2007 Chesapeake Bay Hypoxic Volume Forecast

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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.

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

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 km³.

There is an 84% probability that hypoxic volume will be greater than 7.0 km³.

There is a 67% probability that hypoxic volume will be between 7.0 and 11.5 km³.

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


