Ulanowicz, R.E.1978. Eutrophication in the Chesapeake Bay. pp. 269-273. In: W.T.Chen et al., eds. Application of Remote Sensing to the Chesapeake Bay Region, Vol. II, NASA Conf. Publ. 6.

EUTROPHICATION IN THE CHESAPEAKE BAY

Robert E. Ulanowicz
Center for Environmental and Estuarine Studies,
University of Maryland
Solomons, Maryland

The most critical long-term threat to the continued health of the Chesapeake Bay is the addition of excess nutrients to the estuarine waters. Other problems, such as Kepone and the disappearance of aquatic vegetation (which is possibly linked with nutrient loading), may steal our attention for short periods, but these difficulties will, hopefully, recede in due time. The projected growth of population in the near environs of the Bay, however, indicates that, as a problem, eutrophication will probably continue well into the next century.

The etymological roots for eutrophication refer to food and health. Indeed, estuaries are such bountiful waters precisely because the input of natural chemical nutrients is high compared to that of oceanic waters. Unfortunately, the utility of estuaries (or any aquatic system) does not continue to increase with greater nutrient input. Nor does the problem lie completely with the associated pathogens about which Dr. Eisenberg spoke. Rather, there comes a point at which the primary plant growth stimulated by high nutrient values creates respiratory and decompositional oxygen demand that drives the available oxygen levels to catastrophically low values (<4 ppm), thereby threatening or killing the higher trophic level species. The resultant simplified system of primary producers and decomposers usually has little economic, recreational, or esthetic value.

In an earlier survey commissioned by the National Aeronautics and Space Administration (NASA) (Ulanowicz, 1974), the author catalogued the various sources of nutrients into the Bay and some areas in which these sources are causing difficulty. Perhaps a review of the effluent types would be pertinent to this discussion.

Certainly, the most acute eutrophication problems in the Bay arise in proximity to municipal sewage-treatment plants. Although these facilities remove 60 to 80 percent of the carbonaceous oxygen demand, most of the nitrogen and phosphorous in the stream passes into the receiving waters to act as fertilizer. Each of the four major metropolitan districts have associated tributaries of the Bay in which bloom conditions prevail and oxygen deficiencies are frequent. Baltimore's sewage is the major cause of anaerobic conditions in the Back River estuary and is a major contributing factor to dissolved-oxygen sags in the Patapsco estuary. The Potomac Estuary is often covered during the summer with mats of blue-green algae for 55 kilometers downstream of Washington. The upper James Estuary frequently receives pulses of raw sewage when flooding occurs, and the Environmental Protection Agency has found agglomerated fecal material in some of the water samples taken in the Portsmouth/Little Creek area (Lear, private communication, 1972).

Water draining agricultural lands can carry with it significant amounts of fertilizer and animal waste. The Sassafras, Elk, and Northeast Rivers sometimes host blue-green algae booms believed to be the result of fertilizer runoff. Drainage from swine operations along the sub-tributaries of the Potomac and James River Estuaries have caused problems in these embayments.

Septic-tank disposal of domestic sewage is not always totally effective, especially where poor percolation exists because of hardpan soils or high groundwater tables. To date, most difficulties center around the bacterial load from such seepage rather than the associated nutrient load. Affected shorelines include Baltimore and Anne Arundel counties in Maryland and York County in Virginia.

Human waste from recreational and commercial vessels is probably an inconsequential nutrient addition to open waters; however, overboard disposal in small embayments with many marinas or heavy boat traffic may be another matter, even though the law prohibits such disposal while in dock. A preliminary survey in the South River (Dinsdale, 1975) indicates that vessel discharges pale in comparison to the input from natural runoff. The frequency of blooms in other harbor areas, such as Annapolis, Solomons, St. Michaels, Deltaville, Reedville, Yorktown, and Newport News, suggests that input rates and tidal flushing characteristics may make these harbors more susceptible to eutrophication from sewage discharge from boats.

Finally, the remaining nutrient input to the Bay can be lumped into a single category—nonpoint source additions. It is evident from natural history that runoff from most natural areas can be adequately handled by the estuarine cycles. But runoff from suburban and metropolitan areas is often of another order of magnitude. It has been estimated that the total runoff from the urban section of the watershed adds more nutrients to the system than the sewage plant discharges.

From the foregoing, one might deduce that eutrophication is a localized phenomenon in Chesapeake Bay and that the larger mass of water supported a reasonably healthy ecosystem. Until a few years ago, this was a widely held opinion by most of the scientific and management community. Unfortunately, there are signs that the Bay as a whole may be becoming vulnerable to excessive nutrients. Figure 1 illustrates a trend observed in the lower Patuxent Estuary that may indicate the future of the main stem of the Bay. The freshwater region of the Patuxent has been progressively burdened with sewage loading from the Prince George's and Anne Arundel suburban areas. Through the early 1960's, the chlorophyll levels in the lower estuary remained at a normal level for a healthy estuary. With loadings approaching 90 million liters/day in later years, however, chlorophyll levels associated with bloom conditions (40 μg/1 chlorophyll) are being consistently observed.

Likewise, patches of phytoplankton blooms were occasional events in the open Bay during the late summer and early fall months. Although data on such transient events is hard to

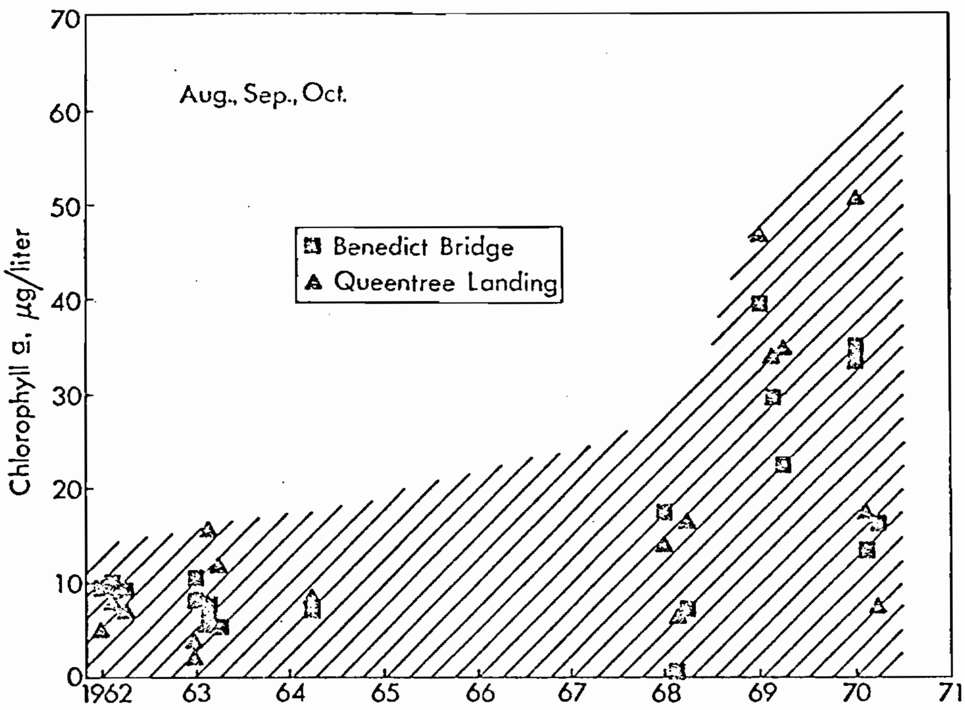

Figure 1. Lower Patuxent Estuary, August through October (Heinle, unpublished data, 1977).

assemble, there are probably few scientists on the Bay who would argue with the author's observation that such blooms are becoming more frequent (to the point of becoming sustained) and are occurring over a longer portion of the year.

Given the magnitude of the problem and the portents of things to come, one might draw some comfort from knowing that the scientific, managerial, and political communities were unanimous in opinion as to what must be done to halt and reverse the nutrient trend. Alas, there are strong differences of opinion on how best to alleviate the difficulties.

One issue revolves around land-versus-water disposal of wastes (and associated nutrients). An attractive alternative to burdening the waterways and estuaries with sewage effluent is the application of wastewater onto the land, where nutrients, and water, rather than oxygen, tend to limit ecosystem productivity. There is question, however, as to whether the public will accept land disposal as a hygenic alternative. There is even further controversy over the relative economics of land-versus-water disposal, because the major capital outlay necessary for acquisition of land to receive the wastes is great. Furthermore, possible problems with the land system remain that, in the eyes of some, have not been adequately investigated. These include heavy metal accumulation, runoff from the disposal area, leaching into groundwater supplies, etc.

In any event, it is unlikely that all sewage generated in the Bay area will be returned to the land in the near future. The question remains as to how to most effectively "retrofit" existing plants to prevent excessive nutrient stimulation in the estuary. The practical choice is between the removal of phosphorous versus the removal of nitrogen. Phosphorous is by far the easier element to eliminate from the effluent, and its removal can significantly inhibit blooms in naturally phosphorous-limited ecosystems, such as those often found in freshwater. However, some investigators are convinced that nitrogen (which is very costly to remove) is the limiting nutrient in estuarine systems and that phosphorous removal alone would be quite ineffective (Heinle, private communication, 1976). Indeed the nitrogen-limitation theory would neatly explain how sewage input from upstream is stimulating productivity in the lower estuaries, because the uptake of some nitrogen species (notably NO_3 and NO_2) is slow enough to permit significant transport of these nutrients downstream.

A strategy for nutrient control will cost hundreds of millions of dollars, and the wrong choice could waste most of the effort. The pressure is on the managers to make a decision soon. A stronger case for good data could not be made.

Remote sensing can be a vital tool for the acquisition of fast, reliable data on the nutrient problem. Synoptic data from large spatial domains are difficult to obtain from other methodologies. However, I would like to mention some shortcomings of remote sensing data.

The reader may have gathered from the foregoing that the primary interest of many investigators is on the nutrient concentrations. Chemically, these nutrients are present in dilute concentrations, usually measured in milligram (or sometimes microgram) atoms per liter. Therefore, with the remote sensing technologies in use we cannot directly measure the nutrient concentrations, but must be satisfied with observing the effects of the nutrients (e.g., chlorophyll) or with following a variable associated with nutrient input streams (e.g., sediment or temperature).

Therefore, a premium exists on the development of any remote sensing technology that would directly sense nutrient concentrations. I know of no techniques under development for the actual remote sensing of nutrient species. However, there is interest in developing *in-situ* techniques such as ion-specific electrodes (Cadman, private communication, 1973) and laser Raman spectroscopy (Freer, private communication, 1973) that could be telemetered to a central location. Although not remote sensing in the pure sense, such techniques would nevertheless obviate the need for wet analysis of all samples and would provide synoptic measurements over a wide area at a variety of depths.

A second major limitation to remote sensing techniques is their relative inability to monitor subsurface events. The Bay, a partially stratified estuary, often first exhibits eutrophic conditions at depth.

These shortcomings are mentioned primarily to give the biological investigator's priorities for defining potential research on the extension of remote sensing capabilities as they relate to research on eutrophication.

Certainly, the foregoing is not meant to minimize the important contributions that remote sensing can make by gathering information on the effects of nutrient loading. Especially useful are the chlorophyll concentration maps that can be derived by multispectral scans or lidar techniques. The possibility of mapping phytoplankton patches according to genera by using multiple wavelength lidar techniques is exciting and extremely labor-saving.

Also of immense value are the old war-horses—black-and-white, color, and color infrared photography. Their use in assessing runoff spotting seepage from holding ponds and septic systems, censusing vessels to estimate discharge, and evaluating vegetational and soil structure changes associated with land disposal has significantly aided those charged with setting and enforcing effluent standards.

There remain, however, some basic issues to be resolved if an optimal solution of the nutrient problem is to be effected. The extension of available technologies would enable the remote sensing community to make an invaluable contribution to charting this key strategy for maintaining the health and utility of the Chesapeake Bay.

REFERENCES

Dinsdale, N., 1975, "Spa Creek Water Quality Study," 53rd Meeting, Atlantic Estuarine Research Society, Annapolis, Maryland.

Ulanowicz, R. E., 1974, "A Survey for the Use of Remote Sensing in the Chesapeake Bay Region," Publication No. 6, Chesapeake Research Consortium, Baltimore, Maryland.