HABSOS

An Integrated Case Study for the Gulf of Mexico

Final Report
July 2004

Submitted To: *USEPA – Gulf of Mexico Program*

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Grant Number: *MX97441301-0*

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Executive Summary

<u>Background</u>: The widespread expansion of Harmful Algal Blooms (HABs) throughout U.S. coastal waters has led to increasing stress on government agencies responsible for protecting public health and providing timely, accurate information to citizens, policymakers and businesses dependent on the health of coastal waters. The Harmful Algal BloomS Observing System (HABSOS) Pilot Project is a "proof of concept" project of the U.S. Global Ocean Observing System (U.S.GOOS) and the National Association of Marine Laboratories (NAML). The goal of the HABSOS Pilot Project is to design a HAB data management and communication system by establishing a network of coastal laboratories (state, federal, academic and private) for rapid collection and dissemination of data and information on *K. brevis* events and related environmental factors. The first task of the HABSOS Pilot Project was to conduct a retrospective Case Study and the second was to develop tools for data integration, management and communication. This report itemizes the challenges and achievements of the retrospective Case Study.

<u>Objectives</u>: Using data from several state, federal and academic laboratories, the Case Study was designed to reconstruct regional environmental conditions and track the occurrence and trajectory of *Karenia brevis* events during 1996, 1997 and 2000. These three years, representing both bloom and non-bloom periods, were intended to provide comparative information relative to bloom formation, movement and termination. The year 2000 was included principally to examine the benefits of satellite (SeaWiFS) coverage for monitoring *K. brevis* blooms. These efforts were designed to:

1. Identify, characterize and organize relevant data and information from across the Gulf region;
2. Select a number of Gulf-wide bloom events for the Case Study effort;
3. Assimilate and Integrate data into a regional format;
4. Assess the essential data requirements for 2-3 day forecasting, and
5. Assess current limitations and needs for capacity building.

The Case Study was also intended to build capacity and infrastructure necessary for eventual success of HABSOS, including the following objectives:

1. Establish networks of algal experts and data management specialists;
2. Characterize and resolve obstacles related to data storage and retrieval;
3. Develop a network and a process for linking and integrating multiple data types from multiple sources; and
4. Initiate a presentation system subject to user feedback.

<u>Accomplishments</u>: During the project we accomplished the following:

1. Identification, characterization and acquisition of HAB data from all five Gulf states;
2. Elucidation of state to state differences in capacity and procedures for acquiring HAB related data;
3. Establishment of the capability to integrate data from the five Gulf states;
4. Development of an ARC IMS system for visualization;
5. Creation of a query system for regional data;
6. Establishment of a HAB data entry tool;
7. Production of a prototype observing system;
8. Generation of a tool for analysis of Gulf-wide data; and
9. Assessment of the essential data requirements for 2-3 day HAB forecasting.

The Case Study also is the foundation for building the capacity and infrastructure necessary for eventual real-time demonstration of HABSOS in support of NOAA's HAB forecasting efforts. Significantly, the Case Study has:

1. Established a network of algal experts and data management specialists;
2. Characterized and resolved obstacles related to data entry, storage and retrieval;
3. Developed a network and a process for linking and integrating multiple data types from multiple sources; and
4. Initiated a web-based presentation system subject to user feedback.

Challenges Identified: While the Case Study effort was focused on assessing the strengths and weaknesses of a regional HAB observing system, the process revealed insight into current limitations in infrastructure and capacity to sustain regional integration. We found several critical limitations to developing a sustained regional HAB observing system, including:

1. *Non-Standardized Support for HAB Enumeration* - Florida and Alabama are the only states that had state personnel dedicated to HAB enumeration. While the remaining states were all able to obtain high quality HAB enumeration from academic institutions in their respective states, this often resulted in long time delays in obtaining results, particularly during non-bloom events.

2. *Dependence on Individuals Rather Than Programs* – In the short period of our study, we had turnover in the leadership in three of our five states as a result of the departures of Quay Dortch, Cynthia Moncreiff and Jonathan Pennock from their academic positions in Louisiana, Mississippi and Alabama, respectively. Long-term success of regional integration will require that these efforts be institutionalized as some level within each state. It is likely that federal support will be required to achieve this, at least for the foreseeable future.

3. *Insecure Funding for Data Integration Efforts* – Despite our clear successes in developing a prototype data management and visualization system through the efforts of the NCDDC, the dependence of NCDDC on 'soft money' and contract employees limits long-term continuity in the regional program.

4. *Lack of Support to Maintain Continuous Input of New Data* – After significant effort to pull together regional HAB data sets for 1996, 1997 and 2000, it is disturbing that there is not support for a continuing effort to add current and near real-time data to the HABSOS database. This is a result of several factors, including each of the issues mentioned above.

5. *Lack of Clarity in the Overall Role(s) of a Regional HAB Observing System* – From the onset of the HABSOS effort, there have been somewhat contradictory views of what the role(s) of a regional HAB observing system are. Early on, the focus of academic researchers on the big issues of why blooms occur in certain places at certain times and a long-term desire for predictability, were superceded by the desire and need to address 'user needs', primarily those of the management community who primarily want to have information that will insure that they meet their management goal of protecting the public from HAB events. While these views are not mutually exclusive, the end result was the focus on data that provides the short-term ability to manage and is insufficient to build and test predictive models on. Without such longer-term efforts, significant advancements in HAB prediction and understanding will be slow to develop.

I. Project Rationale

The widespread expansion of Harmful Algal Blooms (HABs) throughout U.S. coastal waters has led to increasing stress on government agencies responsible for protecting public health and providing timely, accurate information to citizens, policymakers and businesses dependent on the health of coastal waters. Over the last twenty years, harmful algal species have increased in number and extended their range – many species have multiple strains, which can often complicate detection. The movements of these blooms are difficult to predict – they can move across large areas, subject to changing climatic and environmental conditions. Concerns about HABs have increased over the last decade largely because of the effects on fisheries and, in many cases, the associated decline in air and water quality. The toxins produced by these algal species create finfish and shellfish poisoning, and mass mortality of marine animals, including mammals, fish, and waterfowl. Toxic concentrations have caused public health emergencies, closing of shellfish beds, loss of tourism, and severe economic distress in coastal communities. The Gulf of Mexico has experienced intense blooms of the dinoflagellate species *Karenia brevis* in at least 22 of the last 23 years and has been identified as a region that would benefit from a forecasting system.

Karenia brevis is a dinoflagellate found throughout the Gulf of Mexico and in coastal waters of the Atlantic Ocean. The blooms of *K. brevis* impact fisheries and tourist industries through the production of neurotoxin. Ingestion of *K. brevis* toxin by fish paralyzes the respiratory system causing death. Humans eating shellfish with *K. brevis* toxins are susceptible to Neurotoxic Shellfish Poisoning (NSP). In addition, human health is compromised by the presence of dead and decaying fish at beaches, and aerosols produced by wave action affect respiratory systems and cause asthma-like symptoms.

The Gulf of Mexico has a long history of HAB events. Of the 5,000 known species of phytoplankton in the world, about 100 are toxic. Although roughly half of these occur in the Gulf of Mexico, *Karenia brevis* has been responsible for most HAB events along the Gulf coast. For at least the last 50 years, *K. brevis* 'red tides' have been concentrated along the west coast of Florida and, to a lesser extent, along the Texas coast. In 1996, however, red tides occurred in coastal waters of all five Gulf States for the first time in recorded history, resulting in Gulf wide fish mortalities and numerous beach and shellfish bed closures. In addition, red tides persisted for over a year along the coast of Florida, killing 150 endangered manatees.

Coastal economies are affected by these harmful blooms through shellfish closures, fish kills, and beach advisories that reduce tourism and consumer confidence in seafood products. It has been estimated that the annual cost of HAB events throughout the U.S. is estimated at more than $100 million annually, and red tides in the Gulf of Mexico alone can cost $20 million for each major event, including the costs of monitoring and managing the effects of these events.

As a result of heightened awareness of the human health and ecological risks associated with HABs in the U.S., federal and state funding for HAB research increased in the late 1990s. In 1997, the federal interagency ECOHAB (Ecology and Oceanography of Harmful Algal Blooms) program was initiated. ECOHAB has the goal of determining the factors that influence the development of algal blooms in U.S. coastal waters. In the first year, ECOHAB funded a large regional program aimed at understanding and modeling the initiation, maintenance and export of. *K. brevis* blooms on the west Florida shelf. In addition, the EPA's Advanced Measurement Initiative (AMI) funded a joint effort between EPA, NOAA, and the Naval Research Laboratory-Stennis Space Center (NRL-SSC) to develop methods for implementing ocean color imagery for HAB detection in the Gulf of Mexico. Building on AMI successes, the NOAA National Ocean Service (NOS) implemented the Gulf of Mexico HAB Bulletin in 1999. This bulletin, a coordinated effort between NOS, NOAA's CoastWatch, and the five Gulf states, draws on satellite imagery, meteorological data, models, and field observations to aid state resource managers in detecting, tracking, and forecasting HABs.

More than 40 bulletins have been issued since September 1999, and the NOAA bulletins have provided critical forecasts on HAB dynamics in 1999, 2000, and 2001. NOAA continues to expand its work on HABs in the Gulf of Mexico by supporting Florida's development of a historic HAB database for the state, and by continuing the development of forecast models that can be used throughout the Gulf. Timely and effective monitoring and forecasting depend, however, on rapid exchange of information with state and local managers, an interaction that is severely constrained by technical issues in data acquisition and synthesis.

There is a strong need for a monitoring and detection system that will enable local, state, and federal agencies to work together in developing early warning systems and providing accurate forecasts on bloom occurrence, development, and transport. Such capabilities will make it possible to develop realistic mitigation strategies that minimize the risks to human health and reduce the economic impacts. Forecasting is necessary to enable an alert 2-3 days prior to a bloom to allow development of management options and approaches and minimize the risk to living marine resources and humans to HAB or biotoxin exposure

The Harmful Algal BloomS Observing System (HABSOS) is a "proof of concept" project of the U.S. Global Ocean Observing System (U.S.GOOS) and the National Association of Marine Laboratories (NAML). The primary goal of U.S. GOOS is providing practical benefits to society through the development of integrated ocean observing systems. Primary objectives are the sustained collection of ocean observations and the timely distribution of those data and derived products, including analyses, forecasts, and assessments. The Integrated Ocean Observing System (IOOS) is comprised of coastal linkages within a region that systematically acquire and disseminate data and information to serve the needs of many user groups (government agencies, industries, scientists, educators, non-governmental organizations, and the public). The Gulf Coastal Ocean Observing System (G-COOS) is based on observations from the estuaries and near coastal waters in the Gulf of Mexico. The design and implementation of this observing system is based on the HABSOS pilot project for a regional enhancement of the developing national network. The Gulf of Mexico provides a relatively well studied system with a high potential for a successful forecasting pilot project.

The goal of the HABSOS Pilot Project is to design a HAB data management and communication system by establishing a network of coastal laboratories (state, federal, academic and private) for rapid collection and dissemination of data and information on *K. brevis* events and related environmental factors. This system will expand our capability to integrate, interpret and present essential data from across the region in a manner useful to State resource and public health managers. The first task of the HABSOS Pilot Project was to conduct a retrospective Case Study and the second was to develop tools for data integration, management and communication. This report itemizes the challenges and achievements of the retrospective Case Study.

II. Role of the Case Study in HABSOS

One of the first goals of HABSOS was to conduct a retrospective Case Study of red tide blooms in the northern Gulf of Mexico. Using data from several state, federal and academic laboratories, the Case Study was designed to reconstruct regional environmental conditions and track the occurrence and trajectory of *Karenia. brevis* events during 1996, 1997 and 2000. These three years, representing both bloom and non-bloom periods, were intended to provide comparative information relative to bloom formation, movement and termination. The year 2000 was included principally to examine the benefits of satellite (SeaWiFS) coverage for monitoring *K. brevis* blooms. There were several objectives for the Case Study in assessing the requirements of a *K. brevis* forecasting system:

1. Identify, characterize and organize relevant data and information from across the Gulf region;
2. Select a number of Gulf-wide bloom events for the Case Study effort;
3. Assimilate and Integrate data into a regional format;
4. Assess the essential data requirements for 2-3 day forecasting, and
5. Assess current limitations and needs for capacity building.

The Case Study was also intended to build capacity and infrastructure necessary for eventual success of HABSOS, including the following objectives:

1. Establish networks of algal experts and data management specialists;
2. Characterize and resolve obstacles related to data storage and retrieval;
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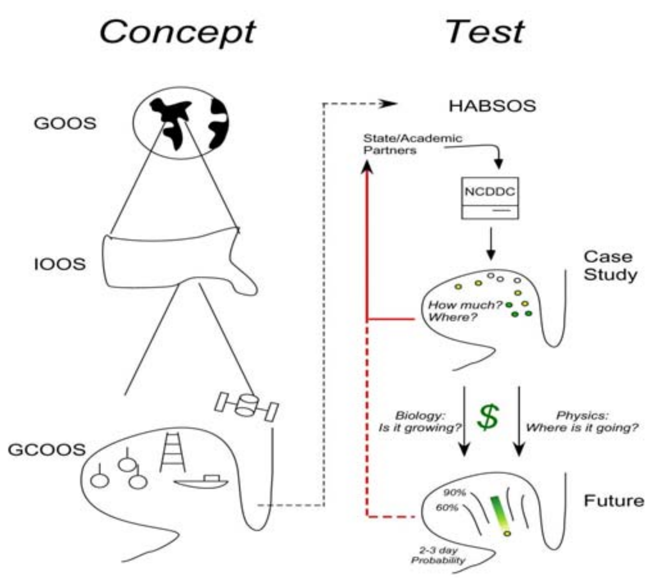
4. Initiate a presentation system subject to user feedback.



Relevance of Case Study to HABSOS

The successful completion of the Case Study satisfied two HABSOS objectives. A network of scientific, public health and resource professionals were engaged in the identification and characterization of data to be included in the Case Study. Many of these professionals were already familiar with the goals of HABSOS through their participation in the initial HABSOS workshop. In particular, state public health and resource managers who provided data from the Case Study years were linked with those who were able to integrate and present the information, namely members of LabNet and the National Coastal Data Development Center (NCDDC). In some cases, state agencies were already interacting across the five states (aquatic mortality events) and in others they were not (shellfish bed closures). The networks generated through completion of the Case Study are the networks necessary for real-time reporting envisioned by HABSOS, although the dependence on individuals rather than programs do not guarantee maintenance of these networks in the future.

The Case Study additionally provided three years of data and information for a prototype data product (Objective 2). It was anticipated that the Case Study product would include a dynamic visualization of events prior to and during red tide blooms and a web-based 'portal' presentation of environmental conditions, *Karenia brevis* concentrations and observed effects (mortality events, shellfish bed closures). The year 2000 was included in the Case Study in order to examine the benefits of satellite (SeaWiFS) coverage for forecasting severity and trajectory of *K. brevis* blooms. One intended data product was time-integrated satellite views of chlorophyll *a* concentrations in the Gulf of Mexico during the known bloom period. *In situ* counts of *K. brevis* were used to confirm that the chlorophyll registered is predominantly red tide.

Additional HABSOS objectives were initiated or advanced through the Case Study. In particular, users were asked to provide feedback on the presentation of data for the Case Study (Objective 3), the network of agencies and institutions needed to provide remote and *in situ* measurements was established (Objective 5), and the products of the Case Study clearly demonstrated the ability of intergovernmental institutions to collaborate on regional issues (Objective 6).

Specific outcomes of the Case Study were: (1) the establishment of the capability to integrate data from the five Gulf states; (2) the development an ARC IMS system for visualization; (3) the creation of a query system for regional data; (4) the establishment of a HAB data entry tool; (5) the production of a prototype observing system; and (6) the development of a tool for analysis of Gulf-wide data. The Case Study also was the foundation for building the capacity and infrastructure necessary for eventual real-time demonstration of HABSOS in support of NOAA's HAB forecasting efforts. Significantly, the Case Study has: (1) established a network of algal experts and data management specialists; (2) characterized and resolved obstacles related to data entry, storage and retrieval; (3) developed a network and a process for linking and integrating multiple data types from multiple sources; and (4) initiated a web-based presentation system subject to user feedback. Each of these is detailed in this report.

Project Participants

A large number of individuals contributed to the HABSOS Case Study effort. These participants are listed here by their role in the project and the states that they represent:

Project Leadership: Jonathan Pennock (Dauphin Island Sea Lab); Richard Greene (USEPA – NHEERL); William Fisher (USEPA – NHEERL); Larinda Tervelt (GMP Program Officer); Fred Kopfler (GMP Program Project Officer)

Florida: Karen Steidinger (Lead Representative; Florida Marine Research Institute); Merrie Beth Neely (FMRI); Earnest Truby (FMRI); Beverly Roberts (FMRI); Darlene Haverkamp (FMRI)

Alabama: Jonathan Pennock (Lead Representative; Dauphin Island Sea Lab); William Smith (ADPH – Mobile Branch); Carol Dorsey (ADPH – Mobile Branch); Lewis Byrd (ADPH – Shellfish Branch); John Carlton (ADEM); Steven Heath (ADCNR – MRD); Keri Duvall (DISL)

Mississippi: Cynthia Moncreiff (Lead Representative; University of Southern Mississippi – GCRL)

Louisiana: Quay Dortch (Lead Representative; LUMCON)

Texas: Tracy Villareal (Lead Representative; University of Texas – Marine Science Institute); James Simons (Texas Parks and Wildlife).

Federal Participants: Richard Greene (USEPA – Gulf Ecology Laboratory); William Fisher (USEPA – Gulf Ecology Laboratory); Richard Stumpf (NOAA – NESDIS); Mary Culver (NOAA – NESDIS); Tim Orsi (NOAA – NCDDC); Jeanne Allen (NOAA – NCDDC); Sonia Gallegos (NRL – Stennis Space Center).

III. Objectives

Overview of Objectives and Process

1. Identify, characterize and organize relevant data and information from across the Gulf region;
2. Select a number of Gulf-wide bloom events for the Case Study effort;
3. Assimilate and Integrate data into a regional format;
4. Assess the essential data requirements for 2-3 day forecasting, and
5. Assess current limitations and needs for capacity building.

Objective 1 – Identify, Characterize and Obtain Relevant Data

Overview: The effort to obtain relevant HAB cell counts, hydrographic and chemical data revealed that significant differences existed in the States' ability to both find and transmit the data. The time lag produced during the process of finding, validating, extracting and transmitting the data was the single greatest delay in implementing the web-based visualization tool. The following text highlights the steps that were required in each state; detailed descriptions are available in the appendices.

Of the five Gulf States, only Florida had complete and ready access to the data in a form that was easily transmitted to the NCDDC. In large part, this was due to the State's historical focus on *Karenia brevis* and on-going research programs funded by ECOHAB that had already established a database for cell count and other information. However, the ongoing research effort prevented release of nutrient data with the cell count information. Concerns of interpretation of raw cell count data required coding the data into broad ranges for presentation on the publicly available version of the HABSOS website. The data was available from a single source (Florida Marine Research Institute), and other than the nutrient data, there were no problems in obtaining it.

Alabama data was derived from several sources, some of which had destroyed the records after a required archival period. Fortunately, the original data sheets from State collections were found and the data was re-transcribed. This resulted in a lengthy delay before submission to the NCDDC. The older state records were initially considered proprietary, had poor metadata, and often were not properly geo-referenced.

Mississippi data were not immediately available. Data for the year 2000 was considered proprietary, and release could only be authorized by the Mississippi Department of Marine Resources. The required approval took almost a year, and significantly delayed the final HABSOS product. Several files had to be combined in order to generate the requested information. Ancillary data on temperature, salinity, chlorophyll and nutrients was sporadically available with the cell count data.

Data from Louisiana were not immediately available. For one project, samples had been collected and archived, but not counted. This process took approximately 6 months. Once counted, the data were immediately transferred to the NCDDC. There were no issues in releasing the data. Event response sampling during the 1996 bloom was available from the Louisiana Department of Health. The lack of funding for data retrieval slowed this process. Other data were available for years not included in the pilot project, but were not used for the Case Study.

Texas data were extracted from two sources: a red tide monitoring study conducted by the University of Texas at Austin Marine Science Institute, and cell count information collected by Texas Department of Health (TDH) during their monitoring of shell fish beds. The former dataset was already in a database and required little effort to extract and send. Since the data had already been submitted to TPWD as part of a contract requirement, there were no issues of proprietary data. Cell counts, nutrients, and chlorophyll data were released. The TDH data had recently been digitized, and no additional problems were presented. Delays were encountered while the remaining State records were searched for additional information. No other data sets were located.

A common problem encountered was the lack of dedicated funding for regular monitoring, and database maintenance required significant dedication of time for Mississippi, Alabama and Louisiana. Both Texas and Florida had ongoing programs that were able to rapidly provide information for the NCDDC. However, only Florida has a commitment to a regular program for sampling. The lack of data in the future will present a serious challenge to the viability of a long-term HABSOS effort.

Florida HABSOS Case Study Process

Florida has had an on-going database project at the Florida Marine Research Institute for Harmful Algal Bloom (HAB) monitoring and event response that made the pilot project comparably easy. This database includes data collected by citizens, commercial fishermen, private and public institutions throughout the state since 1953. This historical data was recently rescued and almost 50 years of data digitized. HAB monitoring cruises in the Gulf of Mexico have been conducted with some regularity since 1954, particularly since 1997 with the advent of the Ecology and Oceanography of Harmful Algal Blooms (ECOHAB): Florida program. In May 2000, the Red Tide Offshore Monitoring Program (a citizen volunteer network) was begun, enhancing the spatial and temporal sampling efforts of federal and state funded HAB monitoring.

Both near shore and offshore counts are available in this database with some hydrographic and nutrient data available sporadically, except for dedicated research cruises. Dedicated research cruises generally have a full suite of hydrographic and chemical data to complement cell count information. The HAB database does not routinely include information from toxin analyses or mouse bioassays associated with shellfish harvesting closures, however, this information is stored in a separate database within the Harmful Algal Bloom section and may eventually be merged with the HAB database. Marine mammal morbidity/mortality, bird and fish kills are recorded in separate databases maintained both at FMRI (other sections) and state or private agencies. This data may be included in the HAB database from time to time. While detailed metadata exists for most entries collected during research cruises since the 1960's, earlier monitoring information and information gathered on small boats or from shore is largely without the benefit of metadata files.

The responsibility for creating, maintaining and managing the HAB database lies with Florida Marine Research Institute (FWC) staff. State general revenue funds were used to finance creation of the database. As a quality control measure, the HAB database incorporates conversion mechanisms for latitude, longitude, time, temperature, salinity and certain physico-chemical parameters to ensure data are reported in a standardized format. The data entry screen also prohibits entries outside specific parameters, minimizing typographical errors. Currently 5 employees have database entry and maintenance capabilities; however, in the future, maintenance will likely be restricted to one or two individuals to minimize errors.

The Florida HAB database is comprised of samples collected primarily during HAB events, however, some research cruises (FSBC, NASA, Mote and ECOHAB:Florida) were part of state and federal HAB monitoring programs. Cell counts and some hydrographic data are usually available within 24 hours following receipt of samples. However, data collected during research cruises, nutrient analyses, or results reported by other agencies may not be available in near-real-time or may be considered proprietary. Some hydrographic and meteorological data from buoys and fixed platforms along Florida's Gulf coastline is available in real-time format via the world wide web. These buoys and platforms were installed and maintained by other state investigators through state and federal funding for a variety of purposes, including HAB monitoring.

Since mid-1998 there has been good spatial and temporal coverage of the offshore region between Tampa Bay and Charlotte Harbor as a result of the ECOHAB:Florida Program. In addition, the state funded Mote Marine Laboratory to provide repetitive coverage along a 30 mile transect off Sarasota and other coverage during red tides in their vicinity. Typical nearshore and onshore monitoring by local and state agencies is driven by events and best coordinated in the southeast Gulf of Mexico; the area routinely affected by red tide between Tarpon Springs (Pinellas Co.) and Naples (Collier Co.). State, private and local agencies in the Panhandle, the Florida Keys, and along Florida's Atlantic coast also sample as needed in response to HAB events, which vary temporally and spatially.

Offshore samples, particularly from depth, are only sporadically collected with the exception of dedicated HAB research cruises. Basic hydrographic and nutrient data for most samples collected by private/local agencies and volunteers is lacking. Volunteers are often not able to provide more than preserved samples and basic location and collection information. However, FMRI is purchasing a new autoanalyzer and can provide sampling kits to collectors. Extracted chlorophyll and relative fluorescence (via CTD mounted *in situ* fluorometer), wind and water currents are usually only provided by universities or other state agencies from dedicated research cruises and these data can sometimes be considered proprietary. Non-proprietary near-real-time wind and water currents are available from selected buoys and fixed platforms along Florida's Gulf coast via the internet (Ckeys, Cman, Ccoos).

Access to Florida's HAB database is currently restricted. Limited portions of this database are available in CDROM format to interested researchers upon inquiry. Some data from dedicated cruises or other funded projects has been, or will be, transmitted to NODC as part of grant reporting requirements. A public internet-based search tool is in the initial stages of development for the HAB database, and will be available through the FMRI website.

Florida's groundbreaking and comprehensive efforts to create and maintain our HAB database through well funded efforts and dedicated personnel at the State level facilitated the timely and thorough cooperation with the HABSOS Case Study pilot program. The distribution of CD ROM's to interested researchers and the planned development of the internet based HAB database search tool underscore Florida's commitment to cooperative, comprehensive, and quality red tide research. Continued funding of these programs (personnel and sampling efforts) is crucial to meeting this commitment and maintaining our position in the HAB Gulf of Mexico scientific research community.

Alabama HABSOS Case Study Process

At the beginning of the HABSOS Case Study, Alabama had modest HAB monitoring programs for its oyster reefs and recreational beaches and no coordinated HAB data management efforts. The agencies involved in HAB monitoring included: (1) the Alabama Department of Public Health – Seafood Branch [ADPH-SB; regulatory authority for oyster reef and beach closures]; (2) the Alabama Department of Public Health – Mobile Laboratory [ADPH-ML; HAB enumeration]; (3) the Alabama Department of Environmental Management [ADEM; development and implementation of the HAB contingency plan}; (4) the Department of Conservation and Natural Resources – Marine Resources [DCNR; fish kills and resource impact]; and (5) the Dauphin Island Sea Lab [DISL; basic and applied research into HAB events].

HAB data for Alabama waters has been collected only since the early 1990s. Most of these data were collected by ADPH-SB and enumerated by the ADPH-ML on a near-monthly basis. Additional data were collected during HAB events by directed sampling in response to reports of respiratory distress or fish kills. The ADPH-ML maintained hard copies of all these data while the ADPH-SB entered grouped data (e.g. *Gymnodinium sp.*) into spreadsheets. ADPH-ML maintained their data for the period of time required by the state (3 years) and then disposed of raw data. As a result of the 1996 *Karenia brevis* event on the northern Gulf Coast, the DISL sampled lower Mobile Bay and offshore waters for HAB species over a two-year period (1997 – 1999) with Sea Grant funding. In addition, DISL received a grant from the Gulf of Mexico Program (GMPO) to develop a prototype database system for integrating HAB data for Alabama waters collected by the various agencies.

Upon initiation of the HABSOS Case Study, efforts were made to integrate the existing data sets described above. The DISL data set was available digitally in both EXCEL and ACCESS formats. Attempts to acquire the state (ADPH) data were complicated by the fact that the ADPH-MB was uncomfortable with releasing data they maintained, even though it had been collected by the ADPH-SB. Efforts to obtain data from ADPH-SB were complicated by the fact that their HAB databases were maintained in a old database format, were averaged and combined by genus, were not geo-referenced by lat/lon or GPS and, ultimately, were destroyed at the end of the required archive period. Fortunately, the

ADPH-ML maintained the original data sheets and ultimately these data were digitized into ACCESS format by the DISL.

Once the various data were digitized, the ADPH and DISL data were moved into the Alabama HAB Monitoring database as part of the DISL portion of the Cast-Net[1] project with the hope and intent that this database would be accessed by NCDDC as part of the HABSOS Case Study effort. In actuality, meshing of the NCDDC HABSOS effort and the Alabama database effort was deemed too difficult to address, and the DISL and ADPH ACCESS databases were imported directly into the HABSOS database. This process was clearly the easiest way to go for the HABSOS Case Study although additional new data are not currently being incorporated into the database on a regular basis.

Much like the overall HABSOS Case Study effort, the success of integrating the Alabama HAB databases was the result of the cooperation and efforts of several dedicated individuals. For Alabama (and several of the other states as well) the loss of one or two key individuals still has the ability to shut down the programs that provide the majority of the data or the initiative to integrate these data. An important contributing factor to such a scenario is the fact that the state of Alabama has yet to provide funding for the integrated effort. Long-term success of the HABSOS effort will require a focus on providing the framework and funding for integration beyond the required focused monitoring programs that existed (and continue to exist) before the initiation of the HABSOS program.

Mississippi HABSOS Case Study Process

State efforts involved in obtaining and transmitting cell counts and associated data to NCDDC for implementation of the regional analysis as part of the HABSOS Case Study effort were accomplished primarily by the research scientist directly responsible for generating cell count data. Ancillary data was collected by staff with the Mississippi Department of Marine Resources (MS DMR), and also by the researcher on limited offshore HAB monitoring cruises.

Information on presence or absence of cells of *Karenia brevis*, the density of cells when present, GIS-based sample location information, air and water temperature, salinity, tide stage, and wind speed and direction were available for samples collected by the MS DMR during the 1996 bloom event, and for the other time frames covered by the analysis. Availability of data for incorporation into the HABSOS Gulf of Mexico database was limited primarily by format (hard copy only) and by the proprietary nature of the information.

For the 1996 bloom event, the following information was available: sampling date, sampling station plus latitude and longitude, cell counts, salinity (ppt), and water temperature. Data collection began immediately prior to the bloom event, and continued until oyster reefs were reopened, beginning on 1 November 1996 and concluding on 26 February 1997. The 1997-1998 and 2000 study periods had data beginning on 27 August 1997 and ending 10 March 1998; 2000 data collection began on 1 June and concluded on 19 December 2000. Samples were collected on essentially a weekly basis, but were not continuous over the time frames (i.e., no daily or remote/automated data collection). Data holders were directly involved in the HABSOS effort. The lower limit of detection was 1,000 cells per liter for all

[1] A Program of the National Association of Marine Laboratories. Cast-Net addresses the need for enhanced connectivity among coastal observing systems by focusing on the sites that generate marine and coastal observing data. www.cast-net.org

years. Cell counts were made as samples were received; no samples were specifically examined for data needs for the Case Study.

Limited associated environmental data was available for all sets of cell count information; no samples were collected in association with phytoplankton samples for nutrient analysis during any of the Case Study time periods. Chlorophyll a samples were collected in conjunction with offshore monitoring during 1997 and 2000; information was not continuous and was not provided for the Case Study. Cell count data for 2000 was specifically proprietary; data for the 1997-1998 time frame was not. Release authority for the 2000 data resided with the MS DMR Fisheries Division; hard copies of the data resided in files at MS DMR and the University of Southern Mississippi's Gulf Coast Research Laboratory (GCRL). Two entities were involved with data collection: the MS DMR and the research scientist at GCRL. Information had to be entered in to an electronic format for use in the Case Study. Metadata associated with the project was collected specifically for a publication describing the bloom event, and has been published (Dortch et al. 1998).

Two databases had to be combined to provide the information needed for the Case Study. All data was either available in an Excel spreadsheet format, or was directly entered in to that format when converting from hard copy files to electronic format. No quality control issues were encountered or reported in importing the information for use in the Case Study.

Limited nutrient data exists for 1997 and 2000 for coastal Mississippi waters, and is held by the Mississippi Department of Environmental Quality. However, very few of the data points overlap with the cell count data locations.

Cell count data for 1996 was generated in direct response to the observed bloom event; no HAB monitoring program existed for the state at that point in time. A basic monitoring program was established during 1997, and was provided with limited funding. Data collection during 2000 was the direct result of a monitoring program.

All cell count data, sampling dates, salinity measurements (ppt), and water temperatures were strictly available in hard copy only; data had to be entered into an electronic spreadsheet for use. Sampling station codes, plus latitude and longitude, were available as an Excel spreadsheet, and had to be extracted from a full list of 177 state sampling locations. Latitude and longitude were entered in decimal degrees, and did not need to be converted for use in the Case Study.

A lack of funded personnel dedicated to data entry was a problem that directly impacted the immediate availability of data for use in the Case Study. Real personnel time needed to assemble the data required for the Case Study was not documented. Estimated time for data entry and quality assurance and control for use in the Case Study was $\leq$ 20 hours. Time for sample collection for each sampling date is estimated at 8-10 hours per date included in the Case Study; generation of cell count data is estimated to be 0.3-0.5 hours per sample. Samples were collected on 38 dates during the 1996 event; 206 phytoplankton samples were examined during the 1 November 1996 - 26 February 1997 time frame. The 1997 data encompassed 45 sampling dates, and 136 phytoplankton samples were examined. During the 2000 monitoring period, samples were collected on 32 dates, and 126 phytoplankton samples were checked for the presence or absence of *Karenia brevis* and other HAB forming species.

Two state entities were involved in the final Case Study product: MS DMR and the University of Southern Mississippi, GCRL. No funding was in place for the direct support of cell count data in 1996; support for data collection in following years resulted in data of a proprietary nature. State support of

HAB monitoring continues in the form of limited water sample collections in conjunction with sampling for fecal coliform analysis in oyster growing waters. No direct support for cell counts exists outside of extramural funding for the present year through a federal coastal impact assistance program.

Louisiana HABSOS Case Study Process

Dr. Quay Dortch, an investigator at LUMCON, has been collecting phytoplankton samples in Louisiana coastal waters, including both estuaries and shelf waters from 1989-present. Upon her departure from LUMCON Dr. Nancy Rabalais took over her programs and research group, and they are continuing to collect data in the same areas. That data set is the most comprehensive compilation of HAB data for coastal Louisiana. They include stations on transects on the Louisiana shelf off of Terrebonne Bay (monthly from 1989 to present) and off the Atchafalaya River (bimonthly from 1991 to present), stations on an annual shelf-wide cruise in July (1990-present), stations on numerous cruises in different seasons from 1990-1994, a station over oyster beds in the Terrebonne Bay estuary (1993-2001) and a suite of stations in the Barataria estuary (1999-present). For the HABSOS Case Study only the data from the shelf for 1996-1997 and 2000 were included. At the time the Case Study began, the 1996-97 data had been counted but no samples from 2000 had been counted. Before these data could be incorporated into the HABSOS web site, they first had to be counted.

When the Louisiana Department of Health and Hospitals (DHH) was notified that a bloom was occurring in Mississippi waters, it started collecting samples over oyster beds and contacted Dr. Quay Dortch at LUMCON to analyze samples for *Karenia brevis*. That sampling continued into the beginning of the next year, after which time there was a sampling lapse. Then Louisiana Sea Grant funded a regional study of *Karenia brevis* in the low salinity estuaries of the northern Gulf of Mexico with Drs. Jonathon Pennock and Cynthia Moncreiff. In Louisiana DHH collected samples over oyster beds from fall 1997 to fall 1999 which Dortch analyzed. DHH took over checking some samples for *K. brevis* after that project ended, but those data are not included in the HABSOS data set.

For the Case Study the data from both types of studies listed above were combined.

<u>Counting Methods and Limits of Detection:</u> Water samples for phytoplankton identification and counting were preserved in the field in 0.5% glutaraldehyde, refrigerated briefly, stained with 0.03% proflavine hemisulfate and filtered onto 8 μm polycarbonate filters. Filters were mounted in immersion oil and cells counted using an Olympus BH2-RFCA epifluorescence microscope with blue and green excitation light (Dortch et al., 1997). The limit of detection in routine counts is 1000 cells/liter. In the samples collected specifically for DHH an effort was made to lower the limits of detection by counting much more of the sample and ranged between 100 and 500 cells/liter.

<u>Ancillary Data:</u> All data have an associated date, location (latitude and longitude), salinity, and temperature. The samples collected as part of other programs may have other data such as chlorophyll and nutrients, but those data have not been included because they "belong" to other investigators (mostly Dr. Nancy Rabalais). The samples collected with DHH have additional data about tides and weather which were also deposited at NCDDC.

<u>Metadata</u>: Jeanne Allen wrote the metadata for the HABSOS Case Study using information provided by Quay Dortch. It was then reviewed by Quay Dortch. Data were stored in Excel files. Some Latitudes and Longitudes needed to be converted to decimal format and some temperatures needed to be converted from ^{o}F to ^{o}C. Jeanne Allen ran routine QC procedures and corrections were made as needed.

Retrieving the data at LUMCON from 1996-1997 was not much of a problem. Obtaining data for other years was more of a problem because there was not specific funding to do it. Thus, there are data for many other years besides 1996-1997 and 2000 that have not been put into HABSOS. Inclusion of that data might enhance the usefulness of HABSOS. Finally, none of the data collected by Louisiana DHH since 1999 has been included and it is not known if they keep a database of samples that have been checked. It would be worth talking with Bruce Champion and Wayne Dupree from Louisiana DHH about depositing old and new data into HABSOS.

Texas HABSOS State Process

Data extraction for the pilot project effort required coordination of both academic and State institutions. Cell count and hydrographic information was available from Texas Department of Health (TDH), and The University of Texas at Austin Marine Science Institute (UT). The individuals responsible for the data were known, but it was not initially known how or where the data was available except at UT. The TDH data spanned the correct time frame; the UT data was only collected post-1999. TDH collects data in response to red tide events that have a public health impact, so these data were localized around reported blooms. The UT data was part of a regular sampling program and was continuous over the time frame it was available. During this writing, it became apparent that the data from cell count samples collected by Texas Parks and Wildlife Department (TPWD) was not archived. It is not known where all of this data is, although a data mining effort is underway at UT to extract that information. A variety of individual investigators may have been collecting cell count data during the bloom. We do not know if we got all this information.

Dr. J. Simons (Resource Protection, TPWD) was charged with obtaining the State data. He contacted K. Wiles at TDH to get the data, which was electronically available, but only because an independent effort by NOAA (Dr. P. Tester) digitized the handwritten records of TDH. State data are public record and no release authority was required. The UT data had already been presented in a final report to TPWD to support their reporting requirements to NMFS. Release authority for the UT data resided in the P.I. of the project (T. Villareal) who was participating in the HABSOS effort. This data was available both as a PDF file and an excel database.

Only the UT data was generated by an HAB monitoring program. However, this study was designed to be a research effort focused on determining the seasonal presence or absence of *K. brevis* in Texas waters. It was not a real time response effort. The TDH data set is event driven. TDH is required to monitor for brevetoxin contamination in shellfish. Their counts stop once brevetoxin contamination is measured, and is not continuous in an area. TPWD responds to fish kills and is mandated to determine the cause. Samples are collected at intervals and shipped to various investigators for identification and sometimes enumeration. For the HABSOS effort, all samples were already enumerated. TDH has a mandate to respond to events, and requires data as quickly as possible. They use their own personnel to collect and enumerate the samples. The UT collections were part of a funded program (2.5 years) that had already concluded. As a result, there was no delay in obtaining the data.

Counting methodology varied between the two programs. TDH used Sedgwick-Rafter counting chambers and live samples (detection approx. 1 cell per ml). The UT samples were preserved and settled for inverted microscopy. Detection limits ranged from 10-15 cells per liter, depending on the settled volume. Some initial errors in converting the data to a common volume format occurred when the data was transferred to the NCDDC; however, the problem was quickly evident when the first web-based presentation was given. Associated environmental data was available for some of the samples. Temperature and salinity was available for most of the of TDH stations in 2000. No ancillary data was available for 1996 and 1997. For the UT data (2000), temperature, salinity, DO, chlorophyll, nutrients (nitrate+nitrite, silicate, phosphate, ammonium) was available. This latter data was fortuitous since Texas has no routine monitoring program for its coastal waters.

The data was retrievable from the UT database (Filemaker Pro, Macintosh) easily. TDH does not have a database for their data although the data had been digitized by NOAA. After the data was submitted and plotted, it became apparent the latitude and longitude had some errors (probably transcriptional) in it. Lat/long was recorded in several formats (degrees decimal minutes versus degrees minutes seconds) and required conversion. They were easily resolved, although it did take some time to track down the original source. The units for cell counts (per ml vs. per L) were unclear at first in NCDDC database and this resulted in a confusing presentation initially where some samples were 1000 X too low. This was not evident until the first pass at the web interface was available. During the writing of this text, it became evident that no formal QC program existed for the various state datasets. No metadata has been entered to this point, primarily due to lack of personnel to enter the information. HABSOS was only able to fund a limited support for academics to extract the data and participate in the pilot program development, and this funding did not permit verification of the metadata. No funding was available for the State to hire additional personnel to extract data or metadata. Data transmission was readily accomplished once the data had been put into Excel worksheets.

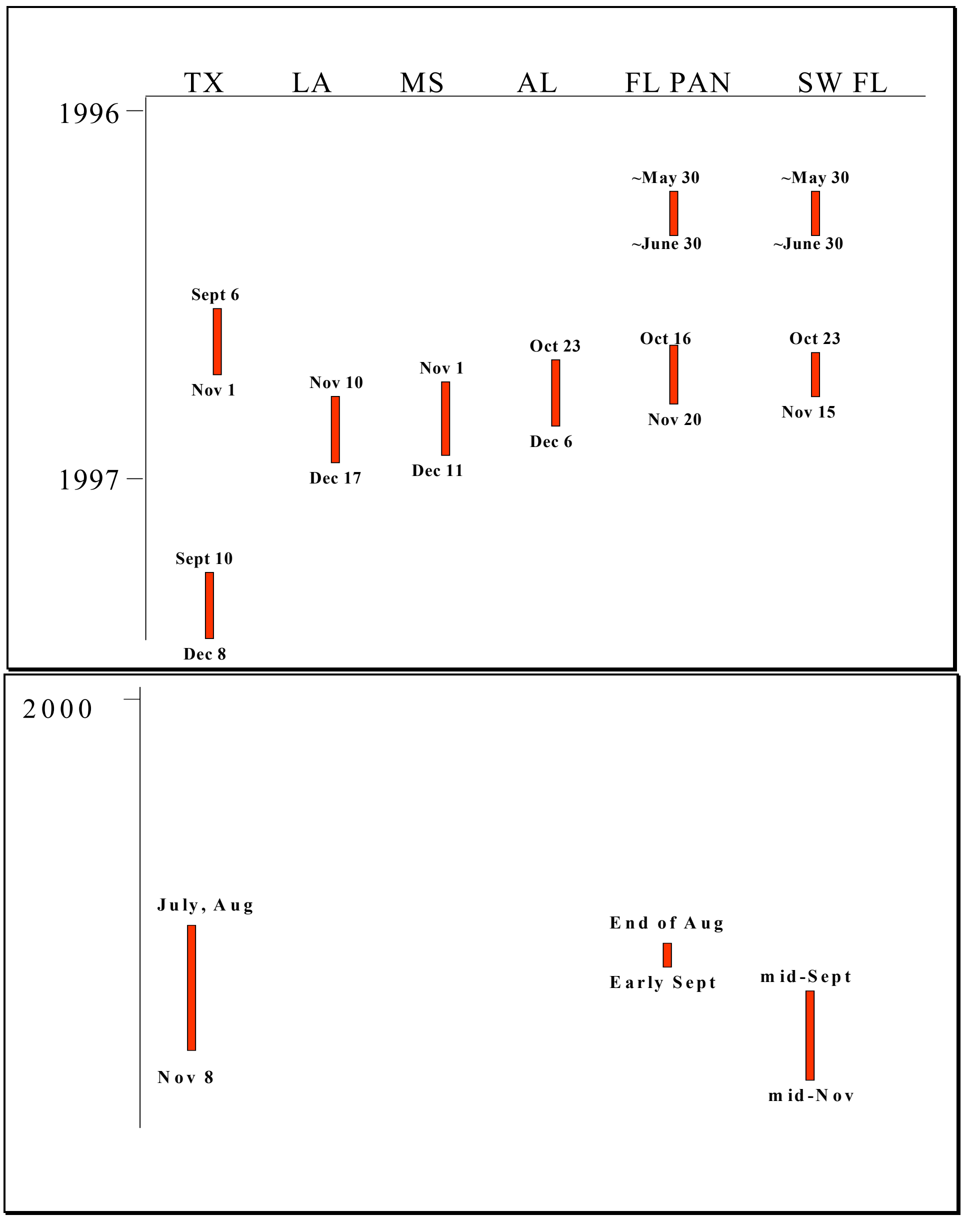
Two people (one TPWD, one UT) participated in the data set acquisition. They are both members of the TEXHAB committee and this effort overlapped with their responsibilities to the committee. They both had access and means of obtaining the data. The UT data was already available in Excel files and required only a minor effort to extract. It took several weeks to extract the TPWD red tide data (occurrence, distribution and fish kill data). An additional month was required for both Simons and Villareal to write up the event summaries. The largest effort was devoted to trying to find data that we weren't sure existed, and to correcting spurious position and unit information. Neither of us had dedicated staff to assist, and the effort was spread over many months since other responsibilities took priority at times. We also had to wait for other investigators to respond to our inquiries.

The final project required input from 2 divisions of TPWD, the TDH, and UT-Austin. No dedicated funding was in place to support the TDH and TPWD data extraction efforts, although the actual data collection is part of the agency mission. The UT data collection effort was research driven and funding cannot be assured for future efforts. The TDH data are limited and are not synoptic thus limiting their utility primary to individual events, not monitoring. At this time, there is no state-wide database for HAB records.

Writing this text highlighted the State's lack of a dedicated database and/or coordinator to insure permanent storage in a retrievable format for all the relevant HAB data. This will continue to be a major problem in making near real-time data available to any future HABSOS effort. HABSOS and NCDDC can serve as a valuable repository of this data if the appropriate data entry and availability issues are resolved.

Objective 2 – Selection of Gulf-Wide Bloom Events for Case Study Effort

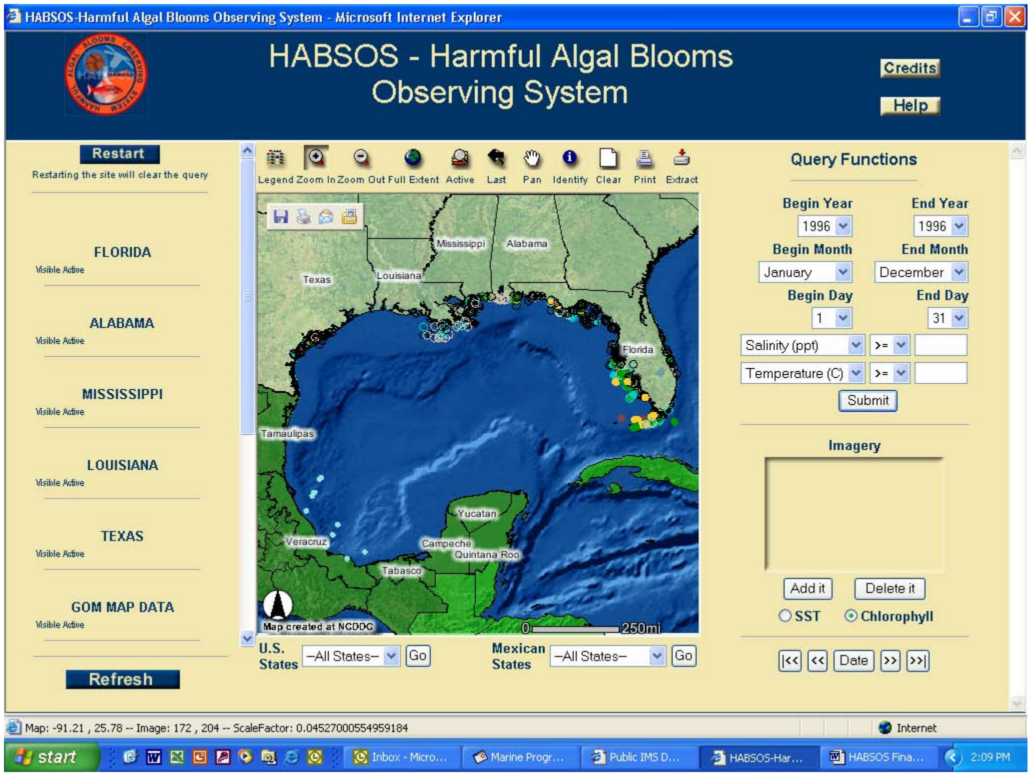
An approximate timeline of red tide events in the Gulf of Mexico as reported by the HABSOS Case Study Working Group is shown in Figure 1. Dates are based on those reported in event reports. Classification of the bloom events were based on parameters such as cell counts and fish kills; it is possible that the durations of the bloom events were in reality longer than summarized here.



Objective 3 – Assimilate and Integrate Data into a Regional Format

A primary obstacle to the study of regional environmental phenomena was the difficulty in identifying, recovering and integrating relevant but disparate data into a useful format for display and analysis. Data assimilation and integration are huge, time-consuming, and generally underappreciated tasks. From its inception, the HABSOS Case Study Working Group recognized this challenge. For example, we understood that the required datasets would be difficult to access and there would be few single points of contact. We knew the data sets would be agency or investigator-specific and in multiple, and more likely than not, non-digital formats. Non-standard units were anticipated as were inconsistencies in values determined by different measurement approaches to a parameter, e.g., buoy winds versus satellite winds. To summarize our understanding of the state of data management within the Gulf of Mexico region, there are presently no common Gulf-wide and few state databases to coordinate these important data sets.

To achieve Objective #2, we developed an ArcIMS application for the HABSOS Case Study. The ability to visualize the spatial characteristics and dynamics of a bloom is critical and the geographical information system (GIS) approach is ideal. In addition, a web site was designed and developed to serve as the regional information center (RIC) for the HABSOS pilot project (www.ncddc.noaa.gov/habsos); see two pages below as examples.



Process/Findings

Collaboration: The level of collaboration in identifying and compiling the required data sets for the HABSOS Case Study has been unprecedented. Numerous agencies and institutions across the Gulf and nationwide have participated, most contributing on a voluntary basis. Although an informal alliance of HAB experts has existed for some time within the northern Gulf of Mexico, the HABSOS Case Study and the pilot project in general, has served to formalize, strengthen, and expand this network, linking existing programs and capabilities throughout the Gulf region. Most recently, Mexican public health officials have expressed interest in HABSOS. As a result, the HABSOS pilot project is being expanded to include the Mexican Gulf states, permitting for the first time, true bi-national HAB collaboration and a regional analysis and monitoring capability that will span international borders.

Realities of sharing data: The economic impact of a HAB event can be severe as coastal communities are affected by the closure of shellfish harvesting areas, fish kills, and beach advisories that reduce tourism and consumer confidence in seafood products. Because of the economically sensitive nature of HAB data, the possibility of over-reactive media coverage, or the potential for malicious manipulation of the data for whatever reason, some Gulf state agencies are hesitant to permit full and unlimited public access to these data. The HABSOS Case Study Working Group acknowledged these requirements from the data provider community and responded by developing a password protected environment within the HABSOS ArcIMS, accessible only to the Working Group and authorized users. A similar sensitivity exists with data provided by Industry. For example, Marathon Oil Company operates the Climatology and Simulation of Eddies ("CASE") Project and has a considerable investment in model development within the Gulf of Mexico. Seeking to verify model simulations of the Loop Current and associated eddies run by the University of Colorado POM model (CUPOM), Marathon and NCDDC entered into confidentiality and nondisclosure agreement, permitting the HABSOS Case Study Working Group use of CASE simulations while securing the economic sensitivity of CASE's data and information.

Data assimilation: The HABSOS Case Study has made one thing very clear -- just because data are available or in hand does not mean they will be usable. We referred to this as "data readiness". Multiple formats for a single data type were indeed the rule. The Case Study clearly revealed the necessity of a process to streamline data flow so that HAB data, mortality sitings, shell bed closures, and public health incidents can be quickly and seamlessly ingested into HABSOS. This is critical if HABSOS is to evolve into a fully operational real-time system. In response, NCDDC is developing an on-line HAB data entry tool so HAB cell counts can be readily entered and ingested into HABSOS for rapid management and decision support (Figure 3).

Because of the labor and costs associated with compiling and integrating some types of data, particularly biological information, the HABSOS Case Study also is leveraging other HAB-relevant programs and databases within the Gulf of Mexico. In one example of emerging capability pertinent to HABSOS, NOS Center for Coastal Environmental Health and Biomolecular Research (CCEHBR) is finalizing the Shellfish Information Management System (SIMS). The purpose of SIMS is to coordinate shellfish resource and water quality information to improve information sharing, thereby promoting shellfish safety, management and habitat restoration. A second example is EPA's Gulf of Mexico Mortality Network (GMNET) Explorer, a system for collection, archiving and distribution of fish, turtle, and mammal mortalities around the Gulf. Leveraging these two applications will be most cost-effective and a powerful example of distributed and interagency cooperation.

Challenges:

- Data took time to gather from all states.
- Data were in multiple formats.
- Data had to be converted (e.g. decimal degrees to latitude/longitude; Fahrenheit to Celsius; #/mL to c/L; dates to mm/dd/yyyy).
- Data QA/QC had to be performed (e.g. If latitude/longitude had no values or a zero value, then that record was thrown out. Some latitude/longitude fields had incorrect values that had to be corrected).
- Data were added to one centralized database. Microsoft Access was used to integrate all state data into one.
- New fields were added to the centralized database. These fields include adding the state name and a field for the person and agency from which the data was received.
- Data were exported as a dbf from Access and imported into ArcGIS where a shapefile was created.
- Several shapefiles were used to create the ArcIMS site. Data that were added include relief image, state boundaries, county boundaries, rivers, buoys, and cell counts. Beach access points and marinas were added later.
- The ArcIMS site had to be customized from the "out of the box" look. This included making changes to the htm pages. (e.g. Customizing text and background colors; sizes of window frames).
- Working group suggested viewing the data over a time period. Javascript code was developed that allowed the user to select a beginning and ending data for a particular time period. The user could then select a time period with the option to break that time period to a day-by-day look at the data.

- The Working group also suggested the use of AVHHR and SeaWIFS imagery in the map display to be used simultaneously. Because of the number of images involved with the Case Study years, a plan was developed to incorporate the images as thumbnail images. As a user looks at the data on a day by day basis, then the user can also visualize the thumbnail image (SST or AVHRR) for that day. The user can choose to add that thumbnail to the map that contains the cell count data.
- The Working group suggested at a later meeting that more data queries would be needed to further analyze the data. Queries mentioned were: salinity, temperature, chlorophyll and dissolved oxygen should be added to the current cell count/date queries.

Data Integration: One of the more important findings of the Case Study was the natural evolution of a conceptual framework within which to plan and manage the development of HABSOS. A number of "development modules" emerged, and although there is some overlap between them, for the most part, each module is generally characterized by a distinct user/provider group and unique aspects to its data stream. Modules identified during the Case Study include the following:

- Foundation Layers
- Meteorology
- Oceanography
- Remote Sensing
- HAB Information
- Aquatic Mortality
- Shellfish Management
- Event Reporting
- Volunteer Watch

The modular approach permits the development of a data flow schematic of each module and aids in identifying key participants and agencies. The framework also is beneficial because it focuses resources, bringing together technical experts and other interested parties under a common issue and it insures continuous operation even in the event one component goes down. The HABSOS modular approach mimics the Integrated Ocean Observing System (IOOS) concept of an end-to-end system (observation to application) in that each module establishes one link of the chain. Ultimately, this framework will lead to more accurate cost estimates for sustaining the operational HABSOS for the Gulf of Mexico.

Additional Required Functionality: Another unique requirement for HABSOS is the need for a geospatial and temporal display functionality to track, forecast and ultimately predict the dynamics of HAB blooms over space and time. Because blooms "evolve", state natural resource managers and public health officials need to know "where" and "when". Although Internet technology and capabilities are progressing rapidly, present applications such as ESRI's ArcIMS, require considerable customization to move beyond the basic map service.

Summary: The HABSOS Case Study has made considerable progress and has resolved or is addressing a number of challenges associated with data assimilation and integration of HAB information throughout the Gulf of Mexico. For example, the HABSOS Case Study Working Group:

- Minimized political and economic barriers to data acquisition and sharing
- Strengthened, formalized and expanded the HAB network throughout the Gulf of Mexico including the Mexican Gulf States
- Created a regional HAB information center (RIC)

- Created a virtual ArcIMS application with customized functions for spatial and temporal analysis and monitoring
- Created a common online data entry tool/database to enhance flow of HAB data streams
- Collaborated with and leveraged other similar biological databases (SIMS, GMNET) for cost-effective use of capabilities and resources
- Created a prototype operational HABSOS ArcIMS application with near real-time capabilities

A critical function of the HABSOS Case Study was to provide momentum for the design, costing and development of the operational or near real-time HABSOS application. This purpose is being fulfilled and the design and development of the operational HABSOS are well underway.

Objective 4 – Assess the Essential Data Requirements for 2-3 Day Forecasting

Process/Approach: A prominent rationale for selecting a Case Study to initiate the HABSOS Pilot Project was the opportunity to examine state and regional data collected during bloom and non-bloom years to determine whether these measurements, when combined, could have been used to forecast bloom events in the 2-3 day time frame identified by the user group. Moreover, analyses could be conducted to determine which data were most influential and which were relatively superfluous to forecasting. This was to be determined through iterative examination of events with specific data sets excluded from consideration. Three years were selected for the Case Study; 1996 (bloom events across all 5 states), 1997 (only minor blooms, but states were still collecting data in response to previous bloom activity), and 2000 (moderate bloom activity across the Gulf). The year 2000, when SeaWiFs data were first available for analysis of chlorophyll a, was included partly to examine the potential benefits of satellite coverage for tracking *K. brevis* blooms. The Case Study was to aggregate regional and state data collected during these years for retrospective comparison of bloom and non-bloom environmental conditions.

Achievement of this objective required collection, compilation and integration of state and regional data across the three years, coupled with the development of tools to retrospectively track the events and analyze the relevance of each data set. Certain aspects of this approach have been previously addressed, *i.e.*, the collection, compilation and integration of state and regional data (Sections III and IV). Remaining aspects of this objective involved the description and characterization of bloom events that occurred during those years, development of tracking and forecasting tools, and analysis of the available data to determine whether events could have been forecast with existing information.

Findings - Description and Characterization of Events: Case Study group members from each of the five Gulf States collected and compiled data and information surrounding each of the events across the Gulf during 1996, 1997 and 2000. Their findings were distributed to all Case Study members for examination and are summarized in Appendix I.

Findings - Development of Tracking and Forecasting Tools: Significant progress was made in the development of Arc/IMS technology for tracking bloom events (described in Section IV). This tool was used to integrate state-collected event data to establish a retrospective trajectory of different events. Examples of this capability are shown for the 1996 events in NW Florida, Alabama, Mississippi and Louisiana (Figure '96 trajectory) and 2000 bloom in Texas (Figure '00TX trajectory). The maps produced by NCDDC provided a unique tool to visualize the displacement of the blooms along the coast. If maps such as these were available on real time, it is possible to estimate, with a high degree of accuracy, the surface displacement of the blooms from day to day with only information on the wind vectors for all the three years examined. The SeaWiFS images compiled by NOAA were highly useful in tracking the red tide blooms and their displacement along the coast after the blooms were identified by in situ collections. SeaWiFS is not a good predictor of red tides because it is unable to distinguish between high concentrations of phytoplankton and high concentrations of sediment. This is especially true in the waters off the Texas-Louisiana coast. The AVHRR satellite imagery is not very useful in tracking and/or forecasting the occurrence of red tide events because there is no guarantee that the color fronts and thermal fronts coincide in the coastal waters. In addition, the thermal data from satellites is subject to the effects of surface heating in the summer months. Examination of the environmental factors during these months is crucial in determining whether the conditions are propitious for the development of a red tide bloom.

With the limited data available for this study, development of a forecasting system was not possible. However, tracking of the red tide fronts could be achieved with a combination of in situ measurements, SeaWiFS imagery and wind vectors. In particular, the ability to forecast the genesis and movement of existing blooms would presumably require reasonable knowledge of wind vectors, currents, ancillary environmental data that has not yet been incorporated with state-generated data at the appropriate space and time scales.

Findings - Comparative Analysis of Data*:* Comparison and iterative examination of data sets could not be performed due to the inability to incorporate regional environmental data and the lack of a model to examine the data. Nonetheless, the Case Study exercise answered the most fundamental question of this objective; currently, the ability to assimilate and apply environmental data into a 2-3 day forecast of *K. brevis* events does not exist. The inability to incorporate regional environmental data affected this process at a very basic level. Any hypothetical model to forecast the movement of an existing bloom must include some information on wind and water currents, and some consideration of temperature and salinity in areas of potential movement.

Summary: The ultimate purpose of the HABSOS Pilot Project is to provide information and insight to requirements for a harmful algal bloom forecasting system. It was never an objective to predict algal blooms *de novo*, but rather to forecast movement and/or expansion of existing blooms. In early HABSOS workshops, resource managers from the 5 Gulf States indicated that a 2-3 day forecast was the most useful time frame. A simple forecasting scenario includes identification of a bloom, characterization of its severity, and recognition and documentation of environmental factors that cause expansion or movement of the bloom.

Identification and Characterization of a Bloom. Currently, most blooms are identified by reported observations of fish kills. The ability to first detect blooms using SEAWiFs satellite data is limited by time delays, cloud covers, and the insensitivity of satellite receptors to chlorophyll a at less than 50,000 cells/L. High chlorophyll registered in satellite images must be confirmed by cell counts. Cell counts are also a means to detect blooms when counts are higher than 'normal', but baseline values across the Gulf are not well-documented. Cell counts are essential to characterize the severity of a bloom. Once *K. brevis* is validated as the source of high chlorophyll readings, satellite images might be used to track growth.

Recognition and Documentation of Factors that Cause Bloom Expansion or Movement. Little is known of the environmental conditions that facilitate bloom growth, so incorporation of such conditions into a forecast is unlikely. However, known salinity and temperature tolerances might be used to forecast areas where a bloom would not expand. Potential movement of a bloom is expected to rely on wind and water current directions and speed. However, movement and expansion of blooms at different depths could confound the forecast model.

Contributions of the Case Study. Technical deficiencies disallowed data comparisons and the iterative testing scenario proposed for the Case Study. Nonetheless, attempts to complete this analysis provided several contributions toward the overall purpose of HABSOS. A primary achievement was the development of Arc/IMS tools to retrospectively characterize the trajectories of algal blooms. A primary finding was the lack of technical capacity to integrate regional environmental data with those trajectories. This deficiency limited the potential to develop a forecast model and examine iterative data sets. These, and other challenges, were identified by the process as described below.

<u>Challenges</u>:

- Identification and characterization of blooms requires greater cell count coverage and continuity.
- Integration of data requires some means to import real-time data in spatial and temporal scales appropriate for a model or for consideration by resource managers.
- Forecasting or estimation of future locations of red tide blooms, requires a long-term environmental data that can be examined for (1) natural trends and oscillations (2) abnormal trends that can be linked to red tide occurrences. These trends must then be quantified with a physics or mathematical based approach. Linear and non-linear relationships must be identified among the various environmental parameters and the red tide occurrences at different times and depths in order to understand the genesis of the processes. The most relevant parameters can then be used as inputs to a new environmental model that links the occurrences to the environment.
- Large oceanographic and atmospheric models such as those developed by the Naval Research Laboratory (NRL) and NOAA could be used to examine trends in parameters such as salinity, temperature, Sea Surface Height (SSH), transport, and wind stress during a red tide bloom. Estimations of probable occurrences can be made from these models.
- Anticipating the expansion of an existing bloom requires better knowledge of the environmental factors that affect blooms on real time.

Objective 5 – Assess Current Infrastructure Limitations and Needs for Capacity Building

While the Case Study effort was focused on assessing the strengths and weaknesses of a regional HAB observing system, the process revealed insight into current limitations in infrastructure and capacity to sustain regional integration. We found several critical limitations to developing a sustained regional HAB observing system, including:

- *<u>Non-Standardized Support for HAB Enumeration</u>* - Florida and Alabama are the only states that had state personnel dedicated to HAB enumeration. While the remaining states were all able to obtain high quality HAB enumeration from academic institutions in their respective states, this often resulted in long time delays in obtaining results, particularly during non-bloom events.

- *<u>Dependence on Individuals Rather Than Programs</u>* – In the short period of our study, we had turnover in the leadership in three of our five states as a result of the departures of Quay Dortch, Cynthia Moncreiff and Jonathan Pennock from their academic positions in Louisiana, Mississippi and Alabama, respectively. Long-term success of regional integration will require that these efforts be institutionalized at some level within each state. It is likely that federal support will be required to achieve this, at least for the foreseeable future.

- *Insecure Funding for Data Integration Efforts* – Despite our clear successes in developing a prototype data management and visualization system through the efforts of the NCDDC, the dependence of NCDDC on 'soft money' and contract employees limits long-term continuity in the regional program.

- *Lack of Support to Maintain Continuous Input of New Data* – After significant effort to pull together regional HAB data sets for 1996, 1997 and 2000, it is disturbing that there is not support for a continuing effort to add current and near real-time data to the HABSOS database. This is a result of several factors, including each of the issues mentioned above.

- *Lack of Clarity in the Overall Role(s) of a Regional HAB Observing System* – From the onset of the HABSOS effort, there were somewhat contradictory views of what the role(s) of a regional HAB observing system should be. Early on, the focus of academic researchers on the big issues of why blooms occur in certain places at certain times and a long-term desire for predictability, were superceded by the desire and need to address 'user needs', primarily those of the management community who primarily required short-term (2-3 day) information to insure that they are able to protect the public from HAB events. While these views are not mutually exclusive, the end result was a focus on data, data integration and visualization processes that provide the short-term information for management. These efforts are insufficient to be able to build and test predictive models without more robust data and data management tools. As a result, longer-term efforts to advance the prediction of HAB blooms will be slow to develop until a focused effort on these broader data needs are incorporated into the HABSOS model.

IV. Conclusions & Recommendations

Overall, the Case Study established that the development of a regional HAB Observing System is possible and that such a system has the potential to benefit regional management and basic research needs. The Case Study also identified a number of obstacles and challenges that must be addressed before a HAB Observing System can become fully developed and functional. These include:

Lack of Clarity in the Overall Role(s) of a Regional HAB Observing System – From the onset of the HABSOS effort, there have been somewhat contradictory views of what the role(s) of a regional HAB observing system are. Early on, the focus of academic researchers was on the big issues of why blooms occur in certain places at certain times and a long-term desire for predictability. Through initial HABSOS efforts, there was consensus that 'user needs', primarily those of the management community who primarily want to have information that will insure that they meet their management goal of protecting the public from HAB events, are a core priority for any observing system effort. While these views are not mutually exclusive, the end result of focusing on the needs of the 'user community' was that we focused on a limited number of parameters (e.g. cell counts, temperature, salinity, etc…) that provide the ability to track blooms in over the 'short-term', at the expense of information that will ultimately be needed to develop, test and implement predictive models. Without such 'longer-term' efforts, significant advancements in HAB prediction and understanding will be slow to develop.

Lack of Support to Maintain Continuous Input of New Cell Count Data – After significant effort to pull together regional HAB data sets for 1996, 1997 and 2000, it is disturbing that there is not support for a continuing effort to add current and near real-time data to the HABSOS database. A common problem encountered was the lack of dedicated funding for regular monitoring and database maintenance.

Currently, only Florida has a commitment to a regular program for sampling and database maintenance. Alabama currently maintains a regular, state-based monitoring and enumeration laboratory; however, without the HABSOS Case Study support these data would not have been available for an integrated regional effort. Mississippi and Louisiana were both significantly dependent on academic laboratories for monitoring, enumeration and database maintenance (notably, the departure of key faculty members in these states have disrupted these efforts). Finally, Texas was the only state besides Florida that had an ongoing program that was able to rapidly provide information to the Case Study, however, long-term support for these efforts is lacking. Long-term success of regional integration will require that these efforts be institutionalized and funded at some level within each state. It is likely that federal support will be required to achieve this, at least for the foreseeable future.

Insecure Funding for Data Integration Efforts – A primary obstacle to the study of regional environmental phenomena was the difficulty in identifying, recovering and integrating relevant but disparate data into a useful format for display and analysis. Despite our clear successes in developing a prototype data management and visualization system through the efforts of the NCDDC, the dependence of NCDDC on 'soft money' and contract employees limits long-term continuity in the regional program. Data assimilation and integration are time-consuming and generally underappreciated tasks. There are presently few state databases and no common Gulf-wide efforts to coordinate these important data sets.

Geospatial Data Integration and Visualization – The ability to visualize the spatial characteristics and dynamics of a bloom is critical and the geographical information system (GIS) approach is ideal. We developed an ArcIMS application for the HABSOS Case Study. Although Internet technology and capabilities are progressing rapidly, present applications such as ESRI's ArcIMS, require considerable customization to move beyond the basic map service.

HAB Forecasting Capabilities – A key question for the Case Study was do we have the ability to track and ultimately forecast the dynamics of HAB blooms over space and time? While we found that state natural resource managers and public health officials have a need to know where the blooms are going and when they can be expected to reach areas where they will have detrimental impacts with a 2-3 day notice, we currently do not have the data and understanding necessary to model bloom movements as a result of insufficient data or, at the very least, a limited capacity to organize and assimilate regional environmental data and the lack of a model to examine the data. Thus, for the periods analyzed for the Case Study and the present, we do not have the capacity of provide a 2-3 day forecast of *K. brevis* events in the Gulf of Mexico. While SeaWiFS data have enhanced our capacity to flag potential bloom events on the west coast of Florida, these techniques are of only limited use in the northern and western Gulf and lack the resolution to identify blooms at the lower levels of current action criteria (i.e. 5000 cells/L).

Dependence on Individuals Rather Than Programs – In the short period of our study, we had turnover in the leadership in three of our five states as a result of the departures of Quay Dortch, Cynthia Moncreiff and Jonathan Pennock from their academic positions in Louisiana, Mississippi and Alabama, respectively. Long-term success of regional integration will require that these efforts be institutionalized at some level within each state. It is likely that federal support will be required to achieve this, at least for the foreseeable future.

To achieve the realization of an operational HAB Observing System, the limitations identified above must be addressed and the vision for our Coastal Ocean Observation System must continue to include a broad combination of methods and technologies and integrate a backbone of new observational sensors with established techniques (e.g. cell counts) that remain at the core of existing management criteria.

Appendix I - Event Overviews

HABSOS Report for 1996 Southwest Florida Coast Red Tide Event

Prepared by:
Merrie Beth Neely, Karen A. Steidinger, Earnest Truby, and Beverly Roberts

1. **What triggered the first alert?** The 1996 Southwest Florida Coast event response was first triggered by *Karenia brevis* counts above background levels noted from live and preserved samples taken as part of ongoing red tide monitoring efforts by local and state agencies and universities (ECOHAB:Florida).

2. **What was the state's event response strategy?** The state event response strategy for this, and every, event was to first verify the species of the bloom organism as *Karenia brevis*, to identify shellfish harvesting beds potentially impacted by the event and close harvesting if warranted, to conduct routine sampling in the area (cell counts in water samples), and define the boundaries of the affected coastline. Later, as part of a Biotoxin Control Plan, shellfish meats are tested for toxicity by mouse bioassay.

3. **What was the chronology of the event (temporal and spatial)?** Cell counts above background level (>1000 cells l^{-1}) were found throughout the Southwest Florida coastline in every month of 1996. The peak red tide occurred spatially between Tarpon Springs and the Keys from February through May of 1996. Peak cell counts, in excess of 1 million cells l^{-1}, were found nearshore in Sarasota between February and May, 1996; at the mouth of Estero Bay between February and April, 1996; and in Florida Bay/lower Keys in February, March and June, 1996. The highest recorded cell counts for this event (up to 197 million cells l^{-1}) were near Sarasota throughout February.

4. **What type of data was collected? What were the inadequacies of the data for monitoring the existing bloom and/or for forecasting the track of the event?** Florida has a widespread red tide sampling network including personnel from various universities, state and local agencies, as well as citizen volunteers. *Karenia brevis* cell counts were taken from live and preserved whole water samples along with location (latitude and longitude), station name, date, comments and name of the collection personnel/agency. Cell count results were available the same day or the next day after FMRI personnel received samples. In some instances, standard hydrographic measurements were taken at stations via CTD, Hydrolab or refractometer/thermometer. When cell counts exceeded 5000 cells l^{-1}, at passes or closer to beds, shellfish harvesting was prohibited. As the red tide appeared to dissipate, shellfish meats from harvesting areas were collected for mouse bioassay tests, with results available within a few days of collection. Inadequacies in the data include a recurrent and profound lack of bottom samples, as well as incomplete or missing hydrographic data measurements for some field samples. In addition, offshore sampling is by ship of opportunity, which limits the spatial and temporal coverage of Florida's Gulf of Mexico and Atlantic coastlines. Lack of bottom and offshore samples can restrict the forecasting and track of blooms both along the coastline and as they proceed toward shore. The time required to complete the testing to reopen shellfish harvesting is an ongoing concern and the State has financially supported the pursuit of an alternative chemical assay.

Range: 24.4333 to 28.0642 Latitude; -80.1333 to -83.0741 Longitude

HABSOS Report for 1996 Florida Panhandle Red Tide Event

Prepared by:
Merrie Beth Neely, Karen A. Steidinger, Earnest Truby, and Beverly Roberts

1. **What triggered the first alert?** The 1996 Panhandle event responses were first triggered by reports of fish kills, primarily baitfish, menhaden and mullet.

2. **What was the state's event response strategy?** The state event response strategy for this and every event, was to first verify the species of the bloom organism as *Karenia brevis*, to identify shellfish harvesting beds potentially impacted by the event and close harvesting if warranted, to conduct routine sampling in the area (cell counts in water samples), and define the boundaries of the affected coastline. Later, as part of a Biotoxin Control Plan, shellfish meats are tested for toxicity by mouse bioassay.

3. **What was the chronology of the event (temporal and spatial)?** There were actually two separate events in the panhandle region in 1996, one from the end of May to the end of June and another one from the end of October to mid-November. Both events were centered around the region from St. Joe Bay to Ochlockonee Bay, with highest cell counts in St. Joe Bay, Apalachicola Bay, south of Alligator Point and off Piney Island. The Fall red tide involved only high cell counts from south of St. George Island and inside St. Joe Bay. Cell counts did not exceed 1 millions cells 1^{-1} for either event.

4. **What type of data was collected? What were the inadequacies of the data for monitoring the existing bloom and/or for forecasting the track of the event?** Florida has a widespread red tide sampling network including personnel from various universities, state and local agencies, as well as citizen volunteers. *Karenia brevis* cell counts were taken from live and preserved whole water samples along with location (latitude and longitude), station name, date, comments and name of the collection personnel/agency. Cell count results were available the same day or the next day after FMRI personnel received samples. In some instances, standard hydrographic measurements were taken at stations via CTD, Hydrolab or refractometer/thermometer. When cell counts exceeded 5000 cells 1^{-1}, shellfish harvesting was prohibited. As the red tide appeared to dissipate shellfish meats from harvesting areas were collected for mouse bioassay tests, with results available within a few days of collection. Inadequacies in the data include a recurrent and profound lack of bottom samples, as well as incomplete or missing hydrographic data measurements for some field samples. In addition offshore sampling is by ship of opportunity, which limits the spatial and temporal coverage of Florida's Gulf of Mexico and Atlantic coastlines. Lack of bottom and offshore samples can restrict the forecasting and track of blooms both along the coastline and as they proceed toward shore. The time required to complete the testing to reopen shellfish harvesting is an ongoing concern and the State has financially supported the pursuit of an alternative chemical assay.

April – June Range: 29.2615 to 29.9969 Latitude; -83.6679 to -84.3083 Longitude

October/November Range: 29.2615 to 29.8585 Latitude; -83.6679 to -85.4947 Longitude

Northern Gulf of Mexico (AL, MS, LA) Fall, 1996

Prepared by:
Cynthia Moncreiff, Quay Dortch & Jonathan Pennock

1. **What triggered the first alert?** The first alerts in Alabama and Louisiana were telephone calls from individuals in regulatory and monitoring agencies in neighboring states. Karen Steidinger in Florida called William Smith in Alabama and Corkey Perrett in Mississippi called Kenneth W. Hemphill in Louisiana. In Mississippi scientists at the University of Southern Mississippi's Gulf Coast Research Laboratory (GCRL) were alerted by a charter boat operator who reported unusual behavior of a school of redfish and collected a water sample. The redfish were avoiding carefully prepared bait and lures, gorging on nearly-dead anchovies; the water sample was full of *Karenia brevis* (Moncreiff 1998).

2. **What was the State's event response strategy?** *Alabama.* The Alabama State Health Department (ADPH), which was the only agency collecting plankton samples at that time, began to collect samples along the gulf beaches, which were not ordinarily monitored, in addition to the shellfish growing areas. When *Karenia* cells began to appear in Alabama waters, there was a cooperative effort by the ADPH, the Alabama Department of Conservation, Alabama Department of Environmental Management, and Auburn University to increase sampling along the beaches and sounds, and within Mobile Bay.

   Mississippi. Following a coordinated GCRL sampling event in late October 1996 that involved aerial reconnaissance of the extent of the bloom and sampling by boat of the bloom in the vicinity of the northwest shore of Horn Island, MS, Department of Marine Resources (DMR) employees began collecting water samples for *K. brevis* counts in conjunction with routine sampling of oyster growing areas for fecal colliform levels. Sampling began on Nov. 1, 1996. Oyster growing waters were closed immediately once exposure to cell counts over 5,000 cells per liter was determined. Oysters harvested from exposed waters on the closure date were recalled from harvesters and processing facilities and returned to the reefs from which they were harvested to depurate. Sampling continued daily and then every two to three days once cell counts returned to zero. Waters were then monitored on a weekly basis for the presence or absence of *K. brevis*; this effort has continued to date prior to and during months in which oysters are actively harvested. Oyster tissues were harvested and prepared for use in mouse bioassays weekly beginning two weeks after exposure; this continued until reefs could be reopened (Moncreiff, 1998).

   Louisiana. The first sample from Louisiana waters with *K. brevis* was collected by the Mississippi DMR. Starting the next day, Nov. 11, 1996, the Louisiana Department of Health and Hospitals began sampling at frequent intervals at selected stations in oyster-growing areas east of the Mississippi River; samples were analyzed for *K. brevis* abundance at Louisiana Universities Marine Consortium. West of the Mississippi River, samples for *K. brevis* abundance were obtained as part of other research programs. The Louisiana Department of Wildlife and Fisheries investigated mortality events that were possibly related to the presence of *K. brevis*.

3. **What was the chronology of the events (spatial and temporal)?** *K. brevis* moved from east to west along the northern Gulf over the course of a month (Table 1). The highest abundance occurred east of the mouth of the Mississippi River, although *K. brevis* was also detected at low levels to the west of the River in Louisiana coastal waters.

Table 1. Dates of occurrence of *K. brevis* in the water and oyster bed closures. Adapted from Dortch et al. 1998.

State	Present in Water	Oyster Beds Closed
Florida panhandle	10/16/96 to 11/20/96	
Alabama	10/23/96 to 12/6/96	11/10/96 to 12/6/96
Mississippi	11/1/96 to 12/11/96	11/2/96 to 2/26/97[a]
Louisiana	11/10/96 to 12/17/96	11/13/96 to 4/1/97[b]

[a]Some areas closed 11/07/96; some opened 12/10/96 and 2/25/97
[b]Some areas opened 2/28/97

4. **What type of data was collected? What were the inadequacies of the data for monitoring the existing bloom and/or for forecasting the track of the event?** The data from all three states consist of cell counts of *K. brevis*, latitude and longitude of sampling locations, salinity, and temperature. All samples were surface grab samples. Some data on weather and tides are also available. Some data for other HAB organisms are also available for some stations. The data were available within 1-5 days of sample collection.

   The data were generally adequate for monitoring the existing bloom in that no incidents of human illness occurred. This event, however, highlighted inadequacies that have not yet been solved. Improvements in cell counting technology are needed to speed up counts and improve the limits of detection. The 5000 cells/liter regulatory cut off is very near the limits of detection of standard counting methods, especially in highly turbid waters with high total phytoplankton abundance. To achieve lower limits of detection required more time for counting, slowing the timely reporting of cell count data.

   Since this was the first known *K. brevis* outbreak in the northern Gulf of Mexico, it would not have been possible to predict the event. Analysis of data collected during the bloom suggests that it was an unusual combination of a large bloom in the Florida panhandle and a transport event during the period from Sept. 26 to Oct. 10, 1996 when surface drifters (Niiler, personal communication) moved rapidly from east to west. There are insufficient data to rule out alternate hypotheses, such as transport from offshore, because there was no sampling at all prior to the bloom and insufficient coastal sampling at any time. Although low levels of monitoring are now conducted in all states, there is heightened concern when blooms of *K. brevis* occur along the Florida panhandle.

1996 Texas HAB Event Report

Prepared by:
Tracy Villareal and James Simons

1. **What triggered the first alert? (i.e., fish kill, discolored water)** Dead fish reported on Mustang Island on 11 September 1996 is apparently the trigger event for the 1996 Texas red tide event. There are no reports of red tide before this fish kill was reported.

2. **What was the State's event response strategy?** The State response to the red tide included an alert of the Texas Department of Health (TDH), who began response efforts to collect water samples and conduct cell counts on those samples. Texas Parks and Wildlife Department's Coastal Fisheries and Resource Protection Divisions responded to the red tide also. The CF Division conducted fish kill surveys, which included counts and estimates of dead fish and assisted in the collection of water samples for cell count analysis. The RP Division assisted in collection of water samples for cell count analysis, conducted aerial reconnaissance flights to locate and track the bloom and conducted ground surveys for red tide and dead fish.

   TDH initiated cell counts near oyster harvesting areas in order to determine if shellfish harvesting should be allowed or prohibited. TDH issued health advisories as appropriate regulating the collection of shellfish commercially or recreationally for human consumption. In areas where shellfish were exposed to red tide, TDH monitored shellfish toxicity until shellfish were no long toxic or the shellfish harvesting season had closed.

   TPWD monitored fish mortality in order to determine impacts to fish populations and evaluate possible fisheries management implications of the red tide. For example, in the 1996 red tide, a large number of spawning red drum were killed and as a result juvenile red drum were stocked more intensively in the bay systems affected.

   TPWD monitored locations of dead fish and locations of visible bloom in order to determine where red tide was located and predict where it might go. This information was also provided to the public. Information was made available on the TPWD's toll-free phone line about where red tide and fish impacts were occurring in order to help members of the public make informed decisions about their plans involving travel to the coast. Information on the toll-free phone line was updated daily during the most intense periods of red tide.

3. **What was the chronology of the events (spatial and temporal)?** The first reported coverage of the red tide indicated that it was present mainly the Gulf of Mexico off of Port Aransas, from south of Corpus Christi Bay to Aransas Bay. This was the extent reported on 16 September 1996. From reports on the 19th and 25th of September, the red tide appeared to be dissipating, and was still located mostly in the Gulf of Mexico, almost up to Matagorda Bay on the 19th. On 1 October, the red tide bloomed again, generally occurring in the Gulf of Mexico from Pass Cavallo to the south end of Corpus Christi Bay, with red tide also found in Aransas Bay. By 7 October, the bloom has shifted into the bays (Corpus Christi, Aransas, Redfish and San Antonio) and one small patch was seen at Port Isabel at the south end of Lower Laguna Madre. By 21 October, the red tide was dissipating with only small patches in Espiritu Santos and Corpus Christi Bays. By 1 November the red tide was no longer found along the Texas coast.

4. **Data: What (type of) data was collected? What were the inadequacies of the data for monitoring the existing bloom and/or for forecasting the track of the event?** Data collected during the red tide included: lat/long of water samples (TDH), cell counts (TDH), salinity (TDH), aerial surveys (TPWD), ground surveys (TPWD,) and dead fish counts (TPWD). A total of 228 cell counts were conducted, of which 94 had detectable cells (range: 900-23,667,000). The mean cell count for samples with cells was 1,423,935 cells per liter (SD=3,465,710). Cell counts with detectable cells were conducted in the following bays: Aransas (13), Corpus Christi (15), Espiritu Santo (10), Lavaca (7), Matagorda (20), Redfish (1), San Antonio (19) and in the Gulf of Mexico (6). On a monthly basis, cell counts were conducted from September through December, with

detectable cells recorded in all months but December The highest mean cell count for any month was in September (mean=3,557,336, SD=5,220,007) and the lowest was in November (mean=83,529, SD=219,227). An estimated 3.0 million fish were killed during the red tide event. Species of concern that were killed in the greatest numbers included: Atlantic croaker (28,000/0.93%), spotted seatrout (13,500/0.45%), and red drum (12,300/0.41%). The species with the greatest number included: Atlantic threadfin herring (686,200/22.9%), Gulf menhaden (681,800/22.7%), and striped mullet (563,300/18.8%).

It appears that the red tide event was tracked well, but the level of effort, except for the number of cell counts conducted, is difficult to ascertain. Records indicate that six aerial surveys were conducted, but the aerial extent of the surveys is not indicated. Aerial surveys allow more of the coast and nearby waters to be quickly observed with two or three people than could be done by crews on land and water. However aerial surveys have limitations. Surveys do not reveal areas where blooms are below the surface of the water as sometimes is the case with *Karenia brevis* blooms. Rough water may spread the cells throughout more of the water column further reducing their detection. Blooms may be difficult to detect when turbidity levels are high in bay and nearshore Gulf waters. Information on the nutrients and circulation, both the near shore Gulf of Mexico, bays and passes would be valuable information toward developing predictive models for red tide bloom formation and movement.

1997 Texas HAB Event Report

Prepared by:
Tracy Villareal and James Simons

1. **What triggered the first alert? (i.e., fish kill, discolored water)** Cell counts with detectable cells indicating a bloom were first reported from water samples collected from Espiritu Santo Bay on 18 September 1997, which apparently triggered the response to the 1997 red tide in Texas.

2. **What was the State's event response strategy?** The State's response included systematic sampling for salinity and water samples to do cell counts by TDH, aerial and ground surveys to track the extent and movement of the red tide, and dead fish counts were conducted by RP Division, and assistance with dead fish surveys and collection of water samples was conducted by CF Division.

   TDH initiated cell counts near oyster harvesting areas in order to determine if shellfish harvesting should be allowed or prohibited. TDH issued health advisories as appropriate regulating the collection of shellfish commercially or recreationally for human consumption. In areas where shellfish were exposed to red tide, TDH monitored shellfish toxicity until shellfish were no long toxic or the shellfish harvesting season had closed.

   TPWD monitored fish mortality in order to determine impacts to fish populations and evaluate possible fisheries management implications of the red tide.

   TPWD monitored locations of dead fish and locations of visible bloom in order to determine where red tide was located and predict where it might go. This information was also provided to the public. Information was made available on the TPWD's toll-free phone line about where red tide and fish impacts were occurring in order to help members of the public make informed decisions about their plans involving travel to the coast. Information on the toll-free phone line and on the web page was updated daily during the most intense periods of red tide.

3. **What was the chronology of the events (spatial and temporal)?** The first cell count samples to indicate a bloom were taken from Espiritu Santo Bay on 18 September 1997. Several more samples collected up until the 29th of September also indicated red tide. Then on 29 September a large bloom was reported in the Gulf of Mexico in south Texas, from Boco Chica Beach, along South Padre Island, Padre Island National Seashore, to about 35 miles north of the Port Mansfield jetties. In addition, red tide was reported along the Mexican coast south of the Texas border off of Tamaulipas, for about 60 miles. On 1 October the red tide was found in the Gulf of Mexico from Port Aransas down to 60 miles south of the Texas-Mexican border and also into the Lower Laguna Madre. By 3 October, the red tide was in much the same location, with additional red tide found at Brazos Santiago Pass and inside the Port Mansfield jetties. Reports on 6, 7, 8 and 10 October did not reveal any major changes in location of the bloom, although the red tide was now five miles up into Lower Laguna Madre and at San Martin Lake. On 14 October, the red tide was still in south Texas, with reports of it located in Port Isabel Shrimp Boat Basin. By 17 October it was reported that the presence of red tide aerosol had greatly decreased, although exact areas were not reported. On 22 October no red tide was reported from Port Aransas to the mouth of the Rio Grande River. On 7 November there was a suspected red tide reported 10 miles north of Brazos Santiago Pass. Then on 24 November red tide was reported in Corpus Christi Bay, and continued to be reported there on both 25 November and 2 December. The last report of cell counts on 8 December had positive numbers of red tide cells in Corpus Christi Bay and Redfish Bay.

4. **Data: What (type of) data was collected? What were the inadequacies of the data for monitoring the existing bloom and/or for forecasting the track of the event?** Data collected included: lat/long of water samples (TDH), water samples for cell count data (TDH, CF-TPWD), salinity (TDH), aerial over flight observations (RP-TPWD), dead fish counts (RC and CF-TPWD). A total of 75 water samples were collected for cell count analysis, of which 22 had positive counts (range: 5,600-26,667,000). The mean cell count at sites

with detectable cells was 1,465,908 cells per liter (SD=5,396,299). Samples with detectable cell counts were located in the following bays: Aransas (2), Corpus Christi (7), Espiritu Santo (3), Matagorda (3), Redfish (4) and the Gulf of Mexico (3). Corpus Christi Bay had the highest mean cell counts (mean=4,436,714, SD=9,811,069), followed by Redfish Bay (mean=831,250, SD=1,017,244). On a monthly basis cell counts were conducted from September through December, with all months having detectable cell counts except November, and there was only one detectable cell count in October. The highest mean monthly cell count occurred in December (mean=2,669,692, SD=7,237,839), followed by September (mean=43,363, SD=57,258). Fish kill counts and estimates from CF-TPWD put the total estimated number of fish killed at about 19.4 million. Fish reported to dominate the fish kills included: Atlantic bumper, menhaden, scaled sardine, striped mullet and bay anchovy.

It appears that the red tide event was tracked well, but the level of effort, except for the number of cell counts conducted, is not available. Records indicate that six aerial surveys were conducted, but the aerial extent of the surveys is not indicated. Aerial surveys allow more of the coast and nearby waters to be quickly observed with two or three people than could be done by crews on land and water. However aerial surveys have limitations. Surveys do not reveal areas where blooms are below the surface of the water as sometimes is the case with *Karenia brevis* blooms. Rough water may spread the cells throughout more of the water column further reducing their detection. Blooms may be difficult to detect when turbidity levels are high in bay and nearshore Gulf waters. Information on the nutrients and circulation, both the near shore Gulf of Mexico, bays and passes would be valuable information toward developing predictive models for red tide bloom formation and movement.

HABSOS Report for 2000 Southwest Florida Coast Red Tide Event

Prepared by:
Merrie Beth Neely, Karen A. Steidinger, Earnest Truby, and Beverly Roberts

1. **What triggered the first alert?** The 2000 Southwest Florida Coast event response was first triggered by *Karenia brevis* counts above background levels noted from live and preserved samples taken as part of ongoing red tide monitoring efforts by local and state agencies and universities (ECOHAB:Florida).

2. **What was the state's event response strategy?** The state event response strategy for this and every event, was to first verify the species of the bloom organism as *Karenia brevis*, to identify shellfish harvesting beds potentially impacted by the event and close harvesting if warranted, to conduct routine sampling in the area (cell counts in water samples), and define the boundaries of the affected coastline. Later, as part of a Biotoxin Control Plan, shellfish meats are tested for toxicity by mouse bioassay.

3. **What was the chronology of the event (temporal and spatial)?** This event persisted from mid-September through mid-November 2000 and was most intense between September 24 and October 19. The highest cell counts were recorded between October 4 and 6, 2000. Spatially, two peaks in the red tide were found off the southwest Florida coast during this time period. The red tide was centered offshore west of St. Petersburg extending northward to about 30 miles offshore of Tarpon Springs and southward to the mouth of Tampa Bay. The southern peak in the red tide region was centered off Boca Grande to about 50 miles offshore and extending southward along shore to Naples. Although spatially disjunct, temporally the peaks in cell counts co-occurred during the first week in October. Cell counts higher than background levels (>1000 cells 1^{-1}) were recorded longitudinally from about 30 miles NW of Key West to Tarpon Springs and extended latitudinally from onshore to more than 50 miles offshore throughout Southwest Florida from mid-September through mid-November, 2000.

4. **What type of data was collected? What were the inadequacies of the data for monitoring the existing bloom and/or for forecasting the track of the event?** Florida has a widespread red tide sampling network including personnel from various universities, state and local agencies, as well as citizen volunteers. *Karenia brevis* cell counts were taken from live and preserved whole water samples along with location (latitude and longitude), station name, date, comments and name of the collection personnel/agency. Cell count results were available the same day or the next day after FMRI personnel received samples. In some instances, standard hydrographic measurements were taken at stations via CTD, Hydrolab or refractometer/thermometer. When cell counts exceeded 5000 cells/liter, shellfish harvesting was prohibited and shellfish meats from harvesting areas were collected for mouse bioassay tests, with results available within a few days of collection. Inadequacies in the data include a recurrent and profound lack of bottom samples, as well as incomplete or missing hydrographic data measurements for some field samples. In addition, offshore sampling is by ship of opportunity, which limits the spatial and temporal coverage of Florida's Gulf of Mexico and Atlantic coastlines. Lack of bottom and offshore samples can restrict the forecasting and track of blooms both along the coastline and as they proceed toward shore. The time required to complete the testing to reopen shellfish harvesting is an ongoing concern and the State has financially supported the pursuit of an alternative chemical assay.

Range: 24.8333 to 28.0698 Latitude; -81.8233 to -83.4202 Longitude

HABSOS Report for 2000 Florida Panhandle Red Tide Event

Prepared by:
Merrie Beth Neely, Karen A. Steidinger, Earnest Truby, and Beverly Roberts

1. **What triggered the first alert?** The 2000 Panhandle event response was first triggered by *Karenia brevis* counts above background levels noted from live and preserved samples taken as part of ongoing red tide monitoring efforts in shellfish harvesting waters by the Florida Department of Agriculture.

2. **What was the state's event response strategy?** The state event response strategy for this, and every, event was to first verify the species of the bloom organism as *Karenia brevis*, to identify shellfish harvesting beds potentially impacted by the event and close harvesting if warranted, to conduct routine sampling in the area (cell counts in water samples), and define the boundaries of the affected coastline. Later, as part of a Biotoxin Control Plan, shellfish meats are tested for toxicity by mouse bioassay.

3. **What was the chronology of the event (temporal and spatial)?** This event was confined to the region within and near the mouth of St. Joe Bay from the end of August through early September. The highest cell count was 1.67 million cells 1^{-1}.

4. **What type of data was collected? What were the inadequacies of the data for monitoring the existing bloom and/or for forecasting the track of the event?** Florida has a widespread red tide sampling network including personnel from various universities, state and local agencies, as well as citizen volunteers. *Karenia brevis* cell counts were taken from live and preserved whole water samples along with location (latitude and longitude), station name, date, comments and name of the collection personnel/agency. Cell count results were available the same day or the next day after FMRI personnel received samples. In some instances, standard hydrographic measurements were taken at stations via CTD, Hydrolab or refractometer/thermometer. When cell counts exceeded 5000 cells 1^{-1}, shellfish harvesting was prohibited and shellfish meats from harvesting areas were collected for mouse bioassay tests, with results available within a few days of collection. Inadequacies in the data include a recurrent and profound lack of bottom samples, as well as incomplete or missing hydrographic data measurements for some field samples. In addition offshore sampling is by ship of opportunity, which limits the spatial and temporal coverage of Florida's Gulf of Mexico and Atlantic coastlines. Lack of bottom and offshore samples can restrict the forecasting and track of blooms both along the coastline and as they proceed toward shore. The time required to complete the testing to reopen shellfish harvesting is an ongoing concern and the State has financially supported the pursuit of an alternative chemical assay.

Range: 29.7713 to 29.9447 Latitude; -85.3050 to -85.4161 Longitude

2000 Coast-wide Texas HAB Event Report

Prepared by:
Tracy Villareal and James Simons

1. **What triggered the first alert? (i.e., fish kill, discolored water)** The trigger event for the response to this red tide event was a report by fishermen on 11 August of thousands of dead black drum in the Gulf of Mexico SSE of Sabine Pass.

2. **What was the State's event response strategy?** The State's response strategy to the event was to activate the HAB response effort. This included water sampling (TDH, TPWD, UTMSI), cell count analyses of the water samples by TDH and UTMSI, aerial and ground surveys by RP-TPWD to track the red tide, dead fish surveys and counts by both CF and RP-TPWD.

   TDH initiated cell counts near oyster harvesting areas in order to determine if shellfish harvesting should be allowed or prohibited. TDH issued health advisories as appropriate regulating the collection of shellfish commercially or recreationally for human consumption. In areas where shellfish were exposed to red tide, TDH monitored shellfish toxicity until shellfish were no longer toxic or the shellfish harvesting season had closed.

   TPWD monitored fish mortality in order to determine impacts to fish populations and evaluate possible fisheries management implications of the red tide.

   TPWD monitored locations of dead fish and locations of visible bloom in order to determine where red tide was located and predict where it might go. This information was also provided to the public. Information was made available o the TPWD's toll-free phone line about where red tide and fish impacts were occurring in order to help members of the public make informed decisions about their plans involving travel to the coast. This information was also made available on the TPWD red tide web page. Information on the toll-free phone line and on the web page was updated daily during the most intense periods of red tide.

   UTMSI, as part of an ongoing study of seasonal red tide dynamics, collected water samples in five near shore Gulf of Mexico regions (See Figure 1). These areas are sampled on a bi-monthly basis by the CF Division of TPWD as part of their fisheries independent monitoring program. UTMSI measured water temperature and salinity, conducted cell counts and analyzed the water samples for chlorophyll a, silica and nutrients (See Table 1).

   Assessments were made of the estimated distribution of red tides provided by NOAA's Rick Stumpf and Mary Culver based upon SeaWIFs satellite imagery to determine the utility of satellite imagery in locating red tides in Texas coastal waters.

3. **What was the chronology of the events (spatial and temporal)?** The bloom was first verified on 14 August from a TPWD overflight in the area reported by fishermen on 11 August. From 14 August until 30 September there were repeated observations of red tide in the Gulf of Mexico in the area of the San Bernard River, Surfside, Sargent Beach, Freeport and San Luis Pass. On 31 August red tide was first reported in Galveston Bay, where it continued to be reported through 18 September. On 18 September red tide was first reported in Matagorda Bay, then at Port O'Connor, San Jose Island and Cedar Bayou on 21 September. On 22 September the red tide was reported in Corpus Christi Bay, Mesquite Bay, Oso Bay, and the west end of Matagorda Bay. Reports from 26 September through 2 October still found the red tide to be in the area of Corpus Christi Bay, Redfish Bay and Aransas and Copano Bays. A few days later on from 3-6 October, there were reports of red tide in the Lavaca Bay, Surfside, Cedar Bayou and San Antonio Bay areas. From 12 October through 1 November there are sporadic reports of red tide from East Matagorda Bay down to Boca Chica, including Espiritu Santo Bay, San Antonio Bay, Lavaca Bay, Mesquite Bay, Rockport Harbor, Nueces Bay, Corpus

Christi Bay, Padre Island National Seashore and South Padre Island. On 8 November there was no red tide ported along the Texas coast.

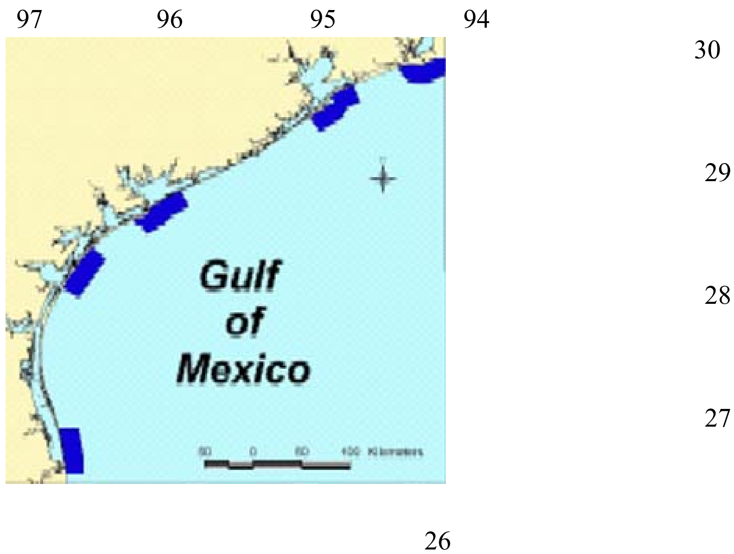


Fig. 1 Sampling regions for the UTMSI red tide monitoring program are indicated by the black rectangular areas.

4. **Data: What (type of) data was collected? What were the inadequacies of the data for monitoring the existing bloom and/or for forecasting the track of the event?** The data collected included lat/long of water samples (TDH, UTMSI), water temperature (UTMSI), salinity (TDH, UTMSI), chlorophyll a (UTMSI), nutrients (UTMSI), cell count data (TDH, UTMSI), aerial over flight observations (TPWD), and dead fish counts (TPWD). See Table 1 for a listing of physical/chemical data collected by UTMSI

   A total of 407 water samples were collected for cell count analysis, of which 215 had detectable cells (range: 100-25,000,000). The mean cell count at sites with detectable cells was 767,157 cells per liter (SD=2,589,615). Samples with detectable cell counts were located in the following bays: Aransas and Copano (7), Corpus Christi (18), Galveston (84), Lavaca (2), Matagorda (29), San Antonio and Espiritu Santo (24) and the Gulf of Mexico (17). Corpus Christi Bay had the highest mean cell counts (mean=1,430,114, SD=5,882,554), followed by San Antonio and Espiritu Santos Bays (mean=1,026,450, SD=1,609,893). On a monthly basis, cell counts were conducted from August through November, with all months having detectable cell counts, although there were only two samples with detectable cell counts in November. The highest mean monthly cell count occurred in September (mean=892,231, SD=2,522,279), followed by October (mean=741,345, SD=2,800,635).

   A fish kill report conducted by RP-TPWD reported a total estimate of 6,771,137 dead fish. Species of concern that were killed in the greatest numbers included: Atlantic croaker (530,441/7.83%), spotted seatrout (9,253/0.14%), red drum (5,805/0.09%) and southern flounder (3,655/0.05%). The species with the greatest number killed was by far Gulf menhaden (3,552,884/52.5%), followed by hardhead catfish (613,531/9.06%), and Atlantic croaker (530,441/7.83%).

Table 1. Summary of hydrographic, nutrient and chlorophyll data from water samples analyzed by UTMSI. The year runs from Nov. 1, 1999 to 31 Oct. 2000. Area 17 = Sabine Pass, Area 18 = Bolivar Roads Pass, Area 19 = Cavallo Pass, Area 20 = Port Aransas Pass, Area 21 = Brazos Santiago Pass.

		Temperature ◦C	Salinity (ppt)	Chlorophyll (μg L^{-1})
Area	Year	Max/min/average/S.D.	Max/min/average/S.D.	Max/min/average/S.D.
17	1999/2000	32.0/13.8/23.3/5.9	36.0/21.0/31.4/4.0	11.6/0.8/2.6/2.1
18	1999/2000	30.2/14.7/22.9/5.2	39.0/25.0/33.6/3.4	4.5/0.4/1.7/1.1
19	1999/2000	30.5/13.2/23.7/4.9	36.0/28.0/33.1/1.6	1.9/0.1/0.6/0.5
20	1999/2000	28.9/14.4/22.1/6.1	36.0/31.6/33.5/1.5	2.4/0.1/0.6/0.5
21	1999/2000	27.3/15.3/22.9/3.3	37.0/33.0/35.5/1.0	1.0/0.1/0.4/0.3

		Nitrate (µM)	Phosphate (µM)
Area	Year	Max/min/average/S.D.	Max/min/average/S.D.
17	1999/2000	13.3/0.0/1.5/3.5	1.0/0.0/0.3/0.3
18	1999/2000	5.2/0.1/1.3/1.3	1.0/0.0/0.3/0.2
19	1999/2000	0.5/0.0/0.1/0.1	0.3/0.0/0.1/0.1
20	1999/2000	1.8/0.0/0.5/0.5	0.4/0.0/0.1/0.1
21	1999/2000	1.6/0.0/0.3/0.4	0.4/0.0/0.1/0.1

		Ammonium (µM)	Silicate (µM)
Area	Year	Max/min/average/S.D.	Max/min/average/S.D.
17	1999/2000	1.8/0.0/0.8/0.5	95.2/3.9/25.1/23.1
18	1999/2000	23.8/0.1/3.1/5.8	29.8/1.9/11.3/7.6
19	1999/2000	0.4/0.0/0.1/0.1	38.7/0.0/9.9/8.8
20	1999/2000	3.1/0.0/0.5/0.6	17.6/0.0/8.1/4.2
21	1999/2000	0.8/0.0/0.2/0.2	25.6/1.4/8.8/6.4

It appears that the red tide event was tracked well. Records indicate that 9 aerial surveys were conducted, but the aerial extent of the surveys is not indicated. Aerial surveys allow more of the coast and nearby waters to be quickly observed with two or three people than could be done by crews on land and water. However, aerial surveys have limitations. Surveys do not reveal areas where blooms are below the surface of the water as sometimes is the case with *Karenia brevis* blooms. Rough water may spread the cells throughout more of the water column further reducing their detection. Blooms may be difficult to detect when turbidity levels are high in by and nearshore Gulf waters. Information on the nutrients and circulation, both the near shore Gulf of Mexico, bays and passes would be valuable information toward developing predictive models for red tide bloom formation and movement. In addition, more sample coverage in the Gulf of Mexico, and continual monitoring would help in early warning and tracking of the blooms.

2000 South Texas HAB Event Report

Prepared by:
Tracy Villareal and James Simons

1. **What triggered the first alert? (i.e., fish kill, discolored water)** The trigger event for this red tide event was a report of discolored water and dying menhaden in Brazos Santiago Pass on 28 June, although there had been an earlier UTMSI report of K. brevis cells at 150 cells per liter on 16 May off of Brazos Santiago Pass.

2. **What was the State's event response strategy?** There is very little data on this event, and the state's response is not clear. No TDH cell count data was reported, nor were any over flights conducted by TPWD. Coastal Fisheries personnel did conduct shoreline surveys for dead fish and evidence of red tide. Water samples were collected at Brazos Santiago Pass approximately twice monthly as part of an ongoing study of seasonal red tide dynamics along the Texas coast conducted by UTMSI. The stations sampled are regular sampling sites for the Coastal Fisheries Division's (TPWD) fisheries independent surveys.

3. **What was the chronology of the events (spatial and temporal)?** The first report of K. brevis cells in Brazos Santiago Pass came from samples collected on 16 May from a UTMSI ongoing study of red tide dynamics. A bloom was first reported on 28 June at Brazos Santiago Pass by TPWD. On 3 July TPWD reported a small bloom near Isla Blanca Park and the Children's Beach. On 10 July red tide was reported along the gulf beach near the Mansfield Pass, where throat irritation was noticed first hand and reported second hand from near the narrows north to the Mansfield Pass. These are the only recorded evidence of red tide for this event.

4. **Data: What (type of) data was collected? What were the inadequacies of the data for monitoring the existing bloom and/or for forecasting the track of the event?** Very little data was collected from this red tide event. Aside from the reports of discolored water and dead fish provided by TPWD, cell counts, salinity, temperature, chlorophyll a, and nutrient data were collected by UTMSI (See Table 1), and cell counts were provided by the Marine Experiment Station and UT Pan Am. A cell count of 150 cells per liter was reported by UTMSI on 16 May, a count of 49 cells per liter was reported by the Marine Experiment Station and counts of 130-140 cells per liter were reported in water samples collected by UT Pan Am (the number of samples was not reported).

   Dead menhaden, barred grunts, and sand trout were observed along the beach from two miles north of the narrows to the Mansfield Pass. Species reported from Mansfield Pass included Atlantic cutlass fish, menhaden, sand trout, and red drum.

   This appears to have been a very minor event, and the level of effort may have been appropriate for the event.

Table 1. Summary of hydrographic, nutrient and chlorophyll data. The year runs from Nov. 1, 1999 to 31 Oct. 2000. Area 21 = Brazos Santiago Pass.

		Temperature ◦C	Salinity (ppt)	Chlorophyll (µg L^{-1})
Area	Year	Max/min/average/S.D.	Max/min/average/S.D.	Max/min/average/S.D.
21	1999/2000	27.3/15.3/22.9/3.3	37.0/33.0/35.5/1.0	1.0/0.1/0.4/0.3

		Nitrate (µM)	Phosphate (µM)
Area	Year	Max/min/average/S.D.	Max/min/average/S.D.
21	1999/2000	1.6/0.0/0.3/0.4	0.4/0.0/0.1/0.1

		Ammonium (µM)	Silicate (µM)
Area	Year	Max/min/average/S.D.	Max/min/average/S.D.
21	1999/2000	0.8/0.0/0.2/0.2	25.6/1.4/8.8/6.4

References

Dortch, Q., C.A. Moncreiff, W.M. Mendenhall, M.L. Parsons, J.S. Franks, and K.W. Hemphill. 1998. Spread of *Gymnodinium breve* into the northern Gulf of Mexico. In: Harmful Algae, edited by B. Reguera, J. Blanco, M.L. Fernandez, and T. Wyatt, Xunta de Galicia and Intergovernmental Oceanographic Commission of UNESCO, pp. 143-144.

Moncreiff, C.A. 1998. Toxic Red Tides in Coastal Mississippi Waters. In: Marine Resources and History of the Mississippi Gulf Coast, vol. II. Mississippi's Coastal Environment. Mississippi Department of Marine Resources, Biloxi, MS, pp. 67-73.