Water Quality and Food-Web Dynamics in Chesapeake Bay

Xinsheng Zhang

University of Maryland Center for Environmental Science
Cambridge, Maryland, USA
Chesapeake Bay is very productive

Adapted from Nixon (1988)
Population levels have shown a steady increase in the Bay watershed (Chesapeake Futures: Choices for the 21st Century).

Eutrophication

Human activities associated with agriculture and fossil fuel combustion account for well over half of nutrients reaching the Bay (Boesch et al., 2001).
Harmful algal blooms and their impacts

HABs are caused by microscopic algae (e.g. *Pfiesteria*-like dinoflagellates) that are harmful to shellfish, fish or humans.

Worldwide increase in PSP toxin

GEOHAB, 2001
Numerical modeling

An important diagnostic and predictive tool

Zhang et al., 2003
A new modeling approach for tracking abundance, size, and biomass

**Abundance**

- Graph showing changes in cells/ml over time.
  - Blue line: NON_IND
  - Pink line: TOXIC-A

**Size**

- Graph showing changes in pmole N/cell over time.
  - Blue line: NON_IND
  - Pink line: TOXIC-A

**Biomass**

- Graph showing changes in uM N for different species over time.
  - Non-Ind:
    - Black line: Pfiesteria
    - Pink line: Diatom
    - Green line: Cryptophyte
    - Blue line: DIN
    - Purple line: DON
    - Cyan line: Detritus
  - Toxic-A:
    - Black line: Pfiesteria
    - Pink line: Diatom
    - Green line: Cryptophyte
    - Blue line: DIN
    - Purple line: DON
    - Cyan line: Detritus

*Zhang et al., 2004.*
Top-down control and trophic cascades

Stoecker & Zhang, 2004 NSF Proposal
Effects of spatial and temporal physical structures on the coupling of zooplankton and fish production in Chesapeake Bay

Spatial and temporal variability of fish and plankton populations on a variety of scales
Optical Plankton Counter Measurements

Abundance (# L⁻¹)

Biomass (ml m⁻³)

Equivalent Spherical Diameter (mm)
By using a Scanfish, TIES program collected one of the largest, most spatially extensive and high-resolution physical and biological data set of the Bay.
Freshwater Input

Monthly (m\(^3\) sec\(^{-1}\)) and Annual (10\(^6\) m\(^3\) y\(^{-1}\)) Inflow to Chesapeake Bay

1995 - 2000

Total Annual Inflow

1951 - 2000
Location & Timing are the key.

Courtesy of Houde & Jung

Mean Fish Biomass
1995 -1999

Mean fish biomass for the 15 cruises from 1995 to 1999 (unit: grams/20-mat tray)

Estuarine Processes for Chesapeake Bay

- Lateral Front / Pycnocline
- Estuarine Turbidity Maximum
- River Plumes
- Hydraulic Control
- Convergence Eddy
- Tidal Front
Chlorophyll (mg m$^{-3}$)

Salinity

Temperature (°C)

Oxygen (ml L$^{-1}$)

Spring 1996
Chlorophyll (mg m⁻³)  

Zooplankton (ml m⁻³)  

Day

Latitude (deg)

Depth (m)

Summer 1996
Fall 1996
Spring 1996, Averaged over Water Column

Location, location, location
Spring 1996 Anomalies

- Zooplankton (ml m\(^{-3}\))
- Chlorophyll (mg m\(^{-3}\))
- Salinity
- Oxygen (ml L\(^{-1}\))
- Temperature (°C)

- Upper-Bay
- Mid-Bay
- Lower-Bay

- Spectral analysis
- Lagged autocorrelation
Regression between Zooplankton Biomass and each Hydrographic Variable

<table>
<thead>
<tr>
<th>Region</th>
<th>temp</th>
<th>salinity</th>
<th>oxygen</th>
<th>chl</th>
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<tbody>
<tr>
<td>Bay</td>
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</table>

Map showing Upper-Bay, Mid-Bay, and Lower-Bay regions.
Multiple Regression between Zooplankton Biomass and Temperature, Salinity, Oxygen, and Chlorophyll

![Graphs showing regression results for different regions and years.](image)
Bay Anchovy
Bay-wide Geometric Mean Index Catch per Haul

Maryland DNR seine

Year

Index
0.00 2.00 4.00 6.00 8.00 10.00

Ecological importance
forage fishes
Atlantic silverside
bay anchovy
Atlantic menhaden

piscivorous fishes

zooplankton

phytoplankton

Wood & Houde, 2003
Hypoxic Volume (O₂<0.7 mg/l)

- More Nutrients
- More Phytoplankton
- More Carbon Reaches the Bottom
- More Oxygen Consumed
- More Hypoxia

Hagy, 1999
Ecological Forecasts

Using bioenergetic, numerical, and statistical models to synthesize a variety Chesapeake Bay data collected by us and others to:

- forecast how nutrient loading reduction goals might influence bay anchovy habitat quality and growth, and zooplankton production
- provide useful diagnostic and predictive tools for environmental and fisheries managers.

Zhang et al. (2004) MD Sea Grant Proposal

In making ecological forecasts it is important that managers account for differing degrees of uncertainty inherent in the predictions.
Restore and Sustain the Bay Ecosystem

- Reduce nutrient inputs
- Develop effective agricultural methods
- Control land development
- Enhance nutrient sinks
- Protect and restore SAV
- Decrease hypoxia and HABs
- Increase water clarity
- Maintain suitable fisheries habitat
- Improve fish and shellfish production
Strategies and Plans

Cooperative efforts

- Individuals
- Businesses
- Schools and universities
- Communities and governments

Identify key processes and develop predictive tools

- Hydro-climatic changes and anthropogenic modifications
- Long- and short-term trends
- Large- and small-scale spatial variations
- Bioenergetic and statistical modeling
- Numerical food-web model and biophysical coupling
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