WHITE PAPER

TO

IMPROVE MONITORING OF THE GULF OF MEXICO HYPOXIC ZONE IN SUPPORT OF THE HYPOXIA TASK FORCE'S COASTAL GOAL

BY

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Table of Contents

EXECUTIVE SUMMARY

Hypoxia is one of the many symptoms of nutrient over enrichment of coastal ecosystems. Sustained or recurring low oxygen conditions can lead to faunal mortalities, food web alterations, loss of habitat, and impacts to fisheries. 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 off Louisiana, Texas and Mississippi. Ongoing monitoring efforts that characterize the hypoxic zone dynamics are insufficient to adequately define its magnitude and characterize the processes that lead to its development, maintenance, and distribution.

The need for monitoring Gulf of Mexico hypoxia is clearly identified in several documents. The interagency Mississippi River/Gulf of Mexico Watershed Nutrient Task Force, as authorized through the Harmful Algal Bloom and Hypoxia Research and Control Act of 1998, 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* calls 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 *Action Plan* cited a critical scientific need for an expansion of monitoring efforts to better characterize the impact of nutrient loading from the Mississippi River watershed and other factors on hypoxic zone dynamics. Such improvements in monitoring have not been made, as emphasized in the 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* (MMR Report) and the *Hypoxia in the Northern Gulf of Mexico Science Symposium*, a component of the science reassessment process to evaluate the 2001 *Action Plan*, http://www.epa.gov/msbasin/taskforce/reassess2005.htm.

The *Summit on Long-Term Monitoring of the Gulf of Mexico Hypoxic Zone: Developing the Implementation Plan for an Operational Observation System*, held on 30-31 January 2007 at Stennis Space Center, Mississippi, 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. This group worked to develop the foundation for 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 size of 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.

The *Summit*'s targeted outcome is an implementation plan that details the scientific, technical, operational, and financial plans for a 5-year (2007-2011) cooperative monitoring program for the northern Gulf of Mexico hypoxic zone.

Management Drivers:

The main management driver for the *Summit* is the need to 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, down from the 2002-2006 average of 15,000 km^2. Monitoring improvements are needed to: a) follow the 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; and b) provide adequate data for predictive models in order to develop accurate forecasts of hypoxic zone properties given alternative management targets for nutrient reduction and alternative scenarios of climate change. Another important management driver is the need to follow the relationship between hypoxic zone magnitude, timing, and distribution, and the distribution, production, and health (e.g. growth potential, reproductive potential) of ecologically and commercially important finfish and shellfish. The backbone of a hypoxia monitoring system will also facilitate the monitoring of ecosystem and human health issues related to harmful algal blooms, potential for mercury methylation in hypoxic environments, and improved information on coastal currents for tracking and predicting material transport, including contaminants.

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:

1. the need to 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. the need to 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. the need to 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. the need for information on nutrient transformation processes that lead to hypoxia formation and sustenance, particularly with respect to benthic dynamics.

5. the need for 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. the need to 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. the need for 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 *Summit* identified the following system requirements:

1. Increased frequency of shelf-wide ship surveys and cross-shelf transects

    a. Monthly shelf-wide surveys in January, March, April, and October, and biweekly shelf-wide surveys in May through September.

    b. More frequent cross-shelf transects year-round.

    c. Integrated sampling approach with a variety of in situ sensors and remote sensing.

2. Increase in instrumented observing systems - additional 5 moored sites within the hypoxic zone; use models to assist in determining the location of moored sites.

3. Outfit existing in situ instrumentation arrays with appropriate biological and environmental sensors.

4. Develop better biological/chemical models and integrate them with the physical models. Coupled physical-biological-chemical process models should help guide monitoring needs and monitoring data should be sufficient to determine uncertainty levels of the models and their subsequent improvement.

5. Additional focus on hypoxia volume quantification and other measures of oxygen deficiency.

6. Conduct monitoring cruises to the east of the Mississippi River delta

7. Incorporate Gulf Alliance monitoring guidelines and the National Water Quality Monitoring Network (NWQMN) Plan into monitoring activities.

8. Improved bathymetry in order to better quantify physical processes.

9. Improved accuracy of Nutrient Loading Data with lower error in monthly load estimates (e.g. enhanced temporal data from NWQMN)

Building the Implementation Plan

The building blocks for developing the Implementation Plan were separated into two categories. The first category, *Infrastructure*, addressed components used to collect and manage data - i.e. these are the components of the monitoring system that extend monitoring of the hypoxic zone (Table 1). The second category, *Synergistic Elements*, includes other components of the observation system that are not directly collecting data within the hypoxic zone, but whose data and information can be used in a complementary way to lead to an improved regional ecosystem management capability (Table 2). Lastly, an *Organizational Structure* was established to ensure that the Plan gets implemented.

Table 1: *Infrastructure*: components used to collect and manage data in the hypoxic zone
*** indicates that the person was not present at *Summit* – i.e. name suggested but not confirmed**

Infrastructure	Who?	Affiliation
Ships (surveys)	Nancy Rabalais	Louisiana Universities Consortium (LUMCON)
	Steve DiMarco	Texas A&M
	Rick Greene	USEPA
	Nelson May	National Marine Fisheries Service (NMFS)
	*Jim Hanifen	Louisiana Department of Wildlife & Fisheries (LADWF)
Moorings & Platforms	Nancy Rabalais	LUMCON
	Steve DiMarco	Texas A&M
	Steve Lohrenz	USM
	Norman Guinasso	Texas A&M
	*Greg Stone	LSU
	Stephen Howden	USM
	Rick Crout	National Data Buoy Center (NDBC)
	*Buzz Martin	Texas General Land Office
	Jim Ammerman	Rutgers University
AUV	*Vernon Asper	USM
	*George Rey	COTS Technology
	Nancy Rabalais	LUMCON
	*Bill Boicourt	UMCES
	*Dick Blidberg	Autonomous Undersea Systems Institute (AUSI)
Remote Sensing	Nelson May	NMFS
	*Nan Walker	LSU
	Bob Arnone	Naval Research Laboratory (NRL)
	Bruce Spiering	NASA, AUSI
Data Management	Sharon Mesick	National Coastal Data Development Center (NCDDC)
	Don Conlee	NDBC
	Nancy Rabalais	LUMCON
	*Brenda Babin	LUMCON
	*Greg Stone	LSU
	*Matt Howard	Texas A&M
Models	*Rob Hetland	Texas A&M
	*Dubravko Justić	LSU
	*Vic Bierman	Limno-Tech
	*Don Scavia	U Michigan
	*Katja Fennel	Dalhousie
	*Courtney Harris	VIMS
	*Stephen Brandt	Great Lakes Environmental Research Laboratory (GLERL)
	Eric Chassignet	FSU
	*Peter Ortner	Office of Oceanic and Atmospheric Research (OAR)

	*Gene Turner	LSU
Education/ outreach	*Sharon Walker *Lee Yokel *Michael Spranger *Dianne Lindstedt *Jessica Kastler *Kerry St. Pé *Roger Zimmerman *Terry Romaire	USM Mobile Bay National Estuary Program UF, FL Sea Grant LSU Sea Grant LUMCON Barataria Terrebonne National Estuary Program NMFS LaDWF

Table 2: *Synergistic Elements*: other components of the observation system that are not directly collecting data within the hypoxic zone, but whose data and information can be used in a complementary way to lead to an improved regional ecosystem management capability.

Synergistic Elements
USGS stream monitoring
US Army Corps of Engineers discharge
State and Federal fish surveys
Remote sensing
Bathymetry
Waves-Current Information System (WAVCIS)
Deep water platform current profiles
Modeling of Mississippi River Basin nutrient transport (e.g. SPARROW)
Texas Automated Buoy System (TABS)
Central Gulf of Mexico Ocean Observing System (CENGOOS)
Gulf of Mexico Coastal Ocean Observing System (GCOOS)
Navy Layered Ocean Model (NLOM) water level network
NDBC weather buoys
Texas Coastal Ocean Observation Network (TCOON)
Gulf States Marine Fisheries Commission (GSMFC)
Coastal Ocean Monitoring & Prediction System (COMPS)

Organizational Structure:

The attendees decided that a core group should write the 5-year monitoring implementation plan document. Alan Lewitus and Nancy Rabalais will be co-chairs of this Steering Committee for the Gulf Hypoxia Monitoring Implementation Plan. This group will work closely with a Gulf Hypoxia Monitoring Stakeholder Committee (GCOOS, Gulf of Mexico Alliance, and Task Force) which will provide the portal to the stakeholders and assist with the education and outreach portion of the plan. Also, a Gulf Hypoxia Monitoring Technical Committee will be formed to provide advice on system requirements. Several *Summit* participants have ties to the MMR Work Group of the Task Force and will update that group on this *Summit*'s efforts. The Steering Committee will define products, performance measures, and a timeline.

Summit on Long-Term Monitoring of the Gulf of Mexico Hypoxic Zone: Developing the Implementation Plan for an Operational Observation System**:**
Rationale, Background, and Objectives

SUMMIT RATIONALE

I. Scientific Background

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). 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 recent 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. subm., Rabalais et al. in press, subm.). 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 1993-2004, with a peak of 22,000 km^2 in 2002 (Rabalais et al., 1999; Rabalais et al. subm.). The intensification and expansion of Gulf hypoxia over recent decades have been related to increases in nitrate loading, and scientific consensuses (CENR 2000, Rabalais et al. 2002, subm.) support the conclusion that the worsening hypoxia in this region is nutrient-induced.

II. Relationship between Monitoring and Action Plan

Since 1985, monitoring of the northern Gulf hypoxic zone has included a mid-summer survey as a measure of its annual extent (Rabalais et al.2002, subm.), a key metric of the 2001 *Action Plan for Reducing, Mitigating and Controlling Hypoxia in the Northern Gulf of Mexico*, http://www.epa.gov/msbasin/taskforce/pdf/actionplan.pdf. This *Action Plan*'s Coastal Goal calls for the hypoxic zone to be reduced to an annual average size of 5,000 km^2 by 2015, down from the 2002-2006 average of 15,000 km^2. 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* (a component of the science reassessment process, http://www.epa.gov/msbasin/taskforce/reassess2005.htm, to evaluate the 2001 *Action Plan*), 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. subm.). 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* itself (e.g. Action Item #4) and the 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").

The mid-summer surveys are part of the monitoring effort that 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 in order to assess management efficacy in meeting the 2001 *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.

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. 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 planning effort could result in the establishment of the NOAA Northern Gulf Cooperative Institute as a research center for cooperative sustained monitoring of the Gulf hypoxic zone.

SUMMIT OBJECTIVES

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 size of 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. GCOOS network) and national monitoring networks (e.g. IOOS, NWQWN);

4. develop a near-term 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.

TARGETED OUTCOME

The *Summit*'s targeted outcome is a planning document that details the scientific, technical, operational and financial plans for a 5-year (2007-2011) cooperative monitoring program for the northern Gulf of Mexico hypoxic zone.

CURRENT HYPOXIC ZONE MONITORING ACTIVITIES

SEAMAP - The Southeast Area Monitoring and Assessment Plan (SEAMAP) summer groundfish survey is conducted by the NOAA National Marine Fisheries Service (NMFS) in the Gulf of Mexico aboard the NOAA Ship Oregon II. The survey follows a stratified random design to sample fishes and invertebrates with a bottom trawl, ichthyoplankton with neuston and bongo nets, and acquire environmental profile data at stations East of the Mississippi River and in the area between the 10 m and 200 m isobaths in the Western and North-central Gulf of Mexico. About 200 to 250 environmental profiles are acquired during three cruise legs conducted in June and July. The profiler is equipped with sensors to measure pressure, water temperature, conductivity, fluorescence, and transmittance. The environmental data are processed aboard the vessel to derive salinity, dissolved oxygen (DO), DO percent saturation, and water density. Since 2001, the bottom DO data have been available to researchers in near real time to support hypoxia research. The data are also used to generate bottom DO maps to support the Gulf of Mexico Hypoxia Watch program (http://www.ncddc.noaa.gov/ecosystems/hypoxia) jointly operated by the NOAA National Coastal Data Development Center and NMFS.

NGOMEX Studies – NOAA's NGOMEX Program awarded 5 grants in FY06 that included a continuation of, and embellishment upon, the long-term monitoring program conducted by Louisiana Universities Marine Consortium (N. Rabalais, PI, LUMCON) and Louisiana State University (R. E. Turner, PI, LSU). Monitoring includes continuation of the 22-year mid-summer shelf-wide survey used to measure hypoxic zone areal extent, which is the metric used to assess progress towards achieving the *Action Plan* Coastal Goal (see above). Also, two cross-shelf transects are continued that are sampled either monthly (Transect C south of Terrebonne Bay, initiated in 1985) or bimonthly (Transect F off the Atchafalaya River, started in 2000). Variables collected include conductivity/temperature/depth/fluorescence/transmission, light penetration and PAR, DO, suspended solids, nutrients, phytoplankton (taxonomy and HPLC pigments), and chlorophyll. Continuous flow-through surface water data are collected (temperature, salinity, light transmission, and fluorescence) underway and compiled with meteorological, position, and underway current profile data (*R/V Pelican*'s MIDAS system). Numerous additional research programs have been supported with these cruises and data collected support several modeling efforts.

A moored instrument array was deployed in 1989 in 20-m water depth in the area of high frequency hypoxia (LUMCON station C6C, or WAVCIS station CSI-06, 29º15.2' N, 90º39.8' W), and has been improved incrementally since then. The WAVCIS/BIO2 sensor package includes above water meteorological sensors and underwater hydrodynamic sensors. The meteorological sensors provide measurements of wind speed, wind direction, air temperature, and barometric pressure, and hydrodynamic sensors provide measurements of directional waves, near-surface current speed, water level, and near-surface water temperature. A NortekUSA Aquadopp Current Profiler (2 MHz model) is mounted on the bottom at a distance of 50 m from the platform. Biological instrumentation includes near-surface, mid-water and bottom YSI 6600 EDS sondes with oxygen, conductivity, temperature, fluorescence, turbidity, and mid-water conductivity/temperature meters. A SBE-3S-4 oceanographic temperature sensor and a SBE-4C-4 conductivity sensor are mounted between the surface and middle oxygen sondes and between the middle and bottom oxygen sondes to better define the stratification. Data are transferred to LSU via cell phone, where the data are post-processed, quality checked and posted on the WAVCIS web site, http://wavcis.csi.lsu.edu/index.asp. Data are automatically FTPed to LUMCON for posting on the LUMCON monitoring web site, http://weather.lumcon.edu/, and the Gulf Hypoxia web site, http://www.gulfhypoxia.net/. Data are also logged internally and made available through an online archival system once quality controlled. Two light meters (Biospherical Instrument, Inc. Profiling Natural Fluorometer System) are used periodically to measure the solar-induced fluorescence of chlorophyll *a*, upwelling radiance and downwelling irradiance, PAR, and nadir irradiance at 683 nm (the peak emission wavelength of chlorophyll *a*). An automatic nutrient analysis system (under development to replace in situ instruments) will sample various nutrients in the water at hourly intervals at multiple levels (up to five depths) in the water column. An AutoLAB Automatic Nutrient Analysis System (ANAS), housed in a weather proof, air-cooled chamber, also provides for additional auxiliary flow-through for additional sensors such as conductivity, temperature, and fluorescence. The chamber is housed on the oil platform at least 50 ft above sea level. Additional WAVCIS/BIO2 instrument systems with oxygen are planned for the area off Grande Isle, LA, and Isle Dernieres, LA (with funding from the Gulf of Mexico Program). This series of instrumentation will provide a system of sensors in approximately 20 m water depth over a distance of 80 km.

Operation of a second instrumented mooring site in the hypoxic zone ("mooring C", 29º N, 92º W) and ongoing construction of a third ("mooring D", 29.3º N, 93º W) are currently underway through Texas A&M University with support from NGOMEX (Steve DiMarco, PI). The mooring includes a bottom mounted upward-looking acoustic Doppler current profiler. Dissolved oxygen sensors (Aanderaa Optode optical), fluorometers, temperature/salinity sensors, and nutrient (nitrate) sensors are placed above and below the pycnocline on a separate mooring line close to the current profiler. Directional waves spectra and sea surface height are collected by additional sensors on the acoustic current profiler. Continuous measurements of total particulate matter, as well as colored dissolved organic matter are obtained using FLNTU-Wetlabs scattering/chlorophyll fluorescence sensors on the moorings at about 8-m depth. Data from moored instrumentation are telemetered to shore in real time using a combination of inductive, acoustic, and cellular communications packages. Instruments on the mooring line and the bottom use a Seabird SBE44 Underwater Inductive Modem to transmit data from the instrument to an IMM nodal interface. The data are transmitted along an armoured ground line to a receiving station placed on the nearby oil platform. At the platform, incoming data are then relayed to shore using a cellular communications package similar to that used by the TABS program.

USEPA – The USEPA's Gulf Ecology Division (R. Greene, PI) has conducted seasonal surveys of the northern Gulf of Mexico hypoxic zone since December 2002. Starting in 2006, cruises were divided into two legs, a Survey Leg occupying a subset of LUMCON's mid-summer station grid, and a Process Leg involving intensive process-oriented experiments at three stations, ranging from near the Mississippi River plume, to the shelf region off the Atchafalaya River. Additional stations are included at the mouths of the major outlets of the Mississippi River and up river about 20 km. CTD casts measure temperature, conductivity, depth, DO, optical backscatter, chlorophyll fluorescence, and PAR. Also deployed with the CTD is a Chelsea Instruments fast-repetition-rate fluorometer to collect phytoplankton variable fluorescence parameters (Fv/Fm, Sigma, Tau). Discrete water samples are processed for nutrients, chlorophyll *a*, phytoplankton taxonomy, and DO via Winkler titration. At most stations, community respiration assays are conducted using BOD bottle incubations, in addition to primary production assays using ^{14}C incorporation. Nutrient addition bioassays and microzooplankton dilution experiments are conducted at selected stations. Water from the ship's hull pump (5 m) is continuously pumped through a surface mapper system, which logs temperature, salinity, chlorophyll fluorescence, optical backscatter, and GPS coordinates at 5 minute intervals. The Process Leg focuses on water column and benthic biogeochemical fluxes (C, O, N, P, S, Fe) at three sites along the 20 m isobath in areas known to experience summer hypoxia with differing regularity.

SCIENCE NEEDS

The need for a coordinated and improved monitoring program in the Gulf hypoxic zone was stated explicitly in the *Action Plan* and the MMR report (USGS 2004), and reaffirmed during the current *Action Plan* scientific reassessment process (e.g. Rabalais et al. subm.). Consensus system requirements for improved monitoring include:

- an expansion of the spatial boundaries of shelf-wide monitoring. 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.

- an increase in the frequency of shelf-wide monitoring surveys to improve resolution of seasonal and storm-related variability in hypoxia development, duration, and extent. The MMR report recommended at least monthly surveys from May to September.

- an increased focus on quantifying hypoxia volume. Volume is 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.

- a greater use of in situ moored observation systems for fixed site temporal resolution. This includes outfitting existing instrumentation arrays (e.g. Texas Automated Buoy System) with appropriate biological and environmental sensors, and establishing new moored systems.

LINKAGE TO NATIONAL/REGIONAL MONITORING NETWORKS

The U.S. component contribution to the Global Ocean Observing System (GOOS) is the national Integrated Ocean Observing System (IOOS). IOOS is a system of systems designed to provide sustained quality controlled data and information on current and future states of the oceans and Great Lakes. The goals of the system relevant to water quality monitoring include: more effectively protect and restore healthy coastal ecosystems; enable the sustained use of ocean and coastal resources; and understand/improve the effects of coastal waters on public health. IOOS involves cross-cutting partnerships among federal and state agencies, the private sector, and academic institutions.

Regional Associations (RAs) of coastal ocean observing systems will be an important component of IOOS as they supplement the federal backbone of observational programs. Geographically organized to focus on the large (regional) marine ecosystems, RAs are being formed to further develop, coordinate, operate, and improve non-federal observing systems. Regional observing systems are intended to provide a regionally coordinated network of sustained data collection applicable to addressing marine and estuarine systems issues important to the stakeholders in the region, and to enhance access to, and interoperability of, the regional data, derivative information and products to a wide variety of user communities. Currently, there are 11 groups funded by grants from NOAA to form RAs, including the Gulf of Mexico Coastal Ocean Observing System (GCOOS). Their members include representatives from federal, state, and local agencies, private sectors, non-governmental organizations, tribes and academia. RAs and their user communities have already indicated a keen and growing interest in water quality, harmful algal blooms (HABs), and hypoxia. Within GCOOS, the RA has already formed a special task force for Public Health issues. HABs and hypoxic events are found along much of the Gulf coast at varying time and space scales. Water quality has been identified as a priority issue by all Gulf states and GCOOS is presently working with the National Coastal Data Development Center (NCDDC) to develop a high priority product that will provide web-enabled, Gulf-wide water quality information. Similar interest in enabling accessibility to water quality information has been expressed by other RAs.

The National Water Quality Monitoring Network (sometimes called the National Monitoring Network) emerged from the recommendations of the U. S. Commission on Ocean Policy and is still evolving. Eventually networks like this should become components of the national IOOS program, and this is currently under consideration. Like IOOS, the NWQMN is a network of networks, but its primary focus is on water quality parameters in coastal and marine systems. This network will have a spatial range from major coastal rivers out into the Exclusive Economic Zone (EEZ), with a significant focus on estuaries. This network will also be a cooperative effort between federal, state, tribal, local and non-governmental organizations, including the private sector and academia.

DEVELOPING THE IMPLEMENTATION PLAN

The purpose of the *Summit* is to provide the foundation for writing an Implementation Plan that describes the justification for establishing the Observation System, the system design, and mechanisms for ensuring short- and long-term development and maintenance. The framework of the Implementation Plan will include sections on "Guiding Principles," Building the Observation System," and "Ensuring Progress."

"Guiding Principles" will articulate the *Summit*'s consensus vision for developing the Observation System, which will include the user needs that drive its design, and the Implementation Plan goals and objectives. "Building the Observation System" will focus on the building blocks for the Plan that encompass components needed to extend monitoring within the hypoxic zone ("Infrastructure") and components outside the hypoxic zone that provide complementary data and information for development of the Observation System ("Synergistic Elements"). System requirements include extension of spatial and temporal coverage by ship surveys, integrating new sensors to existing buoy systems, establishing new buoy systems, and other components recommended at the *Summit*. System building blocks also entail measures needed to ensure a strong integrated data management framework (e.g. discovery, quality control, access, delivery, storage). There are several strategies identified in the Integrated Ecosystem Assessment (IEA) Template (NOAA SES Summit) related to data management of the identified IEA core data variables, e.g. dissolved oxygen. These strategies include: developing consistent data standards and procedures among and within IEA regions, e.g. Great Lakes, Gulf of Mexico or sub regions, Chesapeake Bay; and engaging regional partners and stakeholders in the identification of important issues and assembly of data. With coastal ecosystem health and productivity at risk, improved ecosystem assessments and models will require long-term data series varying in scale and resolution to provide improved decision support products and services. Establishing consistent NOAA standards for the core data variables will also meet strategies identified in the IOOS Program Plan (NEP_NEC Virtual IOOS Brief, December 2006). The development of the monitoring plan will also incorporate findings of NOAA's Alliance for Coastal Technology (ACT) in its development of criteria and testing of alternative sensor technology. For all implementation activities and products, programmatic and funding resources will be identified. "Ensuring Progress" will identify mechanisms for ensuring that the Implementation Plan achieves its stated goals. Barriers to implementation and potential solutions will be identified. The organizational structure to track progress will be established. Individuals/organizations will be identified to have oversight over the progress of the Observation System.

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***Summit on Long-Term Monitoring of the Gulf of Mexico Hypoxic Zone: Developing the Implementation Plan for an Operational Observation System*:**
Proceedings (presentations can be found at: http://www.ngi.msstate.edu/hypoxia/janconference.html)

Day 1: January 30, 2007

Welcome and Opening Remarks

I. *Russ Beard* (NOAA National Coastal Data Development Center) gave the opening welcome and went over some meeting logistics. He also introduced the support staff.

II. *Alan Lewitus* (NOAA Center for Sponsored Coastal Ocean Research) gave opening remarks. The overall goal of the *Summit* is to improve hypoxia monitoring in the northern Gulf of Mexico. The focus should be on integrating hypoxic zone monitoring more fully into the existing Gulf Observation System and in doing so, create a greater regional research capability in the Gulf to better inform stakeholders, including resource and water quality managers. The Steering Committee wants to have an implementation plan that will describe the justification for the monitoring program, the system design, and mechanisms for ensuring short- and long-term development.

Going over the *Summit* Agenda, the first session will set the *Context and Drivers* for the monitoring program, why is it needed, and what are the benefits. The second session, *Relevance of Existing Programs and Assets for Implementation*, has to do with partner building; what are the monitoring activities of existing programs in the Gulf and what role will they have in contributing to the monitoring program. The third session is *Defining the Drivers and System Requirements*. Here we will identify the relevant management science needs, what research gaps exist that limit our ability to inform management, and what activities (system requirements) are needed to improve monitoring to fulfill those needs. Session 4 wraps up the first day with a discussion of *New Tools and Technologies* that would be applicable to monitoring the hypoxic zone.

During Day 2 of the summit we will develop the foundation for the Implementation Plan. First, we will review the science needs and system requirements, assets and resources that come out of the first day's talks and discussions. Then in the *Guiding Principles* session, Bill Corso will lead us in discussing the building blocks for the Plan based on two broad categories. The first category, *Infrastructure,* addresses components that are used to collect and manage data in the hypoxic zone - i.e. these are the components of the monitoring system that extend monitoring of the hypoxic zone. The second category, *Synergistic Elements*, includes other components of the observation system that are not directly collecting data within the hypoxic zone, but whose data and information can be used in a complementary way to lead to an improved regional ecosystem management capability. Lastly, we want to establish an organizational structure and timeline that will ensure that the Plan actually gets implemented, specifically an oversight committee to watch progress, reports, and milestones.

Session 1: Context and Drivers

III. *Bill Corso* (NOAA National Ocean Service) spoke on the need to integrate between and across organizations including IOOS. He outlined the desire to set up an implementation plan and weave existing organizations (e.g. IOOS, GCOOS) together to make a Northern Gulf of Mexico model. The overall goal should be to better understand the phenomenon, provide information to the public, and understand how to better manage it. Management of hypoxia needs to be able to react to the problem in a timely manner. For example: "What happens if the location of the hypoxic zone moves?" Furthermore, we need to be cognizant of apparent policy conflicts. For example, the desire to become energy efficient through increased ethanol production will have ramification in terms of the amount and timing of fertilizer applications in the Mississippi River watershed.

IOOS is officially a NOAA "program" and tangible progress is being made. The hypoxia monitoring effort should tie in to IOOS wherever possible but especially in terms of taking advantage of the sustained integrated end-to-end data system to feed DMAC (Data Management and Communications).

Given the uncertainty of any new funding, it is critical to learn how to leverage efforts with multiple organizations to use what's already in place.

Audience Questions and Comments:

> **Without new funding it will be difficult to integrate systems currently in place.**

IV. *Rob Magnien*, (NOAA Center for Sponsored Coastal Ocean Research) spoke on lessons learned from monitoring activities in Chesapeake Bay as it relates to hypoxia in the Gulf of Mexico. The management structure is already in place (Governors Action Plan) but the science/monitoring information is needed to drive the plan. A good standard is to keep in front of the task force a hypoxic zone model. The model can be used to develop forecasts, which can be used to move the management forward. When designing a monitoring plan, it is critical to keep in mind the underlying questions. For example, understand why samples are necessary from a specific location. We have a general understanding of how the system works and this should be used to structure the monitoring. Establishing a data analysis and reporting strategy as early as possible will make the production of data products easier. Because leaving the monitoring up to one institution/entity is not sustainable, it is important to develop and leverage "robust partnerships".

A recent review of the *Action Plan* detailed progress, including where things are behind schedule. For example, Action #11 is 2 years behind. The revision to the *Action Plan* includes issues like the Farm Bill as well as other topics which have surfaced since the original *Action Plan* was written.

Audience Questions and Comments:

> **Eleven actions were mentioned. It would be nice to review all of them and where they are on each of the actions.** The *Action Plan* also says to improve monitoring and

this is an opportunity to push this item forward through this effort. There has been no significant progress on this item.

Given that the Bay has improvements to make, what lessons do you have to share? Chesapeake actually has goals. We have a monitoring system that tells us that management actions are not making any progress. This may not sound impressive, but it is very important to have a monitoring program to be able to evaluate progress. State standards are starting to be driven by the Bay's results. This is a model we can learn from.

In funding and the GOM program, how important is the State partnership? State partnership is very important. It gives leverage and is very critical. Gulf coast state involvement is critical.

V. *Alan Lewitus* (NOAA Center for Sponsored Coastal Ocean Research) talked about past monitoring in the northern Gulf and future science needs. What are the research gaps that limit understanding of the causes and impacts of the hypoxic zone? A key finding from past research is that, while there is significant interannual variability, the size of the hypoxic zone is increasing over time. The 5-year running average of the hypoxic zone during mid-summer has been around 15,000 km^2. A combination of hindcast model results and sediment core studies suggests that the extent of hypoxia increased since the 1950's and didn't become extensive until the 1970's. Areal extent is a good indicator of the extent of the zone and is the metric on which the *Action Plan* is based. The data collection system that is in place is a good one, but it was designed to be a hypoxia research program not a hypoxia monitoring program. There is a need to develop a sustainable multi-partnered integrative program to ensure long-term monitoring and that allows extension of what is currently done. 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, to define boundaries, characterize seasonality, and support modeling efforts. The MMR report called for an expansion of surveys and an incorporation of observing systems, the things we're driving toward at this *Summit*.

Science needs include:

a. The need to extend spatial boundaries that were identified in 2001. How far does the hypoxia extend past the Southwest Pass? We need to resolve and distinguish between hypoxia development from the Miss. Plume vs. the Atchafalaya, and link these to nutrient loading to both areas of the shelf.
b. We need to better temporally resolve the association between nutrient loading, and other causative factors and the development, maintenance, and movement of the hypoxic zone. It's clearly a dynamic feature that is highly variable and marked by a high degree of horizontal and vertical structure.
c. There is a general lack of information on nutrient transformation processes, particularly with respect to benthic dynamics.
d. Calculating the hypoxic volume, not just the size of the area, would add an additional useful metric.
e. The effects of hypoxia on commercially important species (fish, shrimp, etc.) are poorly understood. Spatially-explicit food-web models are needed to understand the various trophic effects.

f. All of the models have too many black boxes and need more data to improve model development. In addition to collecting new data, we need to continue to collect the data we have been (e.g. riverine nutrient loads and hypoxic zone size) in order to support and improve current models which show relationships between nutrient load and hypoxia. Ultimately we need extended monitoring to best support models used to inform management of the quantitative relationship between nutrient loading, other factors, and hypoxia. We need monitoring data to ensure accurate predictions, validate those predictions, and evaluate the effectiveness of management actions, and we need data to support the models that target understanding of causes and impacts of hypoxia.

Audience Questions and Comments:

Northern Gulf of Mexico cruises in the past have been research driven in the past; are we focusing on monitoring or research for the *Summit*? Monitoring and research go hand in hand. It is important to know how monitoring can support the modeling work. Food-web models are starving for information.

Monitoring is put in a context of what the managers will need to know in order to manage better.

Rob's comment: Our focus for this workshop is the monitoring, but we're not attempting to divorce the demands and what are the uses from this monitoring.

Not a competitive process – should be base funded or contractor support? This isn't clear at this point, but will probably depend on eventual funding sources.

Missing infrastructure? What do we do? Russ will talk more about the details of the infrastructure needs.

Thought the key point was that the probability of success is clear management decisions. What are the management questions and issues? The primary management question is 'how big is the zone?' [how does its size vary with anthropogenic nutrient inputs]. We need to identify other key management questions.

Session 2: Relevance of Existing Programs and Assets for Implementation

VI. *Nancy Rabalais* (Louisiana Universities Marine Consortium). Any research/monitoring effort needs to know the goals of the observations to develop those observations. Specifically we need to define causes, dynamics, and consequences of hypoxia. Furthermore, we need to define relationships of physical, chemical, and biological processes. Temporal and spatial characteristics are important metrics of hypoxia; specifically information that is required is the seasonal and interannual variability of the onset, duration, and extent of hypoxia. Current monitoring efforts are getting more and more data and better temporal and spatial data with annual summer cruises usually taking place in late July. In early years of the monitoring effort, data collection was weather dependent. Now, due to better research platforms, year round and monthly data are gathered. It is apparent that some models are data rich and others are not. Data gaps required to improve the models should be identified. One potential research platform would be oil platforms that could be used to anchor buoys or support instrumented observing systems.

SEAMAP, Southeast Area Monitoring and Assessment Program, is another hypoxia monitoring program in the northern Gulf. The data are similar to the LUMCON cruises, but they are not synoptic. Having synoptic data is important because of the physical oceanographic processes influencing the hypoxic zone. SEAMAP in '05 had many tropical storms and boat malfunctions. Data have been pieced together from many sources over long periods of time. Knowing the riverine loadings of nitrogen and phosphorus to the system is a critical question to answer in addition to the size of the hypoxic zone. More monthly measurements and additional transects are needed. The more data that can be collected the better so that we can evaluate our management progress. Progress will garner more attention from Congress.

VII. *Rick Greene* (EPA Office of Research and Development) spoke about EPA's hypoxia monitoring efforts in the northern Gulf. EPA's involvement began in 2002 to develop a suite of applications, data products, and other tools. The intent is not to duplicate ongoing efforts by Nancy Rabalais' group, but to focus on the non-summer conditions and events leading up to the development of hypoxia. There have been some gaps in the timing of cruises. EPA is also working to implement a sediment diagenesis model, a water quality model, and other models. There are currently not a lot of data on the sediment processes in the hypoxic zone. The future of EPA investment in long-term monitoring is unclear. EPA only has one research vessel. Historically, the research vessel works on the East coast. On the northern Gulf survey cruises, there is usually space available for people who want to do complementary research.

Audience Questions and Comments:

> **How do you get space on the cruise?** Contact Rick to get on the cruise. Timing is based on the EPA and the ship request.
> **How do you get attention at the highest levels to get the resources needed?** There are mechanisms which can be used to get attention at the highest level. There is currently a report out to the Environmental Work Group. What is especially relevant to managers is the relative importance of freshwater discharge vs. nutrient load to hypoxia, including the nutrient concentrations, load and sources.

VIII. *David Shaw* (Mississippi State University) spoke on the role of the new Northern Gulf of Mexico Cooperative Institute. The institute is an opportunity to break down barriers between institutions (not just academic). Also allows for collaboration between NOAA line offices. Overall, the Institute is trying to fill major research voids and provide the opportunity for interaction between federal, state, and local. One goal is to improve watershed modeling and hypoxia modeling, but good resolution in monitoring data is necessary in order to improve model resolution.

Audience Questions and Comments:

> **Is there a place for this institute to assist with this effort?** Due to funding constraints the CI is trying to target specific projects, but yes.

IX. *Phil Bass* (EPA Gulf of Mexico Program) [coauthor *Bryon Griffith*, EPA Gulf of Mexico Program] spoke about the role of the Gulf of Mexico Alliance in this effort. The Alliance is trying to maintain state leadership. The Gulf of Mexico Action Plan has been signed by 5 governors. This process needs to be driven from the bottom up (from the state and local level).

The focus of the Action Plan was on issues on which there was a consensus. Movement forward on each issue is led by an individual state. The state and federal partners are well on the way to accomplishing what they said they would. There is a strong tie-in between the Alliance and this workshop. A primary action item (#N-3) is a reduction in nutrient loading to the Gulf as it pertains to hypoxia. The Alliance's goal is to get all 5 states to recognize this. The states are particularly interested in the size and location of hypoxic areas, including if multiple hypoxic zones exist. At the end of 3 years there will be a progress report that will report what has been accomplished with limited resources. This report will be leveraged to obtain additional resources.

X. *William Walker* (Gulf Coast Research Lab) discussed next steps for the Alliance. Ocean policy reform is not progressing fast enough and funding is being removed. The Alliance is trying to pull together a plan that will work in the GOM region at the end of the 36 months and say here is what we can do as a region to improve water quality. The task now is to align the other states and get a plan for after the 36 months. It is critical to get Congress to recognize this as a priority.

XI. *Bob Arnone* (Naval Research Laboratory) talked about the new data products available from NRL which may be useful to the hypoxia monitoring effort. Data products are put out daily and include: salinity, advection, river plumes, filaments, eddies, loop current intrusions, and upwelling. Data is distributed via an OPeNDAP server to different entities. It is important to realize that remotely sensed data (satellites or aircraft) only provide information about the surface of the water, which is a limitation. Models are being developed to try to project data downward into the water column based on optical layers. Models can also use daily data for short term forecasts (e.g. 24 hours). In the future, physical models will have embedded optical models, such as embedding an optical model inside a physical model. Models can only progress with better monitoring systems to collect better data to assimilate into the models.

Audience Questions and Comments:

> **Are the products available to everyone?** All distributed through NOAA and are available to everyone. There are currently operational websites/data portals. The EDAC server will eventually have over 500 products
>
> **Who's using the products?** Users are still being identified, but the users vary by specific products. Users, such as MS DNR, generally want fairly simple products.
>
> **What's the concern about data coverage and data gaps, specifically satellites getting old/going out of service?** We are getting ready for NPP and NPOESS to start up. New research missions are coming up. NASA is trying to launch new satellites. Several opportunities will be available over the next few years.
>
> **Is there a way to remotely sense oxygen?** No.

XII. *Don Conlee* (NOAA National Data Buoy Center) spoke of NOAA's buoy system and how it relates to hypoxia monitoring. The NDBC's Ocean Observing System (NOOS) operates the typical 3 meter buoy that makes up the bulk of the "yellow fleet". There would be a huge benefit to placing a new buoy in the hypoxic zone (currently there isn't one). Oil company partnerships are excellent for leveraging their existing platforms and other resources. NOOS is currently communicating with Shell to place new buoys. Most buoys do not have oxygen sensors on them.

They can be added but the frequency of trips to service the buoy would have to increase for every several years to every several months.

Audience Questions and Comments:

> **Mention of a platform for instruments? Abandoned rigs? Abandoned rigs have to be removed.** In the case of Shell, we are talking about active rigs. The opportunities are there; Chevron/Texaco, Shell, ExxonMobil, British Petroleum and Unocal are all approachable companies. A coordinated effort with the Offshore Operators Committee would be beneficial.

XIII. *Zdenka Willis* (NOAA National Oceanographic Data Center) spoke about IOOS and how it relates to the hypoxia monitoring effort. IOOS is trying to collaborate with federal and non-federal to create an IOOS, but will not recreate existing program. IOOS now exists within NOAA as a program which will allow it to have a staff and develop more funding opportunities through the budget process. Currently, the existing data collections are not integrated. The initial IOOS effort will focus on 5 variables to be gathered and integrated (temperature, salinity, sea level, currents, and ocean color). The initial effort is focused on delivering variables as final products as a framework for how to proceed in the future. For these five variables it is assumed that the platforms are there to monitor and gather the data.

Audience Questions and Comments:

> **What do you see as your biggest challenge?** We've got to show something real in a year from now. There's got to be something that VADM Lautenbacher can touch. We are convinced that the capacity is there, but a tangible product needs to be developed.
> **How do you see your office interacting with the regional associations?** We're spending time to continue to move the RA's forward. IOOS is using the regional structures that are there and their RCOOS' that are there to move forward. There is a person on the IOOS staff that is the RA point of contact.
> **We're going to "build the go-cart with the parts that are there" for the initial 5 variable effort, but the hypoxia "parts" aren't there.** We have to build and continue to keep the momentum. IOOS needs to continue to vocally help the hypoxia effort in the first year and work on getting the dollars for the next years.

XIV. *Worth Nowlin* (Texas A&M University) [coauthor Ann Jochens, Texas A&M] spoke about how GCOOS is involved in the hypoxia monitoring effort. GCOOS has no new money, but can help with the integration of existing pieces. GCOOS has both a global and coastal component. IOOS monitoring will be based on a federation backbone as well as a regional contribution. To date GCOOS has spent a lot of time educating people about what IOOS and GCOOS are. There is an inventory of existing monitoring, especially who is making real time observations. Currently GCOOS has a list of products as well as a "wish list" of products (i.e. current data gaps). One challenge is the integration of data between institutions; for example, trying to make observations that will be of use to NDBC. IOOS and the region associations are a system of systems.

Audience Questions and Comments:

What is the current status of operation center? A letter of intent goes to NOAA tomorrow. There are several potential partners to help work on that.
What are the specifics on GCOOS in terms of dealing with the hypoxic zone? To date, GCOOS has not done anything explicitly in the hypoxic area.
If something comes out of this workshop it will feed into the GCOOS? Yes. There is an equal effort on assessing what the various stakeholders would like to have.
It seems that GCOOS has a good handle on the education and outreach side. What are you hearing from non-scientists as far as hypoxia is concerned? GCOOS has an education and outreach coordinator and an action plan, but there is no money to implement the action plan.
What scale of funding is necessary? Each Regional Association was encouraged to plan for about 30 million for 5 years and money each year to continue. $30 million would cover what is currently being done (not filling any data gaps).

Session 3: Defining the Drivers and System Requirements

XV. *David Whitall* (NOAA Center for Coastal Monitoring and Assessment) moderated a discussion on the drivers and system requirements. The drivers refer to information needed to inform management of the hypoxia issue, and 'system requirements' refers to activities needed to improve monitoring to provide that information. The following items were identified:

a. **Drivers:**
    i. Physical processes that influence hypoxia (e.g. wind stress, stratification, freshwater loading)
    ii. Nutrient loading:
        1. Which nutrients lead to hypoxia development and maintenance?
        2. What is the quantitative relationship between nutrient loading and the magnitude of hypoxia – i.e. what reductions in nutrient loading would be needed to reduce the mid-summer extent of the hypoxic zone to 5,000 km^2?
        3. What is the seasonal relationship between nutrient loading and hypoxia formation and duration?
        4. What are the contributions of the Mississippi River vs. the Atchafalaya River to hypoxic zone development?
        5. What nutrient reduction goals are manageable and what are not?
    iii. Economic cost – benefit
        1. What are the costs of mitigation (e.g. nutrient load reduction measures needed to reduce the size of the hypoxic zone)?
        2. What are the benefits in terms of fisheries production?
    iv. Effects of hypoxia on living resources
        1. Relationship between distribution of hypoxia and distribution of living marine resources – e.g. habitat loss
        2. Impacts on benthic community
        3. Impacts on fishing
    v. Extent of hypoxic zone – area, volume

vi. Indicators of effects of hypoxia including faunal stress
vii. Characterization of hypoxic zone – boundaries, seasonality
viii. Supporting predictive models
ix. Relationship between wetlands loss and hypoxia (linked integrally in some areas)
x. Education and outreach

b. System Requirements

i. Increased frequency of shelf-wide ship surveys and cross-shelf transects
   1. Monthly shelf-wide surveys in January, March, April, and October, and biweekly shelf-wide surveys in May through Sept.
   2. More frequent cross-shelf transects year-round
   3. Integrated sampling approach with a variety of in situ sensors and remote sensing

ii. Increase in observing systems - additional 5 moored sites within hypoxic zone area; use models to determine moored sites.
iii. Outfit existing instrumentation arrays with appropriate biological and environmental sensors.
iv. Develop better biological models and integrate them with the physical. Also, adapt and improve the physical models. Use them to capture our monitoring.
v. Additional focus on hypoxia volume measurement
vi. Conduct monitoring cruises east of the Pass
vii. Incorporate Gulf Alliance monitoring guidelines and National Water Quality Monitoring Network Plan into monitoring activities
viii. Improved bathymetry
ix. Improved accuracy of Nutrient Loading Data with lower error in monthly load estimates (e.g. NWQMN)
x. Integrate CEAP models for inflow

***Detailed discussion minutes for this portion available upon request.*

Session 4: New Tools and Technologies

XVI. *Jim Ammerman* (Rutgers University, U.S. Oceans, ORION) spoke about the rapidly evolving new technologies which may be useful for hypoxia monitoring. Long term deployments should consider anti-biofouling strategies. However, using copper to prevent biofouling interferes with the oxygen sensors. Biological and chemical sensors are to the point that they are just becoming useful. Nutrient sensors, especially nitrate sensors, are more problematic, but becoming useful. Good data can be collected for nitrate and silicate, but need lots of maintenance. Bio-optical sensors can measure chlorophyll, turbidity, and other parameters. These data correlate well to the satellite data. Other available sensors are a bit more exotic such as a fast repetition rate fluorometer. A flow cytometer can count phytoplankton in situ. There are also instruments which can collect DNA (has been used for Harmful Algal Bloom research). Video plankton recorders can give phytoplankton pigments. There are a range of towed undulating platforms, ranging in size from those which can be towed with small boats to those which require large ships. These platforms can be used to obtain subsurface data, which is very important for hypoxia monitoring. Autonomous Underwater Vehicles (AUVs) range in size from small to 21 feet long. Larger AUVs have much higher power requirements. Gliders have lower power requirements and can be deployed for 15-30 days. This may be optimal for use in the Gulf hypoxic zone. Gliders are currently being used near Palmer Peninsula (Southern Ocean) so they have been tested in extreme environments.

Audience Questions and Comments:

Comment: On the sensing platform they are using the antibodies created by invertebrates and isolating based on certain chemicals.
Also have been sensing based on the protein secreted in the intestine to determine sources. Hypoxia effects on wildlife can have the same effect as low levels of toxins. Gene tips and protein tips are possible.

Comment: An opportunity in the Gulf is the use of autonomous airborne vehicles with an array of sensors to detect different things and possibility exists for dissolved oxygen sensing, for example.

Comment: Steve Lohrenz is getting a glider for their area.

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January 31, 2007

Developing the Implementation Plan

Continuing Working Group Sessions

XVII. *David Shaw and Sharon Hodge* (Mississippi State University, Northern Gulf Cooperative Institute) mediated a working group session to identify partners and linkages.

Partners

Gulf of Mexico Alliance – includes state agencies
Minerals Management Service
Petroleum Industry
Transportation Industry
Commercial Fisheries
Recreational Fisheries
Gulf of Mexico Coastal Ocean Observing System
U.S. EPA
NOAA
NOAA National Data Centers
Integrated Ocean Observing System
NOAA National Ocean Service
NOAA National Marine Fisheries Service
NOAA National Coastal Data Development Center
NOAA National Data Buoy Center
NOAA Northern Gulf Cooperative Institute
Other NOAA Cooperative Institutes
NOAA National Estuarine Research Reserves
Gulf of Mexico Accord
Fisheries Councils + Committees
USGS
Non-governmental Organizations
USDA
Naval Research Laboratory
US Army Corps of Engineers
Academia
NASA
NSF Ocean Research Interactive Observatory Networks
US Coast Guard
Naval Oceanographic Office
NOAA Sea Grant

XIX. *William Corso* (NOAA National Ocean Service) discussed the NOS perspective on what this workshop should accomplish. Possible goals include: obtaining funding from Congress, drafting a long term monitoring strategy, continue to support research, link monitoring/research/stakeholder groups together, improve outreach and data dissemination, translate the research/monitoring into publicly useful products, and identify the core group of people who can accomplish these things. Individuals identified will put together a plan that has everything, but tiered. Here's what we would like and what we can do with funding and what we can't do now.

The group filled in Tables 1 (*Infrastructure*: components used to collect and manage data in the hypoxic zone) and 2 (*Synergistic Elements*: other components of the observation system that are not directly collecting data within the hypoxic zone, but whose data and information can be used in a complementary way to lead to an improved regional ecosystem management capability). These tables are presented in the "Executive Summary" section of this report.

XX. *Sharon Mesick* (NCDDC) spoke of NCDDC's new data management capabilities. NCDDC and NDBC will provide data management for the northern Gulf hypoxia effort. Providing access to data is NCDDC's purpose, so there would be no cost. The data flow was reviewed, which emphasized the need to treat this as one project with a principal scientist coordinating the distribution of station locations and data. High level QC was emphasized as a routine part of the protocol, and procedures in statistical analysis, metadata recordkeeping, data archiving were also discussed. It is important that files be augmented so there is one record published at the end of the survey. Fisheries does data QC in real time. There's a person on every step of this process.

The West Coast Observing system project is more automated, with an End-to-End Data Management process. Divers collect data. Converted from a sensor format to an ASCII format. Automatically retrieve new data and create FGDC record. Same publishing steps that were done before. Packages are on the FTP server & NODC archival. Automated, so the computer archives it, not dependent on a person. Multiple access points for the information. This process is a conduit that has multiple standardized products coming out. Proposed how this would work for Hypoxia. Repeatable process. Goal is to take the sting out of standardization. It takes time to set this up, but there are many benefits. Routinely publish when you want.

Questions and comments:

Where do things stand with being able to share data across agencies? Strides are being made. There are some technology issues, but progress has been made through USGS and the federal government.

Have we gotten over the barriers? Five things identified in the GOMA have enabled the data for access and developed a common access portal. Some issues have been resolved. So there's hope.

For the individual investigator, is there any sort of incentive? If they were funded by project with a policy that requires it. We don't expect you to format the data and create the metadata. All of that is done automatically. We put the money in your hand to develop it, or we do it in-kind. We can't fund the sensor or the hardware end, but we can fund the five – discovery, access, etc. Sometimes its acquisition because they don't want to maintain it anymore. We adopt the datasets. Motivation is for the infrastructure working group, that we don't have to do data management ourselves. We can go to a center that does this. Two complementary groups are the quality assurance group Courtad and MMI.

XXI. *David Whitall* (NOAA Center for Coastal Monitoring and Assessment) led a group discussion of next steps and ways to ensure implementation. The attendees decided that there should be a core group of people in order to write the 5-year monitoring implementation plan document. Alan Lewitus and Nancy Rabalais will be co-chairs of this Steering Committee for the Gulf Hypoxia Monitoring Implementation Plan. This group will work closely with a Gulf Hypoxia Monitoring Stakeholder Committee (GCOOS, Gulf of Mexico Alliance, and Task Force) which will provide the portal to the stakeholders and assist with education and outreach portion of the plan. Also, a Gulf Hypoxia Monitoring Technical Committee will be formed to provide advice on system requirements. Several *Summit* participants have ties to the MMR Work Group of the Task Force and will update that group on this *Summit*'s efforts. The Steering Committee will define products, performance measures, and a timeline. The Steering Committee will coordinate with GOMA to have a proposal for State leadership by late Spring/ Summer. Potential barriers to implementation include a lack of new money and a lack of coordinated state backing for this plan.

Appendix: List of participants at the *Summit on Long-Term Monitoring of the Gulf of Mexico Hypoxic Zone: Developing the Implementation Plan for an Operational Observation System*

Steering Committee	**Affiliation**	**Email address**
Russ Beard, co-Chair	NOAA National Environmental Satellite, Data and Information	Russ.Beard@noaa.gov
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