A Shallow-water Coastal Habitat Model for Regional Scale Evaluation of Management Decisions in the Chesapeake Region


Smithsonian Environmental Research Center

Overview

- Study Systems
- Stressors of Interest
- Objectives and Tasks
- Modeling Approach
- Model Structure
- Users, Products, and Progress

Importance of Shallow-water Tributary Embayments (STE) in Chesapeake Bay

Formation of estuaries as drowned river mouths has resulted in highly articulated shorelines for east coast estuaries.

Shallow-water Tributary Embayments are Critical to Two of the Designated Use Categories

High Phytoplankton Productivity Results in Low A.M. D.O. and Large Diurnal Swings

Susceptible to Large Phytoplankton Blooms due to Shallow Water and Proximity to Nutrient Sources


http://mddnr.chesapeakebay.net/momentachrr/reef/rhode_river/rhode_river_graphs.cfm?station=SERC
Catastrophic Losses of SAV in Chesapeake Bay Occurred First in Western Shore STE

Areas Slated for Restoration of SAV are Concentrated in Shallow Tributary Embayments and Tidal Creeks

Main CB Model Segmentation Scheme Treats Most STE as 1 to 3 Cells

Premise: The ecological importance of shallow-water tributary embayments far exceeds their volumetric contribution to the Bay, and the main-stem concentrations of water quality constituents.

Global Change-related Stressors of Interest

Atmospheric CO₂

Potential Impacts on Shallow Tributary Embayments
- Altered growth rates of emergent vegetation
- Uncertain effects on export of carbon from wetlands
- Uncertain effects on seasonally average temperatures
- Uncertain effects on rainfall and runoff patterns

Global Change-related Stressors of Interest

Elevated UV Radiation

- Incident UV-B has increased ca. 1.3% per year since the mid-70’s (Neale et al. 1999).
- Despite strong attenuation by CDOM, UV inhibits phytoplankton production by ca. 50% at the surface, with average of 15% inhibition over a 1.5 m water column (Neale 2001).
Global Change-related Stressors of Interest

Land-use/Climate Change Interactions

- Increased frequency of droughts and flashier flow regimes due to climate change
- Altered flow regimes and changes in land use patterns will have consequences for the delivery of nutrients and sediments to estuaries

Objectives and Tasks: Estuarine Modeling End Points

Objective: To provide a tool to predict the magnitude and trends of existing and emerging indicators of the ecological condition of critical shallow water habitats.

Important Stressors:
- Suspended Sediments
- Nutrients
- UV Irradiance

Model Output:
- Phytoplankton Chlorophyll
- Water Clarity (diffuse attenuation coefficient)
- Dissolved Oxygen

Questions of Interest

- How do nutrients and suspend sediments interact to determine the growth of phytoplankton under altered land-use and climate regimes?
- How will concentrations of CDOM respond to changes in land use (e.g. wetland coverage) or in situ eutrophication, and what are the implications for penetration of UV radiation?

Objectives and Tasks: Watershed Inputs to STE

- Use spatial analysis to describe the “population” of STE around the shore of Chesapeake Bay and its major tributaries
- Apply previously developed statistical models relating land cover and physiographic province to nutrient discharges to quantify the distributions of local watershed inputs of water and nutrients across the population of STE

Objectives and Tasks: Carbon Export from Wetlands

- How does export of DOC from wetlands depend on concentration of atmospheric CO₂?
- How does export of CDOM vary among physiographic province and land cover?

Modeling Approach

- STE exhibit a wide range of sizes, shapes, influence by local watershed, and exchange with main stem estuary
- STE are far too numerous to model individually, on a creek-by-creek basis
Modeling Approach

• We will employ an approach that uses a large number of simple, generic models of subestuaries and tidal creeks, incorporating inputs from local watersheds, internal processing, and exchange at the seaward boundaries.

• Our approach will make extensive use of Monte Carlo simulation and generalized sensitivity analysis to determine a range of outcomes, under different management scenarios, for the diversity of shallow-water systems encountered around Chesapeake Bay.

Model Structure: Conceptual

• We conceive of STE as part of a continuum of aquatic ecosystems linking watersheds with coastal marine waters.

• Focus on well-mixed estuarine tidal waters, which contain a mixture of freshwater from their local watershed, and more saline water from adjacent estuarine or coastal waters.

Model Structure: Stressor Interactions

• Important stressors vary in different component ecosystems in the landscape.

• Response variables in watersheds and wetlands are sources of stressor inputs to STE.

• Response variables within STE are the indicators being used to evaluate management success.

Model Structure: Flow

• Climate-related flow modification (user-selected contingencies)

• Rising CO2 (fixed scenario)

• Rising UV-B (probabilistic scenarios)

• Rising temperature (primarily winter)

Land-use Decisions

• Gross composition

• Management practices (Ag: BMPs, Urban: BNR)

Wetlands

• Destruction/Mitigation

• Sediments

• Nutrients

• CDOM

Estuary Response

• Size-structured NPZ model

• Suspended sediment, with seasonal net resuspension

• Water Quality Criteria: Chlorophyll, Water clarity, Dissolved oxygen

Estuary Management

• Oyster restoration contingency

Endpoints

• Water Quality Criteria: Chlorophyll, Water clarity, Dissolved oxygen

Products and Users

• Cumulative distribution functions of indicators being used for assessment of CWA compliance

• Chesapeake Bay Program

• State agencies

• Tributary strategy teams

• Watershed planners

Progress

<table>
<thead>
<tr>
<th>Scheduled Activity</th>
<th>2001</th>
<th>Actual</th>
</tr>
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<tbody>
<tr>
<td>Measure CDOM export from wetlands &amp; watersheds</td>
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<td>1</td>
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<tr>
<td>GIS analysis of subestuaries</td>
<td>1</td>
<td>1</td>
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<tr>
<td>GIS analysis of coastal plain watersheds</td>
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<td>1</td>
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<tr>
<td>Statistical analysis of nutrient exchange rates</td>
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<td>Limited progress</td>
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<tr>
<td>Modeling of subestuary component models</td>
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