Chesapeake Update
Issue 2
May 05

Ecological Forecast ~Summer 2005~

Ecological forecast produced by the Monitoring and Analysis Subcommittee (MASC).
MASC coordinates and supports the monitoring activities of the Chesapeake Bay Program .

This newsletter summarizes the main findings and methods of a new initiative to forecast ecological conditions of Chesapeake Bay for the coming summer. This year's forecast focuses on three important elements of the Bay's health—dissolved oxygen (DO) in the Bay's mainstem, harmful algal blooms (HABs) in the Potomac River, and changes in submerged aquatic vegetation (SAV) distribution. Additional components of the Bay's ecosystem, such as fish abundance, will be forecast in coming years. This newsletter focuses on the DO and HAB forecasts only, as the SAV forecast is being released at the end of May, in conjunction with the annual SAV survey results.

Expect harmful algal blooms in the Potomac River and low mainstem dissolved oxygen this summer

Forecasting ecological conditions has many benefits, including aiding management, building awareness, and providing guidance for restoration efforts. Nutrient loads are strongly linked to river flow rates and have an overriding influence on many aspects of the Bay's health. For this reason, the dissolved

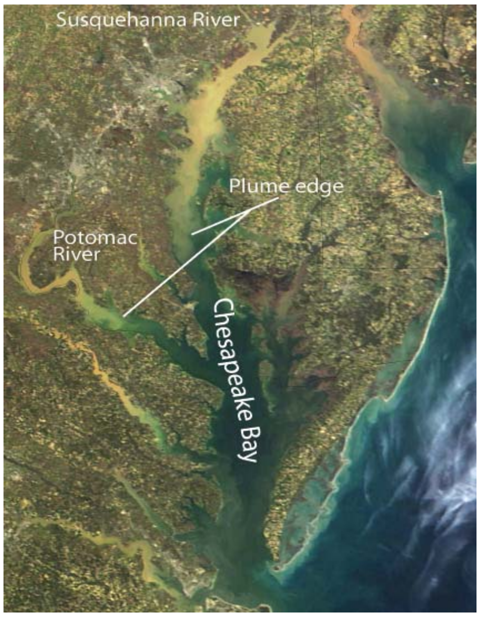
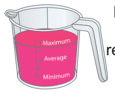


Figure 1. Chesapeake Bay on April 10, 2005. Satellite image shows an extensive sediment plume in the mainstem and many tributaries. (Source: MODIS Rapid Response Project at NASA/GSFC.)

oxygen (DO) and harmful algal bloom (HAB) forecasts are based on nutrient loads and flow, respectively. Flow and loads in the Chesapeake Bay watershed have been above average so far this spring leading to large sediment plumes in the Bay and many tributaries (Figure 1). These conditions are likely to have an important effect on the DO and harmful algal bloom levels this summer.

While this forecast focuses on dissolved oxygen in the Bay's mainstem and HABs in the Potomac River, it is important to note that other regions of the Bay and tributaries also experience similar issues.

Dissolved oxygen



Based on the nutrient loads delivered to the northern Chesapeake Bay this spring, the Chesapeake Bay Program forecasts that the mean anoxic (dissolved oxygen <0.2 mg/l) volume in the Bay this summer will be approximately 1.7 cubic kilometers (+/- 0.64). Relative to previous summers, this volume of anoxia is considered 'moderate to severe'.

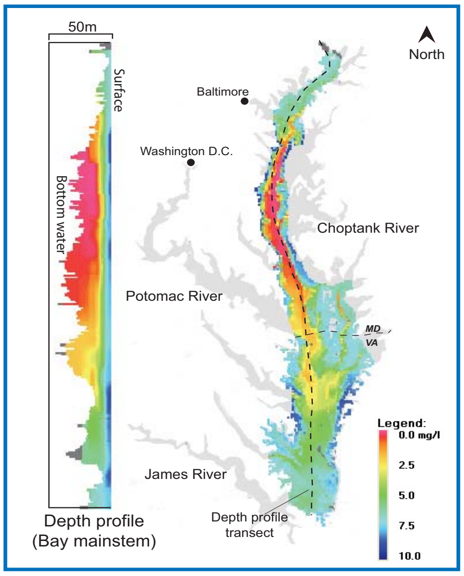
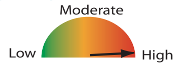


Figure 2. 1998 mean summer dissolved oxygen distribution - anoxic conditions colored red. 1998 had a mean summer dissolved oxygen level similar to that forecast for this summer.

1998 had a similar mean anoxic volume and spring nutrient load. The 1998 mean summer DO map is provided (Figure 2) to illustrate possible DO distribution this summer.

Given that the prediction is of a mean condition, we would expect some fluctuation around this value through the summer. The Chesapeake Bay Program will continue to monitor the numerous factors that affect the development of anoxia in the Bay through the summer and update the forecast accordingly (see Keeping Track, page 4).

Harmful algal blooms



The Chesapeake Bay Program forecasts a high likelihood of harmful algal blooms in the Potomac River this summer. This forecast is based on a model that relates spring and previous year Potomac River flow rates to the onset period, duration, and extent of the bloom. Given that Potomac River flow rates were categorized as 'wet' in 2004 and so far this spring as 'moderate', we forecast the following bloom conditions.

- Bloom onset: *Late spring (June)*
- Bloom durations: *approx. 2.5 months*
- Bloom extent: *>10 miles (length)*

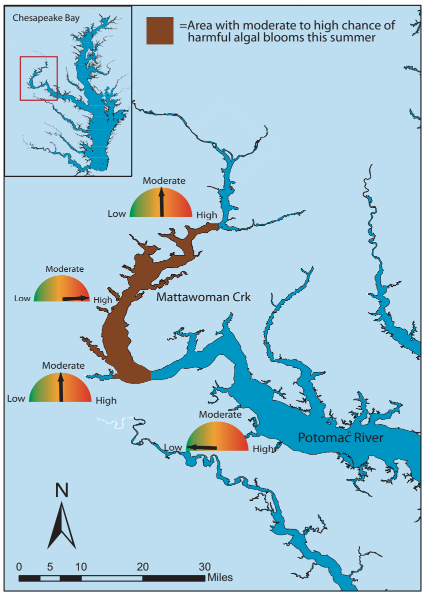


Figure 3. Region of Potomac River where harmful algal blooms are expected to occur this summer.

Unseasonable temperatures and unexpected flow conditions such as hurricanes may affect the accuracy of this forecast. Routine water quality monitoring will be used to track and report actual bloom conditions during the summer (see Keeping Track, page 4).

Forecasting dissolved oxygen in the Bay

Dissolved oxygen (DO) is critical for the survival of aquatic organisms, including key species such as rockfish, blue crabs, and shad. Reduced DO levels can lead to physiological stress or death of an organism if it is unable to migrate to regions of sufficient DO availability. In this section we explain what factors influence the amount of DO in the water column and how the forecast of summer anoxic (DO <0.2 mg/l) conditions was calculated.

There are many factors that determine the dissolved oxygen content of the tidal waters of Chesapeake Bay. Nutrient loading, water column stratification, wind and tidal mixing, and water temperature are but a few of these factors. The two most important determining factors are water column stratification and nutrient loading (Figure 4).

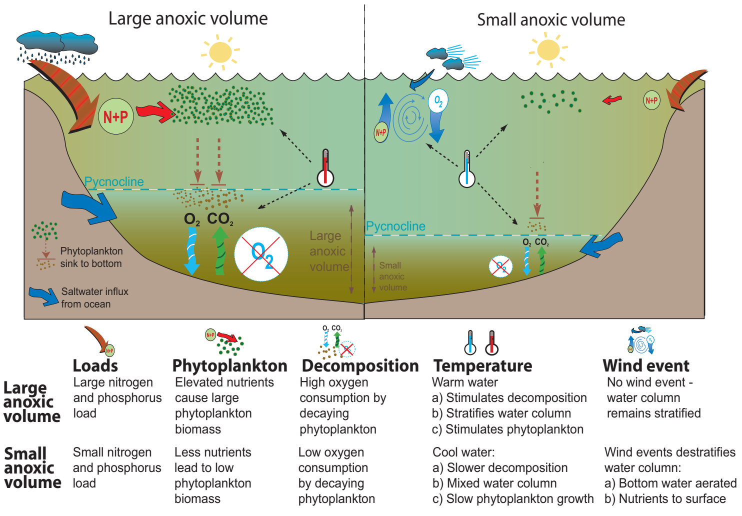


Figure 4. Conceptual diagram illustrating the environmental conditions that will lead to large or small volumes of anoxic water in the mainstem of Chesapeake Bay.

Water column stratification is caused by density differences between the surface and deeper waters of the Bay. Cooler, saltier (more dense) water from the ocean flows underneath the warmer, fresher (less dense) water from the rivers which flow into the Bay. Between the lighter surface water and heavier deeper water is a boundary called the pycnocline. Oxygen consumed beneath the pycnocline cannot be replenished from above, and this leads to lower dissolved oxygen concentrations below the pycnocline. The pycnocline is typically strongest in spring and early summer when fresh water flows are usually at their highest.

Nutrient inputs to the Bay from the land are directly related to precipitation and therefore river flow. Nutrient loads from land-based sources (agriculture, urban runoff, etc.) are higher in the spring when river flows are typically at their highest. Nutrients that flow directly into the Bay from a pipe (sewage treatment plants, industry, etc.) are generally less sensitive to flow and are more consistent through the year. There is a direct relationship between the magnitude of these nutrient loads and the severity of low DO the Bay experiences. Nutrients— nitrogen and phosphorus—fuel the growth of the phytoplankton that make up the base of the Bay's food web. Unconsumed phytoplankton settle below the pycnocline and are decomposed by oxygen-consuming bacteria living in the mud on the bottom of the Bay. Since this is occurring below the pycnocline, this oxygen is not replenished from surface waters. This process occurs every year in Chesapeake Bay, fueled by spring flows that wash large amounts of nutrients into the Bay. Examination of the Chesapeake Bay Program's 20 year data set has shown that the severity of summertime low DO is directly related to the magnitude of spring nutrient loads.

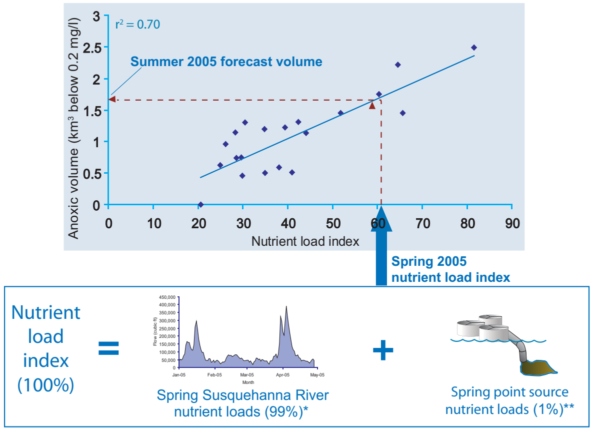


Figure 5. Historic (1985–2004) relationship between nutrient loads and mean summer volume of anoxic water in the Bay's mainstem. This relationship is used to forecast the summer 2005 mean anoxic volume. (*derived from spring flow rates and nutrient concentrations: **derived from upper western, upper eastern and Potomac River point sources)

The DO forecast was developed based on this relationship which we express as mean June to September anoxic volume(0.2 mg/l) versus nutrient loads to the northern Chesapeake Bay (Figure 5). Relationships for other concentration of DO were also investigated (1, 3 and 5 mg/l); however the strength of these relationships was considered too weak for use in forecasting. Nutrient loads are the combined total nitrogen (TN) and total phosphorus (TP) loads from the Susquehanna River and point sources on the upper western shore, upper eastern shore and the Potomac River. Flow related nutrient from the Susquehanna River accounted for approximately 99% of the nutrients and point source loads accounted for the remaining 1%.

Water quality probe used to measure dissolved oxygen in Chesapeake Bay. (Source: MD DNR.)

Summer 2005 compared to the past

The Chesapeake Bay program forecasts that the mean anoxic volume will be 1.7 cubic kilometers (1.1 cubic miles). Compared to the previous 19 summers, 2005 could have the 4th highest anoxic volume if this prediction holds true. Like any forecast, there is a degree of uncertainty in this value. Based on the forecast relationship only (not accounting for summer climatic influences) we are 95% certain that the mean volume of anoxic water this summer will be between 1.109 and 2.381 cubic kilometers (0.69 and 1.48 cubic miles).

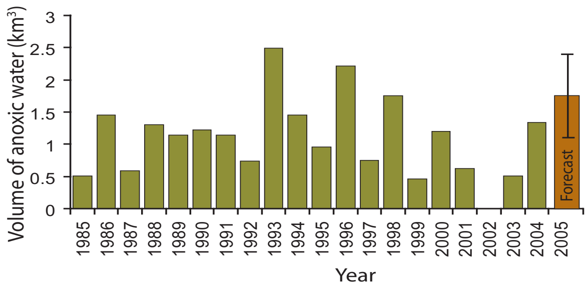


Figure 6. Summer 2005 anoxic volume forecast for Chesapeake Bay mainstem compared to previous year mean summer anoxic volumes.

Forecasting Potomac River harmful algal blooms

Harmful algal blooms (HABs) occur in many regions of Chesapeake Bay. In this forecast we focus on the Potomac River, where blooms of predominantly *Microcystis aeruginosa* (cyanobacterium or blue-green algae) have been occurring for most summers since the 1960s. These blooms have had numerous ecological, economic, and human health implications for the region and have been the impetus for major nutrient reduction programs.

The main factors that determine HAB occurrence and characteristics in the Potomac River are nutrient availability (primarily phosphorus), salinity, water temperature, and light availability. For blooms to occur, the water temperatures have to be above 15 °C (59 °F) and salinity below 5 ppt. More intense blooms are also likely to occur if conditions are still (little wind mixing) and cloud free (higher sunlight). An overriding influence on bloom occurrences is river flow rates, most likely due to its effect on nutrient availability (Figure 7). As a result, monitoring has shown HAB variability associated with annual and seasonal weather patterns effecting nutrient delivery to the estuary.

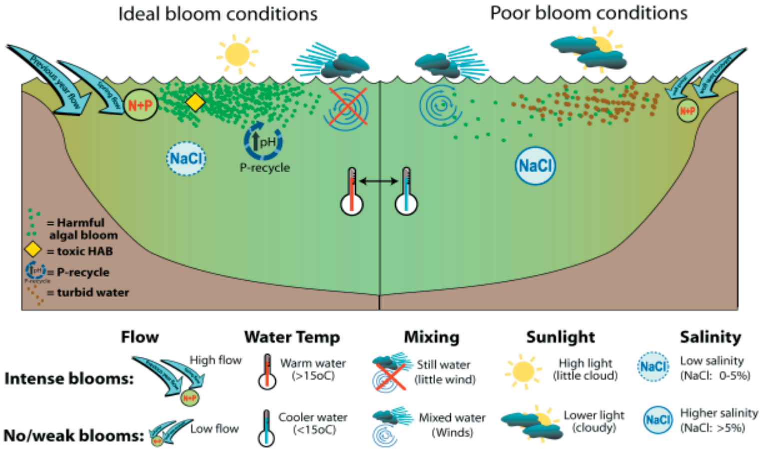


Figure 7. Conceptual diagram illustrating environmental conditions that are ideal for harmful algal blooms to form, and those that are considered poor bloom conditions.

Forecast approach: Summer *Microcystis* bloom conditions were compared with patterns of water flows on the Potomac River from preceding seasons and years using water quality monitoring data from 1984–2004 (Figure 8). Flow characteristics of a season or year were grouped statistically into three categories: Dry, Moderate, or Wet.

Characteristics of the bloom that were analyzed were:

1. Presence or absence of blooms being detected.
2. Timing of the first bloom sample.
3. Extent of bloom between stations where bloom levels were detected.
4. Intensity measured as a mean or median of the samples where *Microcystis* was detected.
5. Duration as the total number of months between the first and last bloom sample collected on the river during normal monitoring.

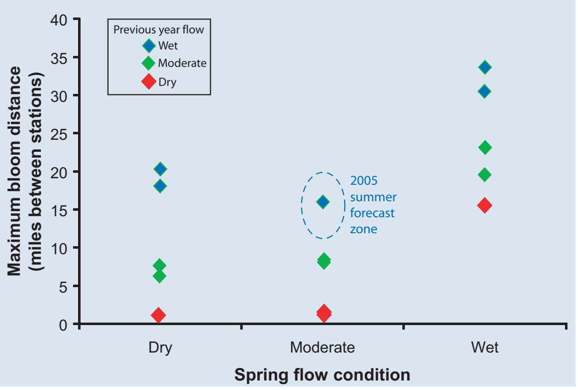


Figure 8. Relationship between Potomac River flow rates (previous year and spring) and harmful algal bloom geographic extent.

Using relationships uncovered from this analysis, a general model was developed (Figure 9). This model uses the total annual flow from the previous year and spring flow conditions immediately before the summer season to forecast the timing, duration and probable extent of the bloom.

Surface bloom of the cyanobacterium* Microcystis aeruginosa *in the Potomac River in August 2004. (Source: Morgan State University Estuarine Research Center.)

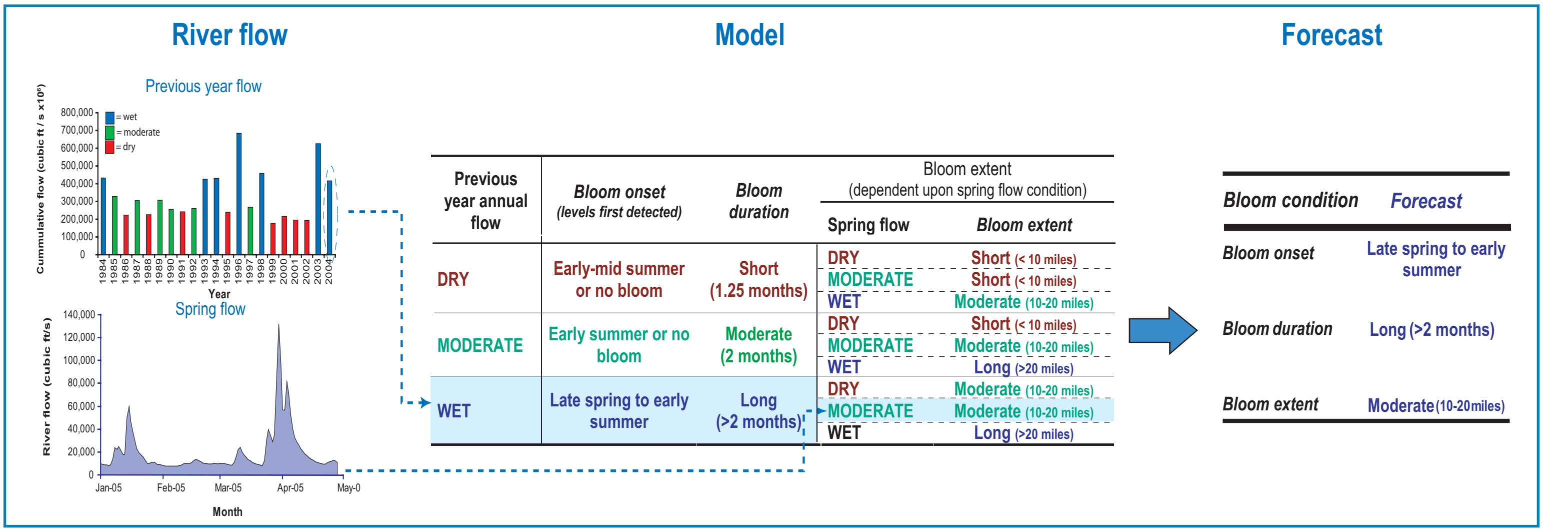


Figure 9. General model used to describe the relationships between Potomac River flow and bloom conditions. Total 2004 and spring 2005 Potomac River flow rates are presented to illustrate how the model was interpreted to generate this summer's harmful algal bloom forecast.

How certain are we?

These forecasts are built on simple relationships or models that correlate historical DO or bloom conditions with a single environmental pressure—river flow or nutrient loads. While these pressures are known to be the overriding influence on the conditions, and hence are the basis for the forecast models, there are numerous other environmental conditions that cannot be accounted for in the current models. For example, mainstem dissolved oxygen levels can rapidly improve in response to mixing of the water column by a wind event. Similarly, HAB conditions in the Potomac River may be different to those forecasted due to cooler water temperatures or lower light conditions than average.

Satellite image of Hurricane Isabel on September 18, 2003. Hurricanes and tropical storms such as this can have a significant effect on the Bay's water quality but cannot accounted for in the forecast models. (source: NASA)

While the forecast models are based on preceding flow and loads, they do not account for flow conditions in the summer months—a summer time tropical storm or hurricane in the Bay region could have a significant effect on the Bay's ecosystem that is not accounted for in the forecast models.

In summary, the forecast models are not replicas of all the processes, natural and man-made, that determine how the environment behaves in a particular year. Our forecast models capture the essence of the environmental patterns in Potomac River blooms and bottom water DO during the last 20 years. These models will be updated and improved as new data and analysis techniques are applied, leading to improved forecasting accuracy.

Keeping Track

Water quality in Chesapeake Bay and its tributaries is monitored at approximately two-week intervals during the summer. The dissolved oxygen and harmful algal bloom conditions will be regularly updated from this monitoring data. This update provides an opportunity to report on actual conditions and to make comparisons to forecast conditions. The updated conditions will be reported on the Chesapeake Bay Program web site: *www.chesapeakebay.net/bayforecast.htm*

Restoration aims to improve conditions

Restoration leaders have worked for more than two decades with farmers, citizens, wastewater treatment plant operators, conservation organizations, and local, state and federal officials to reduce pollution and bring the Bay ecosystem back into balance.

Reducing excess algae and improving oxygen levels will take time. Past Bay restoration efforts have resulted in improving trends in some areas, but there is a long way to go before all parts of the Bay are healthy enough for the plants and animals.

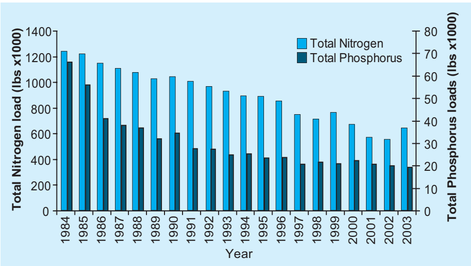
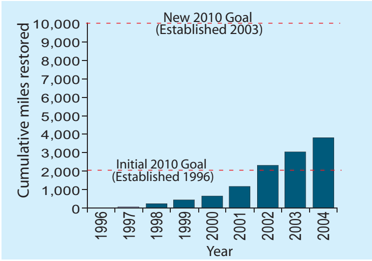


Figure 10. Changes in point source nitrogen and phosphorus loads in the northern Bay (upper eastern shore, upper western shore and Potomac River) over the past 20 years.

Improving DO levels in the Bay's deeper waters requires nutrient pollution reductions across a significant expanse of the Bay's watershed. Chesapeake Bay Program partners are working on several fronts to improve the way we manage our land and infrastructure:

Agriculture. Scientists and researchers are working with farmers to put in place improved land management techniques that prevent excess nitrogen, phosphorus, and sediment from flowing into local streams and rivers that feed into the Bay. Innovative approaches being employed include no-till farming, winter cover crops, and better management of animal waste.

Figure 11. Miles of riparian forest buffers planted in the past nine years. Riparian buffers help prevent nutrients and sediment washing into the waterways.



Sewage Treatment. Local governments and wastewater treatment plant operators are installing nutrient removal technologies, that reduce the amount of nitrogen in treated wastewater. Currently, 56% of wastewater is treated using advanced nutrient removal technology and plans are in place to have 80% of the total annual wastewater flow treated by 2010. Figure 10 illustrates changes in point source nutrient loads to Northern Chesapeake Bay over the past 20 years.

Stream Corridor Restoration. Private landowners, conservation organizations, and government agencies are focusing on improving the quality of local streams and rivers that feed into the Bay. In the last decade, riparian forest buffers have been planted along more than 3,700 miles of rivers and streams in the Bay watershed (Figure 11). These buffers prevent nutrients and sediment from reaching rivers and streams.

The dissolved oxygen forecast was conducted by David Jasinski and Gary Shenk, with technical review provided by Drs. Michael Kemp, Walter Boynton and Jim Hagy. The HAB forecast was conducted by Dr. Peter Tango, with technical review provided by Drs. Judy O'Neil, Hans Pearl and Wayne Carmichael. Forecast analysis was directed by the Chesapeake Bay Program's **Tidal Monitoring and Analysis Workgroup** (TMAW).

Current TMAW members and their affiliations:

Bill Dennison – Chair, David Jasinski, Ben Longstaff, Michael Williams
Steve Preston – Coordinator, Jurate Landwehr, Mary Ellen Ley
Bruce Michael, Mark Trice, Christopher Heyer, Peter Tango, Ben Cole, William D. Romano, Renee Karrh, Elizabeth Ebersole
Daniel M. Dauer, Mike Lane
Richard Lacouture
Jamie Bosiljevac – Fellow
Rick Hoffman
Joe Beaman
Ken Moore
Peter Bergstrom, Marcia Olson
Carlton Haywood, Claire Buchanan
Roberto Llanso
Consultant Elgin S Perry

Newsletter prepared by:
Ben Longstaff (NOAA-UMCES Partnership)
David Jasinski (Chesapeake Bay Program/UMCES)
Peter Tango (MD Department of Natural Resources)
on behalf of TMAW members

For further information go to the forecast web page located at *www.chesapeakebay.net/bayforecast.htm*
Additional water quality and harmful algal bloom information can also be found at *www.eyesonthebay.net*