DEVELOPING A CHESAPEAKE BAY REPORT CARD

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Cambridge wastewater treatment plant. Sewage effluent has a high $\delta^{15}N$ signature which can be detected by analyzing organisms incubated in the area.

Fish kills were a common occurrence during sampling in July 2003, associated with toxic algal blooms and periods of hypoxia/anoxia.

Abstract

Coordination and feedback between monitoring, management and research is essential in achieving healthy Chesapeake waterways. There is a need for a scientifically rigorous, spatially explicit ecosystem health report card on Chesapeake Bay and its watershed, and so a pilot study was conducted in July 2003 on the Patuxent and Choptank Rivers. δ^{15}nitrogen signatures in the Choptank River showed elevated sewage nitrogen levels adjacent to and downstream from sewage treatment plants. The Choptank River had generally lower ecosystem health than the Patuxent River although in both rivers there was a gradient from poorer to better ecosystem health from upstream to the mouth. The Cape Charles region had significantly higher ecosystem health than either the Patuxent or Choptank River. Incorporating seasonal sampling and a broader range of indicators from different ecosystem elements would produce a complete and more robust report card. This study indicates the potential for a Bay-wide ecosystem health report card to provide rapid, effective, and spatially and temporally explicit monitoring feedback to managers, scientists and the broader community.

Deploying the incubation rig with buoy, perforated macroalgal chamber, sinker and bricks.

Incubation chamber deployed in the upper Choptank River.

Introduction and methods

Management objectives such as clear water and reduced nutrient inputs can be linked to ecosystem health indicators which can then be quantified, mapped and integrated. A reference value for each of these indicators provides information on whether the management objectives are being met. These indicators should ideally provide information on various aspects of the ecosystem. The *Chesapeake 2000* Agreement highlighted four interconnected ecosystem elements: **Living Resources**, **Water Quality**, **Land Use** and **Habitat.** A monitoring strategy including indicators from each of these categories would provide integrated ecosystem information about whether the goals of *Chesapeake 2000* are being met. A conceptual diagram of potential ecosystem health indicators for Chesapeake Bay has been created (Figure 1). This study utilized six of these indicators derived from the management objectives outlined in *Chesapeake 2000* (Figure 2).

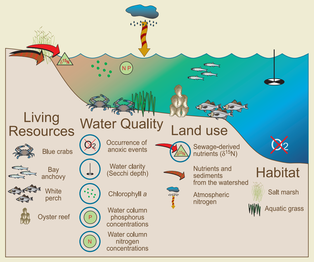

Figure 1. Conceptual diagram of ecosystem health indicators appropriate for use in Chesapeake Bay and its tributaries. Circled indicators were monitored in this study.

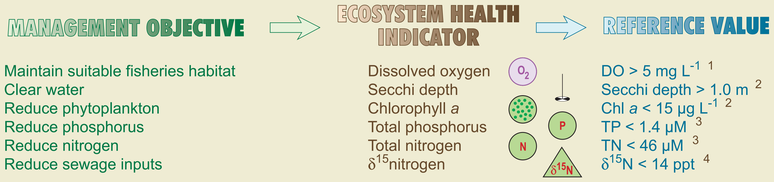

Figure 2. Management objectives for Chesapeake Bay and its tributaries together with ecosystem health indicators and reference values to determine the status of the objectives.

Patuxent River

- Largely forested watershed
- Extensive urban development
- Upstream sewage treatment plants (STPs; Figure 3)
- Laurel STP discharge 30,210 kg nitrogen year^{-1}
- Bowie STP 25,810 kg N yr^{-1}
- Upper Marlboro STP 186,342 kg N yr^{-1} [5]

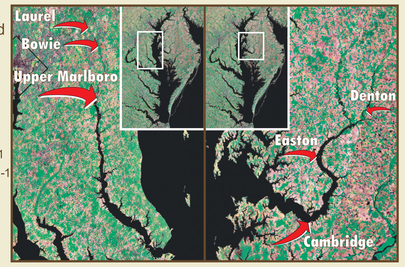

Figure 3. Location of sewage treatment plants in the Patuxent (left) and Choptank (right) Rivers (image courtesy USGS).

Choptank River

- Largely agricultural watershed
- Moderate urban development
- STPs located along the length of the river (Figure 3)
- Denton STP 2,541 kg N yr^{-1}
- Easton STP 21,347 kg N yr^{-1}
- Cambridge STP 55,447 kg N yr^{-1} [5]

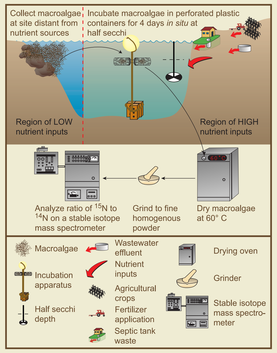

Figure 4. Sewage mapping technique showing deployment of macroalgae at half secchi in perforated plastic jar using a system of weight, rope and buoy, and subsequent grinding and analysis on a stable isotope mass spectrometer.

A technique has been developed to detect and integrate the effects of anthropogenic nitrogen inputs by analyzing the isotopic signature of nitrogen ($\delta^{15}N$) in bioindicator organisms actively deployed and incubated *in situ* (Figure 4). [4,6]

The Choptank River (105 sites) and the Patuxent River (67 sites) were sampled along with a region at the mouth of the Chesapeake Bay near Cape Charles (8 sites), providing a reference location (Figure 5). Site locations were generated randomly using GIS software, producing a spatial grid to facilitate the production of statistically valid interpolated maps.

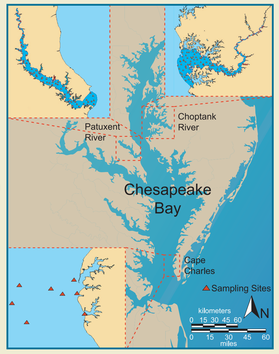

Figure 5. Map of Chesapeake Bay with insets showing sampling sites in the Patuxent River (67 sites), Choptank River (105 sites) and Cape Charles (8 sites).

Results

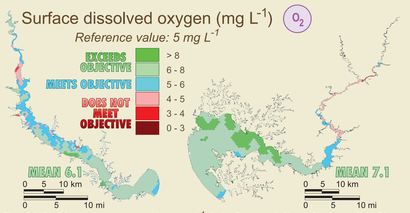

Figure 6. Dissolved oxygen concentrations (mg L^{-1}) in the Patuxent (left) and Choptank (right) Rivers.

- Surface dissolved oxygen (DO) generally adequate in both rivers, meeting or exceeding reference value of 5 mg L^{-1} necessary to sustain fisheries (Figure 6)
- DO not measured in the bottom waters, where hypoxia generally occurs

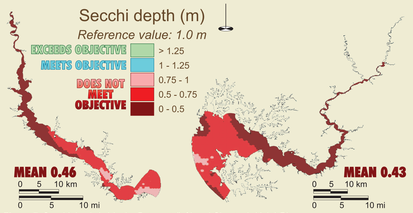

Figure 7. Secchi depth (m) in the Patuxent (left) and Choptank (right) Rivers.

- All areas of both rivers failed to meet the reference secchi depth value of 1.0 m (Figure 7)
- Most areas had a secchi depth of less than 0.75 m
- This level of light penetration is considered inadequate for the survival and growth of aquatic plants like seagrasses
- **Cape Charles mean secchi was 1.16 m**

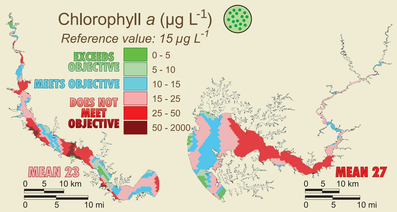

Figure 8. Chlorophyll *a* concentrations (µg L^{-1}) in the Patuxent (left) and Choptank (right) Rivers.

- Chlorophyll *a* concentrations higher in the mid reaches of both rivers (Figure 8)
- High chlorophyll was associated with high nutrients and clearer water
- Excessive phytoplankton can reduce the amount of light reaching aquatic plants and may also result in hypoxia
- **Cape Charles mean chlorophyll *a* was 10.8 µg L^{-1}**

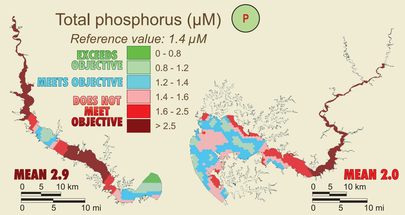

Figure 9. Total phosphorus concentrations (µM) in the Patuxent (left) and Choptank (right) Rivers.

- High concentrations of total phosphorus in upper reaches of both rivers, improving towards the mouth (Figure 9)
- There was a region in the middle Patuxent River which met the reference value of 1.4 µM
- Excess nutrient concentrations can result in excessive phytoplankton in the water column
- **Cape Charles mean total phosphorus was 1.5 µM**

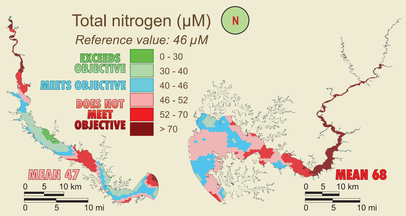

Figure 10. Total nitrogen concentrations (µM) in the Patuxent (left) and Choptank (right) Rivers.

- Total nitrogen showed a similar pattern to phosphorus, with high levels in upper reaches, improving downstream (Figure 10)
- **Cape Charles mean total nitrogen was 30 µM**

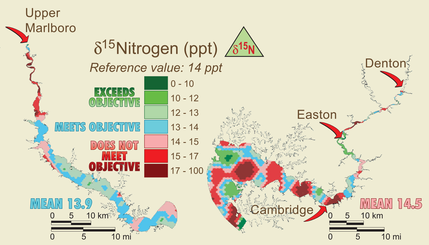

Figure 11. $\delta^{15}N$ isotopic signature (ppt) of deployed macroalgae in the Patuxent (left) and Choptank (right) Rivers.

- $\delta^{15}N$ analysis effectively detected sewage input in both rivers (Figure 11)
- Patuxent River showed generally low levels of $\delta^{15}N$, except in the upper reaches, consistent with the lack of STPs in mid and lower river
- Choptank River showed well-defined areas of elevated $\delta^{15}N$ adjacent to and downstream from STPs
- Areas of elevated $\delta^{15}N$ evident downstream from Cambridge, suggesting sewage nitrogen may become tidally retained in the Choptank River
- **Cape Charles mean $\delta^{15}N$ was 13.8 ppt**

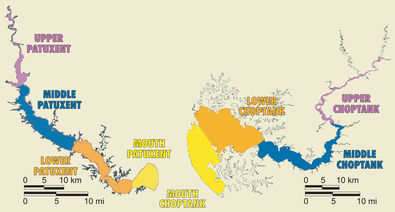

Figure 12. Reporting regions for the Patuxent (left) and Choptank (right) Rivers.

- Spatially explicit data can be used to identify reporting regions
- Both rivers divided into upper, middle, lower and mouth regions (Figure 12)

Discussion

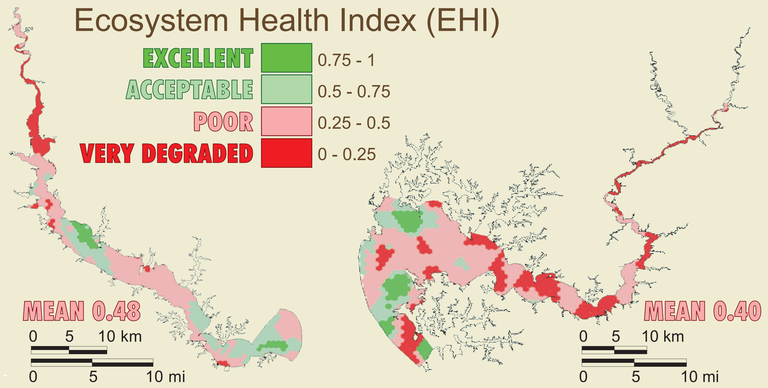

Figure 13. Ecosystem Health Index (EHI) for the Patuxent (left) and Choptank (right) Rivers.

- A quantitative measure of ecosystem status was developed - the Ecosystem Health Index (EHI)
- EHI was calculated by assigning a value of 1 to each indicator complying with the reference value, and 0 otherwise
- Patuxent River had high EHI values in the middle and mouth, with low ecosystem health in the upper and lower reaches
- Choptank River had generally lower overall EHI values (0.40) than the Patuxent River (0.48), with only some areas around the mouth showing higher ecosystem health (Figure 13)
- Cape Charles region had a significantly higher EHI (0.75) than any other region in either of the rivers. This result is indicative of the lower nutrient inputs and improved flushing in this region

Region	EHI	Region	EHI
Upper Patuxent	0.21	Upper Choptank	0.20
Middle Patuxent	0.52	Middle Choptank	0.26
Lower Patuxent	0.48	Lower Choptank	0.44
Mouth Patuxent	0.58	Mouth Choptank	0.49
Patuxent Overall	0.48	Choptank Overall	0.40
Cape Charles City	0.75		

EHI range	Grade
> 0.81	A
0.66 - 0.80	B
0.51 - 0.65	C
0.50 - 0.26	D
< 0.25	F

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Upper Patuxent	F	Upper Choptank	F
Middle Patuxent	C-	Middle Choptank	D-
Lower Patuxent	D+	Lower Choptank	D+
Mouth Patuxent	C	Mouth Choptank	D+
Patuxent Overall	D+	Choptank Overall	D
Cape Charles City	B+		

Figure 14. Ecosystem Health Index (EHI) and report card values for the Patuxent and Choptank Rivers, and the Cape Charles region.

- EHI ratings converted into report card values (Figure 14)
- Grades ranges from B+ (Cape Charles) down to F for the upper reaches of both the Patuxent and Choptank Rivers
- Report card approach translates scientifically rigorous data for broader communication and understanding of results

Conclusions

- Ecosystem health indicators, based on management objectives, can be modeled, measured and mapped
- Maps of ecosystem health indicators can be combined into overall ecosystem health map
- Report card values can be assigned for reporting regions
- Effective communication of report card values and integration into management programs can lead to ecosystem health improvement
- EHI and report card approach together are a useful monitoring tool to help focus management and research efforts by providing rapid and effective feedback on the health of Chesapeake Bay

Recommendations

- Develop a Bay-wide $\delta^{15}N$ sampling program
- Incorporate fisheries and habitat indicators as well as watershed indicators into ecosystem health assessment
- Use field sampling, remote sensing, autonomous sampling and underway sampling programs to produce ecosystem health indicator maps
- Develop a monitoring framework to produce annual report cards

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Acknowledgements

Financial assistance provided by the Coastal Zone Management Act of 1972, as amended, administered by the Office of Ocean and Coastal Resource Management, National Oceanic and Atmospheric Administration (NOAA). A publication of the Maryland Coastal Zone Management Program, Department of Natural Resources pursuant to NOAA Award No. NA17OZ1124. Contract No. 14-03-849 CZM 046.