2007 Chesapeake Bay Hypoxic Volume Forecast

Donald Scavia
University of Michigan

The model **-** The 2007 forecast was done with a model that was developed to assess the impacts of changes in nitrogen loads on Chesapeake Bay hypoxia (Scavia et al 2006). The model is an adaptation of a river model that predicts oxygen concentration downstream from point sources of organic matter loads using two mass balance equations for oxygen-consuming organic matter, in oxygen equivalents (i.e., BOD), and dissolved oxygen deficit. The equation for dissolved oxygen (DO), solved at steady state is:

$$DO = DO_S - \frac{k_1 BOD_u}{k_2 - k_1}\left(e^{-k_1 \frac{x}{v}} - e^{-k_2 \frac{x}{v}}\right) - D_i e^{-k_2 \frac{x}{v}}$$

where DO = the dissolved oxygen concentration (mg/L), DO_s = the saturation oxygen concentration, k_1 = the BOD decay coefficient (1/day), k_2 = the reaeration coefficient (1/day), BOD_u = the ultimate BOD (mg/L), x = the downstream distance (km), v = stream velocity (km/day), and D_i = the initial DO deficit (mg/L). This approach to modeling coastal and estuarine hypoxia has also been used successfully for Gulf of Mexico hypoxia (Scavia et al. 2003, 2004).

Recalibration - The original model was calibrated and tested against 1950-2003 nitrogen load and hypoxic volume estimates assembled by Hagy (2002). The Chesapeake Bay Program provided load and hypoxic volume updates for 1986-2006, and even though the new estimates varied little from the original ones (Figure 1); the model was recalibrated for this application to the new 1986-2006 estimates.

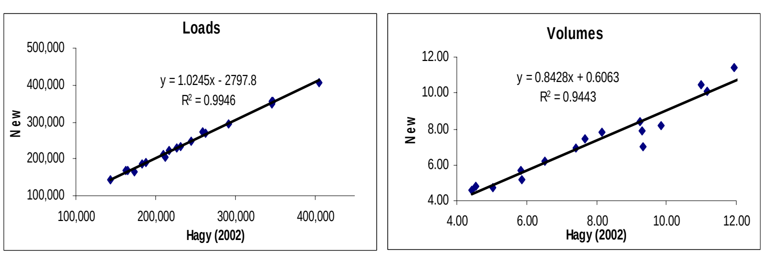


Figure 1. Comparison of Hagy (2002) and CBP estimates of Loads and Volumes

As in the original application, most of the interannual variability was captured by varying only the advection term, v, and initial deficit, D_i, from year to year (Figure 2). Therefore Monte Carlo simulations and forecasts were based on 1000 runs made with values of v and D_i selected randomly from normal distributions.

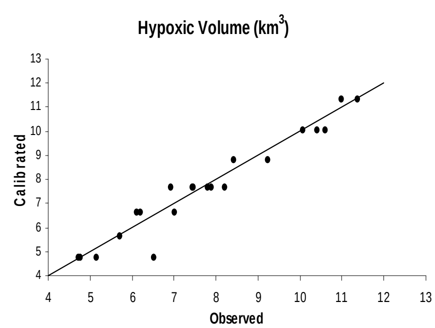
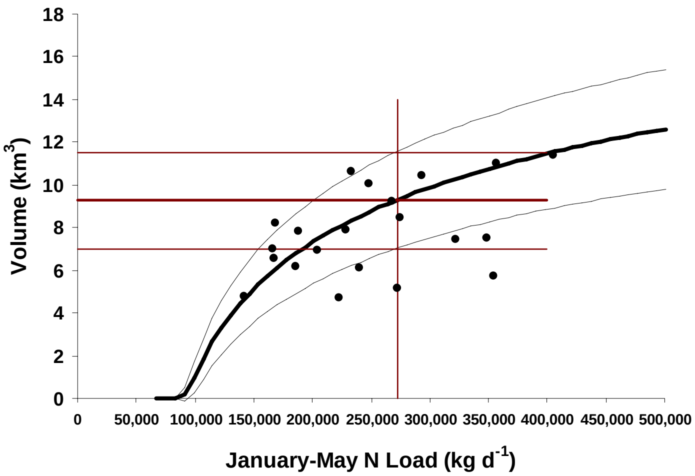


Figure 2. Predicted vs. Observed Volume

The Forecast - Given the Jan-May 2007 total nitrogen load of 272,628 kg/day, the summer hypoxic volume forecast, shown in Figure 3, can be interpreted in the following ways:



The average forecast is 9.3 km^3.

There is an 84% probability that hypoxic volume will be greater than 7.0 km^3.

There is a 67% probability that hypoxic volume will be between 7.0 and 11.5 km^3.

Figure 3. Dots represent observed volume and loads for 1986-2006. Dark and lighter curves represent means +/- one standard deviation of Monte Carlo model output. Vertical line represents 2007 Jan-May TN load. Horizontal lines represent the mean of hypoxic volume forecasts (middle), and the mean minus one standard deviation (lower) and mean plus one standard deviation (upper).

References

Hagy, J. D., 2002. Eutrophication, hypoxia and trophic transfer efficiency in Chesapeake Bay. PhD dissertation, University of Maryland at College Park, College Park, Maryland.

Scavia, D. N.N. Rabalais, R.E. Turner, D. Justic, and W. Wiseman Jr. 2003. Predicting the response of Gulf of Mexico Hypoxia to variations in Mississippi River Nitrogen Load. Limnol. Oceanogr. 48(3): 951-956.

Scavia, D., D. Justic, and V.J. Bierman, Jr. 2004, Reducing hypoxia in the Gulf of Mexico: Advice from three models. Estuaries 27(3): 419-425.

Scavia, D., E.A. Kelly, and J. D. Hagy III. 2006 A simple model for forecasting the effects of nitrogen loads on Chesapeake Bay hypoxia. Estuaries and Coasts 29(4): 674-684.