GULF OF MEXICO HYPOXIA MONITORING IMPLEMENTATION PLAN
(2012 REVISION OF MATRIX FOR TIERS 1 AND 2)

An outcome from the *Summit on Long-Term Monitoring of the Gulf of Mexico: Developing the Implementation Plan for an Operational Observation System*

By

Gulf of Mexico Hypoxia Monitoring Implementation Plan Revision Steering Committee:

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Original Implementation Plan - January 2009; Tiers 1 and 2 Revised Matrix - August 2012

GULF OF MEXICO HYPOXIA MONITORING IMPLEMENTATION PLAN MATRIX

(REVISED AUGUST 2012)

Tier 1 (Core Requirements): These system requirements are needed to determine the annual maximum area of hypoxia in support of the *2008 Gulf Hypoxia Action Plan* Coastal Goal metric, and to disseminate this information to managers.

System Requirement	Lead (L) and Collaborators (C)	FY12 Plans	FY12 Funding	Critical Needs for FY13	Estimated FY13 Cost	Long-term Goal & Cost
1: Expand spatial boundaries of shelf-wide surveys	LUMCON (L); TAMU (L); USM (L)	Survey includes 80-90 sites extending from approx. 89.5˚ W to 94.5˚ W and offshore to 28.5˚ N, to the most inshore and offshore edge of hypoxia	See System Requirement 2	Same as FY12	See System Requirement 2	Same survey over 5 years
2: Increase number of monthly shelf-wide surveys	LUMCON (L); TAMU (L); USM (L)	3 surveys/year = Jun, Jul, Aug,	LUMCON: per survey = $200; TAMU per survey = $150; USM per survey = $35K; Total = $605K	Same as FY12	$605K	Same protocol over 5 years

3: Fill in temporal gaps of shelf-wide surveys with cross-shelf transects	LUMCON (L)	Monthly sampling at Transect C south of Terrebonne Bay, and Transect F off the Atchafalaya River in Feb, Mar, Apr, May, Sept, Oct (6 cruises/year)	$250K	Same as FY12	$250K	Same protocol over 5 years
4: Add deployments of Autonomous Underwater Vehicles (AUVs) with dissolved oxygen sensors	NGI (L) ; USM (L); LUMCON (L); TAMU (L); NRL (C)	Workshop to determine optimal glider design and glider monitoring strategy for temporal/spatial coverage that complements ship surveys and observing systems.	Planning workshop = $50K	Retrofit available gliders with dissolved oxygen sensors and new pistons to allow coverage of entire water column under high vertical density gradient test cruise; Pilot studies to test application of AUVs with dissolved oxygen sensors to study areas conducted by LUMCON, TAMU, and USM	Retrofit available gliders (6 X $25K = $150K); purchase 3 Webb Research Slocum Gliders with Aanderaa Oxygen Optode: $360K; trials east and west of Miss River plume, in conjunction with survey cruise CTD profiles; $30K X 3 zones = $90K Total = $600K	Monthly deployment of gliders east (1 grid) and west (2 grids) of the Mississippi delta from April through September to cover the hypoxic zone area. This would require 9 gliders (2 deployed per grid and 1 backup). The gliders could be piloted from a central site, but response teams from both locations would be needed for glider recovery; fleet deployment = $30K/month X 6 months = $180K/year

5: Maintain current observation systems and ensure all are outfitted with dissolved oxygen sensors	LUMCON (L); TAMU (L); USM (L) ; LSU (C)	Six observing platforms, four west of Mississippi River plume and two east of plume: Dissolved oxygen sensors currently on LUMCON *C6C* (3 depths), LUMCON *CSI-9* (2 depths), and TAMU *C* and *D* (2 depths) West of plume: 1) -90º29' W, 28º52' N (LUMCON *C6C* = WAVCIS/BIO2 *CSI-6*) 2) -89º58' W, 29º06' N (LUMCON and WAVCIS/BIO2 *CSI-9*) 3) -93º W, 29º20' N (TAMU *D*) 4) -92º W, 29º N (TAMU *C*) East of plume: 1) -88°39' W, 30° N (USM *USM3M01*) 2) -89° 02’ W, 29º24’ N (LSU *CSI-16*)	LUMCON mooring maintenance = $100K; TAMU maintenance = $150K; USM maintenance = $100K LSU maintenance = $100K	Maintenance of 6 current systems and outfit USM and LSU platforms with dissolved oxygen sensors at bottom depth.	Maintenance of 6 systems @ $125K/sys. = $750K; $100K to outfit 2 buoys with oxygen sensor Total cost = $850K	Maintenance of 6 systems over 5 years = $750K/yr

6: Create a portal to maximize accessibility to, and exchange of, hypoxia data	NCDDC (L); NODC (C); GCOOS/IOOS (C); LUMCON (C); TAMU (C)	1) three operational websites: a) Hypoxia Watch Website, http://ecowatch.ncddc.noaa.gov/hypoxia, b) LUMCON's Hypoxia Website, http://www.gulfhypoxia.net, c) Gulf Hypoxia Monitoring Stakeholder Committee Website, http://www.ncddc.noaa.gov/activities/gulf-hypoxia-stakeholders; 2) Data ingest to Hypoxia and REDM portals underway; 3) NCDDC and IOOS Program actions underway to assure data management best practices and adherence to accepted community standards (e.g. IOOS DMAC, FGDC, etc.)	none	1) Continue operations and maintenance of websites, and expand capabilities and ingest toward hosting national hypoxia observations; 2) Continue technology development and transfer (e.g. ontology and data bus development, archive to CLASS of appropriate NNDC) to improve discovery, access, transport, and archive of hypoxia and ancillary data; 3) Continue partnerships in QARTOD, MMI, IOOS Program, and International groups`; 4) LUMCON, TAMU, and GCOOS data assembly, QA/QC, metadata (ISO), and ensuring timely delivery of the data to the NODC/NCDDC.	NCDDC archiving at no cost; 1 LUMCON, 1 TAMU, and 1 GCOOS FTE @ $100K = $300K	O&M for a National Monitoring Network with continued data management and technology transfer development; Creation of a National Hypoxia Database. NCDDC FY12 Gulf Data Atlas will provide the NMFS SEAMAP Hypoxia Watch historical dBase; also developing a frequency of occurrence over the historical record, animated plates for the dBase. Maintenance of FTE positions over 5 years.

7. Dissemination of relevant data and findings to management community	NCDDC (L); LUMCON (C); GCOOS/IOOS (C); GOMA (C); EPA (C)	1) Gulf Hypoxia Stakeholder Committee Website (GHSC), http://www.ncddc.noaa.gov/activities/gulf-hypoxia-stakeholders, is operational, membership determined, and Terms of Reference developed; 2) Communications links established between GHSC and Gulf Hypoxia Task Force Communication Subcommittee, Gulf of Mexico Alliance Environmental Education Network, and GCOOS Education and Outreach Council.	none	Review data needs of the management community and the mechanisms to disseminate data; Adjust the methods for data dissemination as identified in the review; Establish protocol for disseminating data.	1 FTE to coordinate education/outreach activities and maintain website = $150K.	Follow protocol for disseminating data to management community. Maintain FTE over 5 years.

Tier 2 System Requirements: These are needed to expand on spatial and temporal coverage to allow a more comprehensive characterization of hypoxic zone dynamics.

System Requirement	Lead (L) and Collaborators (C)	FY12 Plans	FY12 Funding	Critical Needs for FY13	Estimated FY13 Cost	Long-term Goal & Cost
1: Increase number of monthly shelf-wide surveys	LUMCON (L); TAMU (L); USM (L)	3 surveys/year = Jun, Jul, Aug,	See Tier 1 System Requirement 2	Add surveys in April, May, and September	LUMCON: per survey = $200; TAMU per survey = $150; USM per survey = $35K; Total = $605K	Same protocol over 5 years
2: Include hypoxic volume measurements on shelf-wide surveys	LUMCON (L); TAMU (L); USM (L)	Calculate hypoxic volume from depth profiles of dissolved oxygen on shelf-wide surveys	Included in Tier 1 System Requirement 2	Same as FY12	Included in Tier 1 System Requirement 2	Same measurements over 5 years
3: Increase number of observation systems	LUMCON (L); TAMU (L);	Six observing platforms, four west of Mississippi River plume and two east of plume:	See Tier 1 System Requirement 5	Addition of 2 observation platforms west of the delta with full suite of sensors (e.g. the WAVCIS/BIO2 model): 1) -89º35' W, 28º57' N (close to the Mississippi River outflow); 2) -93º36' W, 29º27' N (west of Atchafalaya River outflow)	2 new systems @ $300K/sys. = $600K;	Maintenance of 2 new systems: $250K/yr over 5 years

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By

Gulf of Mexico Hypoxia Monitoring Implementation Plan Steering Committee

January 2009

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INTRODUCTION

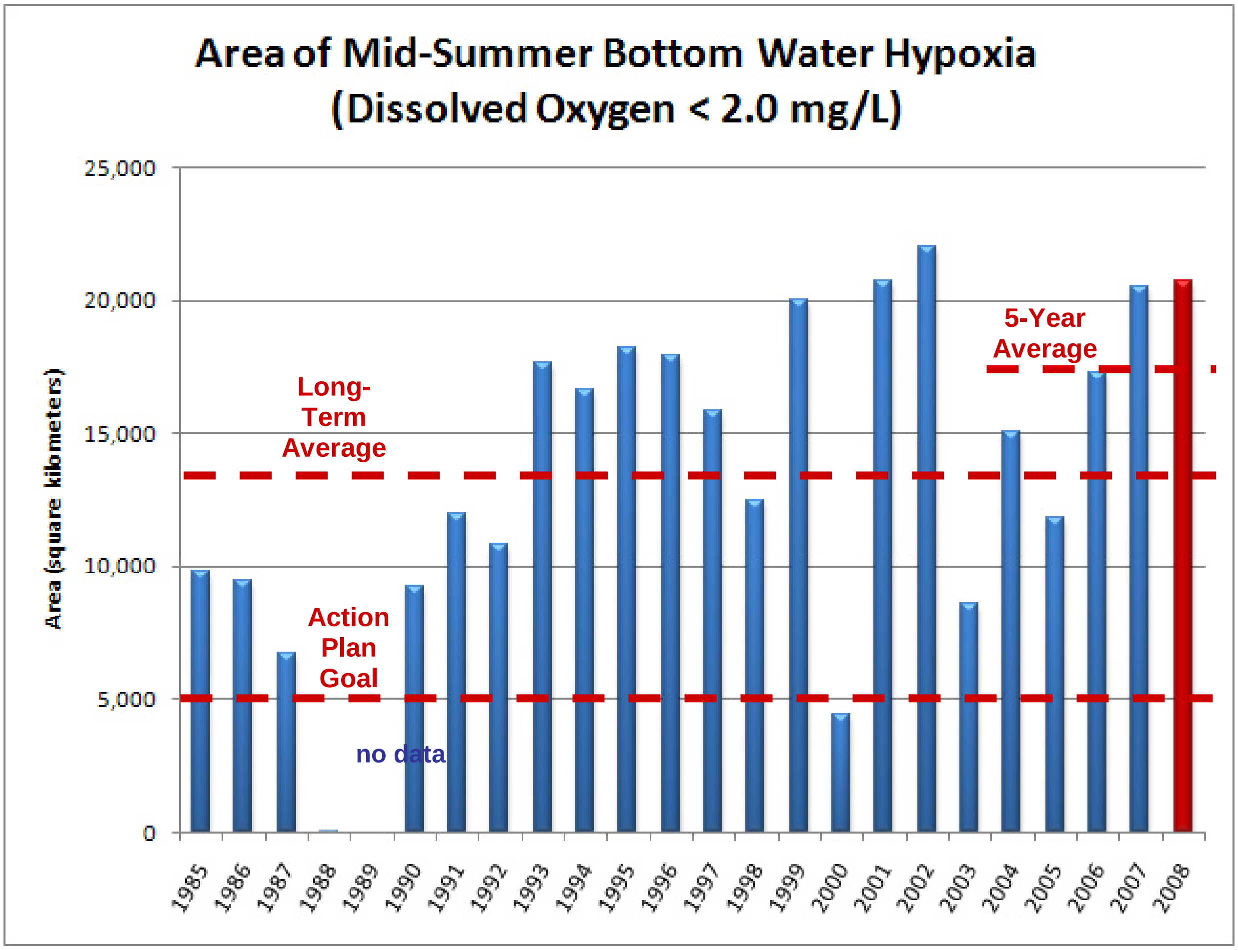
Northern Gulf of Mexico Hypoxic Zone

Hypoxia is one of the many symptoms of coastal eutrophication. Sustained or recurring low oxygen conditions can lead to faunal mortalities, food web alterations, loss of habitat, and impacts to fisheries. Hypoxic and anoxic waters have existed through geologic time, but the frequency of their occurrence in shallow coastal and estuarine areas worldwide is increasing (Howarth et al. 2000, Diaz 2001, Diaz and Rosenberg 2008). The importance and national scale of hypoxia and nutrient pollution in United States waters is evidenced by the passage of the Harmful Algal Bloom and Hypoxia Research and Control Act (HABHRCA**;** http://www.cop.noaa.gov/stressors/extremeevents/hab/habhrca/welcome.html) in 1998 and its reauthorization in 2004. The HABHRCA legislation and several national reports, including the United States Commission on Ocean Policy Report (http://www.oceancommission.gov/), describe the need and identify priorities for research related to hypoxia and the related issue of nutrient pollution.

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 Justić et al. 2007, Rabalais et al. 2007a). The areal extent of the hypoxic zone, monitored in mid-summer since 1985, has increased from an average of 6,900 km^2 from 1985-1992 to 13,600 km^2 from 1993-2008, with a peak of 22,000 km^2 in 2002 (Rabalais et al., 1999; Rabalais et al. 2007b); Fig. 1. Over the past 5 years, this hypoxic zone has averaged 17,010 km^2 and the 2008 documented area was 20,721 km^2, the second largest measured. 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 (CENR 2000, Rabalais et al. 2007a, EPA SAB 2008) supports the conclusion that the worsening hypoxia in this region is linked to eutrophication.

Gulf of Mexico Hypoxia Task Force *Action Plan*

The interagency Mississippi River/Gulf of Mexico Hypoxia Task Force (http://www.epa.gov/msbasin/taskforce.htm) was established in the fall of 1997 as part of a process of considering options for responding to the northern Gulf of Mexico Dead Zone. In 2001, the Task Force issued an *Action Plan* (http://www.epa.gov/msbasin/actionplan.htm) that set a goal to reduce the size of the hypoxic zone to 5,000 km^2 by 2015 (Fig. 1). The *Action Plan*, which included 11 specific implementation actions, suggested that a 30% reduction in nitrogen load was needed to reach the goal. Over the last 4 years, a Science Reassessment (http://www.epa.gov/msbasin/actionplan.htm) was conducted to update the *Action Plan* in an adaptive management framework. Elements of the Science Reassessment process included several state-of-knowledge symposia, including the *Hypoxia in the Northern Gulf of Mexico: Assessing the State of the Science Symposium* (http://www.cop.noaa.gov/stressors/pollution/features/fs-2006-05-05-hyp.html) in April 2006 that resulted in proceedings papers in *Estuaries and Coasts* (Dagg et al. 2007, Justić et al. 2007, Rabalais et al. 2007a, Turner et al. 2007). Also, workshops were convened to advance understanding and develop recommendations for management needs on this issue, the *Summit on Long-Term Monitoring of the Gulf of Mexico: Developing the Implementation Plan for an Operational Observation System* (http://www.ngi.msstate.edu/hypoxia/janconference.html) and *Ecological Impacts of Hypoxia on Living Resources Workshop* (http://www.ngi.msstate.edu/hypoxia/index.html). These symposia and workshops provided information to facilitate an evaluation of the science by an EPA Science Advisory Board Hypoxia Advisory Panel (EPA SAB 2008).



Source: N. Rabalais, LUMCON

Figure 1. Mid-summer annual areal extent of hypoxic zone – metric for the *Action Plan* Coastal Goal assessment.

The results from the Science Reassessment of the *2001 Action Plan*, combined with the independent science review by the EPA SAB Hypoxia Advisory Panel, has 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 has been incorporated into a revised *2008 Gulf Hypoxia Action Plan* (http://www.epa.gov/msbasin/actionplan.htm) which retains the Coastal Goal of reducing the hypoxic zone areal extent to 5000 km^2 by 2015, but calls for nutrient loading reduction targets of 45% for both nitrogen and phosphorus, based on revised model predictions. In addition, the Task Force developed the *FY2008 Operating Plan: A Compilation of Actions to Implement the 2008 Gulf Hypoxia Action Plan* (http://www.epa.gov/msbasin/implementation.htm), which details cooperative activities between federal and state partners.

Need for Improved Monitoring Program

The mid-summer survey that measures the annual areal extent (Rabalais et al. 2002, 2007a) is the key metric of the *Action Plan* Coastal Goal. Use of the metric, annual extent based on a mid-summer survey, has advantages in terms of longevity, practicality, and public understanding. By consensus from the *Hypoxia in the Northern Gulf of Mexico Science Symposium*, this metric was considered a valuable indicator of 'hypoxic condition' in support of the *Action Plan*; however, greater spatial and temporal coverage during the summer was recommended to compensate for variability and pre-cruise storm events (Rabalais et al. 2007a). It was also concluded that ongoing monitoring efforts that characterize the physical, chemical, and biological variables associated with hypoxic zone dynamics are insufficient to adequately define its magnitude and characterize the processes that lead to its development, maintenance, and distribution. This consensus mirrors emphases from the:

- 2001 *Action Plan*: Action 4, "…greatly expand the long-term monitoring program for the hypoxic zone, including greater temporal and spatial data collection, measurements of macro-nutrient and micronutrient concentrations and hypoxia…"

- United States Geological Survey (USGS) 2004 report, A Science Strategy to Support Management Decisions Related to Hypoxia in the Northern Gulf of Mexico and Excess Nutrients in the Mississippi River Basin, prepared by the Monitoring, Modeling, and Research Workgroup of the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force (aka the "MMR Report"): "…(monitoring) efforts need to be increased in frequency, at a minimum monthly from May through September. To develop a more complete understanding of ecosystem dynamics, selected sites should be monitored year-round. The spatial boundaries of some of these existing monitoring efforts should be expanded to collect data for defining boundary conditions in modeling efforts."

- EPA SAB 2007 report: "…affirms and reiterates the CENR's call to improve and expand monitoring of the temporal and spatial extent of hypoxia and the processes controlling its formation…"

- *2008 Gulf Hypoxia Action Plan*: Action 9, "…improved characterization of nutrient flux and hypoxic zone properties is needed to further refine management strategies…Improvements in hypoxic zone monitoring are needed to better characterize its magnitude and the processes that lead to its development, maintenance, and distribution as well as its impacts. Greater temporal and spatial coverage in monitoring efforts are needed to account for variability and pre-cruise storm events, define boundaries, characterize seasonality, and support modeling efforts."

The mid-summer surveys are part of a research project that the NOAA National Centers for Coastal Ocean Sciences (NCCOS) has supported through extramural research programs (first through the Nutrient Enhanced Coastal Ocean Productivity Program, NECOP, http://www.cop.noaa.gov/pubs/das/das14.pdf, then through the Northern Gulf of Mexico Ecosystems and Hypoxia Assessment Program, NGOMEX, http://www.cop.noaa.gov/stressors/pollution/current/gomex-factsheet.html) since 1991. The programs' objectives were to use this monitoring to provide data for a series of ecosystem studies to gain understanding of, and predictive capabilities for, both the causes and consequences of hypoxia in the Gulf. These studies were not intended to be sustainable long-term monitoring programs. A more robust, integrated, and multi-partner monitoring effort is critically needed to assess management efficacy in meeting the 2008 *Gulf Hypoxia Action Plan* Coastal Goal to reduce the hypoxic zone, and to support on-going modeling and ecological forecasting efforts. This integrated monitoring strategy should be linked to regional and national monitoring networks.

Summit on Long-Term Monitoring of the Gulf of Mexico Monitoring Zone

To meet this need for improved monitoring, the *Summit on Long-Term Monitoring of the Gulf of Mexico Hypoxic Zone: Developing the Implementation Plan for an Operational Observation System* convened key officials with responsibilities and resources for monitoring environmental conditions in the Gulf of Mexico (especially those with regional and national observing system responsibilities), researchers with intimate knowledge of spatial and temporal dynamics of the hypoxic region in the northern Gulf of Mexico (physical, chemical, biological), and users of monitoring data that have decision-making authority for coastal management; http://www.ngi.msstate.edu/hypoxia/janconference.html. This group worked to develop a long-term comprehensive monitoring plan for the hypoxic zone that can be implemented in the near-term, including specific commitments and plans for long-term fiscal support.

The objectives of the *Summit* were to:

1. assess existing monitoring and observing program capabilities in and surrounding the Gulf of Mexico's hypoxic zone;
2. identify long-term monitoring and observing needs for optimizing management capabilities (e.g. tracking the size of the hypoxic zone in support of the 2001 *Action Plan*; supporting fishery assessments) and supporting ongoing and planned ecosystem modeling efforts;
3. identify programmatic opportunities to achieve needed level of monitoring through integration with new or existing Gulf hypoxic zone monitoring/observing efforts (e.g. Gulf of Mexico Coastal Ocean Observing System network, GCOOS) and national monitoring networks (e.g. Integrated Ocean Observing System, IOOS, and National Water Quality Monitoring Network, NWQMN);
4. develop an implementation plan for achieving a comprehensive, integrative, 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 current fiscal year.

IMPLEMENTATION PLAN

Steering, Technical, and Stakeholder Committees

The *Summit*'s targeted outcome is an implementation plan that details the scientific, technical, operational, and financial plans for a 5-year cooperative monitoring program for the northern Gulf of Mexico hypoxic zone. The organizational structure for Implementation Plan development included a Steering Committee to write the Plan, a Stakeholder Committee to provide the portal to the stakeholders and assist with the education and outreach portion of the plan, and a Technical Committee to provide advice on system requirements.

Table 1. Gulf of Mexico Hypoxia Monitoring Implementation Plan Steering Committee.

Steering Committee	
Name	Affiliation
Alan Lewitus, co-Chair	NOAA
	Center for Sponsored Coastal Ocean Research
Nancy Rabalais, co-Chair	Louisiana Universities Marine Consortium
Phil Bass	USEPA
	Gulf of Mexico Program
Russ Beard	NOAA
	National Environmental Satellite, Data and Information
Rick Greene	USEPA
	Gulf Ecology Division
Ann Jochens	Texas A&M University
	Department of Oceanography
Steve Lohrenz	University of Southern Mississippi
	Department of Marine Science
David Shaw	Mississippi State University
	GeoResources Institute/Northern Gulf Cooperative Institute
Janice Ward	USGS
	Office of Water Quality
David Whitall	NOAA
	Center for Coastal Monitoring and Assessment

Table 2. Gulf of Mexico Hypoxia Monitoring Implementation Plan Technical Committee.

Technical Committee	
Name	Affiliation
James Ammerman	Rutgers University
	Oceans U.S., Ocean Observatories Initiative (NSF)
	Currently New York Sea Grant
Robert Arnone	US Navy
	Naval Research Laboratory
Brenda Babin	Louisiana Universities Marine Consortium
Charles Crawford	USGS
	National Water-Quality Assessment Program
Richard Crout	NOAA
	National Data Buoy Center
Steve DiMarco	Texas A&M University
	Department of Oceanography
Sharon Mesick	NOAA
	National Environmental Satellite, Data and Information
James Hagy	US EPA
	Gulf Ecology Division
Richard Patchen	NOAA
	Coast Survey Development Laboratory
Nancy Rabalais	Louisiana Universities Marine Consortium

Table 3. Gulf of Mexico Hypoxia Monitoring Implementation Plan Stakeholder Committee.

Stakeholder Committee	
Name	Affiliation
Joe Stinus, Chair	NOAA
	National Environmental Satellite, Data and Information
Ed Buskey	University of Texas
	Marine Science Institute
Gregory DuCote	Louisiana Department of Natural Resources
	Coastal Management Division
Mark Fisher	Texas Commission on Environmental Quality
Henry Folmar	Mississippi Department of Environmental Quality
	Office of Pollution Control
Charles Kovach	Florida Department of Environmental Protection
Scott Phipps	Alabama Department of Conservation and Natural Resources
Kris Pintado	Louisiana Department of Environmental Quality
Dugan Sabins	Louisiana Department of Environmental Quality

The Gulf Hypoxia Monitoring Stakeholder Committee (GHMSC), http://www.ncddc.noaa.gov/activities/gulf-hypoxia-stakeholders/view, was established to ascertain the needs of the stakeholder communities for a comprehensive, integrative, sustainable monitoring program for the northern Gulf of Mexico hypoxic zone. The GHMSC provides guidance to the Steering Committee for the Gulf Hypoxia Monitoring Implementation Plan on: 1) the specific management questions and key management decisions of stakeholders relative to hypoxia; 2) the needs of the stakeholder communities for monitoring, measurements, and products related to hypoxia; and 3) the priorities for education and outreach activities that are necessary to make the U.S. public aware of what hypoxia is and how it can impact them. The Stakeholder Committee will consist of a broad range of constituents and expertise, including representatives from resource management agencies, ocean observing systems, commercial and recreational fishing, tourism, education and outreach, modeling, and data management. Representatives from the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force, Gulf of Mexico Alliance (GOMA), and Gulf of Mexico Coastal Ocean Observing System Regional Association (GCOOS-RA) will provide the initial portal to stakeholder groups that are identified for involvement.

Management Drivers

Management drivers for an improved monitoring program include the need to:

1. provide sufficient monitoring data to ensure that management is adequately informed in efforts to achieve the Coastal Goal of the *Action Plan*. The Coastal Goal calls for the hypoxic zone to be reduced to an annual average size of 5,000 km^2 by 2015;

2. assess annual changes in the magnitude, seasonality, duration, and distribution of hypoxia, and relate these to management activities that affect nutrient loading and other influences on hypoxia;

3. provide adequate data for predictive models to develop accurate forecasts of hypoxia given alternative management targets for nutrient reduction and alternative scenarios of climate change;

4. determine the relationship between hypoxic zone magnitude, timing, and distribution, and the distribution, production, and health of ecologically and commercially important finfish and shellfish [*Gulf Hypoxia Action Plan* Action 5].

Science Needs

The original *Action Plan* and the MMR Report both called for greater temporal and spatial coverage in monitoring efforts to account for variability and pre-cruise storm events, define boundaries, characterize seasonality, and support modeling efforts. Science needs that can be met by an operational observation system include the following:

1. extend spatial boundaries that were identified in 2001. The western and eastern boundaries of hypoxia vary annually, and are not always well-defined under current

sampling designs. The nearshore (as shallow as ~4-5 m) and offshore (up to ~35-45 m) boundaries also require better definition;

2. resolve and distinguish between hypoxia development from the Mississippi River Plume versus the Atchafalaya, and link these to nutrient loadings to both areas of the shelf;

3. better temporally resolve the association between nutrient loading and other causative factors on the development, maintenance, and movement of the hypoxic zone. The hypoxic zone is a dynamic feature that is highly variable and marked by a high degree of horizontal and vertical structure. Improved resolution of seasonal and storm-related variability in hypoxia development, duration, and extent is needed;

4. information on nutrient transformation processes that lead to hypoxia formation and maintenance, particularly with respect to benthic dynamics;

5. estimates of hypoxic volume as a complementary (to areal extent) indicator of the magnitude of hypoxia. Area versus volume can vary with causative factors, and volume calculations will provide additional information on hypoxia extent and response;

6. improve understanding of the effects of hypoxia on commercially important species (fish, shrimp, etc.). Monitoring data are needed to support spatially-explicit food-web models used to evaluate the various direct and indirect effects of hypoxia;

7. monitoring data to support and improve current models that predict quantitative relationships between nutrient loading and hypoxia. Monitoring data are needed to ensure accurate predictions, validate those predictions, and evaluate the effectiveness of management actions.

System Requirements

System requirements refer to implementations needed to improve monitoring to meet the science needs. The Implementation Plan includes the following system requirements:

1. Expand spatial boundaries and increase frequency of surveys;

2. Increase coverage by instrumented observing systems;

3. Integration with data from AUVs and satellite remote sensing;

4. Improve models on hypoxia causes and effects;

5. Improve accuracy of nutrient loading estimates;

6. Create a portal to maximize accessibility to, and exchange of, hypoxia data;

7. Outreach program to promote effective communications to increase awareness of hypoxia.

The Steering and Technical Committees established a prioritization of system requirements. The criteria were:

- Tier 1 (Core Requirements): needed to determine the maximum extent of hypoxic zone in support of the *Action Plan* Coastal Goal metric, and to disseminate information to researchers and managers (Management Driver 1);
- Tier 2: needed to improve understanding of hypoxic zone temporal and spatial dynamics (Management Driver 2);
- Tier 3: needed to improve understanding of causes and impacts of hypoxia (Management Drivers 3 and 4).

Tier 1 System Requirements (Core Requirements)

These requirements are needed to characterize the annual maximum area and volume of hypoxia as metrics to determine whether mitigation measures on nutrient reductions are having an effect on the hypoxic zone size. The two cross-shelf transects (off Atchafalaya and Terrebonne/Timbalier) are maintained for the continuity and for the relationships with river constituent data. The core requirements include dissemination of hypoxic zone magnitude to managers using web site information, archival of the data in NODC, and rapid dissemination of data with verifiable quality review.

System Requirement 1: Expand spatial boundaries of shelf-wide surveys.

Currently: One mid-summer survey is conducted per year, which includes 80-90 sites extending from approximately 89.5˚W to 94.5˚W and offshore to 28.5˚N, to the most inshore and offshore edge of hypoxia (Fig. 2, 3).

FY10 Needs: The western extent was expanded for the 2008 survey (Figs. 2 and 3) by including Transects Q, S, and T, and now is adequately covered by the shelf-wide survey, but hypoxia also occurs east of the Mississippi plume that can have mixed influences, including discharges from the Mississippi, Pearl, and Mobile Rivers (Brunner et al. 2006). The Implementation Plan calls for an additional 20 stations east of the Mississippi River plume in a transect from the Mississippi River Delta northeastward to the Mississippi-Alabama barrier islands (Fig. 4, Table 4). This will require an additional ship besides the RV Pelican, and the R/V Tommy Monroe is a likely candidate.

Long-term Goal: same survey over 5 years.

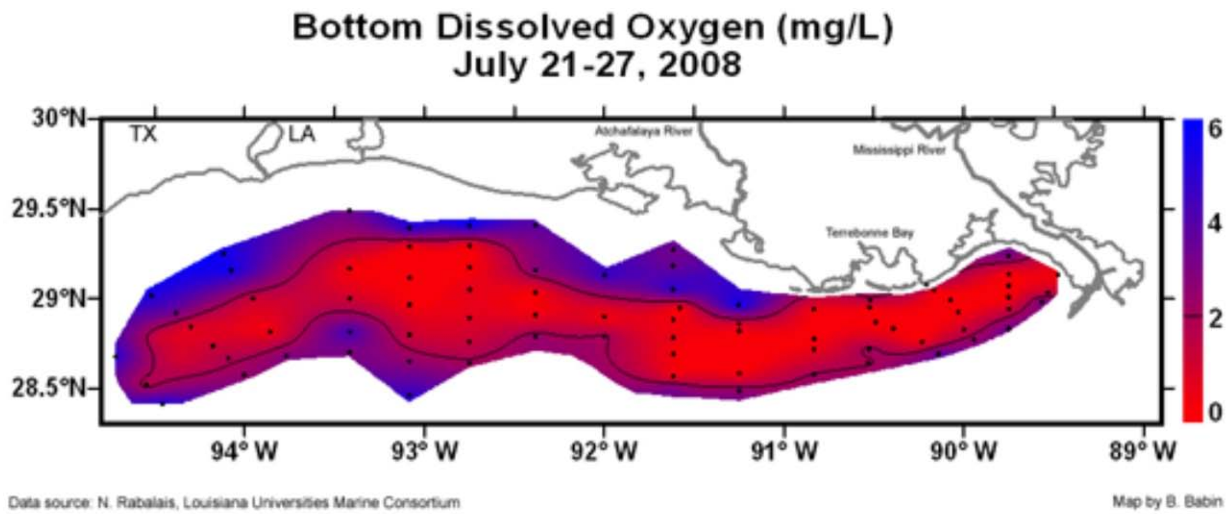


Figure 2. Map of bottom water oxygen levels in mg L^{-1} (or ppm). Black line is less than 2 mg L^{-1}. Data source: N. Rabalais, Louisiana Universities Marine Consortium.

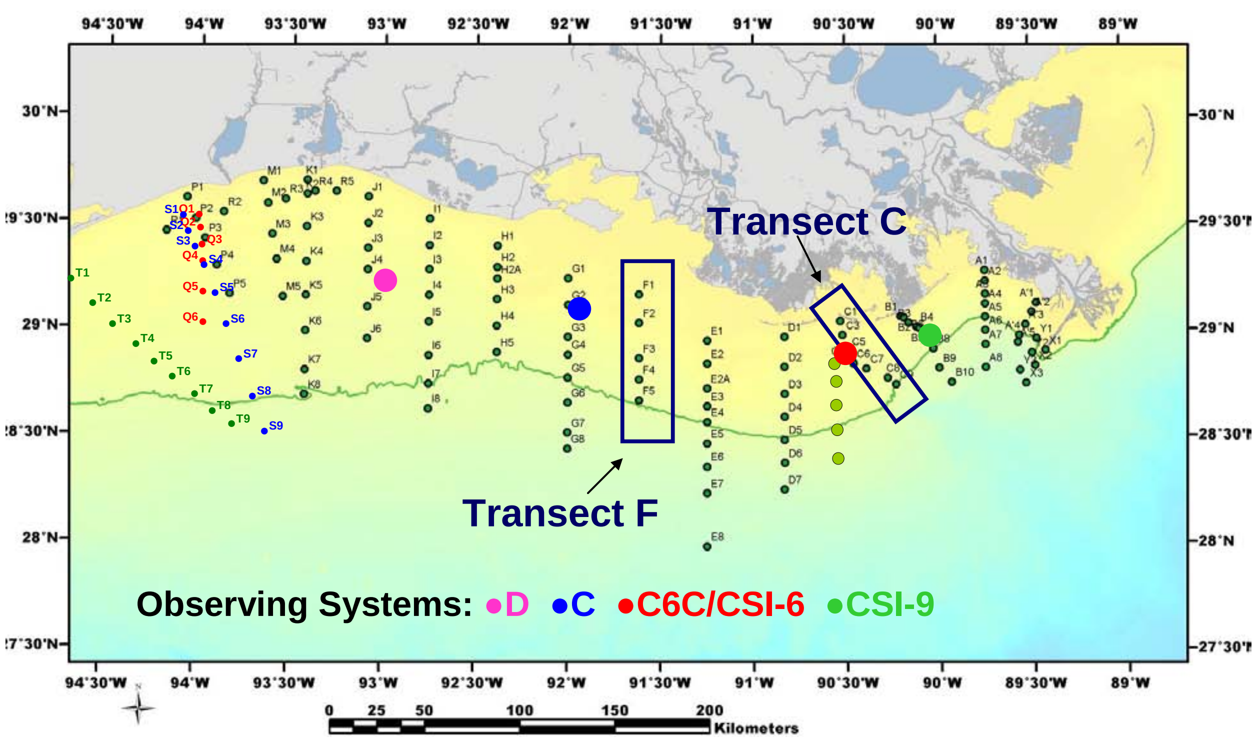


Figure 3. Site locations in current monitoring sampling design for the Gulf hypoxic zone. Small circles are sites sampled during mid-summer survey to determine annual hypoxic zone

areal extent, used as the *Action Plan* Coastal Goal metric. Transects C and F are the cross-shelf transects sampled monthly to bimonthly. Observing systems "D" and "C" are maintained by Texas A&M, and "C6C/CSI-6" and "CSI-9" by LUMCON.

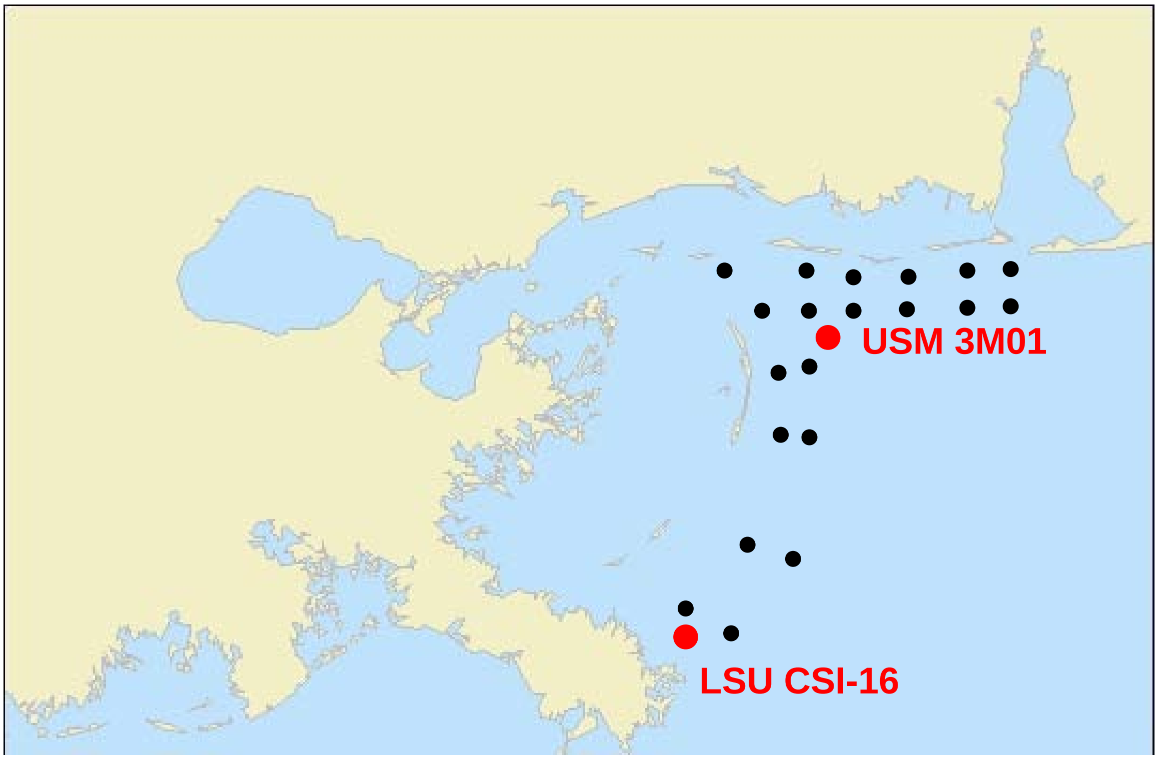


Figure 4. Proposed sampling sites for monitoring transect east of Mississippi River. The University of Southern Mississippi's observing system, "USM 3M01", and LSU WAVCIS observing system, "CSI-16", are shown in red.

Table 4. Locations of sites east of Mississippi River plume.

Latitude	Longitude		Latitude	Longitude
89˚00´ W	29˚20´ N		88˚32´ W	30˚06´ N
89˚05´ W	29˚23´ N		88˚22´ W	30˚06´ N
88˚55´ W	29˚30´ N		88˚14´ W	30˚06´ N
88˚45´ W	29˚27´ N		88˚07´ W	30˚06´ N
88˚40´ W	29˚40´ N		88˚55´ W	30˚12´ N
88˚46´ W	29˚42´ N		88˚41´ W	30˚12´ N
88˚47´ W	29˚55´ N		88˚32´ W	30˚10´ N
88˚41´ W	29˚56´ N		88˚22´ W	30˚10´ N
88˚48´ W	30˚06´ N		88˚14´ W	30˚12´ N
88˚41´ W	30˚06´ N		88˚07´ W	30˚12´ N

System Requirement 2: Include hypoxic volume measurements on shelf-wide surveys.

Currently: Areal extent is calculated from a mid-summer survey conducted once per year. This is the metric used to guide progress of management activities as directed by the *Action Plan*.

FY10 needs: Calculate hypoxic volume from depth profiles of dissolved oxygen on shelf-wide surveys. Estimates of hypoxic volume are a complementary (to areal extent) indicator of the magnitude of hypoxia. Area versus volume can vary with causative factors, and volume calculations will provide additional information on hypoxia extent and response.

Long-term goal: same measurements over 5 years.

System Requirement 3: Increase number of shelf-wide surveys

Currently: One mid-summer survey is conducted per year, which includes 80-90 sites extending from approximately 89.5˚W to 94.5˚W and offshore to 28.5˚N, to the most inshore and offshore edge of hypoxia (Fig. 2, 3).

FY10 Needs: Increase to 6 monthly shelf-wide surveys per year encompassing spring and summer periods (April through September). The increase in temporal coverage of the areal extent and volume of hypoxia would ensure that the annual characterization is more representative of a given year's hypoxic zone magnitude because it could more adequately account for variability caused by events such as pre-cruise storms.

Long-term Goal: same protocol over 5 years.

System Requirement 4: Fill in temporal gaps of shelf-wide surveys with cross-shelf transects.

Currently: Monthly sampling at Transect C south of Terrebonne Bay, and bimonthly sampling at Transect F off the Atchafalaya River (11 cruises/year); Fig. 3.

FY10 Needs: From October through March, monthly sampling at Transect C, and bimonthly sampling at Transect F (6 cruises/year). The two transects (off Atchafalaya and Terrebonne/Timbalier) are maintained for the continuity and for the relationships with river constituent data.

Long-term Goal: same protocol over 5 years.

System Requirement 5: Add deployments of Autonomous Underwater Vehicles (AUVs) with dissolved oxygen sensors.

Currently: None.

FY10 Needs: Pilot study to test application of AUVs with dissolved oxygen sensors to study areas. A Webb Research Slocum Glider will be purchased and outfitted with an Aanderaa Oxygen Optode 4330 (http://www.aadi.no/Aanderaa/Document%20Library/1/Data%20Sheets/Oxygen%20Optode.pdf), and deployed to cover the fixed monitoring sites east of Mississippi River plume (Fig. 4) and at selected sites west of the plume (Fig. 3), in conjunction with survey cruise CTD profiles.

Long-term Goal: Monthly deployment of gliders east and west of the Mississippi delta from April through September to cover the hypoxic zone area. This would require 4 gliders (a backup for each transect). The gliders could be piloted from a central site, but response teams from both locations would be needed for glider recovery.

System Requirement 6: Create a portal to make data accessible and to facilitate exchange.

Currently: The Hypoxia Watch website (http://ecowatch.ncddc.noaa.gov/hypoxia), Lumcon's Hypoxia website (www.gulfhypoxia.net), and the Gulf Hypoxia Monitoring Stakeholder Committee website (http://www.ncddc.noaa.gov/activities/gulf-hypoxia-stakeholders) are operational, including interactive mapping capabilities. Data ingest to Hypoxia and Regional Ecosystem Data Management (REDM) portals are underway. NCDDC and IOOS Program actions are underway to assure data management best practices and adherence to accepted community standards, including IOOS DMAC, FGDC, etc.

FY10 Needs: Create capability to ingest and host hypoxia observations. Continue technology development and transfer (e.g. ontology and data bus development, archive to CLASS of appropriate NNDC) to improve discovery, access, transport, and archive of hypoxia data and ancillary data. Continue partnerships in QARTOD, MMI, IOOS Program, and International groups.

Long-term Goals: Operations and maintenance for a National Monitoring Network with Data Management and technology transfer development. The creation of a National Hypoxia Database.

System Requirement 7: Dissemination of data and findings to research and management communities.

Currently: The Gulf Hypoxia Monitoring Stakeholder Committee (GHMSC) website is operational, membership determined, and Terms of Reference developed. Communication links are established with the Gulf Hypoxia Task Force Communication Subcommittee, Gulf of Mexico Alliance Environmental Education Network, and the GCOOS Education and Outreach Council.

FY10 Needs: Review data needs of the research and management communities and the mechanisms to disseminate data. Adjust the methods for data dissemination as identified in the review. Establish protocol for disseminating data.

Long-term Goals: Follow protocol for disseminating data to management community.

Tier 2 System Requirements

These system requirements are needed to improve understanding of hypoxic zone temporal and spatial dynamics (initiation, duration, seasonality, spatial variability). These implementations are focused on increasing coverage of hypoxia by expanding the current observation system network.

System Requirement 1: Maintain current continuous observation systems and increase number of observation systems.

Currently: Six observation systems, four west of the Mississippi River plume (Fig. 3) and two east of the plume (Fig. 4).

Four observing systems in hypoxic area west of Mississippi River:

1) LUMCON *C6C* or WAVCIS/BIO2 *CSI-6*: -90º29' W, 28º52' N;

2) LUMCON and WAVCIS/BIO2 *CSI-9*: -89 º58'W, 29º06'W;

3) TAMU *D*: -93º W, 29º20' N;

4) TAMU *C*: -92º W, 29º N.

Two observing systems east of Mississippi River:

5) -88° 39' W, 30° N (USM *USM3M01*)

6) -89° 02' W, 29º24' N (LSU *CSI-16*)

FY10 Needs: Maintenance of 6 current systems and addition of 2 observation platforms with full suite of sensors (e.g. the WAVCIS/BIO2 model). One system would be closer to the Mississippi River outflow at -89º35' W, 28º57' N (Fig. 5, System #4) and the other west of the Acthafalaya River outflow at -93º36' W, 29º27' N (Fig. 5, System #1).

Sensors included in WAVCIS/BIO2 observation system model

- Meteorological sensors = windbird, barometer, and electronic thermometer, measure:

    - wind speed and direction
    - barometric pressure
    - air temperature
- Hydrodynamic sensors = Digiquartz pressure transducer, March-McBirney current meter, Acoustic Doppler Velocimeter, electronic thermometer, measure:
    - directional waves
    - near-surface current speed
    - water level
    - near-surface water temperature
- Biological = YSI 6600 EDS sondes, measures:
    - dissolved oxygen
    - chlorophyll fluorescence
    - turbidity
    - conductivity
    - temperature
- Light = Biospherical Instrument, measures:
    - upwelling radiance
    - downwelling irradiance
    - photosynthetically available radiation (PAR)

<u>Long-term Goal</u>: Two observation platforms added in FY11, one west of the Mississippi River at -91º W, 28º48' N (Fig. 5, System #3), and one east of the Mississippi River at -88º46' W, 29º37' N (Fig. 5, System #6), and one more added in FY12, west of the Mississippi River at -91º37' W, 28º53' N (Fig. 5, System #2), for a total of 11 systems (8 west and 3 east of the Mississippi River).

System Requirement 2: Outfit existing observing platforms with dissolved oxygen sensors at selected depths.

<u>Currently</u>: *C6C* has oxygen sensors at 3 depths, *CSI-9* at 2 depths, *C* and *D* at 2 depths, *USM3M01* at 1 depth (near-surface).

<u>FY10 Needs</u>: Outfit *USM3M01* and *CSI-16* systems with oxygen.sensor at bottom.

<u>Long-term Goal</u>: no further additions

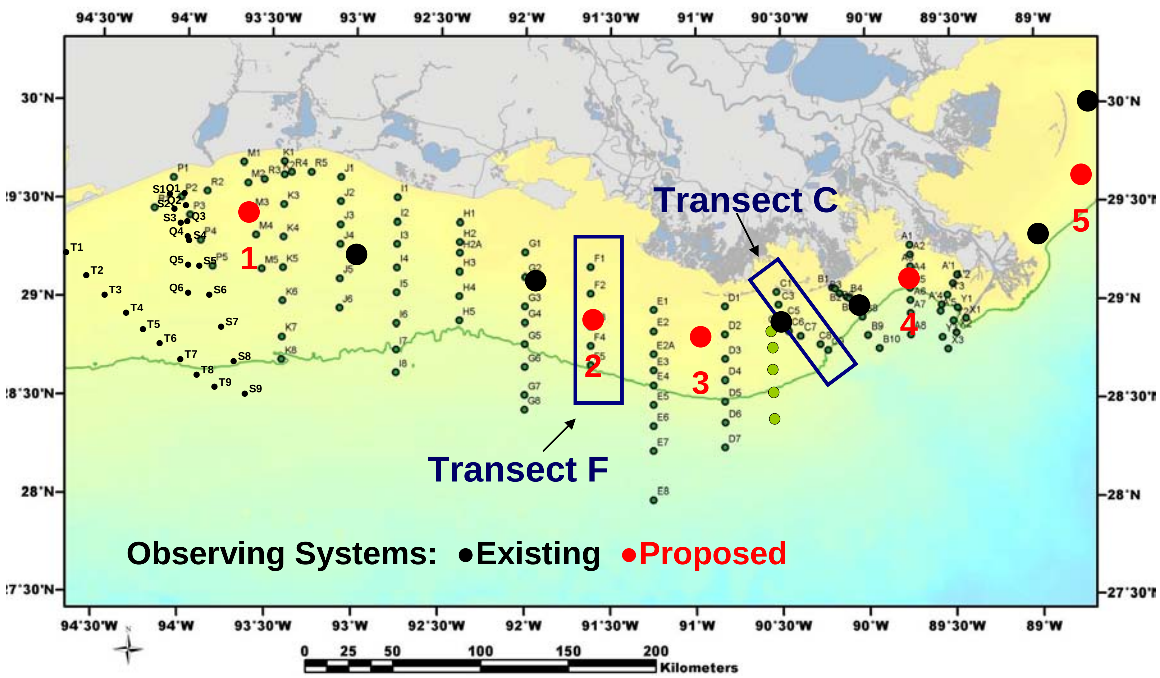


Figure 5. Observing systems that currently exist (black) and those proposed (red) under Tier 2 of the Implementation Plan.

Tier 3 System Requirements

These system requirements are needed to improve understanding of causes and impacts of hypoxia.

System Requirement 1: On shelf-wide surveys and cross-shelf transects, collect meteorological, sea surface hydrographic, and ADCP data with underway acquisition systems.

> Currently: One mid-summer shelfwide survey west of Mississippi plume and 11 cross-shelf transect cruises/yr with underway MIDAS and ACDP data collection systems.
>
> FY10 Needs: Eight shelf-wide surveys with expanded spatial boundaries and 10 cross-shelf transect cruises/yr with underway MIDAS and ACDP data collection systems.
>
> Long-term Goal: same measurements over 5 years.

System Requirement 2: On shelfwide surveys and cross-shelf transects, collect hydrographic profiles.

Currently: One mid-summer shelfwide survey west of Mississippi plume and 11 cross-shelf transect cruises/yr with hydrographic profiles collected with CTD (includes oxygen, conductivity, temperature, PAR, Transmission, chlorophyll fluorescence) and Biospherical light meter (includes % incident light, PAR).

FY10 Needs: Eight shelf-wide surveys with expanded spatial boundaries and 10 cross-shelf transect cruises/yr with hydrographic profiles.

Long-term Goal: same measurements over 5 years.

System Requirement 3: On shelfwide surveys and cross-shelf transects, collect water samples at discrete depths and analyze for phytoplankton biomass and species composition.

Currently: On the mid-summer shelfwide survey west of Mississippi plume and 11 cross-shelf transect cruises/yr, surface and bottom chlorophyll and phaeopigment collected at all stations and species composition by microscopy at surface at some stations (3 per transect on shelfwide survey = 42, and 3 per cross-shelf transect = 6/cruise) and by HPLC at all stations.

FY10 Needs: Eight shelf-wide surveys with expanded spatial boundaries and 10 cross-shelf transect cruises/yr, determine phytoplankton biomass and species composition using same sampling design as FY09.

Long-term Goal: same measurements over 5 years.

System Requirement 4: On shelfwide surveys and cross-shelf transects, collect water samples at discrete depths and analyze for nutrients and collect depth profiles of nitrate (add nitrate sensor to CTD).

Currently: On the mid-summer shelfwide survey west of Mississippi plume and 11 cross-shelf transect cruises/yr, surface and bottom dissolved inorganic nutrients, TP, TN, but not profiles.

FY10 Needs: Eight shelf-wide surveys with expanded spatial boundaries and 10 cross-shelf transect cruises/yr.; same sampling design as FY09; add NO_3 sensors to existing CTDO's.

Long-term Goal: same measurements over 5 years.

System Requirement 5: Collect sediment core samples at selected sites and dates to determine benthic biogeochemical fluxes (C, O, N, P, Si).

Currently: Benthic biogeochemical fluxes measured at selected sites by Texas A&M (DiMarco et al.), U. Texas (Gardner et al.), and U.S. EPA cruises.

FY10 Needs: Eight shelf-wide surveys with expanded spatial boundaries and 10 cross-shelf transect cruises/yr.; at selected stations (3 per transect on shelfwide surveys = 42/survey, and 3 per cross-shelf transect = 6/cruise), collect sediment core samples to determine benthic biogeochemical fluxes (C, O, N, P, Si).

Long-term Goal: same measurements over 5 years.

System Requirement 6: Include nitrate, chlorophyll (fluorescence), turbidity, ADCP, and PAR sensors at selected depths on observing platforms.

Currently: Observing System *C6C* has bottom mounted upward pointing ACDP, nitrate at 5 depths using a flow-through AutoLab Automatic Nutrient Analysis System (ANAS), C, T, DO, turbidity and chl fluor sensors at 3 depths, and irradiance and PAR deployed at selected times and depths; Observing System *CSI-9* has bottom mounted upward pointing ADCP, C, T, DO, turbidity and chl fluor sensors at 2 depths; Observing Systems *C* and *D* collect near-bottom ADCP, *in situ* nitrate and chl fluor sensors at 2 depths, a fluorometer that measures particulates and CDOM at 1 depth; Observing System *USM3M01* collects surface C, T, and nitrate (Satlantic Nitrate Sensor), and ADCP profiles.

FY10 Needs: Outfit Observing System *CSI-9* with nitrate and light sensors, *C* and *D* with light sensors, and *USM3M01* with chlorophyll fluorescence, turbidity, and light sensors.

Long-term Goal: same – all 11 observing systems would have nitrate, chlorophyll fluorescence, turbidity, ADCP, and light sensors.

System Requirement 7: Add nitrate and chlorophyll sensors to deployed AUVs

Currently: none.

FY10 Needs: Add nitrate and chlorophyll fluorescence sensors to AUVs in pilot study.

Long-term Goal: fleet of 6 Slocum gliders includes nitrate and chlorophyll fluorescence sensors.

System Requirement 8: Obtain remote sensing data (satellite imagery) to provide shelf-wide measurements of suspended sediments, chlorophyll, colored dissolved organic matter, and sea surface temperature.

Currently: Naval Research Laboratory currently obtaining remote sensing data and passing > 2000 products to NOAA and EPA. Ongoing efforts are accessing data from new satellites (OCM, MERIS, MODIS) and expanding satellite products (e.g. POM, PIM, etc.).

FY10 Needs: Validation of satellite algorithms using *in situ* data – establish real-time validation sites; establish new algorithms for Hypoxia Watch; generate real-time long-term satellite time series.

Long-term Goal: same measurements over 5 years.

System Requirement 9: Maintain and increase sampling frequency of USGS fixed-site monitoring stations in the lower Mississippi and Atchafalaya Rivers.

Currently: Constituent Loads and Trends at 7 NASQAN Sites: Mississippi River at St. Francisville; Mississippi River at Baton Rouge; Mississippi River at Vicksburg (proposed); Mississippi River at Belle Chase; Atchafalaya River at Morgan City; Atchafalaya River at Mellville; and Wax Lake at Calumet; 12 samples/year for nutrients, major ions, suspended sediment, pesticides, and field parameters (dissolved oxygen, pH, specific conductance, alkalinity). Continuous monitoring of nitrate and 4 field parameters (dissolved oxygen, pH, specific conductance, alkalinity) at Mississippi River at Baton Rouge; Atchafalaya River at Morgan City; and Wax Lake at Calumet.

FY10 Needs: Maintain operation of continuous nitrate monitoring at 3 sites and reduce error associated with estimates of weekly and monthly nutrient loads by increasing collected water sampling frequency to 24 samples/site/yr.

Long-term Goal: same measurements over 5 years. Report comparing calculated loads of nitrogen entering the Gulf of Mexico to continuously measured nitrate loads from Mississippi and Atchafalaya.

System Requirement 10: Coupling of 3-D hydrodynamical models with biogeochemical models to quantify effects of river flow and nutrient flux on spatiotemporal extent of hypoxia.

Currently: Naval Research Laboratory running real-time hydrodynamical and 3-D bio-optical models; Texas A&M (DiMarco et al.) developing coupled 3-D hydrodynamical models with biogeochemical models.

FY10 Needs: 3-D model to assimilate real-time glider and fixed stations data; real-time bio-optical and physical data needed for validation.

Long-term Goal: Coupled hydrodynamical and biogeochemical models, and real-time data validation.

System Requirement 11: Conduct groundfish surveys at selected fixed sites, coinciding with the timing of the hypoxic zone, in a design that complements data collected at randomized sites by SEAMAP – analyze for species composition, diet, energy density, and physiological condition (e.g. lipid content, size).

Currently: none.

FY10 Needs: Synoptic sampling of 2 areas (1 hypoxic, 1 normoxic) in mid-summer, 40 sites per area – following Kevin Craig's NGOMEX 2003-2005 design.

Long-term Goal: same protocol over 5 years.

System Requirement 12: Conduct box core surveys at selected sites to determine benthic condition indices.

Currently: Box cores at 3 stations on Transect C and selected stations on shelfwide survey – following Rabalais.

FY10 Needs: Continue design of Rabalais

Long-term Goal: same protocol over 5 years.

System Requirement 13: Simulation models

Currently: K. Rose and K. Craig using simulation models to predict population level impacts of hypoxia on croaker and copepods based on reproductive biomarkers – in Thomas et al. (NGOMEX 2005-2008)

FY10 Needs: Continue design of Thomas et al.

Long-term Goal: same protocol over 5 years.

System Requirement 14: Bioeconomic models

Currently: Craig et al. (CHRP 2005-2007) bioeconomic model that links hypoxia effects on shrimp population dynamics to the behavior, catch, and rents (profits) of the commercial shrimp fishery

FY10 Needs: Continue design of Craig et al.

Long-term Goal: same protocol over 5 years.

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GULF OF MEXICO HYPOXIA MONITORING IMPLEMENTATION PLAN MATRIX

Tier 1 (Core Requirements): These system requirements are needed to determine the annual maximum area and volume of hypoxia in support of the *2008 Gulf Hypoxia Action Plan* Coastal Goal metric, and to disseminate this information to managers.

System Requirement	Lead (L) and Collaborators (C)	FY09 Plans	FY09 Funding	Critical Needs for FY10	Estimated FY10 Cost	Long-term Goal & Cost
1: Expand spatial boundaries of shelf-wide surveys	LUMCON (L); USM (L)	Survey includes 80-90 sites extending from approx. 89.5˚ W to 94.5˚ W and offshore to 28.5˚ N, to the most inshore and offshore edge of hypoxia	$158K; Includes 4 months of data manager	Same as FY09 for west of Miss R, but need to add 20 stations east of Miss R – this will require additional ship (e.g. R/V Tommy Monroe)	Per survey: $158K + $50K	Same survey over 5 years
2: Include hypoxic volume measurements on shelf-wide surveys	LUMCON (L); USM (L)	Areal extent is calculated from shelf-wide survey	Included in System Requirement 1	Calculate hypoxic volume from depth profiles of dissolved oxygen on shelf-wide surveys	Included in System Requirement 1	Same measurements over 5 years
3: Increase number of monthly shelf-wide surveys	LUMCON (L); USM (L)	One mid-summer survey	Included in System Requirement 1	6 surveys/year = Apr, May, Jun, Jul, Aug, Sep	6 x ($158K + $50K) = $1,248K	Same protocol over 5 years

4: Fill in temporal gaps of shelf-wide surveys with cross-shelf transects	LUMCON (L)	Monthly sampling at Transect C south of Terrebonne Bay, and bimonthly sampling at Transect F off the Atchafalaya River (11 cruises/year)	$148K; includes 4 months of data manager	From October through March, monthly sampling at Transect C, and bimonthly sampling at Transect F (6 cruises/year).	$81K	Same protocol over 5 years
5: Add deployments of Autonomous Underwater Vehicles (AUVs) with dissolved oxygen sensors	USM (L); LUMCON (C); TAMU (C); NRL (C)	none	none	Pilot study to test application of AUVs with dissolved oxygen sensors to study areas	Webb Research Slocum Glider with Aanderaa Oxygen Optode 4330: $120K; deployment to cover monitoring sites east and west of Miss River plume, in conjunction with survey cruise CTD profiles: $180K	Monthly deployment of gliders east and west of the Mississippi delta from April through September to cover the hypoxic zone area. This would require 4 gliders (a backup for each transect). The gliders could be piloted from a central site, but response teams from both locations would be needed for glider recovery; 3 gliders ($360K) to be purchased in FY11 or later depending on results of FY10 Pilot study; fleet deployment = $20K/month X 6 months = $120K/year

6: Create a portal to maximize accessibility to, and exchange of, hypoxia data	NCDDC (L); NODC (C); SEAMAP(C); GCOOS/IOOS (C)	1) three operational websites: a) Hypoxia Watch Website, http://ecowatch.ncddc.noaa.gov/hypoxia, b) LUMCON's Hypoxia Website, http://www.gulfhypoxia.net, c) Gulf Hypoxia Monitoring Stakeholder Committee Website, http://www.ncddc.noaa.gov/activities/gulf-hypoxia-stakeholders; 2) Data ingest to Hypoxia and REDM portals underway; 3) NCDDC and IOOS Program actions underway to assure data management best practices and adherence to accepted community standards (e.g. IOOS DMAC, FGDC, etc.)	none	1) Continue operations and maintenance of websites, and expand capabilities and ingest toward hosting national hypoxia observations; 2) Continue technology development and transfer (e.g. ontology and data bus development, archive to CLASS of appropriate NNDC) to improve discovery, access, transport, and archive of hypoxia and ancillary data; 3) Continue partnerships in QARTOD, MMI, IOOS Program, and International groups.	4 NDDC FTE @ $125K & 1 LUMCON FTE @ $100K = $600K	O&M for a National Monitoring Network with continued data management and technology transfer development; Creation of a National Hypoxia Database. Maintenance of FTE positions over 5 years.

7. Dissemination of relevant data and findings to management community	NCDDC (L); EPA (C); GCOOS/IOOS (C); GOMA (C)	1) Gulf Hypoxia Monitoring Stakeholder Committee Website (GHMSC), http://www.ncddc.noaa.gov/activities/gulf-hypoxia-stakeholders, is operational, membership determined, and Terms of Reference developed; 2) Communications links established between GHMSC and Gulf Hypoxia Task Force Communication Subcommittee, Gulf of Mexico Alliance Environmental Education Network, and GCOOS Education and Outreach Council.	none	Review data needs of the management community and the mechanisms to disseminate data; Adjust the methods for data dissemination as identified in the review; Establish protocol for disseminating data.	Face-to-face GHMSC meeting = $20K; 5 workshops @ $45K = $225K; Report = $5K; Total = $250K 1 FTE to coordinate education/outreach activities and maintain website = $150K. Total cost = $400K	Follow protocol for disseminating data to management community. Maintain FTE over 5 years.

Tier 2 System Requirements: These are needed to improve understanding of hypoxic zone distribution, with the focus on expanding the temporal coverage of hypoxia by extending the current observation system network.

System Requirement	Lead (L) and Collaborators (C)	FY09 Plans	FY09 Funding	Critical Needs for FY10	Estimated FY10 Cost	Long-term Goal & Cost

1: Maintain current observation systems and increase number of observation systems	LUMCON (L); TAMU (L); USM (L)	Six observing platforms, four west of Mississippi River plume and two east of plume: West of plume: 1) -90º29' W, 28º52' N (LUMCON *C6C* = WAVCIS/BIO2 *CSI-6*) 2) -89º58' W, 29º06' N (LUMCON and WAVCIS/BIO2 *CSI-9*) 3) -93º W, 29º20' N (TAMU *D*) 4) -92º W, 29º N (TAMU *C*) East of plume: 1) -88°39' W, 30° N (USM *USM3M01*) 2) -89° 02’ W, 29º24’ N (LSU *CSI-16*)	LUMCON mooring maintenance, including 4 months data manager = $100K; TAMU maintenance = $150K; USM maintenance = $100K LSU maintenance = $100K	Maintenance of 6 current systems and addition of 2 observation platforms west of the delta with full suite of sensors (e.g. the WAVCIS/BIO2 model): 1) -89º35' W, 28º57' N (close to the Mississippi River outflow); 2) -93º36' W, 29º27' N (west of Atchafalaya River outflow)	Maintenance of 6 systems @ $125K/sys. = $750K; 2 new systems @ $300K/sys. = $600K; Total cost = $1,350K	FY11: Two observation platforms added: 1) -91º W, 28º48' N (west of Mississippi River plume); 2) -88º46' W, 29º37' N (east of Mississippi River plume) FY12: One observation platform added: 1) -91º37' W, 28º53' N (west of Mississippi River plume); <u>Cost/year</u>: FY11: maintenance of 8 ($1,000K) + 2 new ($600) = $1,600K FY12: maintenance of 10 ($1,250K) + 1 new ($300) = $1,550K FY13: maintenance of 11 = $1,375K FY14: maintenance of 11 = $1,375K

2: Outfit existing observing platforms with dissolved oxygen sensors at selected depths	USM (L); LSU (L)	Dissolved oxygen sensors currently on LUMCON *C6C* (3 depths), LUMCON *CSI-9* (2 depths), and TAMU *C* and *D* (2 depths)	none	Outfit USM and LSU platforms with dissolved oxygen sensors at bottom depth	$100K to outfit 2 buoys with oxygen sensor	No additional costs

Tier 3 System Requirements: These are needed to improve understanding of the causes and impacts of hypoxia.

System Requirement	Lead (L) and Collaborators (C)	FY09 Plans	FY09 Funding	Critical Needs for FY10	Estimated FY10 Cost	Long-term Goal & Cost
1: On shelf-wide surveys and cross-shelf transects, collect meteorological, sea surface hydrographic, and ADCP data with underway acquisition systems	LUMCON (L); USM (L)	One mid-summer shelf-wide survey west of Mississippi River plume and 11 cross-shelf transect cruises/year with underway MIDAS and ADCP collection systems	$190K for data analyses	Eight shelf-wide surveys with expanded spatial boundaries and 10 cross-shelf transect cruises/year with underway MIDAS and ADCP collection systems	$852K for data analyses	Same measurements over 5 years

2: On shelf-wide surveys and cross-shelf transects, collect hydrographic depth profiles	LUMCON (L); USM (L)	One mid-summer shelf-wide survey west of Mississippi River plume and 11 cross-shelf transect cruises/year with hydrographic profiles collected with CTD (includes D.O., C, T, PAR, Transmission, chl fluorescence) and Biospherical PNF (includes %incident light, PAR)	Data analyses costs included in System Requirement 1; $10K for equipment maintenance of PNF	Eight shelf-wide surveys with expanded spatial boundaries and 10 cross-shelf transect cruises/year with hydrographic depth profiles	Data analyses costs included in System Requirement 1; $20K for equipment maintenance of 2 PNFs	Same measurements over 5 years
3: On shelf-wide surveys and cross-shelf transects, collect water samples at discrete depths and analyze for phytoplankton biomass and species composition	LUMCON (L); USM (L)	On the mid-summer shelf-wide survey west of Mississippi River plume and 11 cross-shelf transect cruises/year, surface and bottom chl and phaeopigments collected at all stations and species composition by microscopy conducted at surface at selected stations (3 per transect on shelf-wide survey = 42; and 3 per cross-shelf transect = 6/cruise), and by HPLC at all stations	Data analyses costs included in System Requirement 1; $30K for supplies	Eight shelf-wide surveys with expanded spatial boundaries and 10 cross-shelf transect cruises/year with samples collected for phytoplankton biomass and species composition following same sampling design as FY09	Data analyses costs included in System Requirement 1; $135K for supplies	Same measurements over 5 years

4: On shelf-wide surveys and cross-shelf transects, collect water samples at discrete depths and analyze for nutrients, and collect hydrographic depth profiles of nitrate (add nitrate sensor to CTD)	LUMCON (L); USM (L)	On the mid-summer shelf-wide survey west of Mississippi River plume and 11 cross-shelf transect cruises/year, surface and bottom dissolved inorganic nutrients, TP, TN collected	Data analyses costs included in System Requirement 1	Eight shelf-wide surveys with expanded spatial boundaries and 10 cross-shelf transect cruises/year with same sampling design as in FY09, and add nitrate sensor to existing CTDO systems (LUMCON, USM).	Data analyses costs included in System Requirement 1; Cost of outfitting 2 CTDO's with nitrate sensor = $30K/system = $60K	Same measurements over 5 years
5: On shelf-wide surveys and cross-shelf transects, collect sediment core samples at selected sites and dates to determine benthic biogeochemical fluxes (C, O, N, P, Si)	TAMU (L); U Tex (L); LUMCON (C); USM (C)	At selected sites, TAMU and U. Texas collect sediment cores and measure benthic biogeochemical fluxes		Eight shelf-wide surveys with expanded spatial boundaries and 10 cross-shelf transect cruises/year; at selected stations (3 per transect on shelf-wide surveys = 42; and 3 per cross-shelf transect = 6/cruise), collect sediment cores to determine benthic biogeochemical fluxes (C, O, N, P, Si)	396 samples/year = $8K	Same measurements over 5 years

6: Include nitrate, chlorophyll (fluorescence), turbidity, ADCP, and light sensors at selected depths on observing platforms	LUMCON (L); TAMU (L); USM (L)	LUMCON system *C6C* has bottom mounted upward pointing ADCP; nitrate at 5 depths using a flow-through ANAS; C, T, DO, turbidity, and chl fluorescence at 3 depths, and irradiance and PAR deployed at selected times and depths; LUMCON system *CSI-9* has bottom mounted upward pointing ADCP; C, T, DO, turbidity, and chl fluorescence at 2 depths; TAMU systems *C* and *D* collect near-bottom ADCP; *in situ* nitrate and chl fluorescence sensors at 2 depths; a fluorometer that measures particulates and CDOM at 1 depth; USM system *USM3M01* collects surface C, T, and nitrate (Satlantic Nitrate Sensor); and ADCP profiles	Maintenance costs included in Tier 2, System Requirement 1	Outfit system *CSI-9* with nitrate ($30K X 2 depths = $60K) and light sensors ($15K X 2 depths = $30K); Outfit systems *C* and *D* with light sensors ($15K X 2 depths/system = $60K); Outfit *USM3M01* with chl fluorescence and turbidity ($12K X 2 depths = $24K); and light sensors ($15K X 2 depths = $30K)	Total cost = $204K	No additional costs

7: Add nitrate and chlorophyll fluorescence sensors to deployed AUVs	USM (L); LUMCON (C); TAMU (C); NRL (C)	none	none	Add nitrate and chlorophyll fluore4scence sensors to AUVs in Pilot Study	Outfit Slocum glider with nitrate ($30K) and chl fluorescence sensor ($12K); Total = $42K	Outfit additional 5 Slocum gliders with nitrate ($30K X 5 = $150K) and chl fluorescence ($12K X 5 = $60K) sensors; Total = $210K
8: Obtain remote sensing data (satellite imagery) to provide shelf-wide measurements of suspended sediments, chlorophyll, colored dissolved organic matter, and sea surface temperature	NRL (L); LSU (C)	NRL currently obtaining remote sensing data and passing > 2000 products to NOAA and EPA; Ongoing efforts are accessing data from new satellites (OCM, MERIS, MODIS) and expanding satellite products (e.g. POM, PIM, etc.)		Validation of satellite algorithms using *in situ* data – establish real-time validation sites; establish new algorithms for Hypoxia Watch; generate real-time long-term satellite time series	$300K	$300K/year over 5 years

9: Maintain and increase sampling frequency of USGS fixed-site monitoring stations in the lower Mississippi and Atchafalaya Rivers	USGS (L)	Constituent loads and trends measured at 7 NASQAN Sites: Mississippi River at St. Francisville; Mississippi River at Baton Rouge; Mississippi River at Vicksburg (proposed); Mississippi River at Belle Chase; Atchafalaya River at Morgan City; Atchafalaya River at Mellville; and Wax Lake at Calumet; 12 samples/year for nutrients, major ions, suspended sediment, pesticides, and field parameters (dissolved oxygen, pH, specific conductance, alkalinity). Continuous monitoring of nitrate and 4 field parameters (dissolved oxygen, pH, specific conductance, alkalinity) at Mississippi River at Baton Rouge; Atchafalaya River at Morgan City; and Wax Lake at Calumet	$590K	Maintain operation of continuous nitrate monitoring at 3 sites and reduce error associated with estimates of weekly and monthly nutrient loads by increasing collected water sampling frequency to 24 samples/site/yr.	$625K - assumes same 7 sites	Same measurements over 5 years; Technical report comparing loads of nitrogen entering the Gulf of Mexico to continuously measured nitrate loads from Mississippi and Atchafalaya Rivers

10: Coupling of 3-D hydrodynamical models with biogeochemical models to quantify effects of river flow and nutrient flux on spatiotemporal extent of hypoxia	TAMU (L); NRL (L)	TAMU developing coupled 3-D hydrodynamical models with biogeochemical models; NRL running real-time hydrodynamical and 3-D bio-optical models		3-D model to assimilate real-time glider and fixed station data; real-time bio-optical and physical data needed for validation	$500K	Coupled hydrodynamical and biogeochemical models, and real-time data validation; $500K/year for 5 years
11: Conduct groundfish surveys at selected fixed sites, coinciding with the timing of the hypoxic zone, in a design that complements data collected at randomized sites by SEAMAP – analyze for species composition, diet, energy density, and physiological ncondition (e.g. lipid content, size)	Florida St (L); U Texas (L); LSU (L); LUMCON (C)	none	none	Synoptic sampling of 2 areas (hypoxic vs. normoxic) in mid-summer, 40 sites per area, following Craig et al.	$200K	Same protocol for 5 years

12: Conduct box core surveys at selected sites to determine benthic condition indices	LUMCON (L)	Box cores at 3 stations on cross-shelf Transect C and selected stations on shelf-wide survey, following Rabalais	$475K	Continue design of Rabalais	$475K	Same protocol for 5 years
13: Simulation models to assess ecological impacts of hypoxic zone on living resource populations	LSU (L); Florida St (L); U Texas (L)	Simulation models being developed by Thomas et al. to predict population level impacts of hypoxia on croaker and copepod populations based on reproductive biomarkers	$100K	Continue design of Thomas et al.	$100K	Same protocol for 5 years
14: Bioeconomic models to assess the net economic costs of the hypoxic zone on the commercial shrimp fishery	Florida St (L); Duke U (L); NMFS (L)	Craig et al. bioeconomic model links hypoxia effects on shrimp population dynamics to the behavior, cqatch, and rents (profits) of the commercial shrimp fishery in the Neuse River	$200K	Continue design of Craig et al.	$200K	Same protocol for 5 years