HARMFUL ALGAL BLOOMS OBSERVING SYSTEM (HABSOS)

Workshop Report

Design and Implementation Plan for a Pilot Project for the Coastal Component of the U.S. Integrated Ocean Observing System: Detection and Prediction of Harmful Algal Events in the Northern Gulf of Mexico

Gymnodinium breve

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Harmful algal bloom web sites
http://www.habhrca.noaa.gov
http://www.redtide.whoi.edu/hab

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HABSOS Workshop

PREFACE

The U.S. and the international community are in the process of developing the global ocean observing system (GOOS). A preliminary plan for U.S. GOOS has been drafted and submitted to Congress in April, 1999 under the auspices of National Ocean Research Leadership Council ("Toward a U.S. Plan for an Integrated, Sustained Ocean Observing System"; http://core.ssc.erc.msstate.edu/NOPPobsplan.html). The prospectus for the international Global Ocean Observing system can be found at http://ioc.unesco.org/goos/Prospe98/Contents.html.

The coastal component of this system is in the early stages of development. Its goals are to (1) improve local and regional weather forecasts; (2) minimize or eliminate public health risks associated with environmental changes (e.g., coastal flooding) and biological events (e.g., harmful algal blooms); (3) improve predictions of the effects of global weather patterns and climate change on coastal populations and the safety and efficiency of marine operations, and (4) improve the efficacy of management actions intended to control and mitigate the effects of human activities and natural hazards on coastal ecosystems (to protect and restore healthy coastal marine ecosystems and sustain living resources) and protect and restore critical habitats and biodiversity. The design strategy is to build a national network that will be regionally enhanced based on local and regional needs. The national network will provide information on a small number of variables required to address a broad spectrum of issues (e.g. from changes in sea state for the shipping industry to harmful algal blooms for state managers and policy makers). The system will be built in a systematic and considered fashion, and it will occur region by region in a step-by-step fashion. **The design and implementation of an observing system for harmful algal blooms and events (HABSOS) is a pilot project for a regional enhancement of the developing national network.**

EXECUTIVE SUMMARY

The Harmful Algal BloomS Observing System (HABSOS) is a "proof of concept" project of the U.S. Global Ocean Observing System (USGOOS) and the National Association of Marine Laboratories (NAML). The HABSOS Workshop was conducted to bring data providers (scientists) together with data users (state agencies) to develop plans for the design and implementation of a regional observing system for the detection and prediction of harmful algal blooms and their effects. Workshop results and recommendations were developed in three categories: (1) user requirements for data products, (2) data communications and management requirements, and (3) requirements for measurements, sensors and platforms. For all three categories, the design and implementation of HABSOS must build on, enhance and supplement existing programs.

User Requirements

The primary issues that state agencies must deal with are (1) protecting public health, (2) economic effects of harmful algae (wild fisheries, aquaculture, tourism, property values), (3) dissemination of useful information to the public. Managers need information, not data. The following information are high priorities:

- an alert that an event is in progress;
- forecast of the trajectory of the event in time and space; and
- an alert of where and when conditions are favorable of a HAB event (advance notice of the probability an event will be initiated).

Gymnodinium breve, the cause of neurotoxic shellfish poisoning, was identified as the target species for the initial HABSOS.

Data Communications and Management

The design and implementation of the data communications and management system component of the observing system was considered to be the highest initial priority. The objective is to develop a system for both real-time and delayed mode data that provides the means to integrate diverse data from disparate sources in a timely fashion. The system is envisioned as a web-based interactive network (a distributed system) of data providers, data managers, and data users. The building blocks of the initial system should include LabNet, GMNET, NODC, NCDDC, and state data centers. A data portal (hub) and information center are to be established to serve the northern Gulf of Mexico region (Florida to Texas). The following are high priorities:

- Inventory existing data sets and their locations; and
- Develop an integrated and comprehensive data base of all past HABs, HAB events and associated environmental conditions that will be available to all participating institutions.

The initial data communications and management system will grow in an incremental way by linking and integrating existing networks and data management effort. It is recommended that the NCDDC function as both the data portal and the Regional Information Center (RIC).

Measurements, Sensors and Platforms

When fully developed, HABSOS will provide the data and information required to control and mitigate HABS and their effects. HABSOS must work with existing programs to establish data requirements for and obtain access to data on (1) surface winds, precipitation, river flows and associated inputs of sediments and nutrients and (2) water column temperature, salinity, and concentrations of nutrients, dissolved oxygen, chlorophyll, colored dissolved organic matter and *G. breve* cell densities. Measurements will be integrated from a mix of platforms including shore-based sampling, ships, autonomous *in situ* sensors and remote sensing and made available to all participating institutions via the Internet. The first step is to coordinate and link

existing monitoring systems to insure continuity, achieve larger scale regional perspectives, minimize redundancy, improve access to data, and produce timely analyses that benefit state agencies and researchers in the region.

Regional Collaboration

The success of HABSOS will require an unprecedented level of coordination and collaboration among government agencies (state and federal) and academic institutions to make more effective use of collective resources and to develop the technical capabilities required by the observing system.

- Many state agencies do not have the resources to develop and maintain databases or relational data systems. A regional, federally funded approach is needed to train state personnel, to help build the required infrastructure, and provide technical assistance.

- High priority must be placed on R&D in the areas of data assimilation and modeling and *in situ* and remote sensing that will improve the system and make it more cost-effective.

Synergy between research and monitoring and data collection and analysis must be promoted at all levels.

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1. WORKSHOP GOALS

The purpose of the HABSOS Workshop was to formulate plans for the development of a user-driven, end-to-end (measurements to applications) observing system for the northern Gulf of Mexico (Texas to Florida) that will provide more timely access to data and information on the initiation, evolution, and effects of harmful algal looms and related events (e.g., fish kills, human pathologies caused by algal toxins).

HABSOS is a pilot (proof of concept) project to develop and test the required infrastructure using the detection and reporting of HAB events as a test case. If successful, the goal is to grow the system into a fully integrated and sustained observing system for the northern Gulf of Mexico and to begin the development of similar systems in other coastal regions to form a national federation of regional observing systems. **We emphasize that this must begin by linking and enhancing existing programs and capabilities in the region**.

Two immediate objectives are to (1) **network government agencies (state and federal) and coastal research laboratories (state, federal and academic)** to develop the communications and data management infrastructure required for more timely access to data and information on HABs and coastal ecosystems in the northern Gulf of Mexico; and (2) **test the hypothesis that more effective use of the collective resources of government agencies and coastal laboratories on a regional scale (multi-state)** will lead to improved and more timely detection and prediction of harmful algal events and their effects on people.

To these ends, representatives from government agencies, coastal research laboratories (Southern Association of Marine Laboratories, SAML), and the research community at large were invited to participate in the workshop. Participants included professionals from State agencies responsible for water quality, living marine resources, public health and coastal zone management (the users); data managers; and scientists (academic and government) involved in research and monitoring programs (observations and modeling) concerned with the causes and consequences of harmful algal events in terms of public health, fisheries, diseases in marine animals, and mass mortality events (Appendix 5.1).

2. BACKGROUND

2.1 The Coastal Component of the Global Ocean Observing System (GOOS)

2.1.1 Rationale and Goals for a Coastal Ocean Observing System

Given the concentration of resources in coastal ecosystems, the rapid increase in the number of people living, working and playing in the coastal zone should not come as a surprise. The pressures on these ecosystems to provide commerce, recreation, and living space and to receive, process, and dilute the effluents of human society will continue to grow. At the same time, coastal ecosystems are experiencing unprecedented changes that affect their capacity to provide these services and support valuable resources, e.g., habitat loss (tidal wetlands, sea grass beds, coral reefs, oxygen depletion), harmful algal blooms, fish kills, declining fish stocks, beach closures, coastal erosion and flooding. The resulting conflicts between

commerce, recreation, development, and conservation will become increasingly contentious, politically charged, and expensive. Credible, useful, and timely information on the causes and consequences of environmental changes in coastal ecosystems is essential if such conflicts are to be resolved and minimized. The coastal component of GOOS is an attempt to provide such information by making more effective use of our collective resources and by enhancing and supplementing existing research and monitoring programs in coastal ecosystems.

The combined effects of human activities in the coastal zone and natural variability present significant challenges to the goals of protecting, restoring, and sustaining ecosystem goods and services. Meeting these challenges and resolving conflicts in an informed fashion will require (1) **more timely detection and prediction** of environmental changes and their consequences; (2) **more timely access** to relevant environmental information by policy and decision makers; and (3) **more cost-effective use** of existing infrastructure, expertise, environmental data, and knowledge. A sustained and integrated observing system is required to achieve these goals. This is the purpose of developing a Global Ocean Observing System (GOOS).

Coastal GOOS is conceived as a coordinated global system that is regionally enhanced. A global network is needed to measure and analyze a minimum number of variables that are required for a broad range of purposes from forecasting the weather, marine services and compliance monitoring to predicting, managing and mitigating the effects of land-use on coastal ecosystems. Regional enhancements are needed to meet the local and regional requirements of participating nations (e.g., susceptibility to natural hazards, beach and shellfish bed closures, oxygen depletion, HABs, habitat loss).

2.1.2 Requirements

Although, the challenges are significant, we are witnessing a convergence of societal needs and technical capabilities that provide the motivation and means to design and implement such a system. The time is right to begin the development of a coastal ocean observing system that will be

- an end-to-end (from measurements to applications), user-driven system based on sound science;
- responsive to the information needs of many user groups;
- cost-effective through the incorporation of existing infrastructure and the shared-use of collective resources and expertise;
- both sustained (in perpetuity) and integrated (measure physical, biological and chemical variables synoptically in time and space); and
- closely coordinated and linked to the developing oceans and climate component of GOOS.

Linking user needs to measurements requires a managed, interactive flow of data and information among three essential subsystems of the IOOS: (1) the **observing subsystem** (measurement of core variables and the transmission of data), (2) the **communications network and data management subsystem** (organizing, cataloging, and disseminating data), and (3) the **modeling and applications subsystem** (translating data into products in response to user needs). Thus, the observing system consists of the

infrastructure and expertise required for each of these subsystems as well as that needed to insure the continued and routine flow of data and information among them.

If the system is to evolve to meet these requirements, it must promote synergy between environmental monitoring (to detect change), research (to development new technologies and capabilities), and applications (to serve a broader spectrum of user groups). Given the importance of physical processes in structuring marine ecosystems, high priority must be given to improving our ability to detect and predict variability in physical conditions (weather, surface winds, sea level, currents, waves, sea state, location of fronts and pycnoclines, etc.) and their consequences (from safe marine operations to how human activities affect marine ecosystems and the goods and services they support). **At the same time, due consideration must be given to the parallel development of capabilities to detect and predict biological changes that reflect the status of coastal ecosystems, their capacity to support living resources, and risks to public health and safety**. The system must be designed from the beginning to provide the required meteorological, physical, chemical and biological data and to assimilate and analyze such data to meet the needs of many user groups. Implementation will be a step-wise process based on current priorities and capabilities.

2.2 The U.S. Coastal Ocean Observing System: A Federation of Regional Systems

A high priority in the development of coastal GOOS is the design and implementation of a system that makes more cost-effective use of existing infrastructure and data. A large number of state and federal agencies are currently responsible for different but overlapping aspects of environmental change in coastal ecosystems. Agency missions range from forecasting the weather, enabling safer and more efficient marine operations, and predicting the effects of climate change to managing the health of coastal ecosystems and the resources they support, protecting public health, and mitigating the effects of natural disasters and of human activities. The agencies and departments responsible for these services, all of which require environmental observations, research, and forecasts have evolved separate (often redundant and not often compatible) systems for collecting, managing, analyzing, and applying environmental data. At the same time, individual programs, by themselves, are inevitably underfunded, limited in scope, and target a limited number of user groups. Consequently, major gaps exist in our understanding of variability in coastal environments, and our ability to predict future conditions and to mitigate the effects of environmental changes is rudimentary at best.

Many of the elements of an integrated coastal ocean observing system are already in place or in development, and the NOAA Coastal Services Center has established a web site that identifies and provides links to them (http://www.csc.noaa.gov/cts/coos/). In this context, it is clear that a more cost-effective approach must be found that coordinates and integrates many of the elements of these systems in order to minimize redundancy, to provide more timely access to data and information, to be more comprehensive, and to satisfy the information needs of a greater

spectrum of user groups (e.g., government agencies, industries, universities, research institutions, NGOs, and the public at large). An integrated observing system is needed to achieve this vision for coastal ecosystems from estuaries to the outer limits of the EEZ.

Detecting, assessing, predicting and mitigating the effects of natural variability and human activities on coastal ecosystems requires a regional perspective that transcends political boundaries and provides the means to evaluate local changes in marine ecosystems in terms of larger scale changes in climate, ocean circulation, fishing pressure and land-use practices. Regional approaches also provide a practical framework to coordinate the efforts of local, state, and federal programs, involve stakeholders, and enable the timely analysis of data. A nation-wide network can thus be built by coordinating the development and linking of regional observing systems that measure a common set of core variables and are regionally and locally enhanced (additional variables, greater resolution in time and space, data management and synthesis centers) to address those issues that are of greatest interest to user groups in the region.

There are many programs in place that incorporate some of the elements of an integrated and sustained system, but there are no programs that are sufficiently integrated or comprehensive to constitute a complete system. They are not as cost-effective nor as useful as they could be, and they do not serve as broad a spectrum of user needs as an integrated system would make possible. **Given these challenges, and the reality that the boundaries of most environmental issues of local importance are not confined to legal jurisdictions or to the missions of any one government agency, new mechanisms are needed that enable federal and multi-state collaboration in the allocation and management of resources and the periodic assessment of each regional system**. To be successful, the governance of regional programs must harmonize "bottom-up" programmatic development through regional organizations of stakeholders (data providers and users) with "top-down" coordination by federal agencies and national organizations. The success of this approach will depend on the development of programs that are comprehensive in design and enjoy continuity of support that is not susceptible to short term political decisions and the annual funding cycles of state and federal governments. By formulating and implementing a plan for regional (often interstate) observing systems that are **nationally coordinated and locally relevant**, a wider array of users will be more effectively served with relatively modest increases in costs relative to the additional benefits. This is the value added aspect of the proposed system.

The first step is to coordinate and integrate existing efforts to **insure continuity** and to achieve larger scale regional and global perspectives, **minimize redundancy**, **improve access to data**, and **produce timely analyses that benefit a broader spectrum of user groups**. By building on existing capabilities and infrastructure, and by using a phased implementation approach, work can start immediately to achieve the vision. New technologies, past investments, evolving scientific understanding, advances in data communications and processing, and the will to address pressing societal needs combine to provide the opportunity to

initiate an integrated observing system for coastal ecosystems. The major pieces missing are nationally accepted design and implementation plans; federal and state commitments of resources; and an unprecedented level of collaboration among federal and state agencies and data providers and users.

2.3 GMNET and LabNet

Data communications is a critical component of the observing system, and the U.S. GOOS Steering Committee has identified data communications and management as a high initial priority for developing the coastal observing system. Two efforts are underway that provide a starting point for initiating this component of the observing system: GMNET and LabNet.

2.3.1 GMNET

GMNET is an initiative of the Gulf of Mexico Program and the Gulf Ecology Division of the EPA in Gulf Breeze, FL. The Gulf of Mexico Aquatic Mortality Network (GMNET) is a user-driven program comprised of state resource managers from the five U.S. Gulf states (AL, FL, LA, MS, TX) in collaboration with EPA's National Health and Environmental Effects Research Laboratory and the Gulf of Mexico Program. The single objective of GMNET is to share information and expertise to better understand and document aquatic diseases and mortality events in the Gulf of Mexico. To accomplish this, GMNET has worked toward regional standardization of investigative approach and event documentation. The importance of aquatic mortality documentation to HABSOS is clear: mortality event data are integral to the development and testing of a predictive HAB model, and a predictive HAB model will expedite rapid response, and possibly prevention, of aquatic mortalities.

It is well understood by GMNET that states can have different purposes and requirements when monitoring environmental conditions. Consequently, members have developed a three-tiered documentation system to facilitate sharing of mortality data and provide a repository for state-specific information needs.

(1) Data that are essential to document an event (when, what, where, how many, and possible causes). These data may be shared quickly, a critical factor for an observing system, without affecting eventual litigation or other state priorities.

(2) Data and information on the causes of mortality events. These data may not be quickly reported because of the time necessary for laboratory tests. They may or may not support the suspected causes identified in Tier 1. The latter are “best guesses” that can change with additional information.

(3) Proprietary data and information that document the process of responses to mortality events. This may include witness reports, chain of custody records, investigator notes, etc., and is tailored for state-specific information needs.

One goal of GMNET is to aggregate Tier 1 and Tier 2 data across the five states in a repository available to State and Federal resource agencies as well as academic scientists. The data collection system has been designed and the first step toward implementation of an aggregated database (Tier 1) is anticipated within a year.

2.3.2 LabNet

LabNet, an initiative of the U.S. National Association of Marine Laboratories (NAML > 115 coastal research institutions), is a distributed data communications and management system that links data bases at participating coastal laboratories to provide visually integrated environmental data on temporal and geospatial scales via the world wide web. It has been developed with funding from NOAA, EPA and NSF, and it has yet to be tested.

The purpose of LabNet is to provide the infrastructure to access, exchange and integrate data residing at individual coastal laboratories and to analyze and visualize data to address specific problems. **The intent is not to manage all data from coastal monitoring and research programs but to provide the infrastructure required by end-users to access diverse data from disparate sources to address specific problems or issues, e.g., near real-time access to data on harmful algal events in the region or historical records of HAB events over specified periods of time to determine if there are trends.**

In its current configuration, LabNet consists of 4 layers:

- A data source layer where data reside and are accessible via the internet;
- A meta-data layer required to retrieve data (uses a robust data description standard, the FGDC meta-data format) using standard means (http, Z39.50 retrieval protocol to query meta-data and data);
- An integration layer that contains a database of known data sources that comprise a LABNET integrated data set and provides the means to (i) locate and communicate with the meta-data layer, (ii) to query and extract relevant data from the data source, (iii) to normalize different data sources according to the information provided by the meta-data layer, and (iv) to process data into a form that can be used by the output layer; and
- An output layer that processes and presents data in a form that can be used by the end user (e.g., time-series or frequency distribution, numerical model output, GIS output).

Participating institutions will have the option of participating at one of three levels. (1) Level 1 providers have data they wish to serve but cannot do so electronically; (2) level 2 providers have the data and the means to serve them electronically; and (3) lever 3 providers have the capabilities of level 2 and supply the indexing and required meta data. Level 2 or 3 providers will work with level 1 providers to make their data available to LabNet participants using accepted data exchange protocols.

There will also be a 4th level of participation. Four regional hubs will be established to coordinate the regional development of LabNet and provide regional data portals. Together, level 4 participants will form the national LabNet system. The resources required to index, locate and integrate data from a level 2 supplier will typically be provided by level 3 or level 4 institutions. Level 3 and 4 institutions may also provide analytical services to other participants, and level 4 institutions will provide training services as needed. A level 4 participant may also be a level 3 provider. The responsibility for quality control lies with the source of the data. Quality assurance is the responsibility of the regional hubs. The required software for LabNet has been developed, and three

level 4 participants have been established (MBL in Woods Hole MA for the northeast, CSC in Charleston SC for the southeast, and SCCWRP in Huntington CA for the west coast). It has been proposed that a 4th hub be established at the NCDDC for the Gulf of Mexico.

2.3.3 GMNET and LabNet

GMNET links state agencies that are concerned with mortality events in the northern Gulf of Mexico. LabNet links coastal research laboratories that are concerned with a broad range of ecological and environmental issues. Both networks include federal laboratories, including the Gulf Ecology Division of the EPA in Gulf Breeze, FL. Detecting and predicting HAB events are also important to both networks. For the most part, GMNET links state agencies while LabNet links coastal research laboratories that are associated with universities. Clearly, linking the two networks and coordinating their development to achieve common ends will benefit all parties.

3. THE GULF OF MEXICO PILOT PROJECT

3.1 Why Harmful Algal Blooms and Events?

The Harmful Algal Bloom and Hypoxia Research and Control Act became law in 1998 (P.L. 105-383). The Act was passed in response to concerns that HABs and related environmental events (e.g., hypoxia, fish kills) are increasingly a threat to human health and the health of our nation's coastal ecosystems. The act specifically calls for (1) the establishment of an inter-agency task force on HABs and hypoxia; (2) a national assessment of HABs and hypoxia; and (3) an assessment plan for the Gulf of Mexico.

There are approximately 5000 species of microalgae in the world. Of these, about 100 are toxic, and about half of these occur in the Gulf of Mexico (Table 1). Of these, *G. breve* is the most common, especially on the west Florida shelf. Harmful species of microalgae are a public health risk. They cause mass mortalities of marine organisms (fish, birds and mammals) and alter the capacity of ecosystems to support living resources. The scientific community refers to the phenomenon that cause these events as harmful algal blooms (HABs) recognizing that HAB species represent a broad spectrum of taxa (e.g., dinoflagellates, diatoms, cyanobacteria) and trophic levels (e.g., autotrophic, heterotrophic, mixotrophic) and that many HAB species cause problems at low cell densities, i.e., a bloom is not necessarily required for a HAB event to occur. There are two general groups of HABs: (1) those that produce toxins that contaminate seafood and are a public health risk, increase the susceptibility to disease, and kill marine animals, and (2) those that cause problems by virtue of their high abundance or biomass (oxygen depletion, habitat loss, and starvation, respiratory or reproductive failure in marine animals).

The effects of HABs extend well beyond direct effects on human health, living resources, and habitats. When HAB events contaminate or destroy coastal resources and habitats, the livelihoods of local residents are threatened and the sustenance of human populations is compromised. Clearly, there is a pressing need to develop the means to detect and predict the causes and consequences of HABs to prevent

Table 1. HAB Species in the Northern Gulf of Mexico (need list of benthic species)

Effects	HAB Species
Neurotoxic Shellfish Poisoning (NSP) • Fish kills • Public health • Noxious aerosols	*Gymnodinium breve* (brevetoxin) *G. pulchellum* *G. mikimotoi* *G. sanguineum* *G. selliforme* *Chattonella* spp.
Amnesic Shellfish Poisoning (ASP) • Mass mortalities of mammals, birds • Public Health	*Pseudo-nitzschia* spp. (domoic acid)
Diarrhetic Shellfish Poisoning (DSP) • Tumors • Public Health	*Dinophysis* spp. (dinophysistoxin) *Prorocentrum* spp. (okadaic acid)
Paralytic Shellfish Poisoning (PSP) • Public Health	*Alexandrium monilatum*
Ciguatera Fish Poisoning • Public Health	*Gambierdiscus toxicus* *Prorocentrum* spp.
Other Toxins • Tumors • Fish Kills • Public Health	*Pfiesteria* spp. *Pfiesteria* like spp. *Microcystis* spp. *Anabaena* spp. *Lyngbya majuscula* *Aphanizomenon* spp. *Cylindrospermopsis* spp.
Other Effects • Tumors • Habitat loss • Fish and shell fish reproduction	*Aureoumbra lagunensis*

their occurrence and to control or mitigate their effects.

Although definitive scientific evidence is lacking, HAB events appear to be increasing in number, extent and severity. Rapid increases in the number of people living, working and playing in the coastal zone has increased the input of nutrients to coastal waters, and it has been suggested HAB events may be occurring more frequently has a consequence. In addition, increases in shipping (ballast water) and the transport of shellfish between regions and continents may be increasing the

frequency of HAB events by introducing new HAB species. Increases in the size of the human population also increases the demand for food from coastal waters in the form of wild and cultured of fish and shellfish. Both of these sources of food are threatened by HABs, a problem that is particularly acute in the aquaculture industry.

Because of the damage to aquatic ecosystems, fisheries and tourism, the environmental conditions that trigger and control HAB events must be sufficiently understood to predict occurrences and mitigate potential effects. Developing predictive tools depends on more timely detection of events and on constructive and timely interactions among research, monitoring, and the users of the data and information generated by research and monitoring programs. At a minimum, data on the presence of harmful algae and the occurrence of harmful algal events must be documented in the context of changes in the weather and physical and chemical conditions of the water column (e.g., temperature, salinity, nutrients, turbulence, currents).

Much of the data needed to investigate the occurrence and underlying environmental causes of HABs are collected by different state, federal and academic programs. However, there is little consistency in the objectives of these programs and no existing strategy for collaboration and effective regional use of collective resources. A regional framework for integration of data and information will not only serve the principal objectives of these programs, but will focus, standardize and emphasize the value of the measured endpoints.

Finally, research programs such as ECOHAB are not only of fundamental importance to the development of the observing system, it must be recognized that hypothesis-driven research is of limited value if it is not conducted in the context of larger scale observations in time and space. Environmental research is most valuable when conducted in the context of an integrated *observing system* that is sustained over sufficiently large areas with sufficient resolution to document patterns of variability and change. The successful observing system will incorporate key environmental variables that span regional and national interests while remaining locally relevant. Development of a strategy that provides this critical perspective will be an invaluable benefit to future research on causes of algal blooms and aquatic mortalities in the Gulf of Mexico. Such a system will also contribute to better understanding of other changes in coastal ecosystems such as the development and effects of bottom water hypoxia and anoxia.

3.2 Workshop Organization

Speakers were invited to address key issues relevant to the design of HABSOS. Their charge was to provide background and stimulate discussion. Following each plenary session, working groups met to discuss the requirements of each element of the system and to formulate recommendations for the design of the HABSOS pilot project. Invited talks and related working sessions are listed below. The full agenda, abstracts of the invited talks, and working group reports are given in appendices 5.2, 5.3 and 5.4, respectively. In addition, a report on plans for the development of a HABSOS for Irish Waters is given in appendix 5.5.

A. HABS in the Gulf of Mexico

Plenary Session I: Data and Information Needs (Linking Applications to Measurements)

- Jim Giattina (Director, Gulf of Mexico Program Office): *Development of a Gulf-wide Environmental Management and Communication System.*
- Karen Steidinger (Florida Marine Research Institute): *Occurrence and Effects of Harmful Algal Blooms in the Gulf of Mexico*
- Pat Tester (NOAA): *Understanding HABs - Importance of the Larger Picture*
- Jan Landsberg (Florida Marine Research Institute): *Traditional Indicators of Harmful Algae Events*
- Percy Donaghay (University of Rhode Island): *New, In Situ Technologies for Assessing Environmental Conditions and Early Warning Indicators of HAB Events*
- Mary Culver and Rick Stumpf (NOAA): *Remote and In situ sensingRoles in the detection of time-space scales of HABs and the prediction of their occurrence and effects*
- John Walsh (University of South Florida): *Models and Model Requirements for Predicting Harmful Algal Events*

Break Out Session I: Detection and Prediction

Four working groups were asked to independently define and describe the kinds of information (e.g., areal and temporal extent of an even, an alert) required to improve the control, prevention and/or mitigation of harmful algal events and their effects: (1) What variables must be measured and on what time and space scales to produce the required information? (2) What are acceptable lags between the time measurements are made/samples collected and the availability of the required information? (3) How important are real-time measurements and data telemetry? What are our current capabilities for *in situ* and remote sensing and what is on the horizon?

B. Data Communications and Management

Plenary Session II

- Bill Walker and Kevin Summers (EPA): *Coastal 2000, A Regional Approach to Environmental Monitoring*
- Shelly Tomlinson (NOAA): *NODC's Development of a National Data Management System for Harmful Algal Events*
- Ken Tenore (CBL) and David Remsen (MBL): *LabNet, A User-Driven Infrastructure for Data Dissemination*
- Bill Fisher (EPA)**:** *GMNET, Collection of Spatially-Disperse Event Data*
- Lowell Bahner (NOAA): *Data Management in an Advanced Monitoring Program: The Chesapeake Bay Example*

Break Out Session II

Four working groups were asked to independently address the following: (1) Define the principles and guidelines for the design of a user-driven data communications network and management system that effectively links data to quality data-products in a timely fashion; and (2) What are the key characteristics of data communication and management systems and how should they be implemented and maintained?

C. The Design of an End-to-End System: Working Session III

Three new working groups were formed based on the expertise of the participants as listed below. Each group was asked to determine the requirements for each stage in the end-to-end observing system.

Working Group A: User Requirements (Information needs, data-products)
Working Group B: Data Communications and Management Subsystem
Working Group C: Observing Subsystem (Measurements, sensors, platforms)

4. WORKSHOP RESULTS AND RECOMMENDATIONS FOR HABSOS

4.1 Users and User Group Requirements

The initial HABSOS Pilot Project is envisioned as a partnership between government agencies (state and federal) and coastal research laboratories (state, federal and academic). The initial system will be designed to meet the needs of state agencies in the northern Gulf of Mexico region. Initially, the observing system will target *Gymnodinium breve*, a harmful algal species that routinely blooms along the southwest coast of Florida and is often found along the Texas coast during late summer and early fall.

It is expected that the data communications and management network developed for this project will also benefit the coastal research community by providing more timely access to data and information on HABs and the environmental conditions associate with their development and transport in the region. The primary issues that State agencies are concerned with are

- protecting public health (shellfish bed closures, respiratory illnesses in beach goers),
- impacts on aquaculture production (minimize or prevent contamination, incidence of disease, and mortality),
- economic consequences (minimize or prevent declines in revenues from fisheries, aquaculture, tourism; decreases in property value), and
- the dissemination of useful information to the public.

Secondary issues are protecting water quality and responding to mortality events. Thus, the primary users of the initial observing system will be fisheries managers (shellfish in particular), public health officials, the public, and the tourist industry. Additional users include local businesses, residents of coastal communities, local government officials, teachers and the news media.

HABSOS will also provide data required to calibrate and validate remote and *in situ* sensors and algorithms, improve the skill of diagnostic and predictive models, initialize and update nowcasts and forecasts, and document time and spaces scales of variability of key properties and processes. Thus, in addition to its focus on HAB events, the observing system will be extremely useful to and increase the value of marine research on the causes and consequences of changes in coastal ecosystems (e.g., HAB events, oxygen depletion and related effects; declines in fish stocks, loss of biodiversity; habitat modification; trophic shifts; invasive species; carbon cycling, storage and export).

Most resource managers need analyzed data and interpretation, not raw data. Early detection and prediction (at least 24 hour advance notice) are high priorities. These include

- an alert that an event is in progress,
- a forecast of where and when effects are likely to be expressed near shore, and
- an alert of where and when environmental conditions are favorable to the initiation of a HAB event.

In the case of *G. breve*, an event is defined as cell densities above 5,000/liter (the concentration of cells above which oyster beds are closed as mandated by the U.S. Food and Drug Administration).

Although we currently lack the observational capabilities and scientific understanding required to issue credible alerts and forecasts prior to the development of a harmful algal bloom or event, the effort to develop the required understanding and technical capabilities is growing. NOAA recently initiated the "Harmful Algal Bloom Forecast Project" that uses geographic information systems (GIS) to integrate data from multiple platforms and sensors to detect the development and transport of HABs (http://www.csc.noaa.gov/crs/habf/index.htm). Research programs such as ECOHAB are critical to understanding the causes and consequences of HABs and to the development of models that can be used to predict the initiation and evolution of HAB events for management purposes, i.e., to prevent, control and mitigate their harmful effects. These and other emerging programs underscore the importance of a synergy between research and monitoring to the development of a predictive understanding of HABs and HAB events (see section 4.4.3).

The immediate priority is to establish a system that will provide more timely access to data and information (as close to real-time as possible) on HAB events and associated environmental conditions. This will not only reduce the lag time between the occurrence of an event and its detection, it will be invaluable in guiding the implementation of the high intensity monitoring (adaptive sampling for higher resolution in time and space, measure more variables) needed to improve our ability to detect and predict events.

Data-products should provide reliable and accurate information in a timely fashion (routinely updated). They should include visual and text components and provide a regional perspective for local interpretation. For the purposes of this pilot project, a 2-tiered approach is envisioned. **Tier 1** would contain analyzed and integrated information that is available to all users through the Internet. In addition to alerts, data-products should include maps of winds, currents, HAB event locations, status of shellfish beds, location of mass mortalities and the species affected, information on the time-coarse of the event (e.g., magnitude, historical trajectory), contacts in responsible agencies with hotlines, and general information for public education. **Tier 2** would provide access to forecasts of HAB events and trajectories and to all data and metadata (real-time and stored) by a restricted group of users (e.g., government agencies and laboratories participating in GMNET and LabNet).

4.2 Data Communications and Management

Much of the data needed to document the occurrence and determine the underlying causes of HAB events are collected as a part of state, federal and academic programs. However, in the absence of an effective system to collect, disseminate, and store quality controlled data of diverse types from different sources, the goals of the observing system cannot be achieved. A regional system is needed to communicate and manage data and information from all sources that will effectively serve the needs of state and federal agencies, scientists, and other users. Thus, **the development of the data communications and management components of the observing system are of the highest priority**, **and these capabilities must be established before significant investments are made in additional measurements**.

The objective is to develop a system for both real-time and delayed mode data that allows users to exploit multiple data sets from disparate sources in a timely fashion. A hierarchical system of local, state, regional and national organizations is envisioned to provide data, information, and access to users at each level. The system must (1) consider the needs of end users in the initial design; (2) incorporate appropriate meta-data standards; and (3) develop mechanisms for monitoring and assessing the reliability of data flows and the usefulness of data-products.

This will not be a trivial task. There are many challenges. They include the realities that there is little consistency among programs, not all data are in electronic data bases, and much if not most data that are stored in electronic formats are on individual PCs; there is no comprehensive inventory (library) of existing data and metadata[1]; very little data are available on line; and communications among responsible state agencies, federal agencies, and academic institutions are not as effective as they could and need to be.

The HABSOS data communications and management system is envisioned as a web-based interactive network (via the Internet) of data providers, data managers, and data users (Figure 1). The building blocks of the initial system should include LabNet, GMNET, NODC, NCDDC and state data centers. GMNET and LabNet should form the **initial** communications network that will link data providers (state agencies, coastal laboratories and federal agencies) in the region. These two networks, which are currently developing independently of each other, should be linked and enhanced to initiate the development of the communications network. Since participating institutions will have different capabilities, three levels of participation are anticipated. **Level 1 providers** have data they wish to make available but are unable to electronically serve the data from their own facility. Level 1 providers will collaborate with a level 2 or 3 providers to make their data available to HABSOS participants using accepted procedures and data exchange protocols and to insure timely access to data and data-products on larger scales. **Level 2 providers** (data servers) have both the data and the means to disseminate them electronically. In addition to level 2 capabilities, **level 3 providers** (data and index servers) will supply the indexing and meta-data required to locate and integrate diverse data from disparate sources. The responsibility for quality control lies with the data provider.

HABSOS Data Communications & Management

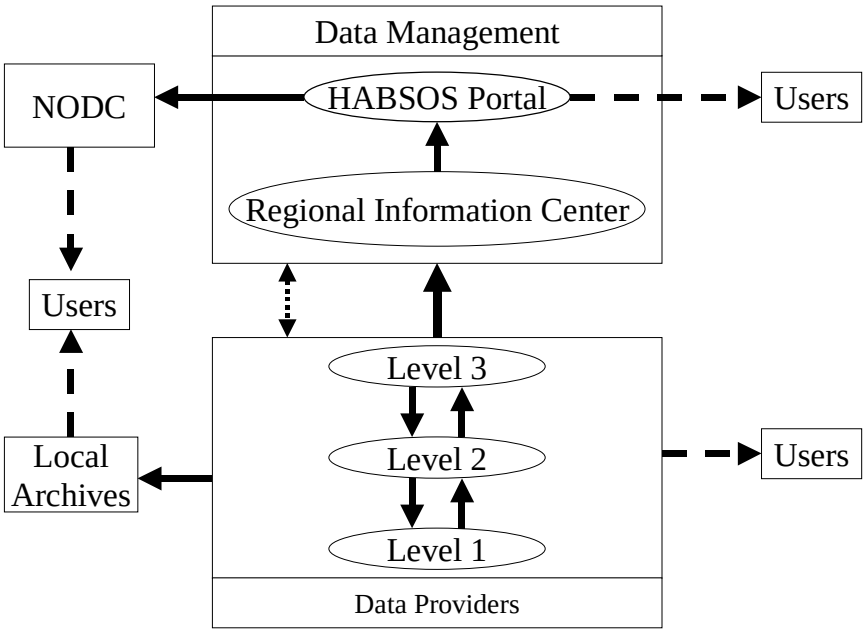

Figure 1. Schematic of the communications network (linking level 1, 2 and 3 data providers via the Internet) and data management subsystem of HABSOS (Regional Information Center and Portal). Data and meta data streams are indicated by the solid, one-way arrows, the flow of data-products by the dashed, one-way arrows; and system maintenance and assessment by the dotted, two-way arrow.

The Regional Information Center (RIC) will serve as the regional clearinghouse for data and information. The RIC should have the following functions:

- work with data providers and users (state agencies, federal agencies, coastal research laboratories) to coordinate the regional development of the communications network, provide training, establish standards of quality control and assurance, and develop common protocols for data exchange; and
- receive data from participating providers (e-mail, ftp, cdrom, etc.), perform quality assurance, ensure that data and metadata are published for web access, and update the data base inventory.

The RIC may also take on the responsibility for coordinating the regional development of HABSOS.

The regional HABSOS portal (which corresponds to a level 4 data hub in LabNet) may or may not reside within the RIC. There are benefits to having staff working together so they may share more easily information, tools, techniques, expertise and infrastructure to provide a cost-effective service to all of the states in the region (e.g., so all states do not have to duplicate the entire data management system). Regional data and data products will be made available via the HABSOS portal. Users of these data

and data-products may have access to either Tier 1 or Tier 2 data depending on whether they have restricted (Tier 1 only) or unrestricted access (Tier 1 and 2). Users of local data have access to Tier 2 data (unrestricted use by state and local agencies and scientists). The Chesapeake Bay Program policies and guidelines for data management should be adopted as a first cut at establishing data communications and management standards for the Gulf coast. These include policies for data location, reporting, metadata, and storage (www.chesapeakebay.net/cims).

Some states already have data management systems in place for their own waters (e.g., Florida) and much of the required data are currently collected by existing programs for specific purposes (e.g., forecasting the weather and coastal hazards, oil spill trajectories, commercial ship routing, and fisheries management). Each of these programs may provide one or more types of data to HABSOS. Each is also likely to involve several organizations with varying expertise and emphasis in operational data assimilation, modeling, data dissemination, meta-data standards, archival, and product development and distribution.

The challenge will be to develop an integrated regional network that builds on and incorporates existing efforts as appropriate. High initial priorities include the following:

- Inventory existing data sets and locations of the data (project information). The EPA MAIA program and the Chesapeake Bay Program have Project Information Systems that could be used, or used as models. A good inventory could be implemented in a few weeks.
- Develop a comprehensive data base of all past HABs and HAB events that is available to all participants.

In practice, the initial data communications and management system will grow in an incremental way by linking and integrating existing communications networks (beginning with GMNET and LabNet) and data management programs that collect and manage the data types required to detect and predict HAB events. The NCDDC may serve as both the RIC and the HABSOS portal. At a minimum, the Center can function as a hub that links state, academic and federal laboratories and agencies which function as both data providers and users. It is anticipated that NODC will serve as a long-term data archive and will work with the NCDDC to develop a regional data manage system for near real time dissemination of quality controlled data. This should include local training to insure the general use of accepted standards and protocols.

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[1] The establishment of a standard meta-data system that provides the documentation required to make numerical data useful to end users is extremely important. There are two kinds of metadata, “directory level” and “archive level.” **Archive level meta-data** provides the detailed, technical information needed to understand the precise characteristics of the data and to assess their adequacy for a particular application. This level of meta-data includes a description of the project or program (spatial and temporal extent and resolution), a description of the variable, units of measure; the name, type and location of the station at which data were collected; period(s) of observation; instrument(s) and platform

used; measurement procedures; algorithms used to convert raw data; the frequency of calibration; level of processing (raw, interpolated, converted, averaged, model output, etc.); type and level of quality control; codes and formats used; availability of the data; and responsible institution or person. **Directory level meta-data** is a subset of archive level meta data and provides the general descriptive information needed by a prospective user to identify the data set in a high-level catalog or listing of C-GOOS data sets. This would include information such as the specific variables and geographic area observed the time and frequency of observations, and the duration of the observation periods. It should also provide information on location, contacts, and access procedures/constraints. Individual institutions participating in the observing system must be responsible for compiling the meta-data that will be collated into the "global" meta-data system for the entire network.

4.3 Measurements, Sensors and Platforms

When fully developed, HABSOS should have the capacity to detect all major HAB species, related events, and key environmental properties (those that regulate the initiation and evolution of HABs and HAB events). **With time, the observing system will provide the data required to issue credible alerts and forecasts**. Initially, HABSOS is intended to be a pilot (proof of concept) project that will develop and test the required infrastructure using the detection and reporting of HAB events as a test case.

HABSOS must also be responsive to the needs of state agencies. Thus, during the early stages of development and testing, the initial system will focus on *G. breve*. Once the basic infrastructure of the end-to-end system is in place and tested, the system should grow to include other species.

The initial observing subsystem should have a nested design with higher resolution measurements organized around hot spots or epicenters of HAB events set in the context of a coarser framework of regional measurements that are made regularly and routinely throughout the northern Gulf. This may include enhancements of the basic framework in certain locations and times (e.g., for *G. breve* the mid Florida Gulf coast and during the fall) as well as enhancements in an event-response mode (adaptive sampling at higher resolution with more variables measured).

The minimum set of common measurements that should be incorporated into the regional framework of HABSOS are as follows:

(1) Inputs: real-time wind fields and precipitation updated 3-4 times daily; freshwater flows and related discharges of sediments and nutrients updated weekly.

(2) Water column: surface currents, temperature and chlorophyll distributions updated daily; vertical profiles (with measurement at surface, pycnocline, near bottom as a minimum) of temperature, salinity, dissolved oxygen, inorganic nutrients (N, P, Si), chlorophyll, colored dissolved organic matter, and *G. breve* cell densities updated at weekly (small number of stations) to monthly intervals (more stations).

Every attempt must be made to make physical, chemical and biological measurements synoptically in time and space and to achieve real time or near-real time data transmission. For sample-based measurements such as *G. breve* cell counts, the initial goal is a 48 hr turn around time. Nowcasts and forecasts of weather and marine conditions (sea state, currents, sea level) will also be needed.

The observing subsystem will incorporate the mix of platforms and methods required to detect time-dependent changes in 3 dimensions. The mix will include (1) discrete *in situ* sampling followed by laboratory measurements (results available within 48 hours of sampling); (2) autonomous *in situ* sensing with real-time data telemetry; and (3) remote sensing with real-time or near-time data telemetry. *In situ* measurements (1 and 2) may be made from docks, small boats, ships, fixed platforms, moorings, drifters, gliders, remotely operated vehicles and autonomous under water vehicles. Remote sensing may be made from space (e.g., SeaWiFS), from aircraft (e.g., hyperspectral imagery), or from land (e.g., high frequency radar). Coastal observatories for *in situ* and remote sensing are likely to become important components of the observing system as the technologies for these platforms and associated sensors develop.

Assuming that data and information on sea surface winds, sea surface temperature, and surface currents and waves will be provided from other sources, the initial infrastructure will include remote sensing to obtain synoptic spatial images of sea surface chlorophyll concentration (SeaWiFS); *in situ* sensing of temperature, salinity and chlorophyll (*in vivo* fluorescence); and *in situ* measurements of temperature, salinity, dissolved oxygen, inorganic nutrients (N, P, Si), chlorophyll, colored dissolved organic matter, and *G. breve* cell density. In addition to the measurement program, a high priority should be placed on developing methods to integrated data from remote and *in situ* sensing and measurements to obtain 4-dimensional visualizations of HAB events and associated environmental variability in a more timely fashion.

4.4 Common Themes and First Steps

The Gulf of Mexico Program (GMP) has the potential to provide the umbrella governance structure for HABSOS. A key issue is the willingness of data "providers" to openly share data in a timely manner. Participants in the distributed data system must be willing to do so. Thus, a high priority must be to establish MOAs among the Gulf states to endorse the approach embodied by HABSOS and insure coordination participation of state and federal agencies. GMNET has developed an alliance with the gulf coast states and could serve as a vehicle to achieve this. The GMP will also need to coordinate with the Oceans.US Office and the U.S. GOOS Steering Committee to insure HABSOS meets the requirements of the emerging integrated observing system for the Nation.

4.4.1 Building and Enhancing Existing Monitoring Systems

The initial products of HABSOS should be (1) alerts that events are in progress (area affected, organisms involved, direction of movement); (2) maps of locations of HABs and HAB events (e.g., GIS product produced

weekly with SeaWiFS imagery); and (3) forecasts of where and when effects are likely to be expressed near shore. During the formative stages of HABSOS, these products will be proprietary, i.e., only participating agencies and institutions will have access.

The first step is to coordinate and integrate existing monitoring systems to insure continuity, achieve larger scale regional perspectives, minimize redundancy, improve access to data, and produce timely analyses that benefit both state agencies and researchers. As this proceeds, it will become necessary to address the problem of undersampling in terms of both the temporal and spatial dimensions of change and the interdisciplinary nature of change (lack of measurements of biological and chemical properties that are synoptic with physical measurements). By building on existing capabilities and infrastructure, and by using a phased approach to implementation, work can start immediately to achieve the goals of HABSOS. The following programs and initiatives are examples of programs that should be considered as candidates for collaboration:

- Coastal 2000 - Coastal 2000 is a regional approach to environmental monitoring. It is a partnership between EPA (EMAP, Office of Water), USGS, NOAA and resource agencies in the 24 coastal states and Puerto Rico. The objectives of Coastal 2000 are: (1) to create an integrated comprehensive coastal monitoring program across the United States (including Alaska, Hawaii, and Puerto Rico) to assess the condition of estuarine and coastal waters at the National, State, and Tribal scales; and (2) to complete this objective with as little modification to existing state programs as feasible. In 2000-2001, all 24 coastal states in the United States and Puerto Rico will be sampled to estimate the condition of their estuarine resources using a probabilistic sampling design and a minimum of 50 sampling sites. At all selected sampling sites, measurements will be focused on ecological and biological response variables, with sufficient environmental stressor and habitat information to enable interpretation of these response variables (http://epa.gov/emap).

- TCOON - The Texas Coastal Ocean Observation Network is run by Texas A&M University (the Conrad Blucher Institute for Surveying and Science). It is a network of over 60 tide gauges that report near-real time data online. TCOON was established in 1989 (http://dnr.cbi.tamucc.edu/).

- TABS - Provides real-time data in support of oil spill prevention and response. The system is operated for the Texas General Land Office by Texas A&M University. The infrastructure includes 10 TABS buoys, 4 NDBC buoys, and 2 C-MAN stations for measurements of physical and meteorological variables. All data are archived and can be accessed on line. The web site also provides links to weather forecasts, gridded wind forecasts, modeled current forecasts, AVHRR imagery, and Navy wave model results (http://gergu3.tamu.edu/Tglo/).

- NDBC and C-MAN Stations - The National Data Buoy Center is a NOAA program with moored buoys and nearshore platforms (C-MAN stations) for oceanographic and meteorological observations. Real-time data are

incorporated into other observing system networks both locally and regionally. There are 8 buoys and 5 C-MAN stations along the coasts of TX, LA, MS, and AL and 6 buoys and 13 C-MAN stations along the coast of Florida (http://seaboard.ndbc.noaa.gov/stuff/westgulf/gomap.shtml; http://seaboard.ndbc.noaa.gov/stuff/florida/flrdmap.shtml)

- NGLI - The Northern Gulf of Mexico Littoral Initiative is a collaboration involving the Gulf of Mexico Program, NAVOCEANO, the University of Southern Mississippi, NRL, the Mississippi Department of Marine Resources, HydroQual, Inc., Scientific Solution, Inc. and Planning Systems, Inc. The goal is to create a modeling and prediction system for the Mississippi Sound and adjoining rivers, bays, and shelf waters that will provide forecasts of currents, waves, sediment transport, and water quality. Real-time data will be provided via the NGLI web site (http://www.navo.navy.mil/NGLI/main_frame.html).

- OMS - The Gulf of Mexico Ocean Monitoring System is a NOPP project, the objective of which is to integrate existing methods of data acquisition and analysis to provide initialization and input data to drive an operational nowcast/forecast numerical model capable of predicting currents and other ocean properties with 3-6 km resolution throughout the Gulf of Mexico (http://www.dynalysis.com).

- NERRs - There are 4 NERR sites administered by NOAA-NOS along the Gulf coast in Weeks Bay, Grand Bay, Apalachicola Bay, and Rookery Bay. Water quality (temperature, salinity, dissolved oxygen, pH, and turbidity) and meteorological data are monitored at 30 minute intervals. Quality assured and controlled data are available on the web within 1 year, and near real-time data are available on a site by site basis (http://inlet.geol.sc.edu/cdmohome.html).

- COMPS - The West Florida Coastal Ocean Monitoring and Prediction System is coordinated by the University of South Florida. The COMPS network consists of offshore buoys and instrumented fixed platforms (meteorological variables and currents, waves, water temperature, salinity, dissolved oxygen, turbidity and chlorophyll) with links to NDBC buoys and C-MAN stations; NOS water level and meteorological sites; the USGS and Florida Department of Environmental Protection stations for water level, temperature, salinity, and meteorological data; and SEAKEYS sites in the Florida Keys (http://comps.marine.usf.edu/).

- SEAKEYS - The Sustained Ecological Research Related to Management of the Florida Keys network makes use of and enhances the C-MAN stations in the Keys by collecting additional oceanographic data in conjunction with the meteorological measurements routinely made at the C-MAN locations. These include transmissivity, chlorophyll and photosynthetically active radiation (http://coral.aoml.noaa.gov/sferpm/seakeys/).

- DODS - The Distributed Oceanographic Data System is the center piece of the Virtual Ocean Data Hub project funded by NOPP. The

goal of the VODHub system is to provide users with the ability to "easily access certain types of data types in specific locations and times regardless to the data source" (http://www.unidata.ucar.edu/packages/dods/).

In this context, the initial focus should be on the development of an integrated data management system for the region. Key organizations and programs are the Gulf of Mexico Program, the NODC, the NCDDC, GMNET and LabNet (Figure 1). Immediate priorities are to

- develop a collaboration with the Virtual Ocean Data System Hub project;
- establish MOA's among the Gulf coast states to participate in HABSOS;
- link GMNET and LabNet and establish the Regional Information Center and portal;
- conduct an inventory of existing data sources from individuals and coastal laboratories to state and federal data bases;
- collate all available data into "standardized" databases that can be easily accessed to establish trends and serve as a baseline for new data; and
- test the ability of the system to deliver the required data and data products in a timely fashion.

To these ends, **representatives of state agencies, the Gulf of Mexico Program, NODC, NCDDC, GMNET, LabNet and the U.S. GOOS Steering Committee will meet at the NCDDC in early 2001**. The purpose of this meeting will be to (1) formulate a governance structure, (2) identify existing programs that can help to build HABSOS, (3) agree on an action plan and associated milestones, (4) design the experiment that will test the system, and (5) develop a strategy for funding the pilot project.

4.4.2 Capacity Building

The success of HABSOS, indeed the entire effort to develop the an integrated ocean observing system for the U.S., will require unprecedented coordination and collaboration among federal agencies, state agencies, and academic institutions. Capacity building must be a significant part of this effort. State personnel are often in a "fire-fighting" mode and do not have the resources to conduct full scale monitoring programs, interpret the data collected, brief their superiors and conduct their day-to-day tasks. Many state agencies do not have the financial or technical resources to develop and maintain databases or relational data systems. A regional, federally funded approach is needed to train state personnel (measurement techniques, QAQC, data documentation and exchange protocols, etc.), to help build the required infrastructure, to provide technical assistance, and to organize and maintain regional data communications and management systems that benefit participating states. The training program developed by E-MAP may be a good model. It is estimated that about 20% of the cost of operating the observing system will be required for data communications and management.

4.4.3 Research Priorities

Given the episodic nature and spatial patchiness of HAB, continuous measurements with *in situ* sensors and spatially synoptic measurements with remote sensors are high priorities. This underscores the need for research in the following:

- Improve the skill of algorithms for chlorophyll-a calculations from case 2 waters (where suspended sediments, organic detritus and colored dissolved organic matter account for a significant amount of light absorption and scattering);

- Increase the spatial resolution of measurements of ocean leaving radiance in the visible (ocean color) to resolve phytoplankton blooms in coastal waters;

- Instrument moorings and fixed platforms with fluorometers and spectroradiometers to measure chlorophyll, photosynthetically active and utilizable radiation, and colored dissolved organic matter synoptically with temperature, salinity and currents;

- Develop and deploy instrumentation for semi-continuous, *in situ* measurement of dissolved organic nutrients (nitrate, nitrite, ammonia, silicate, phosphate)

- Develop techniques for species specific, real-time detection and telemetry of HAB abundance (e.g., molecular probe based *in situ* technologies);

- Develop techniques for more rapid measurement of HAB toxins, including real-time, *in situ* detection and data telemetry.

- Develop coupled physical-ecosystem models both heuristic and predictive purposes.

- Conduct a study of the economic costs of HABs and the economic benefits of an observing system for HABs. Rough estimates suggest that the cost of initiating a sustained observing system is on the order of $3M/yr compared to the economic impacts of a single event which may be on the order of $50-100M/yr or higher.

The design and implementation of HABSOS should go forward now to provide the high resolution, long term measurements required to develop a predictive understanding of HAB events. At the same time, research is required to develop the technologies and knowledge required to achieve the objectives of the observing system. Clearly, synergy between research and the development of an integrated coastal ocean observing system must be promoted at all levels.

5. APPENDICES

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5.2 Workshop Agenda

AGENDA

Monday, 27 November

0900 - 1200 Registration
1300 - 1730 Opening Plenary: HABs in the Gulf of Mexico
Bill Benson (Director, Gulf Ecology Division, U.S. EPA): *Welcoming Remarks*
Tom Malone (UMCES Horn Point Laboratory): *Workshop Goals, Process and Products, Working Group Assignments, Discussion*
Jim Giattina (Director, Gulf of Mexico Program Office): *Development of a Gulf-wide Environmental Management and Communication System.*
1430 BREAK (coffee service)
1500 Opening Plenary (continued)
Karen Steidinger (Florida Marine Research Institute): *Occurrence and Effects of Harmful Algal Blooms in the Gulf of Mexico*
Pat Tester (NOAA): *Understanding HABs - Importance of the Larger Picture*

Tuesday, 28 November

0700 - 0800 Continental Breakfast
0800 - 1230 Plenary 2: Data and Information Needs, Linking Measures to Products
Jan Landsberg (Florida Marine Research Institute): *Traditional Indicators of Harmful Algae Events*
Rick Greene (EPA): *Remote and In Situ Sensing: Detecting Time-Space Scales of HABs*
1000 BREAK (Coffee service)
1030 Plenary 2 (continued)
Mary Culver and Rick Stumpf (NOAA): *Applications of Geographic Information Systems in Environmental Modeling*
John Walsh (University of South Florida): *Models and Model Requirements for Predicting Harmful Algal Events*
1230 - 1330 LUNCH (Brought in)
1330 - 1630 Work Group (WG) Session A: Detection and Prediction
1. Define and describe the kinds of information (e.g., areal and temporal extent of an even, an alert) required to improve the control, prevention and/or mitigation of harmful algal events and their effects.
2. What variables must be measured and on what time and space scales to produce the required information?
3. What are acceptable lags between the time measurements made/samples collected and the availability of the required information?
4. How important are real-time measurements and data telemetry? What are our current capabilities for *in situ* and remote sensing and what is on the horizon?

1630 - 1730 Plenary: WG Chairs present results for discussion

Wednesday, 29 November

0700 - 0800 Continental Breakfast
0800 - 1200 Plenary 3: Toward a User-Driven Data Management System
Kevin Summers (EPA): *Coastal 2000, A Regional Approach to Environmental Monitoring*
Shelley Tomlinson (NOAA): *NODC's Development of a National Data Management System for Harmful Algal Events*
1000 BREAK (Coffee service)
Ken Tenore (CBL) and David Remsen (MBL): *LabNet, A User-Driven Infrastructure for Data Dissemination*
Bill Fisher (EPA): *GMNET, Collection of Spatially-Disperse Event Data*
Lowell Bahner (EPA): *Data Management in an Advanced Monitoring Program: The Chesapeake Bay Example*
1230 - 1330 LUNCH (Brought in)
1330 - 1630 WG Session B: Data Communication and Management
1. Define the principles and guidelines for the design of a user-driven data communications network and management system that effectively links data to quality data-products in a timely fashion.

2. What are the key characteristics of data communication and management systems and how should they be implemented and maintained?

1630 - 1730 Plenary: WG Chairs present results for discussion

Thursday, 30 November

0700 - 0800 Continental Breakfast

0800 - 1600 WG Session C: Toward an End-to-End, Operational System

1. Formulate a design-plan for a sustained and integrated observing system (measurements => data management => models => products) that will provide the data and information required for timely detection and prediction of HABs and related mortality events in the Gulf of Mexico.
2. What existing programs should be incorporated into the observing system? How should the system be structured to minimize redundancy and optimize shared user capabilities?
3. What are the priorities for research and development required to improve the observing system and be more responsive to user group needs?
4. Recommend the steps that should be taken to ensure the successful implementation of the observing system.

1000 BREAK (Coffee service)

1030 WG Session C (continued)

1200 LUNCH (brought in)

1300 - 1600 WG Session C (continued)

1700 RECEPTION & DINNER: EPA Gulf Breeze Laboratory

Friday, 1 December

0700 - 0800 Continental Breakfast

0800 - 1200 Plenary Session 4: Steps to Making HABSOS a Reality

Working Group Chairs: Reports and Discussion of Recommendations

1000 BREAK (coffee service)

Jim Giattina, Director, Gulf of Mexico Program: *Relevance to the Gulf of Mexico Program*

Tom Malone, Horn Point Laboratory, UMCES: *Relevance to the Design and Implementation of the U.S. Integrated Ocean Observing System*

1200 Close

5.3 Abstracts of Invited Talks

5.3.1 Development of a Gulf-Wide Environmental Management and Communications System - Jim Giattina, Director, Gulf of Mexico Program Office, U.S. EPA, Stennis Space Center, Mississippi

The Gulf of Mexico Program (GMP) was formed in 1988 to develop and implement voluntary, incentive-based management strategies to protect, restore and maintain the health and productivity of the Gulf of Mexico ecosystem. The program facilitates protection and restoration of coastal marine waters, habitats and living resources while sustaining the health, food supply and economic well-being of the Gulf citizenry. Our vision of a rich and flourishing Gulf is realized through the determination of a network of citizens and institutions, both public and private, that comprise the GMP. In fact, the success of the program stems from its ability to engage people across the five Gulf sates to lead and implement environmentally sound projects. The program recognizes the importance of a broad range of environmental issues (http://www.gmpo.gov) and currently concentrates on implementing projects that address issues concerning public health, coastal and marine habitats, non-indigenous species, and nutrient enrichment. Harmful algal blooms play a role in three of these four issues. Consequently, the ability to better understand and predict algal blooms in the Gulf is extremely important to GMP and the Gulf community.

Two committees in the GMP will be following closely the activities of this workshop; the Data and Information Transfer Committee and the Monitoring, Modeling and Research Committee. The former coordinates efforts on data acquisition, transfer and information sharing to and among GMP Focus Teams and Support Committees, the five Gulf states, decision makers and the public. The latter guides the application of monitoring data, models, and research findings to support scientific assessments and decision making in response to key environmental issues. Members in both of these committees understand the complexity of the HAB issue and the fact that different types of data from diverse sources across the entire region must be merged into an 'issue-relevant' context in order to predict HAB occurrence. This is not a simple task, yet is the challenge of this workshop. How are we to merge data from existing or future programs into a predictive tool? What types of measurements or programs are needed to make a useful HAB observing system for the Gulf of Mexico? The resolutions proposed by this workshop will not only guide our course on HABs in the Gulf of Mexico but will influence our approach to a variety of other environmental issues (e.g., hypoxia, habitat loss, aquatic mortalities) that require integration of complex and diverse data.

5.3.2 Occurrence of Harmful Algal Blooms in the Gulf of Mexico - Karen Steidinger, Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute, St. Petersburg, Florida

Worldwide, there are about 100 species of microalgae known to produce toxic compounds. Some of these species can be geographically restricted because of temperature regimes, habitat and associated communities, and life history and dispersal strategies. Even among widely distributed species, there can be geographic strains that need to be delineated because of differences in toxin production/potency

or physiological tolerances and adaptive strategies. Species that produce toxic compounds or other bioactive substances are known as harmful algae and when their concentrations are above background levels they are called harmful algal blooms (HABs). More than half of all described toxic species occur in the Gulf of Mexico (GOM) and its contiguous estuaries. Why? The GOM from the Yucatan Peninsula to the Marquesas Keys, is a very diverse, large, marine ecosystem. It covers more than six degrees of latitude and has major rivers and estuaries, a broad continental shelf, dominant currents and eddies, upwelling and downwelling events, and tropical to warm temperate planktonic and benthic environs.

The major HAB in the GOM is caused by a red tide dinoflagellate known as *Gymnodinium breve*. It can reach concentrations in the hundreds of millions of cells/L, cause surface water discoloration with chlorophyll *a* levels exceeding 100 mg/L, can be associated with animal mortalities including birds and mammals, and directly or indirectly cause human illness. Blooms have been recorded in all Gulf states and Mexico. The origin and transport of blooms is a major topic of study in the eastern and western Gulf. The first documented *G. breve* bloom in Alabama, Mississippi, and Louisiana in 1996 appeared to be an expatriated bloom from northwest Florida. The species is well adapted to transport by currents, eddies, and winds. In 1987 a Florida bloom was transported to the Carolinas via the Gulf Stream. *Gymnodinium breve* is a dinoflagellate of wide temperature and salinity tolerances and one that is capable of exploiting neritic and certain estuarine conditions. More recently a similar morphospecies co-occurred during a northwest Florida bloom. This second species needs to be isolated, cultured, and tested for toxins.

Of all the toxic species present in the GOM, there are at least five other species or groups that are of major concern because of their actual or potential impact. Three of these species or groups represent dinoflagellates that can cause marine mortalities and/or impact human health, i.e., *Alexandrium monilatum* (Gulf-wide, estuarine and neritic), a benthic assemblage of toxic dinoflagellates associated with tropical fish poisoning (southern Florida, possibly Texas, coastal), and *Pfiesteria* and *Pfiesteria*-like organisms that may be associated with natural resource and human health impacts (Gulf-wide, estuarine). The fourth group represents diatom species (*Pseudo-nitzschia*) that produce domoic acid, which has been associated with marine animal mortalities and human mortalities or illness elsewhere in the United States and Canada. Several toxic or potentially toxic *Pseudo-nitzschia* occur in the GOM and isolates of *P. pseudodelicatissima* have been documented to produce domoic acid; yet there are no known cases of Amnesic Shellfish Poisoning from shellfish harvested in GOM waters. An emerging HAB issue is the threat of freshwater and estuarine cyanobacteria blooms to human and living aquatic resources.

In addition to toxic species, there are nontoxic species or strains of microalgae that can impact natural resources by causing anoxia or hypoxia, persistent turbidity, altered prey availability, and other acute or chronic impacts to coastal systems, e.g., the Texas brown tide organism, *Aureoumbra lagunensis*, and the blue-green alga, *Lyngbya majuscula*.

5.3.3 Understanding HABS: Importance of the Larger Picture - Pat Tester, National Ocean Service, NOAA, Beaufort, North Carolina

The 1995 National Research Agenda ECOHAB (The Ecology and Oceanography of Harmful Algal Blooms) was developed by a group of ~40 scientists who met in Snow Mountain CO during August 1994. The document, a consensus report, was endorsed by program managers across a number of agencies including NSF NOAA (Coastal Ocean Program, Sea Grant, National Marine Fisheries Service, NESDIS), EPA, NASA and ONR. As a position paper it established the need for a National HAB Program and hastened dedicated funding for research. Yet, even as this National Research Agenda was being developed it was difficult to define unifying concepts that could provide a common thread among the different HAB species and the conditions conducive to blooms. Consequently, part of National Research Agenda ECOHAB document dealt with HABS on a region by region basis.

In the intervening five years, a time of intensive program development and research, there have been a number of approaches developed for one region or for an algal species that have now been transferred to different regions or different HABs. The examples range from oceanographic to molecular. They provide the range of parameters for conceptual and dynamic models of HABs that will link bloom development to similar environmental conditions whether these are off the Pacific, Gulf of Mexico or Gulf of Maine.

5.3.4 Traditional Indicators of Harmful Algae Events - Jan Landsberg, Florida Marine Research Institute, St. Petersburg, Florida

Increased documentation of the frequency of HABs demonstrates their far reaching impacts on ecosystem integrity, species interactions, aquatic animal population growth and health, human health, national and local economies and industries. While this increase partially reflects improvements in technology for accurate identifications of HAB species and their toxins, and increased monitoring and surveillance, it is also associated with continued anthropogenic impacts and interactive natural events.

HABs can cause surface water discoloration, mass animal mortalities, human illness from consumption of toxic shellfish and tropical fish, respiratory irritation, and neurocognitive disease in humans. Because many marine biotoxins associated with HABs tend to be planktonic, visibly obvious, acute in nature, and lead to fast-acting shellfish poisoning events or mass mortalities of aquatic organisms, these are the HABs about which most is known. Filter-feeding bivalves accumulate microalgal biotoxins that in turn become available to consumers, both animal and human, through the food chain. While several toxic dinoflagellates and diatoms are associated with human shellfish poisonings such as ASP, DSP, PSP, and NSP, these same toxins can impact animals through the food chain. Recent examples are bird and seal mortalities associated with *Pseudo-nitzschia* (domoic acid), and dolphin and manatee mortalities associated with *Gymnodinium breve* (brevetoxins). Other species, mainly < 25µm of the genera *Heterocapsa*, *Gymnodinium*, *Gyrodinium*, *Pfiesteria*, and *Chattonella* are typically associated with marine mortalities rather than bioaccumulation of toxins through the food chain.

HAB species may also have sub-lethal effects on aquatic animal health and affect growth, reproduction, and immune function. Many of the longer-term effects of biotoxin exposure on aquatic resources or public health are unknown and have typically been ignored. Recently the potential role of HABs and their associated biotoxins in chronic or sub-lethal disease events has been identified. For example, biotoxins were suspected as a major factor in tropical reef fish disease in the Florida Keys and the Caribbean, as potential tumor promoters in outbreaks of sea turtle fibropapillomatosis, and as potential tumor promoters in the development of shellfish neoplasia. The exact role of heterotrophic dinoflagellates, including *Pfiesteria piscicida* or other species producing bioactive compounds in the development of fish lesions is still unclear. Other HAB species cause indirect effects. For example, blooms of nontoxic diatoms that have setae or spines can become trapped in the gills of fish or shellfish and cause mechanical damage, impair respiration, and may lead to mortality.

The overall effects of harmful algal blooms on food webs are probably the least understood of all impacts. Not only are pathways of transmission of algal toxins complex and not completely known, long-term impacts of sublethal, chronic effects (e.g. recruitment failure and subsequent loss of species within an ecosystem; reduced filtration of overlying water and subsequent impacts on benthic-pelagic coupling) are virtually unknown. Long-term effects (e.g. toxin accumulation) on higher-level consumers also need to be investigated. Other indirect effects of HABs include high algal biomass, low dissolved oxygen, and reduced light penetration.

There is still a critical need for improved technologies that will enhance the diagnosis of HAB toxins in animal tissues and that will track blooms and provide better predictive capabilities for the management of public health, wildlife, fisheries, and aquaculture.

5.3.5 Remote and *in situ* sensing: Roles in the detection of time-space scales of harmful algal blooms and the prediction of their occurrence and effects - Richard Stumpf, NOAA National Center for Coastal Ocean Science and Mary Culver, NOAA Coastal Services Center

Harmful algal blooms (HABs) are a recurrent problem in the Gulf of Mexico, with nearly annual occurrences on the Florida southwest coast, but less frequent occurrences on the northwest Florida and Texas coasts. Understanding the mechanisms for bloom development and movement has been a goal of the science community; predicting the occurrence and landfall has been a goal of the coastal management community. To accomplish these similar tasks, it can be useful to divide forecasting into four different types, in increasing order of sophistication:

(a) monitor and track the movement of an algal bloom that has previously been identified as an HAB,
(b) forecast the location and transport of an identified HAB since the last known position,
(c) detect and distinguish new blooms as HAB or non-HAB,
(d) predict conditions favorable for an HAB to occur where blooms have not yet been observed.

Types 1 and 3 involve methods of bloom detection and require the capability to monitor a bloom using remote-sensing or *in-situ* methods. Prediction (types 2 and 4) builds on a monitoring capability using several different approaches, including numerical modeling and interpretive modeling. We are developing interpretive models for the four types and have begun issuing bulletins and notifications to the Gulf Coast states to aid their field monitoring programs and public health advisories. This approach requires extensive use of detailed information from a variety of sources and a firm knowledge of the interaction of the HABs with the local environment.

To accomplish the forecasts, remote sensing and *in-situ* sensors that routinely monitor the area are essential to the effort because of the large spatial scale and high frequency of observations required to assess bloom location and movements. The data sources used in this effort include ocean color imagery from the SeaWiFS/OrbViewII satellite provided primarily by NESDIS/CoastWatch using coastal-specific algorithms, wind data from coastal and offshore buoys, field observations of bloom location and intensity provided by the Florida Marine Research Institute, and forecasts from the National Weather Service.

The bulletins began in coordination with the state of Florida in autumn of 1999 and included *Gymnodinium breve* bloom monitoring (type 1), with limited advisories on transport (type 2) and the detection of blooms in new areas (type 3). In autumn 2000, we improved the transport forecasts, and detection capabilities (type 3) and began prediction of conditions favorable for bloom development (type 4). In Texas in 2000, we began monitoring (type 1) forecasts.

Analysis behind the interpretive models is being conducted to improve interpretation, and this approach is leading toward a form of expert system. To improve the timing and accuracy of this monitoring approach, additional information on several components is needed: conditions favoring initiation of the bloom offshore, detection of subsurface blooms offshore, and conditions extinguishing the bloom. This information requires a monitoring network with remote-sensing capabilities and is key to accomplishing the goal of understanding and predicting bloom development set by science and coastal management.

5.3.6 Models and model requirements for predicting harmful algal bloom events - John Walsh, College of Marine Science, University of South Florida, St. Petersburg, Florida and Paul Bissett, Florida Environmental Research Institute, Tampa, Florida with Dwight Dieterle, Jason Lenes, Brian Darrow, Scott Milroy, Jason Jolliff, Robert Weisberg, Zhenjiang Li, Huijun Yang and Ruoy He (USF)

Successful ecological models are data-driven, distilling qualitative hypotheses and aliased field observations into simple analogues of the real world in a continuing cycle of model testing and revision. Prediction of the origin, transport and fate of *Gymnodinium breve* blooms on the West Florida shelf is the goal of the ECOHAB:Florida project - based on 1) shipboard and remote sensing surveys of hydrography, nutrients, DOM, species composition, pigments, and zooplankton 2) experimental cruises and laboratory studies describing their physiology, life cycles, optical properties, and toxin transfer, 3) arrays of current meters, 4) circulation submodels, 5) cell metabolism and migration submodels, and 6) coupled bio-optical models. The last component utilizes these submodels and assimilated observations in

a complex, numerical food web to describe the consequences of phytoplankton competition in terms of signals seen by satellite, aircraft, and moored sensors. We have used one-dimensional models to specify the rules of engagement between *G. breve* and other functional groups of phytoplankton, two-dimensional models to explore the consequences of their interaction with the microbial food web, and three-dimensional models to predict their transport, landfall, and residence time at the surface of the sea.

Following competition theory, our present models of the limiting resources of light, nitrate, ammonium, DON, phosphate, DOP, iron, and silicate should allow the coexistence of eight functional groups of phytoplankton, without differential grazing pressure on chromatically-adapted phytoplankton. In our analogue of the West Florida shelf, CO2 and N2 are state variables, but they are considered to be in excess of algal needs. From our simulation analyses thus far, we find that 1) diatoms win when estuarine and shelf-break supplies of nitrate are made available to a model community of small and large diatoms, coccoid cyanophytes and *Trichodesmium,* non-toxic and red-tide dinoflagellates, microflagellates, and coccolithophores, 2) a numerical recipe for large red tides of *G. breve* instead requires DON supplies, mediated by iron-starved, nitrogen-fixers in response to Saharan dust events, while their small blooms may persist on sediment sources of DON, 3) selective grazing must still be exerted on the other non-toxic dinoflagellates by copepods, 4) bacteria drive the outer shelf food web into P-limitation, until coastal supplies of low N/P ratio of ~1 favor nitrogen-fixers, 5) light-cued vertical migration of *G. breve* in relation to seasonal changes of summer downwelling and fall/winter upwelling flow fields determines both their duration within the first optical depth as a remotely-sensed signal and the intensity of red tide landfalls along the barrier islands and beaches of West Florida, and 6) termination of *G. breve* blooms is likely to result from cumulative, biomass-dependent losses in the form of UV-B irradiation, microbial-induced lysis, and unselective grazing pressure from protozoans and heterotrophic dinoflagellates.

5.3.7 Coastal 2000, A Regional Approach to Environmental Monitoring - William Walker and Kevin Summers

Coastal 2000 is a coastal monitoring strategy which responds to the needs of EPA and the coastal states and tribes for information on the condition and integrity of coastal ecosystems that will inform decisions to protect these vital coastal resources. For the past decade, EPA's Environmental Monitoring and Assessment Program (EMAP) has been working with federal, state, and academic scientists to develop cost-effective methods for measuring the physical, chemical, biological, and ecological conditions of coastal waters, bays, estuaries, beaches, and coastal wetlands. EMAP has tested monitoring designs and ecological indicators in surveys used to estimate the condition of estuarine and coastal resources in geographical U.S. provinces including coastal areas of the Gulf of Mexico, the Atlantic and Pacific Oceans, and the Great Lakes. The culmination of this research was a proof-of-concept study of the Mid-Atlantic estuaries which demonstrated the feasibility of regional scale measures of condition as well as the power to detect important spatial and temporal trends.

The objectives of Coastal 2000 are: (1) to create an integrated comprehensive coastal monitoring program across the United States (including Alaska, Hawaii, and Puerto Rico) to assess the condition of estuarine and coastal waters at the National,

State, and Tribal scales; and (2) to complete this objective with as little modification to existing state programs as feasible. In 2000-2001, all 24 coastal states in the United States and Puerto Rico will be sampled to estimate the condition of their estuarine resources using a probabilistic sampling design and a minimum of 50 sampling sites. At all selected sampling sites, measurements will be focused on ecological and biological response variables, with sufficient environmental stressor and habitat information to enable interpretation of these response variables. As recommended by the National Academy of Science, a special effort will be made to test ecosystem-level response variables delineating function (e.g., system productivity, nutrient cycling, and system energetics).

The process of developing ecological indicators for use in Coastal 2000 has been based on the indicator framework previously developed in EMAP. The limited resources available to Coastal 2000 are focused on system attributes that are of greatest concern ecologically and which best address program objectives. Indicators and assessment components are chosen to maximize our ability to discriminate between anthropogenic effects and natural variability, and to expand our interpretive power for identifying those systems that are showing signs of chronic or early stress. Parameters that serve as indicators of ecological condition can be grouped into four categories:

- Biotic Condition Indicators, or characteristics of the environment that provide quantitative evidence of the status of ecological resources and biotic integrity. These measurements quantify the integrated response of ecological resources to individual and multiple stressors. Measurements related to this category are chlorophyll concentrations, primary productivity, system-wide productivity, diversity, benthic community parameters, fish and shellfish community parameters, incidence of gross pathology or disease, and tissue concentrations of contaminants.
- Exposure Indicators which provide measures of the magnitude and extent of pollution exposure. Measurements related to this category include dissolved oxygen concentrations, sediment toxicity, and sediment contaminant concentrations.
- Habitat Indicators which describe the physical and chemical conditions of sample sites and provide basic information about the overall environmental setting. Examples include depth, salinity, temperature, sediment characteristics (grain size, percent water, percent silt/clays, total organ carbon), pH, and water clarity. Habitat indicators are frequently used to normalize exposure and response indicators across natural environmental gradients.
- Stressor Indicators, or economic, social, engineering, and landscape measures that can be used to estimate pollutant loadings to coastal waters and to identify their sources. Examples include land-use patterns, point-source discharge estimates, freshwater inflows, and pesticide use along a watershed. These parameters are not measurable as part of the annual Coastal 2000 sampling efforts but represent data derived from other agencies.

The strategy for Coastal 200 will partner EMAP with EPA Regions, the Office of Water, resource agencies in the 24 coastal states and Puerto Rico, USGS and NOAA to conduct the sampling during the late summer months of 2000 and 2001. The overall management design for the program includes a Coastal 2000 steering committee comprised of members representing ORD, OW, Regions, States, and Tribes. This group will decide the continuing nature of the Coastal 2000 initiative through 2004. In short, the steering committee will determine whether to endorse the proposed monitoring of estuaries in 2001, to continue sampling estuarine resources through 2004, or to re-direct coastal sampling to offshore waters, beaches, or coastal wetlands.

5.3.8 NODC's Development of a National Data Management System for Harmful Algal Events - Michelle Tomlinson, NOAA, NODC, Silver Spring, Maryland

Over the last several decades, a large increase in the number, extent and severity of harmful algal events in U.S. coastal waters has caused significant concern for various federal, state and academic programs. As a result, increased monitoring and research initiatives have been funded to increase our understanding of the dynamics underlying these events and to better predict when they might occur in U.S. coastal waters. As a result of these initiatives, The National Oceanographic Data Center (NODC) of NOAA is developing a system to synthesize data collected from routine monitoring and research programs, to assist in Harmful Algal Bloom (HAB) management and research. The Harmful Algal Bloom Data Management System (HAB-DMS) will provide access to physical, chemical, and biological data acquired from many disparate sources. As the official archive for data collected under NOAA and NSF support through the Ecology and Oceanography of Harmful Algal Bloom (ECOHAB) Program and NOAA support for intense HAB monitoring in various states or regions, the system will initially contain data collected through the Gulf of Maine and Gulf of Mexico ECOHAB projects, as well as state and regional monitoring projects supported by NOAA. This system will be expanded to include data from other sources, in coastal areas where HABs occur.

In the process of developing the HAB-DMS at the NODC, it has become apparent that significant coordination between state, federal and academic institutions in data management practices is needed to produce a robust data management system for coastal issues, such as HABs. Suitable data sets for understanding HABs are frequently dispersed among various state and academic laboratories, and are generally inaccessible or difficult to interpret. These data are stored in various formats, often with inadequate documenta-tion. Many historical data sets are also unavailable in a digital form. Therefore, the NODC intends to work with scientists at a regional level to provide a system which will facilitate the flow of data into the National HAB-DMS by providing tools for managing data locally.

The goals of this effort are to provide centralized access to high quality data which would otherwise be inaccessible for HAB research and decision support. This system will provide a free flow of information for use in regional planning experiments, data analyses, and modeling efforts. The HAB-DMS will initially include biological, chemical and physical oceanographic parameters from *in situ* and laboratory derived measurements (e.g., nutrients, phytoplankon species determination and abundance,

toxins, physical/chemical characteristics of the water column, current speed and direction, etc.). Based on suggestions from the HAB community, data will be provided in a desired format with some visualization capabilities. Future work will be to link the HAB-DMS to sources of satellite imagery and harmful algal event information to provide a complete data set for understanding HABs.

5.3.9 LabNet: Networking Environmental Data Bases of the Coastal Laboratories - Kenneth Tenore, Chesapeake Biological Laboratory, UMCES, Solomons, Maryland and David Remsen, MBL, Woods Hole, Massachusetts

NAML is an association of over 115 coastal laboratories who provide on-site access to environmental data on the diversity of the mosaic of habitats that make up the United States coastal zone. With their local knowledge and monitoring data bases, an interactive network of coastal laboratories can bring collective resources– scientific capabilities as well as infrastructure resources-- to bear on addressing environmental questions in research, management, and education at local, regional, and national scales.

To do so, LabNet, an initiative of NAML, was developed with funds from NOAA, EPA, and NSF to build web-based, applications-based integration of distributed data sets. That is, LabNet will network and visually integrate local environmental monitoring data capabilities at its member coastal laboratories. The data could be historic data sets and/or real time data. What specific data are targeted for LabNet will depend on specific identified regions and environmental data of interest developed in partnerships with stakeholder local, state, and national government agencies and private concerns.

It is important to remember that what is unique about LabNet it is not its underlying standard technologies; these are purposely kept ‘versitile’. What is unique is the collective unique asset of the distribution of NAML members and their willingness to cooperate in providing spatial and temporal scales of coverage. Because NAML institutions have a wide array of technological infrastructure and personnel support, part of the LabNet solution is to have a variety of solutions for the submission and maintenance of the environmental data. Thus we have established a system that allows cooperating NAML nodes to easily measure, maintain, and submit targeted environmental measurements, both 'real time' and historic data sets, to a system which can then collate those data into an integrated display available on the web. We have set up regional service nodes to provide technical support for LabNet participation by participating institutions.

The current LabNet implementation consists of several software layers employing open standards for data exchange. The system is intended to place a minimum burden on the data provider to participate in a given application while having a robust architecture for refinement when needed. Labnet is intended for collaborative work. Data resides at the original institutions. There are few limitations on how these data are maintained, just that there is some mechanism for retrieval and this mechanism is documented. LabNet uses the FGDC data documentation standard for documenting the data sets used in LabNet applications. These FGDC records are stored and served either on the three regional LabNet Z39.50 servers or a user can choose to store and serve their own metadata via the Z39.50 protocol. Data

is retrieved by first querying the Z39.50 servers to determine which datasets are relevant and the means to retrieve them. Custom programming is done at this level to gather and collate the retrieved data. Raw data can then be presented to the user or piped to an output process for visualization or conversion to a desired file format. Currently, LabNet can visualize time series and geographical data using a number of visualization tools.

5.3.10 Roles and Requisites for Aquatic Mortality Data in an Integrated HAB Database - William Fisher, U.S. EPA, Gulf Ecology Division, Gulf Breeze, Florida and Benjamin Sherman, LDEO, Columbia University, Palisades, New York

Harmful algal blooms (HABs) are distinguished from other phytoplankton blooms because they have adverse effects on human health and valued aquatic animals such as fish, shellfish, and marine mammals. Mortalities of aquatic animals in the Gulf of Mexico are frequently attributed to HAB events. More often than not, mortality events are the first signal of a coastal or estuarine HAB event. And tracking mortalities over time and space can often serve as a surrogate measure for tracking HABs. Consequently, mortality events and HAB events are tightly linked environmental concerns. In the near term, mortality event data are a necessary component for the iterative development and testing of a predictive HAB model. In the long term, a predictive HAB model will facilitate rapid response, and even prevention, of aquatic mortalities.

The ultimate utility of aquatic mortality data to development of a predictive HAB model will rely on its quality. But, like any program that covers a broad region using multiple data sources, the quality of aquatic mortality data must be viewed with some uncertainty. Much of this uncertainty can be averted with establishment of consistent data collection and documentation methods. The five states along the Gulf of Mexico have a common purpose to preserve and protect their aquatic resources, but their individual efforts to monitor aquatic animal mortalities have never been compiled across the region. To remedy this, state and federal agencies joined with the Gulf of Mexico Program to form the Gulf of Mexico Aquatic Mortality Network (GMNET). One of the major challenges for GMNET is to ensure consistent high-quality data collection across all five states. To this end, GMNET members have collaborated to improve public reporting, response training, interstate communication, and standardization of response approach and documentation. They have developed a 3-tier reporting system to distinguish different levels of data sharing. The database management system is under development and expected to be available in 2001.

To be successful, a program like GMNET must have longevity; the value of the database will accrue with data collected over long periods of time. To have longevity, participants must be able to easily enter and retrieve their data, and the product must benefit their individual needs in some tangible manner. Fortunately, state resource managers who collect GMNET data recognize that region-wide environmental databases, whether for aquatic mortalities, water quality, or HAB events, can lead to characterization of large-scale environmental factors (e.g., global climate change) that influence the resources they protect. An important next step is to develop a database, such as the HEED prototype, that integrates event and environmental data to generate larger-scale hypotheses.

5.3.11 Data Management in an Advanced Monitoring Program: The Chesapeake Bay Example - Lowell Bahner, Date Center Director, Chesapeake Bay Program, NOAA Chesapeake Bay Office, Annapolis, Maryland

The Chesapeake Bay Program monitors and assesses environmental quality to support restoration and protection efforts in the Chesapeake Bay Basin. Beginning in 1978, research and monitoring of water quality, submerged aquatic vegetation, toxic contaminants, and nutrient enrichment became priorities to help understand what was causing degradation of the Bay water quality and loss of important living resources. In 1984, the states of Maryland, Virginia, Pennsylvania, the District of Columbia, the Chesapeake Bay Commission, and federal agencies led by EPA formed the Chesapeake Bay Program to restore and protect the Bay and its resources. Most recently, the "Chesapeake 2000" agreement (http://www.chesapeakebay.net/agreement.htm) was signed by the Chesapeake Executive Council which establishes quantitative goals for accelerated improvement in restoration efforts, with a strong emphasis toward living resources over the next 10 years.

The many different agencies and organizations in the Program (http://www.chesapeakebay.net/baypartners.htm) collect a widely diverse range of data–from water quality and biological monitoring to agricultural cost share and best management practices. The fundamental data management strategy is to develop a distributed information system that is publicly available for use by all participating agencies and organizations. This system, the Chesapeake Information Management System (CIMS, http://www.chesapeakebay.net/cims/) provides the underlying organizational structure based on common guidelines and policies ("Chesapeake Bay Program Guidance for Data Management") so that data and information can be shared among partner agencies and the public through the Internet.

An important function of data management for the Program is to provide the information delivery tools and interfaces for the wide-range of end users of the information. The majority of end users access the Program web site for summarized interpretations of Bay quality. A second large group of end users are academic, state, and federal technical staff who provide policy makers with analyses and interpretations of monitoring and modeling data. Interactive data delivery (http://www.chesapeakebay.net/data/index.htm) provides access to monitoring and modeling data, while tools (http://www.chesapeakebay.net/cims/>>Tools) such as "Watershed Profiles," provide data, maps, charts, and graphs of information for a wide-range of subjects at the watershed and sub-watershed level. Guidance and data base designs are published (http://www.chesapeakebay.net/cims/>>Guidance, Documentation) to provide consistency, and to reduce the cost of developing data bases by partner organizations. Lastly, but most importantly, sufficient documentation (FGDC and CIMS-compliant metadata, http://www.chesapeakebay.net/comet/) is required for all data and documents. Metadata not only provides the end user with critical documentation, but it also serves as the source data for powerful web site search and retrieval and for creating dynamic web pages.

5.4 Working Group Reports

5.4.1 Groups Working on the Same Topics in Parallel (Detection, Prediction and Data Management)

Lowell Bahner (chair), Bill Benson, Scott Brown, Percy Donaghay, Quay Dortch, Raleigh Hood, Fred Kopfler, Jan Kurtz (rapporteur), Dave Millie, Jeff Williams, Dennis Pridgen, Jim Simons, Shelley Tomlinson, Bob Weisberg

Detection and Prediction

The following were identified as management needs associated with state HABs programs:

- Human health, primarily closing shellfish beds to fishing before humans are poison victims;
- Economic effects on tourism from loss of business;
- Economic effects on Aquaculture--need to protect the investment and product;
- States must respond to constituents asking for food and recreational safety.

Secondarily:

- States must protect the environmental quality;
- States must protect or respond to animal and shellfish health safety or clean-up of mortality events.
- States need advanced warning of events to provide time to collect samples to protect human health.

State personnel often are in the "fire fighting mode" 50% of the time. They do not have the resources to conduct full scale monitoring programs, conduct data analysis and interpretation, brief their superiors, and conduct there full time jobs, all in an 8 hour day.

State resource staff need:

- Coordinated efforts among the Gulf coast states.
- "Contacts" data base for HABs within their states, across agencies, and across states.
- "Tools" that are available for organizing and interpreting information.
- "Communications Plan" to disseminate information with other states and the public.
- Some type of MOU would be beneficial to unite the Gulf states toward a unified approach

Most state upper-level resource managers need analyzed and interpreted information and visualizations in the form of maps. They do not need raw data.

Historical HABs data needs to be assembled and put into "standardized" data bases to serve as a baseline for the new data to be collected. The historical data will provide baselines for status and trends analyses, but also as a reference for new data, methods, and QAQC. [Footnote: new methods need to be used in parallel to old methods to account for method shifts] Not too much of any budget should be spent on preserving old data. Those data sets that require minimal work and documentation (metadata) should be obtained, unless the owner organization takes the responsibility and provides the resources to make their data available.

Many academic organizations and smaller state agencies do not have the financial or technical resources to maintain online data bases or relational data systems. Some federal or state agency must provide these types of data center capabilities with long-term funding to ensure that the data are online and properly documented. A monitoring program without a long-term data delivery system will be of no use.

The HABSOS monitoring program should have two target audiences:

- Operational/resource managers/public
- Technical/research

The monitoring program should be of general nature and not focus strictly on one major species or problem (i.e., G. breve)

- There needs to be a core, standardized and ongoing monitoring system which will provide continuous data that will serve to identify or help to forecast the onset of HABs events. This will include identification of weather, current/wind-driven conditions, and nutrient loadings that are conducive to the initiation of events. Since HABs events appear to often initiate at the pycnocline and not on the surface where they can be sensed with remote sensors, and the HABs layer can be on the order of 12 cm in depth, some continuous monitoring over depth is required. Additionally, monitoring multiple parameters simultaneously on a regular grid of stations provides capabilities for analysis and interpretation not available by any other means. This monitoring program will not provide conclusive information about blooms, but serve as an indicator of where blooms/events are likely to occur or are initiating.

- In addition to the above monitoring system, a response-specific monitoring program must provide additional biological data to validate the onset or existence of an event and identify which organisms are causing the event and to provide measured concentrations of the organisms. A response-specific program must be flexible to provide quick deployment, sampling, analytical quantification, and reporting to the responsible agencies.

There needs to be a process or model which organizes all of the various bits of information that are available from all the various sources, so that a resource manager can identify when conditions are right for an event to occur. The ability to predict the potential onset of an event is a key requirement. Once an event is predicted, response monitoring should be initiated to identify whether an event is

occurring and the extent of the event. 3D circulation models can be used to predict the movement of the event, both in horizontal direction and vertical direction. Often blooms seem to disappear, when in fact they have just moved from the surface due to physical or biological transport. Significant data required to identify conditions for an event include:

- Temperature, salinity, currents, winds and other physical parameters
- Surface flux
- Initial density field
- Surface heat field
- Riverine inputs and nutrient loads
- Other parameters identified by invited speakers

At this time, the causes of event initiation are not known. However, events/blooms can be sensed and tracked.

State resource managers require at least 24 hours warning of events to prepare for a reasonable response to the event before land fall. During an event, resource managers need a constant source of real-time information on the location and extend of the event. Data sources that would be useful include:

- Satellite--for synoptic tracking and qualitative evaluation of the event
- Aircraft--for rapid sampling over a large area, through discrete *in situ* samples, towed arrays, or remotely-sensed information
- Grid of *in situ* samplers over depth

State resource managers need as much time as possible to prepare for an event--5 days warning would provide time to evaluate the event, to monitor and identify whether the event actually exists, whether the event is toxic, what organisms or toxins must be "managed," and to provide for response teams to deploy in an orderly manner. Adequate notice will provide time for the public to be notified and for fisheries to adjust to the information with least economic impact.

Real-time data are most valuable to state resource managers:

- Need to manage events
- Respond to clean-up activities
- Provide public health information
- Quantify the risks involved for human health or environmental health
- Provide maps of information to upper management, response personnel, and the public
- Provide predictions of the movement and transport of the event

Real-time data are not routinely needed by the technical/research community. Typically event data are used to validate model predictive capabilities and for updating status and trends reports.

Other discussion comments not directly related to the topics:

Approximately 20% of the project cost needs to be targeted toward data management, metadata, and data distribution. This does not include analysis, interpretation, and reporting.

Guidance and standards would be beneficial for agencies participating in new monitoring and data management programs.

Program needs funding and participation from federal agencies, including NOAA, EPA, Coast Guard, Corps of Engineers, MMS, commercial fisheries

Need web based clearinghouse for where to find data and information

Prevention and mitigation of many estuarine events might be possible by increasing the number of benthic organisms that would crop down the standing stock of plankton to levels that can not reach event concentrations.

If the primary goal is to protect shellfish, then strings of shellfish can be deployed and checked daily for any sign of toxic conditions. This can be done at lower cost than an elaborate monitoring system.

At this time, *in situ* sensors can not be used to identify organisms or specific pigments.

Data Management

LabNet, GMNET, NODC, NCDDC and state data centers should be linked together to provide a system with the strengths provided by each of these systems.

- LabNet has a powerful design but currently links lab managers. There is no current connection to state resource managers or state agency monitoring programs.

- GMNET capture mortality information, but not associate water quality and non-event or event related information. The states want to see where samples are being taken and the results, whether positive or negative for events and/or mortality. GMNET might serve as a quick platform for displaying this information while the larger monitoring program is being constructed and implemented. GMNET might serve to organize existing historical data and ongoing monitoring data until the larger system is operational. GMNET has already created an alliance with the states, which should be a mechanism to strengthen these ties through some type of MOA process. The MOA should be signed by the governors of the states, if possible.

- NODC might serve as a long-term archive, but it also might serve as the "server" for real-time monitoring data streams that would be available for all to access.

- NCDDC has a mandate to support the Gulf region. NCDDC might use its talents and resources to help in the design and implementation of the data management aspects of the program. They have positioned themselves to be the information portal or broker in the region. States have a critical need in some agencies to have current internet access, email, and other electronic connectivity. In some states the health agencies do not have the connectivity needed to communicate electronically. A possible niche for NCDDC is to provide resources (connectivity, training, etc) to get critical agencies online.

Other linkages exist, including Texas A&M (TABS) monitoring network in the Gulf west of the Mississippi. They are using technology directly applicable to a HABs monitoring network.

Several problems were voiced about existing state data management capabilities related to supporting HABs programs:

- Not all data that are appropriate are published online.
- Not all data that are collected are placed in databases.
- Some data reside on individual PCs.
- Some good web sites exist while others are lacking. Data are not often published.
- Communication between health departments and water quality departments is lacking in some cases, so the connection between water quality and health/toxins is broken.

Using the Chesapeake Bay Program as an example, there seems to be a need for an umbrella organization (perhaps the Gulf of Mexico Program) with the state governors as the head to set policies and program priorities. This is needed to get the top-level focus on Gulf of Mexico issues, one of which is HABs. From the outside, it appears that each state is working independently on environmental issues. By uniting together through one program, over time the issues will become more focused and funding could be obtained that will not otherwise be made available from Congress.

The federal and states agencies need to work together to require that all grants, contracts, and work conducted by state and federal agencies, submit data and metadata to a clearinghouse to build the HABs data bases.

There needs to be an inventory of existing data sets and locations of the data (project information), since there are many valuable efforts underway. The EPA MAIA program and the Chesapeake Bay Program have Project Information Systems that could be used, or used as models. A good inventory could be implemented in a few weeks.

The Chesapeake Bay Program Policies and Guidelines for data management could be adopted as a first cut at establishing data management standards for the Gulf coast. These include locational policies, data reporting policies, data base design and data dictionary guidelines, and metadata policies (www.chesapeakebay.net/cims).

The cost of initiating an ongoing monitoring program is estimated by our workgroup at $2-3M per year for the Gulf coast. The cost of initiating or expanding the <u>response</u>

(biological, event confirmation) monitoring program is estimated by our workgroup at $1M per year for the Gulf coast. In contrast, we estimated (with highly questionable data) the economic risk of a single event might be on the order of $50-100M for the Gulf coast, and the actual $ loss may be much higher. These numbers need to be determined in more detail, since they may provide much of the justification for funding and implementing this program.

While the prototype system that is planned for the near term is limited to using existing data to predict and report HABs events, there is a real opportunity to use an expanded monitoring program to provide data for other environmental problems, including the impact and extent of the "dead zone" and distribution and loading of nutrients from the Mississippi. Linkages to other Gulf of Mexico issues will strengthen the case for the expanded monitoring program.

Kevin Sellner (Chair), Carol Dorsey, Linda Harwell, Steve Lohrenz, Bob Menzer, Cynthia Moncreiff, Jay Pinckney, Kevin Sellner, Greg Steyer, Rick Stumpf, Ken Tenore, Pat Tester (rapporteur), John Walsh, Kirk Wiles

Define and Describe Kinds of Information

This group started with a description of what each participant expected from a proposed Gulf Wide Network and their comments were condensed into the following:

- Integrated Gulf-wide network that was inclusive (all States, all Administrative levels would have access to information on the web) and interface with ongoing Gulf of Mexico programs including interface with NOPP
- Advanced warning of harmful algal events as operational mode forecasts to provided information on when and where to sample
- Probe technology to detect and quantify HAB species of interest
- Management of disparate data sets for faster output

It was our assumption that data gathering systems (CMAN, MET Stations) that are now in place would be a part of this information network and that operational forecasts like the Stumpf/Culver products would continue be available.

There was a discussion on how to define an “event”. For expediency it was defined as above background levels (>1,000 cells/L) of *Gymnodinium breve* cells. There was general agreement that *G. breve*, as the most widely recognized HAB species should be used as a surrogate for the entire group of harmful algae. As techniques to detect and monitor other species of interest become available they should be included in the monitoring and event database.

What to Measure, When & Where

G. breve cell counts are the primary variable of interest because cell concentrations (>5,000 /L) are used to mandate shellfish closures to protect public health. Because of this the group recommendations included the systematic, Gulf wide sampling and analysis of both surface and bottom waters (full profiles where

possible) of the following field parameters: Temperature, salinity, dissolved oxygen, chlorophyll, light and phytoplankton cell sample with time, date and station location (latitude, longitude) information. The source of matching meteorological and oceanographic data, to include, wind speed and direction as well as any information on currents (measured or modeled) should be available. These measurements would be used as first tier or "core" measurements. A secondary level would include nutrients, light and probes. Sampling station locations should be selected using local history, databases or knowledge. Sampling frequency may vary seasonally but in no case be less frequent than once every two weeks.

There was concern about the ability to process large numbers of phytoplankton samples on a routine basis. Contracting a laboratory to provide fast through-put screening of samples using probe technology was a consideration that we would like to put forward. This is something that cannot be dealt with using current resources.

Lag Times for Data Receipt

On automated data gathering systems (CMAN, Met Stations, Satellite imagery) the data gathering rate and distribution time of 0-24 hr is considered acceptable even in an event. In an event the field parameters and phytoplankton cell processing needs to be completed and reported within 12-24 hr. On a routine basis 24-48 hr is acceptable.

Real-Time

For the most part the automated data system display rates and frequency of observations are appropriate even during events. Data from field samplers during an event should be downloaded as soon as possible and from the field if the down load software can be made available (12-24 hr) (e.g. including verification of *G. breve* specific satellite and wind derived forecasts and models).

Other

It would be useful to have a complete inventory of any ongoing sampling programs (Federal, State, Academic, Local) in the Gulf of Mexico as well as a contact person and address. Greg Steyer, as a member of a Gulf of Mexico Program subcommittee is compiling/has complied this information. An inventory of all moorings, sensors and platforms in the Gulf of Mexico and the identification of environmental and biological databases for the region were viewed as useful.

Use of citizen networks (e.g., Nature Conservancy, Coast Guard Aux), charter and head boats and established public monitoring teams (local, state federal) should be provided inexpensive automated profiling packages and sampling equipment (e.g. water column sampling devices) for routine collection of temperature, salinity, DO and phytoplankton samples (min sampling at surface and bottom).

Define the guidelines for the design of a user driven data communications network and management system.

The primary emphasis is on real time communications among local/state level organizations across the Gulf. This will provide immediate information critical to management decisions for protecting human health and mitigating unnecessary economic losses. The number one priority is to provide resources for local/state data delivery of cell counts and environmental parameters. The level of support needed by individual programs may vary but must include resources necessary to produce electronic data files and a mechanism for the development of metadata. It should be emphasized that local/state participation will need buy in by top level administrators facilitated by MOAs between state officials and HABSOS Administration.

The working group recommends construction of a data management/data distribution system with a dual purpose. The first is near real time delivery of visual products to assist local/state managers in focusing their resources to address mandated public health responsibilities and decisions to protect local economies. The second goal is to provide a data access capability to any user for HAB related information. This should include a portal system where queries can be made to access a suite of available data sources. For example a "middle broker " might provide links to data sources LABNET, CIMS, NODC, CSC.....that effectively searches available data in all of these data sources and provides a summary of data types, URLs, points of contact....

Jonathan Pennock (chair), David Brock, Winston Denton, Mike Ford, Jim Giattina, David Heil, Jan Landsberg (rapporteur), Tom Leming, Oscar Schofield, Joe Silke, Steph Smith, Karen Steidinger, Nick Tew, Tracy Villareal, Bill Walker

Overall Strategy For HABSOS

HABSOS is envisioned as an integrated observing system designed to enhance our ability to monitor, understand and predict harmful algal events (HAEs) in the Gulf of Mexico. By design, HABSOS would initially function as a prototype but should have the flexibility to evolve into a multi-functional management and research tool. As a result, HABSOS should initially focus on *Gymnodinium breve*, but be designed such that it can be adapted to other potentially harmful algal species in the future.

The primary focus of first stage of HABSOS should be to provide information that will enhance our ability to provide early warning for public health related management issues. As such, HABSOS should provide a framework that will provide information necessary for resource managers and public health officials to make better-informed decisions. An important part of this information should be information that helps focus expensive and time-consuming measurements (e.g. intensive field sampling, cell counts and toxin analysis) in affected areas. Secondary goals of the HABSOS program should be to provide a framework to enhance information transfer to the public and research on HAEs.

To achieve these diverse goals, HABSOS must incorporate a geographically broad monitoring system with a regionally integrated data and information management system. We believe that such a system must include a suite of 'early warning' parameters, as well as an expanded set of 'research' parameters necessary to establish a better understanding of the ecology and oceanography of HAEs. Such a system would require the flexibility to provide detailed assessment of areas of known *Gymnodinium breve* activity (e.g. the 'epicenter' on the west Florida shelf) and a geographically broad and consistent set of data for the entire Gulf.

HABSOS Information Requirements

At a minimum, the 'early warning' component of HABSOS would have the following requirements:

- Weather: Wind Forecast, Real-Time Observations of Speed & Direction (NWS & Buoys), Historical Climatology to be able to Assess Anomalies

- Physics: Currents (Speed & Direction), Water Mass (Temperature; Salinity), Particle Transport Model

- Biology: Chlorophyll/Fluorescence, *G. breve* Concentration & Spatial Data

A key component of these basic parameters are that they are needed in real/near-real time. In addition, there must be the capability to integrate additional 'early warning' symptoms (e.g. fish kills, respiratory problems, etc...) into the data management and information system. Finally, it is essential that the data distribution/information system integrates across all Gulf states.

For implementation of HABSOS in support of research, the following parameters should also be included:

- Biology: Functional Group and Anomaly Assessment, Rate Process Measurements (e.g. growth rates), Molecular/Probe Based Assays For Cells And Toxins

- Chemistry: Fixed Automated Sites for Nutrients, CDOM Measurements

Temporal and Spatial Considerations

- Temporal: Real-Time is essential and needs to be web-assessable; Satellite-derived chlorophyll distribution and forecast trajectories are adequate on a daily basis but may need to be supplemented with aircraft overflights during periods of cloud cover or when events move to nearshore waters; Data from mooring instruments would be adequate at a frequency of 2-3 times per day seems for early warning requirements but models would likely require a higher frequency input.

- Spatial: Focus on epicenters for initiation may be a workable strategy in Florida (e.g. one offshore buoy off of Tarpon Springs, Sarasota, etc...); however, this will not necessarily work in other areas (e.g. the Texas coast); In general, regional *in*

situ measurements need only use relatively simple CTD/Flouorometer arrays while sentinel systems in selected areas should also include ADCP and automated nutrient sensors; In many areas, existing platforms (e.g. the TABS arrays in Texas and existing oil/gas platforms in between Alabama and Mexico could provide extensive opportunities for deployment.

Data And Information Management System

HABSOS should be a distributed data system that has a centralized clearing house for collating and visualizing data and producing the necessary products for addressing HAB issues important to the public, managers and researchers.

The value of the system is in the information that it provides at a regional scale and the increased level of knowledge and, ultimately, prediction that this will provide at both the regional and local scales.

We see HABSOS as an integrated observing system that includes the following components:

- Observatory ('weather station'): Common platforms in areas where none exist; data handled 'centrally'
- Forecast Center ('biological weather'): Initially a research mode with 'products' to management
- Data Clearing House ('linked data'): Initially as a clearing house for distributed data; eventually data integration; also a component integrating historical data

Principles and Guidelines for HABSOS DMS

The dual public and management/research objectives of HABSOS require a distinction between in the way in which 'information' and 'data' are made available. We suggest an open access Public/Media component of the Data/Information Management System and a limited access Management/Research component containing the following minimum of parameters:

Public/Media Visualization of Data at the HABSOS Web Site:

- Visualization of Currents & Winds
- Remote Sensing Derived Chlorophyll, Anomaly-based HAB Estimates
- Map of Daily, Weekly and Monthly HAB distributions
- Map of Shellfish Bed Closures (HAB-related)
- Map of Shellfish Toxicity
- Listing of Public Health Advisories
- Important to have Education Component for Background Information
- 'Bloom Cam' of Recent Bloom Events

Management/Research Level Data Access:

- Use LabNet Model of Access based on participation
- Predicted Trajectories for Bloom Transport (probabilities of movement)
- Individual Data Access using NCDDC Concept of Accessing Distributed Data
- Real-Time Data would be Centralized (NODC type archiving)

While every effort should be made to make data fully available as soon as possible, specific State restrictions may require control of how certain count, toxin and (perhaps) mortality data will be released.

Bill Fisher (Chair), Chris Brown, David Buzan (rapporteur), Mary Culver, Fred Deegan, Darlene Haverkamp, Scott Hold, Dan Kamykowski, Gary Kirkpatrick, Tiffany Moisan, Shane O'Boyle, Dan Roelke, Ben Sherman, Nan Steedley, Gabe Vargo

Information Needs

States need to know when concentrations of *G. breve* meet or exceed 5000 cell/liter. As mandated by the U.S. Food and Drug Administration, this is the level above which commercial harvest of oysters is prohibited.

A variety of physical, chemical and biological factors were then identified as required information. These include the following:

- Windfields - It is important to know the direction and speed of the wind and wind-driven currents may supply nitrogen for growth.

- Knowledge of the types of harmful algae present and their cell densities are valuable in preparing responses since some species, for example, may kill fish but not pose a direct threat to human health while others may threaten human health as well as kill fish.
- Shellfish closure information which state agencies require to effectively communicate where and when it is safe to harvest oysters.

- Life histories of HAB species particularly related to the typical seasonal occurrence of the species, their geographic distributions, and the typical temporal and spatial characteristics of events caused by HAB species.

- Location of HABs in 3-dimensions should be available in easily understood graphics.

- Communication avenues should be established which facilitate effective communication between agencies and decision makers and agencies and the public.

- Public reporting/concern should be tracked in order to understand better where and when events may have originated. It is common now that the first reports of a

HAB event come from the public sector when dead fish, discolored water, or aerosols on the beach are observed or experienced. These reports frequently provide direction for the states' initial response.

- Seafood safety is one of the questions most frequently addressed to states. All state organizations should be prepared to respond effectively to questions about seafood safety.

- Toxin concentrations should be measured because there may be HABs present which are not producing toxins such as *Pseudonitzschia* in LA.

- Approved methods for measuring toxin concentrations at low concentrations need to be developed and applied.

- Current direction and speed are important to know in order to help understand which HABs may come from or go to, or how cells may become concentrated by currents.

- Predictions of HAB events is important to the states. If states know where they might occur, they may be able to implement actions to minimize their impact. For example, if the occurrence of a red tide and its impact on oyster beds can be anticipated a few days in advance, the state may increase the daily harvest to minimize the economic impact on fishermen.
-

Variables to be measured and the importance of real-time data

It would be beneficial to have daily remote sensing of chlorophyll concentrations. Real-time monitoring of *G. breve* is expected to be available in the future. Other factors may be measured within 2-3 days but preferably no longer than 10 days. Real-time current data should be available. Near real-time satellite imagery should be available. Volunteers can provide real-time notification of blooms and their impacts.

Data communications and management

The Chesapeake Information Management System (CIMS) and the Florida Marine Research Institute web site were identified as positive models for possible data management and display systems. The CIMS model makes effective use of other databases and displaying information in components. The system may also rely on existing or planned sources of data (e.g., physical and chemical data collected as part of the Northern Gulf Littoral Initiative). The data communications system should be able to also utilize different models such as the Navy's model for hindcasting the source of oil spills and the Natural Resource Damage Assessment model for estimating the impacts of spilled hazardous materials. It should be able to access information from real-time remote monitoring devices such as drifters. Any system should include tracking and communications of economic benefits associated with having an effective data management/communications system. This would be important to justifying the expense of building the system. There is recognition that

there are many sites currently available about HABs and many other sites available with physical and chemical data which could be used to analyze HABs. The site in question should be unique in its ability to answer questions asked by resource managers and the public, particularly those questions associated with forecasting where the HAB will go in the future.

5.4.2 Groups Working on Different Components of the Observing System

User Information Needs and Data Products

Users

Primary users are managers of shellfish beds. Secondary users are managers of other living resources, public health officials, and tourism. Local businesses, government officials, health departments, the media, educators, students, researchers and the general public are also users.

Information Needs

- Immediate needs include information on HAB cell density and ancillary environmental data, shellfish toxicity, the locations and distribution of events, early warning (including information from Mexico), and prediction information.

- Longer-term research needs include improvements in the detection and analysis of HABs in shellfish beds. Simple, rapid detection of toxins in water, shellfish tissue, and in the air would increase the efficiency of management actions (e.g., shellfish bed closures) and reduce the need for mouse bioassays. Information on detoxification of oyster and other shellfish meats would improve sampling efficiencies. An estimate of the economic costs associated with a bloom event would help to retain interest and funding in an observation system. The economic cost of an event can be extensive and include the cost of lost harvest, loss in harvest due to the halo effect on other fisheries and loss of tourism.

- Information needs for secondary users of a system may include those listed above and, in addition, information on the type and number of fish killed, impacts on other animals and the ecosystem, long-term trends in HAB events, and information on harmful aerosols that may warrant public health advisories.

Data Products

Data products should have the following characteristics: reliable and accurate information content, routinely updated during the season of interest, contain visual and text components, retain the ability to access raw data, have a regional perspective for local interpretation, and have an education component. Data products were divided into two tiers. Tier 1 would contain analyzed, integrated information that is available to all users through the internet. Tier 2 would contain raw data that may be available to a limited audience.

Tier 1 products would follow a bulletin type format and (for now) contain information regarding blooms already identified as harmful. Data products would include an interpreted map of HAB distributions; a capability to access event progression; a general (not-location specific) prediction of bloom progress; the status of shellfish beds; mortalities; contact list for responsible agencies including hotlines; and general information and education materials.

Tier 2 products would contain raw data from inshore and offshore monitoring programs and other sources. The product would have access to real-time data with updates 1-3 times/day. There would also be the capability to access archived data on line. These characteristics would allow users to implement their own analysis for management and research needs.

Data Communications and Management

The Data Management workgroup recommends that an inventory of existing data, data sources, and contact information be collected to identify those agencies and data management staff that need to participate in the HABSOS pilot program. The approach would begin with conducting one-on-one interviews to obtain the following information:

- agency, department, director, technical contact, data contact
- what data parameters are collected
- where does the data reside
- what frequency are the data collected
- what formats are the data
- what media (paper forms, disks, tapes, CD-ROMs, online)
- data access
- data integrity
- monitoring program descriptions
- an indication of how well the agency feels they are doing in managing the data
- metadata, data dictionaries, QA/QC plans, methods, other pertinent descriptors
- issues: security, cost recovery, sensitivity, comparability to data from neighboring states
- reality check: is this data set needed for HABSOS products?

This information would serve as a valuable resource requested by state agencies that want to know who are contacts that can provide information to them and to the public.

The interview process should also be used to determine how the agency could participate as part of the HABSOS program. For instance, do they have the internal resources to already manage their data, document the data, and publish the data online? Or at the other extreme, do they barely have enough resources to run a basic response-monitoring program, and have little or no data management capabilities?

Depending on the responses from above, several options exist: if the agency is willing to participate in HABSOS, and needs assistance, how much assistance is

required? A) A PC with data entry program would help; B) a data manager onsite would resolve the data management constraints; C) the agency is willing to share their data in its existing format but can't be further impacted; or, D) some variation of the above options will provide a mechanism for collaboration.

Each situation needs to be evaluated and some agreements negotiated, including how frequently the data can be provided to HABSOS. Timeliness is an important issue, since some data are required within narrow timeframes to be useful (i.e. within 24 hours).

During the interview process, agencies will want to know what they are going to get by being a collaborating or cooperating agency. In response, the agency will have access to data from other programs within their own agency and from other agencies--for instance a health department may need water quality data obtained by a sister department but has not been successful in obtaining that data in a timely manner. They may benefit for the first time having their data organized into electronic format that will allow them to report to their agency in a timely manner. It may benefit them in responding to other state or federal reporting requirements. The HABSOS products will provide a wide range of analytical tools and information summaries that have not been available in the past, for their state and Gulf-wide. The proposed event tracking maps will serve as early warning tools to help them prepare for responding to an event and may help the planning for closing down a response effort. Event maps may provide valuable information as to the size of the event, which benefits the event management response.

Once the inventory of data sources is compiled, that information can be used to define the data management support requirements for a HABSOS regional information center (RIC). The RIC would provide data managers whose responsibilities would include:

- work with the state agency data providers
- receive the data from the data providers (by email, ftp, cdrom, etc)
- run data integrity checks and range checks
- check for duplicate records and missing data
- trigger the metadata writing/update process (metadata may be handled by a different person)
- ensure that the data and metadata are published for web access
- update the data base inventory

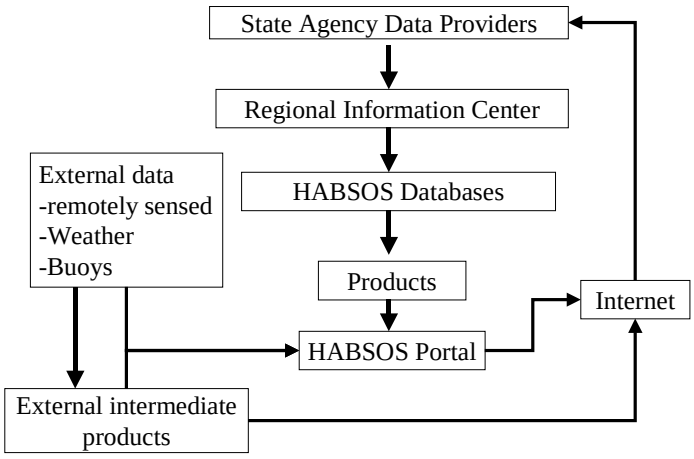
Such a data manager may service one or more databases depending on the workload. The data managers may all be stationed at the RIC or the RIC could operate in a distributed manner with staff at various locations. The RIC could consist of data managed by Labnet, GMNET, NCDDC, other organization, or any combination that works in an efficient manner, but there must be a focus on serving the state agencies that collect the data and require the interpreted information for protecting human health and the environment. There are some benefits to having a staff working together so that they can more easily share information, tools, techniques, and infrastructure. Maintaining data managers over a number of years is also important

so that there is not a loss of corporate knowledge. Corporate knowledge is very important, and turnover in staff can be very expensive in the long run, both in direct costs of training and down time, but also in data integrity and fixing human errors. Cross training among staff will be required to meet the 24 hour time limit for processing and publication of critical event data. For agencies that have their data online and documented, the above process will not be used. They can choose to serve their data, which will be used directly by HABSOS.

Once the data and metadata have been added to the appropriate HABSOS databases, the data are available for generating products. Products that are required are defined by another workgroup--refer to that report. In addition to the monitoring data in the above HABSOS data bases, other discrete sample and real-time data are also available from a number of sources, including meteorology data, buoy data, currents, salinity, temperature, dissolved oxygen, remotely sensed chlorophyll, temperature, turbidity, etc. Also there are intermediate data products provided as a service of other organizations, such as, SeaWIFs images and advisories from NOAA that can be considered as data for HABSOS. All of these data serve as the data for developing HABSOS products for the state response agencies, research, and the public when appropriate. Electronic photographs should be specifically included on the HABSOS portal as visual evidence as to environmental or health conditions.

Data products will be made available over the internet through the HABSOS portal. The portal will be somewhat intelligent and will provide data, data products, maps, images, and summary reports for the HABSOS program. The portal will also provide connectivity to other related HABSOS product web sites, and will provide some level of intelligent information fusion and analysis capabilities. The HABSOS portal will have to resolve the issues of fusing data from several different servers across agency firewalls. The workgroup recommends that a distributed data model be used from the beginning of the pilot program so that a truly distributed system will be developed and tested before full implementation. Lastly, NODC can provide the archival service for the HABSOS data as part of their federal mandate.

Proposed Data Management Design for HABSOS



5.5 Priorities of the Marine Institute on Harmful Algal Events in Irish Coastal Waters

Briefing Paper for NOAA/ECOHAB,
November, 2000
The Irish Marine Institute and U.S. National Oceanic and Atmospheric Administration

The interest in harmful algae events (HAEs) in Irish coastal waters has dramatically increased in recent years. The presence of harmful algal species, which produce toxins, pose a significant threat to public health and coastal aquaculture activities. Estimated losses due to biotoxin closures have cost the Irish shellfish industry $4 million in 2000.

Biotoxins, which have the potential to cause diarrhetic, paralytic, amnesic and azaspiracid shellfish poisoning (DSP, PSP, ASP and AZP, respectively), have been detected in shellfish in Ireland. The toxic phytoplankton species of concern in Irish waters are *Dinophysis* spp. (DSP), *Alexandrium* spp. (PSP), and *Pseudo-nitzschia* spp. (ASP). The marine source of AZP has yet to be confirmed.

In addition, harmful algal events have been linked to the mortality of commercial shellfish stocks and indigenous benthic invertebrates. The most recent example of this type of impact occurred in Bantry Bay (southwest Ireland) during summer 2000 when an abalone shellfishery was decimated following the appearance of a large bloom of the dinoflagellate *Gyrodinium aureolum* in the region.

Phytoplankton Monitoring

The Irish Marine Institute's Biotoxin Unit is currently in the process of restructuring its phytoplankton monitoring capability to help predict, manage and minimize the impacts of marine biotoxins and potentially harmful algal species on public health and the aquaculture industry.

In the short-term the priorities of the Marine Institute's priorities for 2001 are as follows:

(1) Advise the aquaculture industry on early detection and mapping of harmful algal species.

(2) Develop and update the MI/NOAA data base sets relevant to HAEs in Irish waters.

(3) Development of physical circulation models and simulation of historic HAEs using passive particle tracking models.

(4) Evaluate the use of SeaWiFS, AVHRR and SAR remotes sensing data in the detection and mapping of HAEs and physical features relevant to those events (i.e., fronts, upwelling zones).

Early Detection and Mapping of HAEs

- Ensure the rapid communication of information regarding HAEs to the aquaculture industry, Food Safety Authority and public health officials. Toward this aim, the Marine Institute's new monitoring programme is to use microscopic techniques to detect the presence of potentially harmful algal species in aquaculture production areas. Between 60-80 samples will be analyzed on a weekly year-round basis (approx. 3,000 pa). Results, which will include information on abundance of potentially harmful algal species, dominant phytoplankton species and a generic comment on species trends, will be made available by telephone, fax, e-mail and the world wide web within 48 hours of collection. To investigate the relationship between phytoplankton species and environmental factors, we propose that the following parameters be recorded by remote sensors at a subset of sampling sites: temperature, salinity, nutrients (nitrate, ammonium, phosphate, and silicate), and wind velocity.

- Determine the 2-d and 3-d distribution (cysts and non-cyst forming species, respectively) of the over-wintering population in selected key areas.

- Develop immunoassays and gene probes for the detection of Irish phytoplankton species and biotoxins. Initial trials by the Marine Institute on gene probes from MBARI have shown the need to calibrate these for Irish species of interest.

Develop and update the MI/NOAA database with data sets relevant to HAEs in Irish waters

Access to accurate, pertinent and quality assured data and information regarding HAEs in Irish waters is essential in assessing cause, and in developing management and mitigation procedures to deal with these events. The database will provide support for research programmes investigating the interactions between HAE occurrence and environmental factors and form the basis for future modeling efforts. The MI/NOAA database will contain the following data sets relevant to HAEs:

- The MI's data set of potentially harmful algal species dating back to 1985 (in electronicd format 1990 to present). This data set will be significantly augmented by data generated by the new National Phytoplankton Monitoring Network (see above);

- All data associated with the HAEs described in Dr. Robin Raine's case studies (i.e., CTD, nutrients, chlorophyll, species composition, light attenuation coefficients and remote sensing data);

- CTD/STD and current meter data sets from the Irish near-field study area;

- ICES hydrochemistry and phytoplankton/harmful algal species data sets from the near-field study area. The ICES/IOC Harmful Algal Event Database (HAEDAT) and maps of decadal occurrences in the North Atlantic;

- Meteorological data sets (wind speed and direction, daily irradiance, air temperature) from regional meteorological stations, weather buoys and model outputs (ECMWF);

- Existing NOAA climatology data sets describing the Irish near-field study area.

Development of physical circulation model and simulation of historic HAEs using passive particle tracking models

- Development of a coastal circulation model

  One of the long-term end goals of the MI/NOAA collaboration is the development of biophysical models for harmful algal events in Irish coastal waters. The main priority at the moment is the construction of a 3-dimensional coastal circulation model, which will be an essential component for the future development of biophysical models. Dr. Dan Lynch (Dartmouth College) is in the process of developing a diagnostic circulation model, based on the observed distribution of temperature and salinity for the region and data which has recently been supplied by the MI.

- Simulation of historic HAEs using passive particle tracking models

  In the short-term, once the 3-d circulation model has been developed, the main priority is to simulate past HAEs in Irish coastal waters using simple single species passive-partical tracking models. These models treat phytoplankton cells as passive tracers and follow the trajectory of these particles in the computational flow fields. In the medium-term, this approach can be refined by the inclusion of growth and mortality rates of the population. The output from these models will help elucidate the role of physical mechanisms in the transportation and distribution of harmful algal species in Irish coastal waters.

In summary, the immediate priority is to develop the physical model and, over time, to add the biological data from the MI monitoring programme.

Priorities, 2002-2003

The longer term goal of the MI's monitoring and management programme is to develop forecasting capabilities for the occurrence and projected impacts of HAEs. The priorities are to develop biophysical models of HAEs and establish an offshore data buoy network.

Development of Biophysical models of HAEs

To provide an effective forecasting capability, it will be necessary to improve our modeling capacity from simple single species models to more complex coupled physical-biological models. Development of such models will require a better understanding an knowledge of

- Linkages between the Irish Coastal Current (ICC) and harmful algal events;
- Underlying physical mechanisms controlling the flow of the ICC along the west coast of Ireland, i.e., what is the relative role of bottom density fronts and wind-driven advection in forcing the ICC?
- Geographical source of each species of concern; and
- *In situ* growth rates, grazing rates, growth-irradiance relationships and nutrient uptake kinetics of each species of concern.

Establish an offshore data buoy network

The MI, in collaboration with the Department of Marine and Natural Resources, Met Eireann and the UK Met Office, is in the process of deploying 5 marine weather data buoys at strategic points around the Irish coast (2000 - 2002). Three of these buoys will be capable of collecting oceanographic data such as temperature, salinity and currents. This network will be complemented by the deployment of additional offshore data buoys in HAE hot spots. These additional buoys will collect parameters pertinent to detecting HAEs, such as temperature, salinity, fluorescence, light transmission and currents. The application of digital camera and video technologies and remote *in situ* gene probe devices will also be examined.

Appendix 5.6 Acronyms

CBL	Chesapeake Biological Laboratory
COMPS	Coastal Ocean Monitoring and Prediction System
CSC	Coastal Services Center (NOAA)
DODS	Distributed Oceanographic Data System
ECOHAB	ECOlogy of Harmful Algal Blooms
GMNET	Gulf of Mexico aquatic mortality NETwork
GMP	Gulf of Mexico Program
GOOS	Global Ocean Observing System
HAB	Harmful Algal Bloom
HABSOS	Harmful Algal BloomS Observing System
LabNet	Laboratory Network (NAML)
MBL	Marine Biological Laboratory (Woods Hole, MA)
NAML	National Association of Marine Laboratories
NCDDC	National Coastal Data Development Center (NOAA)
NDBC	National Date Buoy Center
NERR	National Estuarine Research Reserve
NGLI	Northern Gulf Littoral Initiative
NGO	Non-Governmental Organization
NODC	National Ocean Data Center (NOAA)
RIC	Regional Information Center
SAML	Southern Association of Marine Laboratories
SCCWRP	Southern California Coastal Water Research Program
SEAKEYS	Sustained Ecological Research Related to Management of the Florida Keys

TABS	Texas Automated Buoy System
TCOON	Texas Coastal Ocean Observation Network