Harmful Algal Blooms Integrated Observing System (HABIOS)

1.0 Vision Statement

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

To establish a sustained observing system as part of the U.S. IOOS that will facilitate and enhance efforts to 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 socioeconomic impacts of HABs on coastal communities.

2.0 Terms of Reference

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. 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

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1 The states have 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) has the Harmful Algal Bloom-related Illness Surveillance System (HABISS). 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).
Health Small group

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 objective 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. The resultant system 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 system over time. Although the system does not explicitly include research needed to improve detection and prediction capabilities, performance assessment 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 conservative manner. 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 will be consistent with design principles in the First IOOS Development Plan and will incorporate the ideas expressed in workshop reports and other documents, particularly those prepared or assembled for this design activity and made available via the GCOOS HAB web site: http://ocean.tamu.edu/GCOOS/Office/HAB.htm. 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), and the Ocean.US workshop on Public Health Risks: Coastal Observations for Decision Making (January 2006). These documents 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.

Terms of Reference

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2
3.0 Goals and Objectives

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

[One reviewer mentions need to address balance of costs versus returns. Do we need a statement to that effect?]

These critical gaps will be addressed by achieving several objectives:

1. Identify areas where HABs are most likely to occur (based on both past observations and knowledge of environmental conditions associated with an increase the probability of HAB events) and monitor them on time and space scales needed for rapid detection. Areas of concern include such areas should include shellfish beds, beaches frequented by people, areas most frequented by protected species at risk of HABs, and selected offshore areas known as HAB initiation or high-impact sites/hotspots.

2. Integrate relevant data in consistent and understandable products and formats. Data includes where ‘relevant’ includes data on the abundance and distribution of HAB species, their toxin concentrations, environmental parameters influencing abundance and distribution, and human health, and animal health, living marine resources, and socioeconomic impacts.

3. Provide for timely archival of and easy access to all data on phytoplankton species (including HABs), associated environmental data, human illnesses, and morbidities, and mortality events involving marine organisms.

Access to human health data will be restricted, but we will be able to form collaborations with appropriate scientists to ensure access to data.
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(4) Track in real time and provide timely forecasts (with error estimates) of the location, time-space extent, bloom, cell, and toxin characteristics of HABs.

(4A) Track in real time and provide timely forecasts (with error estimates) of HAB-concentration and toxicity of HABs and associated human illnesses and animal morbidity/mortality pathologies;

(5) Distribute the information in ways that are timely, meaningful, relevant, and readily accessible to the various management and public communities;

(6) Monitor the effectiveness of the system using quantifiable performance metrics that gauge both system functionality (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 end users);

(7) Identify human health risks from HAB events
2. Identify living marine resource risks from HAB events
3. Identify the environmental conditions epidemiologic studies should take into account as possible risk factors for exposure/development of disease.

[[Three reviewers did not like this as written: they claim it is not clear and needs specific example of what constitutes improvement in assessments.]] and

(8) Identify areas of research and operations that will improve the system and prioritize these areas;

(9) Encourage workforce development particularly focusing on taxonomy.

(10) Encourage interdisciplinary collaboration, research, and training.
4.0 Objective-Specific Activities

To achieve these objectives, the observing system will be established and evolve as follows:

**Objective 1**

1. Identify initiation sites, hot spots, 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 process 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, the HAB-FS (Forecasting System) bulletins).
4. Monitor critical areas of concern, e.g. shellfish areas and critical beaches, for presence and impact of HABs with appropriate sampling rates.
5. Determine species and concentration (intensity) of detected algal blooms.
6. Determine the toxicity of cells associated with detected algal blooms, in addition to species identification and cell counts; toxin level will influence the extent of negative human/ecosystem health and socioeconomic impacts.

**O1 Activities**

| 5 | 4 | 3 | 2 | 1 |

**Objective 2**

1. Expand and improve the efficiency of networks for data and information exchange among the responsible state, local, and federal agencies, and in cooperation with Mexican and Caribbean partners. This includes use of IOOS DMAC standards for data and metadata and enhancement of the HABSOS capability.
2. Provide nowcasts and forecasts, e.g. from NOAA HAB-FS into format compatible with monitoring data.

**O2 Activities**

| 5 | 4 | 3 | 2 | 1 |

**Objective 3**

1. Provide secure provision for storage and archival of data and information. Recognize that access to some kinds of non-aggregated data (including human health data and detailed commercial fishing data, public access may be determined on a case-by-case basis) will be restricted (due to privacy issues), need to encourage collaboration to ensure access. Storage of human health data will likely be elsewhere.
2. Ensure that all stored data and information can be discovered and retrieved from archives by machine. Build system to acknowledge differences in data restrictions.
3. Provide mirror (backup) storage for data and information.
Different data and information types have different restrictions for sharing.

**Objective 4**

1. Produce reliable predictions of the onset of HABs in areas of concern
2. Make all monitoring data for sampling cell locations and bloom characteristics intensity available in a coherent form for operational nowcasts and forecasts. Improve HABSOS capability (or equivalent) to support the HAB-FS system
3. Link observations and models more effectively through data assimilation as well as OSSEs that can be used to improve the cost-effectiveness of monitoring,
4. Have necessary circulation output from models available in common 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 5**

1. Provide the foregoing information, including 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, managers, users, media and public to increase understanding and value of the products of the HABIOS
3. Maintain retrievable archives of pertinent information

**Objective 6**

1. Determine and implement performance metrics for the efficacy of observing system functions (the efficiently of linking observations, DMAC, and modeling linked for sustained product delivery with metrics monitored 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); these are monitored by users;
3. Establish a key users group and have periodic annual feedback reviews of the system;
4. Regularly review the HABIOS using quantitative performance metrics.

**Objective 7**

1. Perform a retrospective analysis of risk relating the locations and times of HABs occurrences to human population concentrations.
(2) Coordinate epidemiological studies with observations of the distribution and abundance of HABs/toxicity, environmental conditions associated with them as determined from data provided by the Integrated Ocean Observing System.

1) Identify human health risks
2) Identify health databases
3) Identify living resource databases
4) Support development of human disease surveillance, e.g., HABISS, vibrio wound infections, waterborne disease outbreaks
5) Include environmental data as risk factors in human epidemiology
6) 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, ER visits, etc.
7) Assess how to involve veterinarians in relevant companion animal disease surveillance
8) Create links for abstracting limited human health data to non-health databases/importing relevant environmental data to health-based databases.
9) Coordinate epidemiological studies (animal and human) with HABs observations and associated environmental conditions
10) Create a model to integrate human health or living marine resource health and environmental data.

a. e.g., Lazinski and Hoagland paper (poster at WHOI-HAB conference, Woods Hole, October, 2007)

O7 Activities

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[NOTE from 9 November conference call: CDC organized HAB Surveillance System for HAB related illnesses – HABISS]
[Need to identify epidemiological data sources — and pathology data on marine populations (animal health data collection systems) to begin process on integrating IOOS data with epidemiological data; build data dictionaries; make data bases interoperable. Florida in the lead and can work with other states to address these issues including web-based access via portals.]
[Knowing where to go and how to get approval.]
[Interface between IOOS sampling-data analysis and sampling-data analysis for epidemiology]

O7 Activities commentary

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Objective 8

(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 common standards and protocols for measurements and data integration/fusion).

O8 Activities

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5. Implementation I: Observations and Models

The implementation plan for observations and models will address the goal and objectives and address the activities given in previous sections. It provides a prioritized, phased plan based on the objectives stated above, user needs, and technical capabilities.

Section 5 Intro

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5.1 In situ observations

5.1.1 Routine monitoring by people in the field

5.1.1.1 State efforts

Key components of the in situ measurements and surveillance would include are those supported by Gulf coastal states. Each state makes regular observations on beaches, shellfish beds, or other HAB areas of concern, fish kills, animal morbidities and mortalities, and human health outcomes. Hot spots in the coastal zone. In addition, each state makes regular observations of fish kills and human illnesses such as reports of respiratory affects caused by HAB toxins.

However, it is important to note that each state makes different measurements on different time and space scales and use different data formats and metadata. Thus, priority should be given to the following:

(1) Agree on and implement common standards and protocols for measurements, data transmission, and data/metadata management;
(2) Agree on and implement a sampling scheme for the region as a whole; and
(3) Work to optimize sampling schemes and measurement protocols over time.

The current status of these ‘anthropic’ observing subsystems are described in Appendix 1.

5.1.1.1

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5.1.1.2 Volunteer-based efforts
Appendix:

Break into 2 groups: Volunteer monitoring and Volunteer sampling

Volunteer-based sampling and surveillance networks expand the state-supported efforts. Among these are the Southeast Volunteer Plankton Monitoring Network organized by NOAA's Holling’s Marine Laboratory (NCCOS, Charleston, SC). The network 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.

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.

NCDDC has developed an on-line data entry tool which allows data to flow to NCCOS where it uploaded to an internet map service (IMS). Personnel at NCDDC plan to "move" the volunteer data into the HABSOS database instantaneously and without problems because they host both databases.

Currently there are 25 groups in TX and seven in AL. NCCOS supplies each group with a plankton net, refractometer, and a digital microscope so each group can send pictures and movies for identification. Each site costs $1,200 for the equipment needed for the monitoring effort, including the digital microscope. Training workshops are conducted in each state involved with the monitoring network; these workshops require about a week of travel time for contracted outreach staff.

For more information, go to http://www8.nos.noaa.gov/nccos/npe/projectdetail.aspx?id=51&fy=2008

In collaboration with NOAA, state agencies in Florida and Texas also support networks of volunteers to collect water samples in the field and return them to the laboratory for microscopic examination. Some are shown in Table 5.1.1.2-1. These networks should be expanded to establish a volunteer network for all states Gulf-wide. In so doing, they should agree on and implement common standards and protocols for sampling, observations, and reporting data.

In a unique collaboration, the Florida Dept of Health, CDC and its public and private partners have established a linked network of public health information coupled with exposure and disease surveillance on Florida red tide. NOAA (coastwatch.noaa.gov/hab/bulletins_ns.htm) and Florida Wildlife Research Institute (866 300 9399) produce weekly reports of red tide location based on remote sensing and water monitoring available by phone and web. This exposure information is linked to South Florida Poison Information Center Hotline (888 232 8635) which
provides 24 hour/day toll free health information in multiple languages; the Hotline also reports
cases to the Dept of Health as part of ongoing harmful algal bloom surveillance.

Beach conditions needs to be described as volunteer effort.

5.1.1.2

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Table 5.1.1.2-1 Volunteer plankton observing systems

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<th>Network</th>
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<tr>
<td>Oyster Sentinel</td>
<td>Gulf of Mexico</td>
<td><a href="http://www.oystersentinel.org">http://www.oystersentinel.org</a></td>
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<tr>
<td>Microalgal Lab at DISL</td>
<td>Alabama</td>
<td><a href="http://tidings.disl.org/">http://tidings.disl.org/</a></td>
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Texas volunteers are partnered with NOAA’s volunteer Phytoplankton Monitoring Network—(1" in-table)
Louisiana—Oyster Sentinel (2nd in table)
Mississippi—no volunteer efforts noted—all seems to be tied to the MS DMR and DEQ water sampling programs for oyster bed monitoring.
Alabama—once again part of NOAA's Phytoplankton Monitoring Network (1" in-table)
Florida—in-situ or automated monitoring

5.1.1.2-1

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5.1.1.3 Data quality

Private and research entities also perform anthropic in situ measurements. For these efforts to be
effective, common standards and protocols for measurements and delivery of data and
information are needed that correspond to state-supported efforts. [Can a summary
table/appendix be prepared?]

5.1.1.3

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5.1.2. Routine observations from moorings and autonomous under water vehicles
Routine, real-time in situ measurements are needed, especially in recognized areas of concern for hot-spots for HAB events. These include both measurements of environmental parameters and the abundance of HAB species.

5.1.2 Intro

5.1.2.1 What can unattended in situ instruments measure?

Environmental parameters
T, S, currents and waves can be done in real time now. In situ nutrient sensors for real time measurements are now being tested and these should be ready to mount on mooring and AUVs in the relatively near future. [Need to elaborate this a bit and provide an appendix or references to publications that describe existing capabilities and R&D activities in this arena.]

Detection of HAB species
Although still largely in the research phase, unattended, in situ measurement systems reporting in real time are now being utilized. High priority should be given to the development of cost-effective bio-optical and molecular methods for detecting species and toxins in real-time, and make them widely available. [Need appendix or references to publications that describe existing capabilities and R&D activities in this arena.]

5.1.2.2 Criteria for site selection

Fixed point measurements for only environmental parameters just as a part of the HABILOS is likely cost prohibitive. However, use can be made of fixed point measurements made for other purposes or made for joint use in HAB monitoring and for other purposes. Among such measurements already in place are prominently NOAA's National Water Level Network and National Data Buoy Center among others and the Texas General Land Office's Texas Automated Buoy System. Most of these are reported in real or near-real time.

Another important class of fixed point environmental measurement are HF radars for measurement of surface currents and, for some typed or radars, surface waves. As a part of IOOS plans are being made to populate the nations coasts with HF radar systems for the continuous, real-time measurements of near shore surface currents. In particular, GCOOS is developing a plan, starting with integration of current HF radar assets in the Gulf, for an interoperable suite of radars covering the near shore regions of U.S. coastal waters.

When selecting fixed sites or glider paths for measurements as part of the HABILOS, one criteria for would be that there are some resources that require protection. This then becomes a scale issue depending on how much lead time is needed for protection. An example would be shellfish beds or mariculture farms. They have high priority, but fairly localized concern. Another example would be beaches which are not quite as critical for early notification, but are more widely dispersed around the Gulf. A second important criteria should be that there is some history of HAB events in the area in question. That pretty much covers the whole Gulf now, but
the intensity of effort may be appropriate to the likelihood of HAB events. Clearly, it is easier to sustain deployments of such measurements at choke points such as mouths of estuaries or near aquaculture facilities than at locations removed from shore support, such as offshore; however some such locations may be needed, e.g., for model verification.

5.1.2.2

| 5 | 4 | 3 | 2 | 1 |

5.1.2.3 How many locations are needed in U.S. Gulf waters?

This is a huge question, best answered by the various Gulf state concerns. The current implementation effort along the west Florida coast from Tampa Bay to Naples is aiming at a set of 10 fixed detectors (about 20 km spacing) just offshore (10-m isobath) to track movement along the coast. These are augmented by four additional detectors located around two shellfish farms in the Charlotte Harbor area. Since those HAB events most often initiate 15 to 40 km offshore they are increasing their HAB detector-equipped glider fleet to five units so they can have two gliders patrolling the offshore waters. Although they do not currently have plans to deploy them, chlorophyll fluorometer-equipped AUVs would be a great asset to look for chlorophyll that is not in view of the satellites either due to depth or weather. Numbers would depend on the type of AUV and length of coastline. With 200 km of coastline to observe, it would require three of the smaller propeller-driven AUVs to be able to respond to gaps in satellite coverage.

5.1.2.3

| 5 | 4 | 3 | 2 | 1 |

5.1.2.4 What should those stations measure?

Whether it is the optical absorption-based BreveBuster or a genetic probe device (in some cases both), each platform is expected to provide HAB presence/absence information needs a HAB detector. Some assets, such as the fluorometer-equipped AUVs, may be specialized for specific tasks and may not have to include HAB detection.

5.1.2.4

| 5 | 4 | 3 | 2 | 1 |

5.1.2.5 What are temporal reporting requirements?

Real-time (or near real-time) data are essential due to the dynamic nature of HABs. Default times of up to six hours for data from gliders seems reasonable. Relying on human intervention to recover data is fraught with unexpected delays and loss.

5.1.2.5

| 5 | 4 | 3 | 2 | 1 |

5.1.2.6 How frequently must stations be serviced?
This depends on what type of device is being used and where it is located. The BreveBuster in estuaries needs to be cleaned of biofouling about every 30 days. The BreveBusters on the COMPS C10 buoy lasts up to 90 days. A BreveBuster on a glider can go 30 days between service.

In addition to R&D, issues to be addressed include quality control and the use of common standards and protocols for data telemetry and other data management meeting IOOS DMAC standards.

### 5.1.2.6

| 5 | 4 | 3 | 2 | 1 |

### 5.2 Remotely Sensed Observations

**NOTES: QA/QC**

When this is turned into objectives, we will comment.

Both federal and university based facilities downlink and/or process satellite data that are useful for HABS detection and tracking. However, careful attention and expertise are required to distinguish HABs and other phenomena. Although the HABIOS must depend on that availability of satellite data determined by national priorities, the GCOOS Regional Association should weigh in on priorities for improving satellite-based remote sensing needs that will influence NASA mission priorities. IOOS requirements for HABs and key environmental parameters are only partially addressed by existing and planned satellite missions for several reasons. Those that are particularly significant for elucidating HAB dynamics and for early detection of HABs are elucidated in the USGSC background paper prepared by Malone and provided for the GCOOS HABs Observing Plan Workshop (14-16 November 2007).

Using approaches developed by NASA (e.g., the WorldWind tool) and other groups, integrate data on ocean leaving radiance from all available sensors (SeaWiFS, MODIS, OCM, OSMI, MERIS) to provide maps of sea surface chlorophyll-a and diagnostic pigment ratios daily during periods when blooms are most likely to occur (late summer-fall) and weekly during the remainder of the year.

### 5.3 Adaptive Observations

Adaptive observations are triggered by 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), by detection of a bloom indicator (e.g., pigment signatures detected bi-optically from AUVs and/or ocean color images from satellite sensors), and/or by 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). 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.

### 5.3

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**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).

Add to trigger examples: human health events, animal morbidity and mortality

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<tr>
<th>Trigger</th>
<th>Objective</th>
<th>Adaptive Sampling Scheme</th>
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<td>(1) Environmental conditions favorable for a bloom and/or a <em>Trichodesmium</em> bloom</td>
<td>Weekly nowcasts of where and when a bloom is likely to occur during late summer-fall</td>
<td>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</td>
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<td>(2) Detection of a chlorophyll-a patch</td>
<td>Validate the indicator &amp; determine patch size; An alert giving the location &amp; areal extent of a new bloom followed by daily nowcasts of location and extent</td>
<td>One time, ship-based survey of the patch in 3-D to confirm the presence of a HAB species &amp; 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)</td>
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<td>(3) Validation that the chlorophyll-a patch is caused by <em>K. brevis</em></td>
<td>Daily nowcasts of bloom status (growing or dissipating) &amp; toxicity (low, moderate, high); 2-3 day forecasts the patch’s trajectory updated daily</td>
<td>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)</td>
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### 5.4 Models

**NOTES:** We will comment on modeling group amendments.
5.4.1 Determine the critical data and information requirements for modeling, forecasting, and validation, and also inventory existing data systems, including state, federal, local, research and Mexican for their ability to provide data for models and forecasts.

5.4.2 Track and forecast (with error estimates) the location, intensity and characteristic toxicity of HABs.

5.4.2.1 Determine areas of greatest need for HAB forecasts and the minimum accuracy requirements.

5.4.2.2 Inventory environmental parameters observational requirements specific to forecasting HABs.

5.4.2.2a Inventory the environmental parameters specific to forecasting human exposure/effects. The inventory should also include those for human and animal health effects.

5.4.2.2b Inventory the environmental parameters specific to forecasting human exposure/effects.

5.4.2.3 Make circulation output from models available in common standard formats for nowcasts and forecasts.

5.4.2.4 Develop nowcasts and forecasts

Link observations and models more effectively through data assimilation (include real data, taken into model in near-real time, to ground-truth the model)

5.4.2.4.a Integration – incorporating different types of data, including human health data and living marine resources data.
5.4.2.4 Validation (withholding some real-time data and use it to compare with model output)

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.

5.4.2.5 Produce reliable predictions of the onset of HABs in areas of concern by expanding and improving the current HAB-FS with the use of other deterministic, probabilistic and heuristic models.

5.4.2.6 Implement location uncertainty statistics into forecast models, with information based on both location uncertainty and the use of ensemble models for modeling uncertainty.

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

5.4.2.8 Use OSSEs to improve the cost-effectiveness of monitoring (sampling schemes and measurements).

5.5 Harmful Algal Forecast System for the Gulf of Mexico

5.5.1 Background

NOTE: This should be provided as a case study. In addition, it should be noted that other human health/living marine resources data may be incorporated in the future.

The Harmful Algal Bloom (HAB) Forecast System provides nowcasts and forecasts of Karenia HABs 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.

### 5.5.1 Location Data

**NOTE:** Note the issues associated with incorporating human health/living marine resources data

A HAB Field is created as a key part of the forecasts. The location data is 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 at 10 km d\(^{-1}\).** 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.
5.5.2.1

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5.5.2.2 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. This would need to be at least 10 km d⁻¹, as well as 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.

NOTES: Allow for expansion of the sources of data, including poison information center data, hospital admission data, ER visits, etc.

5.5.2.3 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.

NOTES: Incorporate real-time wind data instead of forecasting from forecasts.

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 should be kicked out as a research requirement.

6) Public health models.

5.5.2.3

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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. In this context, the following are priorities:

- Inventory current data transfer, formats, databases and archives involved in data transfer including those used by the HAB-FS, HABSOS, and states.
- Perform a gap analysis between elements of the system that exist and those that are needed.
- 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 Recommended improvements to the HABSOS

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). Enhancements to HABSOS are recommended as part of this HABIOS Plan.

In FY07, upgrades to HABSOS began under EPA funding and direction. During FY08 the following enhancements are programmed and will be 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)
- 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-based efforts), agreeing on and using standard definitions of abundance classes and common standards and protocols for data collection, discovery, exchange and dissemination.
- Improving 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.)

NOTES: We are unclear about what HABSOS is.

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?

6.2

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6.3 Performance Metrics: 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)

6.3.1 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.

6.3.2 Develop and implement performance metrics for how well the information provided meets the needs of user groups (user satisfaction); these are monitored by users.
6.3.3 Produce a periodic review of the HABIOS observations network using performance metrics.

6.0 Implementation III: Link *Public Health* Epidemiology and Ocean Observations

**NOTES:** Marine mammal health experts (and others, such as turtles and birds) should be involved in developing this section.

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**Teri Rowles**

**LeAnn Flewelling**

**NOTES:** This is a narrative and doesn’t include objectives

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**Sibel Bargu**

**Objectives:**

Predicting human and animal health effects is one of the key activities of the HAB Forecast System in the Gulf of Mexico. Abstracting human and animal health data from various systems will allow ground-truthing of the predictions. Sources of human and animal health data include:

1) Near real-time respiratory irritation data collected by lifeguards.

2) Review of hospital records for emergency room visits and hospital admissions for respiratory irritation.

3) Review of local physician records for reports of asthma exacerbations.

4) Review of calls to the Poison Information Center hotline.

5) Review of reports collected in the Harmful Algal Bloom-related Illness Surveillance System (HABISS).

6) Review of admissions to veterinary clinics and/or animal hospitals.

7) Review of unusual mortality events.

---

**Objectives**

- Identify existing human health databases, including the expert contact
- Identify existing veterinary health databases, including the expert contact
- Identify existing living marine resources databases, including the expert contact
- Identify databases of experts

**Suggested additions/enhancements to these ends are:**

- Support development of human health assessments
- Support human health surveillance activities
- Support new epi studies for the definition of HAB-related illnesses
- Improved utilization of near real-time multisensor satellite data and products for public health applications and develop new and improved remote sensing capabilities
- Develop case definitions for HAB-related illnesses
• Conduct baseline assessments of HAB-related illnesses

- Connect environmental and epidemiological databases to improve risk assessment capabilities
  - Surveillance activities

- Provide the data and information needed to quantify relationships between changes in land use and land-based inputs to coastal waters and changes in public health risks
  - Review existing databases (e.g., TMDL) 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 a new paradigm of coordination among public health and environmental protection officials, living resource and coastal zone managers, and oceanographers and coastal hydrologists

- Enhance effective use of the internet and other electronic media to transmit relevant data to public health officials so that they can issue timely warnings to the public

#### 7.0

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#### 7.1 Implementation IIIA: Link living marine resources and ocean observations

**Objectives:**

Enhanced physical, chemical, and biological monitoring systems for HABs will improve our public health protection and management abilities. This will provide more accurate and timely data. This should help to identify blooms earlier, predict where they may be transported to, better understand causal mechanisms that lead to formation and intensification of HABs, predict the likelihood of fish and shellfish poisoning, predict the extent of dispersal of aerosolized toxins, etc.

Coordinating and interfacing these monitoring systems with epidemiological surveillance systems 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 responses; while health responses must guide additional sampling strategies for HABIOS. We should look for opportunities to coordinate these systems as epidemiological studies are performed.
Objectives

- Identify existing human health databases
- Identify existing veterinary health databases
- Identify existing living marine resources databases

• Support development of human health assessments
- Support human health surveillance activities
  > Add description of HABISS in appendix

- Support new epi studies for the definition of HAB-related illnesses
- Develop case definitions for HAB-related illnesses

• Conduct baseline assessments of HAB-related illnesses

- Connect environmental and epidemiological databases to improve risk assessment capabilities
  > Surveillance activities

• Review existing databases (e.g. TMDL) 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

• 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

7.0

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In Appendix

Shellfish (GCOOS website, MS)

NOTES: Need input from marine mammal specialists

8.0 Implementation IV: Improving Operational Capabilities through Research

8.1 Remote Sensing

Given existing satellite-based sensors, research priorities are as follows:
• improve algorithms used to retrieve optical properties;
• improve characterization of aerosols for atmospheric corrections;
• create blended surface chlorophyll products from multi-sensor data streams (e.g., SeaWiFS, MODIS, MERIS, OCM);
• quantify relationships between estimates of biological and biogeochemical variables derives from ocean color and SAR measurements (e.g., chlorophyll, turbidity, colored dissolved organic matter, surfactants, waves, and buoyant plumes); and
• improve algorithms for extracting information on floristic composition from measurements of ocean leaving radiance (e.g., pigment ratios).

8.2 In Situ Sensing and Field Measurements

• Facilitate technology transfer to public health and LMR
  • For example:
    )o Develop cost-effective bio-optical and molecular methods for detecting species and toxins in real-time, and make them widely available.
    )o Develop validated, standardized, field methods for rapid detection of toxins in seafood.
  o Develop validated, standardized field methods for rapid detection of toxins in biological samples.

8.3 Modeling

• 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 OSSEs/OSEs to evaluate existing and proposed sampling schemes for improving model-based forecast skill and guide adaptive sampling strategies in order to employ an optimal mix of in situ measurements and remote sensing;
• Coupled physical biological models, grids and boundary conditions;
• Properly coupling 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.

8.3

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8.4 Human health

- Epi studies to define chronic sequellae from acute and chronic exposures
- Epi studies to define adverse health effects from chronic, low-dose exposures
- Epi studies of sensitive populations
- Risk assessments
  - e.g., RfD (acute reference doses) need to be developed
- Epi studies of real-life exposures (mixtures)
- Clinical studies for treatment
- Develop methods to mitigate exposure and disease
- Develop models of socio-economic impact
- Surveillance?

8.5 Living Marine Resources health

- Epi studies to define chronic sequellae from acute and chronic exposures
- Epi studies to define adverse health effects from chronic, low-dose exposures
- Epi studies of sensitive populations
- Risk assessments
  - e.g., RfD (acute reference doses) need to be developed
- Epi 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,
  - e.g., 5,000 cell action level for *Karenia brevis* as it equates to toxin levels,
  - ? for *K. mikimotoi*, etc.
  - Determine toxicity of different *K*. species.
- Develop models of socio-economic impact
- Surveillance
9.0 Implementation V: Information Delivery

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 rations) 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 multi-variate 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.

[Need to add information on (1) Ongoing human health impact capture such as the CDC HABISS SYSTEM and (2) Delivery of information on other HABs]
Appendices

Appendix 1  State-supported HAB monitoring

1.1 Alabama

Alabama’s State-Supported HAB Monitoring

1.0 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

1.1 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.

1.2 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.

1.3 Sample data include:

- water temperature,
- salinity,
- wind direction and speed,
- tidal stage,
- date,
- time,
- phytoplankton density per liter (acidified Lugols preserved)
- harmful and non-harmful dinoflagellates with emphasis on *Karenia brevis* (Organisms are identified to species where possible.)
- *Pseudo-nitzchia* identified to genus by light microscopy
- observations by ADPH Seafood Branch personnel

1.4 Data management is in-house electronic database and hard copies. No data are submitted to HABSOS.

Contact:
Jeff McCool
AL Dept. of Public Health
Seafood Branch
4168 Commanders Drive
Mobile, AL 36615
251 432-7618

2.0 Other monitoring efforts
2.1 A voluntary effort by AL Dept Environmental Management and Baldwin Co Health Department personnel for surveillance on the Gulf beaches uses the EPA BEACH sites for collection points.

Sites are selected to be representative of the coast from the AL-FL border to the Public Beach on Dauphin Island. Sampling frequency is once per week during swimming season (May until October) and once per month in the off season.

Sample data include:
- Water Temperature
- Salinity
- Date
- Time
- Phytoplankton density per liter (acidified Lugol’s preserved)
- Harmful and non-harmful dinoflagellates with emphasis on *Karenia brevis*. Organisms are identified to species where possible.
- *Pseudo-nitzschia* identified to genus by light microscopy
- Observations of the collectors e.g. discolored water, jellyfish (may be contribute to complaints by beach goers), rough surf

3.0 Data management by ADPH Laboratory

- Reports of samples are faxed to Seafood Branch.
- Turnaround time for results return to the collecting agency is no more than 2 days.
- The laboratory maintains an Access database.
- Data are checked for accuracy.
- Supervisor checks about every 20th entry for accuracy.
- Decisions to share data are made on a case by case basis.

In event response an HAB Alert list email is sent to agencies, FDA, neighboring states, and other ADPH management.

No data are sent to HABSOS.

Contact: Bill Smith, Lab Manager or Carol Dorsey, Microbiologist Supervisor

Mobile Division Laboratory
757 Museum Drive
Mobile, AL 36608
251 344-6049

Appendices

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