



GULF OF MEXICO COASTAL OCEAN OBSERVING SYSTEM

Harmful Algal Bloom Integrated Observing System (HABIOS) Plan

Prepared by

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1.0 Vision Statement

The vision statement for the Harmful Algal Blooms Integrated Observing System (HABIOS) for the Gulf of Mexico is:

To establish a sustained observing system as part of the U.S. IOOS (Integrated Ocean Observing System) that will facilitate and enhance efforts to monitor, manage, and reduce detrimental effects of harmful algal blooms (HABs) on human health and living marine resources (non-human animals and plants) and to mitigate impacts of HABs on coastal communities.

2.0 Terms of Reference

Numerous microalgae have the potential of producing harmful effects in the Gulf of Mexico. The most significant from the perspective of human or animal health are those microalgae that produce toxins. Some microalgae have an impact by being a poor food source or causing mechanical damage to fish gills. Others are concentrated by filter-feeding shellfish, which are rendered toxic to human consumers. Still other microalgae can be detrimental to the environment through impacts

on the ecosystem (shading of sea grasses, development of hypoxia). The observing system, HABIOS, will address those algae that have a direct impact on the environment, including the human component. Of these, the best known and most important in the Gulf of Mexico is *Karenia brevis*, which is the organism responsible for frequent "Florida red tide" events. However, other species also produce toxins that adversely impact the environment; these are sometimes monitored in the Gulf and also will be considered. While the HABIOS will be designed in such a way as to generally support observing of all harmful algal species, particular emphasis will be placed on observations and impacts of *K. brevis*, given its recognized importance in various regions in the Gulf of Mexico. In the remainder of this document, aspects of HABIOS specific to *K. brevis* will be clearly identified as such to distinguish them from more general HAB monitoring capabilities.

The Gulf of Mexico contains multiple existing systems that are operated by state, federal, and local agencies and by researchers for the purpose of monitoring and forecasting harmful algal blooms and oceanographic conditions that influence their frequency, distribution and fate. The existing efforts include:

- State monitoring and management programs for "red tide" and for shellfish safety, and some have additional information for public health and recreation;
- Federal capabilities include the NOAA operational Harmful Algal Bloom Forecast System (HAB-FS), which provides nowcasts and forecasts of HABs through the HAB Bulletin, and the Harmful Algal Blooms Observing System (HABSOS), which provides integration and dissemination of geographic data relevant to HABs. The Centers for Disease Control and Prevention (CDC) is developing a HAB-related illness surveillance module in its National Outbreak Reporting System (NORS). The module will allow reporting of outbreaks and single cases of human and other animal illnesses as well as some environmental data.
- A coupled federal-state effort involves the Marine Mammal Stranding Networks. The Phytoplankton Monitoring Network has developed a volunteer monitoring network.
- The various ocean observing systems for the Gulf of Mexico provide a variety of oceanographic measurements including observed and modeled winds, currents, temperature, salinity, waves, and others (links to the various systems are provided at gcoos.org).

These systems already provide information for decisions by public health and resource managers. However, they tend to operate independently of each other so that full advantage of all observations is not achieved. In this regard, both the user communities and managers of these systems have identified critical deficiencies that can be addressed through a more comprehensive and integrated approach that will improve our ability to detect HABs more rapidly and provide more accurate and timely predictions of potential impacts. The goal of this plan is to provide the design for such a system.

The plan must include the needed expansion, enhancement, and maintenance of current individual systems into an integrated system of systems that will provide the information needed

for managing and mitigating ill effects of harmful algal blooms on living marine resources, human health, and the socioeconomic state of coastal communities. In particular, the linkage between climate changes and HABS, as waterborne pathogens, is an important impetus for maintaining, expanding, and enhancing the HABIOS (Figure 1). Research has demonstrated spatial range expansions of HABS with climate changes (e.g., Hallegraeff, 1993; Tester et al., 1993). Additionally, because of their short generation times and longevity, many harmful phytoplankton can respond to climate change with a very short time lag. They can spread quickly with moving water masses into climatic conditions that match the requirements of a species in terms of temperature, salinity, land runoff and turbulence (Hallegraeff, 2014).

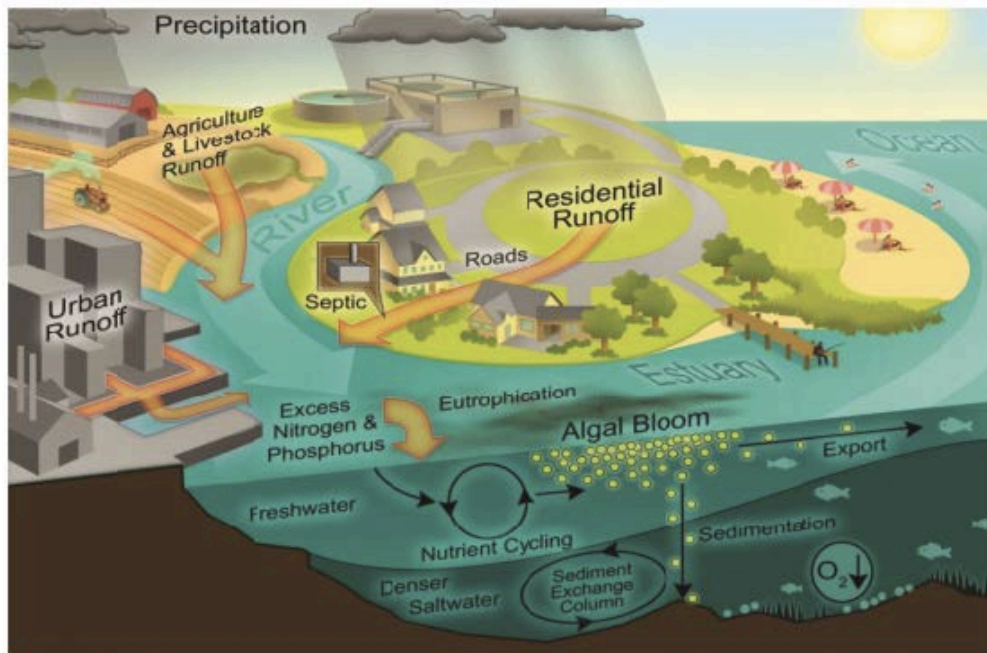


Figure 1. Waterborne Disease Pathways in the Freshwater-Marine Continuum. Many factors link climate change to waterborne diseases and water-related illnesses. Climate drivers such as increasing ocean temperatures, ocean currents, and sea level interact with exposure to contaminants from human activities or wildlife. Humans may be exposed to pathogens or other contaminants through drinking water, seafood consumption, or recreational or occupational water uses (National Research Council, 2015).

The resultant HABIOS to help understand and mitigate the relatively rapid climate change impacts on HAB blooms and address the many user requirements must be 'end-to-end', meaning that it efficiently links observations (in situ and remotely-sensed), data management and communications, and modeling and analysis for the timely provision of data and information in forms and at rates required by decision makers and other users. Of critical importance to the evolution of such an approach are performance assessments by both system operators and users that are used to improve the HAB Integrated Observing System over time. Although the system does not explicitly include research needed to improve detection and prediction capabilities, performance assessments should include the identification of deficiencies that can be used to determine research priorities and a process by which advances in research and operational capabilities are used to improve its

capabilities.

The system must be designed and built in a systematic and efficient manner, and we must be conservative in making decisions to alter or remove existing elements. Step one is to identify the existing capabilities (observations, data management and modeling) that will form the core of the integrated system of systems. At the same time, data providers and end users must work together to identify gaps in needed data and information that would improve the value of the integrated approach for addressing and responding to public and management concerns regarding the health of people, marine organisms, and marine ecosystems. The next step is to systematically enhance the observations, modeling, analyses, and data management and communications so as to fill the gaps in needed information and improve its delivery to users. An ongoing activity is to specify and use system performance metrics and evaluate new research and operational capabilities in order to plan system improvements.

The system design is consistent with design principles in the First IOOS Development Plan and will incorporate the ideas expressed in workshop reports and other documents. Sets of recommendations for observations appropriate and necessary for public health were made at the Workshop on Harmful Algal Blooms Observing System (November-December 2000), the Workshop on Integrating Harmful Algal Bloom Observations into the Gulf of Mexico Coastal Ocean Observing System (April 2004), the Ocean.US workshop on Public Health Risks: Coastal Observations for Decision Making (January 2006), and the Harmful Algal Bloom Observing System Plan for the Gulf of Mexico Workshops, November 2007, April 2009, and March 2012. These documents and workshop notes identify important gaps between the ability to rapidly detect and provide timely predictions of HAB events and their potential impacts. This report sets forth a set of objectives and actions that will begin the process of filling these gaps and developing an observing system that can become operational.

3.0 Goals and Objectives

The overarching goal of the HABIOS is to provide information in forms and at spatial and temporal scales required by decision makers and the public to manage and mitigate environmental and public health impacts of HABs. This shall be accomplished through improvements in monitoring, data management, data integration, and modeling capabilities that address critical gaps in the existing monitoring, observing, forecasting, and information systems as they are identified.

These critical gaps will be further articulated and addressed by achieving several objectives, progressing through the fundamental steps of identifying user requirements, analyzing gaps in meeting these requirements, designing an integrated system, and implementing and evaluating the system:

(1) Identify stakeholder (user) groups and their needs and preferred delivery systems.

(2) Identify areas where HABs are most likely to occur and would have the greatest impact. Areas of concern include shellfish beds, beaches frequented by people, areas most frequented by protected species at risk from HABs, and selected offshore areas where HABs are known to initiate or occur frequently;

- (3) Integrate relevant data in consistent and understandable products and formats.
- (4) Provide for timely archival of, and easy access to, available data on phytoplankton species (including HABs), associated environmental data, and morbidity and mortality events involving marine organisms, and develop methodology for obtaining access to human health data as required;
- (5) Track in real-time and provide timely forecasts (with error estimates) of the species, location, time-space extent of the bloom, cell counts, and toxin levels and characteristics of HABs as well as HAB-associated human illnesses (via NORs) and animal morbidity/mortality;
- (6) Distribute the information in ways that are timely, meaningful, relevant, and readily accessible to the various management and public communities;
- (7) Monitor the effectiveness of the observing system using quantifiable performance metrics that gauge system functionality (e.g., sustained, quality controlled data streams), user satisfaction (e.g., are the data provided in forms and at rates that are most useful to end users), and costs versus benefits;
- (8) Identify human health risks from HAB events, living marine resource risks from HAB events, and the environmental conditions epidemiologic studies should take into account as possible risk factors for exposure/development of disease; and
- (9) Based on stakeholder input, identify areas of research and operations that will improve the system and prioritize these areas.

To reach these objectives will require interdisciplinary and international collaboration and the development of the necessary workforce, with a particular focus on observing technology and taxonomy.

4.0 Objective-Specific Activities

To achieve these objectives, the observing system will be established and evolve to accomplish the activities stated below.

Objective 1- Identify stakeholder (user) groups and their needs and preferred delivery systems.

1. Identify potential user groups, which include: the medical community and departments of health, tourism, beach goers, living marine resource managers, fishing industry, HAB researchers, coastal managers, product providers (e.g., HAB FS, K-16 educators, media, and the public).
2. For each stakeholder group identify specific needs and determine their preferred mode(s) of information delivery. Examples of information for delivery include: web sites, email, NOAA weather radio reports, text message, cell phone, kiosk, brochures, posters, and existing outreach mechanisms (e.g., Gulf of Mexico Alliance (GOMA) or GCOOS).

Objective 2- Identify areas where HABs are most likely to occur and would have the greatest impact.

1. Identify bloom initiation sites and areas of concern for impacts that should be monitored with higher time-space resolution than other areas and that may enhance understanding of bloom initiation and improve forecasting capabilities.
2. Design decision processes to determine pre-planned and adaptive sampling strategies.
3. Determine the presence, location, and extent of algal blooms before they have impacted an area of concern (with enhancement and integration of the several current monitoring programs, including state programs, phytoplankton monitoring network, and HAB-FS bulletins).
4. Monitor, with appropriate sampling methods, the critical areas of concern, e.g. shellfish areas and recreational beaches, for presence and impact of HABs.
5. Determine species and concentration (intensity) of detected algal blooms.
6. Determine the toxicity levels associated with detected algal blooms. In addition to species identification and cell counts, toxin levels influence the extent of negative human/ecosystem health and socioeconomic impacts and the need for response and mitigation.

Objective 3- Integrate relevant data in consistent and understandable products and formats.

1. Identify data, including the abundance and distribution of HAB species, their toxin concentrations, environmental parameters influencing abundance and distribution, human health, animal health, living marine resources, and socioeconomic impacts.
2. Using appropriate analytics, develop algorithms that may be used to develop products useful to stakeholders in shellfish resources, human health, marine animal health, and habitats affected by HABs. The products should assist in forecasting, risk assessment, and estimating potential impacts to the health and economics of the affected areas.
3. Seek access to human health data, which will be restricted, but use collaborations with appropriate scientists to help ensure data access.
4. Expand and improve the efficiency of networks for data and information exchange among the responsible local, state, and federal agencies, and in cooperation with Mexican and Caribbean partners. This includes use of Data Management and Communications (DMAC) standards for data and metadata and enhancement of the HABIOS capability for data management.

Objective 4- Provide for timely archival of and easy access to available data on phytoplankton species (including HABs), associated environmental data, and morbidity and mortality events involving marine organisms, and develop methodology for obtaining access to human health data as required.

1. Provide secure provision for storage and archiving of data and information. Recognize that access to some types of non-aggregated data (including human health data and detailed commercial fishing data) may be restricted due to privacy issues and that access may be

determined on a case-by-case basis. Thus, there is the need to encourage collaboration to ensure access. Storage of human health data will likely be outside the HABIOS.

2. Ensure that all stored data and information can be discovered and retrieved from archives by machine. Build the system to acknowledge differences in data restrictions.
3. Provide mirror (backup) storage for data and information.

Objective 5- Track in real-time and provide timely forecasts (with error estimates) of the species, location, time-space extent of the bloom, cell counts, and toxin levels and characteristics of HABs as well as HAB-associated human illnesses (via NORS) and animal morbidity/mortality.

1. Produce predictions with uncertainties of the onset of HABs in areas of concern.
2. Make all monitoring data for sampling locations and bloom characteristics available in a coherent form for operational nowcasts and forecasts. Improve HABSOS capability (or equivalent) to support the HABs forecasting systems, such as the HAB-FS system.
3. Link observations and models more effectively through data assimilation or data simulation products, such as observing system simulation experiments (OSSEs), that can be used to improve the effectiveness and efficiency of monitoring.
4. Have necessary circulation output from models available in standard formats for nowcasts and forecasts.
5. Implement location uncertainty statistics into forecast models, with information based on both location uncertainty and the use of ensemble models for modeling uncertainty.

Objective 6- Distribute the information in ways that are timely, meaningful, relevant, and readily accessible to the various management and public communities.

1. Provide all pertinent information, including forecasts with error estimates, in a timely and secure manner, to appropriate local, state, and regional coastal managers, using IOOS DMAC standards and protocols.
2. Develop educational materials for system operators, coastal managers, educators, and HABs researchers to increase understanding and value of the products of the HABIOS.
3. Develop outreach materials for identified stakeholders and media in formats specified by the user group and to the general public to increase understanding, usefulness, and value of the HABIOS.

Objective 7- Monitor the effectiveness of the observing system using quantifiable performance metrics that gauge system functionality (e.g., sustained, quality controlled data streams), user satisfaction (e.g., are the data provided in forms and at rates that are most useful to end users), and costs versus benefits.

1. Determine and use performance metrics for the efficacy of observing system functions (the efficiency of linking observations, DMAC, and modeling for sustained product delivery using information provided by data providers and modelers).
2. Determine and implement performance metrics for how well the information provided

- meets the needs of user groups (user satisfaction), with information from users.
3. Establish a users group and have periodic feedback reviews of the system.
 4. Regularly review the HABIOS using quantitative performance metrics.

Objective 8- Identify human health risks from HAB events, living marine resource risks from HAB events, and the environmental conditions epidemiologic studies should take into account as possible risk factors for exposure/development of disease.

1. Identify human health risks from HABs.
2. Identify human health databases.
3. Identify living resource databases.
4. Support development of human disease surveillance, e.g. NORS vibrio wound infections, waterborne, disease outbreaks. Include environmental data as risk factors in human epidemiology studies. Assess how to incorporate other health-related data into the process (from identifying health risks to modeling), including poison information center calls, local physician networks, hospital admissions, emergency room visits, etc. Assess how to involve veterinarians in relevant companion animal disease surveillance.
5. Assess how to involve veterinarians in relevant companion animal disease surveillance.
6. Use links for abstracting limited human health data to non-health databases and import relevant environmental data to health-based databases.
7. Coordinate epidemiological studies (animal and human) with HABs observations and associated environmental conditions.
8. Create, or collaborate to use, a model to integrate human health e.g. Environmental Public Health Tracking Network.
9. Create living marine resource health and environmental data model.

Objective 9- Based on stakeholder input, identify areas of research and operations that will improve the system and prioritize these areas.

1. Based on user needs and current operational capabilities identify research priorities for species identification and enumeration; measurements of toxicity; measurements of physical, chemical and biological variables made synoptically in time and space and with sufficient resolution to improve predictive capability.
2. Identify research priorities for improving data assimilation techniques and numerical model predictions.
3. Identify research priorities for improving interoperability among contributing systems and components (e.g., the establishment of standards and protocols for measurements and data integration).
4. Assist stakeholders in data management by providing templates for metadata and educating these entities in platforms and transfer protocols that enhance data assimilation.

The following sections are organized according to implementation categories, followed by appendices with program-specific recommendations for enhancement:

- Implementation I = Observations and Models;
- Implementation II = Data Management, Communications, and Performance Metrics;

- Implementation III = Linking Public Health and Living Marine Resources with Ocean Observations;
- Implementation IV = Improving Operational Capabilities through Research;
- Implementation V = Information Delivery; and
- Implementation VI = Integration

5.0 Implementation I: Observations and Models

5.1 User Requirements

The development of an integrated observing system that addresses multiple goals, a variety of data needs, and multiple impacts must consider the range of HAB occurrences with regard to specific species and their toxin production or potential for toxin production, characteristics of bloom formation and transport, routine and 'event' driven observations, and data necessary to populate and verify multiple models. To meet management needs for rapid HAB detection and response, and HAB prediction, prevention, control, and mitigation, the monitoring and modeling capabilities of the HABIOS should strive to:

- Detect and quantify a broad range of HAB types across the region. HABs should be considered a 'moving target', and novel occurrences or anomalous distributions (i.e., new introductions) of HABs should be expected (e.g., brown tide in Texas). There are currently known HABs in the Gulf of Mexico that threaten human health and living resources, such as *Karenia brevis* and a series of toxic cyanobacteria. Other HABs known to cause problems elsewhere also occur frequently across regions of the Gulf of Mexico, such as *Pseudo-nitzschia*, additional dinoflagellates, and raphidophytes. The types of observations and models proposed for an observing system must remain flexible to changes in the HAB conditions of regions around the Gulf.
- Implement regional specificity in monitoring and modeling approaches to maximize cost-effectiveness and operation efficiency. Regional differences in monitoring approaches are expected in the use of cost-prohibitive technologies such as the BreveBuster or genetic probe analyses. The HABIOS should take into account the needs of different regions across the Gulf of Mexico and within specific water bodies (e.g., upper estuary, lower estuary, shorelines, and offshore waters). It is essential that observations and models be identified by, and developed with, multiple stakeholders and users of the information, and aspects such as monitoring and modeling should be developed in a complementary manner.

Existing observations and models are not adequate to address the system requirements listed above. This may be due to a lack of technologically advanced observing tools, insufficient number and distribution of observation systems and sites, inadequate coverage of the range of observations from species counts to emergency room visits for respiratory problems, and lack of appropriate models. All these needs cannot be addressed at once. Steps towards a fully implemented observing system are to identify existing assets including current and potential technology, information needs for multiple users, initial steps towards populating an observing system, and a timed, phased and

prioritized plan. The eventual observing system will inevitably be driven by regional needs, costs, and technologies.

5.2 Existing *In situ* Observations and Preliminary Gap Analysis

5.2.1 State monitoring

Key components of the *in situ* measurements and surveillance should include regular observations for bacteria and toxin-producing HABs on beaches, shellfish beds, and other water bodies of HABs concern in the coastal zone. Other key areas for measurements and surveillance are fish kills, animal morbidities and mortalities, and human health.

Each Gulf of Mexico state has a similar shellfish monitoring program driven by the Food and Drug Administration and the National Shellfish Sanitation Program regulations. The EPA's BEACH program sites are tested for determination of swimming advisories. These programs are intended primarily for bacteria, such as, fecal coliforms for shellfish growing waters and *Enterococcus* at the swimming beaches. These sites may be part of required sampling or may be used as collection sites of opportunity for observation of HABs in near shore water. Shellfish producing states also monitor for potentially toxic HABs and their toxins in a biotoxin contingency plan for the National Shellfish Sanitation Program. The target organism for most monitoring is *Karenia brevis*, but some states (e.g., Alabama, Florida, and Mississippi) do counts for all dinoflagellates, raphidophytes, and *Pseudo-nitzschia*. There are routine sites and sampling frequencies for each state, but there is also event driven monitoring.

The states of Mexico have routine monthly monitoring of water bodies at specified locations (mostly near population centers) for bacteria and HABs. The states conduct shellfish monitoring with products from the seafood markets. If a sample (water or shellfish) is found to be toxic, an event response study to better identify the location and organisms is conducted with aerial surveys and water samples taken by naval ships. The Mexican red tide national program started in March 2005 under the Federal Commission for Sanitary Risk Protection (COFEPRIS), with the participation of coastal states aimed to establish a harmful algal bloom early detection system, by monitoring the phytoplankton and marine bio-toxins. These efforts have been key as Mexican states establish appropriate preventive measures, such as, avoiding mollusks consumption during red tides events. Public notices are posted for shellfish contamination, beach advisories, and in some cases beach closures.

The details of state agency monitoring programs, with gaps identified, are in [Appendix 1](#).

The former Water Quality Team, now Water Resources Team, of GOMA has worked to develop an interstate agreement on standard collection methods and sample protocols for analyses. One resource for this standardized approach is the Gulf Monitoring Network Design (GOMA and GCOOS, 2013).

The GOMA team has identified the need for standard protocols for:

- Chlorophyll *a* measurements;
- Taxon specific procedures for chain of custody, collection, preservation, and enumeration

of HAB species; and

- Mandated or recommended thresholds for non-*Karenia* HABs that are a problem, such as *Pseudo-nitzschia*, *Alexandrium*, *Dinophysis*, toxic cyanobacteria, and others. U.S. action levels for biotoxins in shellfish tissue produced by HAB species (e.g., *K. brevis*, *Pyrodinium bahamense*, *Dinophysis* spp., *Pseudo-nitzschia*) exist, but not for other species (e.g., cyanobacteria). Only *K. brevis* has cell concentrations established for actionable management decisions.

In lieu of standard protocols, the relevant state agencies should compare measurements made according to their agency with those of other states. For example, an inter-state comparison for determination of chlorophyll *a* can be conducted to determine the level of similarity of results. Such a comparison is currently being undertaken the auspices of the GOMA. The results may be seen at <http://www.gulfofmexicoalliance.org/2013/11/round-robins/> . Additional workshops can be held to optimize protocols for sampling and detecting specific HAB organisms.

Standardization is a first step towards optimizing sampling schemes, but additional human resources are necessary to provide the level of sample processing that is necessary to adequately monitor HABs. Funding is necessary for the training of personnel to collect and accurately identify HABs and to use instrumentation. GOMA is a mechanism for training workshops for agency personnel. In the long-term, high-end technology that can count, image and identify HAB organisms will increase the efficiency and accuracy of counts. For regulatory purposes, microscope verification is required for HABs, such as, *K. brevis* and *Dinophysis* spp,

In addition to identification protocols, there is a need to optimize toxin assays for performance and affordability. Technology-based solutions will increase the efficiency and accuracy of toxin detection, which better protects the public from disease and illness and living resources from negative impacts.

There also is the need for *in situ* instrumentation that would help identify the potential for a bloom of a HAB via chlorophyll biomass. Deployment of optical instrumentation for chlorophyll fluorescence detection (see Table 1.) is one potential method for identifying a bloom and initiating an event response. In the same way that chlorophyll anomalies can be detected from a series of satellite imagery, an *in situ* instrument can identify an increase in phytoplankton biomass. Real-time data relay would optimize field sampling for potential HABs. While not the same as a chlorophyll detector, the BreveBuster can provide an early warning by measuring indicators of high numbers of a few species and initiate an event response.

5.2.2 Volunteer-based efforts

Volunteer-based sampling and surveillance networks expand the states' monitoring efforts by gaining more observations and expanding observations to locations where state agencies do not sample. The usefulness and quality of the observations depends on the protocols of the various programs. A volunteer generated sample identification and count could not be used for regulatory purposes. These efforts do, however, provide valuable information, such as:

- 'First alert' information that can be subsequently investigated;

- Additional knowledge of the distribution of harmful algae;
- Phytoplankton community data for regions that would not be available otherwise; and
- Outreach and education tools for phytoplankton ecology and HAB awareness.

A limitation of these programs is the number of agency-supported personnel that are required for some steps in the process, but this is the same limitation for state agency programs.

Volunteer programs include the Plankton Monitoring Network (PMN) organized by NOAA's Hollings Marine Laboratory of the National Centers for Coastal Ocean Science, Charleston, SC and the Florida Volunteer Offshore Sampling Program run by the State of Florida.

The PMN was established as an outreach program to unite volunteers and scientists in monitoring marine phytoplankton community and harmful algal blooms. Objectives are to create a comprehensive list of marine phytoplankton and potentially harmful algal species, identify trends and hot spots (times and places where HABs are more likely to occur), and increase public awareness of phytoplankton and HABs through education and outreach. The network uses trained volunteers to collect water by plankton net and identify phytoplankton by microscopy. Rough count estimates are made of relatively abundant phytoplankton or recognized harmful algal species, and these samples are sent to the Hollings Marine Laboratory for verification of identity. The data are not quantitative and the 20- μ m net does not capture smaller HABs, including an unknown percentage of *Karenia brevis* cells.

Volunteer groups measure the abundance of 36 different taxa of phytoplankton as well as salinity and temperature. Efforts are underway to obtain probes to measure dissolved oxygen, pH, and nutrients. Each group monitors at least twice a month and most measure weekly. Sampling is along the coast, mainly along piers and docks and in places of historical HAB outbreaks. The NOAA National Coastal Data Development Center, now the National Center for Environmental Information (NCEI) at Stennis, has developed an on-line data entry tool, which allows data to flow to NCCOS where it is uploaded to an internet map service (IMS). Personnel at NCEI plan to "move" the volunteer data into the HABSOS database instantaneously and without problems because they host both databases. The data flow, transfer, and public access through this system are not yet clear.

There are 25 PMN groups in Texas and seven in Alabama. Alabama has modified the standard PMN approach by requiring a scientist to accompany the volunteers during sampling and analysis. This can improve the reliability of identification data, but requires significant people hours. For more information, go to <http://www.nos.noaa.gov/nccos/npe/projectdetail.aspx?id=51&fy=2008>.

The Florida Fish and Wildlife Conservation Commission's Fish and Wildlife Research Institute (FWRI) maintains a Florida Volunteer Offshore Red Tide Sampling Program <http://myfwc.com/research/redtide/monitoring/current/offshore-monitoring/> in which volunteers (stakeholders with HAB interests and offshore access, such as charter fishermen and Coast Guard Auxiliary Units) assist the state with *K. brevis* monitoring efforts by collecting and providing water samples to the state for analysis. Water is collected by volunteers both at defined monitoring sites and in response to events, primarily at offshore sites difficult for FWRI scientists to access. Samples are transported to FWRI within 1-2 days, where they are enumerated for more than 70

HAB species. These data are included in biweekly state HAB reports, which also include data and results from samples provided by subcontractors as well as state and local entities, which provide water samples to FWRI as part of various ongoing coastal monitoring programs. All monitoring data is entered into the Florida HAB historical data base and provided to Florida Department of Agriculture and Consumer Sciences (FDACS) for commercial shellfish management decisions, to interested state and county agencies, to NOAA for ground truthing of the NOAA HAB Bulletin, and to HABSOS for inclusion in HAB databases. The Florida Department of Health, CDC (Center for Disease Control) and public and private partners have also established a linked network of public health information coupled with exposure and disease surveillance on Florida red tide. State red tide monitoring information is linked to the South Florida Poison Information Center Hotline (888 232 8635), which provides 24-hour health information on HAB related health and safety concerns in multiple languages. The Hotline also reports cases to the FL Department of Health as part of ongoing harmful algal bloom surveillance. Florida also maintains several hotlines for the purposes of accessing Florida regional red tide status reports (866-300-9399 or outside Florida 727-552-2448) and reporting HAB impacts, including a fish kill hotline (800-636-0511) to report fish kills, diseased fish, or fish with other abnormalities, a Wildlife alert hotline (888-404-3922) for reporting wildlife in distress from HABs. All calls are entered into a database and investigated for appropriate followup.

The Oyster Sentinel program <http://www.oystersentinel.org> is supported by private funds and the Texas Department of Parks and Wildlife, and uses volunteers to sample oysters at 90 sites (50 routinely sampled) from Charlotte Harbor to Lower Laguna Madre. The oysters are analyzed for *Perkinsus marinus*, a protozoan parasite that causes Dermo, a fatal disease of oysters. The incidence of the disease is used as a bioindicator of the freshwater requirements of estuaries and overall estuarine health.

The relevant aspects of these volunteer networks should be expanded into a coordinated and systematic network for all Gulf of Mexico states.

5.2.3 Private and research-based efforts

Private organizations and academic and research institutions also collect data on phytoplankton community composition, distribution, toxin levels and general ecology. Depending on the funding source and type of data collected, many of these data (with required metadata) are submitted to centralized archival systems, such as NOAA's National Ocean Data Center. These data, where relevant, provide additional information on phytoplankton ecology, including noxious and harmful species. Most of these programs are funded based on competitive research awards and are not long-term commitments to monitoring.

5.2.4 Observations from moorings and autonomous underwater vehicles

Routine, real-time *in situ* measurements are needed, especially in locations that are known to have frequent HAB events. These include both measurements of environmental parameters (physical, water chemistry, temperature, salinity, etc.) and biological parameters, including the abundance of HAB species and toxin levels.

5.2.4.1 HAB and toxin identifications

Light microscopy is sufficient for identification and enumeration of the majority of HAB species in the Gulf of Mexico. For selected genera, e.g., *Pseudo-nitzschia*, toxic species are difficult to distinguish from non-toxic species under light microscopy and therefore may require further examination with electron microscopy or molecular methods. These identifications are time consuming, expensive, require expertise, and are not real-time. Therefore the development of rapid, accurate and simple detection and quantification methods for harmful algal cells, as well as for their discrimination from morphologically similar species, are necessary for monitoring efforts. Besides microscopy, these detection methods can include a variety of molecular, optical, and satellite techniques. Method development, inter-comparisons, and assessments for appropriate management uses for each HAB species are needed for each of these methods. Proven and emerging technology, such as described below, can be placed on platforms, moored buoys or autonomous underwater vehicles (AUVs) or incorporated into a laboratory setting.

Molecular techniques are helpful when a) taxonomic expertise is not available and b) a rapid throughput of samples is required. A variety of molecular based techniques are under development for HAB species, including whole cell analyses (e.g. Fluorescence *in situ* hybridization [FISH] Assays) and extracted DNA assays (e.g., Sandwich Hybridization Assays). Real-time PCR (polymerase chain reaction) assays have potential, but require extensive development to provide quantitative results.

Optical detection methods include fluorescence and image based systems. Pigment based systems include HPLC for detection of HAB specific pigments (e.g., gyroxanthin di-ester in *Karenia* species). Most imaging systems are based on flow cytometry, which count and image microscopic particles suspended in a stream of fluid (e.g. the Imaging Flow CytoBot and FlowCAM).

A variety of toxin detection methods are available for HABs (e.g., fish and mouse bioassays, High Pressure Liquid Chromatography (HPLC) analysis, Liquid Chromatography-Mass Spectrometry (LC-MS) analysis and Enzyme-Linked Immunosorbent Assay (ELISA). Mass spectrometry is required for confirmation of toxin identity, however ELISA based assays are the most promising assays under development and assessment for rapid assessment and throughput.

5.2.4.2 Ancillary environmental data

As much environmental data (see Table 1) as possible should be collected to define the system in which the HAB events occur, including meteorological and oceanographic data that provides for modeling, prediction and forecasting.

Table 1. Examples of probes and instrumentation; these may be placed on platforms, moored buoys, or autonomous underwater vehicles (AUVs).

Environmental Parameter	Example
Wave height	
Current	Teledyne ADCP
Temperature	YSI sonde etc.
Salinity (conductivity)	YSI sonde etc.
pH	YSI sonde etc.
Dissolved oxygen (electrode or optrode)	YSI sonde etc. Ocean Optics
CDOM fluorescence	YSI sonde etc.
Turbidity	YSI sonde etc.
Particle size	Sequoia LISST
Irradiance or reflectance	Satlantic OCR or TSRB
Attenuation/transmission Single-channel beam <i>c</i> Multi-channel <i>a, b</i> Hyperspectral <i>a</i>	WETLabs C-Star WETLabs ac-9 Kirkpatrick BreveBuster
Nutrient (optical and wet chemistry)	Satlantic ISUS Envirotech NAS-3X
Bulk Biological Parameter	Example
Active fluorescence (single-channel Chl or phycobilin)	Turner Designs Cyclops
Active fluorescence (multi-channel excitation; detection of Chl FI)	Moldaenke Fluoroprobe, Walz PhytoPAM
Variable fluorescence (F_v/F_m)	Chelsea Fastracka
Sub-assembly Biological Parameter	Example
Imaging flow cytometry	FlowCam, FlowCytobot
Gene probes	McLane ESP

5.3 Monitoring Program Design

A sampling scheme for the Gulf of Mexico can provide a general plan for the overall region, but the exact design for a sub-region will depend on the current occurrence of HAB events and the potential for emerging HAB conditions. For example, it is obvious that *Karenia brevis* blooms are a widely distributed and recurring event on the western Florida shelf, the south Texas coast, and along regions of the Mexican coast. Monitoring programs there would differ from areas where *Pseudo-nitzschia* blooms develop or where toxic cyanobacteria develop in the upper parts of estuaries.

The concept of 'site' is also variable across the Gulf of Mexico and depends on the type of HAB bloom and the mechanisms of monitoring. A 'site' can be an instrumented array, an AUV track, a location where water samples are collected, or a region that can be imaged by remote sensing. The type and number of 'sites' will depend on whether the intent is to maintain background information and to develop an alert of a bloom initiation or perhaps to clearly define the extent of

a bloom and its progression in development. Suggestions for sampling design may be found in the Gulf Monitoring Network Design document (http://www.gulfofmexicoalliance.org/projects/files/goma_gulf_monitoring_network_design_report.pdf).

5.3.1 Site selection

Ideally in the next two decades, there should be a substantial population of high technology platforms from the Yucatan to the Florida Keys. Fixed-point measurements focused on environmental parameters solely for HABIOS is likely cost prohibitive. A simpler, but still valuable beginning would be the placement of HAB instrumentation on existing assets, such as those in the NOAA National Water Level Observation Network and National Data Buoy Center, U.S. Geological Survey, the Texas General Land Office's Texas Automated Buoy System, LSU's Wave-Current-Surge Information System (WAVCIS) sites (some already instrumented with water chemistry, fluorescence and dissolved oxygen), Louisiana Universities Marine Consortium (LUMCON's) environmental monitoring System, National Estuarine Research Reserve (NERR) sites, Florida Coastal Ocean Monitoring and Prediction System (COMPS) buoys, and state agency instrument deployments, many of which provide real- or near-real time observations.. The initial addition would be chlorophyll fluorescence detectors, which could be added easily to these existing assets.

Other existing assets are High Frequency (HF) radar sites for measurement of surface currents and, for some types of HF radars, also surface waves. IOOS has coordinated a National Surface Current Monitoring Plan to populate the U.S. coasts with HF radar systems for continuous, real-time measurements of near shore surface currents. Within the National Plan, GCOOS and SECOORA have developed a coordinated plan to integrate and expand the existing HF radar assets in the Gulf. This resultant surface current and wave information will be invaluable for understanding and tracking HABs.

Eventually, HABIOS would need to extend beyond existing assets and strategically place HAB-specific platforms (moored buoys, profilers). An important criterion should be that there is some history of HAB events in the area. While HABs have been reported over most of the coastline of the Gulf, the intensity of effort in an area should correspond with the likelihood of HAB events in that area.

Site selection is often a result of optimizing information, logistical ease, and/or or identification of areas where there are likely to be problems, e.g., mouths of estuaries, on bridges or near aquaculture facilities. Offshore deployments have significant logistical problems for access, power, telemetry, etc. When selecting fixed sites or glider paths, another important criterion should be asset protection.

5.3.2 Number of sites

The spatial distribution of monitoring sites is highly dependent on the nature of the HAB history, frequency and distribution of HABs, and emerging HAB issues—all of which vary by region around the Gulf of Mexico.

For HABs, such as *K. brevis*, that cover large areas, systematic sampling during an event is required. For some blooms, this may be adaptive; a bloom extent or presence may be indicated from satellite imagery and moorings, and the exact bounds need to be identified, particularly for modeling purposes.

The spatial distribution of a HAB is a key part of a nowcast or forecast, and is required to initialize transport models. Location data from a variety of sources is interpreted to create the HAB Field, and the quality of the field is limited by the resolution of the available data. *In situ* and ground-based samples are necessary.

For example, the current implementation effort along the west Florida coast from Tampa Bay to Naples aims to deploy 10 fixed detectors (about 20 km spacing along the 10-m isobath) to track movement along the coast. Four additional detectors are located near two shellfish farms in the Charlotte Harbor area. Because Florida HAB events most often initiate 15 to 40 km offshore, the state is increasing their HAB detector-equipped fleet of AUVs to five units so they can have two AUVs continuously sampling offshore waters.

While Florida's current *Karenia* monitoring effort is extensive, the minimum resolution of determining bloom presence (with a minimum of high, medium, low concentrations) by satellite along and near the coast is $10 \text{ km}\cdot\text{d}^{-1}$ (one sample every 10 km on each day). Areas with critical public health concerns may require $1\text{-}4 \text{ km}\cdot\text{d}^{-1}$. The current combination of satellite and cell counts can identify general areas of HABs, but cannot provide details for the coast at resolutions better than $10\text{-}50 \text{ km}\cdot\text{d}^{-1}$. It is critical that during an event, the sampling is sufficiently systematic to confirm where a bloom is not present, as much as where it is.

Respiratory irritation requires equivalent measurement resolution (better than $10 \text{ km}\cdot\text{d}^{-1}$ and $1\text{-}4 \text{ km}\cdot\text{d}^{-1}$ in critical public health areas). These data are essential for validation of forecasts of respiratory irritation.

Fluorometer-equipped AUVs would be an ideal mechanism for increasing the number of 'sites' that can provide information on general phytoplankton ecology and information that could lead to a HAB event. AUVs also have the advantage of providing chlorophyll data that is not in view of satellites either due to depth or weather. The spatial distribution of AUVs would depend on the type of AUV and length of coastline. For instance, a 200 km coastline would require three of the smaller propeller driven AUVs to be able to respond to gaps in satellite coverage.

For fully equipped HAB and associated environmental parameter instrumented sites, a preliminary count for such needed assets is: Florida add 5 or 6 to existing 5 or 6, Alabama add 1, Mississippi add 2, Louisiana add 3, Texas add 6, Tamaulipas add 2, Vera Cruz add 2, Tabasco add 1, Campeche add 2, and Yucatan add 1.

5.3.3 Suite of measurements

Besides the obvious need for taxon specific identification and enumeration of HABs and toxins, there are several environmental parameters that are necessary for a complete understanding of bloom initiation, bloom distribution, and bloom movements. These data are also critical for

modeling efforts. For instance, because the source of *Karenia brevis* blooms off the Florida panhandle is advection of bloom waters from the southwestern Florida coast, the need for meteorological and physical oceanographic measurements in that area are critical for predicting where the bloom may eventually move. Ancillary data concerning nutrients, light fields, temperature and salinity also support better understanding of bloom initiation and maintenance for ecosystem-level models. The list of moored instrumentation (Table 1) is a guide for the potential ancillary data.

5.3.4 Reporting requirements

Real-time (or near real-time) data are essential due to the dynamic nature of HABs. Some of the ancillary data should also be provided real time, e.g., currents. Other instrumentation may record the ancillary data for eventual downloading and use in models and development of forecasting capabilities.

5.3.5 Logistics

In design of monitoring systems, particularly deployed instrumentation, the logistical needs of deployment, servicing, calibration and recovery of data need to be considered. The cost of the instrumentation and the eventual platform (mooring, buoy, etc.) is a small portion of the overall cost. Maintenance of the system requires full attention and quality technological support.

5.4 Remotely Sensed Observations

Remotely sensed observations used for routine detection and monitoring of HABs are typically satellite-based. Satellites provide ocean color (i.e., water-leaving radiance) and sea-surface temperature (SST) that have been used either to identify oceanographic features linked to HABs or signatures of HABs themselves. In particular, the calibrated ocean color sensors, the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) and the Moderate Resolution Imaging Spectrometer (MODIS), are used to identify optical features that are distinctive of *Karenia brevis* blooms. Unusual blooms of other algae may be found under certain conditions, although resolution and spectral bands limit the value of satellites for HABs in many Gulf estuaries. SeaWiFS operated from 1997 to 2010. MODIS on the Aqua sensor (starting in 2002) has better quality for ocean color than MODIS on Terra (starting 1999), although MODIS-Terra can provide qualitative data.

For SST, the Advanced Very High Resolution Radiometer (AVHRR) and the MODIS sensor provide the best data. Both of these are 1-km data sets, and processed with standard algorithms, with routine validation by NOAA and NASA. There are normally two AVHRR sensors operating, and currently MODIS is working on two satellites; the combination provides up to eight passes per day.

SeaWiFS and MODIS 1-km field-of-view data are the best available for working with satellite ocean color. MODIS also has 500 m and 250 m bands that can be used to provide observations at higher spatial resolution, and these products need to become part of the standard capability and merged with the 1 km data to ensure continuity at the coast and in estuaries. Other sensors that provide data of potential value include the Indian Ocean Color Monitor (OCM) and the European Medium Resolution Imaging Spectrometer (MERIS). These are standard ocean color sensors, but the calibration of these sensors is not as well developed as for SeaWiFS and MODIS. Furthermore,

strategies are needed for integrating ocean color data from multiple sensors with differing band characteristics and performance. A comprehensive MERIS 1 km data is available during the sensor life of 2002-2012; 300 m data is available, although not with the same frequency. While satellite observations can aid in detection and monitoring of HABs, it is important to note that the information provided by satellites is not specific to HABs. As an example, the HAB Forecast System uses a combination of satellite algorithm ensembles and a set of heuristic rules in order to locate and identify blooms. Several satellite algorithms are combined in order to identify the presence of blooms and the likelihood that the blooms are *Karenia*. This ensemble strategy allows for incorporation of new algorithms, rather than using exclusively one algorithm or another. The current ensemble uses an anomaly, the chlorophyll to backscatter relationship, and spectral shape in the blue wavelengths. In addition, a set of rules based on the environmental conditions, prior knowledge of bloom events in specific regions, and information from field observations enhance monitoring from day to day. New satellite algorithms are being evaluated to explore additional information from the imagery. These include approaches that examine backscattering to chlorophyll a ratios, RGB (red green blue) composite images, and MODIS fluorescence in order to distinguish and track *Trichodesmium* specific blooms (from *Karenia* blooms) in Florida coastal waters.

Sensors on aircraft for monitoring and assessing HABs are available and should become operational as part of the HABIOS. Aircraft-borne sensors can provide high spatial and spectral resolution and can sample on cloudy days. At present, aircraft observations are used for spotting blooms, but not for quantitative analysis. With the application of high spectral resolution radiometry, discrimination of phytoplankton from other constituents in optically complex coastal waters is more feasible. Types of aircraft-based sensor observations include radiometry (getting a line of measurements), as well as imagery (acquiring an array of pixels each containing spectral data that can be used to form an image).

Both federal and university-based facilities downlink and/or process satellite data, that is useful for HAB detection and tracking. The NOAA CoastWatch program (and others) provides standard products, and several university and research laboratories (e.g., the Naval Research Laboratory at Stennis Space Center, University of South Florida) produce experimental products.

Although the HABIOS must depend on the availability of satellite data as determined by national priorities (e.g., the National Research Council Decadal Survey), the GCOOS Regional Association should weigh in on priorities for improving satellite-based remote sensing capabilities that will serve regional needs and be consistent with NASA and NOAA mission priorities. IOOS requirements for HABs and key environmental parameters are only partially addressed by existing and planned satellite missions. Information requirements that are particularly significant for elucidating HAB dynamics and for early detection of HABs are outlined in the background paper prepared by Thomas Malone and were provided for the GCOOS HABs Observing Plan Workshop (14-16 November 2007).

5.5 Adaptive Observations

Adaptive observations are triggered by: a) detection of conditions that are likely to lead to a bloom (combination of environmental factors that favor the development of a *K. brevis* patch and/or a *Trichodesmium* bloom), b) detection of a bloom indicator (e.g., pigment signatures detected bio-

optically from AUVs and/or ocean color images from satellite sensors), and/or c) direct measurements of *K. brevis* abundance. Adaptive sampling increases the time-space resolution of observations in the domain where a bloom is likely to occur or is occurring, depending on what triggers adaptive sampling and the objectives (Table 2). Adaptive observations could include a modeling strategy that could be adjusted in response to events.

Table 2. Examples of three adaptive sampling schemes, each with a different objective. The schemes could be implemented sequentially. Scheme (3) would be implemented only after (2). Note that adaptive observations may be initiated with any one of the three schemes or may involve phased implementation of schemes (1), (2) and (3), respectively.

Trigger	Objective	Adaptive Sampling Scheme
(1) Environmental conditions favorable for a bloom and/or a <i>Trichodesmium</i> bloom	Weekly nowcasts of where and when a bloom is likely to occur during late summer-fall	Monitor key environmental variables and phytoplankton species composition daily in the targeted area in 3-D until a bloom occurs or conditions change to unfavorable. AUVs, mobile moorings, ship-based sampling
(2) Detection of a <i>chlorophyll-a</i> patch	Validate the indicator & determine patch size An alert giving the location and extent of a new bloom followed by daily nowcasts of location and extent	One time, ship-based survey of the patch in 3-D to confirm the presence of a HAB species & estimate patch size; microscopic analysis and/or molecular probes Aircraft-based remote surveys of the patch domain (using ocean-color sensors similar to the Sea-viewing Wide Field-of-view Sensor)
(3) Validation that the <i>chlorophyll-a</i> patch is caused by <i>K. brevis</i>	Daily nowcasts of bloom status (growing or dissipating) & toxicity (low, moderate, high); 2-3 day forecasts the patch's trajectory updated daily	Monitor patch in 3-D at 2-day intervals to estimate abundance and determine toxin levels per cell. AUVs, mobile moorings, ship-based sampling, aircraft-based remote surveys of the patch domain (using ocean-color sensors similar to the Sea-viewing Wide Field-of-view Sensor)

5.6 Models

Models will be used in conjunction with observations to accomplish the following:

- Determine the critical data and information requirements for modeling, forecasting, and validation, as well as inventory existing data systems;

- Track and forecast the location and characteristics of HABs (with error estimates); and
- Validate forecasts (improving on the current HABS-FS validation) and relevant models, both operational and retrospectively.

5.6.1 Determine the critical data and information requirements for modeling, forecasting, and validation, and inventory existing data systems, including state, federal, local, research and Mexican Navy for their ability to provide data for models and forecasts.

- Inventory environmental parameters required for forecasting HABs.
- Inventory the environmental parameters specific to forecasting human exposure and effects.
- Inventory the environmental parameters specific to forecasting animal exposure and effects.

5.6.2 Track and forecast (with error estimates) the location and characteristics of HABs.

- Determine areas of greatest need for HAB forecasts and the minimum accuracy requirements.
- Make circulation output from models available in common standard formats for nowcasts and forecasts.
- Link observations and models more effectively through data assimilation. Develop and implement data assimilation techniques and associated standards for improving numerical model nowcasts and forecasts of HAB events. The observations, models, and forecasts should strive to be inclusive of human and animal health effects.
- Produce predictions with associated uncertainties of the onset of HABs in areas of concern, for example by expanding and improving the current HAB-FS with the use of other deterministic, probabilistic and heuristic models.
- Implement location uncertainty statistics into forecast models, with information based on both location uncertainty and the use of ensemble models for modeling uncertainty.

5.6.3 Validate forecasts (improving on the current HAB-FS validation) and relevant models, both operationally and retrospectively.

- Conduct validation studies as models and forecasts are improved, such as Stumpf, et al, 2009.

6.0 Implementation II: Data Management, Communications, and Performance Metrics

6.1 Consistency with IOOS DMAC standards

This should be done as part of the GCOOS DMAC effort consistent with Ocean.US DMAC plans and the IOOS Data Integration Framework. The following are priorities for HABIOS:

- Inventory current data transfer, formats, databases and archives involved in data transfer including those used by the HAB-FS, HABSOS, and states.
- Perform a comparison between elements of the system that exist and those that are needed so as to identify gaps in the system.
- Based on the inventory and gaps, determine a phased strategy for formats, transfer protocols, and databases data integration that builds on existing capabilities to assure the necessary data integration to meet modeling, forecasting, and general user requirements and is consistent with IOOS DMAC requirements. Priorities should be on integration that will

meet the most critical user requirements.

6.2 The Regional Data and Information Dissemination Tool: HABSOS

Harmful Algal Blooms Observing System (HABSOS) is a regional, web-based data aggregation and dissemination tool developed by EPA and NOAA and hosted at NOAA's National Centers for Environmental Information (NCEI). HABSOS relies on data partners across the Gulf of Mexico to provide HAB information and HABSOS provides a comprehensive picture of the information. States submitting HAB data is key to the success of HABSOS and observing networks.

HABSOS contains current and past *Karenia brevis* observations viewable in a web map. HAB observations are ingested automatically from the data providers and added to the HABSOS database. The HABSOS database is capable of including multiple species and is archived periodically. Non-HAB observation data include National Weather Service's meteorology forecasts, Naval Oceanographic Office's Navy Coast Ocean Model (NCOM), and remotely sensed imagery from NOAA CoastWatch and University of South Florida's Optical Oceanographic Laboratory.

Enhancements to HABSOS are recommended as part of this HABIOS Plan. Details are given in [Appendix 2](#).

6.3 Performance Metrics

These should monitor the effectiveness of the system in terms of both system functions (e.g., sustained, quality controlled data streams) and user satisfaction (e.g., are the data provided in forms and at rates that are most useful to decision makers?).

- Determine and implement performance metrics to assess how efficiently observations, DMAC, and modeling are linked for sustained product delivery. These should be monitored by data providers and modelers and should include metrics for observations, distribution, storage and archive (retrospective), and operations of models.
- Develop and implement performance metrics for how well the information provided meets the needs of user groups (user satisfaction).
- Produce a periodic review of the HABIOS observations network using performance metrics.

7.0 Implementation III: Linking Public Health and Living Marine Resources with Ocean Observations

Enhanced physical, chemical, and biological monitoring systems for HABs will provide more accurate and timely data, will improve public health protection and management abilities, and will enhance protection of living marine resources. Coordinating and interfacing these monitoring systems with epidemiological surveillance systems and data on living marine resources will help meet four of the IOOS societal goals, namely: mitigate the effects of natural hazards more effectively, reduce public health risks, protect and restore healthy coastal ecosystems more effectively, and enable the sustained use of ocean and coastal resources.

The HABIOS must inform health responders; while health responders must guide additional sampling strategies for HABIOS. We should look for opportunities to coordinate these systems as epidemiological studies are performed.

7.1 Predicting human and animal health effects is one of the key activities of the HAB Forecast System in the Gulf of Mexico

The HAB Forecast System provides information about potential health impacts associated with confirmed HABs. If health impacts (such as respiratory information) have been reported by volunteers, that information is provided in the Conditions Report. The publicly available Conditions Report only provides information on verified blooms and their potential health impacts.

7.2 Abstracting human and animal health data from various systems will allow validation of the predictions

Sources of human and animal health data include:

- Near real-time respiratory irritation data collected by lifeguards;
- Hospital records for emergency room visits and hospital admissions for respiratory irritation;
- Local physician records for reports of asthma exacerbations;
- Calls to the Poison Information Center hotline;
- Reports collected in the Harmful Algal Bloom-related Illness module in NORS;
- Admissions to veterinary clinics and/or animal hospitals;
- Unusual mortality events; and
- Marine Mammal Stranding Network data.

7.3 Actions that address linking observations with human and living resource information include:

Identify databases, including:

- Human health databases, including the expert contact;
- Veterinary health databases, including the expert contact;
- Living marine resources databases, including the expert contact; and
- Databases with expert information on human and animal health effects.

Support development of human health assessments, such as:

- Human health surveillance activities;
- New epidemiological studies for the definition of HAB-related illnesses;
- Development of case definitions for HAB-related illnesses;
- Conduct baseline assessments of HAB-related illnesses, and connect environmental and epidemiological databases to improve risk assessment capabilities. This includes surveillance activities;
- Review existing databases (e.g. Total Maximum Daily Loads) for applicability to assessing changes in public health risks;
- Foster cooperation and collaboration among research disciplines, e.g., between medical

- practitioners and ocean scientists;
- Encourage coordination among public health and environmental protection officials, living resource and coastal zone managers, and oceanographers and coastal hydrologists; and
 - Enhance effective use of the internet and other electronic media to transmit data to public health officials so that they can issue timely warnings to the public.

8.0 Implementation IV: Improving Operational Capabilities through Research

One requirement for improving operational capabilities is that research or other needs should be addressed in annual reviews and assessments of the forecasts. These needs should also be prioritized based on the annual reviews. Previous reports, such as the *HARRNESS, Harmful Algal Research and Response National Environmental Science Strategy 2005-2015*, have articulated these recommendations, which are endorsed in this plan (HARRNESS, 2005).

8.1 Remote Sensing

The lack of sufficient spectral, spatial, and temporal resolution from the available satellite ocean color sensors is a limitation to detecting HABs. Key areas of research for remote sensing of HABs will involve the following:

- Improving the quality of remotely sensed observations through rigorous calibration and validation efforts;
- Developing novel approaches for integration of data from different sensors on different platforms (e.g. aircraft, satellite) and with different spectral, temporal and spatial resolution (e.g., SeaWiFS, MODIS, MERIS, OCM, airborne radiometers, National Polar-orbiting Operational Environmental Satellite System Preparatory Project (NPP) Visible Infrared Imager Radiometer Suite (VIIRS));
- Developing an operational capability that is aircraft-based;
- Developing improved sensor technology for future NASA and NOAA missions; and
- Exploring the utility of other remotely sensed observations, for example synthetic aperture radar (SAR), which is not sensitive to cloud cover and can provide information both night and day on surface features (surfactants, plumes, wind and wave fields) that may be helpful in tracking HAB phenomena.

With respect to spectral resolution, most of the ocean color satellite sensors have 7-8 potentially useful bands in the visible and near-infrared spectral regions. MERIS has 10 bands, which offers the potential for greater discrimination. Improved spectral resolution may be beneficial for the application of spectral algorithms used to discriminate algal taxa and water constituents (including phytoplankton, colored dissolved organic matter, particulate detritus, suspended particulate matter). This capability is especially important in optically complex coastal waters. Aircraft-borne sensors can provide extremely high spectral resolution information, but research is required to achieve significantly improved products in a timely fashion, and to merge the high spectral resolution with the lower resolution on most satellites.

To solve the challenge of temporal resolution, multiple images per day will help minimize the impact of clouds and can be used to discriminate transient signals, such as those associated with tidal oscillations or vertical migration of bloom populations. Improving temporal resolution can be partially achieved by integrating data from multiple existing sensors. However, each satellite has a slightly different band suite and associated sensitivities, and may exhibit biases in retrieved products. So research is needed to determine optimal approaches for effectively and validly combining products from different sensors.

To address insufficient spatial resolution, several sensors, such as OCM and MODIS, have high-resolution bands. Progress on the calibration and integration of these bands with the standard 1-km SeaWiFS and MODIS products is being made, but considerably more work is needed to refine and validate these products. Additionally, MERIS has a high-resolution (300 m) mode, but U.S. investigators have had limited access to these data and so data quality remains poorly characterized. Aircraft-based sensors, either imaging or along-track radiometry, could provide much higher spatial resolution in the critical area within 1-2 km of the shore, as well as in estuaries and bays. Algorithm-development and instrument testing are necessary to transition these from occasional research tools to routine operational capabilities.

8.2 *In Situ* Sensing and Field Measurements

There is the need to facilitate the development and transfer of technology to improve the health of the public and living marine resources. For example:

- Cost-effective bio-optical and molecular methods for detecting species and toxins in real-time, and make them widely available;
- Validated, standardized field methods for rapid detection of toxins in seafood; and
- Validated, standardized field methods for rapid detection of toxins in biological samples.

8.3 Modeling

Results from models that are components of HABIOS should provide identification of research needs for the improvement of models in HABIOS. Actions to be taken include:

- Evaluate the impacts of natural and anthropogenic influences (e.g., climate change, nutrient enrichment, harvesting shellfish) on the abundance and distribution of *K. brevis* and other toxic species;
- Synthesize diverse measurements into coupled physical-ecosystem models that incorporate species-specific growth, loss and toxin production rates (including the development and improvement of individual-based models of population dynamics and species-specific models that link physical-biological models);
- Develop food web models for fate and effects of toxins;
- Establish test beds for model development, validation and skill assessments;
- Conduct Observing System Simulation Experiments (OSSEs) and Observing System Experiments (OSEs) to evaluate existing and proposed sampling schemes for improving model-based forecasts and guide adaptive sampling strategies to optimize in situ measurements and remote sensing;
- Develop coupled physical-biological models, grids and boundary conditions;
- Couple statistical methods (e.g., data assimilation) with deterministic models to estimate

- uncertainty;
- Conduct re-analysis of model outputs and develop climatologies for annual cycles of key environmental variables, HAB species, and phytoplankton species that portend HAB events;
 - Document empirical relationships between *K. brevis* abundance and distribution and physical-chemical conditions for the development of habitat-domain models;
 - Develop models that predict the location and extent of human and animal health effects, including model-based predictions of long term risk of individual and population exposure to HAB toxins; and
 - Develop models of socioeconomic impacts and costs of mitigation at local and regional scales.

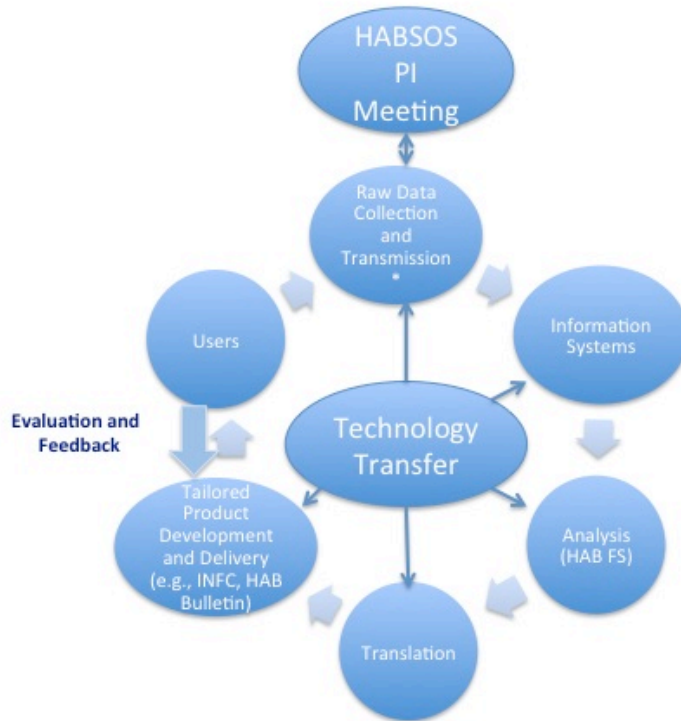
8.4 Health of humans and living marine resources

Research needs for these aspects of HABIOS include:

- Epidemiological studies to define chronic sequelae from acute and chronic exposures;
- Epidemiological studies to define adverse health effects from chronic, low-dose exposures;
- Epidemiological studies of sensitive populations;
- Develop risk assessments, e.g., acute reference doses (RfD), need to be developed;
- Epidemiological studies of real-life exposures (mixtures);
- Clinical studies for treatments;
- Develop methods to mitigate exposure and disease;
- Develop new and validate currently established action levels for HABs. As examples, 5,000 cell action level for *Karenia brevis* as it equates to toxin levels, for *K. mikimotoi*, etc.;
- Determine toxicity of different *Karenia* species;
- Surveillance studies to identify chronic sequelae from acute and chronic exposures; and
- Develop models of socio-economic impact.

9.0 Implementation V: Information Delivery

Information delivery from the multiple facets of HABIOS will be accomplished through information collection, analysis, translation, product development and dissemination, and product iteration based on user feedback (Figure 2).



*Sources: Science Community, HABSOS, HAB Forecast System (FS), My Florida Town Hotline, Beach Conditions Report

Figure 2. Information flow from HABIOS to users, with feedback loop back into the system.

The information delivery process incorporates existing tools for information dissemination, including HABSOS (described briefly in [Section 6.2](#) with recommended improvements listed in [Appendix 2](#)) and the NOAA HAB Bulletin. The Bulletin provides information on the location, extent, and potential for development or movement of *K. brevis* blooms in the Gulf of Mexico using satellite imagery, vector winds from buoys, NWS forecasts and field measurements from State agencies. Conditions are posted on the Web twice a week during a HAB event. More information on the Bulletin and recommendations for improvements are given in [Appendix 3](#).

10.0 Implementation VI: Integration

Integration of the components of HABIOS will be achieved through multidisciplinary and cross disciplinary coordination and communication. As with many other natural phenomena that cross over physical, chemical, and biological science boundaries, HABs in the Gulf of Mexico, and worldwide will require a village to achieve public and animal health and safety.

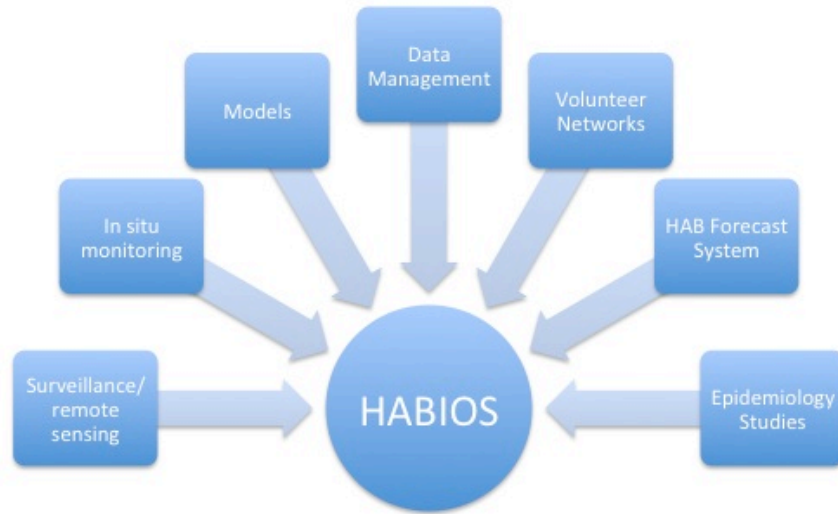


Figure 3. Integrated components comprising the HABIOS.

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Appendix 1: State-supported HAB monitoring

A state by state listing of HAB occurrences is listed in the Gulf of Mexico Alliance Water Quality Team's White Paper, [Resource Guide for Harmful Algal Bloom Toxin Sampling and Analysis](http://www.gulfofmexicoalliance.org/tools-and-resources/tools/#water). The link to the document is <http://www.gulfofmexicoalliance.org/tools-and-resources/tools/#water>.

The National Shellfish Sanitation Program (NSSP) mandates phytoplankton monitoring as part of the biotoxin contingency plan required for interstate shipment of shellfish. Components of the monitoring plan include:

- Sample sites are selected to provide surveillance of waters near and at shellfish growing areas. They are identified by latitude and longitude. Long established sites were selected with the approval of the USFDA.
- Sampling frequency is about 10 times per year as determined by NSSP and more with event response. There are no estimates for worst case scenarios.

A1.1 Alabama

Alabama has about 100 miles of coastline along the Gulf of Mexico and in Mobile Bay and Mississippi Sound. In past years there have been blooms of numerous HAB species (see appendix) including *Karenia brevis*, responsible for fish-kills and hypoxia. There are sharp gradients from very turbid, nutrient-rich, to very clear, nutrient-depleted waters. Consequently, optically based monitoring is very difficult. The high diversity within the microalgae makes chlorophyll an unreliable proxy for HAB abundance.

There are four tiers of monitoring:

1st tier: State and federal agencies, coordinated through Alabama Department of Public Health (ADPH). These agencies monitor Gulf beaches and oyster-growing areas in Mobile Bay, with further adaptive sampling during blooms. ADPH has regulatory authority over oyster harvesting. Routine monitoring is weekly, bi-weekly or quarterly, depending on site and season. Data include cell counts and (usually) temperature and salinity.

2nd tier: Governmental monitoring efforts may be improved with instrumentation becoming available for cell counts, nutrients, chlorophyll in addition to hydrography. These efforts need sustainable financial support to adequately produce useful products.

3rd tier: Volunteer network (initiated by NOAA PMN with reporting to PMN database), is a small but significant effort in the Little Lagoon area of Baldwin County. These inshore waters are not routinely sampled by ADPH. The relatively low level of training can reduce reliability as monitoring tool, but the volunteer network is an excellent outreach and outreach opportunity. Sampling is biweekly. Data include relative abundance of net plankton, physical hydrography, chlorophyll a, nutrients etc.

4th tier: Instrument arrays are maintained by National Data Buoy Center (NDBC) (one site on Dauphin Island), DISL/Mobile Bay National Estuary Program (three sites in Mobile Bay, 1 in

Perdido Bay is pending), US Geological Survey (USGS)/Alabama Department of Conservation and Natural Resources (ADCNR) (one site in Wolf Creek) and the Weeks Bay National Estuarine Research Reserve (four sites in Weeks Bay). Data vary by site but include hourly meteorology and hydrography (temperature, salinity, dissolved oxygen). High fouling rate in Mobile Bay and Weeks Bay limits potential application of optical sensors because of the need for daily or near-daily cleaning. Current monitoring for meteorological/hydrographic information includes these sites:

PORTS: Mobile River, Fort Morgan, Farewell Buoy

NERRS: Weeks Bay

MBNEP/DISL: Meaher Park, Mobile Bay Light, Bon Secour, Cedar Point, Katrina Cut (Dauphin Island west end), Perdido Pass

NDBC: Dauphin Island east end, Orange Beach AL Buoy

State Sponsored HAB Monitoring

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Gulf of Mexico Alliance Contact:

Fred Leslie
Alabama Department of Environmental Management
fal@adem.state.al.us

Monitoring Agencies:

- Alabama Dept. of Public Health Shellfish State Authority
 - Ron Dawsey c/o
Alabama Department of Public Health
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Thomas.dunn@adph.state.al.us
Byron.webb@adph.state.al.us
 - Mandated monitoring Yes No
 - Authority- Required by USFDA and NSSP
 - Water Sample Type
 - Surface grab sample for cell concentrations
 - Multiple sample depths
 - Frequency of Monitoring Efforts (Scheduled Sampling Events)
 - Shellfish growing area sampling sites are determined by evaluation of HAB risk. Monitoring is conducted 10- 12 times per year.

- Event response protocol available
 - Increased sampling when *Karenia brevis* cell counts in growing areas. See protocol in Appendix
 - Arrangements are made for toxin testing when *Pyrodinium bahamense* is detected
- Monitoring Stations-Lat/Long available Yes No
- Hydrographic Data Collected with HAB sample
 - Salinity
 - Water Temperature
 - Wind Speed and Direction
 - Air Temperature
 - Tide
- Method of Phytoplankton Analysis
 - Preserved Material –Acidified Lugol’s
 - Utermohl method
 - Standard operating procedure is available
 - HAB species ID and enumeration
 - *Karenia brevis* Cells per liter >5000 requires action by Shellfish Authority
 - Other *Karenia* spp. are noted cells per liter
 - *Pyrodinium bahamense* cells per liter—requires action by shellfish authority to determine toxicity
 - *Pseudo-nitzschia* spp (identification to genus) cells per liter identified by light microscopy
 - *Prorocentrum minimum* requires no action by shellfish authority
 - *Alexandrium monilatum* requires no action. Other agencies such as Conservation and Natural Resources are notified.
 - Dinophysis spp.
 - Non HAB species ID and enumeration
 - The laboratory identifies and enumerates dinoflagellates to genus and species when possible. Diatoms are identified to genus using light microscopy when counts exceed background levels.
- Data
 - Database- MS Excel Sfd Branch and MS Access- ADPH Lab
 - Accessibility -Data sharing is determined on a case to case basis by the ADPH
- Method of HAB event notification
 - Health alert general
 - Shellfish harvest
 - When cell counts of *Karenia brevis* in shellfish growing areas are >5000 cells per liter shellfish areas are closed to harvest. The State Health Officer issues the closure. Areas remain closed until toxin testing determines levels are <20 mouse units per 100 gm.
 - Beach goers

- Email (the HAB Alert list) to neighboring states and an established list of state, local, and federal regulators or data developers (NOAA)
- Voluntary collections at beach monitoring sites by Alabama Dept of Environmental Management and the Baldwin County Health Department
 - Carol Dorsey, Laboratory Manager
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251 344-6049
carol.dorsey@adph.state.al.us
drew.sheehan@adph.state.al.us
 - Mandated monitoring Yes No
 - Water Sample Type
 - Surface grab sample for cell concentrations
 - Multiple depth sampling
 - Frequency of Monitoring Efforts (Scheduled Sampling Events)
 - Grab samples are collected at BEACH sites across the AL Gulf beaches from FL to Dauphin Island, AL Public Beach once or twice weekly during the swimming season May through September. Samples are collected once per month in the off season.
 - Event response- Currently under development
 - Monitoring Stations- Lat/Long available Yes No
 - Hydrographic Data Collected with HAB sample
 - Salinity
 - Water Temperature
 - Wind Speed and Direction
 - Air Temperature
 - Tide
 - Method of Phytoplankton Analysis
 - Preserved Material –Acidified Lugol’s
 - Utermohl method
 - Standard operating procedure is available
 - HAB species ID and enumeration
 - See above
 - Non HAB species ID and enumeration
 - See above
 - Data
 - Database -MS Access database
 - Accessibility- Data sharing is determined on a case to case basis by the ADPH
 - Method of HAB event notification
 - Health alert general- The ADPH issues health alerts when *Karenia brevis* blooms are causing respiratory symptoms in beach goers or fish kills with

irritating aerosols. Distribution to the media via press release with local contact information.

- Shellfish harvest
 - Beach goers- Currently under development with proposed signage at various public beaches for on-site notification. Developing web based notification including HAB status reports
 - Email (the HAB Alert list) to neighboring states and an established list of state, local, and federal regulators or data developers (NOAA)
- Additional Health Information Databases for State
 - Alabama Incident Management System (AIMS and NEDS)- developing databases of human syndromic data reported by hospitals. This instrument could be modified to include biotoxin related illness surveillance if the State Health Officer makes it reportable.
 - Animal Illness database- not available specifically for Alabama. Living Marine Resources database- DISL's Manatees Sighting Network, headed by Dr. Ruth Carmichael, is part of a larger suite of projects examining the population ecology of West Indian Manatees in Alabama waters including: photo-identification, aerial and ground surveys, tagging and tracking manatee movements, habitat and food resource characterization (application of stable isotope techniques), analysis of population data and comparison to habitat and food supply data. Marine biotoxin testing has been performed for animal necropsy studies. This group is particularly interested in the function of fringe manatees as sentinel species to detect and predict ecosystem level responses to environmental change. A new area of interest is in how climate change may affect habitat and food resources while simultaneously promoting habitat and range expansion.

Project outputs will comprehensively define manatee fringe habitat in the Northern GOM for the first time, predict how future environmental changes are likely to alter habitat and manatee movements, and enable policies to sustain habitat and promote conservation into the future. Specifically, data will inform stakeholders about when and where to expect to find manatees, provide guidance for public notification, help identify recovery priorities with the U.S. Fish & Wildlife Service (USFWS), contribute to policy documents, and reduce the likelihood of strandings or conflicts between manatees and people.

This work also has tremendous synergy, including collaborators at the local, state and federal levels and brings substantial public awareness to our research program and institutions.

The projects, funded by the Alabama Division of Wildlife and Freshwater Fisheries, U.S. Fish and Wildlife Service and Mobile Bay National Estuary Program, are collaborations between Dauphin Island Sea lab and researchers at Sea to Shore Alliance.

A1.2 Florida

Greater than 70 nuisance or toxic harmful algal bloom (HAB) species have been identified in estuarine and marine waters of Florida, which cover thousands of miles of coastline. The state of Florida has tasked the Florida Fish and Wildlife Conservation Commission's Fish and Wildlife Research Institute (FWC/FWRI) to monitor HABs in state waters and mitigate their negative effects. The monitoring efforts of FWC/FWRI largely focus on the dinoflagellates *Karenia brevis* and *Pryodinium bahamense* and diatoms in the genus *Pseudo-nitzschia*, organisms for which regulatory actions (e.g., shellfish harvesting area closures) are established; however, when blooms of other harmful taxa occur, management activities are initiated. HAB monitoring is accomplished through a unique collaboration between FWC/FWRI, the Florida Department of Agriculture and Consumer Services (FDACS), Mote Marine Laboratory, the University of South Florida, county agencies, other private non-profit agencies, and citizen volunteers (i.e., the Red Tide Offshore Monitoring Program). Together, this team collects samples alongshore or by boat; deploys underwater vehicles to map blooms; uses satellite images to measure bloom extent and distribution; and produces short-term forecasts of bloom movement (see organizational efforts below). Ancillary physical, chemical and biological data are available with discrete HAB samples collected through the monitoring efforts of FWC/FWRI and Mote Marine Laboratory, but the remaining network of samplers typically collect samples for HAB analysis only. HAB samples are analyzed via microscopy and the results are reported to managers and stakeholders via daily reports, weekly web bulletins (www.MyFWC.com/RedTideStatus), weekly recordings (866-300-9399), regional conference calls, and social media (e.g., www.Facebook.com/FLHABs, <http://on.fb.me/1Dpq9fu>). At present, weekly web bulletins focus on *K. brevis* and include static tables and maps, interactive Google Earth maps, and custom products (i.e., overlays of cell abundance and satellite images, forecast information). A description of the organizational efforts that support HAB monitoring and management in Florida, as well as product development, follows.

(1) Collaboration between FWC/FWRI and FDACS

Routinely and in response to blooms, FWC/FWRI provides the Florida Department of Agriculture and Consumer Services (FDACS) with HAB abundance and toxicity data used to manage legal shellfish harvesting areas. For *K. brevis*, FDACS closes shellfish harvest areas when concentrations equal to or greater than 5,000 cells L⁻¹ are detected in harvest areas. When *P. bahamense* is present in a harvest area at any level or when *Pseudo-nitzschia* spp. abundance approaches or exceeds 10⁶ cells L⁻¹, shellfish testing begins; harvest is temporarily closed if saxitoxin or domoic acid exceed established guidance levels. Shellfish harvest areas are re-opened only when HABs dissipate from the areas and toxin concentrations in shellfish are below federal guidance thresholds (i.e., brevetoxin <20 MU/100 gm, saxitoxin < 80 µg equivalents/100 gm, domoic acid < 2 mg/100 gm). Researchers at FWC/FWRI are currently working in collaboration with federal partners to validate improved toxicity tests for brevetoxin and saxitoxin.

(2) FWC/FWRI-Mote Marine Laboratory Cooperative Program

FWC/FWRI operates a cooperative program with Mote Marine Laboratory to support monitoring of *K. brevis* in Florida. The ongoing program fills major gaps in red tide monitoring, research, and public education. Through the program, Mote Marine Lab routinely monitors coastal waters

along Sarasota County and the Florida Keys, leads event response efforts, and supports the Sarasota Operations Coastal Ocean Observing Laboratory (SO-COOL), and Beach Conditions Reporting System (BCRS).

- Mote Marine Laboratory's Sarasota Operations Coastal Ocean Observing Laboratory (SO-COOL), (<http://coolcloud.mote.org/socool>) is used to coordinate and report results from the operation of both fixed location and mobile Optical Phytoplankton Discriminators (OPD, or "Brevebusters"). These instruments optically detect the likely presence of *Karenia* species through a statistical Similarity Index. Data are reported on a selectable frequency, and the time series of results are available as either tabular or graphical data through the website and via mobile applications. The mobile OPD are deployed as the payloads of autonomous underwater vehicles or gliders and are launched in routine monitoring efforts and in response to suspected bloom events. Currently, the OPD network consists of three fixed position installations and two autonomous underwater vehicles. The University of South Florida also hosts a fleet of robotic gliders for early bloom detection and 3-D mapping (<http://cotprojects.marine.usf.edu/data/gliders.html>), which are often deployed during event response efforts in coordination with FWC/FWRI and Mote Marine Laboratory.
- The Beach Conditions and Reporting System (BCRS), also reported through Mote's SO-COOL (<http://coolcloud.mote.org/bcrs/>), is a twice-daily, real time beach monitoring system conducted by lifeguards in participating Counties. Developed and maintained by Mote Marine Laboratory, the observations report via cell phone application the presence of respiratory irritation due to HABs if present, together with beach aesthetics such as dark water drift, algae, and dead fish. Results are available via dial-in, mobile or web interfaces. The network presently consists of reports from 28 beaches.

(3) University of South Florida/FWC Collaboration for Prediction of Red Tides (CPR)

The Collaboration for the Prediction of Red Tides (CPR), a joint effort between researchers at the University of South Florida and FWC/FWRI, utilizes physical and biological models in conjunction with monitoring data and satellite imagery to provide forecasts of red tide movements in Florida waters. A HAB tracking tool projects 3.5 surface and bottom movement by using modeled particle trajectories originating from *K. brevis* sampling locations (http://ocgweb.marine.usf.edu/hab_tracking/HAB_trajectories.html). This tool is driven by a fully automated, nested circulation model running daily with the results available on the web (<http://ocgweb.marine.usf.edu/>). In the last few years, the tracking tool has been improved by the transition to FVCOM, an expanded grid, passive tracers, and the incorporation of the vertical dimension of the water column. FWC/FWRI, Mote Marine Lab and the University of South Florida are currently planning an expansion of the core monitoring infrastructure along the southwest Florida Shelf to support the development of seasonal bloom forecasts.

(4) Collaboration between FWC/FWRI and the University of South Florida's Optical Oceanography Laboratory (OOL)

FWC/FWRI routinely uses satellite imagery provided by the OOL at the University of South Florida to detect and track surface blooms of *K. brevis* in coastal waters. Satellite images fill offshore gaps, often providing the spatial extent of blooms that often cannot be accessed due to patchiness in sampling. Overlays of satellite images with sample results are provided as custom

data products in the weekly FWC/FWRI bulletins. In addition, since 2012, the OOL has provided integrated imagery, cell abundance, and surface current files to users at <http://optics.marine.usf.edu/>. This integration provides users with the current status of red tide occurrence (e.g., location, severity, spatial extent), while presenting a simple way to estimate bloom trajectory, thus delivering an effective method for near real-time tracking of red tides.

(5) NOAA Harmful Algal Bloom Operational Forecast System

NOAA's Harmful Algal Bloom Operational Forecast System (HAB-OFS) utilizes *K. brevis* data collected by FWC/FWRI and Mote Marine Laboratory, ocean color satellite imagery, and meteorological observations and forecasts to predict *K. brevis* bloom movement, intensification and associated level of respiratory irritation. The forecasts are communicated through HAB-OFS conditions reports and bulletins (<http://tidesandcurrents.noaa.gov/hab/overview.html>). The conditions report includes a forecast of the potential levels of respiratory irritation associated with a *K. brevis* bloom over the next 3-4 day period. This is posted on the web twice a week after confirmation of a bloom and once a week during the inactive HAB season. Additional bloom analysis is emailed to a subscriber list of state and local coastal resource managers, public health officials and research scientists.

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A1.3 Louisiana

The last occurrence of *Karenia brevis* in Louisiana waters was in winter 1996-1997 and shellfish beds were closed during that bloom. Due to predominant current patterns in the Gulf of Mexico, Louisiana usually receives warnings far in advance of a HAB event, owing to reports from Florida, Mississippi, and Alabama.

The Louisiana Department of Health and Hospitals (LDHH) Molluscan Shellfish Program conducts both a routine Water Quality monitoring program and a HAB monitoring program. Monthly water samples are collected from approximately 700 bacteriological sample stations and examined for fecal coliform. Other parameters recorded include salinity, temperature, and wind speed and direction. Generally at the same time, monthly water samples are collected from 24 HAB sample stations; of these 14 are located east of the Mississippi River. Samples are analyzed

for cell counts of *Karenia brevis*, salinity; and other environmental conditions such as turbidity, tides, wind, etc. are collected. In the event that cell counts exceed 5000/L, additional water samples are taken and analyzed by the state laboratory and oyster meats are analyzed for toxins at either the FDA laboratory or a qualified university or private laboratory. If HAB toxins are detected, the information is shared with NOAA, the FDA Shellfish Specialist, and shellfish officials from neighboring states. If toxins are above allowable threshold, affected shellfish areas would be closed to harvest. If beds are closed to harvesting, public advisories are issued by LDHH through press releases, the news media, and the LDHH website.

LDHH maintains both water quality monitoring data and HAB monitoring data in independent databases in MS Access and Excel formats. Other agencies and the general public may access information from these databases through a written request that stipulates the intended use and distribution of the data.

State Sponsored HAB Monitoring

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Monitoring Agencies:

- Louisiana Dept. of Health and Hospitals
Office of Public Health
Molluscan Shellfish Program
 - Gordon Leblanc
 - Louisiana Office of Public Health
 - Molluscan Shellfish Program
 - 628 North 4th Street
 - P.O. Box 4489, Box 16
 - Baton Rouge, Louisiana 70821-4489
 - 225 342-7539
 - 225 342-7607
 - gordon.leblanc@dhh.la.gov
 - Mandated monitoring Yes No
 - Authority- Required by NSSP and US-FDA
 - Water Sample Type
 - Surface grab sample for cell concentrations
 - Multiple sample depths
 - Frequency of Monitoring Efforts (Scheduled Sampling Events)

- Biotoxin sample stations are set stations collected once monthly.
- Stations are located on the parameter of shellfish harvest areas and in specific harvest areas.
- Event response protocol available
 - Increased sampling when *Karenia brevis* cell counts in growing areas.
- Monitoring Stations-Lat/Long available Yes No
- Hydrographic Data Collected with HAB sample
 - Salinity
 - Water Temperature
 - Wind Speed and Direction
 - Air Temperature
 - Tide
- Method of Phytoplankton Analysis
 - Preserved Material –Acidified Lugol’s
 - Utermohl method
 - Standard operating procedure is available
 - HAB species ID and enumeration
 - Action required by Shellfish Authority when *Karenia brevis* cell count is greater than 5000 cells per liter.
 - *Karenia brevis* cell counts are noted when less than 5000 cells per liter.
 - Non HAB species ID and enumeration.
- Data
 - Database- MS Excel
 - Accessibility – Data sharing is determined on a case to case basis by the Shellfish Authority
- Method of HAB event notification
 - Health alert general
 - Shellfish harvest
 - When cell counts of *Karenia brevis* in shellfish growing water areas are > 5000 cells per liter, the affected shellfish harvested area is closed to harvest.
 - Areas remain closed until toxin testing determines levels are <20 mouse units per 100 gm.
 - Beach goers
- Additional Health Information Databases for State
 - Human Illness Databases – not available for Louisiana
 - Animal Illness Databases – not available for Louisiana
 - Living Marine Resources Databases – not available for Louisiana

Academic Institutions – Active research programs in phytoplankton community composition in inshore and offshore waters, phytoplankton taxonomy, HAB species identification and toxin

analyses are conducted by N. Rabalais and W. Morrison at Louisiana Universities Marine Consortium and S. Bargu at Louisiana State University.

A1.4 Mississippi

In March of 2007, the Mississippi Department of Marine Resources (MDMR) developed a Marine Biotoxin Contingency Plan that defines HAB monitoring efforts for marine and estuarine shellfish growing areas. The contingency plan was revised and updated in 2012. The MDMR Shellfish Bureau conducts bimonthly phytoplankton samples at two oyster reef locations in the western MS Sound. These locations correspond to the northernmost and southernmost perimeter of productive oyster reefs south of Pass Christian. When an influx of freshwater is released into the western Mississippi sound, a third sampling location is added. This additional site is located within the St Joe Oyster reef southwest of Bayou Caddy.

Shellfish Staff follow the procedures of the NOAA Phytoplankton Monitoring Network (PMN) for sampling protocol. All results are reported to PMN and recorded in the MDMR in house data collection spreadsheet. Environmental water quality data is collected during each sample trip. This includes: air and water temperature, salinity, dissolved oxygen, pH, and turbidity. Sample analysis is conducted in house with a phase contrast microscope. Qualitative analysis is recorded however, in the event of a bloom, quantitative analysis will be conducted to determine possible toxicity levels.

MDMR Personnel conduct field observations for water discoloration during routine aerial flights and water sampling. If an area is suspected of a toxic bloom, samples are collected and analyzed. MDMR Personnel investigate possible toxic blooms reported by credible sources, primarily: adjacent state agencies, federal agencies, local health agencies, and academic institutions. In the event of a bloom from a biotoxin-producing organisms, technical assistance from FDA and others will be sought in determining oyster reef closing criteria.

There have been phytoplankton blooms across the Mississippi Sound investigated over the past several years, none of which caused a shellfish reef closure. These include:

- 2014 – *Scrippsiella spp.* bloom
- 2013 – *Ceratium furca* bloom
- 2011 – *Chatonella subsalsa* bloom
- 2010 – *Ceratium furca* bloom

During the fall of 1996, Mississippi experienced a red tide of *Karenia brevis* (reported as *Gymnodinium breve*). Over a four month period, numerous water samples and meat samples were collected. Meat samples were tested using mouse bioassay. This event forced the closure of several oyster harvesting reefs in the western MS Sound.

To request detailed reports of these blooms as well as data on routine phytoplankton sampling history, contact Scott Gordon, MDMR Shellfish Bureau Director. To request public records, visit the MDMR website at www.dmr.ms.gov and go to the contact page to submit a request

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Phone: (228) 374-5000 / 1-800-374-3449
Website: www.dmr.ms.gov

MDEQ, in collaboration with Dr. Cyndi Moncrief, participated in an EPA funded Pfiesteria/HABs monitoring project in 2003 which included phytoplankton sampling at 20 nearshore estuarine sites, MDEQ also conducts ambient water quality monitoring of its coastal waters and routine bacteria and nutrient monitoring of its swimming beaches. These programs provide useful water quality data and accomplish federal mandates, and the data can be used to supplement a HABs monitoring program.

In addition to these routine monitoring programs, a number of Mississippi researchers are involved in HABs related work.

A1.5 Texas

Harmful algal bloom (HAB) monitoring in Texas is case specific for fishery impacts and health concerns, such as the opening/closing of designated shellfish harvesting areas. Although an active routine HAB monitoring program is not established in Texas, a continuous monitoring Image Flow Cyto-bot station in Port Aransas aids both agencies in HAB response activities. Example: In early 2008, the Image Flow Cyto-bot alerted Texas Department of State Health Services (TDSHS) to a *Dinophysis* bloom, which allowed for the closure of oyster beds before the oysters were consumed at a local oyster festival.

Texas Parks and Wildlife Department (TPWD) investigates fish kills and enforces shellfish closures issued by the TDSHS. Water sampling for HAB's during a fish kill is conducted to determine the extent of the bloom and duration of the fish kill event.

TDSHS is tasked to protect the consumer from disease or other health hazards transmissible by oysters, clams, mussels and scallops and crab meat produced in or imported into Texas. Once a HAB is identified, active sampling occurs by TDSHS in shellfish growing areas. Shellfish closures to harvesting are issued as needed by TDSHS with closure enforcement provided by TPWD Law Enforcement.

During a multi-agency response such as a *Karenia brevis* bloom, TPWD works closely with the TDSHS as well as Texas Cooperative Extension, the University of Texas and Texas A&M University to monitor and assess impacts. Coordination with agencies and universities occurs to avoid duplication of efforts, i.e. if another agency is collecting water samples in one area, TPWD will collect samples elsewhere.

There is an interagency HAB working group that is very active and effective; their goals include facilitating research, response, early detection, and outreach with meetings occurring bi-annually.

Monitoring Agencies:

- Texas Department of State Health Services – Shellfish Authority
 - Kirk Wiles
Department of State Health Services
Seafood and Aquatic Life Group
 - P.O. Box 149347
Austin, TX 78714-9347
(512) 825 - 6757
Kirk.Wiles@dshs.state.tx.us
 - Secondary contact: Gary.Heideman@dshs.state.tx.us
 - Mandated monitoring Yes No
 - Authority- Required by USFDA and NSSP
 - Water Sample Type
 - Surface grab sample for cell concentrations
 - Multiple sample depths
 - Frequency of Monitoring Efforts (Scheduled Sampling Events)
 - Shellfish growing area sampling sites are determined by evaluation of HAB risk. Continuous monitoring occurs at the Port Aransas Cyto-bot active sampling occurs when species have been identified.
 - Event response protocol available
 - Increased sampling when *Karenia brevis* or *Dinophysis ovum* cell counts have been identified in growing areas. See protocol in Appendix
 - Monitoring Stations-Lat/Long available Yes No
 - Hydrographic Data Collected with HAB sample
 - Salinity
 - Water Temperature
 - Wind Speed and Direction
 - Air Temperature
 - Tide
 - Method of Phytoplankton Analysis
 - Preserved Material –Acidified Lugol’s
 - Standard operating procedure is available
 - HAB species ID and enumeration
 - *Karenia brevis* Cells per liter >5000 requires action by Shellfish Authority
 - Other *Karenia* spp. are noted cells per liter
 - *Dinophysis ovum* cells per liter—requires action by shellfish authority to determine toxicity
 - *Pseudo-nitzschia* spp (identification to genus) cells per liter identified by Cyto-bot.
 - *Prorocentrum minimum* requires no action by shellfish authority

- *Alexandrium monilatum* requires no action..
 - Non HAB species ID and enumeration
 - The laboratory identifies and enumerates dinoflagellates to genus and species when possible. Diatoms are identified to genus using light microscopy when counts exceed background levels.
- Data
 - Database- MS Excel at Seafood and Aquatic Life
 - Accessibility -Data sharing is determined on a case to case basis by the DSHS and TPWD, and other stakeholders.
- Method of HAB event notification
 - Health alert general
 - Shellfish harvest
 - When cell counts of *Karenia brevis* in shellfish growing areas are >5000 cells per liter shellfish areas are closed to harvest. The State Health Officer issues the closure. Areas remain closed until toxin testing determines levels are <20 mouse units per 100 gm.
 - When cells of *Dinophysis* are identified in the shellfish growing areas levels of cells will determine closure of areas if warranted. Areas will remain closed until laboratory analysis is completed and levels are below 0.20 mg/kg of DTX toxin.
 - Beach goers
- Email (the HAB Alert list) to state and federal regulators.
- Method of HAB event notification
 - Health alert general- The DSHS issues health alerts when *Karenia brevis* blooms are causing respiratory symptoms in beach goers, visible bloom, and or fish kills with irritating aerosols. Distribution to the media via press release with local contact information.
 - Shellfish harvest
 - Beach goers- Currently under development with proposed signage at various public beaches for on-site notification. Developing web based notification including HAB status reports
 - Email (the HAB Alert list) to of state, local, and federal regulators.

A1.6 Mexican States

Descriptions of the monitoring programs in Mexican Gulf States, as well as descriptions of monitoring programs in U.S. Gulf States, are included in Battelle (2008).

Within the National Red Tide Program several guidelines and actions were established as follows:
 1) Establish a data base with historic data for every coastal state to define the baseline of phytoplankton species by region and micro regions around the Mexican waters, to timely identify and prevent the presence of HABs; 2) the Federal Commission COFEPRIS coordinates its work with coastal states health authorities, and have jointly prepared the methodological procedures and

guidelines for the national program such as: instruction for phytoplankton sampling and marine bio-toxins detection, and instruction for the sanitary control of mollusks exposed to harmful algal blooms.

The Federal Ministry of Health through its Directorship on Sanitary Risks Protection in the state of Tamaulipas, Veracruz, Tabasco, Campeche, Yucatán and Quintana Roo have the basic responsibility to monitor and timely detect the HABs in the geographic jurisdiction and to obtain water samples for analysis, identifying and counting the number of species and cells of toxics and harmful blooms.

A1. 6.1 Tamaulipas

Two monthly seawater sampling is conducted using the basic Lugol method and collecting flask in every locality. In each sampling site surface and deep samples are collected for a total of eight localities. The Sedgewick-Rafter technique is used for identification and quantification of phytoplankton. Satellite imagery and remote sensing techniques are also used to support the HABs understanding. The marine bio-toxins in bivalve mollusks is done determining brevetoxins, saxitoxins and domoic and okadaic acids accordingly to the federal official standard NOM-242-SSA1-2009.

Monitoring Agencies:

- Dr. José Norberto Treviño y García Manzo

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E-mail: lespt@prodigy.net.mx

noalvi@hotmail.com

A1. 6.2 Veracruz

Two seawater sample collection are done in several localities and sites of the Veracruz state, a total of sixty four. Samples are obtained using a collecting flask with preserved in basic Lugol's for samples from surface and deep water. Regular optic or inverted microscope is used for the identification and quantification of phytoplankton samples, using the following methods: drop, Sedgewick-Rafter and Utermöhl methods.

Monitoring Agencies:

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A1. 6.3 Tabasco

Two monthly seawater samplings are carried out and preserved in basic Lugol's. Four samples are taken in every locality, eight localities in total. The sedimentation Utermöhl method (inverted microscope) is being used for the identification and quantification of phytoplankton. The marine bio-toxins in bivalve mollusks are monitored through sampling the brevetoxin method, and mice bioassay. Domoic acid determinations are made through HPLC chromatography method.

Monitoring Agencies:

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A1. 6.4 Campeche

Water samples are collated in 20 specific localities, taking samples in water surface and deep areas and preserved with Lugol's. Drop water technique is used to analyses under optic or inverted microscope to identify species of phytoplankton. Final assessment of HABs presence is conducted using satellite imagery, chlorophyll a and others parameters.

Monitoring Agencies:

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jcach2003@hotmail.com

A1. 6.5 Yucatán

Sea water samples are collected using Nalgene bottles and preserved in Lugol's, from 17 coastal stations and three marine stations, all from surface water. A sedimentation technique is also used with Utermöhl (inverted microscope) to identify and quantification of phytoplankton samples.

Monitoring Agencies:

- Dr. Jorge Eduardo Mendoza Mezquita

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A1. 6.6 Quintana Roo

Monthly sampling in 25 localities, sea water sampled at 5 m depth and preserved in Lugol's. Camera Sedgewick-Rafter and light microscope are used for the identification of phytoplankton species.

Monitoring Agencies:

- Dr. Juan Lorenzo Ortegón Pacheco

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Appendix 2. Recommended Improvements to the HABSOS

The Harmful Algal Blooms Observing System (HABSOS) is a regional, web-based data and information dissemination tool developed by EPA and NOAA and hosted at NOAA's National Coastal Data Development Center (NCDDC), now NCEI Stennis. Enhancements to HABSOS are recommended as part of this HABIOS Plan. Details are given in [Appendix 2](#).

In FY07, upgrades to HABSOS began under EPA funding and direction. During FY08 the following enhancements were implemented:

- Implementation of a Common Data Model for HAB observations that will greatly enhance automated metadata generation, tailored data export, as well as National archive;
- Automated archive of HAB observations through the NOAA National Data Centers;
- Enhancement of the HABSOS data base to include multiple species (capability only); and
- Bulk ingest of HABS observations vice single station entry in the Data Entry Tool.

Future enhancements to HABSOS should be driven by user input and recommendations in accordance with the HABIOS Plan. Planned enhancements should be flexible to allow for additional user input during HABIOS implementation. However, based on initial (and limited in terms of comprehensiveness) customer input (Workshop on Harmful Algal Blooms Observing System in 2000, Workshop on Integrating Harmful Algal Bloom Observations into the Gulf of Mexico Coastal Ocean Observing System in 2004, the Ocean.US workshop on Public Health Risks in 2006, and CO-OPS requirements transmitted via the CSC which are still under development), the most useful and feasible improvements are:

- Extend the time period for which observations are available thru HABSOS. (Extend the availability of the cell count data to the previous 120 days.)
- For the purposes of data integration (from state, volunteer, and private/research efforts), agree on and use standard definitions of abundance classes and common standards and protocols for data collection, discovery, exchange and dissemination.
- Improve capability to discover archived data at the NOAA Data Centers (Work with NODC to get all data archived in such a way as to be easily discoverable through HABSOS—ideally co-discoverable, meaning that if you discover one data set such as that provided by PMN you will be directed to related ones such as those provided by CO-OPS.)

Other recommended enhancements and related questions that have been informally proposed but are yet to be validated include:

- Should HABSOS provide more capable analysis (e.g., data layering)?
- Should HABSOS focus on purely data management services?
- Should mapping occur under HABIOS?
- Should HABIOS improve the analysis tools of HABSOS?

- HABSOS should immediately serve the data needed by CO-OPS and the HABS Forecasting System in the required formats. What are these default data sets? (e.g., surface currents, chlorophyll anomaly, backscatter anomaly etc.). What are the formats? How should the data be delivered to the HABS Forecasting?

Appendix 3. The NOAA HAB Bulletin and Recommended Improvements

The NOAA HAB Bulletin provides information on the location, extent, and potential for development or movement of *K. brevis* blooms in the Gulf of Mexico using SeaWiFS imagery, vector winds from buoys, NWS forecasts and field measurements from State agencies. Conditions are posted on the Web twice a week during the HAB season (late summer-fall). The goals of this program can be achieved more effectively in a collaborative effort to improve estimates of phytoplankton pigment fields (chlorophyll-a and diagnostic pigment ratios) by integrating all satellite based measurements of ocean leaving radiance (SeaWiFS, MODIS, OCM, OSMI, MERIS). Forecasts of where and when blooms are likely to develop and of their trajectories once developed can be improved by developing and validating multivariate empirical habitat models that predict the probability of that a bloom will occur based on environmental conditions and coupled, 3-D hydrodynamic-patch dynamic models. Improving the skill of nowcasts and forecasts can be effectively addressed by integrating data from existing satellites and *in situ* observation networks and by using OSSEs to guide cost-effective improvement in sampling schemes Gulf-wide.

These forecasts should ultimately include projections of toxicity of the blooms. These forecasts could then be coupled with predictions of wind and wave conditions and coastal GIS maps of human recreation and occupancy. This should enable prediction of animal and human health effects.

Appendix 4. The HAB Forecast System for the Gulf: Recommended Improvements

Background

The Harmful Algal Bloom (HAB) Forecast System provides nowcasts and forecasts of *Karenia* bloom location and impact in the Gulf of Mexico. Currently analysis is performed separately for the eastern Gulf of Mexico and the western Gulf of Mexico. A bulletin is produced for managers in order to provide information that will aid in guiding sampling, monitoring, and response strategies. Forecasts of HAB impact are provided to the public. The bulletin for managers, sent by email, includes an analysis of field measurements, satellite imagery, and models. The Forecast System, while emphasizing *Karenia* “red tide”, also will respond to other potential HAB events. The system became operational for the eastern Gulf of Mexico in September 2004.

The key forecasts are:

- 1) Nowcast location and extent
- 2) Forecast location and extent (out 2-4 days)
- 3) Forecast respiratory impact
- 4) Forecast intensification
- 5) Forecast and identification of initial HAB

All the forecasts need validation in order to provide uncertainty, capture errors in the input and forecast models, and identify areas needing improvement. In addition, the models require location information in order to achieve accurate forecasts.

Recommended improvements

Significant improvements in HAB Forecasts can be achieved with the HABIOS addressing the areas to follow.

Location Data A HAB Field is created as a key part of the forecasts. The location data are interpreted to create the HAB Field, and the quality is limited by the resolution of the available data. Location information can be the equivalent of “presence/absence” or “medium/low/background”.

- 1) Resolution of HABs along and near the coast. In order to forecast and nowcast HABs, the most critical lack of information is the location of the HABs required to initialize the nowcast/forecast models. The current combination of satellite and cell counts can identify general areas of HABs, but cannot provide details at the coast at resolutions better than 10-50 km d⁻¹. This is insufficient for many of the public health requirements. Areas with critical public health concerns may require 1-4 km d⁻¹.
- 2) Near-real time respiratory irritation. Forecasting is simply more effective if the variable being forecast is also being measured.

- 3) Resolution of HABs at key sites in or near estuaries in order to forecast HABs at shellfish beds. Current capabilities allow forecasts of the presence of blooms immediately outside estuaries, but lack the information to produce the necessary targeted forecasts within estuaries.
- 4) Location of HABs offshore at critical initiation/transport sites. As HABs sometimes appear near the coast without detection by satellite, some mechanism is needed to locate these blooms.

Validation All forecasts require validation in order to identify errors, uncertainties, and areas for improvement.

- 1) Locations, as described above. Several of the forecasts (transport, extent, area, and intensification) can be met by the same location data as collected for initialization.
- 2) Respiratory irritation data. The presence and absence of respiratory irritation/impact must be available at the resolution required. A target would be tracking movements with errors not more than 10 km d⁻¹ and forecasting critical beaches.
- 3) Shellfish toxin levels. Access to shellfish closures that are documented by tissue samples would aid in validation of forecasts over these areas.
- 4) Human health data. This should include poison center information, hospital admission data, and emergency room visit data, among others.

Models Transport models involve a combination of HAB fields and circulation models. Respiratory irritation models involve HAB-aerosol fields with near-shore wind/sea breeze models. As different models can be effective and uncertainties exist in these, a combination of ensemble forecasts, confidence bounds, and real-time model assessment are needed.

- 1) Standard forms for circulation models. As HAB transport models must blend HAB fields with circulation models, the currents from circulation models must be in standard formats and have identified uncertainties, so that they can be easily interpreted and implemented.
- 2) Real-time circulation model comparison. Circulation models need to be compared in real-time with observed currents in standard locations in order for forecasters to evaluate the potential value of each model for the current event.
- 3) Characterization of uncertainty in winds from the forcing meteorological models. This characterization would include the wind forecasts themselves, which are necessary for some models, as well as the impact of the uncertainty on the circulation models.
- 4) Biological “model” transformation. Usable biological models are conceptual, a mechanism needs to be established to transform these into heuristic forms that can be implemented and incorporated into forecasts, such as for initiation and intensification. This would also allow for new models on dissipation or seasonal forecasts.
- 5) Bloom Initiation models. Currently there are no applicable models for bloom initiation for the Florida panhandle and Texas. This is a research topic, but may not be considered as a research priority at this time.
- 6) Public health models.

Appendix 5. CDC's Harmful Algal Bloom-related Illness Surveillance System

The Centers for Disease Control and Prevention (CDC) conducts national surveillance for foodborne and waterborne disease outbreaks and enteric disease outbreaks involving person-to-person, animal contact, environmental contamination, and unknown modes of transmission. Outbreaks are reported to CDC by local and state health departments via the web-based National Outbreak Reporting System (NORS). Outbreaks associated with exposure to harmful algal blooms (HABs) may be reported. However, HAB-associated outbreaks are difficult to detect and provide insufficient data to inform future prevention efforts. There is no national surveillance system that collects information on single cases of illness or the occurrence of HABs, which are recognized as emerging ecologic issues and indicators of climate change. In 2013, CDC initiated a project to improve surveillance for HABs and associated illnesses. CDC established a HAB working group, a collaboration of state and federal partners with expertise in harmful algal blooms and illness surveillance, to develop a HAB reporting system that will be accessible to local and state health agencies via NORS. The system will utilize a “one health” approach to collect data—receiving and linking reports of single cases of human illness, animal illness, and HABs. In 2014, the HAB working group drafted reporting forms for cases of human illness, animal illness, and HABs; and initial case and HAB definitions. Programming the system has begun; launch is anticipated in 2015. CDC plans to pilot the system in 2015, with a full launch following user testing and enhancements.