HYPOXIA ACTION PLAN: WHAT CAN MIDWEST AGRICULTURE DO?

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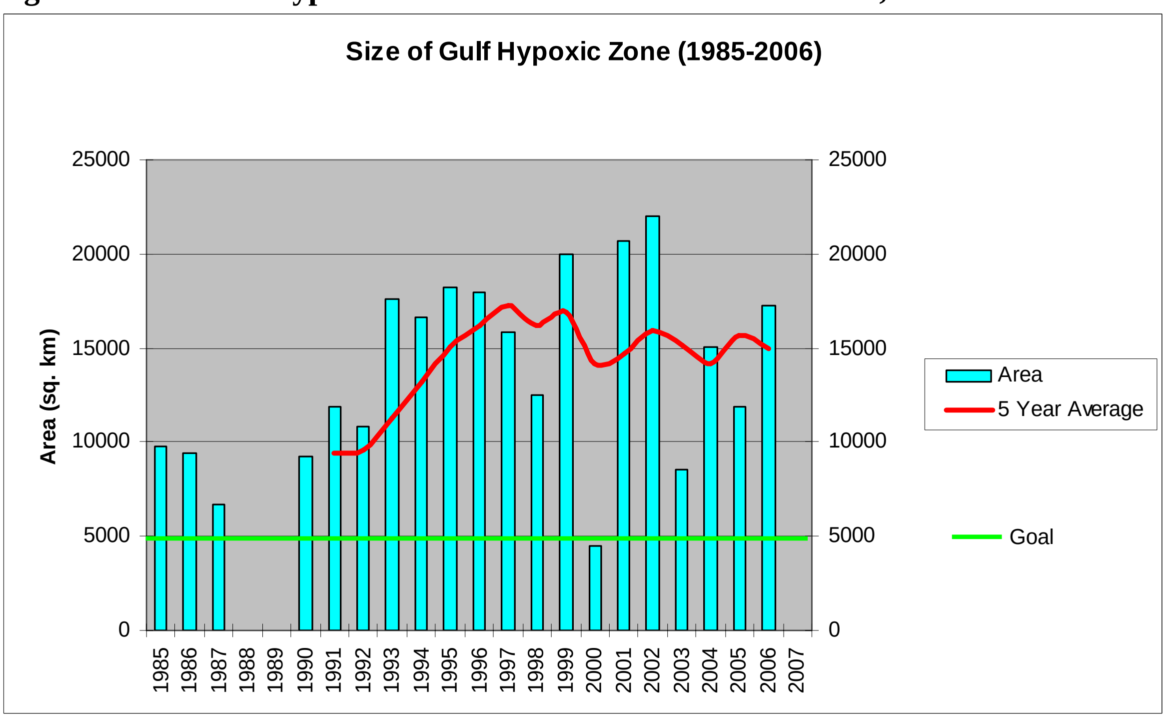
The hypoxic zone is an area in the northern Gulf of Mexico where dissolved oxygen concentrations in the shallow ocean are less than 2 mg/L, the level necessary to sustain most aquatic life. In response to the low oxygen levels, mobile organisms, such as fish and shrimp, leave the hypoxic zone; the others die at varying rates. Although these responses have been observed in the gulf, an economic analysis based on past data did not detect a direct relationship between hypoxia and gulf fisheries (CENR, 2000).

The occurrence of hypoxic conditions depends on stratification of the water column — warm, less dense fresh water above cold, denser salt water — and consumption of oxygen during the decomposition of organic materials. The organic matter in the lower part of the water column is a result of algal growth and death in the surface waters. The growth of the algae is controlled by the presence of nutrients. In salt water systems such as the gulf, nitrogen is commonly the nutrient that limits algal growth. In fresh water systems, phosphorus is the nutrient that most often controls algal growth.

The size of the hypoxic zone varies considerably from year to year, depending on the timing and extent of water-column stratification during the spring and summer, weather conditions, temperature, and the amount of precipitation in the Mississippi River drainage basin. In 1999, the hypoxic zone was almost 20,000 square kilometers, the greatest extent since measurements began in 1985. In summer 2000, it was about 4,400 square kilometers, the smallest area since the drought year of 1988. Hypoxia in bottom waters covered an average of 8,000-9,000 km^2 in 1985-1992 but increased to 16,000-20,000 km^2 in 1993-1999. The five-year running average of the hypoxic zone for 2002-2006 was about 15,000 km^2 (Figure 1).

Figure 1. Size of the hypoxic zone in the northern Gulf of Mexico, 1985-2006.



The widespread occurrence of hypoxia has been attributed to a significant increase in nitrogen loads to the gulf, principally in the form of nitrate, that has been occurring since about 1970. Nitrate loads tripled from about 0.33 million metric tons per year during the 1955-1970 period, to 0.95 million metric tons per year during the 1980-1996 period (CENR, 2000). During the 1980-1996 period, total nitrogen flux was about 1.6 million metric tons per year.

Effects on Midwest Agriculture

Agriculture has been identified as the source of about 74 percent of the nitrate and 65 percent of the total nitrogen reaching the gulf. The principal agricultural areas contributing nitrate are tile-drained cropland in Illinois, Iowa, Indiana, Ohio and southern Minnesota (Goolsby et al., 1999). Indiana contributes an estimated 6 to 9 percent of the total annual nitrogen flux to the gulf.

In order to achieve a significant reduction in nitrogen loading to the gulf, the USEPA proposed that farming practices be changed to reduce nitrogen losses and that 5 million acres of wetlands and 27 million acres of riparian areas within the Mississippi River basin be restored to remove nitrogen from surface and ground water (CENR, 2001). In the Midwest, grain producers may be able to reduce edge-of-field nitrogen losses by 10 to 15 percent with best management practices (BMPs), such as adjusting rates and timing and proper crediting of legumes, without affecting yields. Other producers who have already fine-tuned their nitrogen inputs will not have that management option. The restoration of 32 million acres of wetlands and riparian areas would result in the conversion of only 4.4% of the entire Mississippi River basin. However, creating millions of acres of wetlands or riparian areas could have tremendous impacts on Midwest agriculture.

Excess nitrogen is not a widespread problem affecting the aquatic resources within the Mississippi River basin. Although there are instances where nitrate concentrations exceed the drinking water standard in surface water sources for public water supplies, adequate evidence has not been presented to show that high nitrogen levels are affecting the goals of fishable and swimmable streams within the basin. To address in-state priorities, excessive phosphorus and sediment are likely to remain as the primary pollutants of concern in targeting state resources.

Implementation of the Action Plan for Reducing, Controlling, and Mitigating Hypoxia in the northern Gulf of Mexico (Task Force 2001) will require a significant level of commitment from the federal agencies and state governments and increased awareness and action by hundreds of thousands of stakeholders. A key to achieving these commitments and actions is coordination and outreach by the sub-basin committees established by the states in response to Action Item 2 of the Action Plan:

> “States and Tribes in the Basin, in consultation with the Task Force, will establish sub-basin committees to coordinate implementation of the Action Plan by major sub-basins, including coordination among smaller watersheds, Tribes, and States in each of those sub-basins.”

Clearly, the Task Force recognized that no single approach to nutrient reduction would be effective throughout the portions of 31 states that lie within the Mississippi River Basin. Rather, because the soils, hydrology, land use, and cropping practices vary considerably across the Mississippi River Basin, it was left to the sub-basin committees to develop the appropriate strategies for their portion of the basin.

There are currently three sub-basin committees: the Ohio River Sub-Basin Committee, the Upper Mississippi River Sub-Basin Hypoxia Nutrient Committee (http://www.umrshnc.org), and the Lower Mississippi River Sub-Basin Committee. The Ohio River Sub-Basin Committee includes representatives of state agencies in Ohio, Illinois, Tennessee, Pennsylvania, Indiana, West Virginia, and Kentucky. Indiana is represented by the Department of Environmental Management. The steering committee is chaired by the Ohio Department of Natural Resources. Ohio and Illinois are represented on the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force and the Coordinating Committee of the Task Force.

The Ohio River Sub-Basin Committee is currently forming a stakeholder advisory group to serve as a broad-based input forum that can facilitate two-way communication between and within the primary stakeholder interests of the sub-basin. This goal of this forum is to obtain input, network between, and formulate recommendations from the varied interests of the stakeholders of the states. The primary role of the group is to focus on issues relating to gulf hypoxia, but secondarily the group will consider local water quality concerns as they relate to gulf hypoxia.

The Action Plan proposed 10 short-term actions to achieve the long-term coastal, basin, and quality of life goals. Many of those short-term actions items were assigned to the states through the sub-basin committees. It says, States, Tribes, and Federal agencies within the Mississippi and Atchafalaya River Basin will:

- Expand the existing monitoring efforts within the Basin.
- Develop strategies for nutrient reduction.
- Identify point source dischargers with significant discharges of nutrients and undertake steps to reduce those loadings.
- Increase assistance to landowners for voluntary actions to restore, enhance, or create wetlands and vegetative or forested buffers along rivers and streams within priority watersheds.
- Increase assistance to agricultural producers, other landowners, and businesses for the voluntary implementation of BMPs that are effective in addressing loss of nitrogen to water bodies.

Reassessment of the Hypoxia Action Plan

The Action Plan for Reducing, Mitigating, and Controlling Hypoxia in the Northern Gulf of Mexico included an action item to assess the nutrient reductions achieved and the response of the hypoxic zone, water quality throughout the Basin, and economic and social effects. The reassessment (http://www.epa.gov/msbasin/taskforce/reassess2005.htm) includes a series of actions that will develop the information necessary for the Task Force to review the 2001 Action Plan and make revisions as necessary. It will be completed over the next two years. These actions include reassessment of the primary causes of gulf hypoxia and management approaches to address these causes.

The purpose of this action is to develop an updated, independent assessment of the causes of gulf hypoxia and recommend whether the most recent body of scientific evidence supports or suggests revisions to the assessment that formed the basis of the 2001 Action Plan. After review of several options, the Task Force agreed that an expert panel be chartered through EPA's Science Advisory Board (SAB) to review available scientific information and provide a report that synthesizes the current state of knowledge of the causes of gulf hypoxia.

The Task Force selected the SAB because of the opportunities for public access, timeliness and cost. All SAB panel meetings and deliberations are open to the public in accordance with Federal Advisory Committee Act and EPA administrative policies for advisory committee management. The SAB will hold at least two meetings, one for initial discussion of their charge and the second for deliberations on their findings, both of which will be open to the public.

The EPA Science Advisory Board Hypoxia Advisory Panel is charged with evaluating the scientific basis for, and recommended revisions to, the goals proposed in the Action Plan; and the scientific basis for the efficacy of recommended management. The Panel will review current research activities pertinent to this evaluation, including findings from scientific symposia sponsored by the Task Force. To capture recent advances in our scientific understanding of hypoxia, the causes and potential solutions, the Task Force has sponsored four scientific symposia, including:

- The Upper Basin Science Symposium, September 26-28, 2005, Ames, IA, which evaluated the effectiveness and cost effectiveness of the various management practices currently available to agriculture to reduce nutrient losses (proceedings available at http://www.umrshnc.org.
- Gulf Hypoxia Science Symposium, April 25-27, 2006, New Orleans, LA.
- Lower Basin Science Symposium, June 1-2, 2006, New Orleans, LA.
- Sources, Fate and Transport Symposium, November 7-9, 2006, Minneapolis, MN.

The Task force asked the SAB to develop a report that addresses the state of the science of hypoxia as well as the scientific basis for mitigating hypoxia through management options. The SAB was asked to focus particular attention on scientific advances since 2000 that may have increased understanding and options in three general areas:

1. **Characterization the Cause(s) of Hypoxia**. The physical, biological and chemical processes that affect the development, persistence, and extent of hypoxia in the northern Gulf of Mexico.
2. **Characterization of Nutrient Fate, Transport and Sources**. Nutrient loadings, fate, transport, and sources in the Mississippi River that impact Gulf Hypoxia.
3. **Scientific Basis for Goals and Management Options**. The scientific basis for, and recommended revisions to, the goals proposed in the Action Plan; and the scientific basis for the efficacy of recommended management actions to reduce nutrient flux from point and nonpoint sources.

Any interested parties at any time may submit additional information for the panel to consider. Upon completion in summer 2007, the draft report will be released for public comment.

Management Recommendations Synthesis and Revisions to the Action Plan
The Coordinating Committee of the Task Force will evaluate and synthesize the recommendations for management from the SAB review, the workshops, and the public comments into a set of recommendations and options for the entire basin. This synthesis will form the basis of the recommendation to the Task Force.

Public Review and Comment
The draft Action Plan revision will be made available for public review and comment at the conclusion of the activities described above. Adoption of the revised action plan is scheduled for December 2007.

Two significant, although preliminary and tentative, conclusions in the recent scientific literature and at the public science symposia are:

- The current action plan includes a goal to reduce the five-year running average areal extent of hypoxia to less than 5,000 square kilometers by 2015. In 2000, the best current science indicated that average nitrogen loads to the gulf should be reduced by 30 percent from the 1980-1996 average. Recent analyses of USGS data show that in the period 2000-2004 (most recent data available) total nitrogen flux to the gulf had decreased by 32% from the average flux during the 1980-1996 period. Data source: http://co.water.usgs.gov/hypoxia/html/nutrients_new.html. However, the size of the hypoxic zone has not changed significantly (Figure 1).
- Although recent model simulations indicate that a 40-45 % reduction in annual loads is necessary to achieve the coastal goal (perhaps as much as 50-60% in wet years), other analyses show a low correlation between the size of the hypoxic zone and annual flux (r^2=0.28). A statistical model by Turner and others (2006) indicates that the nitrate flux in May and a term to account for carryover of oxygen demand is a better predictor of hypoxia.

The scientific uncertainties in predicting the size of the hypoxic zone reflect the complexity of the system and the multitude of factors affecting its formation and persistence, such as timing and volume of nutrient and freshwater discharge, and physical processes in the gulf (temperature, wind, and hurricanes). However, it appears likely that nitrogen and phosphorus will be confirmed as primary causes.

Nutrient Reduction in the Midwest

Nutrient impairment of surface and ground waters in the Corn Belt is largely due to a complex set of factors involving landscape and land use changes (which affect ground cover, need for additional nutrient inputs, and hydrology). The current Corn Belt landscape, now dominated by annual row-crop and local concentrations of intensive livestock production systems, will require improved management of fertilizer inputs and manure utilization practices to minimize nutrient losses from those systems. Off-site practices, and possibly some cropping system changes, will likely also be needed to reach water quality goals (Lemke and McKenna, 2005). The potential and limitations of improving both in-field and off-site management practices need to be assessed in order to efficiently plan for future actions. Improvements in current management systems need to be made, and new, innovative technologies designed and tested. Because of the economic and social consequences of returning lands to their prior condition, society will need to decide how far to go in promoting land use changes (e.g., growing fewer row-crops and/or having longer rotations including sod-based crops) and landscape modifications (e.g., creating more wetlands and buffer strips, and possibly redesigning drainage systems).

There are about 100 million acres of cultivated cropland in the Corn Belt states. With limited state and federal resources for technical assistance and cost-sharing, and an agricultural economy buffeted by high input costs and low commodity prices, accurate targeting will be critical to achieving water quality improvements. Because phosphorus is typically the limiting nutrient in freshwater systems and nitrogen is the primary limit on algal growth in the gulf, state and local agencies face a difficult choice in designing programs to meet multiple, if not conflicting, goals. Accurate targeting to achieve reductions in agricultural nonpoint sources is further complicated because potential pollutants from agriculture may have different chemistries and, consequently, different pathways to water bodies. For example, nitrate is a soluble, nonreactive chemical and is readily leached through soils, while phosphorus is slightly soluble and reactive in soils and the highest concentrations are in the upper soil layers.

In most of the Corn Belt, nitrate concentrations in streams and reservoirs are much higher in those areas underlain by flat, black, tile-drained soils and sandy soils. Phosphorus loads attributable to agricultural nonpoint sources are highest in areas with high runoff or erosion rates. In addition, different management practices are often necessary to reduce nitrate and phosphorus movement to surface water: nitrate BMPs modify infiltration, leaching and soil water content; phosphorus BMPs modify surface runoff and erosion. In some instances, practices to reduce nitrate leaching and movement to surface waters may increase losses of phosphorus.
The cost, whether in incentive payments for changes to management practices or construction of erosion control practices, is relatively constant for an acre of land. However, loadings of sediment and nutrients vary greatly across the Corn Belt and within individual states, and even within counties or small watersheds.

Targeting must include the right practice in the right area. For example, educational and incentive programs to encourage changes in nitrogen management practices will be most fruitful if they are targeted to tile-drained areas and erosion control practices are likely to be most efficient if they are targeted to fields contributing high sediment loads. We must also consider variable rates in our financial incentive programs. A higher cost-share rate for installation of erosion control practices on a sloping field immediately adjacent to a stream may be the most cost-effective way to reduce losses of sediment and particulate phosphorus.

Specific practices that can reduce nitrogen losses to streams and rivers include:

- Applying nitrogen fertilizer and manure at recommended agronomic rates.
- Switching from fall to spring application of nitrogen fertilizer.
- Improving management of livestock manures, whether stored or applied to the land.
- Changing from row-cropping to perennial-cropping systems.
- Planting cover crops for fall and winter nutrient retention.
- Modifying drainage management practices, such as tile-spacing and depth.
- Water table management and bio-reactors.
- Routing tile drainage through wetlands.

One management practice that is rarely mentioned as being important in reducing nutrient losses is achieving an optimum level of management in crop production. Maintaining appropriate soil nutrient levels and controlling weeds and pests to ensure high yields ensure maximum use of nitrogen by corn. In recent analyses, David (2005) reported that due to excellent crop yields with steady fertilizer use, net N inputs (fertilizer + fixation minus harvested grain) since 2000 are much lower than the previous 20-year period and have not been this low since the 1950s. For Illinois, recent net N inputs to the state were about 9 lbs N/A/yr for 2000 to 2004, compared to about 27 lbs N/A/yr for 1980 to 1999 (David, 2005).

However, even with the best set of tools, we face an extremely challenging task because of the effects of climate change, probable increases in corn production to produce ethanol, and a lower than estimated potential to achieve reductions in nitrogen losses from cropland through management changes. Another emerging issue is sustaining soil productivity when developing practices to improve water quality. Because nitrogen is a key component of soil organic matter, maintenance of soil organic carbon levels requires sufficient inputs of nitrogen to equal losses
(Jaynes and Karlen, 2005).

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