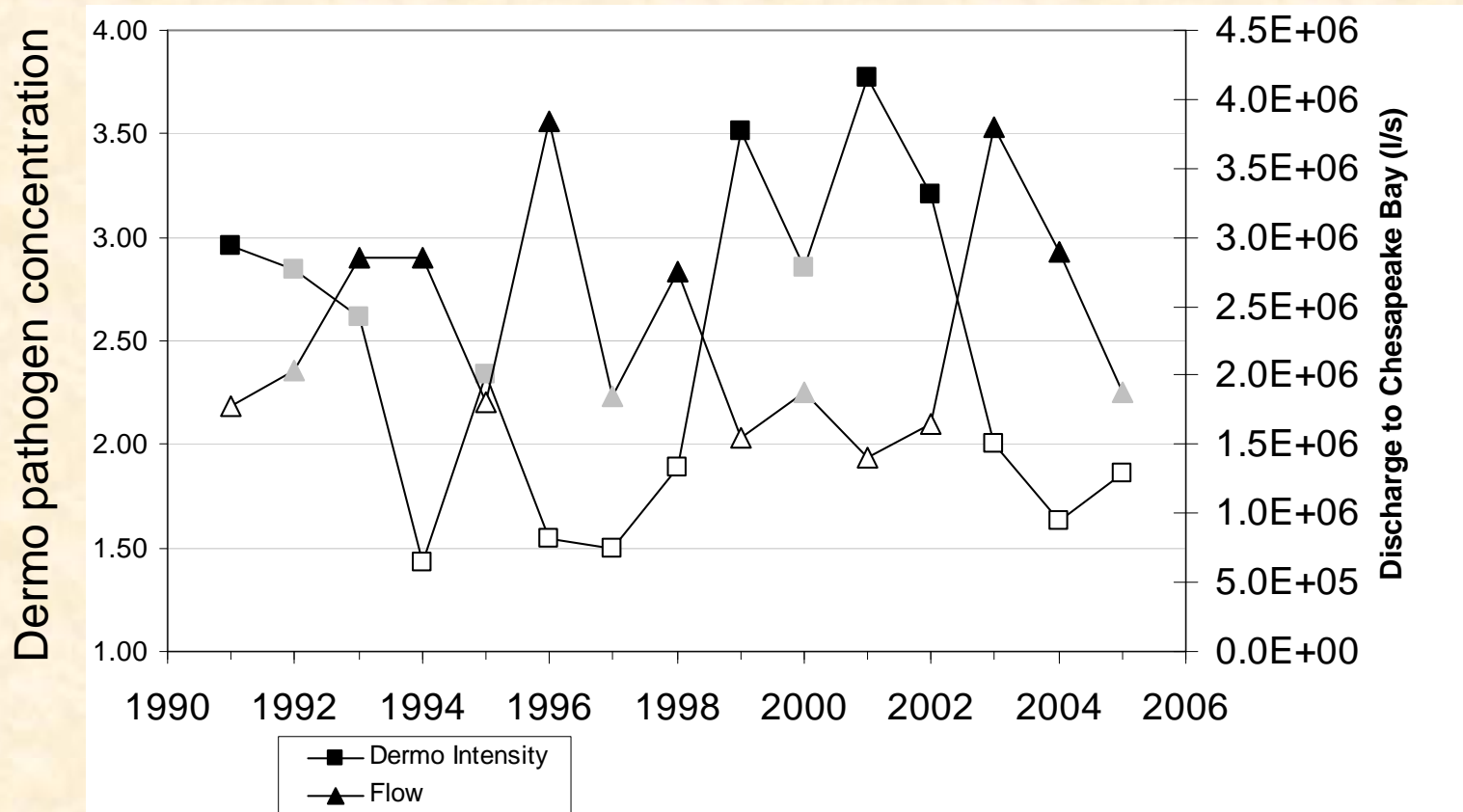
Virginia



# Disease



- Data from MDDNR
- Inversely related to freshwater discharge
- Modeled based on weather years



# Natural Mortality



Maryland fall survey, 1991-2006

Ratios of “Recent” boxes to live oysters

- Boxes are dead oysters with articulated shells
- Recent = Tissue still in shell, or no sediment on inner surfaces
- Time since death estimated to be 1-2 weeks
  
- Calculated by size class, salinity class and disease tier

$$s_{jk} = \frac{\sum_i live_{ijk}}{\sum_i (live_{ijk} + newbox_{ijk})}$$

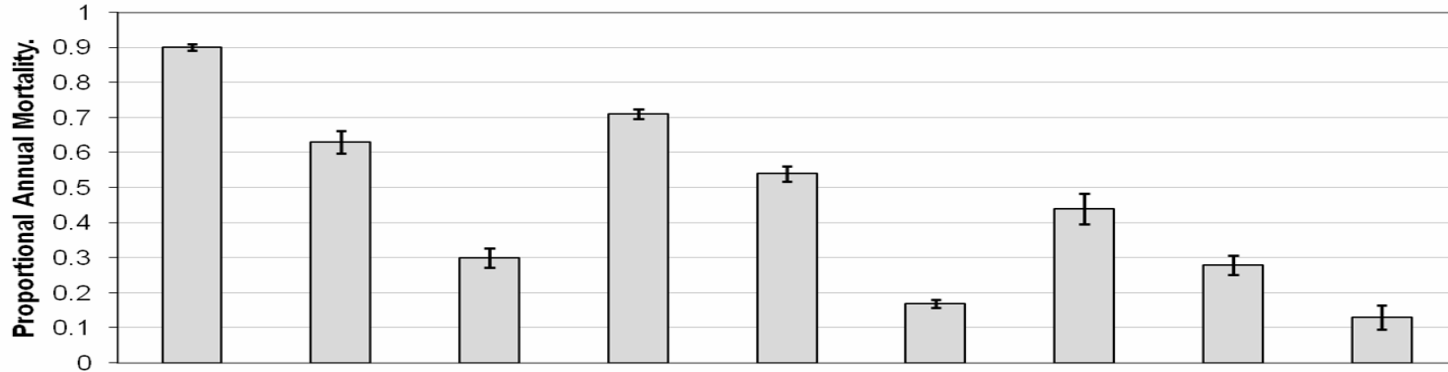
$$m_{jk} = \log(s_{jk})$$

$$totm_{jk} = 1 - \exp^{(-m_{jk} \times T)}$$

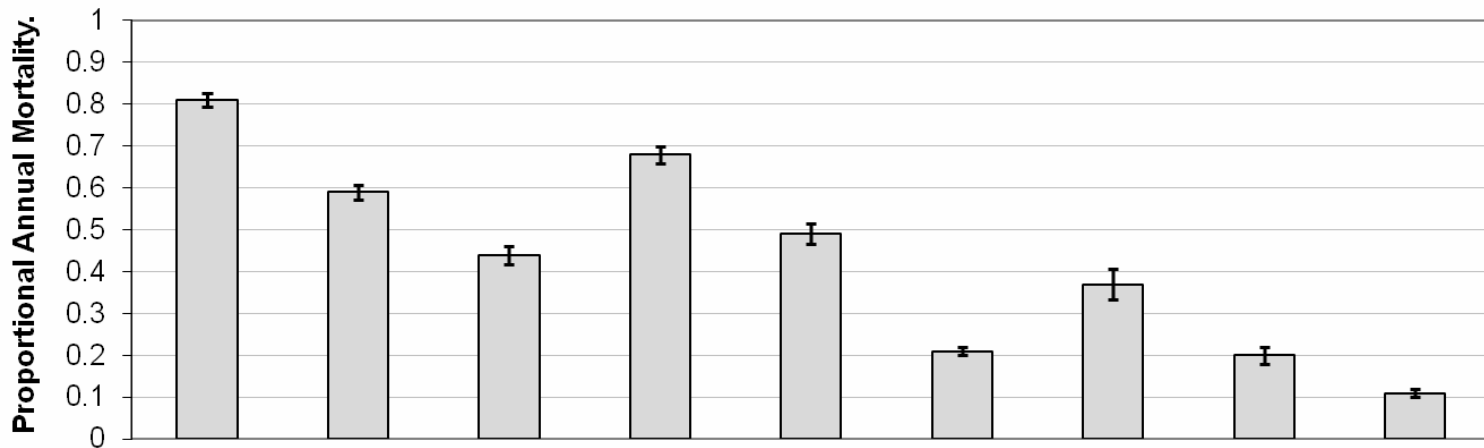
# Natural Mortality



Market Size (shell height  $\geq 75$  mm)



Small Size

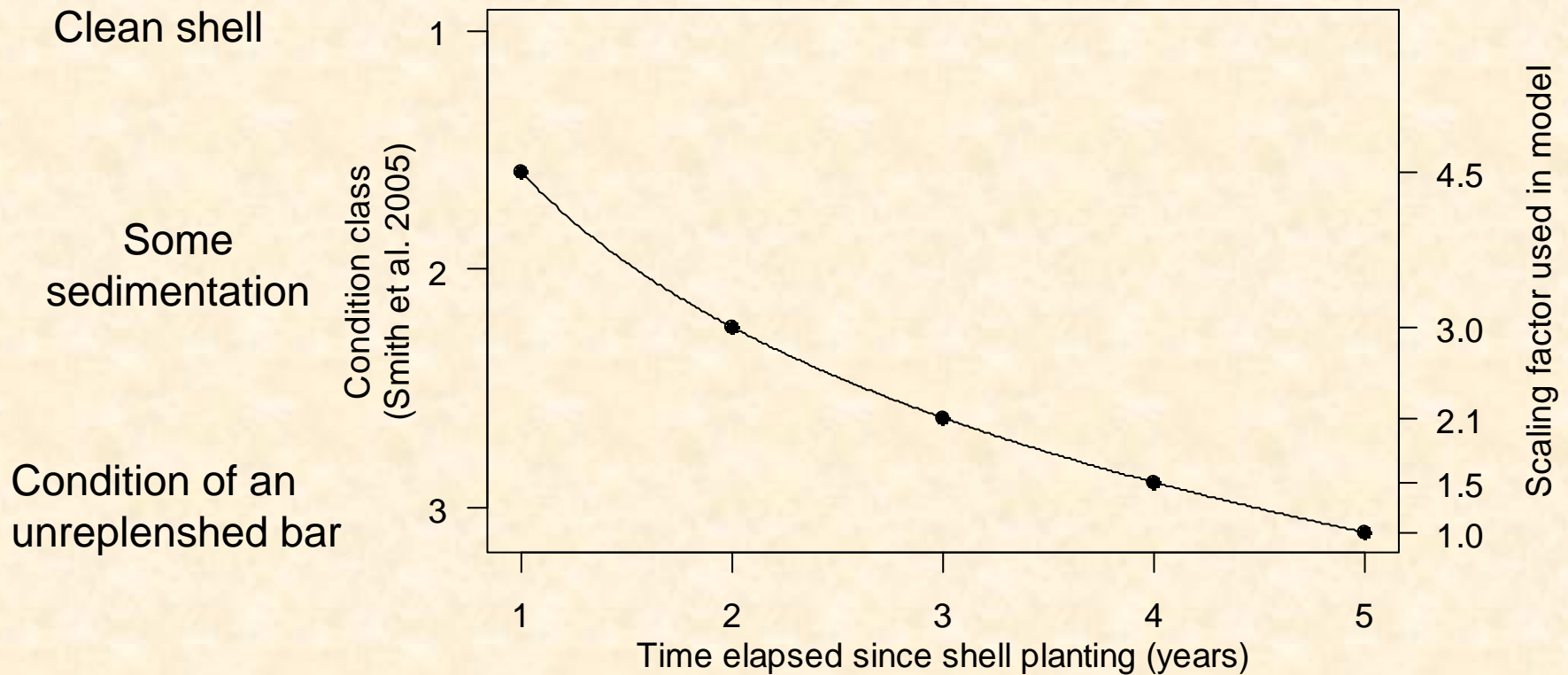


Disease	↑	↔	↓	↑	↔	↓	↑	↔	↓
Salinity	↑	↑	↑	↔	↔	↔	↓	↓	↓

# Habitat Improvement



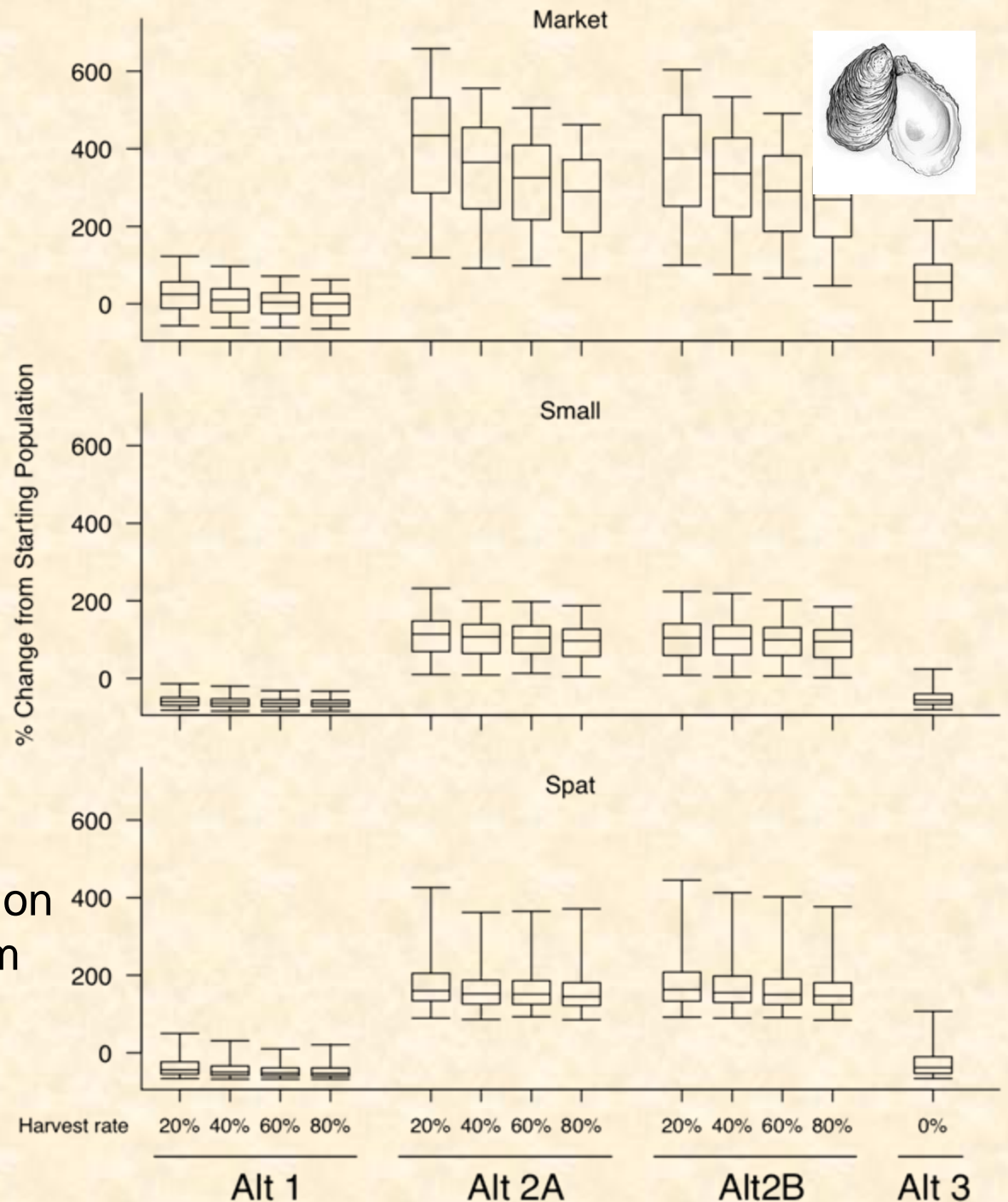
Shell replenishment increases recruitment,  
but the effect is diminished over time



# Model Results

Year 10,  
comparison of  
*virginica*  
alternatives

- Alt 1 = Status quo
- Alt 2 = Enhanced restoration
- Alt 3 = Harvest moratorium



# Explanation for Harvest Effects

Example – High Disease intensity, high salinity

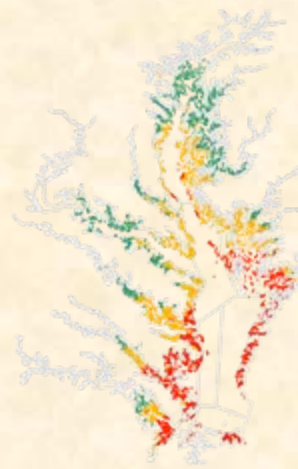
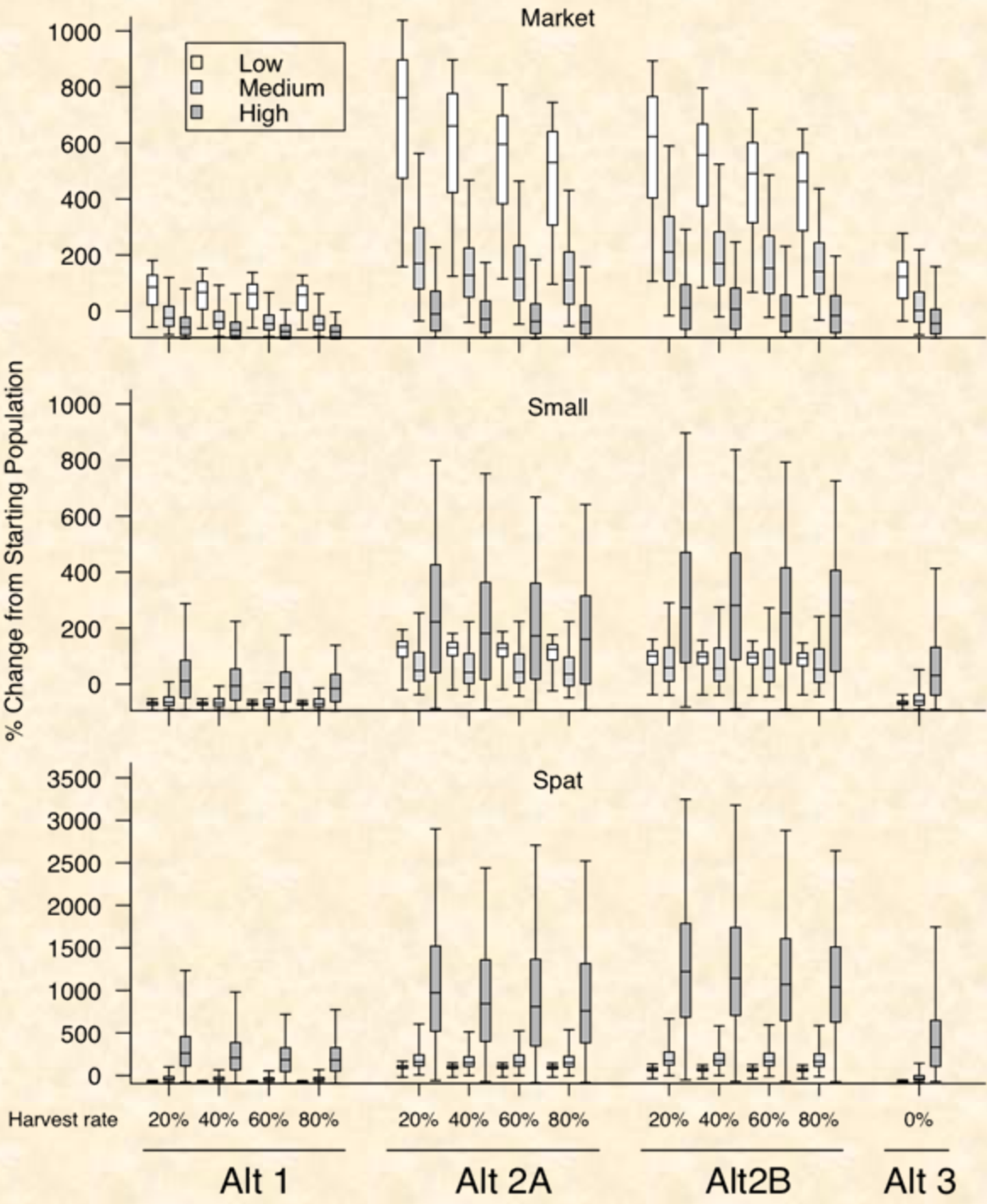
Age	Size Class	Natural mortality rate	No harvest	Harvest rate			
				20%	40%	60%	80%
0	Spat		1,000	1,000	1,000	1,000	1,000
1	Small	0.69	310	310	310	310	310
2	Small	0.69	96	94	92	90	88
3	Market	0.79	20	19	19	18	17
4	Market	0.79	4	3	2	1	1
5	Market	0.79	1	1	0	0	0
6	Market	0.79	0	0	0	0	0
Total market-size oysters			25	23	21	19	17
Percent of market pop with no harvest				91	83	75	69

Refuges are also important



# Model Results

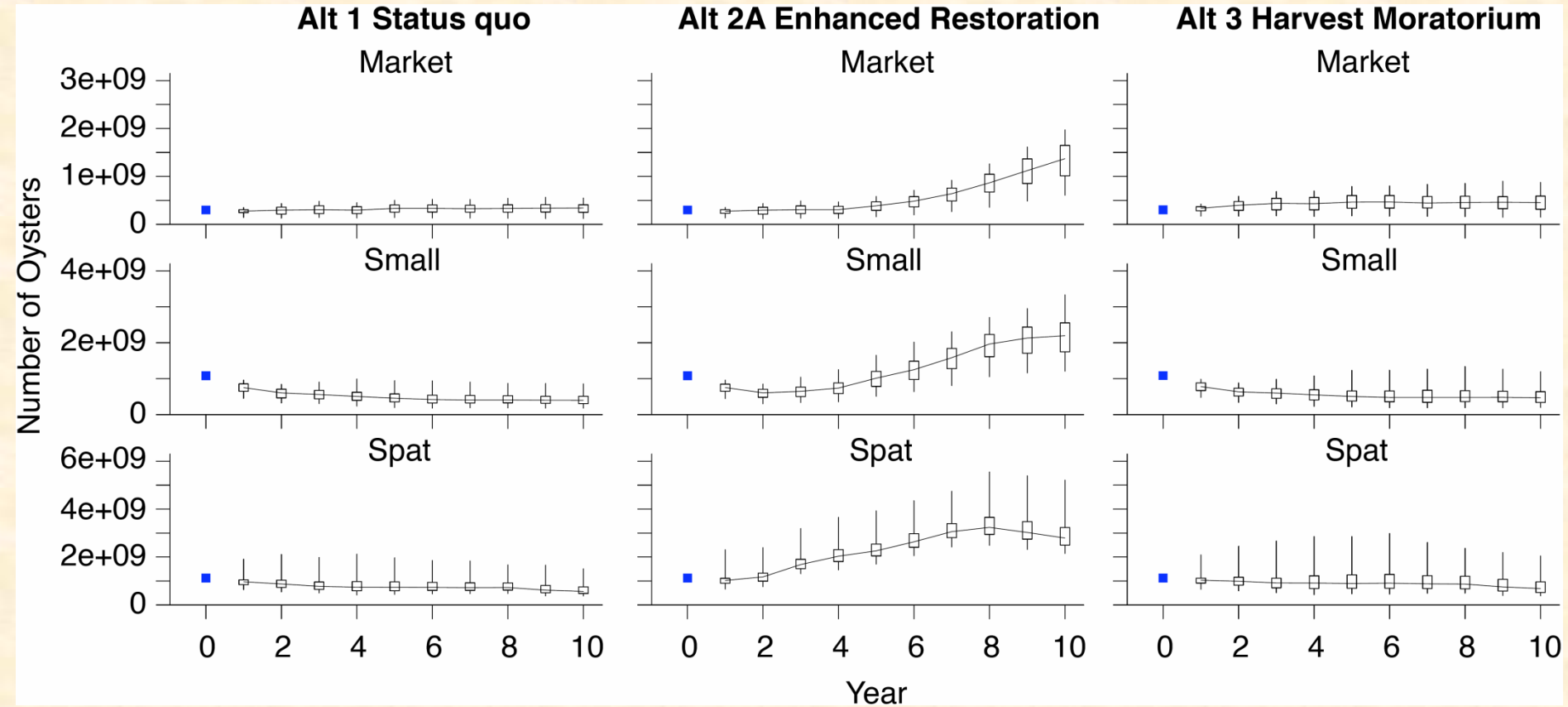
By salinity zone



# Model Results



## Trends



# Conclusions



- Natural mortality dominates
- Harvest rate becomes more important as stock recovers
- Enhanced restoration likely to help, but no option modeled is likely to reach the goal within ten years
- Input data sets create some unquantifiable uncertainty
- *ariakensis* will not be modeled, but model will be used to inform decisions

# Acknowledgements



- Support, survey data, and analysis from the Maryland DNR – particularly L. Barker, E. Cambell, P. Genovese, K. Greenhawk, P. Jones, C. Judy, and T. OConnell, and M. Tarnowski.
- R. Mann (VIMS) for providing 1994-2004 monitoring and growth data from James River
- K. Paynter (UMD) for providing growth data.
- Elizabeth North (HPL) for larval transport modeling & collaboration.
- Many others for collecting and analyzing data, and providing expert opinion for model development.