

Science to Improve Management of the Gulf of Mexico Hypoxic Zone: A Collaborative Approach

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Abstract- Management of the northern Gulf of Mexico large hypoxic zone is driven primarily by the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force (“Hypoxia Task Force”) Action Plan. Both the 2001 and revised 2008 Action Plans called for a reduction in the average areal extent of the hypoxic zone to 5000 km² by the year 2015, less than 1/3 the current typical annual maximum area. To achieve this goal, watershed nutrient loading reductions of 45% total nitrogen and 45% total phosphorus were estimated needs. The science to inform these targets and develop hypoxia mitigation strategies was derived from predictive models based on the quantitative relationship between causative factors (e.g. nutrient loading, stratification) and extent of hypoxia, long-term monitoring, and forecast models to test the validity of predicted relationships. This science provided the foundation for an evaluation by an Environmental Protection Agency Science Advisory Board Hypoxia Advisory Panel which served to update and synthesize research efforts on the causes and consequences of the hypoxic zone and assess progress in implementing nutrient reduction measures in the Mississippi River watershed. This information subsequently led to the adoption of the 2008 Action Plan by the Hypoxia Task Force.

In addition to actions by the Hypoxia Task Force, efforts to advance the research and management capabilities needed for hypoxic zone mitigation have strengthened recently through the cooperative activities of several partnering networks (e.g. Hypoxia Task Force, Gulf of Mexico Governors’ Alliance, NOAA Gulf Regional Collaboration Team, Northern Gulf Institute, Gulf Coastal Ocean Observing System). For example, the Gulf of Mexico Alliance has committed to addressing hypoxia through their recently released Action Plan II. An anticipated outcome of this commitment is a partnership with the Hypoxia Task Force to implement nutrient reduction strategies and improve monitoring. These collaborative efforts have been supported by two workshops, the Summit on Long-Term Monitoring of the Gulf of Mexico Hypoxic Zone and the Ecological Impacts of Hypoxia on Living Resources Workshop. The monitoring Summit subsequently led to a Gulf of Mexico Hypoxia Monitoring Implementation Plan that seeks to establish a sustainable, operational monitoring program. We will summarize the results of these collaborative efforts to advance monitoring and modeling research on Gulf of Mexico hypoxia, and address their anticipated management benefits.

I. INTRODUCTION

The largest zone of oxygen-depleted coastal waters in the United States, and the second largest for the world's coastal ocean, is in the northern Gulf of Mexico on the Louisiana continental shelf. Retrospective analyses of sedimentary records and model hindcasts suggest that hypoxia in this region has intensified since the 1950s, and that large-scale hypoxia began in the 1970s (reviewed in [1, 2]). The areal extent of the hypoxic zone, monitored in mid-summer since 1985, has increased from an average of 6,900 km² from 1985-1992 to 15,733 km² from 1993-2009, with a peak of 22,000 km² in 2002 [3, 4]. Over the past 5 years, this hypoxic zone has averaged 15,620 km². The intensification and expansion of the northern Gulf hypoxic zone over recent decades have been related to increases in nitrate loading, and a growing scientific consensus [5, 2, 6] supports the conclusion that the worsening hypoxia in this region is linked to eutrophication.

Research efforts to develop a quantitative understanding of the causative factors and ecosystem impacts of the Gulf hypoxic zone have been strong, based largely on competitive research grants from NOAA’s Nutrient Enhanced Coastal Ocean Productivity in the Northern Gulf of Mexico Program (NECOP) from 1990-1996, and Northern Gulf of Mexico Ecosystems and Hypoxia Assessment Program (NGOMEX) from 2001 to the present. This science has provided the foundation for informing the major management driver

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for mitigating the hypoxic zone, the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force's *Action Plan for Reducing, Mitigating, and Controlling Hypoxia in the Northern Gulf of Mexico and Improving Water Quality in the Mississippi River Basin* [7, 8]. These founding and sustained multi-partnered activities on hypoxic zone research and management have been joined recently by several collaborative networks, and resulted in a Gulf-wide coordinated focus on mitigating this ecosystem threat. This paper gives a general account of past and more recent collaborative activities addressing the Gulf hypoxia issue, with the intention of relating a success story on how partnering has increased the potential resolution of a complex scientific and management issue.

II. SCIENCE INFORMING THE HYPOXIA TASK FORCE ACTION PLAN

The EPA-chaired interagency Mississippi River/Gulf of Mexico Watershed Nutrient Task Force, also known as the "Hypoxia Task Force", was established in the fall of 1997 as part of a process of considering options for responding to the northern Gulf of Mexico hypoxic zone. As authorized through the Harmful Algal Bloom and Hypoxia Research and Control Act (HABHRCA) of 1998, the Hypoxia Task Force submitted to Congress and the President in January 2001 the *Action Plan for Reducing, Mitigating, and Controlling Hypoxia in the Northern Gulf of Mexico*. The *Action Plan* called for a voluntary and incentive-based management plan that is founded on science and lays out a strategy to reduce the size of the hypoxic zone. The science foundation for the *Action Plan* came from results from the NECOP interdisciplinary projects which provided the informational base for the Committee on Environment and Natural Resources (CENR) integrated assessment in 2000 that was called for in the HABHRCA. This assessment and its six supporting technical reports provided the state-of-knowledge on the characteristics, causes, and effects of the northern Gulf of Mexico hypoxic zone, and guided the scientific consensus leading to the *2001 Action Plan*. The Coastal Goal of the *2001 Action Plan* called for the hypoxic zone to be reduced to 5-year running average size of 5,000 km² by 2015, and based on model predictions, suggested that a 30% reduction in nitrogen load was needed to reach the goal. As mandated by its adaptive management framework, the *2001 Action Plan* underwent an intensive Science Reassessment from 2004 to 2008.

Elements of the Science Reassessment process included three workshops that helped galvanize cooperative efforts in hypoxic zone research and management. EPA and NOAA co-sponsored the *Hypoxia in the Northern Gulf of Mexico: Assessing the State of the Science Symposium* (25-27 April 2006 in New Orleans), whose goal was to assess scientific understanding of the causes and processes regulating the development, persistence and areal extent of the Gulf hypoxic zone. Outputs from the *Symposium*, including state-of-knowledge proceedings papers in *Estuaries and Coasts* [1, 2, 9, 10], provided information to facilitate an evaluation of the Gulf hypoxia science by an EPA Science Advisory Board Hypoxia Advisory Panel [6].

The NOAA-sponsored *Summit on Long-Term Monitoring of the Gulf of Mexico: Developing the Implementation Plan for an Operational Observation System*, held on 30-31 January 2007 at Stennis Space Center, Mississippi, was aimed at developing a long-term comprehensive monitoring plan for the Gulf of Mexico hypoxic zone. The meeting convened multiple state, federal, and academic partners to develop the framework for an implementation plan for achieving a comprehensive, integrative, and sustainable monitoring program for the Gulf hypoxic zone including available mechanisms for long-term funding and starting with actions that can be taken in the short-term. The Gulf of Mexico Hypoxia Monitoring Implementation Plan (<http://www.ngi.msstate.edu/hypoxia/janconference.html>) includes Core System Requirements to expand the number of monitoring surveys west of the Mississippi delta, extend the monitoring survey to waters east of the delta (Mississippi Bight), apply autonomous underwater vehicles (AUVs) for hypoxia monitoring, and establish dedicated FTEs for data management and dedicated personnel for communications (including maintaining the Gulf Hypoxia Monitoring Stakeholder Committee and website formed from the *Summit*). System requirements also include expansion of observing systems in the hypoxic zone, in collaboration and integration with the Gulf-wide observation system coordinated by the Gulf of Mexico Coastal Ocean Observing System (GCOOS).

The NOAA-sponsored *Ecological Impacts of Hypoxia on Living Resources Workshop* in Bay St. Louis, Mississippi on 26-29 March 2007 was convened to bring together leading scientists and managers to evaluate the effectiveness of existing approaches for assessing the impacts of hypoxia on ecologically, commercially, and recreationally important fish and shellfish populations. Outputs from the *Workshop* included a White Paper, Technical Report, and special issue of the *Journal of Experimental Marine Biology and Ecology* (in press) [11].

These workshops and their outputs, combined with the independent science review by the EPA Science Advisory Board Hypoxia Advisory Panel [6], served to update and synthesize research efforts on the causes and consequences of the hypoxic zone and assess progress in implementing nutrient reduction measures in the Mississippi River watershed. This information provided the foundation for adoption of the *2008 Action Plan*, which retained the Coastal Goal of reducing the hypoxic zone areal extent to 5000 km² by 2015. However, the Science Reassessment concluded that nutrient loading reduction targets of 45% for both nitrogen and phosphorus would be required to meet this goal based on revised model predictions. These workshops have also formed the foundation for ongoing efforts to improve monitoring of the hypoxic zone and understand the impacts of hypoxia in the Gulf of Mexico.

III. GULF-WIDE COORDINATION TO MITIGATE HYPOXIA ZONE

Recently, efforts to advance the research and management capabilities needed for hypoxic zone mitigation have been strengthened through the cooperative activities of several partnering networks. For example, the Gulf of Mexico Alliance (GOMA), a partnership developed by the states of Alabama, Florida, Louisiana, Mississippi, and Texas (in collaboration with 13 federal agencies) has committed to addressing hypoxia through their Action Plans. The GOMA was formed in 2005 in response to the U.S. Ocean Action Plan's call for regional ocean governance, with the overarching goal to increase regional collaboration to enhance the ecological and economic health of the Gulf of Mexico. The Alliance identified five issues of regional priority, including the reduction of nutrient inputs to coastal ecosystems, which would benefit from increased collaboration and coordination of resources. In 2006, the Alliance released the *Governors' Action Plan for Healthy and Resilient Coasts* and identified an action under the nutrient reduction priority issue, to "assert an aligned five Gulf State position on the need to address Gulf of Mexico hypoxia". This Action resulted in a position paper (<http://www2.nos.noaa.gov/gomex/nutrients/welcome.html>) providing a consensus position statement on recognition of hypoxia as a Gulf ecosystem threat, and a commitment to consider the control and reduction of hypoxia in Gulf of Mexico coastal waters and estuaries, including the Northern Gulf Hypoxic Zone, as a priority need. GOMAs commitment to address the hypoxic zone was strengthened in the subsequent *Governor's Action Plan II* (http://gulfofmexicoalliance.org/pdfs/ap2_final2.pdf). The *Plan* includes goals to "coordinate strategies and provide guidance to better characterize hypoxia and the resulting socioeconomic impacts", and "develop management tools and implement nutrient reduction activities in cooperation with local communities to reduce excess nutrient inputs to estuaries and coastal waters". A partnership between GOMA and the Hypoxia Task Force is also an expected goal of *Action Plan II*. Several activities under these goals are included in the Hypoxia Task Force Annual Operating Plan as cooperative actions by the State of Mississippi, which facilitates GOMA Nutrient Reduction Priority Issue Team projects through the Mississippi Department of Environmental Quality.

The NOAA Regional Collaboration Teams were formed to enhance NOAA inter-office coordination in addressing unique regional problems that require NOAA's expertise. One of the strategic priorities identified to advance through regional collaboration is Integrated Ecosystem Assessments (IEA). The Gulf of Mexico Regional Collaboration Team recently developed plans for an IEA which includes an objective to provide integrated forecasting, assessment, and management tools to facilitate management of nutrient pollution and its consequences, with an emphasis on the hypoxic zone.

The Northern Gulf Institute (NGI) is a NOAA Cooperative Institute developed in 2005 as a partnership between NOAA, Mississippi State University (lead academic institute), the University of Southern Mississippi, Louisiana State University, Florida State University, and the Dauphin Island Sea Lab. NGI emphasizes integrative research, and includes hypoxia under its Coastal Hazards and Resiliency research theme. NGI research on hypoxia includes monitoring and assessment of hypoxia in the Mississippi Bight, which fulfills the need for an eastern extension in hypoxic zone monitoring proposed as a core system requirement in the Gulf Hypoxia Monitoring Implementation Plan.

In support of science needs identified in the *2008 Gulf Hypoxia Action Plan*, NOAA has renewed its commitment to Gulf hypoxic zone research and management through a reinvestment in the NGOMEX program. Five awards start in 2009 that aim to define more precisely when, where, and how hypoxia develops in response to nutrient loads and other factors, and improve understanding of impacts of the hypoxic zone to communities and living resources of the northern Gulf through development of population and growth models. These studies include an economic analysis of how the dead zone affects the shrimp fishery in the northern Gulf of Mexico, the development of models to forecast how the populations of

important fish species will respond to changes in nutrient pollution and the dead zone and an in depth analysis of the reproductive effects on Atlantic Croaker fish populations. It is noteworthy that each of these projects has a strong link to NOAA's National Marine Fisheries Service (NMFS), another partner targeting the Gulf hypoxic zone as a research and management priority. Results from NMFS' Southeast Area Monitoring and Assessment Program (SEAMAP) groundfish survey will be used both in retrospective analysis of hypoxic zone effects on fisheries, and to enhance hypoxic zone monitoring information. Data on hypoxic conditions sampled via SEAMAP provide near real-time information on hypoxia through NOAA's Hypoxia Watch web site.

Efforts to support science needs of the *2008 Gulf Hypoxia Action Plan* have also been undertaken by EPA. These efforts have focused on sediment biogeochemical processes, carbon deposition and metabolism to improve modeling of sediment-water column exchanges and its significance to hypoxia. These data have been used to develop a suite of models that also explore the relationships between nutrients and the size of the hypoxic zone. NOAA and EPA are actively partnering to share data and information. Further, many of the studies focusing on the development of predictive models to assess the response of hypoxia to varying nutrient loads rely on critical water quality and streamflow data provided by USGS. These data are also a strong driving component for forecasts provided by NOAA and its academic partners on the size of the annual size of the hypoxic zone.

IV SUMMARY

This paper details several collaborative efforts that are contributing to a recent surge in attention to expand research and management efforts aimed at reducing the size of the Gulf hypoxic zone. This paper focuses on partnering activities that are addressing characterization of the causes and impacts of the hypoxic zone so that progress towards achieving the Hypoxia Task Force's *Action Plan* Coastal Goal (which sets an average target size for the hypoxic zone) can be better assessed, and the efficacy of management strategies better evaluated. It should be noted that these partners are also greatly involved in facilitating management activities throughout the Mississippi River Basin. We are hopeful that this regional collaboration will increase the proficiency of ecosystem management, and ultimately improve Gulf of Mexico water quality.

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