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# ENHANCING THE OCEAN OBSERVING SYSTEM TO MEET RESTORATION CHALLENGES IN THE GULF OF MEXICO

BY STEVEN A. MURAWSKI AND WILLIAM T. HOGARTH

*We need to know the state of the system so we can measure change.*

*— From the keynote address by Admiral Thad Allen, USCG (Ret.), at the Gulf of Mexico Oil Spill and Ecosystem Conference, January 21, 2013*

## INTRODUCTION

As a result of fines and penalties generated by the settlement of civil and criminal actions and the Natural Resource Damage Assessment and Restoration (NRDAR) claims resulting from the Deepwater Horizon (DWH) incident, various entities are poised to receive billions of dollars to improve the health and resilience of the Gulf of Mexico large marine ecosystem. While much of the funding will go to economic development in states impacted by the oil spill, the lion's share will be used to restore specific natural resources damaged as a result of DWH and to tackle larger and more chronic environmental issues such as loss of wetlands, nutrient enrichment, fisheries sustainability, and toxic contaminant management. In addition, the federal RESTORE Act directs that some of these funds will be used to improve long-term monitoring of the Gulf of Mexico ecosystem.

It was clear during the DWH response phase that important ocean parameters, such as current speed and direction, water chemistry, air quality, and biological effects of oil exposure, were not being sampled well, necessitating significant technology upgrades (Lubchenco et al., 2012). Many of these observations have not been sustained. Before making new observing investments, however, the objectives, priorities, and governance across the many entities involved (Table 1) need to be critically considered. The outcome of these deliberations should be a coastal and ocean observing system that is right-sized, with a unified set of priorities, that is capable of supplying adequate science to restoration planners, and that realizes the specific intents of these new funds in ways that are both cost-effective and forward-looking.

The President charged the Gulf Coast Ecosystem Restoration Task Force (2011) to develop a Gulf of Mexico Regional Ecosystem Restoration Strategy, and in doing so stipulated four overarching goals: (1) restore and conserve habitat, (2) restore water quality, (3) replenish and protect coastal and marine living resources, and (4) enhance community resilience. These goals are specific and outcome-oriented and therefore should guide the development of priorities for enhancing the science supporting them. The Task Force has since been replaced by the Gulf Coast Ecosystem Restoration Council, which has adopted the four Task Force goals and added a fifth: restore and revitalize the economy (Gulf Coast Ecosystem Restoration Council, 2013).

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## CURRENT STATE OF OBSERVING IN THE GULF

What currently exists in the Gulf of Mexico can hardly be characterized as a coastal and ocean observing *system*. Rather, it is a collection of purpose-built monitoring technologies and projects that support specific uses by various interests. Starting with the Restoration Council's overarching goals as the basis for improving the monitoring system that will support them, an important question to pose is: How can existing and new observing programs be better coordinated and supported to provide the required information? Ocean monitoring programs in the Gulf address a wide variety of sectoral needs (Box 1); some of them provide sufficient information over relevant temporal and spatial scales to meet the needs of the user community, whereas some do not meet those needs because of inadequate funding or low priority. Several of the observing programs can arguably be considered "adequate" to meet most user demands, including ones that:

- Determine the annual extent of the hypoxic area off Louisiana (Rabalais et al., 2001), and some (but not all) others that assess coastal water quality and pathogen content (Wolfe et al., 2012)
- Measure population abundance of *some* fishery and protected species resources (Gulf of Mexico Fishery Management Council, 2008).
- Provide information on sea level height (measured from satellites and gauges), which is used to project surface circulation and sea level rise
- Deploy conductivity-temperature-depth (CTD) sensors or instruments that measure dissolved oxygen or nutrient levels to collect information on ocean conditions
- Use satellite-based measurements of ocean color from SeaWiFS (Sea-viewing Wide Field-of-view Sensor), MODIS (Moderate Resolution Imaging Spectroradiometer), and, in the next few years, the VIIRS (Visible Infrared Imager Radiometer Suite) sensor as a proxy for surface primary productivity (NRC, 2011); Landsat imagery to determine land use trends and wetlands inventories;

Table 1. Some entities currently involved in Gulf of Mexico coastal and ocean observing systems (list does not include state or federal government primary data collection programs).

| ACRONYM | ENTITY | URL |
|---|---|---|
| GCERC | Gulf Coast Ecosystem Restoration Council | http://www.restorethegulf.gov/council/ about-gulf-coast-ecosystem-restoration-council |
| GCOOS | Gulf of Mexico Coastal and Ocean Observing System | http://www.gcoos.org |
| GoMA | Gulf of Mexico Alliance | http://www.gulfofmexicoalliance.org |
| GoMFMC | Gulf of Mexico Fishery Management Council | http://www.gulfcouncil.org |
| GoMRI | Gulf of Mexico Research Initiative | http://gulfresearchinitiative.org |
| GoMURC | Gulf of Mexico University Research Collaborative | http://gomurc.usf.edu |
| GRIIDC | Gulf of Mexico Research Initiative Information and Data Cooperative | https://data.gulfresearchinitiative.org |
| GSMFC | Gulf States Marine Fishery Commission | http://www.gsmfc.org |
| IOOS | Integrated Ocean Observing System | http://www.ioos.gov |
| NAS | National Academy of Sciences | http://www.nasonline.org |
| NCDDC | National Coastal Data Development Center | http://www.ncddc.noaa.gov |
| NFWF | National Fish and Wildlife Foundation | http://www.nfwf.org |
| NRDAR | Natural Resource Damage and Restoration | http://www.gulfspillrestoration.noaa.gov/2012/04/ status-update-on-nrda |
| RESTORE Act | Resources and Ecosystems Sustainability, Tourist Opportunity, and Revived Economies of the Gulf States Act of 2011 | http://thomas.loc.gov/cgi-bin/query/z?c112:S.1400: |
| SECOORA | Southeast Coastal Ocean Observing Regional Association | http://www.secoora.org |

### Box 1 | Some Sectoral Interests Requiring Sustained Coastal and Ocean Observing Programs in the Gulf of Mexico

- Disaster response—weather forecasting
- Fishery management/aquaculture siting
- Pathogen/contaminant management
- Water quality management and nutrient abatement
- Habitat protection/restoration (monitoring specific projects and their cumulative impacts)
- Protected species management
- Coastal development planning
- Hydrocarbon and mineral extraction operations and environmental compliance
- Renewable energy siting
- Sea level rise, ocean acidification, and other climate-related issues
- Air quality and human health monitoring
- Military preparedness
- Other marine and coastal sectoral uses

and the Coastwide Monitoring System (Steyer, 2010) in Louisiana to measure ecological change associated with wetlands restoration

In contrast, the scramble for baselines against which the impacts of DWH can be measured has revealed serious shortcomings in a number of sampling programs and in their integration with one another. For example, some programs that are unable to meet the NRDAR and Restoration Council goals because of previous lack of consistent support include those that assess:

- Contaminants in water and sediments (particularly offshore)
- Polycyclic aromatic hydrocarbons (PAHs) and metabolites in seafood and other species
- Fishery-independent population abundance for many offshore and coastal species
- Abundance and distribution of turtles and mammals
- Fish, mammal, turtle, and invertebrate disease/health
- Deep ocean benthic community health in vulnerable areas

Also included in this category are programs that collect real-time oceanographic and meteorological observations (e.g., use high-frequency radars and other technologies to determine surface and deep water transport), and that monitor economic, social, and public health, and other relevant ecosystem attributes.

A case in point where insufficient data were being collected prior to DWH is monitoring of PAH concentrations in Gulf fishes. Seafood safety is an important societal concern following DWH (Ylitalo et al., 2012). A comprehensive baseline for PAHs in Gulf fishes did not exist prior to the DWH spill. Because of this deficiency, some baseline data were developed on the fly by sampling areas not yet exposed to oil (i.e., west and east of the surface spill area) or by timing the sampling to beat the approaching oil contamination (Ylitalo et al., 2012). Other baseline fish contaminant data were available from a narrowly defined study funded by the Minerals Management Service (now the Bureau of Ocean Energy Management) in the western Gulf of Mexico in the early 1990s (McDonald et al. 1996; Figure 1) and from data collected in the aftermath of Hurricane Katrina (Hom et al., 2008). However, it would seem prudent to have a more routine fish-hydrocarbon surveillance program that placed particular emphasis on impacts of chronic exposures on food species (Dickoff et al., 2007). This is especially true in light of the pervasive nature of the oil and gas industries in the Gulf and of continuing releases of hydrocarbons into the environment in the form of produced waters (waters that are released from wells with the oil and gas), low-level spills, other accidental releases, and natural sources (NRC, 2003a). Such a system does not now exist but would have utility if there were to be future spills of any magnitude and also for monitoring environmental compliance with regulations and detecting pipeline leaks. Importantly, with the current emphasis on seafood safety testing and the pending release of related NRDAR data, there will be a significant and much better baseline that, if sustained, would constitute major elements of such a surveillance program.

The Integrated Ocean Observing

System Regional Associations (IOOS-RA) programs currently either serve data directly or point to locations where data are being served from various monitoring projects. Two IOOS-RA programs are currently operating in different parts of the Gulf: the Gulf of Mexico Region Ocean Observing System (GCOOS) and the Southeast Coastal Ocean Observing Regional Association (SECOORA). There are multiple data archives (e.g., NOAA National Coastal Data Development Center, GCOOS, SECOORA, Southeast Area Monitoring and Assessment Program, Gulf Research Initiative Information and Data Cooperative) and multiple metadata and formatting standards that need to be reconciled to facilitate effective conduct of cross-disciplinary studies in support of management decision making. In addition, various state and federal agencies and academic institutions have collected important data sets and stored them outside publicly available archives; their existence will continue to bedevil the creation of a comprehensive monitoring and analysis *system*. A notable bright spot in this regard that is unprecedented in oil spill history (Lubchenco et al., 2012) is the posting by the relevant federal agencies participating in the response of considerable raw and synthesized data collected during the response phase of the DWH oil spill (http://www.RestoreTheGulf.gov).

## OPPORTUNITIES

Various marine-oriented industries in the Gulf depend upon a robust supply of goods and services (e.g., oil and gas, fishing, shipping, cruise lines, military). Their considerable investment in infrastructure (Figure 1) provides an opportunity for mutually beneficial cost-effective data collection. Marine industries, federal and state researchers, and academics have cooperated in fisheries research (Hogarth, 2006) and have collected samples along standard shipping lanes (e.g., using continuous plankton recorders; Reid et al., 2003), and these groups have also worked with the oil and gas industry (e.g., Hernandez et al. 2001). A few modest-sized observing projects have attached sensors to oil platforms, demonstrating the utility of piggybacking on this infrastructure (e.g., meteorological and ocean condition data are being supplied to the National Data Buoy Center in real time from some platforms, and a few oxygen sensors on oil platforms are supplying real-time data on hypoxia).

Much more could be done using existing industrial infrastructure. For example, Figure 2 illustrates the distribution of hypoxic water in summer 2011, based on traditional ship-based measurements (Rabalais et al., 2001). The spatial distribution of hypoxia occurs roughly in the same locale yearly, fluctuating in time and area. There are hundreds of oil and gas platforms in this region (Figure 2) that, if outfitted with dissolved oxygen and other environmental sensors, could potentially supply continuous high-quality monitoring of the onset, intensity, and termination of hypoxic conditions. That the extent of hypoxia is a likely key ecosystem indicator for nutrient abatement strategies

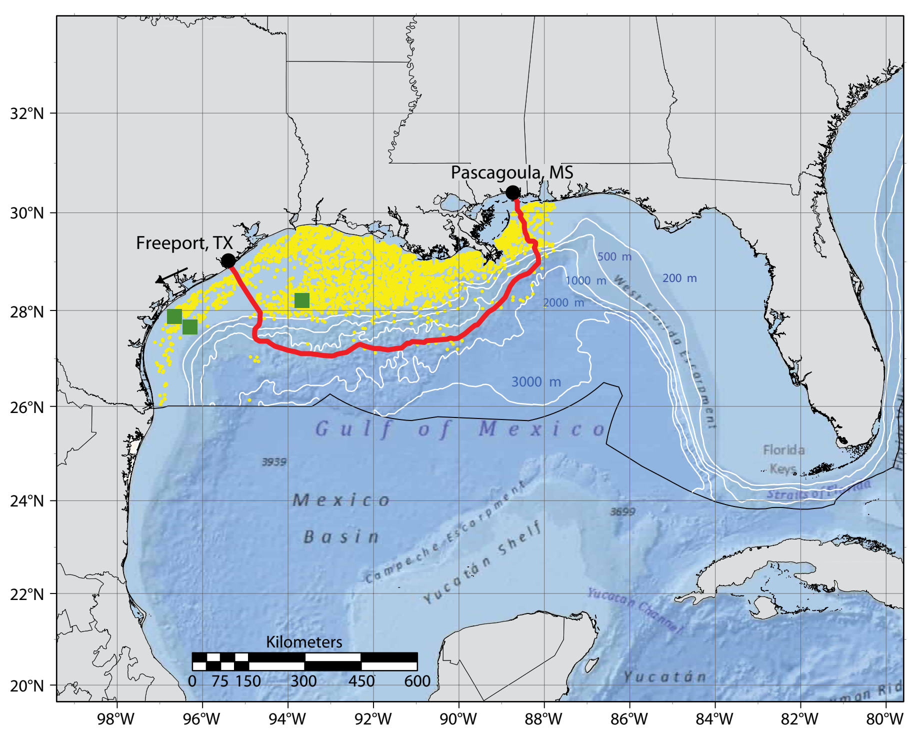


Figure 1. Locations of existing oil and gas infrastructure (yellow dots) and the approximate location of BP's fiber-optic communication cable (red line; Munier and Mendez, 2009). Green squares indicate gas well locations sampled in the early 1990s as part of the Gulf of Mexico Offshore Monitoring Experiment (McDonald et al., 1996). The Bureau of Ocean Energy Management Web site contains data files with locations of Gulf of Mexico oil facilities as of April 12, 2012 (http://www.data.boem.gov/homepg/data_center/mapping/geographic_mapping.asp).

consistent with Restoration Council goals justifies an even better monitoring system than currently exists. From the platform operator's and regulator's standpoint, greater participation in such programs would provide more complete environmental compliance information, and participating companies would be viewed as effective stewards of the public resource if such data sets were made readily available to all.

Novel uses of existing infrastructure could extend to the very deep waters of the Gulf as well, where trends indicate much of the future energy production will occur. One potential opportunity relates to a deep fiber-optic cable installed and operated by BP that has landing points in Mississippi and Texas and extends across the continental shelf, spanning a distance of about 1,200 km (Figure 1; Munier, 2007; Munier and Mendez, 2009). While this cable is used for secure business communications among BP and other companies' platforms and their land-side offices, feasibility studies are ongoing to assess what upgrades in power and bandwidth would be necessary to provide continuing scientific-grade monitoring of the deep offshore environment. If use of the cable for scientific monitoring were to become a reality, it could provide a level of continuous environmental measurements commensurate with similar cabled arrays in the Northeast and on the West Coast that are part of the Ocean Observatories Initiative (NRC, 2003b; JOI, 2006). Use of industry expertise and infrastructure should be viewed as a significant and potentially cost-effective way to increase monitoring in a number of sectors.

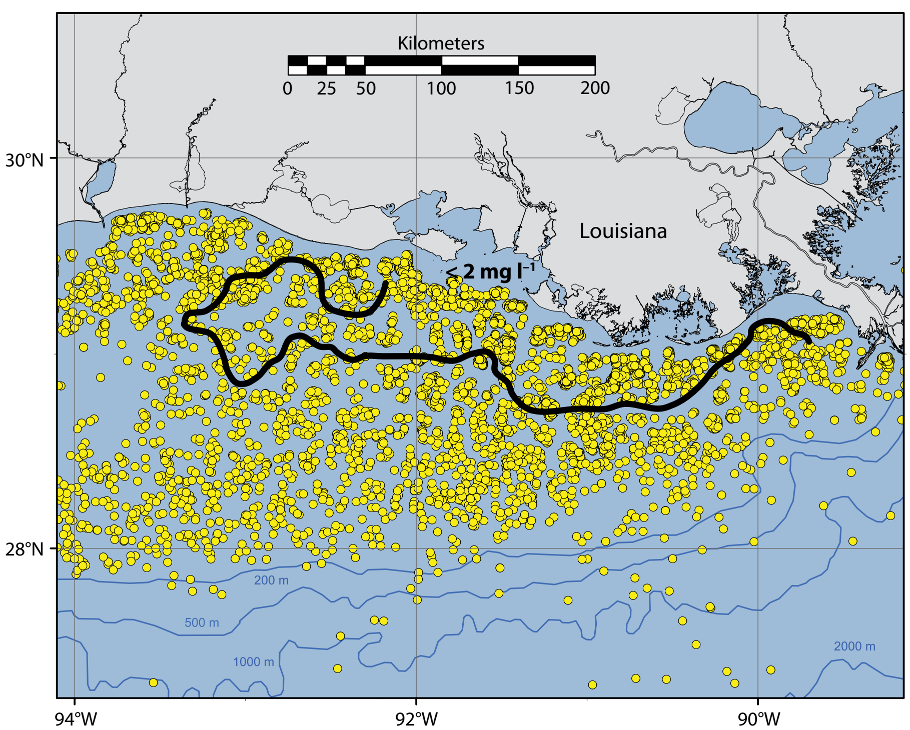


Figure 2. Locations of current oil and gas infrastructure (yellow dots, Figure 1) and the approximate isoline of hypoxic bottom water (< 2 mg $l^{-1}$ dissolved oxygen) based on July 2011 sampling by the Louisiana Universities Marine Consortium (http://www.gulfhypoxia.net/Research/Shelfwide Cruises/2011/PressRelease2011.pdf).

## HOW SHOULD WE PROCEED?

Before investing heavily in observing system enhancements, three main design principles should be considered in developing a system that is responsive to Restoration Council and other high-priority observing goals.

First, priority should be given to funding observing programs that result in the generation of meaningful ecosystem indicators that inform the restoration process. There are a number of considerations in selecting such indicators (Rice and Rochet, 2005) and their associated variables (e.g., biological measurements and related environmental parameters), but they should (1) be responsive to improvements in the management of Gulf resources and restoration programs/projects, (2) be relatively unresponsive to extraneous drivers, and (3) be practical and cost-effective in their implementation. In addition, the process of indicator selection should include input from resource managers, stakeholders (including resource users), and the general public, which would lead to an integrated assessment of the effects of restoration activities and their likelihood of success (Levin et al., 2009). Important and underutilized concepts in ecological monitoring developed during observing system simulation experiments should be considered in developing an integrated Gulf observing system; such simulations are typically used in designing weather and climate observation networks (Masutani et al. 2009), and applying statistical power analyses (Peterman 1990) to them can help to answer the question, how much sampling is enough? Integrating observing as an element of a decision support system also requires development of human and analytic capacity to assess resource status and evaluate societal choices and consequences when making controversial resource management and allocation decisions.

Second, to effectively ascertain the success of restoration efforts and, also, the impacts of significant, ephemeral events, they need to be viewed in the context of the larger Gulf of Mexico ecosystem. This ecosystem approach to science and management is important in separating signal from noise and for identifying conflicting or synergistic management goals. For example, strategies for wetlands rebuilding based on diverting river flows into marshes may also be useful in denitrification of riverine inputs into the Gulf. This required level of ecosystem understanding and broad-based sampling also helps in preparing for and potentially mitigating the effects of the next environmental catastrophe, which is an all-to-frequent occurrence in the Gulf of Mexico. Enhanced observing at a hierarchy of spatial and temporal scales will help address the issue of the cumulative effects of local restoration projects on the overall health of the Gulf of Mexico's large marine ecosystem while also assessing the success of individual efforts and restoration techniques.

Third, a number of sectoral interests have considered their information gaps and how new and enhanced observations would be used (e.g., Gulf of Mexico Fishery Management Council, 2008; Wolfe et al., 2012). Rather than reinventing the wheel, these efforts should be brought together and analyzed as system-wide investments are considered. In evaluating the merits and needs for additional observing to support various sectors, four questions should be asked before any long-term commitments are made: (1) who will use these data? (2) for what purposes? (3) how can novel observing technologies (e.g., Camilli et al., 2010; Glackin et al., 2011) be incorporated to potentially obtain more precise and cost-effective observations? and (4) how will these specific investments advance the stated goals of the Restoration Council?

A Gulf shrimp trawler tied off to an oil platform. Shrimpers sometimes tie off to oil platforms to avoid being run down by other vessels at night. Cooperative research with Gulf industries such as oil and fisheries can provide important expertise and infrastructure for long-term monitoring and decision making.

## SUMMARY

New opportunities stemming from the RESTORE Act and other funding, as well as improved coordination by the many bodies involved in Gulf observing (Table 1), all signal that the time is ripe for governments, academia, and industries to better collaborate in knitting disparate observing efforts into a comprehensive Gulf-wide *system*. Archiving and disseminating data are key to data integration and use; the several extant efforts should be encouraged, rationalized, and, where appropriate, blended. Coordinating deployment and use of technologies such as acoustic Doppler current profilers, gliders, water-quality sensors, camera-based systems, and communications networks can result in cost-effective observing solutions where none have existed in the past or where investments have been insufficient to provide comprehensive or precise monitoring of important ecosystem attributes. Focusing on a few monitoring priorities of interest to the Gulf Ecosystem Restoration Council increases the likelihood of success and will leverage investments and expertise from government, academia, industry, and other private entities, and will also increase public awareness of environmental conditions in the Gulf. Cooperative research with Gulf industries such as oil and gas, fisheries, and shipping can provide important expertise and infrastructure to support long-term monitoring and to encourage greater industry buy-in for science that supports management decisions. A key ingredient for success that is missing is a governance-leadership model that coordinates across state, federal, academic, and industry resources. Such coordination would lead to the development of an integrated modeling and analysis system that supplies timely science products to help guide management decision making for ecosystem recovery. Because of the distributed nature of the funding involved, by its nature, leadership has to be in the realm of "soft governance." Nevertheless, designation of a lead entity or creation of a new science coordination body is a priority if we are to minimize programmatic overlap and maximize our ability to meet stated goals. Now is the time for bold leadership to bring observing efforts together to meet the ecosystem restoration challenges in the Gulf.


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