# Petroleum spills/dispersant systems and the structure and function of Northern Gulf of Mexico ecosystems: A Research Plan

by the

Consortium for Northern Gulf Ecosystem Research (CoNGER)

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# Preface

The Consortium for Northern Gulf Ecosystem Research (CoNGER) brings together multiple institutions with comprehensive capabilities and experience able to effectively address the goals of the Gulf of Mexico Research Initiative (GRI) Request for Proposals. The Northern Gulf Institute (NGI), a NOAA Cooperative Institute at Stennis Space Center, MS, will serve as the lead institution for ConGER. NGI, established in 2006, is itself a multi-state partnership of institutions including Dauphin Island Sea Lab (AL), Florida State University, Louisiana State University, Mississippi State University, and University of Southern Mississippi.

Complementing the existing NGI partners, CoNGER also includes the Cooperative Institute for Marine and Atmospheric Studies (CIMAS: a partnership among all the major research universities in Florida and the U.S. Caribbean) in Miami, FL; the Harte Research Institute for Gulf of Mexico Studies (HRI) at Texas A&M University, Corpus Christi; the University of Louisiana, Lafayette; E2 Consulting Engineers, Maryville, TN; and the U.S. Army Corps of Engineers Engineer Research and Development Center (ERDC, formerly WES), with labs in Vicksburg, MS; Alexandria, VA, Champagne, IL, and Hannover, NH.

The CoNGER institutions have marshaled their complementary strengths in transdisciplinary teams to address the GRI goals, providing long term programs of environmental observations and assessments of biological productivity, marine life abundance, and community composition (FSU, LSU, USM, DISL, HRI, CIMAS); physical and ecosystem modeling and prediction systems (FSU, MSU, USM, LSU, CIMAS, HRI, ULL, E2, ERDC); tropical storm dynamics and effects (CIMAS, FSU, MSU, ERDC); chemical analysis of oil, dispersant and associated degradation products in water column and sediment (LSU, USM, MSU, ERDC); data management, data mining and visualization (MSU, CIMAS, HRI, ERDC); and education and outreach (MSU, DISL, HRI).

This master plan was prepared primarily by the following individuals, with contributions from all the persons named within the text.

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# EXECUTIVE SUMMARY

The Consortium for Northern Gulf Ecosystem Research (CoNGER) begins with the fundamental question: Do petroleum spills/dispersant systems significantly impact the structure and function of Northern Gulf of Mexico (NGoM) ecosystems? CoNGER brings together uniquely qualified researchers from universities, federal agencies, and the private sector in a collaborative effort to answer this question in a transdisciplinary approach.

CoNGER proposes four objectives to answer the question and fulfill the GRI mandate:

- Create fundamental advances in understanding the interactions that occurred and continue to occur between the marine ecosystem and petroleum spills/dispersant systems.
- Address the fundamental question in a scientifically rigorous fashion.
- Contribute to a goal of improving environmental health in the face of human activity.
- Disseminate the research findings to the science and engineering communities and to Gulf of Mexico stakeholders.

This proposal addresses the fundamental question and will fulfill the objectives through observations and theory expressed as a conceptual earth ecosystem model (CEEM) integrating complex human, biotic, chemical, and physical interactions of ecosystems as they respond to human and natural system influences, including petroleum spill/dispersant systems.

The project is organized as a set of interconnected tasks with each Task having team members from two to seven institutions, each chosen for her/his expertise and ability to function in an interdisciplinary team. The tasks will provide data, analyses, and tools focused on northern Gulf ecosystems and a synthesis to extend those findings Gulf-wide, producing an unprecedented capability of "… improving the environmental robustness of the Gulf … " as expressed in the RFP.

Four coastal sites are selected for detailed analyses, having been the subject of previous and continuing investigations by the Consortium members, so there exist a deep understanding of the sites, an immediate spin-up in data collection, and a historical data record with which new data can be compared.

Assessing the impacts of PDS introduced into the Gulf of Mexico on human and environmental health requires quantitative causal relationships to relate the degree and extent of the impact to physical, chemical, and biological processes. Therefore the CEEM will be expressed by a suite of open community models, using and modifying existing models wherever possible, and building a capability to better understand Gulf ecosystems and their health long after this project ends. The models and their results will be made accessible to scientists, resource managers, and the public through unprecedented informatics/data management and Education-Outreach efforts.

# INTRODUCTION

The Consortium for Northern Gulf Ecosystem Research (CoNGER) will address the fundamental question: Do Petroleum spills/dispersant systems significantly impact the structure and function of Northern Gulf of Mexico (NGoM) ecosystems?

The project goals are to a) substantially advance understanding of petroleum spill perturbations to northern Gulf ecosystems, and b) enable the Gulf scientific community to evaluate the ecosystem impacts of future perturbations, including oil spills and other events.

The fundamental question is addressed through four specific questions that address GRI Themes 1 - 3:

- Where are the petroleum/dispersant systems residuals located, how are they transported, and what is their fate? (GRI themes 1 and 2)
- What are the current conditions and projected long-term effects of petroleum/dispersant systems on the structure and function of four selected coastal ecosystems in the NGoM and how are these affected by pre-spill conditions? (GRI theme 3)
- What do differential responses across similar sub-ecosystems tell us about resilience and recovery of all GOM ecosystems from oil spills? (GRI themes 1-3)
- Is the fundamental question answered? If not, what data or tools are needed to answer it?

## OBJECTIVES

CoNGER proposes four objectives to answer these questions and fulfill the GRI mandate:

- Create fundamental advances in understanding the interactions that occurred and continue to occur between the marine ecosystem and petroleum spills/dispersant systems.
- Address the primary and secondary questions above in a scientifically rigorous fashion.
- Contribute to a goal of improving environmental health in the face of human activity.
- Disseminate the research findings to the science and engineering communities, to Gulf of Mexico stakeholders, and to the general public.

## BACKGROUND

The Gulf of Mexico is the ninth largest body of water in the world, and it is economically and ecologically one of the most productive and important (Tunnell 2009). The latter concept makes the Gulf seem like a sea of contrasts where a healthy economy and a healthy environment both coexist and contend with one another.

Economically, the five US states bordering the northern Gulf of Mexico have a gross domestic product of over $2.2 trillion, and the robust economy provides jobs for more than 20 million people. Much of this economy is linked to Gulf of Mexico natural resources, such as tourism and recreation, commercial and recreational fishing, and petroleum production and exploration (NOS/NOAA 2008). In a recent year (2006) 83% of the total US shrimp landings, 56% of the oyster landings, and 14% of the commercial fishery landings came from the Gulf. The average number of pounds of commercial fishery landings from the Gulf totals 1.3 billion per year (in 2006), yielding a dockside value of $662 million (NOS/NOAA 2008).

The oil and gas industry in the northern Gulf of Mexico is one of the most developed in the entire world, and it produces over 52% of the crude oil production in the US, 54% of the natural gas production, and 47% of the crude oil refinery capacity (NOS/NOAA 2008). Over 107,000 petroleum related workers are employed in the Gulf region with over $12.7 billion annual wages earned.

Biologically, the northern Gulf waters are some of the most productive coastal waters in the world. The north-central Gulf is sometimes referred to as the nation's "Fertile Crescent" due to the high productivity, plentiful nutrients, and abundance of critical nursery habitats (Darnell et al. 1983). In addition, the entire Gulf of Mexico with warm temperate waters in the north and tropical waters in the south has been shown to be one of the most biologically diverse large marine ecosystems on Earth (Felder and Camp 2009).

In contrast, and seemingly in opposition, to this high biological productivity and diversity, the Gulf has possibly the largest volume of natural hydrocarbon seepage in the world (NRC 2003). The first reported floating oil fields were noted to be widespread in the Gulf (Soley 1910), and subsequent studies in recent decades have confirmed the locations to be consistent and continuous today with as many as 1000 sites known (MacDonald 1998, Garcia 2009). Over 43 million gallons, the equivalent of a super tanker, are known to be released naturally into the Gulf of Mexico annually (NRC 2003). In addition to low diversity chemosynthetic communities directly associated with hydrocarbon release sites, such as brine pools, asphalt flows, barite chimneys, and methane hydrates (Cordes et al. 2010), the entire Gulf of Mexico is apparently inoculated with petroleum-eating microbes that can consume and break down hydrocarbons because of these chronic, ancient widespread releases (Tunnell 2011).

The Gulf of Mexico region is critically important to the U.S. from cultural, economic, natural resource, and recreational standpoints. In fact, the Gulf accounts for 83% of the total U.S. shrimp landings, 56% of the total U.S. oyster landings, and 14% of the commercial fishery landings (NOAA 2008). The northern Gulf is a particularly rich resource for fisheries and shellfish, where Mississippi and Alabama alone account for 16% of the commercial fishing landings despite having only 6% of the total coastline shared among the 5 Gulf States (EPA 2010, NOAA 2008).

Beyond the direct toxic effects of ~206 million gallons of MC 252 crude and ~1.8 million gallons of Corexit dispersant released into the northern Gulf of Mexico (NGoM), the lasting effects on ecosystem structure, function, and recovery remain unknown. While the higher molecular weight petrochemicals are toxic to living organisms (Collins et al. 1998), those of lower molecular weight are utilized by certain microbial communities as a major source of organic carbon. However, such petrochemical food stocks are almost completely lacking in organically-bound nitrogen and phosphorus; therefore, a shift in the NGoM food web structure, induced by the respiration of these food stocks, would necessarily alter the availability of recycled nutrients. Also, the biodegradation of petrochemicals is a preferentially aerobic process (Cerniglia 1984); hence, microbial remediation of MC 252 residuals is likely to increase the rate of heterotrophy driving the balance between autotrophic production and heterotrophic consumption of dissolved oxygen further into the negative, thereby contributing to the local/regional hypoxia dynamics (Rabalais et al. 1994; Hetland 2005; Brunner 2006; Hetland and DiMarco 2007, Rabalais et al. 2007; Dillon 2008).

Lethal and sub-lethal effects of petrochemical exposure on marine organisms (particularly the more sensitive juvenile forms) are also expected to drive significant shifts in primary and secondary production, larval production and recruitment, and overall community structure within the lower tiers of the marine food web (Gin et al. 2001). The potential incorporation of petrochemical contaminants into local fisheries (Baker 1983) and shellfish (*e.g.* oysters, shrimp, crab) is also a major cause of concern. Modeling the impacts of petrochemical contamination on habitat quality, food web stability, and fisheries production within the selected NGoM ecosystems will not only serve to define the extent of ecosystem impairment from a monitoring perspective, but the proposed modeling approach will also allow investigators to integrate the ecosystem model with physical, chemical, and petroleum/dispersant systems (PDS) models for comprehensive sensitivity analyses of the modeled oil spill effects and interactions with other stressors in the NGoM.

Although no long-term studies were conducted to confirm it, many scientists were dismayed by the fact that the Ixtoc I oil spill of over 140 million gallons in 1979-80 in the southern Gulf seemed to "disappear or vanish" and leave little known, long-term impacts (Jernelov 2010). From this historic case, and in similar ways with the Deepwater Horizon spill, it appears that the Gulf of Mexico has a strong capacity to deal with hydrocarbons, as demonstrated by both natural and anthropogenic releases (Safina 2010). This apparent resilience to petroleum inputs merits further study in the context of current findings, to better understand the consequences of warm water oil spills, not only in the Gulf of Mexico but in other parts of the world as well.

## GENERAL APPROACH

This proposal will address the primary and specific questions and fulfill the objectives through observations within the framework of a conceptual earth ecosystem model (CEEM) integrating the complex human, natural, chemical, and physical interactions of ecosystems as they respond to human and natural system perturbations, including petroleum spill/dispersant systems (PDS).

Assessing the impacts of PDS introduced into the Gulf of Mexico on human and environmental health requires quantitative causal relationships to relate the degree and extent of the impact to physical, chemical, and biological processes. Predicting future impacts from the Deepwater Horizon disaster or other spills requires that those relationships be generalized to the maximum extent possible.

Such generalized quantitative relationships are most commonly expressed in predictive numerical models constructed from sound science backed by field observations and laboratory experiments. The combination of science, observations, and numerical models provides a comprehensive and complementary approach. For example:

- Field observations are essential for characterizing processes and validating conceptual and numerical models, since they include the linear and nonlinear interactions and feedback mechanisms. They also provide our best snapshot of what is actually happening in nature.
- Validated numerical models enable researchers to elucidate multiple contributing factors and evaluate their individual effects. They also provide the ability to project future conditions under different environmental forcings.
- Fully integrating both models and observations provides the basis for truly transformative research to advance understanding of perturbations related to the oil spill and how they have impacted the Gulf ecosystem.

The CEEM will be represented by an ensemble of open community numerical models using and modifying existing models and building a capability to better understand Gulf ecosystems and their health long after this project ends.

The use of numerical models is well established, with models for physical processes such as flooding serving as the standard for about 40 years and models for water quality (as in the regulatory environment to establish waste load allocations, to estimate Total Maximum Daily Loads, to estimate impacts of remediation of contaminated sediments, and a variety of other purposes) for about 30 years, and as primary technique for oceanographic research even longer (see, e.g. Martin and McCutcheon 1999, Lung 2001). Models of open waters and Gulf estuaries most commonly include both hydrodynamic and water quality models, due to the importance of transport on the fate of water quality constituents (Hassanzadeh, et al. 2011, Martin and McCutcheon 1999). The models may then be focused on the kinetic and transformation process impacting the specific issue of concern (dissolved oxygen, nutrients, petroleum spills, etc.) in order to address specific concerns such as bioaccumulation/magnification of toxins, excess algal growth, hypoxia, and others. These predictions are also required to assess remedial alternatives and potential impacts of remedial actions. Models of oil spill physical effects are commonly used (e.g., McKay et al. 2004, Cheng et al. 2011)

Models focused on the advective and dispersive transport of the PDS have already been used to simulate the transport of PDS (without kinetic and transformation processes) from the Deepwater Horizon spill (e.g., Fitzpatrick et al. 2011a). This proposal builds on that work with a suite of numerical models that simulate the multi-directional pathway from physical processes (winds, tides, waves, PDS transport, etc.) through the overlapping biotic processes (water quality, food web, etc.) and human effects (ecosystem services) . Figure 1 illustrates the basic concept through a Venn diagram. Members of the Consortium have used this basic construct to develop a detailed Conceptual Earth Ecosystem Model (CEEM) that describes multiple pathways of matter, energy, and effects through the human ecosystem and the information that captures those flows and states.

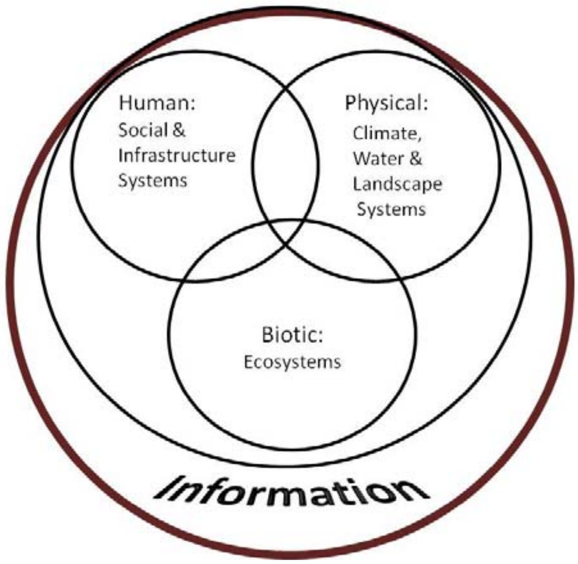


Figure 1. Conceptual Earth Ecosystem Model (CEEM)

## PROJECT STRUCTURE

The project is organized as a set of interconnected tasks (not independent sub-projects) led by Task Leaders with national and international reputations for the quality of their research in that arena. Each Task has team members from two to seven institutions, each chosen for her/his specific expertise and ability to function in an interdisciplinary team. Tasks are structured to use cross-cutting science and technology to develop the necessary knowledge and tools, then apply them to specific sites under the guidance of site experts using data collected by those experts. Findings from Site data and CEEM applications to the sites, organized by state-of the art Informatics, feed the Synthesis and Education and Outreach tasks. Table 1 illustrates the technical structure.

The four CEEM-based tasks in Table 1 will a) develop or improve quantitative models of the dominant processes, and b) apply the improved models to four representative coastal ecosystems which represent a range of physical processes, significant biota, and degree of contact with the Macondo 252 petroleum spill/dispersant. The sites and their characteristics are summarized in Table 2.

All four coastal sites have been the subject of previous and continuing investigations by the Consortium members, so there exist a deep understanding of the sites, an immediate spin-up in data collection, and a historical data record with which new data can be compared. Deep water and coastal waters are considered for their effects on the near-coast sites, including PDS sources, coastal currents, hurricanes, etc. and have been grouped with the CEEM Physical Processes Task for continuity.

Table 1. Cross-cutting science and technology tasks intersect with site-specific data collection and applications of a common CEEM. (*PDS= Petroleum Spill/Dispersant Systems)

<table>
<tr><td rowspan="3">Conceptual Earth Ecosystem Model</td><td colspan="4">Development of CEEM understanding and quantitative modules<br>(4 Tasks: Physical Processes, PDS* and Water Quality, Biotics, and Ecosystem Services)</td></tr>
<tr><td colspan="4">TASK: SITE APPLICATIONS OF CEEM</td></tr>
<tr><td>Barataria Basin/ Wax Lake</td><td>Mississippi Sound/Bight</td><td>Perdido Bay</td><td>Apalachicola Bay</td></tr>
<tr><td>Synthesis</td><td colspan="4">Interpretation of findings and extension to broader Gulf understanding</td></tr>
<tr><td>Informatics</td><td colspan="4">Data management, visualization, information flow, decision support</td></tr>
<tr><td>Education and Outreach</td><td colspan="4">K-Gray education & dissemination of research results<br>to the several levels and kinds of stakeholders.</td></tr>
<tr><td>Management</td><td colspan="4">Coordination, communication, administration, reporting</td></tr>
</table>

Table 2. Sites to be studied and their characteristics.

| SITE | PDS Exposure* | Hydrology | Morphology | Biotic |
|---|---|---|---|---|
| Barataria Basin/Wax Lake Outlet, Louisiana | Heavy to None | Controlled with low to high pulses from diversion | Marshes | Marsh vegetation, oysters, shrimp, crab, & nurseries |
| Mississippi Sound and Bight, Mississippi and Alabama | Moderate | Moderate | Open Water & beaches | Submerged vegetation, oysters, shrimp, & crab |
| Perdido Bay, Alabama and Florida | Light | Low | Estuarine | Marsh vegetation, oysters, crab, & nurseries |
| Apalachicola Bay, Florida | None | Low to high | Estuarine | Submerged vegetation, oysters, shrimp, crab & nurseries (e.g., gag grouper) |

Note: * PDS exposure is based on the National Commission Report (2011) (page 198) and data currently being collected by NGI researchers during field work funded by BP grants to the states. Those results will be published in 2012.

This structure creates nine tasks, with each cross-cutting task performed by an interdisciplinary, multi-institutional team that brings the Consortium's best talents to bear on the questions involved. Interconnections among the Tasks and Task members are described in the following sections, and coordination of those interconnections is a key element of the Management Task and Management Plan. The nine tasks and participating institutions are listed below and described in detail in the next section:

1. CEEM Physical Processes – weather, hydrodynamics, oceanography and application to the sites. (Lead: Chassignet, FSU. Members: CIMAS, NGI, MSU, FSU, LSU, ERDC)

2. CEEM PDS and Water Quality Processes – petroleum and dispersant systems transport and degradation, sediment and water quality interactions, and feedback from biotics and application to the sites. (Lead: Martin, MSU. Members: FSU, USM, MSU, LSU, ERDC)
3. CEEM Biotics – food web, assemblages, and individual species and application to the sites. (Lead: Cebrian, DISL/Milroy, USM. Members: E2, FSU, DISL, USM, LSU, ERDC, EPA)
4. CEEM Ecosystem Services – ecosystem services valuation and application to the sites. (Lead: Yoskowitz, HRI. Members: MSU, HRI)
5. Informatics -- Data management, visualization, information flow, decision support (Lead: Moorhead, MSU. Members: CIMAS, MSU, ERDC)
6. Synthesis -- Interpretation of findings and extension to broader Gulf understanding. (Lead: Tunnell and McKinney, HRI. Members: FSU, DISL, USM, MSU, LSU, ULL)
7. Site Specific Applications – Field and lab investigations of PDS/WQ and biotics and guidance of CEEM application to the 4 northern Gulf ecosystems. (Members: FSU, DISL, USM, LSU, ULL)
8. Education and Outreach - K-Gray education and dissemination of research results to the several levels and kinds of stakeholders, including decision makers (Lead: Hodge, NGI. Member: DISL)
9. Management -- Coordination, communication, administration, and reporting (Lead: McAnally, NGI/Lohrenz, U Mass-D. Members: FSU, CIMAS, DISL, USM, NGI, LSU, ULL, ERDC, E2)

This project structure is more complicated to manage than a set of stand-alone institutional projects, but is far superior in bringing together the most advanced science and engineering from multiple institutions and applying the collective state-of-the-art with the most comprehensive knowledge of the northern Gulf ecosystems, producing an unprecedented capability of "… improving the environmental robustness of the Gulf … " as expressed in the RFP.

This project will produce scores of deliverables, including the following flagship products:

- Data and metadata on four representative ecosystems from Florida to Louisiana from before, during, and after the Deepwater Horizon disaster, available to researchers and the public through the GRI and CoNGER.
- A Conceptual Earth Ecosystem Model (CEEM), based on that extensive data set and expressed quantitatively as a suite of community models for the physical, petroleum spills/dispersants /water quality, biotic, and ecosystem services of the northern Gulf of Mexico, available for openly shared use and improvement.
- Site-specific applications of the CEEM to four representative northern Gulf ecosystems, detailing the effects of petroleum spills/dispersants on the ecosystem, if any.
- A synthesis of all results, extending the site-specific data and model results to the broader Gulf and other potential oil spills through comparative analyses.
- Sulis Decision Support System with a Gulf ecosystem health metric (Report Card)framework offering advanced visualization/interpretation tools and ready access to information.
- An unparalleled Education and Outreach spectrum for teaching and communicating the findings.

## APPROACH

CoNGER's approach is organized around the Conceptual Earth Ecosystem Model (CEEM) shown in Figure 1 and the Task breakout in Table 1. CEEM understanding and quantitative modules constitute 4 Tasks – Physical Processes, PDS and Water Quality, Biotics, and Ecosystem Services – which are derived from a more detailed CEEM diagram, shown in Figure 2. Still greater detail is shown in Tasks 2 and 3 diagrams.

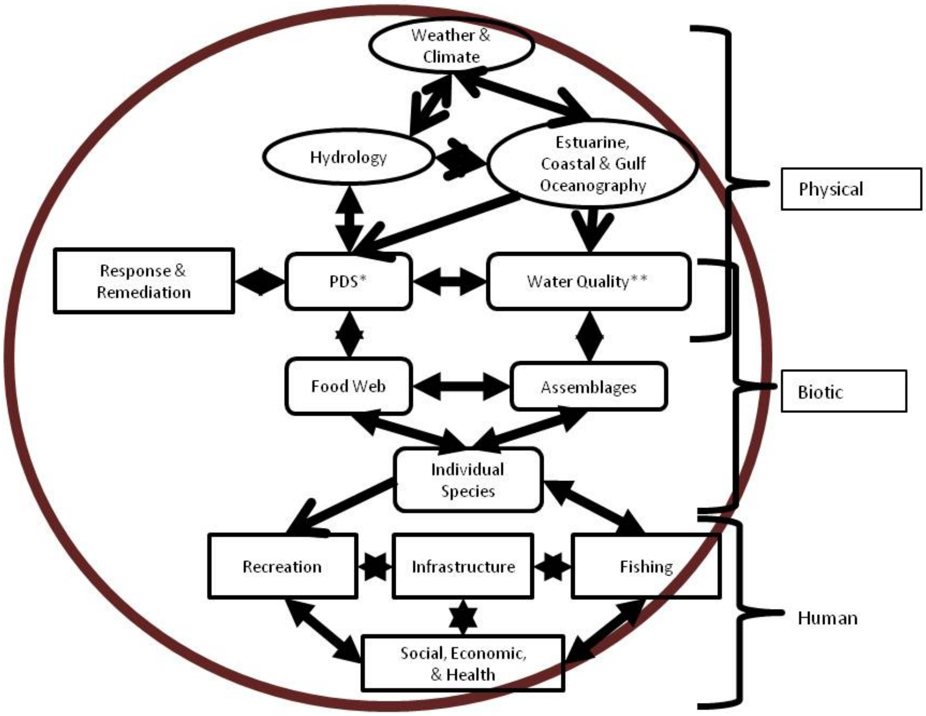


Figure 2. CEEM with additional detail and selected information flow.

TASK DESCRIPTIONS

**Task 1: CEEM: Physical Processes**

TASK LEADERS: Eric Chassignet, FSU, and John Harding, NGI

MEMBERS: Alarcon and Fitzpatrick, MSU; Dukhovskoy and Morey, FSU; Chapman, ERDC; Huang, LSU; Kourafalou, CIMAS

1.0 Objectives

1.1 Provide Deepwater and coastal oceanography results

1.2 Provide Site-specific physical processes model results, including predictions of future conditions.

Sub-Task 1.1: Deepwater and Coastal Oceanography: Chassignet, FSU; Harding, NGI; and Kourafalou, CIMAS

Objectives:

1.1.1. Develop coupled physical-biogeochemical modeling system with tides and waves of the northern Gulf of Mexico (NGoM) nested within the 1/25° HYCOM Gulf of Mexico assimilative model

1.1.2. Investigate transport mechanisms of pollutants (oil products and dispersants) in the NGoM

1.1.3. Study NGoM as an integrated biogeochemical system in order to create fundamental advances in understanding the interactions that occurred or may occur between the marine ecosystem and petroleum pollutants in the NGoM

1.1.4. Provide necessary model output for the high-resolution models of selected estuaries

Introduction

The Northern Gulf of Mexico (NGoM) region can be loosely defined as the northern part of the Gulf. The NOAA Northern Gulf of Mexico Model includes water area within few hundred miles from the coastline of Texas, Louisiana, Mississippi and Alabama but not Florida (Figure 1.1.1). In this proposed research, a different NGoM definition is suggested. The region is defined as an area enclosed within the line that follows the coastline a few hundred kilometers offshore from Galveston Bay to Cedar Key, FL. The studied region is strongly affected by continental runoff, thus characterized by relatively low sea surface salinity (<34 ppt[1]) compared to the central Gulf (Figure 1.1.2).The open boundary line of the proposed domain roughly follows the average position of the 34 ppt isohaline in the northern Gulf in summer.

NGoM is an important fishery region. It includes numerous estuaries and bays that are vital nursery grounds for fish and invertebrate species. The growing population along the coast impacts ecosystem in the NGoM. Nutrient and pollutant runoff from these communities and from the large watershed for the rivers discharging to the basin can affect the chemical and biological properties of the northern Gulf near the coastline as well as far from shore in areas critical to economically important fisheries. Oil and gas exploration is active around the continental shelf of the NGoM. The recent Deepwater Horizon disaster has demonstrated the scope of devastating consequences that may result from an oil spill accident. The Deepwater Horizon oil spill also indicates a lack of knowledge of the nearshore and continental shelf circulation in the NGoM, connectivity between different parts of the NGoM, and pathways of pollutants in the region.

Previous studies demonstrate a seasonally varying interaction among different parts of the NGoM (e.g., Morey et al. 2005, Morey et al. 2009). During most part of the year, the western and eastern parts (relative to the Mississippi delta) of the NGoM can be viewed as dynamically separate parts with limited exchange of water masses between each other. In November – December, the water mass exchange between the western and eastern parts is enhanced (see Morey et al. 2005). Circulation pattern within each part of the NGoM is even more complex with seasonally shifting pathways of low-salinity water, along- and cross-shelf flows, and estuary – continental shelf exchange. Very little is known about the role of sediments in transporting pollutants in the coastal regions. Oil and other pollutants can attach to sediments. Waves or strong currents can resuspend the sediments in the water column, transporting them (with attached pollutants) over a long distance, thus spreading anthropogenic stress on the ecosystem over larger area.

The impact of riverine inflows on coastal regions of NGoM requires evaluation; basin-wide and coastal NGoM simulations need to correctly account for river plume dynamics in the presence of the dynamically and topographically complex NGoM shelf regions. The NGoM shelf areas receive large amounts of river discharges through several sources, the dominant being the Mississippi River (MR) delta. Draining 41% of the continental United States, the MR is the largest river in North America, ranks as the 8th largest worldwide in terms of discharge (mean $1.35 \pm 0.2 \times 104$ $m^3 s^{-1}$ (Hu et al. 2005) and transports about 210 million tons of sediment to the NGoM annually (Milliman and Meade 1983). Understanding and predicting the MR pathways is of vital interest in this project, to ensure appropriate circulation and water properties surrounding the specific study sites (coastal areas and embayments), which are largely controlled by the variability in the low salinity band that expands over the Northern NGoM, through the blending of the MR and all other river plumes.

[1] Parts per thousand (ppt) is commonly used in the Gulf instead of practical salinity units (psu), which are practically equivalent.

The development and evolution of the MR river plume (Schiller et al. 2011) is influenced by: a) buoyancy, which for a large scale plume (influenced by the Earth's rotation) triggers an anticyclonic bulge and a downstream coastal current (in the direction of Kelvin wave propagation); wind stress, that would enhance the downstream current and confine it in a narrow coastal band (if downwelling favorable) or oppose it, inducing offshore transport of plume waters (if upwelling favorable); topography, which modifies plume waters and inhibits cross-isobath flow (due to vorticity constraints); ambient currents, which can enable additional cross-shelf and along-shelf pathways. The proximity of the MR delta to the shelfbreak imposes strong topographic controls on plume development. Other strong bathymetric irregularities (such as the DeSoto Canyon) also play a role. In addition, under the influence of variable wind stress, river plume waters are subject to both "downstream" (westward), but also "upstream" (eastward to northeastward) advection. Simulating the variability of such pathways is crucial for the accuracy of boundary conditions provided to limited area coastal models. Moreover, a unique attribute of the transport and fate of riverine waters on the NGoM is the interaction with shelfbreak and offshore flows, especially the Loop Current and associated eddies. Although such interactions are episodic (during northward intrusions of the Loop Current front or under specific conditions of eddy dipoles near the delta), they have been found to account for freshwater entrainment at an average rate of ~4,000 $m^3\ s^{-1}$ (Schiller and Kourafalou 2011). In order to properly evaluate the impact of riverine inflows on coastal regions of GoM, it is, therefore, necessary to account for both shelf and basin-wide processes that control the transport and fate of low salinity waters resulting from discharges at the MR delta and all other major rivers.

In order to be able to predict ecological consequences of potential oil spills or other pollutants introduced into the NGoM, CoNGER proposes to use the previously developed NGoM FVCOM to:

- Gain knowledge of the circulation in the NGoM
- Study interaction between different parts of the NGoM
- Study estuary – NGoM exchange
- Identify pathways of pollutants within the region
- Investigate sediment exchange between the bays and estuaries and NGoM and look at processes of sediment resuspension, transport and redeposition in the NGoM

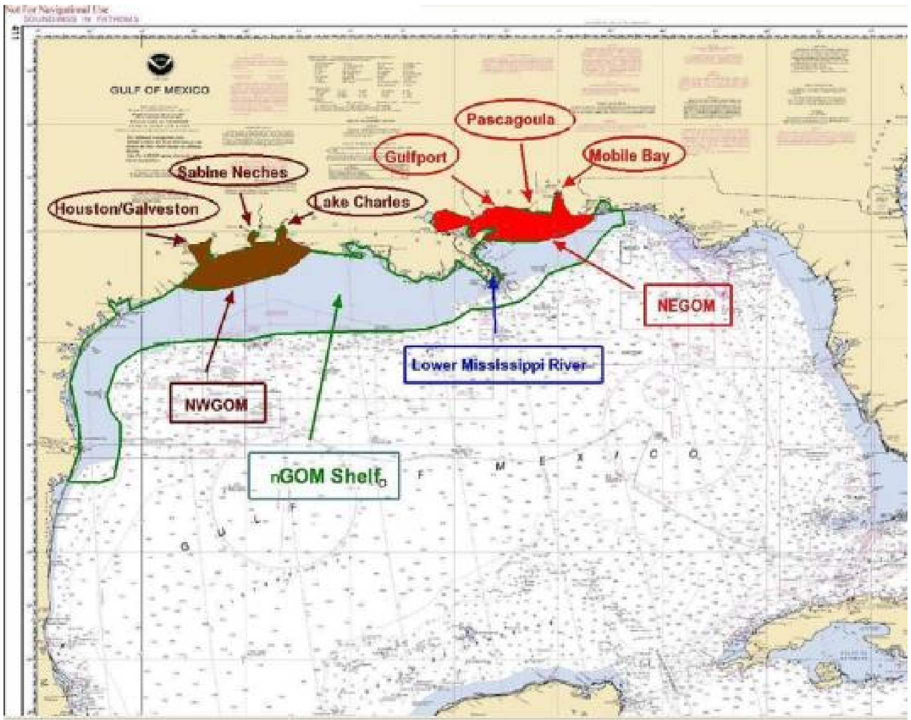


Figure 1.1.1: NOAA CSDL planned coastal physical model implementations (NGoM shelf currently planned for 2nd Qtr FY 12 initial operational capability)

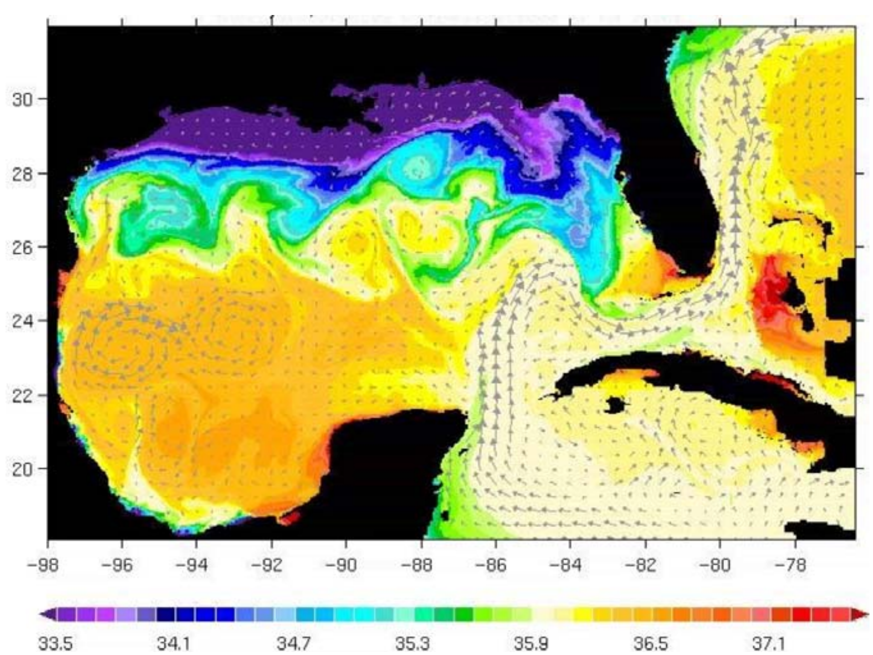


Figure 1.1.2. Surface salinity (ppt) in July from 1/25° GOM HYCOM.

Technical Approach

Model description – the deep and coastal waters models will be developed on the basis of the unstructured grid Finite Volume Community Ocean Model (FVCOM, Chen et al. 2003). The latest version of FVCOM (FVCOM 3.1.4) is a fully coupled ocean-wave-sediment-ecosystem model MPI parallelized system (Figure 1.1.3). The unstructured-grid finite-volume algorithm used in FVCOM combines the advantage of finite-element methods for grid geometric flexibility and finite-difference methods for simple and efficient discrete computation. FVCOM solves the flux form of the governing equations in unstructured triangular volumes with second-order accurate discrete flux schemes. This finite-volume approach provides an accurate presentation of mass, heat and salt conservation in the sense of numerical computation. FVCOM was originally designed for regional, coastal and estuarine problems with complex irregular geometry. However, the flexibility of the triangular grid to resolve the steep bottom topography along continental margins enables FVCOM to accurately simulate slope fronts and currents in basin-scale applications. The modeling system consists of the following coupled modules, shown in Figure 1.1.3.

Ocean Module: FVCOM ocean module is a prognostic, unstructured-grid, Finite-Volume, free-surface, 3-D primitive equation ocean model (Chen et al. 2003, 2006, 2007). The equations are cast in a generalized terrain-following coordinate system with spatially variable vertical distribution (Pietrzak et al. 2002). In the horizontal, the equations are discretized using non-overlapped triangular grids, which provide accurate fitting of irregular coastal geometries and flexibility in refining the grid over steep continental margins, ridges, and around islands. The spatial fluxes of momentum are discretized using a second-order accurate finite-volume method (Kobayashi et al. 1999). A flux formulation for scalars (e.g. temperature, salinity) is used in conjunction with a vertical velocity adjustment to enforce exact conservation of the scalar quantities. A Smagorinsky formulation (Smagorinsky 1963) is used to parameterize horizontal diffusion and turbulent vertical mixing is calculated using the General Ocean Turbulence Model (GOTM) libraries (Burchard 2002), with the 2.5 level Mellor-Yamada (1982) turbulence model used as the default. FVCOM is coded for both spherical and Cartesian coordinates and is solved numerically with an option of either a mode-split or semi-implicit integration method.

Wave Module: an unstructured-grid version of the Simulating Wave Nearshore model (SWAN) (Qi et al. 2009). SWAN was developed originally by Booij et al. (1999). SWAN is a third-generation wave model for obtaining realistic estimates of wave parameters in coastal areas, lakes and estuaries from given wind, bottom and current conditions. SWAN can be used on any scale relevant for wind-generated surface gravity waves. The model is based on the wave action balance equation which forecasts wave energy spectrum in geographic and frequency domains. The model included source/sink term representing effects of wind-wave generation, resonance with wind-induced pressure fluctuations, feedback of wave-induced pressure fluctuations, dissipation (due to whitecapping, bottom friction, and depth-unduced breaking), nonlinear wave-wave interactions.

Model Grid: Unstructured grid for the NGoM will have horizontal resolution within the region of interest about 1 km. Nodes at the lateral OB (red line in Figure 1.1.4) will be collocated with the grid nodes of 1/25° HYCOM NGoM to ease implementation of the open boundary conditions, similar to Dukhovskoy and Morey (2010). Figure 1.1.5 illustrates how the mesh may look for the proposed research. In Figure 1.1.5, the unstructured grid has several regions of varying resolution with the highest resolution is along the northern coast. In the proposed research, the coarse-resolution portion of the grid will not exist. Similar high-resolution grid will be developed for the proposed NGoM domain and will be nested into GOM HYCOM.

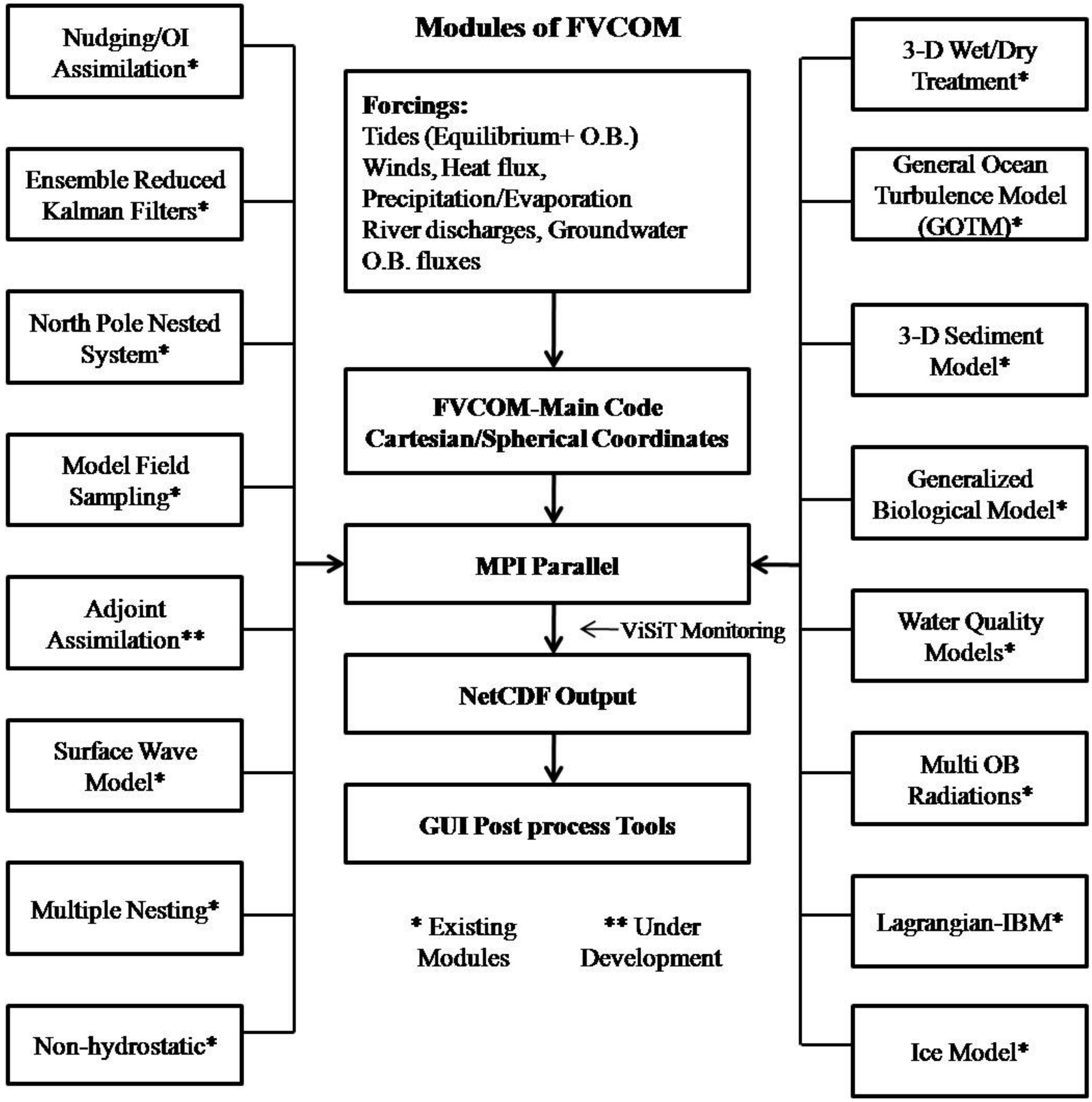


Figure 1.1.3. Schematic of FVCOM

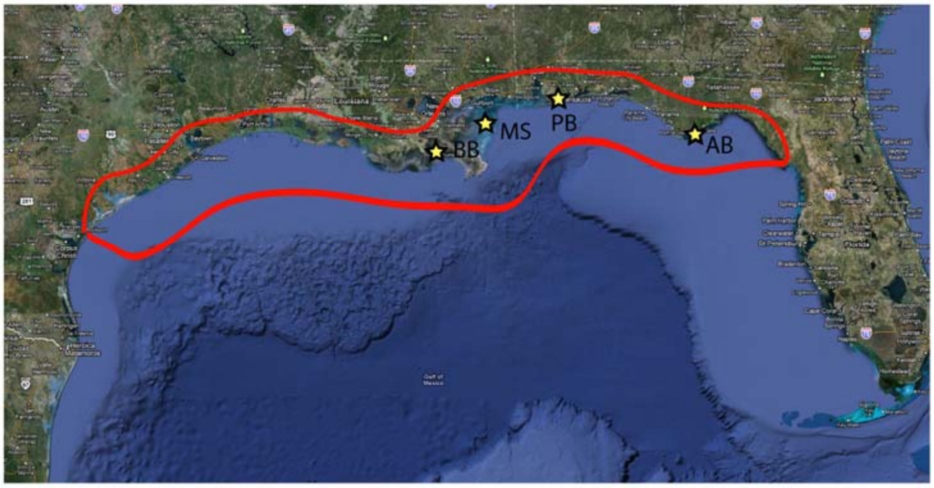


Figure 1.1.4. Approximate domain of the northern Gulf of Mexico FVCOM. The red line demarcates lateral (southern) open boundary of the model. Stars indicate approximate locations of nested models: Barataria Bay (BB), Mississippi Sound (MS), Perdido Bay (PB), Apalachicola Bay (AB)

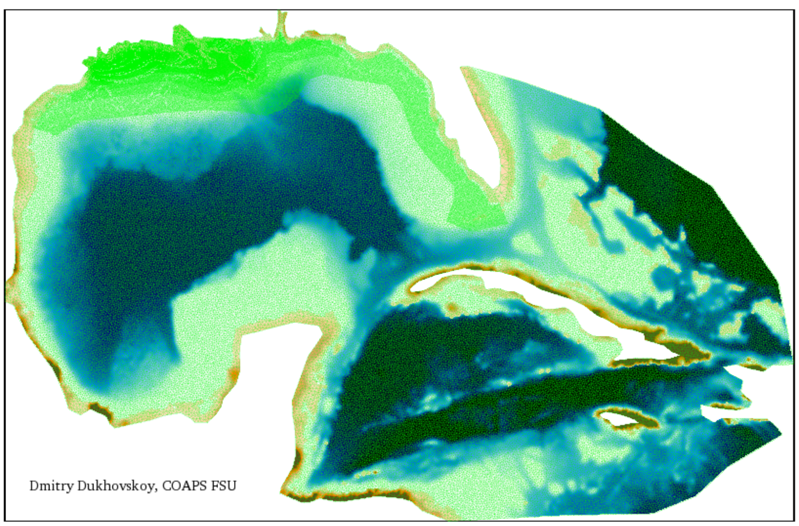


Figure 1.1.5. Example of unstructured mesh of the Gulf of Mexico and Caribbean FVCOM domain. The grid was developed at COAPS FSU for storm surge simulations in the northern Gulf. In the proposed study, the higher-resolution mesh over the northern Gulf will be nested into GOM HYCOM.

Surface Boundary: Atmospheric parameters (momentum flux, radiative fluxes, sensible and latent heat fluxes, net precipitation) will be prescribed at the upper surface of the ocean model interpolated from a NOAA NCEP atmospheric model (e.g., 12-km North America Mesoscale model).

Lateral Open Boundaries GoM HYCOM will provide the following state variables at the NGoM open boundaries: flow vectors, temperature and salinity, and sea surface elevation. Wave characteristics and spectra necessary for SWAN will be provided at the NGoM open boundary nodes from NOAA WaveWatch III.

River Plume Dynamics**.** Existing model parameterizations of river plume dynamics will be evaluated and compared. The technical development will include the parameterization of both salt and momentum fluxes for the river discharges, high frequency river inputs and ability to prescribe vertical and horizontal salinity profiles to match observations. Such methodologies have already been developed for the POM (Kourafalou et al. 1996) and the HYCOM (Schiller and Kourafalou 2010) models.

High resolution coastal and shelf models can be nested within basin-wide GoM models. The downscaling approach will ensure the proper interactions that will allow prediction of seamless pathways from the deep to the shelfbreak and to the nearshore, through the shelf and coastal regions. The summer of 2010 will be an important test case study on the synergy between offshore and shelf circulation (with an emphasis on currents induced by river discharges) on the cross-marginal transport of offshore pollutants (as from the Deepwater Horizon oil patch area) toward the NGoM embayments and coasts.

Test case studies on the effects of riverine waters will be studied, including extreme events, such as hurricanes (Li et al. 2009) and floods. For instance, an unprecedented flood took place in late spring of 2011 (still being surveyed) and effects will be studied and compared with events as in 2008 (White et al. 2009). The plume waters (especially those of the MR that have high concentration of suspended sediments) have relatively high reflectivity. This makes them detectable on satellite ocean color images (Walker 1996, Walker et al. 2005). A detailed visual inspection of satellite image product archives (publicly available at http://www.esl.lsu.edu and also at NRL and USF) will take place to identify major river plume circulation events. The events to be studied and modeled may be revealed in SST imagery, in chlorophyll *a* imagery and in "true color" images, produced using several sensors, including NOAA AVHRR, GOES GVAR, Terra-1 and Aqua-1 MODIS, and Oceansat-1 OCM.  A significant correlation between satellite-derived optical properties and surface salinity, especially near the Mississippi delta has been found (Dr. R. Arnone, NRL-SSC, personal communication). Events which are revealed in time-sequences of imagery will be given priority. In addition, in situ measurements of currents and water properties will be employed to identify events of particular importance for the specific sites.

The removal vs. retention of riverine waters and the flushing time of the specific sites will be quantified. This will be done for the test case study periods and over multi-year simulations that will allow the study of seasonal and inter-annual variability. Twin simulations without freshwater input will be performed to determine the background salinity $S_b$ and compute the shelf and coastal freshwater transport, as the ratio of the difference ($S-S_b$), over $S_b$ over the entire water column (where S is the model salinity from the fully forced simulations). The time series of freshwater transport rates through cross-shelf and along-shelf transects will be computed and correlated with the river discharge rates, the prevailing wind stress and the northward intrusions of Loop Current toward the NGoM shelf. This analysis will set the basis for interdisciplinary prediction on the transport and fate of riverine waters and associated materials (sediments, nutrients and pollutants). The results will guide the evaluation of the relative importance of the tendency for stratification (due to river runoff) and for mixing (primarily due to winds and waves) over the various shelf and coastal model subdomains.

Meteorological Impact**.** Fitzpatrick et al. (2011a) examined the influence of meteorological factors on the transport of the Deepwater Horizon spill. While the trajectories generally followed the ocean currents, weather impulses dramatically altered the transport of oil on occasion. Through a combination of data analysis (buoys, weather reanalysis maps, tide gauge data, scatterometer data, and HF radar) and a Lagrangian particle tracker with random walk diffusion imbedded in the Navy Coastal Ocean Model, Fitzpatrick et al. (2001) showed that two weather systems altered the currents and water levels such that oil was pushed into the western Mississippi Sound and the Rigolets. An easterly wind fetch from intensifying Hurricane Alex provided the first inland push, followed by a westward-drifting non-tropical low which had formed off the western edge of a Gulf cold front. In both cases, a generally weak pressure gradient was replaced by strong easterly winds which not only switched westerly coastal currents to an easterly direction, but also increased inland water levels by 0.6-0.8 m. These results showed that cyclones can dramatically alter oil transport, even by fringe effects.

CoNGER proposes expanding these results to understand the impact of weather impulses on water levels and estuary currents in conjunction with in-situ data analysis and usage of the Lagrangian code in the FVCOM simulations. This assessment provides a means not only to fully comprehend transport issues associated with Deepwater Horizon, but to develop predictive guidelines for future major or minor estuary pollution events from weather impulses. As a subset study, the potential impact of past and future tropical cyclones directly impacting the NGoM region will also be examined. Fitzpatrick et al. (2011b) developed a storm surge module for transporting oil pollutants in the event of a tropical cyclone. This system involved the Advanced CIRCulation (ADCIRC) hydrodynamic model to provide water currents and surge elevations, and the Lagrangian particle model discussed earlier for predicting oil transport. A hypothetical scenario of a category 2 hurricane making landfall in Fourchon, LA, was conducted. This region was particularly vulnerable since beaches from Sandy Point to Chalon Pass, as well as northeast Barataria Bay (near Bay Jimmy), contained oiled shorelines as well as imbedded oil on the sea bottom. In this scenario, oil would have been displaced westward, covering parts of Grant Isle, then moving northwards deep into the marsh north of Barataria Bay. The oil residual would have remained in the marsh as the surge retreated. CoNGER proposes enhancing this system for examining and predicting the impact of future pollutant episodes in the four study regions.

Model experiments: The deepwater and coastal models suite will be run for will be run for 2009 – 2014.

Sub-tasks 1.2 to 1.5 will use the products of Sub-Task 1.1 as inputs to produce hydrodynamic results for each of the four site-specific CEEM models. Because of the great savings in time and cost, existing, validated models will be used. This choice also provides the opportunity to exercise the informatics tools from Task 5 in coupling the Task 2 and Task 3 models to three different hydrodynamic models and reinforce the modularity of the CEEM components.

Sub-Task 1.2: Physical Processes of Apalachicola Bay – Lead: Morey, FSU

Objective

1.2.1 Provide model results of physical processes of Apalachicola Bay, FL, to other components of the CEEM.

Approach

The FVCOM model described above will be applied at a higher resolution to Apalachicola Bay, FL, to produce temporal and spatial distributions of water surface elevation, temperature, salinity, and flow speed vectors for the period 2009-2013, and for additional periods as necessary.

Sub-Task 1.3: Physical Processes of Perdido Bay – Lead: Alarcon, MSU

Objective

1.3.1 Provide model results of physical processes of Perdido Bay, FL, to other components of the CEEM.

Approach

An existing EFDC 3D model built and validated by Dynamic Solutions, LLC, for the State of Florida DEP will be used to produce temporal and spatial distributions of water surface elevation, temperature, salinity, and flow speed vectors will be produced for the period 2009-2013, and for additional periods as necessary.

Figure 1.3.1 shows the computational mesh of the existing Perdido Bay EFDC model. The grid consists of 989 cells on the horizontal plane and each cell is further divided into 4 vertical layers of equal depth.

The locations of freshwater inflow, sea water open boundaries, and available NOAA Stations within the computational domain are indicated.

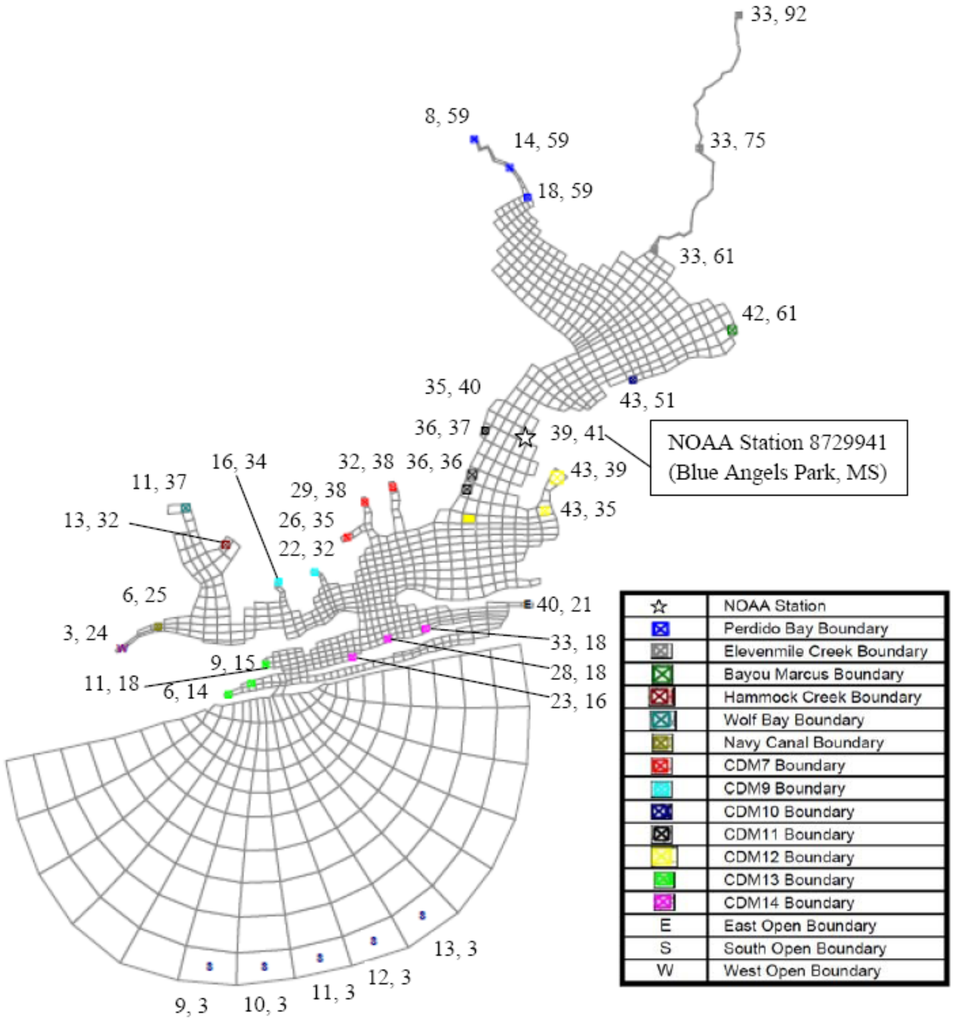


Figure 1.3.1. Existing EFDC model of Perdido Bay, FL.

The EFDC Model solves the three-dimensional, vertically hydrostatic, free surface, turbulent averaged equations of motions for a variable density fluid. The model uses a stretched or sigma vertical coordinates and Cartesian or curvilinear, orthogonal horizontal coordinates. It includes turbulence closure model. A highly efficient finite difference semi-implicit solution is implemented to solve the model equations.

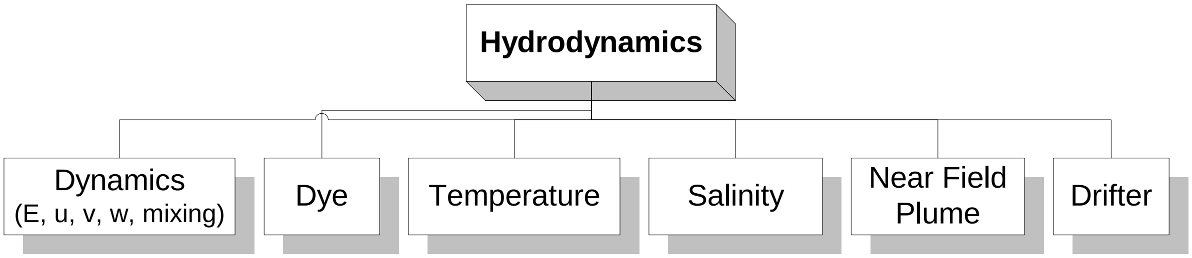

Figure 1.3.2. EFDC model schematic in one of its basic configurations.

There exist several versions of the EFDC code. The version in which the Perdido Bay model was developed is the EFDC_Explorer5. This version provides a Graphical User Interface (GUI) capable of visualizing input and output data, modifying the model, and run the application. See Figure 1.3.3 for an example of data visualization using EFDC_Explorer5.

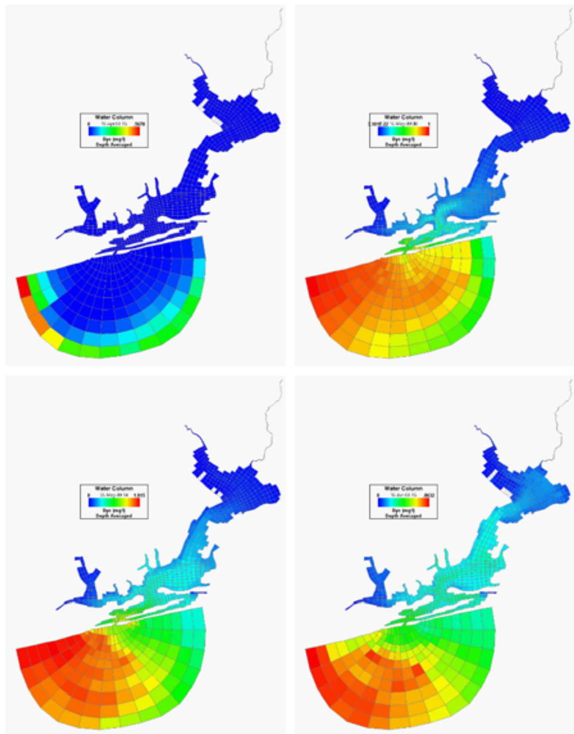

Figure 1.3.3. Dye transport with the Perdido Bay EFDC model

Sub-Task 1.4: Physical Processes of Mississippi Sound/Bight– Lead: Chapman, ERDC

Objective

1.4.1 Provide model results of physical processes of Mississippi Sound/Bight, LA, MS, AL, to other components of the CEEM.

Approach

An existing CH3D model built and validated by the Corps of Engineers will be used to produce temporal and spatial distributions of water surface elevation, temperature, salinity, and flow speed vectors for the period 2009-2013, and for additional periods as necessary. Atmospheric, river, wave, salinity and temperature boundary input forcing will be provided by Task 1.1.

The modeling approach proposed herein is based on the ERDC-CHL Geophysical Modeling System. The system links the shallow water wave model STWAVE (Smith et al. 2001), 2D hydrodynamic model, ADCIRC (Luettich et al. 1992), 3D hydrodynamic model CH3D(Chapman et al. 1996), 3D sediment transport model, SEDZLJ (Jones and Lick, 2001; James et al., 2010) and 3D water quality, CEQUAL-ICM (Cerco and Cole, 1994).

The Curvilinear Hydrodynamic 3-D (CH3D-WES) model is routinely applied in 3-D hydrodynamic and water quality modeling studies at the Engineering Research and Development Center (ERDC), Mississippi. There is an existing single-block Mississippi Sound grid, which is 450x364 with 5 vertical sigma layers. This Mississippi Sound grid extends from Lake Pontchartrain, LA to Mobile Bay, AL. The single-block grid has been then decomposed into 5-block grid (Figure 1.4.1). This allows CH3D to be run in parallel thus increasing the computational efficiency. This multi-block configuration can be modified to address specific regions of interest. CH3D has boundary and radiation stress gradient forcing provided by ADCIRC and STWAVE, respectively.

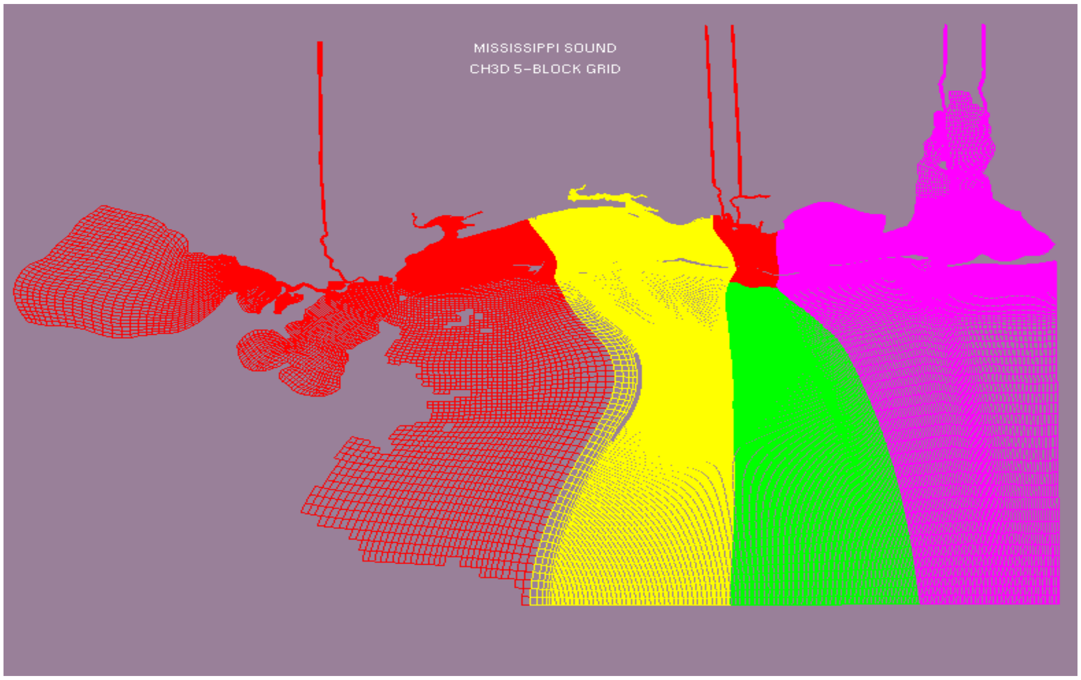


**Figure 1.4.1. Mississippi Sound CH3D 5-block Grid.**

The sediment transport model in CH3D is the SEDZLJ sediment transport model (Jones and Lick, 2001; Hayter and Chapman, 2011). SEDZLJ is dynamically linked to CH3D in that the hydrodynamics and sediment transport modules run concurrently. In addition, the CH3D-SEDZLJ module can be applied to one or more individual blocks within that shown in Figure 1.4.1.

This sub-task will 1) link boundary forcing from the Gulf of Mexico Scale FVCOM model, which will include investigating the use of 3D lateral flow, salinity and temperature boundaries, 2) perform existing calibration and verification simulations to insure the integrity of the linkage, 3) modify the multi-block grid for specific areas of interest, and 4) re-establish and validate the linkages with SEDZLJ.

<u>Sub-Task1.5: Physical Processes of Barataria Basin</u> – Lead: Huang, FSU

Objective

1.5.1 Provide model results of physical processes of Barataria Basin, LA, to other components of the CEEM.

Approach

An existing FVCOM model built and validated by LSU will be used to produce temporal and spatial distributions of water surface elevation, temperature, salinity, and flow speed vectors for the period 2009-2013, and for additional periods as necessary.

Sub-Task 1.6 Data Management – Harding, NGI

Objective

1.6.1 Arrange for all production model results of physical processes to be stored and to be forwarded to GRI in conformance with the Data Management Plan and in coordination with the Project Data Manager.

Approach

The Data Management Plan and Task 5.1 describe the project's data management policies and procedures. Production model results from all the models used in Task 1 will be stored in a standard format with complete metadata and made available as soon as possible after results are published.

Deliverables

1.1 Working models of the Gulf and NGoM

1.2 Working models of each of the four estuaries.

1.3 Technical reports and papers on each component of the physical processes modeling.

1.4 Time-varying water surface elevations, 3D current vectors, salinities, and temperatures for the periods of simulation over the spatial extent of the four estuaries for use by other tasks and for data archiving.

Schedule

| MILESTONE | DATE COMPLETE |
|---|---|
| Initial Deepwater and Coastal Oceanography results | 03/2012 |
| Initial physical model results complete | 08/2012 |
| Deepwater and Coastal Oceanography results complete | 02/2013 |
| Physical model results for ecosystems complete | 06/2013 |

**TASK: 2. CEEM: Petroleum Spills/ Dispersant Systems (PDS) and Water Quality**

TASK LEADER: James L. Martin, Civil and Environmental Engineering, MSU

MEMBERS: Turner, Justic, and Chen, LSU; Milroy, USM; Crocker, ERDC; McAnally, NGI; Bricka, Alarcon, Diaz, McNeal, MSU.

Objectives

2.1. Define the primary processes by which PDS in aqueous and sedimentary environments (a) move, (b) interact with sediment and water organics and inorganics to change and affect water quality, and (c) contact biota.
2.2. Produce data, tools, and models that describe movement and alteration of PDS and water and associated water quality changes in aqueous and sedimentary environments under the forcings of physical and biotic processes. These products will also be used to calibrate/validate WASP performance.
2.3. Predict the path and fate of PDS and water quality for the specific sites of interest for time periods and conditions needed for ecosystem evaluations

Background

The petroleum spill/dispersant systems (PDS) introduced into the Gulf of Mexico may have long-term residual impacts on environmental health, both in deep and near-shore sea waters as well as in Gulf estuaries. In order to assess those impacts, quantitative causal relationships are needed to relate the degree and extent of the contamination to physical, chemical, and biological processes to expected impacts. These relationships are most commonly expressed in predictive mathematical models.

Models provide cause and effect relationships as they impact the PDS and the interaction between the PDS and water quality, providing information for management decisions and site remediation. Models of PDS and water quality will also provide information for the assessment of impacts on biotic and human systems. Models also provide a quantitative framework for assessing the presenting understanding of PDS fate and transport and water quality interactions. The development process and subsequent applications as proposed under this Task are expected to aid in identifying gaps in available data and knowledge which may then lead to identifying and prioritizing future research to advance the state of the art and for the further protection of human and ecological health.

<u>Previous and ongoing projects that support this task</u>

- Integrated Assessment of Oil Spill (PI: William H. McAnally - NGI)
- A comprehensive assessment of oil distribution, transport, fate and impacts on ecosystems and the Deepwater Horizon oil release (PI: Steven Lohrenz - USM)
- Impact of DwH Oil Spill on the Louisiana Coastal Environments (PI: Susan Welsh - LSU)
- Gulf of Mexico Research and Resource Support Tools (GulfBase, Gulf of Mexico Biodiversity Project, Gulf of Mexico books, etc.; PI: Larry McKinney - HRI)
- Impact of Crude Oil on Coastal and Ocean Environments of the West Florida Shelf and Big Bend Region from the Shoreline to the Continental Shelf Edge (PI: Eric Chassignet - FSU)
- Impacts of the Deepwater Horizon Oil Spill on Ecosystem Structure and Function in Alabama (PI: John F. Valentine - DISL)
- Previous and ongoing model development activities for WASP (1983-Present) and hydrodynamic models
- Field and laboratory studies of conventional pollutants in Gulf Estuaries by study participants (e.g. 15 year transect in Barataria Bay, with data for nutrients, pigments, inorganic carbon by LSU, etc.)

<u>State of the Art</u>

The state of the art in modeling water quality and in modeling organic contaminants is well advanced. Eutrophication models are commonly used in the private sector and by the regulatory community for permitting and criteria development (such as nutrient criteria). The state of the art in modeling organic contaminants (such as PCBs, etc.) is also well advanced. However, the state of the art in modeling complex mixed-phase systems is much less advanced as is the modeling the interaction of PDS with sediment transport and water quality and the uncertainty associated with those model predictions. In addition, it is unfortunately presently not common practice to link results from water quality models to those of biota and human systems and activities or to use models as part of education and outreach. Those linkages are not well developed and are needed as part of the proposed holistic technical approach by the CoNGER. Oil-spill-specific models such as SIMAP (McKay et al. 2004) are proprietary and cannot be used as community models in the CEEM

<u>Approach</u>

The proposed research will integrate existing information on the fate and transport of PDS into a predictive model. The effort will build upon the public domain Water Quality Analysis Simulation Program (Wool et al. 2006), distributed by the USEPA. WASP has been under continuous development since the original version was developed by Di Toro et al. (1983), with Version 7.41 (release June 7, 2010) being the latest release (and a release of Version 8.0 planned for late 2011). The WASP modeling system is a public domain modeling system with many of the components needed for this effort already available. However, it is fully expected that model development and modification will be required and that the modeling system once developed be made publically available, which would preclude the use of proprietary modeling systems for this effort (e.g. such as SIMAP and comparable systems).

WASP is a dynamic compartment-modeling program for aquatic systems, including both the water column and the underlying benthos. WASP allows the user to investigate 1-, 2-, and 3-dimensional systems and the time-varying processes of advection, dispersion, point and diffuse mass loading, and boundary exchange . Transport information is commonly provided by hydrodynamic and sediment transport models that provide flows, depths, velocities, temperature, salinity and sediment fluxes. WASP submodels are then coupled to the generalized transport scheme, with kinetics specific to classes of pollutants. WASP submodels are presently available for heat, coliform bacteria (pathogens), eutrophication (cycling of dissolved oxygen, nutrients, and aquatic plants), mercury, metals and metal speciation, and organic chemicals.

This effort will build upon the WASP submodel for organic contaminants. The organic chemical model (formerly called TOXI WASP) was originally developed for the assessment of volatile organic chemical pollution in the Delaware River (Ambrose 1987) but has subsequently been applied to a variety of organic chemicals at sites across the world. The model is generalized so that it is applicable to a variety of ionic and non-ionic organic chemicals. Dynamic (time-varying) processes in the model include:

- Equilibrium Processes
- Sorption
- Ionization
- Kinetic Processes
- Volatilization
- Photolysis
- Hydrolysis
- Bacterial Degradation
- Oxidation
- Reduction

The WASP model can presently simulate multiple chemicals, such as petroleum mixtures, and multiple solids types and can allow for simulation of transformation and daughter products. Process that will be considered in the model development include (but are not limited to): multi-phase transport and transport via spreading, advection, weathering, emulsification; entrainment of and/or sorption to sediments and subsequent impacts on transport, coastal beaching, deposition, burial; and, sediment diagenesis (Figure 2.1).

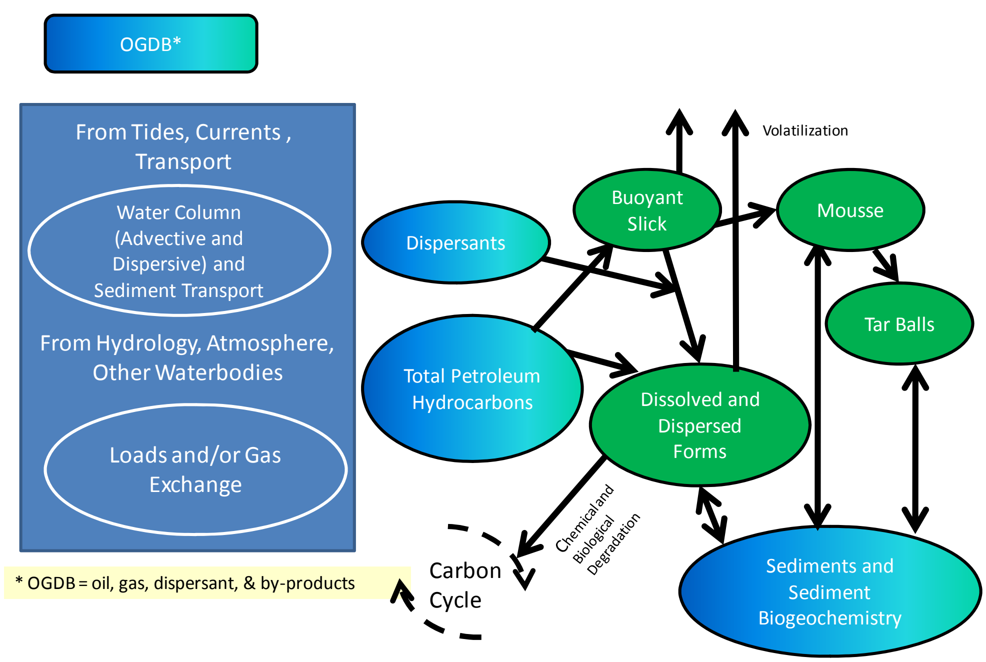


Figure 2-1. Potential pathways and processes for modeling PDS.

An additional advantage of recent versions of WASP is that each of the submodels can pass information to, and receive information from, other submodels through library functions. For example, the WASP eutrophication model can be used to provide biotic solids (e.g. such as for sorption onto plankton) for the organic chemical model or PDS model. Similarly, the proposed model structure will allow for feed-forward, and potentially feed-back, relationships, such as the impact of PDS degradation on oxygen and nutrient cycling and/or on toxicity to aquatic plants. These computations may also then be used to aid in assessing ecological impacts.

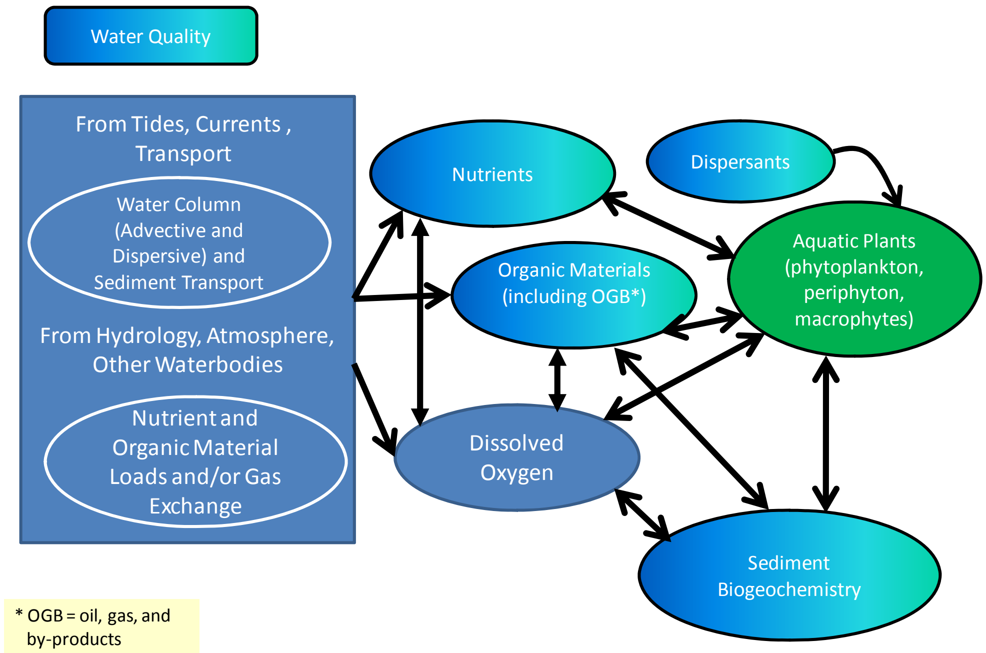


Figure 2-2. Potential feed-back mechanisms between modeled components

WASP models are presently available for many Gulf estuaries and can be used as a basis for this application. Ongoing or recent WASP (and the EFDC hydrodynamic model) applications include the Back Bay of Biloxi, MS (MDEQ 2002 and ongoing studies by MDEQ, pers. comm.); Bay St. Louis, MS (MDEQ 2001, Huddleston et al. 2007, and ongoing studies by MDEQ and MSU), Escatawpa and Pascagoula Rivers, MS (Rodriguez-Borrelli et al. 2006); Mobile Bay, AL (Wool 2003, Wool et al. 2003, McAnally et al. 2007, Martin et al. 2008, Tetra Tech 2008, Diaz et al. 2008, Alarcon et al. 2009, Aziz et al. 2009, and ongoing studies); Weeks Bay, AL (ongoing studies by GOMA), Tampa Bay, FL (Wang et al. 1999 and ongoing studies by GOMA) and many others. The WASP model is presently planned for use in Florida to estimate site-specific nutrient criteria for all Florida estuaries (MDEQ pers. comm.). Other and inland applications include Lake Okeechobee, FL; eutrophication of the Neuse River Estuary, NC; eutrophication Coosa River and Reservoirs, AL; PCB pollution of the Great Lakes, eutrophication of the Potomac Estuary, kepone pollution of the James River Estuary, volatile organic pollution of the Delaware Estuary, heavy metal pollution of the Deep River, North Carolina, and mercury in the Savannah River, GA (USEPA 2010). The majority of existing applications to Gulf estuaries and coastal waters are (or were) for eutrophication related issues (hypoxia, HABs nutrient criteria development, TMDLs, etc.).

Sub-Task 2.1: Needs Assessment

Subtask Leads: Milroy, USM; Justic and Chen, LSU; and Martin, MSU

Under this task, the specific needs and uses of the tools and model structure will be developed in coordination with all other tasks. Specific information that will be obtained from, or passed to, other tasks (physical, biotic, human systems, etc.) will be delineated in terms of magnitudes and spatial and temporal resolution. Specific modeling objectives will be delineated, and data requirements for model initialization, calibration, and validation (to include model boundary conditions) will be identified. The specific needs and objectives will directly impact the model design.

Sub-Task 2.2: PDS Model Design

Subtask Leads: Martin and Mark Bricka, MSU; Justic and Chen, LSU; Scott Milroy, USM; Crocker, ERDC

Under this task the PDS model and associated tools will be designed. Since the modeling system will be based on an established model, much of the architecture needed is complete. The PDS model will also be based, where applicable, on existing models and modeling methods for PSD. Specific design questions, in terms of processes to be included in the model, involve (but are not limited to):

PSD model design

- Identification of the optimal method, such as gravity-viscous formulations, to simulate sheens and sheen spread
- Identification of the number of state variables required to adequately characterize the petroleum mixture and dispersants
- Identification of the requisite transformation and kinetic processes that need to be included, which may vary with concentration (e.g. between zeroth and first order kinetics)
- Identification of available and known constants and coefficients associated with the transformation and kinetic processes
- Identification of the variability in transformation and kinetic constants and coefficients, as they impact uncertainty in model predictions
- Identification of the optimal way to predict weathering and emulsification, both in terms of chemical and biological processes and physical transport
- Identification of optimal ways to incorporate entrainment of PDS and sediment transport, deposition and beaching
- Identification of factors impacting aerobic and anaerobic degradation of PDS in sediments and whether the existing model of sediment diagenesis is applicable
- Identification of optimal methods to incorporate impacts of PDS transformation and kinetic processes on water quality (eg. hypoxia, toxicity to algae, etc.)
- Design of necessary feed-forward and potentially feed-back mechanisms
- Design of methods for linkages with biological effects

QA/QC design

- Determine and apply QA/QC methods for code development to include tests against analytical solutions, line-by-line execution, etc.
- Develop QA/QC design for model performance/fidelity
- Development of systematic methods for testing various aspects of the model
- Development of statistical and graphical methods for model evaluation
- Development of acceptance criteria

This task will build on the Management Plan's QA/QC statement.

Sub-Task 2.3 Integration (with Physical Models)

Subtask Leads: Martin and Alarcon, MSU; Chapman, ERDC

Under this task, the physical models (hydrodynamics) will be linked with the WASP models for the selected study sites (Barataria/Wax Lake, Mississippi Sound/Bight, Perdido Bay, Apalachicola Bay) as applied under Task 1. The WASP structure is indirectly linked with hydrodynamics models. That is the WASP reads and the hydrodynamic information (depths, velocities, volumes, etc.) from a linkage file generated by the hydrodynamic model. For Perdido Bay the hydrodynamic model to be used is EFDC for which the linkage structure exists. For the remaining systems, the applied hydrodynamic models will be modified to develop a hydrodynamic linkage file, the WASP model will be set-up and tested for compatibility and mass conservation. This task will be performed with the Informatics Task so that the linkages will apply to all modules in the community CEEM.

Sub-Task 2.4: PDS Model Development

Subtask Leads: Martin, Bricka, Alarcon, MSU; Chapman, ERDC; Justic and Chen, LSU

Under this task the PDS model and associated tools will be developed based upon the design requirements established under Sub-Task 2.2. The design of the PDS model will be modular in structure, which would allow the module to not only be incorporated into the WASP model but other water quality or hydrodynamic/water quality models (e.g. EFDC). The task will include, but not be limited to, the following subtasks:

- Software analysis and design
- Design of stand-alone modules for PDS transformation and kinetics (based on WASP architecture)
- Development of test cases with known or analytical solutions (as delineated in model QA/QC planning) and code testing (e.g. against test cases and in line-by-line execution)
- Integration of the model into WASP and associated GUI
- Model testing of the combined model

Sub-Task Task 2.5. Development, Evaluation and Compilation of Data

Subtask Leads: Martin, MSU; Barataria/Wax Lake, Bentley, LSU; Mississippi Sound/Bight, Howden, USM; Perdido Bay, Cebrian, DISL; Apalachicola, Coleman, FSU

Under this task, in concert with Tasks 2.1-2.3, data requirements for the model(s) (water quality and PDS) will be delineated based on project objectives and critical time scales associated with effects and remediation. All available, known upcoming (e.g. TMDL studies of Perdido Bay, etc.), and historical model applications to the study sites will be reviewed as they may contribute to this study. Specific sub-tasks will include, for both the conventional water quality and PDS model:

- Assembly of Boundary Condition Data
- Assembly of Initial Condition Data
- Assembly of Calibration and Evaluation data
- Development of Model Input

Data requirements will also include information to be obtained from other study tasks (e.g. Task 1: Physical Processes) and data to be passed to other study tasks.

The data requirements will first be identified and then compiled for each of the potential sites for model application as described under Sub-Task 2.5 and Task 6 (Site-specific Studies). Data deficiencies will be identified for subsequent input to data collection efforts.

An objective of this study is to determine the primary processes by which PDS in aqueous and sedimentary environments move, interact with sediment and water organics and inorganics to change and affect water quality, and contact biota. A number of these processes and their associated rates are poorly understood and poorly quantified. Therefore, an additional component of the study will be coordination of field and laboratory studies conducted under Task 6 to quantify certain rates, such as rates of PDS decomposition under aerobic and anaerobic conditions in the water column and sediments.

Sub-Task 2.6. Sediment Transport and Water Quality Model Application

Sub-task Leads: McAnally NGI; Martin, MSU; Barataria/Wax Lake, Justic and Chen, LSU; Mississippi Sound/Bight, Chapman, ERDC; Perdido Bay: Martin, MSU; Apalachicola: Morey, FSU

Under this sub-task, performed in concert with Sub-Task 2.7, the conventional WASP model (to include sediment transport) will be applied to each of the selected study sites (Barataria/Wax Lake, Mississippi Sound/Bight, Perdido Bay, Apalachicola Bay) using data compiled in Task 2.4 and coupled with output from the physical models developed as developed and tested under Task 2.3. Specific subtasks include:

- Extension of the hydrologic model applied under Task I to the development of nutrient and carbon loadings and incorporation of point-source loads
- Establishing model input and evaluation data (calibration/evaluation) in a “model ready” format
- Model calibration and testing
- Adaptation of sediment transport models/algorithms for application
- Development and testing linkages from (or to, for the case of toxicity) the water quality and sediment transport model to the PDS model
- Development and testing of linkages between the sediment transport and water quality (and subsequent PDS model) and CEEM Tasks (1,3,4)

Sub-Task 2.7: Model Applications

Subtask Leads: Martin, MSU; Barataria/Wax Lake, Chen and Justic, LSU; Mississippi Sound/Bight, Chapman, ERDC; Perdido Bay: Martin, MSU; Apalachicola, Steve Morey, FSU

Under this task the modeling system will be applied to the selected Northern Gulf of Mexico (NGoM) ecosystems. Each system has varying characteristics and limitations which, when combined, will aid in the testing and further development of the modeling system. The applied and tested models can then be used to address the overall study questions and objectives as described at the beginning of this proposal.

The applications will consist of the

- The initial testing and validation (to the extent possible) of water and constituent mass balances
- Initial calibration and evaluation of the model
- Refinement of the model as necessary
- Model validation (to the extent possible)
- Conducting a sensitivity analysis and limited uncertainty analysis to identify greatest contributors to model uncertainty such as to aid in guiding subsequent research
- Creation of linkages to other CEEM components (Task 1, 3,4)

Sub-Task 2.8 Data Management – Alarcon, MSU

Objective

2.1.1 Arrange for all production model results of PDS/Water Quality processes to be stored and to be forwarded to GRI in conformance with the Data Management Plan and in coordination with the Project Data Manager.

Approach

The Data Management Plan and Task 5.1 describe the project’s data management policies and procedures. Production model results from all the models used in Task 2 will be stored in a standard format with complete metadata and made available as soon as possible after results are published.

Deliverables (By subtask)

2.1 Needs Assessment report
2.2 PDS Model Design Document
2.3. Model Integration and Testing report

2.4. PDS Model and User Documentation (written as a supplement to the WASP user documentation)
2.5. Model Application reports and papers, one for each application with an overall introduction and integration report.
2.6. Integration memoranda and files for other project tasks.
2.7 Time-varying, 3D PDS/water quality model results over the modeled estuaries for use in other tasks and for archiving

Schedule

| MILESTONE | DATE COMPLETE |
|---|---|
| 2.1 Needs Assessment | 4/2012 |
| 2.2 PDS Model Design | 10/2012 |
| 2.3. Integration (with Physical Models) | 7/2012 |
| 2.4. PDS Model Development | 6/2013 |
| 2.5. Development, Evaluation and Compilation of Data | 8/2012 |
| 2.6. Sediment Transport and Water Quality Model Application** | 9/2013 |
| 2.7. PDS Model Applications** | 7/2013 |

** Output from these tasks will be coordinated and provided to other tasks as needed but prior to the final task completion dates

**Task 3: CEEM: Biotic Processes**

TASK LEADER(S): Just Cebrian (DISL) & Scott Milroy (USM-DMS)

MEMBERS: Cebrian and Graham, DISL; Bartell, E2; Kimbro and Coleman, FSU; Huo, Bargu, and Rose, LSU; Milroy, Redalje, and Gunderson, USM; Martin, MSU; Fulford, EPA

OBJECTIVES

3.1. Develop the biotic component of the CEEM ecosystem model designed to address issues regarding the impact of the Deepwater Horizon Oil Spill and interactions with other stressors (*e.g.* freshwater diversion, nutrient pollution) on habitat quality, food web stability, and fisheries production. In particular, modeled impacts on fisheries production will focus predominantly on Eastern Oyster (*Crassostrea virginica*), Blue Crab (*Callinectes sapidus*), Penaeid Shrimp, and select ecologically- and commercially-important fishes specific to the proposed CoNGER research sites.

3.2. Develop a research program focusing on data gaps regarding the response of microbial, phytoplankton, and zooplankton processes to Petroleum/Dispersant Systems (PDS) in support of objective 3.1.

3.3. Integrate the resulting biotic model with physical and PDS/WQ models to allow for comprehensive examination of oil spill effects and interactions with other stressors in NGoM.

BACKGROUND

Previous and on-going biotics research in NGoM ecosystems (NGI-BP rapid funding Phases I & II), conducted by those investigators identified as primary collaborators in the CoNGER, will provide critical initialization data and boundary conditions for the highly-integrated models proposed herein. Specific to the biotic processes, model development to date (NGI-rapid funding Phase II) has been structured around three workshops scheduled for 2011-2012. These model workshops are intended to bring together a wider group of researchers with modeling expertise to obtain input on model development and to elicit peer-review of the results in real-time.

The initial modeling workshop was held in January 25-26, 2011 at the Gulf Coast Research Laboratory in Ocean Springs, MS. The general intent of this workshop was to develop a conceptual model structure integrating physical, chemical, biological, and human-dimensions compartments, as well as to enumerate a candidate list of drivers connecting the compartments that will form the basis for model analysis and model output. The workshop was attended by members of two primary groups: the NGoM modeling community and those researchers currently investigating ecological impacts of the oil spill. The specific objectives of the workshop were to: (1) decide on a broad model framework (*e.g.* ECOPATH, ATLANTIS, possible others); (2) develop a list of functional groups and metrics for the ecological compartment, as well as sources for this list; and (3) develop a list of drivers (*e.g.* hypoxia) into the ecological compartment to be converted into model output (*e.g.* effects of hypoxia on tolerance to oil exposure) that will integrate model development into current research.

Currently, the core team is working together to parameterize the food web component of the model based on the Comprehensive Aquatic Systems Model (CASM) framework (Bartell, E2 Consulting Engineers) and to link the ecological compartment of the model with existing hydrodynamic tools available for Barataria Bay (Site Lead Bentley), Mississippi Sound (Site Lead Howden), Perdido Bay (Site Lead Cebrian), Apalachicola Bay (Site Lead Coleman), and the Gulf of Mexico boundary conditions (Leads Chassignet & Harding). The final two model workshops will focus on model refinement (Fall 2011) and validation (early 2012) of the ecological compartment of the model and linkages with hydrodynamic forcing, and will allow for continued feedback from past workshop participants and resource managers.

<u>State of the Art</u>

There are a number of numerical models for biotics, with the best known arguably being Ecopath (with extensions), Atlantis, and CASM. Under the ongoing work the team examined a number of those models and concluded that Ecopath did not provide all the desired capabilities and that Atlantis will require more than three years to apply. (Cebrian et al. 2011) Based on a balance of capabilities, opportunity to modify, CASM was selected by that team and will be continued here.

CASM is tremendously powerful and allows site-specific estuarine/coastal ecosystems models (all based on CASM architecture) to be customized to include several different members within each functional group, and several different functional groups within several different ecosystem guilds. Physio-chemical forcings can also be customized for site specificity; however, general inputs are the dissolved nutrient pools (DIN, DIP, Si), important dissolved and particulate chemical species (PDS, DOC, DIC, POC, TSS, DO), spectral light (either from Secchi depth or diffuse attenuation coefficient data), standard hydrographic data (Temp, Sal, Density, Depth), and 3D currents ($u$,$v$,$w$). The existing I/O subroutine can be programmed to generate custom forms of the output, so any intrinsic or external variable calculated within CASM can be output at any time interval for sensitivity analyses of each variable.

Primary CASM Outputs & Features:

- Daily depth-integrated biomass (g C $m^{-2}$) for each functional group
- Community diversity for defined communities of interest (*e.g.* primary producers, etc.)
- Any other intrinsic/external CASM variable (via customized I/O subroutine)
- Outputs may be sorted/combined to produce qualitative “Ecosystem Goods and Services” results (based on categories defined in the Millennium Assessment Report)
- Horizontal (spatial) resolution is fully customizable
- Vertical resolution has two layers (epilimnion & hypolimnion) to allow for stratification
- Time step is typically 0.1 day, but is fully customizable (for model integration)
- Proposed simulation horizon is 10-20 years, although CASM has been run for 55 years in several applications without loss of stability

<u>APPROACH</u>

Development of an ecosystem model is by nature a collaborative activity that capitalizes on multiple sets of expertise, as well as multiple sets of perspectives about model architecture, initialization, calibration, and validation. Model development is an iterative process involving numerous opportunities for external review and comment separated by model refinement and data analysis. For this project, emphasis is placed upon understanding oil spill impacts at the ecosystem level, which requires both the integration of ongoing compartment-specific research into the model as well as looking at synergistic effects that extend across individual compartments. This will be accomplished with a team approach which is centered on a core group responsible for each compartment of the model in conjunction with a thoroughly dove-tailed plan for integration across all compartments of the model. The core group for the ecological compartment will be comprised of numerical modelers and ecosystem scientists from five gulf coast institutions (USM, FSU, DISL, MSU, LSU, and EPA). Members of this core will work together to adapt a general model framework (*q.v. general model structure* section below) into a synthetic product.

*General model structure* – The model developed as a part of this project will build upon the expertise of the overall team members to adapt existing model frameworks to the specific objectives of this project. Ecosystem models take many forms, but most involve the spatial analysis of how natural commodities (*e.g.* energy) move through the ecosystem. The most straightforward are food web models that track carbon movement through the food web as a measure of ecosystem connectivity. Food web models can be powerful tools for ecosystem management, as a myriad of ecosystem influences (*e.g.* fishing, shoreline development, climate change) can be expressed in terms of their impacts on food web interactions. They can also be used as a springboard to develop holistic macro-models integrating physical, chemical, and human-dimension compartments such as the macro-model proposed herein. For instance, climate change can be incorporated into food web models based on the impact it can have on species diversity and habitat quality, as trophic level production and connectivity. Such models are relatively simple when one considers the wide variety of impacts that must be considered, yet they are powerful tools for understanding ecosystem responses that may be non-linear and synergistic. One key limitation of food web models is their inability to account for 'non-trophic' responses, such as alterations in nutrient availability or toxicological impacts. Nonetheless, food web model structure can be adapted to account for non-energetic influences. The objective of this study will be to develop a general ecosystem model that is based upon carbon movement throughout the food web, but adapted to examine whatever non-energetic drivers are identified as important.

The holistic model framework linking physical, chemical, ecological, and human-dimension compartments together will emerge from the CASM (Figure 3.1). The model will be designed to address ecological questions related to the oil spill and interactions with other environmental stressors in the northern Gulf of Mexico, thereby taking maximum advantage of ongoing BP-funded oil spill research at NGI. To that end, the broad focus of the model analysis will be on probable impacts of the oil spill, arranged as Sub-tasks 3.1 to 3.6, listed below.

The overall Biotic Processes Task team will compile these results into a broader analysis and examine synergistic effects not considered by the individual studies.

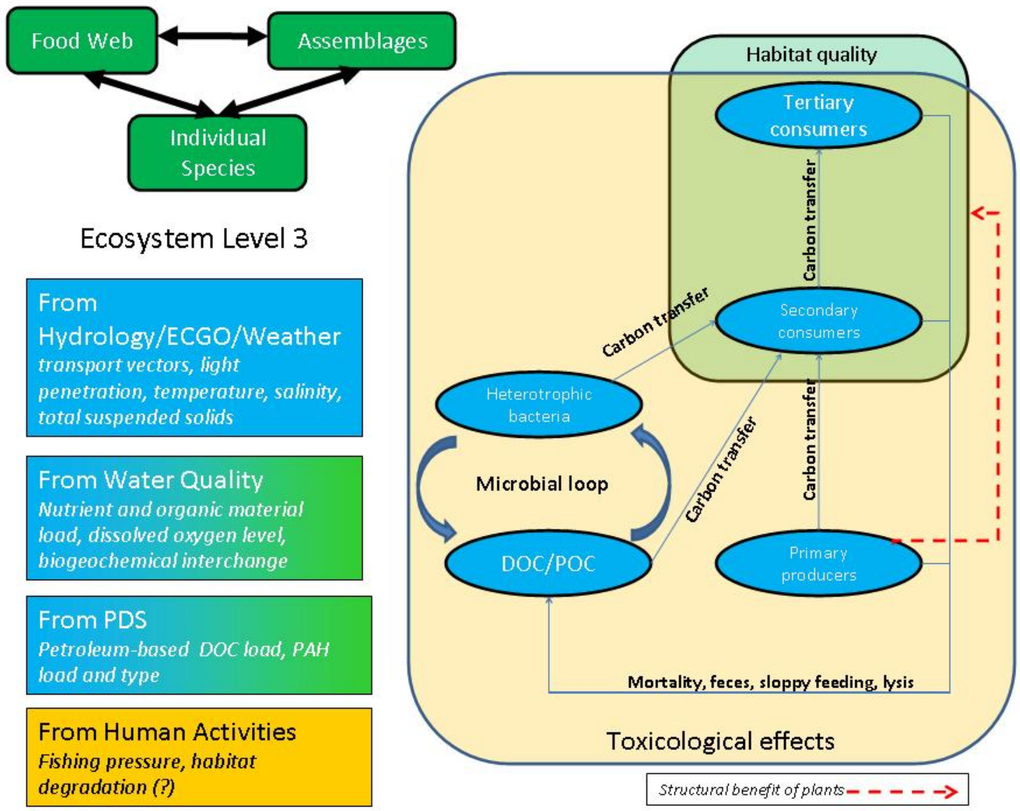


Figure 3.1. The detailed feedback mechanisms within the ecological compartment of the proposed model, coupled with the physical, chemical, and human-dimension components. Note that the structure of the ecological model has been designed to provide answers to the Sub-tasks.

All Sub-tasks listed below will be accomplished in such a way as to address the questions and objectives posed for the overall CoNGER proposal. Within the sub-tasks Preliminary Questions (PQ) will be addressed based on previously-funded (NGI-BP rapid funding Phases I & II) research and/or projects proposed as an integral part of the CoNGER. Data acquired to address PQs will be used to structure CASM simulations to investigate a series of Focal Questions (FQ) regarding more specific interactions between PDS and other environmental stressors and their effects on the target living resources named in the objectives of the Biotic Processes Task (Task 3). The main Biotic Processes Sub-tasks shall explore:

Sub-Task 3.1 Trophic Perturbations and Functional Group Mortality due to Oil Exposure

Investigate the magnitude and consequences oil-induced mortality to target living resources (PQ), which shall lead to parameterization of CASM to simulate trophic disruption(s) for specific functional groups, or as a cascading effect throughout multiple functional groups and across multiple ecosystem guilds (FQ). Model fidelity shall be augmented by the incorporation of data from toxicity assays for relevant functional groups and the associated field/laboratory work.

Sub-Task 3.2 Alteration of Microbial Processes

Determine the enhancement or depression of microbial respiration of oil hydrocarbons (PQ) as a driver of decreased carbon cycling, potential "bottom-up" trophic enhancement, and heterotrophy/hypoxia (FQ). Model simulations shall require oil-based carbon food stocks with factors for bioavailability, bioconversion, and dispersant use within the microbial respiration; initialization data and/or model structure shall depend upon field/lab assessments of microbial respiration and remediation dynamics.

Sub-Task 3.3 Changes in Primary Producer Communities

Determine the reductions of (or other oil-associated impacts on) the community structure and productivity of primary producers (PQ) as a result of decreased photosynthetic efficiency, reduced biomass/biodiversity within the primary producer communities, or regime shifts in the consumer populations (FQ). Model simulations shall build upon previous sub-tasks and incorporate alterations to the food web base and other "bottom-up" effects. Model fidelity will require extensive field assessments of primary producer community structure, dynamics, and net productivity.

Sub-Task 3.4 Changes in Consumer Communities and Larval Recruitment

Quantify the changes in consumer community structure and age class due to potential limitations on larvae production and/or recruitment (PQ), as evidenced by potential year-class losses and prey base reductions in coastal food webs (FQ). Alteration of biomass in early life sub-pools (and the trophic connectivity of those sub-pools) will require model simulations informed by extensive surveys of zooplankton diversity, biomass, nutrient status, and overall ecosystem function.

Sub-Task 3.5 Cascading Effects of Oil + Fishing Pressures on Commercially-important Fisheries

Investigate changes in commercially-important fisheries (PQ) relevant to potential oil impacts (from any number of the Sub-tasks listed above) or abatement of fishing pressures in 2010 (FQ). Evidence of these impacts will be manifest in the fisheries landings and/or CPUE data acquired from resource managers for each of the Sites listed in the CoNGER. These data will ultimately be used to inform CASM initialization and conduct calibration/validation of CASM simulations of fisheries production for those target species cited in the Task 3 objectives.

Sub-Task 3.6 Impacts on Ecosystem Services and Habitat Quality

Simulate the overall impacts of oil on NGoM ecosystem services and habitat quality (PQ), as a complex interaction between those forcing functions within CASM and integrated with physical, chemical, and petroleum/dispersant systems CoNGER models (FQ). These will be the ultimate model outputs and forecast products, to assist resource managers to evaluate the far-reaching ecological and financial ramifications of the oil spill in the NGoM. It will be coordinated with Task 4. Ecosystem Services.

Sub-Task 3.7 Data Management – Milroy, USM

Objective

3.7.1 Arrange for all production model results of biotic processes to be stored and to be forwarded to GRI in conformance with the Data Management Plan and in coordination with the Project Data Manager.

Approach

The Data Management Plan and Task 5.1 describe the project's data management policies and procedures. Production model results from all the models used in Task 2 will be stored in a standard format with complete metadata and made available as soon as possible after results are published.

Deliverables (as products of the enumerated Sub-tasks)

3.1 Assessment of Functional Group Mortalities due to Oil Exposure
- Compiled from existing NGI-BP Phase I & II data of CoNGER participants
- Data disseminated to CoNGER (and larger GRI community) via Informatics Task

3.2 Field/Laboratory Assessments of Microbial Processes & Alterations

- Continuing in situ counts of microbial biomass and/or abundance
- Field/Laboratory data of microbial remediation dynamics under "natural" vs. petroleum/dispersant systems; BOD analyses
- Data disseminated to CoNGER (and larger GRI community) via Informatics Task
- Parameterization of microbial dynamics within CASM
- CASM calibration/validation of microbial dynamics
- CASM simulation output and sensitivity analyses of microbial dynamics in the larger context of ecosystem function and habitat quality

3.3 Field/Laboratory Assessments of Primary Producer Processes & Alterations

- Continuing in situ surveys of primary producer biomass, abundance, & diversity (to include emergents and SAV where applicable)
- Field/Laboratory data of primary producer nutrient status and net productivity
- Data disseminated to CoNGER (and larger GRI community) via Informatics Task
- Parameterization of phytoplankton/emergent/SAV dynamics within CASM
- CASM calibration/validation of phytoplankton/emergent/SAV community dynamics
- CASM simulation output and sensitivity analyses of phytoplankton/emergent/SAV dynamics in the larger context of ecosystem function and habitat quality

3.4 Field/Laboratory Assessments of Consumer Community Recruitment, Processes, & Alterations

- Continuing *in situ* surveys of holo/meroplankton biomass, abundance, & diversity (with specific focus on larvae of relevant target species)
- Field/Laboratory data of holo/meroplankton nutrient status- Data disseminated to CoNGER (and larger GRI community) via Informatics Task
- Parameterization of holo/meroplankton community dynamics within CASM
- CASM calibration/validation of holo/meroplankton community dynamics
- CASM simulation output and sensitivity analyses of holo/meroplankton community dynamics in the larger context of recruitment, age structure, ecosystem function, and habitat quality

3.5 Cascading Effects on Commercially-important Fisheries

- Continuing data acquisition/compilation from state resource managers regarding target commercially-important fisheries landings, age-structure, year-class, CPUE, etc.
- Data disseminated to CoNGER (and larger GRI community) via Informatics Task- Parameterization of fisheries data within CASM
- CASM calibration/validation of fisheries trends/impacts
- CASM simulation output and sensitivity analyses of fisheries trends/impacts in the larger context of recruitment, age structure, ecosystem function, and habitat quality

3.6 Model Simulations of Impacts on Ecosystem Services & Habitat Quality

- Continuing sensitivity analyses and synthesis of CASM output regarding overall effects of DWH oil residuals on the ecosystem services and habitat quality of the NGoM
- Data disseminated to CoNGER (and larger GRI community) via Informatics Task
- CASM calibration/validation of ecosystem services and habitat quality
- CASM refinement; analyses of near-term hindcasting vs. long-term forecasting capabilities
- Gap analysis for CASM refinement; adjustment of CoNGER Tasks to improve model fidelity

Schedule

| MILESTONE | DATE COMPLETE |
|---|---|
| 3.1 Compilation of NGI-BP Phase I & II data relevant to Sub-task 3.1 | 1/2012 |
| 3.2 Microbial Processes – Field Assessments & Data Dissemination | QUARTERLY |
| 3.2 Microbial Processes – CASM Model Structure Completed | 4/2012 |
| 3.2 Microbial Processes – CASM Model Calibration/Validation | UPDATED QUARTERLY |
| 3.3 Primary Producers – Field Assessments & Data Dissemination | QUARTERLY |

| | |
|---|---|
| 3.3 Primary Producers – CASM Model Structure Completed | 7/2012 |
| 3.3 Primary Producers – CASM Model Calibration/Validation | UPDATED QUARTERLY |
| 3.4 Holo/Meroplankton – Field Assessments & Data Dissemination | QUARTERLY |
| 3.4 Holo/Meroplankton – CASM Model Structure Completed | 10/2012 |
| 3.4 Holo/Meroplankton – CASM Model Calibration/Validation | UPDATED QUARTERLY |
| 3.5 Fisheries Landings – Compilation of State-managed Resource Data | 1/2012, then QUARTERLY |
| 3.5 Fisheries Landings – CASM Model Structure Completed | 1/2013 |
| 3.5 Fisheries Landings – CASM Model Calibration/Validation | UPDATED QUARTERLY |
| 3.6 CASM Synthesis – Integration with other CoNGER Models | CONTINUOUS |
| 3.6 CASM Synthesis – First fully-integrated Simulations with CASM | 1/2013 |
| 3.6 CASM Synthesis – CASM Model Calibration/Validation | 1/2013, then REGULARLY |
| 3.6 CASM Synthesis – Complex CASM Sensitivity Analyses | 1/2013 |
| 3.6 CASM Synthesis – Revision of CoNGER Tasks/Sub-tasks as needed | 6/2013, then QUARTERLY |
| 3.2 – 3.6 Task/Sub-task Revisions – CoNGER revisions made | 1/2014 |
| 3.6 CASM Synthesis – 3-Yr Analysis of CoNGER model performance | 4/2014 |
| 3.6 CASM Synthesis – Synthesis, Conclusions, Forecasts, & Next Steps | 8/2014 |

**Task 4: CEEM: Ecosystem Services**

TASK LEADER(S): David Yoskowitz (HRI/TAMUCC) and Dan Petrolia (MSU)

COLLABORATORS: Matthew Freeman (MSU), Matthew Interis (MSU), Cristina Carollo (HRI/TAMUCC)

Objectives:

- 4.1. Identify primary ecosystem services in selected coastal and estuarine systems.
- 4.2. Produce data, tools, and models that describe ecosystem services under the conditions of Tasks 1-3.
- 4.3. Estimate effects on human well-being of changes in ecosystem services for the specific sites of interest.

Background:

Ecosystem services (ES) are the contributions that the natural environment makes that impact the human well-being (Daily et al., 1997; Boyd & Banzhaf, 2007; EPA Science Advisory Board, 2009; Millennium Ecosystem Assessment, 2005; Yoskowitz, et al., 2010). Examples consist of storm protection and nutrient removal provided by marsh to recreational fishing opportunities and food provided by oyster reefs. Changes in the ecosystem conditions due to natural or anthropogenic influence will likely lead to a change in the quantity and quality of habitat linked ES.

HRI and NGI are focused on identifying, mapping, and quantifying the values of ecosystem services (ES) that occur in the Gulf of Mexico. The two institutions, with support from NOAA, held the first Gulf wide ecosystem services workshop in June of 2010. The multidisciplinary participants identified Gulf specific ES and then assigned them to Gulf habitats using the Coastal and Marine Ecological Classification Standard (CMECS) (Yoskowitz et al, 2010). Additionally, the Gulf of Mexico Ecosystem Services Valuation Database (GecoServ), which was developed by HRI, has allowed the cataloging of relevant studies as well as a gap analysis (Santos et al., in press).

Approach:

Defining ES requires a multidisciplinary approach involving natural and social scientists in order to meet the first objective. Working with the science teams at each of the four study sites and following the recommendations made at the Gulf of Mexico Ecosystem Services Workshop in June of 2010 (Yoskowitz et al, 2010), habitats will be classified using CMECS and ES will be attributed to the classified habitat in a geospatially explicit manner. The approach is shown in Figure 4.1. Ecosystem service data layers will be generated in a GIS and used as input in the tool development.

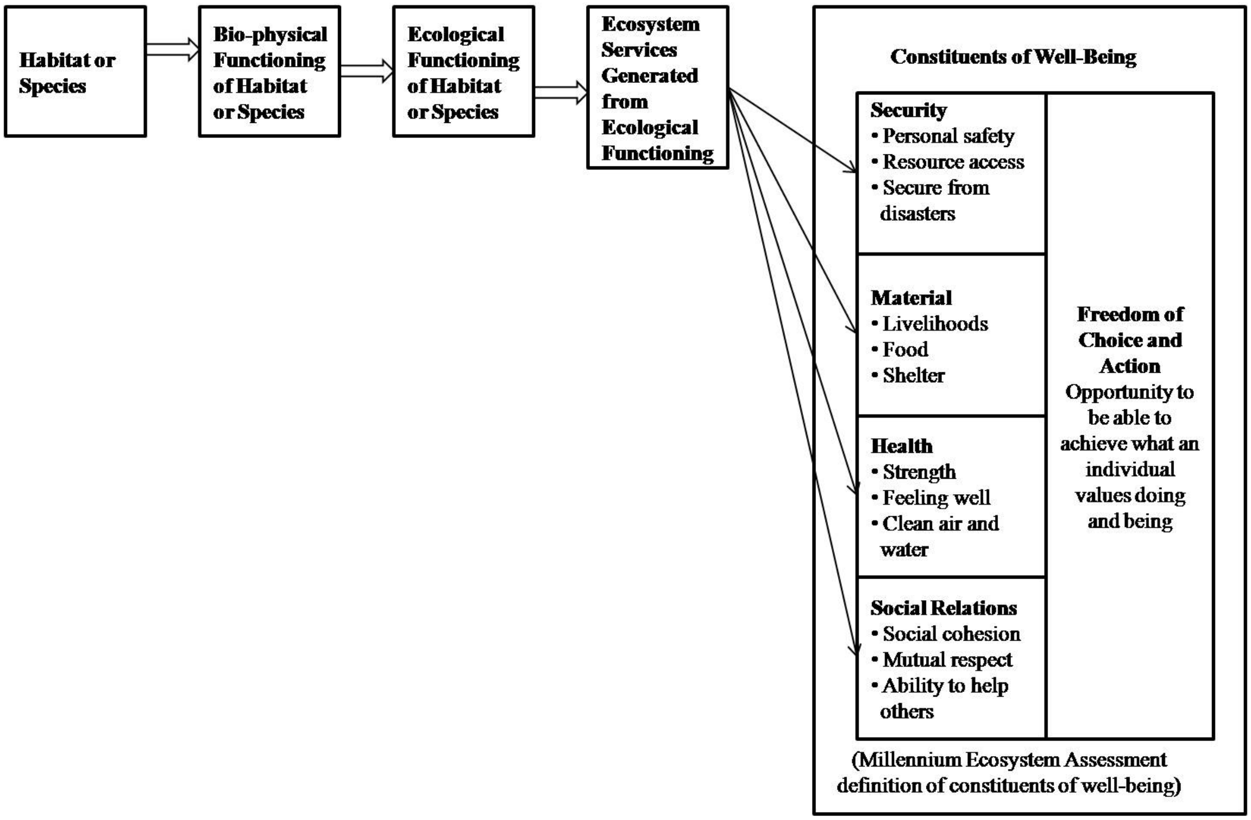


Figure 4.1. Ecosystem Services Provisioning

The approach will be to link ecological functioning to ES provisioning and the impact on human well-being. CoNGER will accomplish this by looking within and between three of the study sites most directly impacted by the oil spill for commonalities and differences from which predictions can be made.

Output from Tasks 1-3 and site specific characteristics of the ecosystem will lead to the development of a mechanistic ecosystem services production function (ESPF) that have been similarly developed in terrestrial systems (Barbier, 2007; Daily et al., 2009, Tallis and Polasky, 2009) to meet objective two. Estimating the impact on human well-being given a change in ES provisioning will be accomplished through a variety of metrics including ecosystem service valuation (ESV) and bio-physical rankings (EPA, 2009). To view the output geospatially CoNGER will leverage the Gulf of Mexico Alliance Spatial Viewer (currently in development) by building a specific ES module in collaboration with the Informatics Task 5.

Following the identification of key ecosystem services by site and habitat in Objective 4.1 and in coordination with the tools developed in Objective 4.2, ecosystem service valuation models will be developed to estimate changes in human well-being. These models will use as inputs the results of system disturbances modeled in Tasks 1-3. Because well-being derived from ecosystem services manifests itself both in market transactions and as non-market services, the models developed will rely on both stated- and revealed-preference economic valuation methods, as appropriate. These methods include, but are not limited to, contingent valuation, contingent behavior, discrete choice experiments, the travel cost method, and hedonic pricing.

CoNGER proposes to focus this work on three of the four research sites: Barataria Bay, Mississippi Sound, and Perdido Bay. This work will build upon recent and ongoing NGI research focused in two of the proposed sites: Barataria Bay and Mississippi Sound.

Ongoing work in Barataria Bay applies a dual stated-preference method approach (contingent-valuation and choice-experiment) to estimate changes in human well-being for proposed coastal restoration policies, which explicitly models three key ecosystem services: flood/storm surge hazard mitigation, commercial and recreation fisheries productivity, and provision of wildlife habitat (Petrolia, Interis, and Hidrue 2011). Related Northern Gulf Institute work found flood/storm surge mitigation to be the ecosystem service driving changes in well-being due to changes in Louisiana's coastal wetlands (Petrolia and Kim 2011; Petrolia, Moore, and Kim 2011). Recent work on Mississippi Sound includes application of the contingent valuation method to estimate changes in well-being of Mississippi residents under alternative barrier-island restoration regimes (Petrolia and Kim 2009). This work also maps changes in well-being to a generalized set of ecosystem services: flood/storm surge mitigation, recreational opportunities, and habitat provision.

All data generated from this task will be made available to the CoNGER and will be submitted upon the completion of the QC/QA process.

<u>Sub-Task 4.1: Identify ES in the study sites for the habitats/species of interest.</u>

Lead: Yoskowitz; Collaborators: Petrolia, Interis, Freeman, Carollo

<u>Sub-Task 4.2: Develop new GIS layers of ES for the study sites by the various habitats.</u>

Lead: Yoskowitz; Collaborators: Carollo

<u>Sub-Task 4.3: Develop ecosystem service valuation instruments for the site-specific ES identified.</u>

Lead: Petrolia; Collaborators: Interis, Yoskowitz, Freeman

<u>Sub-Task 4.4: Collect data required to estimate valuation models.</u>

Lead: Petrolia; Collaborator: Interis, Freeman

<u>Sub-Task 4.5: Estimate the impact of ecosystem disturbances on human well-being using ecosystem service valuation methods.</u>

Lead: Petrolia; Collaborators: Interis, Yoskowitz, Freeman

<u>Sub-Task 4.6: Develop a mechanistic ES production function that utilizes input from Tasks 1-3 and 4.1,4.2, 4.5.</u>

Lead: Yoskowitz; Collaborator: Petrolia, Carollo

<u>Sub-Task 4.7: Develop the ES module for the Spatial Viewer for the three study sites in collaboration with the Informatics Task.</u>

Lead: Yoskowitz; Collaborator: Carollo, Amburn

<u>Sub-Task 4.8 Data Management </u>– Carollo, HRI

Objective

4.8.1 Arrange for all production model results of biotic processes to be stored and to be forwarded to GRI in conformance with the Data Management Plan and in coordination with the Project Data Manager.

Approach

The Data Management Plan and Task 5.1 describe the project's data management policies and procedures. Data collected as part of this task will be stored in a standard format with complete metadata and made available as soon as possible after results are published.

Deliverables

4.1 GIS layers identifying ecosystem services in each of the study sites.

4.2 Ecosystem services production function that is integrated into the CEEM.

4.3 Ecosystem service value estimates for each of the study sites.

4.4 Ecosystem services module for the Spatial Viewer.

Schedule

| MILESTONE | DATE COMPLETE |
|---|---|
| 4.1 Identified ES in the study sites | 6/2012 |
| 4.2 Developed new GIS layers of ES for the study sites | 12/2012 |
| 4.3 Developed ES valuation instruments | 4/2013 |
| 4.4 Collected data for valuation estimation | 6/2013 |
| 4.5 Estimated impact on human well-being | 9/2013 |
| 4.6 Developed mechanistic ES production function | 6/2014 |
| 4.7 Developed ES module for Spatial Viewer | 7/2014 |
| 4.8 Data immediately submitted upon completion of QC/QA | 9/2014 |

## Task 5. Informatics

TASK LEADER: Robert Moorhead. MSU

The goal of the informatics task is to provide advanced information technology to all other tasks in order to produce and share useful data, tools, and models that enable scientific discovery and creatively integrate research and education for the benefit of technical specialists, resource managers, and the general population.

Objectives

5.1. Provide requisite data management for the other tasks (Sub-Task 5.1)
5.2. Increase the coupling between selected models to decrease the time to solution (Sub-Task 5.2)
5.3. Advance the visualization, uncertainty analysis, and other data analysis tools of the science tasks (Sub-Tasks 5.3-5.6)
5.4. Provide the informatics support for the State of the Gulf Report Card (Sub-Task 5.6)

Sub-Task 5.1 Data Management

Members: Moorhead , MSU; Gayanilo, UM; Harding, NGI; and Data Management Leads from other Tasks.

The overall goals and approach are described in the Data Management Plan.

Sub-Task Objectives

5.1.1. Design, develop, and deploy a web-based common data portal to facilitate the encoding, archiving, and access of scientific data, raw and computed, generated by CoNGER
5.1.2. Establish data access, archival, and distribution protocols to ensure integrity of the system and data provenance.
5.1.3. Design, develop, and deploy information system components to facilitate the distribution of data and promote interoperability in the community models.

CoNGER Data Portal (CDP) System Design. CoNGER will commence with a series of meetings with task leads to review and assess the needs of each task (i.e. need assessment) and to review existing data portals. System functional requirements will be listed and prioritized. A prototype will be developed and presented to task leads to validate the functional requirements and system features. The prototype and the detailed functional requirements will be the basis for the design document for the CDP. Content Management System (CMS) and related technologies will be identified, resources will be allocated, development strategies (iterative spiral process) will be programmed, test and module validation procedures and deployment schedules will be prepared. Standards (metadata, vocabularies, ontology) will also be reviewed and agreed upon.

Component Development. CoNGER will acquire and install the required servers (development and production servers). To establish a community, an *Open Source* environment (Google, SourceForge) will be used throughout the development process. As modules are completed, they will be internally component-tested (within the Informatics Group) against the product specifications as stipulated in the design document. Integrated and system test to review the performance and against system level functional specifications will also be conducted. Moreover, a technical collaboration wiki (e.g. Confluence; http://www.atlassian.com/software/confluence/) will be installed and used to facilitate the exchange of ideas, mockups, diagrams, specifications, files and other technical materials.

An issue and programming defect tracker system (e.g. JIRA; http://www.atlassian.com/software/jira) will be installed to manage user feedbacks (bug reports, feature requests, general comments). When all observed defects have all been corrected and required features implemented, a BETA version will be released to the consortium for testing. The features of the first release will include all required features to submit data, edit metadata, modify attributes and explore collections. After all code modifications to correct defects, the version will be moved to a production server and the first operational version will be announced to the public.

Installation of Supporting Data Services. It is not the intent of the consortium to re-develop technologies that are already available and had gained recognition in the community. Several services will be reviewed and seamlessly integrated onto the CDP. This will include *Data Access Protocol* (DAP) servers, a software framework for a simple access to a remote scientific data as well as metadata editors used by scientists and data providers of the consortium.

CDP Data Catalogue and Search Engine. The CDP will include a standard search engine to extract data from metadata records and will be supplemented by a system-wide Data Catalogue. The Graphic User Interface (GUI) for the Data Catalogue, generic data search form and how the search results are returned will be designed jointly by the CoNGER scientists and GRI-AU to ensure that the portal can be navigated with ease and facilitates data discovery.

Installation of Web Services. To promote interoperability, *Web Services* will be developed for the repository using *Web Service Description Language* (WSDL) and *Simple Object Access Protocol* (SOAP) technologies as the standard protocol for machine-to-machine communication. The services will provide several functions that will include, among others, functions to list and describe the databases or collections in the repository, download full or partial data from a database (in XML), filter queried data by date/time, geographic location and or source. The testing will be done in close collaboration with CoNGER scientists and GR-AU identified representatives.

Technology Transfer and System documentation. The source codes of CDP will be made public via Open Source systems (e.g. *Sourceforge*, Google Codes) and will be promoted as such to gain community following among software developers who may be willing to share their modules and talents to add more functionality or improve the components. Beyond the life of the project, MSU is committed to provide the infrastructure that will be used during the project and will continue to be in service to the public and other scientists beyond the life of this project.

CoNGER will also document the system completely. This will include, among others: (i) Quick reference Guide, a short reference on the use of the CDP, (ii) CDP System Reference, a complete user and administrative reference to the use and application of the CDP, and (3) CDP Technical Documentation, a complete technical documentation of the data portal. Although CoNGER will actively participate in seminars, workshops and meetings to promote the products and obtain feedbacks from the community, CDP developers will also make themselves available for training and tutoring opportunities to stakeholders.

Schedule and Deliverables

| MILESTONE | DATE COMPLETE |
|---|---|
| 5.1.1. Design of the data portal and phase development plan | 12/2011 |
| 5.1.2. Version release of the CoNGER Data Portal (CDP) | |
| 5.1.2.1. BETA version | 06/2012 |
| 5.1.2.2. Fully operational version 1.0 | 10/2012 |
| 5.1.3. Supporting Data Services | |
| 5.1.3.1. Operational DAP/THREDDS Servers | 03/2013 |
| 5.1.3.2. Operational metadata editors | 04/2013 |
| 5.1.4. Publication of the data catalog and search engines | 10/2013 |
| 5.1.5. Publication of the Web Services | 05/2014 |
| 5.1.6. Final report and documentation | 08/2014 |

Sub-Task 5.2: Model Coupling

Sub-Task Leader: Ray Chapman, ERDC. Members: Martin and Amburn, MSU

Objectives:

5.2.1 Provide model coupling algorithms and routines that transform output from one model to required input for another model in a consistent, conservative manner.

A single, coupled model for the CEEM is not a reasonable goal, given that the significant temporal and spatial scales for the various processes range from seconds to decades and microns to kilometers. However, at the point of handoff between models the results must match, and long experience has shown that simple averaging or linear interpolation creates unacceptably large errors (e.g., Martin and McCutcheon 1989, Tillman 2008). This task will provide model coupling algorithms and routines for the physical to PDS to biotics models using techniques developed at the Engineer Research and Development Center. See also sub-task 2.4

Schedule and Deliverables

| MILESTONE | DATE COMPLETE |
|---|---|
| 5.2.1 Algorithms complete | 6/2012 |
| 5.2.2 Routines installed | 9/2012 |

TASK: 5.3: Visualization of measured and modeled data

Task Leader: Phil Amburn

Objectives

The Sub-Task will provide scientific visualization capabilities for scientists and engineers in a three stage hierarchy: *I-See*, *We-See*, and *They-See*. *I-See* visualizations refer to a researcher working to understand data from a model run of a collection effort. Here the visualization is closely coupled with research efforts. In *I-See* visualizations, researchers routinely use visualization tools they are familiar with and provide them with quick and effective evaluation. *We-See* visualizations are instances where a researcher wants to convey a visual analysis to technical collaborators. The group members may be from different disciplines and may not have been directly involved in the on-going research. Here the researcher may need to spend additional time refining his visualizations and putting his results in context to ensure that they effectively convey the data and analysis. However, these visualizations are not necessarily suitable for publication or public dissemination. Finally, *They-See* visualizations are needed when a project has progressed to the point that results need to be presented to audiences with a much broader, and possibly less technical, background, with a focus on providing decision makers and the general public with information needed to decide on a course of action, approve a plan, etc. Different visualizations are routinely needed in each of these stages of visualization.

The project will enable researchers, scientists, and managers to make the transition from data to knowledge to insight, and the following bulleted list summarizes the approach to providing visualization:

1. *I-see*
    a. Researchers, scientists, and engineers continue use of existing visualization tools.
    b. These are often 2D visualization tools and provide quick, effective review and evaluation of data.
2. *We-See*
    a. New and custom visualization techniques.
    b. Explore the benefits of combining analysis with visualization.
    c. Incorporate 3D visualization techniques where appropriate
3. *They-See*
    a. Increasingly custom visualizations needed that shift focus from researchers to decision makers and general public
    b. Judicious amount of contextual information

Previous and ongoing projects that support this task

Mississippi State University has extensive experience in scientific visualization. The following is a list of previous and ongoing projects by MSU visualization experts related to the proposed effort:

- Multiple visualization projects of data from weather and ocean numeric models. (Sanyal 2010, Martin 2008, Irby 2009, Wu 2009)
- ISTV – "Interactive Structured Time-varying Visualizer" was designed for high-performance, interactive visualization of very large oceanographic model data. (Chupa 1999)
- WISDOM viewer – virtual environment tool to visualize real-time data from the NOAA WISDOM (weather in-site deployment optimization method) project. (Irby 2009)
- CTHRU – an interactive visualization tool for oceanographic model data, which was the front end for an oceanographic computational steering system
- GeoVol – a visualization application that takes advantage of advances in computer graphics hardware to interactively explore oceanographic and atmospheric model data using advanced volume visualization techniques and GPU capabilities. (Amburn 2009)
- FloodViz – an interactive, desktop visualization tool currently under development planned for operational use at NOAA river forecast centers to present and evaluate the output of the HEC-RAS river model.

State of the Art

The state of the art in *I-see* is primarily 2D visualization tools and techniques, incorporating line graphs, statistical analysis and associated plots, and GIS representations. These techniques are essential and effective and CoNGER encourages their continued use. The field of scientific visualization has been maturing significantly, and as a result, there is a growing collecting of commercial-off-the-shelf and Open

Source products that are available, such as IDV, ParaView, VTK, SAS, R, MATLAB, VAPOR, Scilab, OpenDX, and gnuplot, as well domain-specific tools (SMS, GMS, XMS). Additionally, over the last 12-15 years there has been an exponential increase in capability of the GPUs on video cards. This has led to significantly expanded capabilities in 3D visualization, parallel visualization, and GPU acceleration of algorithms that were previously only possible on CPUs.

Approach

- Encourage continued use of existing and familiar visualization tools. Store visualization products from current tools in *CoNGER Data Portal*.
- Provide custom visualization support which includes data format translators and visualization experts to assist with custom visualizations.
- Provide easy access to visualization tools with custom wrappers, some web-based and others GUI-based hosted on a local computer.

Sub-Task 5.3.1 Develop 2D visualization tool for large data sets. While many of the models provide a visualization capability, they are often limited. For example, some versions of EFDC provide a graphical user interface that can visualize model output. However, it is limited to data sets with approximately 5500 nodes. The Corps of Engineers has a very powerful 2D viewer in their Surface Water Modeling System (SMS), but use by other than Corps-affiliated organizations requires purchase of a license from a private vendor. CoNGER will provide a custom 2D visualization tool capable of visualizing much larger output data from models over grids such as EFDC.

Sub-Task 5.3.2 Develop custom GIS viewers for model data. While ESRI provides generic viewers for some data, substantial improvement can be achieved by customizing the ESRI viewer architecture to provide customized visualization of the data.

Sub-Task 5.3.3 Develop 3D visualization tools which CoNGER expect to be particularly useful for hydrology/hydraulic and PDS/WQ data sets. To provide a tool usable for multiple model output CoNGER will need to standardize on a limited and specific number of data formats. Associated with this task will be development of software translators that will convert model output to a standard output such as the Network Common Data Form (netCDF). Once the data is in a standard format, a customized 3D visualization tool will be developed. Additionally, will make it possible to export KML/KMZ representations of the data so that it can be imported into Google Earth and Google Maps.

Sub-Task 5.3.4 Extend the current FloodViz 2D and 3D visualization tool to visualize output from all the hydrology models in use in this project.

Schedule

| MILESTONE | DATE COMPLETE |
|---|---|
| 5.3.1 Design and implementation of custom 2D Visualization desktop tool | |
| 5.3.1.1 Initial version with data from EFDC | 9/12 |
| 5.3.1.2 Expanded version for data from FVCOM and CH3D models | 9/13 |
| 5.3.1.3 Final version supporting multiple models | 9/14 |
| 5.3.2. Design and implementation of custom GIS Viewers using the ESRI toolkit. Choose a model and develop a new viewer each year | |
| 5.3.2.1 PDS viewer | 9/12 |
| 5.3.2.2 Physical processes viewer | 9/13 |
| 5.3.2.3 Human/Ecosystem services viewer; viewer for collected data | 9/14 |
| 5.3.3. Design and implementation of 3D Visualization tools | |
| 5.3.3.1 Select standard data formats for model data; support for structured | 6/12 |

| | |
|---|---|
| and unstructured grids | |
| 5.3.3.2 Implement readers and visualization techniques for data that can co-locate collected and modeled data in same view volume | 9/13 |
| 5.3.3.3 Develop output techniques to save visualization data as KML/KMZ and shape files to support other visualization tools | 9/14 |
| 5.3.4. FloodViz adapted to work with hydrology models | |
| 5.3.4.1 Design and develop readers for selected models | 6/12 |
| 5.3.4.2 Design and implement visualization techniques for new models | 9/12 |

Sub-Task 5.4: Visualization and risk/uncertainty analysis for each model

Task Leaders: Song Zhang and William McAnally, MSU

Objectives:

5.4.1 Develop a core set of risk and uncertainty modeling and visualization techniques for 2D or 3D geospatial data and integrate into the Sulis toolkit.

5.4.2 Evaluate the developed techniques on simulation events by a combination of expert evaluation and user studies.

5.4.3 Apply the risk and uncertainty modeling and visualization techniques to models in CoNGER in each site.

Background

Uncertainty, (e.g. model ensemble spread, measurement error, calculation error) is inherent in all scientific data and models. Risk associated with a hazardous event is often modeled as $r=l\times c$, where $r$ is the risk of the event, $l$ is the likelihood of that event happening, and $c$ is the cost of that event. To understand the likelihood of an event, uncertainty in scientific data must be properly quantified, propagated through the modeling pipeline, and visualized. Risk can then be assessed for more informed decision making.

Previous and ongoing projects that support this task

NGI has developed the **Noodles** system for ensemble uncertainty visualization under previous NGI projects **Visualization Techniques for Improving Public Understanding of Catastrophic Events** and **Visual Analytics for Assessment and Interpretation of Simulated River Flooding**. The NSF proposal **Quantification and Visualization of Ensemble Uncertainty** has been recommended for funding by the NSF program director. If the NSF project is funded, CoNGER will apply the uncertainty quantification and visualization methods developed in the NSF project to this effort.

State of the Art

Currently, risk and uncertainty analysis are often underdeveloped or missing in scientific modeling. For example, *spaghetti plots* are often used to display the spread of uncertainty between ensemble members in geospatial simulations. However, these plots typically show spatial differences in predicted atmospheric characteristics, as opposed to the uncertainty of the calculated values.

CoNGER has conducted several preliminary studies on uncertainty modeling and visualization including a quantitative comparison among several uncertainty visualization methods and a toolkit **Noodles** for uncertainty analysis and visualization on ensemble data sets. Expert evaluation on meteorological data shows that uncertainty visualization greatly improved the understanding of the data. The results of these studies have been published in several high-impact journals including the IEEE Transactions on Visualization and Computer Graphics and won a best poster award at IEEE VisWeek 2008.

Approach

The goal is to model and visualize risk and uncertainty in various models to facilitate a holistic understanding of the data and improve model-based decision making. The team will examine each model and quantify uncertainty with statistical methods. It will then develop uncertainty visualization methods in an integrated user interface. Eventually the team will apply uncertainty quantification and visualization to each model for each of four sites in CoNGER. Products of this study will enable domain researchers to present their results with associated uncertainty to the decision makers. Risk assessment will allow for better decision making in ecosystem management.

Sub-Tasks Descriptions

5.4.1. Uncertainty quantification. Examine quantification of uncertainty in scientific data sets with a focus on ensemble data. Preliminary study shows that the distribution of the ensemble members is usually unknown. Non-parametric statistical methods (i.e. bootstrapping) allow for the computation of uncertainty by confidence intervals without prior knowledge of the underlying data distribution, so these methods will be used to quantify uncertainty.

5.4.2. Risk assessment. Identify a group of hazardous events like hurricanes, river flooding, oil spills, or water pollution. CoNGER will model the risk on human lives, properties, and environment when one or more of these hazardous events occur.

5.4.3. Risk and uncertainty visualization. Upon quantification of uncertainty, the investigators will design and implement a number of uncertainty visualization methods for 2D and 3D data and employ user studies to evaluate these methods. All of the uncertainty visualization will be fully integrated into Sulis Toolkit II.

5.4.4. Applications. Work closely with experts from ecosystems, meteorology, and hydrology/hydraulics on risk/uncertainty study in each of the four sites selected for study. In hydrology/hydraulics, The team will apply uncertainty quantification and visualization to WASP models for flow and transport predictions. In meteorology, the team will apply uncertainty quantification and visualization to WRF model for weather prediction. In ecosystems, task leaders will apply risk assessment to a hazardous event such as the oil spill.

Deliverables

5.4.1. Risk and uncertainty quantification on various models employed by the CEEM.

5.4.2. Risk and uncertainty visualization in an integrated interface.

5.4.3. Expert studies on risk and uncertainty of each of the four sites using the methods developed in this effort.

Schedule

| MILESTONE | DATE COMPLETE |
|---|---|
| 5.4.1 Risk/uncertainty quantification methods – Best Existing Practices | 9/2012 |
| 5.4.2 Risk/uncertainty visualization methods – Advanced Practices | 8/2013 |
| 5.4.3 Risk/uncertainty analysis for each of the four sites. | 7/2014 |

Task 5.5 Informatics for Report Card and Sulis

The informatics portion of the Report Card is described under Task 7 (Synthesis) with all the other synthesis sub-tasks for clarity. It is subtask 8.2.4.

All informatics work and community modeling work will be accomplished consistent with NGI's Sulis master plan (McAnally et al. 2010). During an emergency, water and land resources managers are required to make decisions quickly and often on the basis of information of poor quality, or needed data are inaccessible and/or incomprehensibly displayed. Frequently, they need to ask a series of "what if" questions to rapidly determine the next actions to take and are often frustrated by not getting the help and information they need. Sulis is a computer-based decision support system to help decision makers of many types make not only routine decisions but also decisions needed in an emergency. Sulis was initiated with NGI funding and is the subject of on-going development of adding tools and research on an inference engine with funding provided by NSF, Corps of Engineers, NOAA, and BP grants to the states.

A link to the Gulf Report Card (Sub-task 8.4) will be added as a Sulis enhancement.

Deliverables

Enhanced Sulis Decision Support System

Schedule

| MILESTONE | DATE COMPLETE |
|---|---|
| 5.5.1 Enhanced Sulis System | 6/2014 |

**Task 6. Site Applications**

Task Leaders: Felicia Coleman, FSU; Just Cebrian, DISL, Stephan Howden, USM; Sam Bentley, LSU; Robert Twilley, ULL, Deepak Mishra, MSU

OBJECTIVES

6.1. Produce data to define effects of Petroleum Spill/ Dispersant Systems (PDS) on ecosystem structure, function, and services as separable from other drivers and pressures in four representative ecosystems: Barataria Basin/Wax lake Outlet, Mississippi Sound-Bight, Perdido Bay, and Apalachicola Bay.

6.2. Produce data for validation of the CEEM and its PDS/Water quality and biotic models.

BACKGROUND

CoNGER researchers have been conducting field observations of the selected sites and adjacent Gulf for decades and measuring to define the effects of PDS from the Deepwater Horizon spill since May 2010. Hundreds of publications and an experienced cadre of researchers are the foundation that this proposal builds on as it continues that work.

APPROACH

A remote sensing task (begun in 2010 with NGI funding) covers all four sites. Four site-specific tasks beginning years to decades earlier (with various funding sources) examine the ecosystem structure and function in detail, and all provide information and analyses to the CEEM Tasks, Synthesis Task, and Education and Outreach Task. Data and metadata are archived according to the Data Management Plan.

Sub-Task 6.1 Remote Sensing of Marshes

Lead: Deepak Mishra, MSU

Objectives:

6.1.1. Quantify the photosynthetic activity, physiological status, and primarily productivity of the coastal salt marshes across all four sites

6.1.2. Map results assessing and evaluating the productivity of marshes that were impacted by the PDS

This sub-task was funded by NGI with the initial allocation of funds to the states and has been proposed for continuation to the GRI III RFP. If funded, efforts under this proposal will begin when the GRI III bridge funding is exhausted.

The overall goal of the proposed research is to quantify and map the ecological impact and degree of recovery of the oil spill on the photosynthetic activity, physiological status, and primarily productivity of the coastal salt marshes to facilitate the prioritization of future restoration actions. The field data collected during the NGI Phase 1 and 2 will be used in satellite model calibration through a remote sensing mapping protocol to generate monthly time-series Landsat derived map products for the salt marsh biophysical properties along the LA-MS-AL coast. The marsh biophysical products developed through this project will be used in combination with the climatological data for assessing and evaluating the productivity of marshes that are impacted by the massive oil spill, thus providing state regulators important information for restoration and management. The specific questions to be answered are: (1) What is the degree of damage and extent of recovery in the spill impacted marsh habitats? (2) Was some of the damage due to local climatic perturbation and early senescence rather than the spill? (3) What will be the impact of a hurricane on the spill impacted wetland patches? The proposed research develops scientific products that can be used to assess marsh physiological characteristics at large spatial scales, which will directly inform restoration and conservation decision-making. The maps and tools produced by this study will be immensely helpful to the other field observation sub-tasks, CEEM biotics modeling, and coastal managers across LA-MS-AL to evaluate and prioritize the massive marsh restoration effort that is going to take place because of the spill.

Work will consist of comprehensive long-term assessment of the PDS-impacted coastal salt marsh habitats with extension of present monthly remote and ground sampling from 61 locations throughout 2012-2014. The technique employs cutting edge hyperspectral and multispectral imagery products to visualize and detect stress induced in sensitive estuarine vegetation, using Moderate Landsat 30-m datasets to retrieve the biophysical characteristics in salt marshes; Ocean Optics (USB 4000) hyperspectral radiometer to detect Top of Canopy (TOC) reflectance and leaf level reflectance measurement and leaf clip, SPAD chlorophyll meter for leaf level chlorophyll content, LiCOR's LAI meter (Plant Canopy Analyzer) for green LAI readings, digital photographs for VF readings (Gitelson et al., 2002), and time-series analyses of all these.

Deliverables

6.2.6. Year 1 journal paper on data

6.2.7. Year 2 journal paper on data

6.2.8. Year 3 journal paper on data

6.2.9. Final report on data and results

6.2.10. Semi-annual presentations of results

Schedule

| MILESTONE | DATE COMPLETE |
|---|---|
| 6.1.1 Year 1 Results Complete | 9/12 |
| 6.1.2 Year 2 Results Complete | 9/13 |
| 6.1.3 Year 3 Results Complete | 9/14 |

Subtask 6.2 Barataria/Wax Lake

Lead: Bentley, LSU

Barataria Bay is central to oil spill recovery and deltaic conservation/restoration efforts in the Mississippi Delta region. Because oil spill impacts have become intertwined with state and national plans for Mississippi delta management, research related to oil spill recovery in this geographic region must also address the related issues of wetland loss and diversions for water and sediment supply. Wax Lake Outlet shares many of the same characteristics except that it received no petroleum spill products and serves as a parallel site.

The Barataria Bay estuary, shelf, and wetland region was strongly impacted by oil from the Macondo spill in 2010, and remains one of the regions with the highest remnant oil residue and ecosystem impacts from the spill. The bay is a sediment-starved estuarine system that once received abundant sediment from the Mississippi River; those fluvial sediment supply connections are now severed, due to the effects of the Mississippi River and Tributaries flood control system of the US-ACE, but large diversions are being considered for the near future. At present, one of the few sediment sources to the submarine areas of the bay is erosion of wetland sediments along bay margins. Most of the impacts to wetlands by oil that are hypothesized in this proposal and elsewhere point to increasing vegetation loss (sub-task 6.2.4), weakening of wetland soils (6.2.1), and resulting wetland erosion.

Wax Lake Outlet, a nearby growing delta, did not receive direct oiling, and serves as a compare and contrast site to the Barataria Basin

Questions:

- How does the release of oil and oil/dispersant mixtures impact aquatic and wetland ecosystem productivity and health, and the closely related issues of wetland stability, and sediment erodibility, transport, and deposition?
- Did oil/dispersant releases accelerate wetland loss, and if so, why and how, and what is the fate of the eroded oil/dispersant/sediment mixtures?
- Are diversions effective mitigation strategies for oil transport into estuaries, and if so, at what are the associated ecological impacts?
- What is the ultimate fate of oil/dispersant mixtures that enter the estuary to be deposited on sediment substrates?

Objectives

6.2.1. Evaluate the initial and continuing impact of oil/dispersant releases on:
- water quality
- phytoplankton community response
- sediment erosion, transport, and deposition, particularly associated with wetland loss

6.2.2. Evaluate efficacy and impacts of water diversions as mitigation strategies to counter oil transport into estuaries (Huang, Justic, and Rose)

6.2.3. Interface with overarching CEEM and with other site-specific programs

Sub-Task 6.2.1 Effects of oil spill on the physical strength and erosion of bay substrates and wetland sediments

Leads: Zhang and Chen, LSU

The stability of wetland foundation soils directly controls the resilience and health of the coastal ecosystem (Howes et al. 2010). Likewise, the stability of bay substrates governs the transport and ultimate fate of oil/ dispersants contained in the bottom beds. The study proposes to develop a monitoring and predictive capability for the impacts of oil spill on the physical strength, erosion, and transport of both wetland sediments and submarine bottom beds within/near the bay using highly integrated activities consisting of field measurements, laboratory testing, and contributions to the numerical modeling of Task 2.

Overall, research is proposed in two major sub-tasks: (1) Field measurements will be conducted to obtain the critical erosional resistance and shear strength of the oil contaminated wetland sediments using a cohesive strength meter (Tolhurst et al. 1999); Moreover, in-situ monitoring of waves, currents, and water turbidity will be performed to collect data as input for subsequent modeling work; (2) laboratory characterization of both wetland and bay bottom sediments (sampling of submarine sediments will be coordinated with Bentley) will be performed to characterize their physical, chemical, and biological properties (e.g., oil concentration, biofilm production) (Friend and Amos 2007; Perkins et al. 2004).

Sub-Task 6.2.2 Sediment transport and deposition in an oil-impacted, degrading deltaic estuary

Lead: Bentley, LSU

Connect anticipated wetland impacts with the vast submarine regions of the bay, by studying temporal and spatial shifts in sediment deposition, by radioisotope geochronological analyses of sediments on the bay floors, coupled with petroleum hydrocarbon analyses of sediments. Through the analysis of sediment cores for sediment-bound radioisotopes with different source terms and half lives (anthropogenic [Cs-137, half life 30y], cosmogenic and fluvial [Be-7, half life 54 d], and cosmogenic/marine [Pb-210, half life 22y], CoNGER will be able to determine short-term changes in sediment deposition rates from longer-term patterns, and evaluate these changes in conjunction with associated detailed studies of wetland impacts.

Field work will be undertaken in Barataria Bay, along sampling transects undertaken in sub-task 6.2.4., and field studies will allow expansion of the findings of Zhang and Chen to be extended from wetland to submarine settings. Sediment cores will be collected from a small vessel at submarine stations along a nominal N-S transect of the bay. Sampling will occur in late winter, early summer, and early Fall, to evaluate effects of cold fronts, river discharge, especially through diversions, and tropical cyclone activity during the year. Cores will be analyzed for hydrocarbon content by a contract laboratory, and for particle bound radioisotopes via gamma spectrometry; replicate cores will be imaged via digital X-radiography, to help interpret processes of sediment delivery, mixing, and deposition. During these time periods, instrumented tripods will measure current strength and sediment resuspension using methods similar to Zhang and Chen. These results will be incorporated into regional modeling efforts. At the start and end of the project, high-resolution submarine bathymetry will be measured using a swath-mapping sonar system, to detect larger-scale changes, and to provide context for core measurements.

Sub-Task 6.2.3 Examining the phytoplankton community responses to oil contamination in Barataria Basin

Lead: Bargu, LSU

This project will evaluate the phytoplankton community responses to oil contamination in the Gulf of Mexico to help predict the long term ecosystem consequences while giving particular attention to oil impact on harmful algal bloom occurrences. There is a critical need to determine the effect of oil on phytoplankton as this carbon pool comprises a vital link to the higher trophic levels in terms of food resources as well as integrity of coastal ecosystem stability. Although a substantial amount of research has established that crude oil are toxic to marine life, relatively little is known at the base of the marine food web.

Objectives:

- 6.2.3.1 Evaluate how crude oil, with and without the chemical dispersant, affects the phytoplankton species community structure and growth in the Gulf of Mexico.
- 6.2.3.2. Examine the uptake of crude oil, with and without the chemical dispersant, for specific phytoplankton species predicted to dominate the community based on objective 1.
- 6.2.3.3 Assess the crude oil contribution to harmful algal bloom events, giving particular attention to commonly observed toxic diatom Pseudo-nitzschia spp. blooms vs. flagellate blooms (frequently observed after the Deepwater Horizon oil spill).
- 6.2.3.4 Determine cellular level responses of crude oil and its components in phytoplankton using biomarkers under acute and chronic crude oil exposure.

6.2.3.5. Observe the changes in phytoplankton metabolic activities (nutrient uptake efficiency and rate of oxygen consumption) in the presence of oil and chemical dispersant, and to examine the influence of photo-induced toxicity of oil on specific phytoplankton groups.

Sub-Task 6.2.4 Water Quality Sampling – Barataria Basin

Objective

6.2.4.1 Determine the water quality effects of the Deepwater Horizon spill in Barataria basin

Approach

This task will collect monthly samples from the Barataria Basin and one offshore station, from January to June, 2011, (a) to make comparisons with the long-term data record (+15 years), (b) to assess if the Deepwater Horizon oil 'spill' significantly affected water quality, and (c) to address the health of the ecosystem(s). The primary focus is on dissolved nutrients, phytoplankton, microbes, and oil; importantly, we also collect water samples for others as time and space allows – thus continuing our indirect participation with others.

Methodology: Monthly sample collections stations in the Barataria watershed consist of 37 stations sampled since 1994 and eight stations sampled since 1999. The sampling transect begins offshore of Grande Isle, La. and goes through the estuarine tidal pass and northward into a freshwater stream entering Lac des Allemands (discussed in the 'Field Locations' section). Samples from the 7 stations on the Causeway over Lake Pontchartrain have been samples since 1996, with others before then. These sampling efforts were continued until December 2010 under the NGI BP funding source. These two time-series measurements, and the 25-year hypoxia research offshore (NOAA funded), are the only station-dense and long-term water quality monitoring program like this for these waters. They provide excellent baseline data for what is recognized as an essential component of modern environmental science (Ducklow 2009). Complimentary determination of oil concentrations, however, began only just before the oil from the Macondo disaster reached coastal waters this summer (Rosenbaueer 2010). This pre-impact sampling was done through the 6-month NGI-sponsored project ending this June 2011. It is important to continue this sampling effort because of the prolonged impact of oil on aquatic systems, including plankton communities. De la Cruz (1982), for example, observed that a 'light' oiling of marsh ponds affects metabolism for several months. Varela et al. (2006), in contrast, could not detect a change in phytoplankton off the Spanish coast after the Prestige oil spill, a difference that Gonzalez et al.'s (2009) results suggest may be different in coastal waters, because of the higher sensitivity of small diatoms to oil. Graham et al. (2010) describes how oil from the Macondo 'spill' in Alabama coastal waters did enter the planktonic web. The impacts in marshes will be consequential for decades (Teal et al. 1992; Culberton et al. 2008).

Analyses of all samples will include phytoplankton pigments, nutrients (nitrate+nitrite; phosphate, silicate, etc.), salinity, suspended sediments, inorganic carbon, and many others. Standard EPA approved methods will be used. Subsamples for algal pigments (HPLC) and identification will be given to LUMCON to analyze. A key use of the NGI-BP monies is to also quantify the oil in these waterbodies and to assist others who need water for their projects. The samples for phytoplankton ID and pigments, and for oil will include 3 stations in Lake Pontchartrain and 4 from Barataria Bay. Phytoplankton composition samples of 100 ml are preserved in 0.5% 2 gluteraldehyde, refrigerated until analysis, size fractionated (0.2, 3, and 8 μm polycarbonate filters), and stained with proflavin (3 and 8 μm filters). The phytoplankton will be identified to the nearest taxon using epifluorescence microscopy (Murphy and Haugen 1985; Dortch et al. 1997). Phytoplankton counts will be done by Ms. Wendy Morrison, who has over 10 years of experience identifying offshore, coastal, estuarine, and brackish and freshwater phytoplankton. Phytoplankton community composition will be determined by HPLC (high performance liquid chromatography) for taxon-specific pigments. HPLC samples are collected on GF/F filters and stored in liquid N2 for pigment analysis on a Waters HPLC (Wright et al. 1991). The composition and abundance of phytoplankton populations will be determined using CHEMTAX (Mackey et al. 1996) and pigment ratios developed for species in this region and verified with phytoplankton counts (W. Morrison, ongoing taxonomic studies). Background data for comparison with the NGI Barataria transect and the Lake Pontchartrain samples will come from the phytoplankton database maintained by LUMCON, developed over the years under the supervision of Drs. Quay Dortch and Nancy Rabalais, and Ms. Wendy Morrison. The Barataria transect data were collected from early 2002 through 2009, but dropped in 2010 for lack of funding. The EMPACT stations were collected starting in April 2001 through December 2002. Four of the original EMPACT stations were continued as part of the Barataria Transect sampling. Background data (13 March 1997 through 20 December 2000) are available for comparison with Lake Pontchartrain will come from stations 1 (north lake), 4 (mid lake), 7 (south lake). Additional data are from July to June 2011. Oil identification and quantification will be done at LSU using the assets of the primary chemical hazard assessment support team (School of Coast and Environment) for NOAA's Office of Response and Restoration for 25 years, and most of the oil spill samples from the current incident. Samples are collected and analyzed using accepted standard operating and QA/QC procedures to prevent contamination and avoid sample degradation. The samples will be analyzed by gas chromatography/mass spectrometry for petroleum hydrocarbons including the normal and branched saturated hydrocarbons (from C10 to C35), the one- to five ringed aromatic hydrocarbons and their C1 to C4 alkyl homologs, and the hopane and sterane biomarkers. All GC/MS analyses use an Agilent 7890A GC system configured with a 5% diphenyl/95% dimethyl polysiloxane high resolution capillary column (30 meter, 0.25 mm ID, 0.25 micron film) directly interfaced to an Agilent 5975 inert XL MS detector system. The MS is operated in the Selective Ion Monitoring (SIM) to maximize the detection of the target constituents unique to crude oil. The metabolic ‘footprint’ of the microbial community will be analyzed using a commercially available 96-well plates embedded with 32 different substrates. These systems are designed to establish specific species, but are adapted for use here to identify substrate reduction abilities of the entire plankton community. The results will be analyzed for clustering of responses by station groupings, and linked to the presence-absence of algal blooms.

Samples from the Barataria transect show the lowest density and microbial metabolic ‘footprint’ at the seaward end of the estuary and highest in Lake Des Allemands (Figure 6.4.1). There are few indications from data collected before the Macondo spill to show that the Davis Pond diversion water has affected the microbial community in Lake Salvador. There were no unusual changes in the microbial fingerprint in April and May 2010, two months after the Deepwater Horizon oil spill, but before oil entered the estuary. However, oil moved into the lower estuary in June 2010 and is still there (November 2010). Re-oiling of some marshes has happened in 2011.

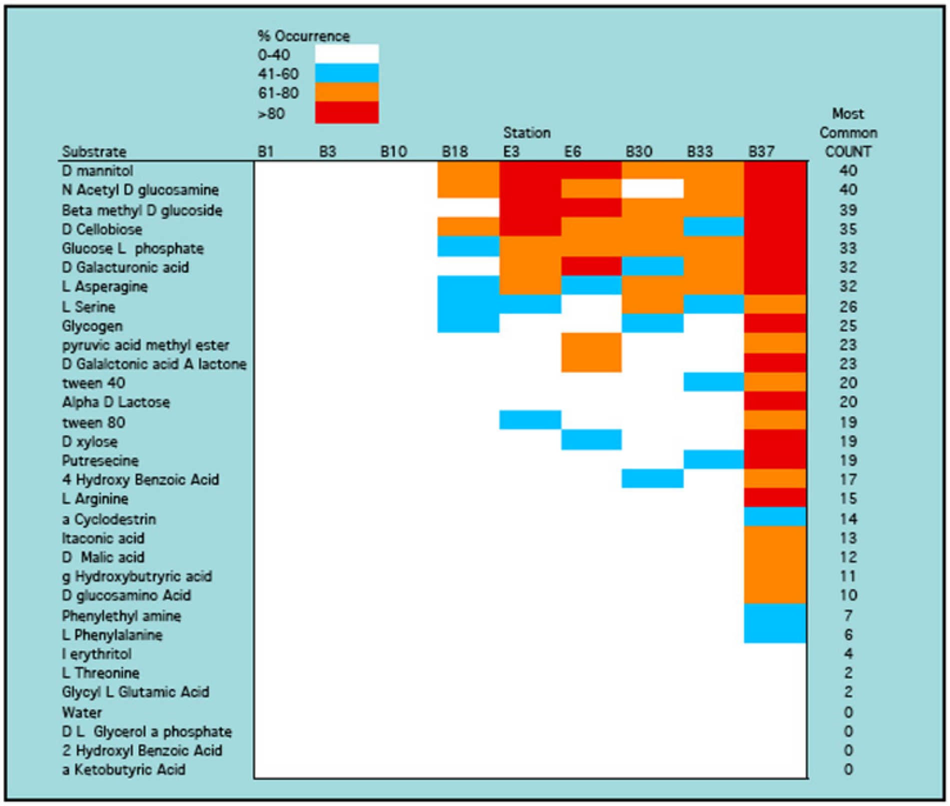


Figure 6.4.1. An example of a twelve-month pattern in substrate preferences by microbes in Barataria Bay. Station locations are arranged from sea (left) to inland freshwater lake (Lac des Allemands; right). The most commonly used substrate is on the top-left side, and the least on the bottom. The percent occurrence is color-coded, with red the most commonly used substrate. This is a pre-oil impact summary.

The basic data set has been used to calibrate a biophysical model of Barataria Bay estuary, which was then used to determine the flux of carbon from estuary to offshore (Das et al. 2010).

Monthly field efforts occur for each of 6 months, from January through June 2011 at the locations shown in Figures 6.4.2 - 6.4.3. Data are recorded on in the field and, once in the lab, are immediately entered into appropriate computer programs, and backed up in multiple places. Data repositories accepting oil-spilled related data will be sent copies (e.g., NOAA, Louisiana Oil Spill Coordinators Office). Data for journal papers will be stored on journal web pages, if available. The *timetable* for completion of the water quality analyses is within 1 month of each field effort, 3 months for the pigment and phytoplankton ID, and 4 months for the oil analyses. Field Locations associated with research: The sampling stations are identified in Figures 6.4.2- 6.4.3.

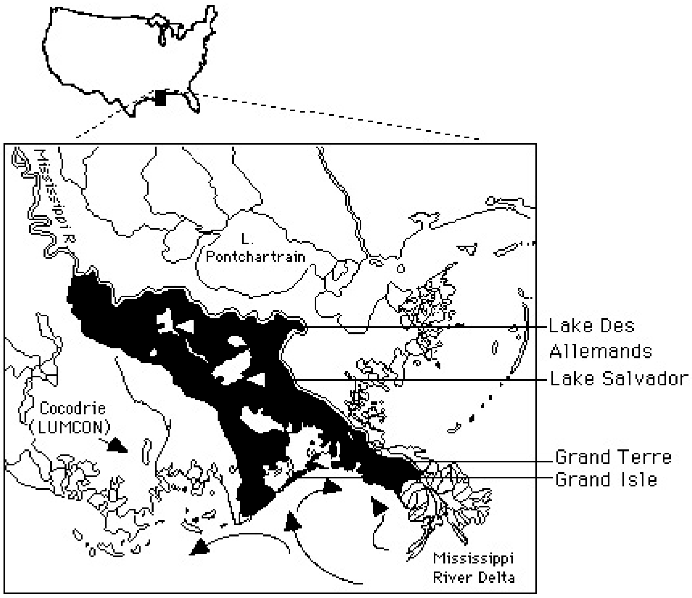


Figure 6.4.2. General location map for sites sampled: The Barataria Bay watershed is shown in black and Lake Pontchartrain is the lake to the northeast. The Mississippi River levee forms the eastern boundary of the Barataria estuary. A former tributary of the Mississippi River, the LaFourche delta distributary, separates the Terrebonne and Barataria bay estuaries on the west. The major entrance to the estuary is between the barrier islands of Grande Isle and Grand Terre. The water supply of Lac Des Allemands (also called Lake des Allemands) is primarily rainfall through swamp and freshwater marsh. It exits almost exclusively through the southern end of the lake. The predominant offshore surface currents are shown with arrows.

Subtask 6.2.4. Wax Lake Outlet Observations

Lead: Robert Twilley, ULL

There is a series of long-term data sets on both the ecogeomorphic processes of delta evolution, but also on the biogeochemistry of larger deltaic coastal waters surrounding this delta observatory. (1) *Trajectory of soil development and ecological processes*: This component will build on seven transects and 87 plots that have been monitored for seven years by co-PI Twilley's group. In addition to these vegetation and elevation surveys (e.g. plant type, density, and height), this project will add intensive flow measurement to determine the effect of the plants on the flow field (drag, redirection) and of the flow field on the plants (e.g. shear stresses on vegetation fields). The field results will feed directly back into numerical models, which can readily be adapted to include vegetation effects. (2) *Spatial integration of delta ecogeomorphic characteristics*: CoNGER will develop relationships between the ecological patterns and processes (plant communities, soil development, nutrient burial) to the physical elevation of delta islands. That is, how well can sediment elevation explain habitat types and concomitant soil characteristics and burial processes? Using 2009 LiDAR data and infrared photography, NGI is intersecting these data to develop a rule-based predictive model of plant community change with inundation (elevation) as a primary driver. Elevation distributions and type mapping the plant communities are currently being analyzed. CoNGER will also use the analysis of this imagery to quantify the degree of physical-biological spatial correlation which can facilitate the development of sediment and nutrient budgets. As the delta ages, the organic matter storage term in the wetland habitat becomes increasingly important to elevation compensation to sea level rise. Solving this organic burial term—and by extension, quantifying nutrient burial rates—is one of the central goals of CoNGER's proposed studies. **(3)** *Quantifying nutrient removal capacity of delta marshes* To resolve general hydrodynamics at the delta island scale, CoNGER will array six current profilers (PC-ADPs) that are optimized for shallow water flow and designed to detect a range of flow velocities. These current profilers will be complemented by three continuous nitrate sensors, and ISCO autosamplers allowing for discrete measurements of total nitrogen, phosphorus and suspended solids. One nitrate sensor and ISCO sampler set will be located in the main channel and two will be within the intra-island marsh/mudflat habitats arranged along the dominant flow direction to capture an upstream-downstream signal. Data from the current profilers will be processed to create contour plots of current velocity and direction. The advective flux data will be combined with measurements of nutrient and suspended sediment loading rates to develop nutrient and sediment flux models for WLD islands across instantaneous and event timescales. In addition to island-level modeling of nutrient fluxes, in situ

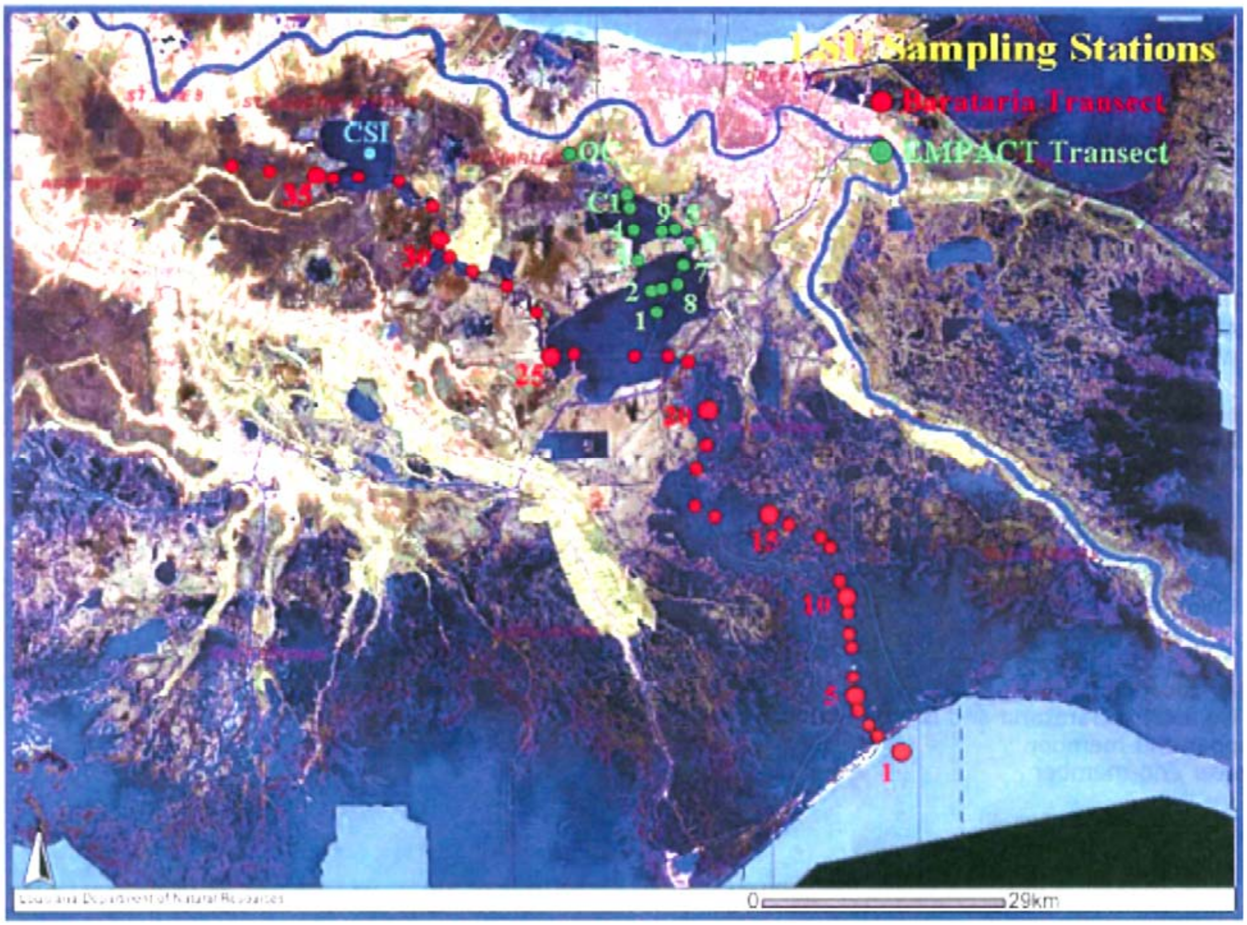


Figure 6.4.3. Stations sampled in the Barataria Bay estuary. Numbers 1-37 have been sampled since 1994. The four 'Empact' stations were first sampled in 2001 and are occasionally inaccessible because of the increased amounts of submerged aquatics that clog small boat motors. Note that station 1 is offshore; station 2 is in the tidal pass between Grande Terre and Grande Isle.

mesocosms will be used to directly measure nutrient fluxes. (4) *Biogeochemistry of coastal waters*: Water samples will be collected along transects upstream and downstream (coastal) of the delta observatory and analyzed for total nitrogen and phosphorus, inorganic nutrients ($NH_4^+$, $NO_3^-$, $NO_2^-$, $PO_4^{-3}$, and Si), total suspended solids, and chlorophyll a. Flow data will be recorded continuously throughout the landscape using CTD data sondes will be placed on selected platforms, to measure water levels, specific conductivity, and water temperature.

Deliverables

6.2.1. Year 1 journal papers on data

6.2.2. Year 2 journal papers on data

6.2.3. Year 3 journal papers on data

6.2.4. Final reports on data and results

6.2.5. Semi-annual presentations of results and forwarding of data to database

Schedule

| MILESTONE | DATE COMPLETE |
|---|---|
| 6.2.1 Year 1 Results Complete | 9/12 |
| 6.2.2 Year 2 Results Complete | 9/13 |
| 6.2.3 Year 3 Results Complete | 9/14 |

Subtask 6.3 Mississippi Sound/Bight Site

Lead: Howden, USM

Before the Deepwater Horizon oil spill the coastal environment of the Northern Gulf had been experiencing change related to a variety of local, regional, and global factors. At the local level the stressors include increased population and development/redevelopment near and adjacent to the coast (e.g., changing land-use, wetland destruction and loss, and local pollution sources). At the regional level change has occurred due to natural and human modification of upland areas that can have profound effects on the river exports of carbon and nutrients to the coastal estuaries and ultimately to the Gulf of Mexico. The composition and fluxes of the river-borne carbon and nutrient species can reflect changes in their watersheds, making rivers good indicators of land-use, human impacts, and vegetation and environmental changes. This export of carbon and nutrient species across the land-ocean interface from inland drainage basins to the ocean represents a major component of the global carbon and nutrient cycles and so represents a coastal role in the global change of the oceans and climate. The role of coastal oceans influencing air-sea flux of $CO_2$ and their sensitivity to increasing atmospheric levels of $CO_2$ and associated pH changes (e.g., ocean acidification) is poorly understood. Global climate change, in turn, affects the northern Gulf ecosystem through, for example, sea level rise and changes to the hydrological cycle. Within the northern Gulf coastal ocean itself, these various fluxes and transformations have resulted in ecosystem degradation including eutrophication, hypoxia, wetland loss and pollution.

An important element to understanding the variability in these ecosystems is the role that fluvial inputs play and the processing and transformation of the inputs that occurs through the coastal transition zone. A basic step in understanding the effects of inputs from rivers and estuaries on coastal ecosystems is measuring the variability of stream flow and associated concentrations of the constituents and tracking the concentrations offshore from the input regions. However, bulk concentrations are only part of the story. Dynamic change and flux of both organic and inorganic species and subspecies, and their seasonal and longer-term variations, provide more information about variations in the watersheds and coastal

Since 2007 the NGI project Monitoring and Assessment of Coastal and Marine Ecosystems (MACME) has been working with partners of the NGI, and state and federal agencies, to carry out a multi-faceted approach for building a land-to-sea monitoring and assessment strategy in selected key coastal regions in the northern Gulf. The initial efforts were focused on the lower Pearl River estuary (LPRE), the Bay of St. Louis (BSL), the western Mississippi Sound (MSS), and the western Mississippi Bight (MSB). In subsequent years the study area was expanded to include new sampling stations in the Pearl and Mississippi Rivers, enhanced nutrient and carbon analyses at the two new sites and at the Central Gulf of Mexico Ocean Observing System (CenGOOS) buoy, a pilot project for examining the importance of submarine groundwater discharge in the MSS and some of its estuaries, and more development of remote sensing algorithms for monitoring aspects of the carbon cycle.

The backbone of the MACME has been the monthly sampling transects from the Bay of St Louis out to the 20 m isobath of the MSB (Figure 6.3.1; hereinafter referred to as the "NGI transect") and from the Bay of St. Louis to the mouth of the East Pearl River through the MSS (Figure 6.3.1; hereinafter referred to as the "BCS transect"),. The measurements of the physical properties and biogeochemical constituents have been collected since 2007 for the NGI transect and since 2008 for the BCS transect. Table 6.3.1 lists both the profile data and the analyses of discrete water samples for the NGI and BCS transects. Additionally, at some of the stations, for some of the months, benthic samples were collected for macrofauna and microfauna.

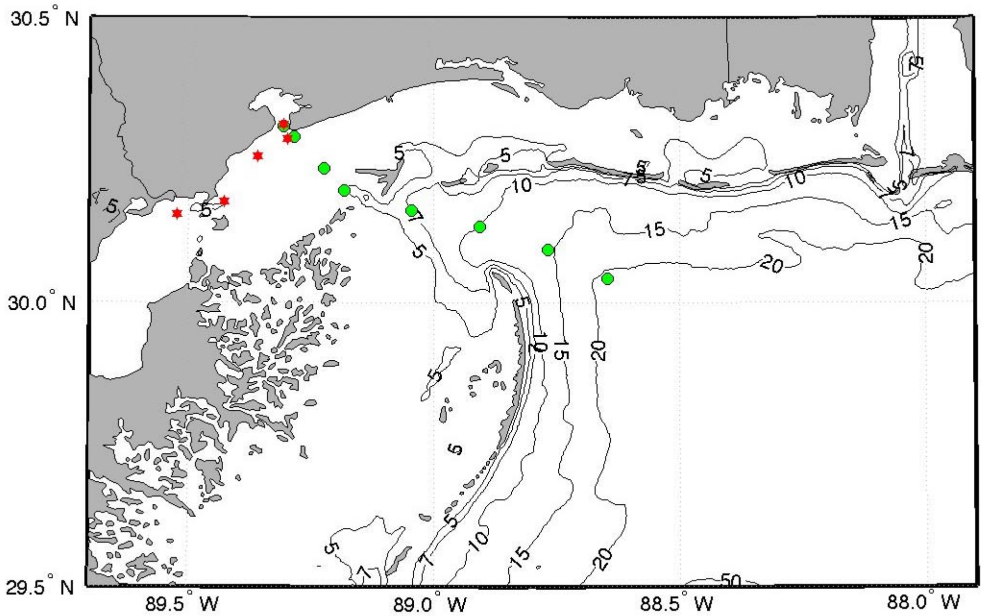


Figure 6.3.1. Study area of the western Mississippi Bight and Mississippi Sound. Green circles are stations of the "NGI line". Red stars are stations of the "BCS line".

<u>Previous and ongoing projects that support this task</u>

In addition to the previously mentioned NGI/MACME project, there are two other projects that support this task. The first is the Central Gulf of Mexico Ocean Observing System, that operates a buoy in the study region at the furthest offshore site along the NGI line, and three CODAR long-range High Frequency Radar (HFR) stations that measure surface currents over most of the continental shelf offshore of the 20 m isobathfrom the Louisiana-Mississippi line to Destin, FL.

The second supporting project is a CIAP project titled "Acquiring Real-Time, Continuous Surface Circulation Data in the Mississippi Sound in Support of Resource Management and Environmental Quality Applications", which will operate 2 short range CODAR HFR stations that will provide surface currents in the MSS in the Gulfport region.

<u>APPROACH</u>

The approach of the MSB Site Team is to leverage the data of the NGI MACME project before, during, and after the DwH spill and continuing the time series of critical water properties and constituents to produce data to demonstrate effects of Petroleum and Dispersant Systems (PDS) on ecosystem structure, function, and services as separable from other drivers and the Mississippi Sound-Bight. These data will be available to the Water Quality and PDS Team, the Biotics Team, and the Physical Characterization Team as appropriate.

Table 6.3.1. Data collected during a typical monthly transect cruise. Shown are MACME NGI and BCS lines and proposed CoNGER NGI and BCS continuation transects.

| Samples collected during a typical, monthly, transect cruise | | | | | |
|---|---|---|---|---|---|
| | | NGI | BCS | GRI/NGI | GRI/BCS |
| SBE CTD | T, S, DO | x | x | x | x |
| Optics package | Chlorophyll fluoresence | x | x | x | x |
| | Optical backscatter | x | x | x | x |
| | Turbidity | x | x | x | x |
| In-Situ Troll 9500 | Turb | x | x | x | x |
| | pH | x | o | x | o |
| Water samples | Nutrients | x | x | x | x |
| | HPLC | x | o | x | o |
| | DOC | x | x | x | x |
| | OIW | o | x | | |
| | SAL | x | | x | o |
| | Winkler DO | x | o | x | o |
| | Trace Metals | x | o | o | o |
| | CDOM | x | o | x | o |
| | Filter pads | x | o | x | o |
| | Phyto abund | x | o | x | o |
| | Heterotrophic Bacteria | o | o | x | x |

x = sampled

o = not sampled

Sub-Tasks Descriptions

6.3.1. Cruises: Leads Kjell Gundersen, Stephan Howden, Laodong Guo and Scott Milroy
6.3.2. Continuous Profile Data Leads: Stephan Howden and Kjell Gundersen,
6.3.3. Nutrient Analyses: Don Redalje
6.3.4. HPLC: Don Redalje
6.3.5. Winkler Titrations: Kjell Gundersen
6.3.6. Water samples run through Autosal: Kjell Gundersen
6.3.7. DOC, DIC and CDOM analyses: Laodong Guo
6.3.8. Data Management: Stephan Howden, Kjell Gundersen, Laodong Guo and Scott Milroy
6.3.9. Analyses of status and trends of data: Stephan Howden, Kjell Gundersen, Laodong Guo, Donald Redalje and Scott Milroy

Deliverables

6.3.1. Monthly sampling along the NGI line.
6.3.2. Monthly sampling along the BCS line.
6.3.3. Processed profiled data at each station (SeaBird SBE25 CTD, optics, and dO) placed in project database.
6.3.4. Processed nutrient data (Nitrate, Nitrite, Ammonium, Phosphate and Silicate) for each station. using Astoria-Pacific 2+2 nutrient analyzer system, and placed in project database.
6.3.5. Processed water samples taken for salinity at stations using Autosal placed in project database.
6.3.6. Processed dissolved oxygen data from water samples using Winkler titration placed in project database.
6.3.7. Water samples for heterotrophic bacteria and PDS given to Biotics team.
6.3.8. Processed DOC, CDOM from water samples placed in project database.
6.3.9. Processed chlorophyll samples placed in project database.
6.3.10. Processed phytoplankton pigments using HPLC systems placed in project database
6.3.11. Links (TBD) between project database and GRI/Harte Institute database.
6.3.12. Analyses of status and trends of data including database from NGI Monitoring and Assessment of Marine and Coastal Ecosystems.

Schedule

| MILESTONE | DATE COMPLETE |
|---|---|
| Determine metadata file format for project files | 1/2012 |
| Collect Water Samples along NGI Transect (see Table 1) | Monthly |
| Collect Water Samples along BCS Transect (See Table 1) | Monthly |
| Profile CTD and dO data processed and put into database | Monthly |
| Run nutrient samples on autoanalyzer | Every 2 months |
| Run water samples through Autosal | Monthly |
| Run Winkler titrations of water samples for dissolved oxygen | Monthly |
| Water samples for heterotrophic bacteria and PDS given to Biotics team | Monthly |
| DOC, DIC and CDOM | Every 2 months |
| Chlorophyll | Monthly |
| HPLC | Every 2 months |
| Links between project database and CoNGER database | 1/2012 |
| Data Status and Trends Analyzes pre-DwH | 1/2012 |
| Data Status and Trends Analyzes | Annually |

Subtask 6.4 - Perdido Bay

Lead: Just Cebrian

Objectives:

6.4.1. Provide data to support the CEEM structure

6.4.2. Provide data to validate the CEEM PDS/WQ and biotics models

6.4.3. Develop an understanding of the dynamics of Perdido Bay

Approach

Perdido Bay is a coastal lagoon-type shallow estuary with a small upstream watershed, leading to high salinities except during freshets. Three lagoons within the Bay were studied – State Park, Kee's Bayou and Gongora. The lagoons are moderate in size and, as typically found for other coastal lagoons, they are shallow and connected to a sound through a relatively narrow mouth (Figure 6.4.1). The lagoons also have other similar physical properties but differ in degree and type of human impacts.


Figure 6.4.1. Perdido Bay and Sites

The State Park site, as the name indicates, resides within Big Lagoon State Park, Florida and represents the most pristine lagoon with the least amount of human alteration. It is entirely surrounded by salt marsh and maritime forest with no residential development. Kee's Bayou is developed on the northern and eastern sides (i.e. condominium complex and houses) and bordered by marsh vegetation on the southern and western sides. In addition, a 2 m wide channel along the center of the lagoon is periodically dredged for navigation. Finally, Gongora is bordered by residential development on its northern and eastern sides and by marsh vegetation on the southern and western sides, although a newly developed condominium lies behind that marsh vegetation. The lagoon is periodically dredged along its central axis for navigation, which, given the narrow, spindle shape of the lagoon, has a large impact in the lagoon. (Cebrian 2009).

An extensive set of measurements from these three locations over the past decade are now being supplemented with data collection for hydrodynamics, salinity, sediment, nutrients, and oil with funding from BP through NGI. Those field exercises will continue under this project.

<u>Deliverables:</u>

6.4.1. Year 1 Data

6.4.2.Year 2 Data

6.4.3.Year 3 Data

Schedule

| MILESTONE | DATE COMPLETE |
|---|---|
| 6.4.1 Year 1 Results Complete | 9/12 |
| 6.4.2 Year 2 Results Complete | 9/13 |
| 6.4.3 Year 3 Results Complete | 9/14 |

Subtask 6.5 – Apalachicola Bay

Lead: Felicia Coleman, FSU

Objectives:

6.5.1. Determine where the petroleum/dispersant systems residuals are located, how they are transported, and their effect on the overall productivity of the system.

6.5.2. Empirically test the forecasting capability of Apalachicola physical model developed by establishing ecological linkages from river flow and nutrients to the production of phytoplankton as well as dependent fisheries, including oysters and groupers.

6.5.3. Develop a trophic model that defines the system and can forecast the influence of oil and other pollutants on biological productivity.

Background and Motivation. Variation in fisheries productivity is significantly influenced by processes that act during the egg, larval, and early juvenile stages (Rothschild 1986, Chambers and Trippel 1997). Indeed, larval survival and subsequent year-class strength can be influenced by river plumes that mediate the spatial and temporal overlap of larvae with local physical and biological conditions that enhance growth and survival (the match-mismatch hypothesis; Cushing 1975, Grimes and Kingsford 1996) and affect the nature of biological interactions at the land-sea interface (Jackson *et al.* 2001, Pringle 2001, Milly *et al.* 2008, Breitburg *et al.* 2009). These can also be impacted at every developmental stage by both natural (e.g., hurricanes) and anthropogenic events (e.g., oil spills, hypoxia) over which we have no control.

In the Gulf of Mexico, fisheries productivity is highest along the West Florida Shelf (WFS), which comprises 75% of the total U.S. Gulf continental shelf and contains some of the most diverse and economically-important marine habitats and fisheries in the nation (Coleman *et al.* 2000, Koenig *et al.* 2000, Koenig *et al.* 2005). The influence of the Apalachicola-Chattahoochee-Flint (ACF) rivers drainage system (50,000 $km^2$) is immense. The ACF is the 2nd largest watershed in the U. S. Gulf, providing 35% of the freshwater input to the NE Gulf of Mexico (Richter *et al.* 2003), and considered a biodiversity 'hotspot' that harbors one of the higher concentrations of threatened and endangered species in the U. S. (Stein *et al.* 2000). The end point of the system, Apalachicola Bay, is one of the more productive estuaries in North America (Livingston *et al.* 1974, Livingston *et al.* 1997, Edmiston 2008). Given these superlatives, one can understand the immense concern aroused by the very real threat of the DwH oil spill on the integrity of this system, particularly if reduced freshwater flow would allow greater intrusion of oil up the river.

Of considerable concern to the region was the possible impact on Apalachicola's Eastern oyster (*Crassostrea virginica*) population, which supplies ~ 90% of the oysters in Florida and 10% nationally, and which influences energy flow, trophic organization, and availability of structured habit in estuarine ecosystems (Baird and Ulanowicz 1989, Grabowski *et al.* 2005). Despite its importance, the drivers of oyster productivity are not well known. This is due not only to the complex underlying mechanisms influencing vital rates of oysters (Livingston 2000, Wang *et al.* 2008), but to the relatively limited datasets and analytical approaches used to date (Wilbur 1992, Turner 2006). Thus, a major component of CONGER will be to explore in greater detail existing data sets and to build upon the only spatially-balanced study conducted on oyster vital rates in this system (Livingston 2000). Repeating this experiment allows us to infer how physical processes such as river flow, primary production, and the distribution of predators interactively influence the growth, survivorship and recruitment of oysters throughout Apalachicola.

Also of concern is the combined influence of pollution events and river flow on productivity as far offshore as the watershed has any influence. In Figure 6.5.1, for instance, we see emanating from the Apalachicola River a significant phytoplankton plume known as the *Green River Phenomenon* (GRP) (Gilbes et al. 1996). This seasonal event persists for weeks, extends hundreds of miles beyond the confines of Apalachicola Bay, and overlaps with the spawning season and spawning locations for gag grouper (*Mycteroperca microlepis*) when this feature is typically most intense (Coleman et al. 1996). After an extended pelagic larval phase, gag settle in seagrass habitats close to shore, where interannual variation in abundance can vary by as much as 200-fold (Koenig and Coleman 1998, Fitzhugh et al. 2005). Part of this variation may be attributed to annual variability in the GRP (Morey et al 2008).

Following from this background, CoNGER proposes a study that focuses on linking stressors that originate either within coastal watersheds or offshore with their ecological and fishery impacts in downstream coastal ecosystems (e.g., Lubchenco 1998, National Research Council 1999, Pikitch et al. 2004). As a proximal step, the team will conduct a retrospective analysis of relevant, existing datasets that relate to these issues. This approach will be coupled with field studies to target specific influences on food webs and population dynamics caused by nutrients, oil, and other types of pollutants. While the numerical modeling in Tasks 1-3 will promote predictions regarding the vulnerability and resilience of the Apalachicola Bay ecosystem, testing these predictions requires that we (a) establish linkages among the different biological components of the Apalachicola ecosystem and (b) quantify variation in these linkages in the presence and absence of natural and anthropogenic disturbances.

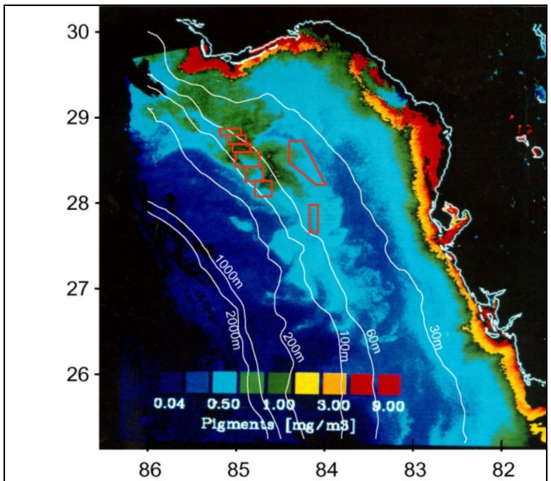


Figure 6.5.1. Satellite image of the phytoplankton plume known as the Green River Phenomenon extending from the Apalachicola River watershed. Note that the plume occurs between the 30 and 100 m isobaths and crosses over significant reef fish spawning habitat. White lines = isobaths; red boxes = grouper spawning sites.

<u>Fate and effect of transport of petroleum residuals</u>. The ecological pathways by which nutrients enter aquatic food webs can be traced by isotopic signatures (carbon, sulfur, nitrogen) that appear in the tissues of resident organisms (Fry 2006). In Apalachicola Bay, we used isotopic signatures (e.g., carbon, sulfur, and nitrogen) to elucidate whether productivity of small fishes within the bay was enhanced by nutrients from terrestrial or riverine sources (Chanton and Lewis, 2002, 1999). We propose to employ isotopic tracers to examine the follow-on question to our studies of trophic linkages within the bay, extending our observations to the continental shelf and to examine the distribution of oil that emanated from the DwH oil spill. The questions are:

- Does the river/bay influence productivity of adult fish on the continental shelf, and if so, does this enhancement occur as a result of nutrients enhancing shelf primary productivity or does organic matter outwelling contribute?
- Is the intrusion of petroleum into the Apalachicola system reflected in isotope ratios indicated by depletion in $^{13}C$, $^{14}C$ and N?

These two questions are inexorably linked because of the influence that hydrocarbon pollution can have either directly (via death) or indirectly (via growth or reproduction) on productivity.

The isotope approach takes advantage of the fact that oil residues are depleted in $^{13}C$ relative to carbon fixed in the surface of the water column. For example, oil may vary from -26 to -30‰, while marine carbon is -22 to -18‰. Isotopic depletion measured by Graham et al. (2010) in $\delta^{13}C$ in gulf phytoplankton coincided with the arrival of petroleum in the system indicating that oil carbon was being transferred into the planktonic food web. The assimilation of oil/methane can also observed in shifts in the biomass C/N ratio as oil is enriched in C and relatively depleted in N. The natural abundance of radiocarbon, $^{14}C$, is a third powerful tracer which the team will employ. The difference in $^{14}C$ content between recently photosynthesized organic matter and petroleum is on the order of 1000‰.

Methodology: The team will use a two-source mixing approach with marine-modern carbon as one end member, and with petroleum-fossil carbon as the second. Sedimentary organic matter in the estuary and on the shelf will be examined along in addition to consumer organisms at the base of the food web. We have an extensive catalog of pre-spill samples collected from the site for comparison to post spill effects. We also will obtain specimens of adult fish on the continental shelf to examine both the contributions of nutrients to fishery productivity and the fate and impact of oil by examining isotopic signatures in muscle tissue and in liver and gonads when possible, given the lipophilic nature of oil.

*Tracking* the relationship between river flow and the distribution and abundance of fisheries species. The team will use a combination of existing data and data derived from this project to evaluate oyster and gag grouper productivity in relation to seasonal and annual variability in river flow associated with physico-chemical factors in Apalachicola Bay. In particular, the task will address the following questions:
For oysters:

- Can the spatial and temporal variation of oyster production (abundance, biomass) be predicted by the variation in freshwater inflow into Apalachicola Bay.
- Does river flow either directly or indirectly control oyster mortality by limiting the distribution of oyster predators and by governing nutritional sources and thereby the rate at which oysters grow through vulnerable (small) size classes?
- Are the community composition and trophic structure of animals associated with oyster reefs at large temporal and spatial scales respond more strongly to river flow and associated salinities in the Bay?

Methodology: The task will integrate data from long-term monitoring programs with existing data on river flow, nutrients, and physico-chemical conditions in Apalachicola Bay to address these questions and evaluate the predictions of the modeling Objective (2). The team will use a 35-year oyster demographic dataset (Florida Department of Agriculture and Consumer Services Shellfish Management group) to address the 1st question and a 10 –year trawl survey and hydrographic dataset (Apalachicola National Estuarine Research Reserve) to evaluate the 3rd question. Question 2 will be addressed through field sampling and experimentation intended to evaluate the utility of the existing data, and to establish mechanistic linkages between river flow and oyster productivity by quantifying causes of variation in oyster vital rates. This involves repeating Livingston's (2000) spatially-balanced experiment with replicated treatments of oysters in predator exclosures, exclosure-controls, and no-exclosures.

To assess how growth rate and resultant size of oysters is influenced by vulnerability to predators and disease, we will also manipulate oyster size within these treatments. To assess it across growing seasons, the team will collect oysters throughout Apalachicola Bay and examine growth bands on oyster shells (Kirby et al. 1998), concave bands representing rapid shell growth during warm/food rich periods, and convex bands representing slower shell growth during cold/food poor periods. The number of concave/convex bands can be used to estimate oyster age and thereby generate a baseline describing inter-annual size-at-age relationships for oysters at different sites. Finally, the task will conduct isotopic analyses of oyster tissue to evaluate the influence of nutrients on oyster productivity.

Questions being addressed for reef fish component include the following:

- Is annual variability in recruitment of juvenile gag to inshore seagrass habitats related to variability in river flow and the associated intensity of the *Green River Phenomenon* (GRP), the oil spill, or other extreme events on the West Florida Shelf (WFS)?

- Is annual variation in the abundance and spatial distribution of adult gag grouper in the fishery related to variability in the intensity and spatial structure of the GRP, the oil spill, or other extreme events on the WFS at appropriate temporal lags.

Methodology.-- We will analyze data on juvenile gag grouper recruitment in relation to variability in river flow and the GRP from an ongoing (since 1992) annual trawl survey of inshore seagrass habitats (Koenig and Coleman 1998) encompassing most of the range of juvenile gag along the WFS, from Marco Island to Panama City, FL. Information on the abundance, age structure, and spatial distribution of adult gag grouper is available from our data and from the stock assessments conducted by NOAA for the Gulf of Mexico Fishery Management Council. These data will be used to investigate relationships between fishery harvest, adult abundance, indices of juvenile year-class strength, and Apalachicola River flow and the associated intensity of the GRP. We also will capture juvenile and adult fish for isotopic analyses to evaluate any trophic connection of the bay with the productivity of adult fish on the continental shelf, and of any linkages to the DwH oil spill.

Deliverables

6.5.1 An isotopic analysis tracing oil residuals throughout the Apalachicola Bay & Shelf System and within tissues of oysters and both juvenile and adult fishes.
6.5.2 An analysis of oyster and gag grouper productivity in relation to seasonal and annual variability in river flow associated with physico-chemical factors in Apalachicola Bay, including the presence of nutrients and oil.
6.5.3 Development of a trophic model involving key economically important species, including oysters and gag.

| MILESTONE | DATE COMPLETE |
|---|---|
| 6.5.1 Year 1 Results Complete | 9/12 |
| 6.5.2 Year 2 Results Complete | 9/13 |
| 6.5.3 Year 3 Results Complete | 9/14 |

Sub-Task 6.6 Data Management

Leads: Each Sub-Task Lead

Objective

6.6.1 Arrange for all production model results of biotic processes to be stored and to be forwarded to GRI in conformance with the Data Management Plan and in coordination with the Project Data Manager.

Approach

The Data Management Plan and Task 5.1 describe the project's data management policies and procedures. Data collected in this task will be stored in a standard format with complete metadata and made available as soon as possible after results are published.

Schedule

| MILESTONE | DATE COMPLETE |
|---|---|
| 6.6.1. Define metadata file format for project files | 12/2011 |
| 6.6.2. Year 1 Results and Report | 9/2012 |
| 6.6.3. Year 2 Results and Report | 9/2013 |
| 6.6.4. Year 1 Results and Report | 9/2014 |

**Task 7. Synthesis**

Task Leaders:John W. Tunnell, Jr. and Larry D. McKinney, HRI

Members: John Harding, NGI; Felicia Coleman, FSU; Just Cebrian, DISL; Stephan Howden, USM; Sam Bentley, LSU; James Martin, MSU; W. H. McAnally, NGI

OBJECTIVE(S)

7.1 Provide integrated interpretation of petroleum spills/dispersant systems ecosystem effects for Gulf-wide application and knowledge extension.
7.2 Develop a Gulf of Mexico Ecosystem Report Card

BACKGROUND

Two scientifically broad and geographically encompassing tasks are proposed under the Synthesis Task: 1) integrated interpretation of all research and 2) a Gulfwide ecosystem health metric (Report Card). For a multi-institutional consortium to successfully function as a unified research center, there must be an integration of the various components and research findings. The Synthesis Task will bring together the research task leaders with their results to gain a synthesized view of the petroleum spills/dispersant systems ecosystem effects on the Gulf of Mexico. Secondly, in order to guide and inform the success (or failure) of policy, management, monitoring, and research to achieve a healthy Gulf of Mexico, a metric (report card or scorecard) must be established. The collective vision is to develop a graphical representation of the environmental condition of the Gulf that will be scientifically based, widely accessible, and readily understandable by policy-makers, stakeholders, scientists, and most importantly the American public. Such a Report Card will provide the scientific information and understanding necessary to evaluate the health of the Gulf, clearly demonstrate how well it is or is not progressing towards desired long-term goals, and inform the decision-making process on the policies and resources needed to achieve sustainability of a healthy Gulf of Mexico. Development of the Report Card will be broadly inclusive of scientists and stakeholders across the Gulf, and it will be uniquely linked to the CEEM and the Sulis Decision Support System (sub-task 5.5)

Previous and ongoing projects that support this task

Synthesis Lead PI Wes Tunnell has been working in the Gulf of Mexico for 45 years, including 40 years in Mexico and 9 in Cuba. He wrote a synthesis on the status of Gulf fisheries regarding the Deepwater Horizon oil spill for the Gulf Coast Claims Facility (Tunnell 2011), and he has written and edited two books synthesizing all knowledge about two Gulf ecosystems, the Laguna Madre (Tunnell and Judd 2001) and coral reefs of the southern Gulf of Mexico (Tunnell et al. 2007). Tunnell has been engaged in teaching and research related to oil spills for 35 years.

The Harte Research Institute for Gulf of Mexico Studies at Texas A&M University-Corpus Christi (HRI), along with its partners Harwell-Gentile & Associates, LC, and the University of Maryland Center of Environmental Science (UMCES), started developing the Gulf of Mexico Report Card concept in February 2011 and produced a prospectus for a Gulf of Mexico Report Card Initiative in May 2011 (McKinney et al. 2011). This is currently a HRI initiative, but it is without funding.

State of the Art

Larry McKinney and Wes Tunnell are the Lead PIs on the Report Card team from HRI. Together they have over 85 years of work and study in the Gulf of Mexico and over 50 years of program and project management experience. Mark Harwell and Jack Gentile of Harwell-Gentile are leaders in ecological risk assessment framework and guidelines and the development of conceptual ecosystem models, and Bill Dennison and Heath Kelsey of UMCES have created report cards in the United States, including the Chesapeake Bay, Europe, Australia, the Pacific, and the Caribbean. Merging the talents of these two world-class teams brings a state-of-the-art approach to tackle this new report card initiative at an unprecedented scale never attempted before.

Approach

Two separate, but linked, sub-tasks will be involved in the Task: 7.1 Science Synthesis and 7.2 Report Card. These two sub-tasks are detailed below.

7.1 Subtask: Science Synthesis

Emphasis will be placed in two areas: 1) review and synthesis of historical natural and anthropogenic releases of petroleum into the Gulf of Mexico from all three surrounding countries (US, Mexico, and Cuba) and 2) integrated interpretation of processes tasks and site-specific research findings for the wider Gulf of Mexico and beyond.

The Gulf has possibly the largest volume of natural hydrocarbon seepage in the world (NRC 2003). The first reported floating oil fields were noted to be widespread in the Gulf (Soley 1910), and subsequent studies in recent decades have confirmed the locations to be consistent and continuous today with as many as 1000 sites known (MacDonald 1998, Garcia 2009). Over 43 million gallons, the equivalent of a super tanker, are known to be released naturally into the Gulf of Mexico annually (NRC 2003). In addition to low diversity chemosynthetic communities directly associated with hydrocarbon release sites, such as brine pools, asphalt flows, barite chimneys, and methane hydrates (Cordes et al. 2010), the entire Gulf of Mexico is apparently inoculated with petroleum-eating microbes that can consume and break down hydrocarbons because of these chronic, ancient widespread releases (Tunnell 2011).

Although no long-term studies were conducted to confirm it, many scientists were dismayed by the fact that the Ixtoc I oil spill of over 140 million gallons in 1979-80 in the southern Gulf seemed to "disappear or vanish" and leave little known, long-term impacts (Jernelov 2010). From this historic case, and in similar ways with the Deepwater Horizon spill, it appears that the Gulf of Mexico has a strong capacity to deal with hydrocarbons, as demonstrated by both natural and anthropogenic releases (Safina 2010). This resilience to petroleum needs to be reviewed and studied, as well as integrated with current findings, to better understand warm water oil spills in the future of the Gulf of Mexico and in other parts of the world.

The purpose of this first portion of the Science Synthesis will be to compile, review, and synthesize all known information about Gulf of Mexico natural and anthropogenic hydrocarbon releases. Perhaps Gulf of Mexico hydrocarbons should not only be considered as a "pressure" or "stressor" on the Gulf ecosystem but also a "driver" within the ecosystem model?

The second portion of the Science Synthesis will consider observational data from the site-specific studies (Barataria Basin/Wax Lake Outlet, Mississippi Sound/Bight, Perdido Bay, Apalachicola Bay) plus observations from deeper offshore waters to integrate and interpret findings for Gulf-wide application and knowledge extension. This kind of "satellite 4-D view" of the fate and effects of hydrocarbons in the Gulf of Mexico ecosystem will be vertical in the water column and sediments, horizontal in geography both along the coast, as well as from the shore to offshore, and present-day to historical in timing. Observational and model data will be examined to identify similarities and differences in ecosystem responses among the sites. Results from other research groups will be examined as they are produced to add confidence to the conclusions drawn from this work.

These new data and stronger CEEM, along with other regional studies outside of CoNGER, will assist in the overall interpretation and synthesis of "improving fundamental understanding of the dynamics of such (spill) events and the associated environmental stresses and public health implications" (CoNGER Goal). In summary, the CoNGER results and synthesis will "improve society's ability to understand, respond to, and mitigate the impacts of petroleum pollution and related stressors of the marine and coastal ecosystems, with emphasis on conditions found in the Gulf of Mexico"…and the…"Knowledge accrued will be applied to restoration and to improvement of the long-term environmental health of the Gulf of Mexico" (remaining CoNGER Goal).

7.2 Subtask: Report Card

The project will develop a comprehensive framework, and then implement an ecosystem Report Card on the health, or desired condition, of the Gulf of Mexico. The vision, led by the Harte Research Institute (HRI) partner, is to develop a graphical representation of the environmental condition of the Gulf that will be scientifically based, widely accessible, and readily understandable by policy-makers, stakeholders, scientists, and, most importantly, the American public. Such a Report Card will provide the scientific information and understanding necessary to evaluate the health of the Gulf, clearly demonstrate how well it is or is not progressing towards desired long-term goals, and inform the decision-making process on the policies and resources needed to achieve sustainability of a healthy Gulf of Mexico.

When President Obama announced by Executive Order the formation of the Gulf Coast Ecosystem Restoration Task Force, he said that within one year of the date of the order (5 October 2010) "the Task Force shall prepare a Strategy that proposes a Gulf Coast ecosystem restoration agenda, including goals for ecosystem restoration, *development of a set of performance indicators to track progress*, and means of coordinating intergovernmental restoration efforts guided by shared priorities". Because of the scale and complexity of the Gulf, achieving a healthy and sustainable Gulf of Mexico will require an extensive, sustained National effort that addresses not only the consequences of the Deepwater Horizon oil spill and the suite of recent devastating storms such as Hurricanes Katrina, Rita, and Ike, but also the myriad of other impacts on the Gulf from human activities. These range from: increased nutrients and chemicals that flow into the Gulf from the watershed that drains more than half of the continental US, including America's agricultural heartland; rapidly expanding development of cities and industry fueled by energy, transportation, tourism, and other major industries; harmful invasive species that have spread across the region; and the pervasive consequences of global climate change, including the specter of rapidly rising sea levels along highly vulnerable coastlines.

To capture the effects of these and many other pressures impinging on the Gulf, HRI has developed a conceptual framework for a Gulf of Mexico Report Card that is unequaled in the world in its scope and potential utility. The Report Card, when fully developed, will be directed at a diversity of audiences, from the highest levels of decision-making to the most-detailed scientific investigations. This hierarchical structure, unified by a common conceptual framework, will provide the optimal basis for informing multiple audiences at the appropriate level of detail and aggregation, allowing one to dig deeper into the reasons for the various assigned grades of environmental health. Additionally, the Report Card will be spatially explicit yet scalable, providing a way to compare the successful and not-so-successful outcomes across regions, habitats, and political boundaries.

As the Report Card is populated and updated over intervening years and decades, patterns of pressures and impacts will emerge, giving guidance to what policies have accomplished or failed to accomplish their objectives. This type of feedback from scientific information into the decision-making process promises to be an invaluable tool for improved environmental management, guiding Gulf–wide research, policy, and ecosystem restoration. Indeed, because of the scale and comprehensiveness of the proposed Gulf of Mexico Report Card, CoNGER believes it has the potential to be an unprecedented advance in how the Nation manages and sustains its environmental heritage.

Proposed Framework. Over the past decade or so, a number of environmental report cards have been developed and presented that characterize the health of ecosystems. The HRI-led team (McKinney and Tunnell), has already engaged Mark Harwell and Jack Gentile of Harwell Gentile and Associates, LC, and Bill Dennison and Heath Kelsey of the University of Maryland, Center for Environmental Science, who are active leaders in the development and implementation of environmental health report cards for a diversity of ecosystems, ranging from Chesapeake Bay and the Florida Everglades, to Prince William Sound and the Gulf of Alaska, and across to the Great Barrier Reef.

The HRI-led team recently surveyed several existing environmental report cards and assessed their conceptual foundations. Two basic approaches exist: one based on the Drivers-Pressures-State-Impacts-Response construct, aimed especially at synthesizing scientific indicators to inform decision-makers; and the other based on the ecological risk assessment framework, focused on the cause-effects relationships between environmental stressors and ecological effects, and aimed especially at the scientific and risk-assessment communities. The team has integrated these two approaches to create a new Drivers-Pressures-Stressors-State-Impacts-Response (DPSSIR) conceptual framework, designed not only to reach decision-makers and stakeholders, but also to guide and focus scientific research on identifying and addressing the most important risks to the ecosystem.

The DPSSIR conceptual framework (Figure 7.1) distinguishes the following elements: 1) Drivers—these are the fundamental forces that affect the environment, whether societal drivers, such as energy development and demographics, or natural drivers, such as climatic and oceanographic processes; 2) Pressures—these are the human activities and natural processes that cause environmental stressors; human activity examples include coastal development, oil and gas exploration and spills, and commercial and recreational fishing; natural processes in the Gulf include the dynamics of the Loop Current, and hurricanes and tropical storms; 3) Stressors—these are what the ecological system "sees", defined as chemical, physical, or biological agents that can cause ecological effects; examples include habitat alteration, changes in the salinity regime, sea-level rise, harmful algal blooms, toxic chemicals, and excess nutrients; 4) State—this is the condition of the environment, which is measured in terms of Valued Ecosystem Components (VECs), i.e., those particular ecological attributes that are important to humans and/or to the functioning of the ecosystem itself; examples include fisheries populations, marine mammals, important habitats such as wetlands, seagrasses, and coral reefs, and critical or endangered species; 5) Impacts—this is a measure of how far the condition of the ecosystem is, in terms of the VECs, from a desired condition, such as the condition that existed before an oil spill occurred, or the desired environmental goal for ecological recovery and sustainability; and 6) Response—this is what society does to reduce, mitigate, or adapt to stressors; often response actions are aimed at reducing the Pressures on the environment, such as through pollution controls, regulations to improve the safety of ships or oil platforms, or land-use and water-conservation measures.

The DPSSIR conceptual framework is comprehensive, providing the scientific foundation and structure to organize and report information across the broad spectrum of needs for regional-scale environmental management, as well as reaching the breadth of audiences with interests in the health of the Gulf of Mexico. Figure 7.2 illustrates how different layers in the DPSSIR conceptual framework address targeted audiences. The highest level, aimed at decision-making officials and the general public, focuses on Pressures, State, and Responses, with emphasis on the State, i.e., the bottom-line conclusions about the health of the environment. Policy- and decision-makers and stakeholders, shown at the second level, would be presented with report card indicators for Pressures, State, Impacts, and Response, with the emphasis on the latter, i.e., what to do about environmental problems. More hands-on environmental managers, such as managers in state-level environmental agencies, would focus on Pressures and Impacts, but also with interest in the Stressors and State of the environment. And, finally, scientists focus particularly on Stressor-State-Impacts relationships, within the context of the Drivers and Pressures.

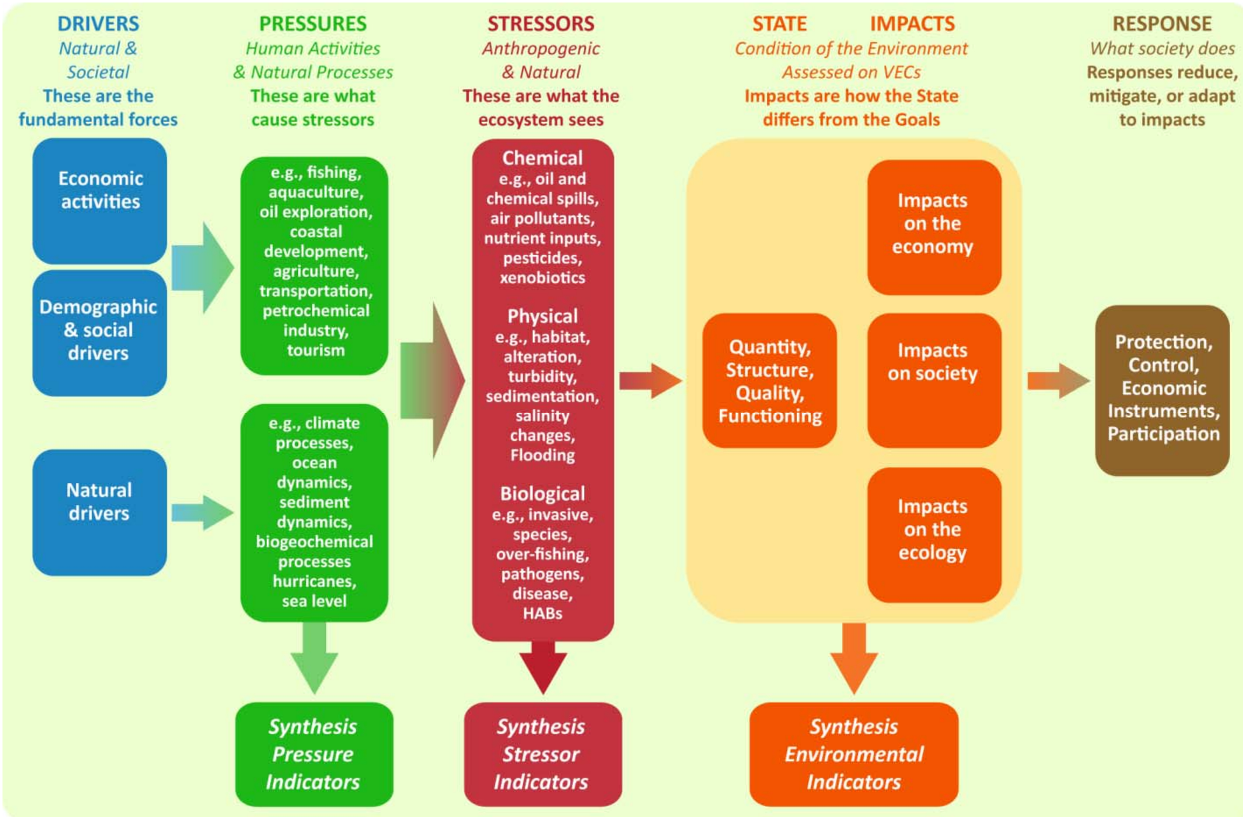


Figure 7.1. – The DPSSIR Conceptual Framework. This new integrated framework provides the foundation for a science-based, policy-relevant, environmental health report card commensurate with the scale and complexity of the Gulf of Mexico.

This structure allows, for example, an elected official to ask why the health of her/his state is as it is, and being provided with the appropriate information from the more detailed, lower layers that indicate what Pressures and Stressors are of primary concern, and what may be appropriate Responses to mitigate the Pressures of concern. At the other end of the spectrum, this conceptual framework can help scientists identify uncertainties in those aspects that matter the most to the health of the ecosystem, and then allocate resources towards those studies that will best reduce uncertainties and improve critical understanding of the ecosystem. Moreover, the hierarchical nature of the DPSSIR framework (Figure 7.2) provides the structure for most effectively aggregating and combining data to create synthetic indicators as one moves up the tiers, as well as to organize and communicate information most effectively to stakeholders and the public.

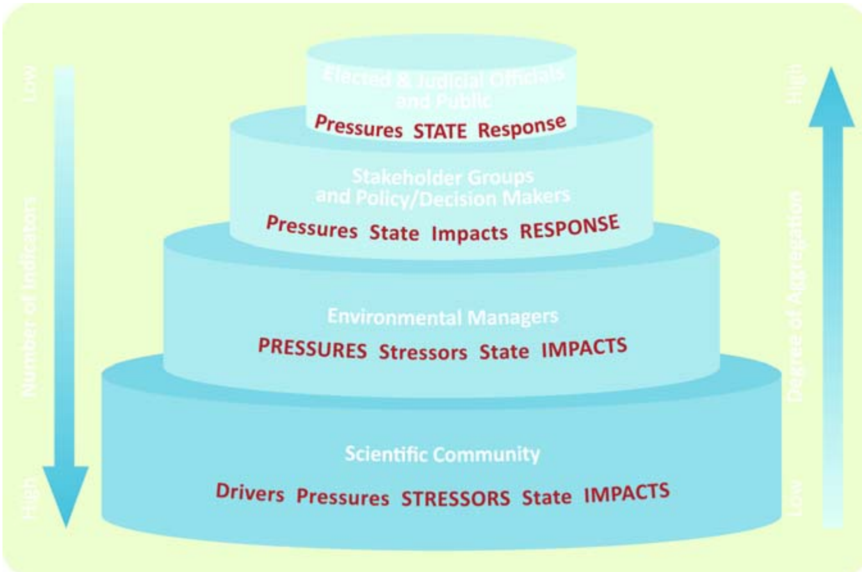


Figure 7.2. – Hierarchical Structure of the Gulf of Mexico Report Card. This reporting structure captures and integrates the information relevant to each layer of a diverse set of audiences.

Process to Develop the Gulf of Mexico Report Card. CoNGER proposes to develop the Gulf of Mexico Report Card through a systematic process that will engage scientific and management expertise and experience relevant to the Gulf. This process will build on previous success in report card development by the development team, including ecosystem assessments at Prince William Sound, and report cards for Chesapeake Bay and Australia's Great Barrier Reef. CoNGER will first convene an Initial Stepping-Stone Workshop, consisting of scientists, environmental managers, and stakeholder representatives. The charge to the participants in this workshop is to decide how to divide the Gulf into manageable reporting units. Unlike many existing report cards, the one for the Gulf must include a broad diversity of ecosystem types, from deep water bottom communities, pelagic habitats, coral reefs, seagrass communities, salt and freshwater marshes, and riverine systems to barrier islands, coastal forests, and the larger watershed. Additionally, there are quite different environmental issues across the spatial extent of the Gulf—for example, the components of South Florida's environmental report card likely will differ substantially from Mississippi's or the Yucatan's. Further, the Gulf's Report Card must also incorporate some VECs that are trans-boundary, crossing geographic or governance divisions, such as the health of important pelagic fish populations or sperm whales. Consequently, the product of the Initial Stepping-Stone Workshop will be to clearly define how the Gulf of Mexico will be divided into appropriate and relevant reporting units. That workshop will also begin the process of identifying the important Pressures and Stressors impinging on the Gulf's ecosystems.

The Second Stepping-Stone Workshop will follow a few weeks later. This workshop will have additional scientific expertise, organized around those habitats and regions selected for the Report Card. Each habitat- or region-specific workgroup will develop an initial conceptual ecosystem model of the system of interest, including identifying the full suite of VECs for the system, ranking the relative importance of the Stressors that affect that habitat or region, and the Pressures causing them, as well as proposing an initial set of indicators or indices for the Report Card.

Completion of the Second Stepping-Stone Workshop will provide the team with the ideas and information needed to construct the Gulf of Mexico Report Card Framework. This Framework will be presented at the State of the Gulf of Mexico Summit to be convened on 4-8 December 2011 in Houston, Texas, by the Harte Research Institute. A summary document will be prepared for distribution at the Summit, that includes a description and rationale for the DPSSIR approach, the geographic units of the

Gulf that will be assessed, and the specific set of indicators proposed to constitute the Report Card. CoNGER also intends to present selected indicators with existing data to illustrate the nature and utility of the Report Card, along with a plan for full implementation across all indicators.

Fully constructing the Gulf of Mexico Report Card will be an iterative process that will continue to unfold over several years following the Summit. In this final phase, HRI will lead this CoNGER effort and integrate activities to collect and analyze environmental data, develop integrative metrics, with emphasis on synthesizing Pressures, Stressors, State, and Impacts indicators, and create the reporting process. CoNGER will plan for the latter to be an online-based system for accessing the Gulf of Mexico Report Card and its associated data, recognize important trends, and readily understand the health and remaining threats to the Gulf. It will be fully coordinated with the ongoing NGI work on developing Integrated Ecosystem Assessment methods and tools.

This Report Card will be the first such metric of this magnitude ever attempted, and it will contain cutting-edge methodology at an unprecedented scale. Not only will the Report Card help guide research and monitoring activities, it will include policy- and regulatory-relevant metrics and analyses that will help guide and unify restoration activities in a cost-effective manner. It will also help to evaluate the efficacy of restoration efforts within the limitations of natural variability.

The Report Card will be linked with the Sulis Decision Support System, as described in Task 5.

Sub-Tasks Descriptions

7.1.1 Tunnell and Moretzsohn: Review and catalog the number, kind, and volume of known Gulf of Mexico natural petroleum seep sites in US, Mexican, and Cuban waters.

7.1.2 Tunnell and Moretzsohn: Review and catalog the number, kind, and volume of known anthropogenic petroleum spills and releases into the Gulf of Mexico by state and country.

7.1.3 Tunnell et al.: Coordinating with all of the CoNGER task leads, provide integrated interpretation of CoNGER research by processes tasks and site-specific studies.

7.1.4 Tunnell and Moretzsohn: Compare and contrast an integrated interpretation of chronic vs acute and natural vs anthropogenic petroleum spills within the Gulf of Mexico and outside the Gulf of Mexico to similar warm water ecosystems.

7.2.1 McKinney and Tunnell with Harwell, Gentile, Dennison, and Kelsey: Hold two stepping-stone workshops to develop the Gulf of Mexico Report Card Framework with leading scientific experts and stakeholders on Gulf of Mexico habitats and geographic regions. This process will start the overall project objective of developing a Gulf of Mexico Report Card from indicators suitable for evaluation of Gulf ecosystems. These indicators will vary by habitat and geographic region, and will be determined for each component of a Drivers, Pressures, Stressors, State, Impacts, and Response (DPSSIR) assessment framework.

7.2.2 Harwell, Gentile, Dennison, and Kelsey: Construct the Gulf of Mexico Report Card Framework (this task is shared with Informatics and Education-Outreach Tasks).

7.2.3 McKinney and Tunnell with Harwell, Gentile, Dennison, and Kelsey: Roll out the Report Card Framework at the HRI State of the Gulf of Mexico Summit in Houston during 4-8 December 2011 (this task is shared with Informatics and Education-Outreach Tasks).

7.2.4 McKinney, Tunnell, Harwell, Gentile, Dennison, and Kelsey: Continue iterative process to fully develop Report Card with Gulf of Mexico science and management community. Dennison and Kelsey will use the support capacity of the Integration and Application Network (IAN) at UMCES to oversee and supervise these three elements: 1) data integration and scoring – evaluate and integrate indicators for report card with science providers and partners, and develop desired conditions or threshold values with them; 2) reporting and visualization development – develop Gulfwide report card and regional summaries products to convey major ecosystem processes and specific indicator elements derived from the DPSSIR framework (IAN Science Integrator and Science Communicator will lead the development or reporting presentation and visualization framework for synthesis products); and, 3) web site development and design – although the printed products will be the flagship of the Gulf of Mexico Report card, a strong, interactive, and educational web presence will be a major support product (this task is shared with Informatics and Education-Outreach tasks).

Deliverables

7.1.1 and 7.1.2 Combined technical report and peer-review article.

7.1.3 Technical report and peer-review article by all lead PIs on various processes tasks and site-specific studies. Technical report should be annual, whereas peer-review article could be annual or might not be until after three-year summary. This will depend on annual significance of findings.

7.1.4 Technical report and peer-review article. These will be after a three-year summary of data and information synthesis for Gulfwide and worldwide comparison.

7.2.1 Workshop proceedings prepared for each of these two workshops and then used to develop Report Card Framework.

7.2.2 Preparation of Gulf of Mexico Report Card Framework in written text (technical report and peer-review article), as well as Power Point presentation for 7.2.3 (Summit).

7.2.3 Formal presentation of Gulf of Mexico Report Card at State of the Gulf of Mexico Summit 2011 in Houston during 4-8 December 2011.

7.2.4 Full development of functional Gulf of Mexico Report Card with many partners, including annual (or biennial or triennial, tbd) Report Card in paper form and on World Wide Web.

Schedule

| MILESTONE | DATE COMPLETE |
|---|---|
| 7.1.1 & 7.1.2 Combined technical report and peer review article on natural and anthropogenic oil spills/releases in Gulf of Mexico | 9/2012 |
| 7.1.3 Synthesis technical report/synthesis peer-review article | 9/1012 & 9/2014 |
| 7.1.4 Synthesis comparison tech report and peer-review article | 9/2014 |
| 7.2.1 Stepping-stone workshops | 12/2011 |
| 7.2.2 Report Card Framework | 12/2011 |
| 7.2.3 Report Card Framework roll-out at Summit 2011 | 12/2011 |
| 7.2.4 Development and implementation of Report Card | 2012-2014 |

## Task 8. Education and Outreach

Leaders: Sharon Hodge, NGI; Tina Miller-Way, DISL

Objectives:

CoNGER's E & O Task addresses ongoing efforts toward the Gulf Research Initiative's ultimate goal "to improve society's ability to understand, respond to and mitigate the impacts of petroleum pollution and related stressors of the marine and coastal ecosystems, with an emphasis on conditions found in the Gulf of Mexico."

The central objectives of the Education and Outreach (E & O) Task are to:

8.1 Translate and disseminate concepts of modeling and stressors of the northern Gulf of Mexico ecosystem.

8.2 Translate and disseminate findings of the impact of PDS on the northern Gulf of Mexico ecosystem.

A narrative description of the Education and Outreach plan is given in Section 2e.

Sub-Tasks Descriptions:

Subtask 8.1 Establish base content by loading CoNGER projects into the CoNGER project database hosted by NGI; conduct quality control projects visible/searchable on CoNGER web page.

Members: Hodge and NGI Staff

Subtask 8.2 Convene virtual meeting of all CoNGER E & O principals and key staff to develop integrated messaging and outreach process.

Members: Hodge, NGI and Miller-Way, DISL

Subtask 8.3 Develop project outreach materials format and coordinate plan for presentation in CELC public venues; Draft outreach materials and meet with principal education coordinators for the public venues to coordinate posting. Notify CoNGER principals of important appropriate conference and presentation venues.

Members: Hodge, NGI, and Prince, MSU

Subtask 8.4: Support the Gulf of Mexico Report Card Framework (this task is shared with Informatics and Synthesis Tasks). Develop related introductory explanatory materials.

Members: Hodge, NGI, and Prince, MSU

Subtask 8.5 Develop first half of CoNGER program and project Research Spotlights; draft flyers and vet with project leads.

Members: Hodge, NGI and Miller-Way, DISL

Subtask 8.6 Develop draft presentations on modeling, ecosystems, and northern Gulf of Mexico. Vet with project task leads and other experts.

Members: Miller-Way, DISL; Hodge, NGI; Prince, MSU: and NGI/DISL staff:

Subtask 8.7 Revise, post and distribute presentations to target audiences at a variety of venues.

Members: Hodge, NGI; Miller-Way, DISL; and Prince, MSU

Subtask 8.8 Develop, publish CoNGER Newsletter; gather from all partners, vet stories, work with publishing division to develop final product

Members: NGI Staff

Subtask 8.9 Support the Report Card Framework at the HRI State of the Gulf of Mexico Summit in Houston during 4-8 December 2011 (this task is shared with Informatics and Synthesis Tasks).

Members: Hodge, NGI

Subtask 8.10 Develop remainder of project Research Spotlights; publicize availability and access to the materials

Members: Hodge, NGI; Prince, MSU; Miller-Way, DISL; and NGI and DISL staff:

Subtask 8.11 Produce and distribute project Research Spotlights to public venues, including CELC.

Member: Prince

Subtask 8.12 Develop remaining sub-task Research Spotlights, based on program development and research results

Members: Prince and NGI Staff

Subtask 8.13 Evaluate and modify outreach materials as deemed appropriate

Members: Hodge, NGI; Miller-Way, DISL

Subtask 8.14 Develop draft presentations on modeling and stressors. Vet with project leads, other experts.

Members: Miller-Way, DISL; Hodge, NGI; and DISL Staff:

Subtask 8.15 Complete additional enhanced Research Spotlights as identified by program development and research results

Members: Prince, MSU; Miller-Way, DISL; and DISL staff:

Subtask 8.16 Develop, publish CoNGER Newsletter

Members: Hodge, NGI; Prince, MSU; and NGI staff:

Subtask 8.17 Develop CoNGER Annual Report

Members: Hodge, NGI; Prince, MSU: and NGI staff

Subtask 8.18 Develop outreach materials to teach the public about the GoM Report Card. Materials will be presented to the general public in the Coastal Ecosystem Learning Center venues with other CoNGER materials and complement the web based Report Card product.

Members: Prince, MSU; Hodge, NGI; Miller-Way, DISL

Subtask 8.19 Accommodate CoNGER task leaders presentation needs with revised standard presentations slides and notification of appropriate conferences and venues.

Members: Hodge, NGI; Miller-Way, DISL; and Prince, MSU

Subtask 8.20 Translate outreach materials into Spanish. CoNGER E & O Team will assess interest in translating the outreach products into Spanish and coordinate the technical translation using English/Spanish proficient students at CoNGER partner institutions to produce the materials

Members: Hodge, NGI; Prince, MSU; and Tunnell, HRI.

Deliverables

8.1 CoNGER Web Site

8.2 Research Spotlights – quarterly

8.3 Annual Reports – Yearly

8.4 Outreach Materials on Report Card

8.5 CoNGER Newsletter – semi annually

8.6 Contributions to Gulf Research Initiative – annually

8.7 Spanish translation – annually

In Years 2 and 3, outreach materials will be updated to reflect the maturity of the research tasks and a focus on transitioned research. Additional emphasis will be placed on video production focusing on research tasks, accomplishments and transitions to applications.

Quarterly status reports will be provided by teleconference led by the NGI Program Office. (Project Lead or designee of record must participate). Project report will be submitted to NGI Program Office at year end. Copies of or links to project-related publications will be included.

Schedule

| MILESTONE | DATE COMPLETE |
|---|---|
| 8.1. Establish base content by loading CoNGER projects into the project database hosted by NGI; conduct quality control projects visible/searchable on CoNGER web site. | 12/2011 |
| 8.2 Convene meeting of all CoNGER E & O principals and key staff to develop integrated messaging and outreach process. | 12/2011 |
| 8.3 Develop project outreach materials format and coordinate plan for presentation in public venues; Draft outreach materials and presentations, and meet with principal education coordinators for the public venues to coordinate posting. Notify CoNGER principals of important outreach events | 12/2011 |
| 8.4 Construct the Gulf of Mexico Report Card Framework (this task is shared with Informatics and Synthesis Tasks). | 12/2011 |
| 8.5 Develop first half of ConGER program and project Research Spotlights; draft flyers and vet with project leads | 3/2012 |
| 8.6 Develop draft presentations on ecosystems, modeling, and northern Gulf of Mexico. Vet with project leads and other experts. | 3/2012 |
| 8.7 Revise, post and distribute presentations to target audiences at a variety of venues. | 3/2012 |
| 8.8 Develop, publish CoNGER Newsletter; gather from all partners, vet stories, work with publishing division to develop final product | 3/2012 |
| 8.9 Roll out the Report Card Framework at the HRI State of the Gulf of Mexico Summit in Houston during 4-8 December 2011 | 3/2012 |
| 8.10 Develop remainder of project Research Spotlights; publicize availability and access to the materials | 6/2012 |
| 8.11 Produce and distribute project Research Spotlights to public venue, including CELC sites.s | 6/2012 |
| 8.12 Develop half sub-task spotlights, based on program development and research results | 6/2012 |
| 8.13 Evaluate and modify outreach materials as deemed appropriate | 9/2012 |
| 8.14 Develop draft presentations on modeling and stressors. Vet with project leads and other experts. | 9/2012 |
| 8.15 Complete additional enhanced spotlights as identified by program development and research results | 9/2012 |
| 8.16 Develop, publish CoNGER Newsletter with contributions from all CoNGER participants. | 9/2012 |
| 8.17 Develop CoNGER Annual Report | 9/2012 |
| 8.18 Conduct iterative process to fully develop Report Card with Gulf of Mexico science and management community. | 9/2012 |
| 8.19 Develop outreach materials to teach the public about the GoM Report Card. Materials will be presented to the general public at a variety of venues including the Coastal Ecosystem Learning Center. | 9/2012 |
| 8.20 Accommodate CoNGER task leaders with revised presentation needs with standard presentation slides and notification of appropriate conferences and venues. | 9/2012 |
| 8.21 Assess which outreach messages are important for Spanish speaking stakeholders and coordinate production and dissemination of web-based and hardcopy materials. | 9/2012 |

| | |
|---|---|
| 8.22 Set remaining Milestones based on evaluation of initial efforts | 10/2012 |

**Task 9: Project Management**

Task Leader: W. H. McAnally, NGI

Team Members: S. Lohrenz, U. Mass-D; J. Easley, MSU; M. Dannreuther, NGI and steering committee members.

Objectives

9.1 Support team efforts
9.2 Sustain teams' focus on the objectives
9.3 Ensure consistency and timeliness of work
9.4 Effective and efficient expenditure of funds
9.5 Maintain liaison with GRI and other consortia

Approach

The Management Plan (Section 4g) describes how this task will be accomplished.

Schedule

| MILESTONE | DATE COMPLETE |
|---|---|
| 9.1 Notice of Award (assumed) | 9/2011 |
| 9.2 All sub-awards complete | 10/2011 |
| 9.3 First Annual Report | 10/2012 |
| 9.4 Second Annual Report | 10/2013 |
| 9.5 Third Annual Report | 9/2014 |
| 9.6 Project Complete | 9/2014 |

Qualifications of the Consortium

The Consortium for Northern Gulf Ecosystem Research (CoNGER) brings together multiple institutions with comprehensive capabilities and experience able to effectively address the goals of the Gulf of Mexico Research Initiative (GRI) Request for Proposals. The Northern Gulf Institute (NGI), a Cooperative Institute based at Stennis Space Center, MS, will serve as the lead institution for CoNGER. NGI, established in 2006, is itself a multi-state partnership of institutions including Dauphin Island Sea Lab (AL), Florida State University, Louisiana State University, Mississippi State University, and University of Southern Mississippi. Its themes are Ecosystem-based management, Geospatial data/information and visualization in environmental science, Climatic change and climatic variability effects on regional ecosystems, and Coastal hazards and ecosystem resiliency.

Complementing the existing NGI partners, CoNGER includes the Cooperative Institute for Marine and Atmospheric Studies (CIMAS), a partnership among all the major research universities in Florida and the U.S. Caribbean, in Miami, FL; the Harte Research Institute for Gulf of Mexico Studies (HRI) at Texas A&M University, Corpus Christi; the University of Louisiana, Lafayette (ULL), E2 Consulting Engineers, Maryville, TN, and the U.S. Army Corps of Engineers Engineer Research and Development Center (ERDC, formerly WES), with laboratories in Vicksburg, MS; Alexandria, VA, Champagne, IL, and Hannover, NH.

CIMAS is a Cooperative Institute with a 33 yr. history of successfully conducting and coordinating interdisciplinary multi-institutional research programs. Relevant to CONGER, the CIMAS research portfolio includes inter alia Ecosystem Management, The Protection and Restoration of Resources, Ocean Modeling, Tropical Weather and Sustained Observations. CIMAS is based at University of Miami/ Rosenstiel School of Marine and Atmospheric Science and overlaps in institutional scope with the NGI (FSU is included in the eight Florida and U.S. Caribbean Universities represented by CIMAS). Beyond the faculty of the eight partner Universities, CIMAS employs nearly a hundred additional scientists and researchers with an annual budget of more than fifteen million dollars. Since the inception of the NGI, CIMAS and the NGI have collaborated with respect to physical modeling of the Northern Gulf and have focused that work upon the Mississippi River plume and interactions of the coastal and offshore circulation. Moreover, CIMAS is the lead in the MARES (www.sofla-mares.org) project which has been developing integrated ecosystem models (DPSIR based) and consensus ecosystem goals for the South Florida coastal ecosystem.

The CoNGER institutions bring together a rich background of prior research, modeling, and monitoring experience in the Gulf of Mexico plus an established education and outreach program. In addition, all actively participated in addressing the distribution, fate and impacts of oil released from the MC252 site and dispersant applied as a result of the Deepwater Horizon catastrophe. With funding from BP block grants to NGI, Alabama, LSU, Florida, and others, plus NSF Rapid Response awards, CoNGER researchers have already developed an extensive set of observations and models that contribute to understanding the near-term and long-term impacts of the spill and associated response. These efforts are grounded upon extensive previous experience and a substantial database of Gulf environmental conditions, marine life, and ecosystem processes from pre-spill through post-spill.

The CoNGER institutions provide complementary strengths to address the GRI goals. These include: long term programs of environmental observations and assessments of biological productivity, marine life abundance, and community composition (FSU, LSU, USM, DISL, HRI, CIMAS); physical and ecosystem modeling and prediction systems (FSU, MSU, USM, LSU, CIMAS, HRI, ULL, E2, ERDC); tropical storm dynamics and effects (CIMAS, FSU, MSU, ERDC); chemical analysis of oil, dispersant and associated degradation products in water column and sediment (LSU, USM, MSU, ERDC); data management, data mining and visualization (MSU, CIMAS, HRI, ERDC); and education and outreach (DISL, NGI, CIMAS).

This complementary expertise embodied in the CoNGER institutions and their prior track record of collaborative research makes CoNGER an ideal GRI research consortium. The ongoing monitoring and modeling programs of the various member institutions span a broad range of ecosystems and degrees of exposure to the impacts of the MC252 oil release, thereby enabling comparative analyses across a range of spatial and temporal scales. The CoNGER research program will examine the effects of petroleum and dispersant systems on multiple ecosystems including Gulf and coastal waters, wetlands, barrier islands, and beaches. The ecosystems of interest will extend from Gulf estuaries out to deep water from Texas (HRI), through Louisiana (LSU, ULL), Mississippi (USM, MSU), Alabama (DISL) and Florida (FSU, CIMAS). All of the CoNGER partners have worked together extensively over the last 5 years, developing knowledge of each one's capabilities and the trust that is at the core of any successful partnership.

Understanding the current, projected, and synergistic impacts of petroleum/dispersant systems on the coastal ecosystems of the northern Gulf and determining correct restoration and management processes requires sufficient knowledge of pre-spill structure, function (including ecosystem services), and processes of these ecosystems, including both natural and anthropogenic drivers and pressures. The Consortium will build on its existing large-scale coordinated monitoring, modeling, and research efforts and preliminary Conceptual Earth Ecosystem Model (CEEM) by developing an eco-regional approach to assessing ecosystem conditions around the Gulf. This will be accomplished across eco-regions by: (1) initiating targeted research projects that address significant knowledge gaps identified in the preliminary CEEM; (2) using models and case studies to define spatially-differentiated stressors (including oil/dispersants) and quantitative estimates of actual and potential impact; and (3) developing ecosystem forecast capabilities that can be used to further refine the necessary long-term monitoring network and provide an improved understanding of the structure, function, and processes of ecosystem responses across the northern and eastern Gulf of Mexico. In addition to scientific expertise and regional experience, the CoNGER institutions provide an existing, highly lauded education and outreach network, ensuring that research and activities of CoNGER will be effectively communicated to a broad audience.

Public Education and Outreach Objectives of the Consortium

CoNGER's Education and Outreach (E-O) Task offers ongoing efforts toward the Gulf Research Initiative's ultimate goal "to improve society's ability to understand, respond to and mitigate the impacts of petroleum pollution and related stressors of the marine and coastal ecosystems, with an emphasis on conditions found in the Gulf of Mexico." As an indication of how important CoNGER views E-O, it has made it a separate, specific, and fully funded Task 8 in the overall plan.

The central objectives of the CoNGER E-O are to: Translate and disseminate concepts of modeling and stressors of the northern Gulf of Mexico ecosystem; and Translate and disseminate findings of the impact of PDS on the northern Gulf of Mexico ecosystem.

CoNGER research results will be shared with Gulf of Mexico stakeholders, the research community, and the general public. Particular emphasis will be placed on informing the general public the concepts of modeling the Gulf of Mexico ecosystems, as it relates to CoNGER research, and the impacts of stressors on the ecosystems. The E-O task is integrated and comprehensive, addressing opportunities to engage audiences on many levels, including students and researchers with interests in the Gulf, science technology, engineering and math teachers, civic groups, the curious science layperson and the general public.

Background:

An engaged and informed public is a great partner in the effort to protect the Gulf of Mexico ecosystem. By relating findings in an understandable and accessible manner, research becomes relevant to stakeholders and citizens. This integrated comprehensive approach to outreach includes developing a series of materials and presentations at the ready for use to inform civic groups, environmental messaging services, and local audiences throughout the Gulf region via mass media.

Previous and ongoing projects that support this task:

Synergies from existing E-O efforts at the Northern Gulf Institute and its partner institutions, Mississippi State University and the Dauphin Island Sea Lab and NGI MOA signatory Harte Research Institute provide an essential foundation upon which to build the CoNGER E-O Program. Funded projects include the Northern Gulf Institute Education and Outreach Projects (a series of ongoing, annually supported projects since 2006), NGI GRI Phase I and II Outreach Program, and internship projects that fund graduate and undergraduate students for guided tasks and training in high demand areas of coastal and oceans research.

Several years ago the NGI E-O program began a series of well-received outreach flyers focusing on "Research Spotlights" that translate the research project and describe scientific terminology and phrases. The flyers are published online and printed hardcopies have been distributed at numerous topical workshops, conferences, and public gatherings such as "Celebrate the Gulf" and "Bays and Bayous". E-O team members, research scientists, program staff, and project graduate students assist in developing the flyers. Project leads vet the materials to ensure correct and beneficial translation.

Approach:

The project will develop web content highlighting the program and the individual projects and develop print materials outlining the CoNGER program, the projects, and some of the sub-tasks. The E-O Task will be the key mechanism for CoNGER to incorporate educational components, and summarize and publicize the substantial research endeavors. Illustrating the benefits of research helps in transitioning information to stakeholders and citizens in the Gulf of Mexico. The Sulis Decision Support System and the Report Card on the health of the Gulf of Mexico will provide keystone elements of the outreach message. They will help illustrate the connections of the modeling work, the importance of the ecosystem approach to management, and the solutions to problems CoNGER knowledge can generate.

CoNGER proposes to develop a comprehensive framework for a Report Card on the health of the Gulf of Mexico. The vision, led by CoNGER Harte Research Institute partner, is to develop a graphical representation of the environmental condition of the Gulf that will be scientifically based, widely accessible, and readily understandable by policy-makers, stakeholders, scientists, and, most importantly, the American public. Such a Report Card will provide the scientific information and understanding necessary to evaluate the health of the Gulf, clearly demonstrate how well it is or is not progressing towards desired long-term goals, and inform the decision-making process on the policies

The CoNGER E-O team consists of NGI E-O Program participants from NGI, MSU and DISL and contributors to the Gulf of Mexico Report Card Initiative led by HRI. The E-O Team will develop a messaging program that provides a cohesive instruction on ecosystem models concepts, specific models applied in CoNGER research projects, and important research results related to anthropogenic stressors with resource management implications. All content will employ user-friendly language. Material content will be transferable from one medium to another, enhancing efficacy from translation efforts.

This integrated comprehensive approach to outreach includes developing a series of materials and presentations at the ready for use to inform civic groups, environmental messaging services, and local audiences throughout the Gulf region via mass media. Borrowing from the types of presentations NGI has provided over the past 5 years, CoNGER E-O will develop a collection of presentations appropriate for a variety of audiences. Presentations will be vetted and tested to ensure quality and clarity.

Many CoNGER outreach materials will emphasize models and modeling and how they help better understand the GoM ecosystem's reaction to stressors. This product will be useful for the science-curious public and suitable for incorporation into classroom activities. The enhanced Research Spotlight materials will be presented at high traffic venues such as the Dauphin Island Estuarium, the Infinity Center at Stennis Space Center, MS, the Aquarium of Americas in New Orleans, LA, and the Texas State Aquarium in Corpus Christi, TX and other participants in the Coastal Ecosystem Learning Center network. This target audience is interested in the Gulf ecosystem, and it is ready for their next science lesson – "What are models and why are they important?" Research Spotlights are written in language understandable by the average person with an 8$^{th}$ grade education. Creating these documents without scientific jargon and overly technical narratives makes research more accessible to stakeholders and citizens.

The translation process products include curricular materials based on research results for formal and informal educators. As part of the integrated E-O program, DISL will develop curricular materials in compliance with state guidelines describing ongoing research and research results.

The Gulf Report Card Framework outreach will be part of the CoNGER E-O task. Initial outreach will include materials supporting the its presentation at the State of the Gulf of Mexico Summit to be convened on 4-8 December 2011 in Houston, Texas, by the Harte Research Institute. A summary document will be prepared for distribution at the Summit, that includes a description and rationale for the DPSSIR approach, the geographic units of the Gulf that will be assessed, and the specific set of indicators proposed to constitute the Report Card. CoNGER also intends to present selected indicators with existing data to illustrate the nature and utility of the Report Card, along with a plan for full implementation across all indicators.

Data Management Objectives of the Consortium

CoNGER fully supports the data management objectives of the GRI and believes in full and open access to all data, models, and findings produced by research.

Robert Moorhead, MSU, will serve as overall Data Manager for the consortium, working with 5 Task data managers, one in each original-data-producing task, and Louis Wasson and Rita Jackson, NGI's metadata managers, to ensure that all data generated by this project conform to the CoNGER and GRI policies.

CoNGER is composed of a diverse group of scientists with diverse information needs and level of expertise in the use of computational equipments. Sharing data among scientists in a single discipline has traditionally been a challenge since the individual needs and requirements differs. This challenge is exacerbated in a multi-disciplinary environment. Information systems projects that address multi-scale, multi-discipline, and even multi-national science data, e.g. DataOne (https://www.dataone.org/) and EPA's Central Data Exchange (CDX; http://www.epa.gov/cdx/), have come to realize the absolute importance of data management.

Developments in computer and Internet technology have provided means to facilitate data sharing across scientific disciplines but there is no one-size-fits-all solution. It is for this reason that data portals have become a standard fixture in multi-scalar and multi-disciplinary projects, providing unhampered access to field surveys, remote geospatial data, model outputs, and data management services. Multi-disciplinary data portals do not provide a common database engine but rather, serve as a gateway to diverse sources of information in the format that the investigators find most useful. Data portals also provide a focal point to direct users to analytical tools and visualization utilities.

In the backend, the use of *Data Access Protocol* (DAP) servers, a software framework for a simple access to a remote scientific data, has become a common practice. There now exist DAP servers supporting several data formats (e.g. OPeNDAP netCDF Server, OPeNDAP HDF Server, OPeNDAP RDBS Server, ERDAP (NOAA's Environmental Research Division's Data Access Program), THREDDS (Thematic Real-time Environmental Distributed Data Services) Data Server, OPeNDAP Matlab, and GeoDAP). The use of object-relational database engines also provides a venue for the management of such diverse data forms and very often used in conjunction with DAP Servers.

On the frontend, the use of a *Content Management System* (CMS) has become a choice of most developers in organizing the links and repositories as it is highly scalable, allows the portal's parameters to be stored on a database (search-engine-friendly). *Drupal* (http://drupal.org/) is one example of such technology that is free and open-sourced, flexible, robust, well documented and has a wide user community. It has over 6,000 ready-to-use modules that reduces the time needed to realize portal features, allowing more resource to be allocated to making them more efficient. The wealth of data the consortium is expected to generate, including in situ observations, field surveys, ecological transects, geospatial and remote sensing products, and simulation model outputs, will be shared to all the members of the consortium, other consortia and general public through a common data portal. At the level of a user, the use of resource catalogs and search engines are sufficient for data discovery requirements. However, to promote interoperability across the scientific community, deployment of *Web Services* (WS) has become a common method for machine-to-machine communication over a network. A CMS like *Drupal* has all the modules necessary to create sufficient web services to facilitate the extraction of data from the repository using standard WSDL/SOAP implementations (e.g. http://cdmo.baruch.sc.edu/webservices.cfm) or other standards such as those implemented by IOOS/GCOOS (http://gcoos.rsmas.miami.edu/DIF_SOS.php).

Moving data onto a central repository is simple, but to facilitate data discovery and data provenance in a multi-disciplinary/multi-institutional collaborative environment, the use of metadata becomes mandatory. Metadata is widely used to facilitate the process of tracing the origin of data, sensors or process used, and transformations (if any) and to allow the scientific database to be validated. The metadata standards commonly used include standards established by *National Biological Information Infrastructure* (NBII), *Biological Data Profile* (BDP), *Ecological Metadata Language* (EML) as established by the *Ecological Society of America,* the *Federal Geographic Data Commission* (FGDC) standards as established by the US Federal Metadata standard, the Content Standard for Digital Geospatial Metadata (CSDGM), ver.2 (FGDC), and *Common Information Model* (CIM) as established by METAFOR.

It is essential to collect metadata along with the data (either sampled data or model output) for searching, organizing, and managing data. However, metadata generation is often labor intensive. Manual generation of tags requires personnel responsible for the data to provide metadata information, and often a data manager has to carry a proverbial big stick since scientists often feel like they have more important tasks to accomplish. There are a number of tools available to scientist and these include: (i) NCDDC web tool, Metadata Enterprise Resource Management Aid (MERMAid) (http://www.ncddc.noaa.gov/activities/mermaid/), (ii) *Morpho* (http://knb.ecoinformatics.org/morphoportal.jsp), (iii) ESRI's ArcCatalog (http://www.esri.com/), and (iv) EPA's Metadata Editor (EME; https://edg.epa.gov/EME/). NGI brings its active and experienced metadata team to the CONGER.

Maintaining metadata also requires the use of a common vocabulary. The *Marine Metadata Interoperability* (MMI; http://marinemetadata.org/), a NSF-funded project, has compiled vocabularies that can be used as a reference. While there are no established standards, it has become a common practice to use *Climate and Forecast* (CF) standards (http://cf-pcmdi.llnl.gov/documents/cf-standard-names/) and GCMD (Global Change Master Directory; http://gcmd.gsfc.nasa.gov/Resources/valids/) for climate and atmospheric data; U.S. IOOS Vocabulary (Integrated Ocean Observing System; http://mmisw.org/orr/#http://mmisw.org/ont/ioos/parameter) for ocean observing data, CMECS (Coastal and Marine Ecological Classification Standard; http://www.csc.noaa.gov/benthic/cmecs/CMECS_Overview_Presentation20100915.pdf) for generic ecological data, CoRIS (Coral Reef Information System; http://coris.noaa.gov/glossary/) for coral reef studies -- to name a few.

To address the issue of persistent citation, it is also a common place to use *Digital Object Identifier* (DOI; http://www.doi.org/) to identify an object in a metadata document. The DOI may also include a URL (Uniform Resource Locator), a W3C and IETF recommendation, where the object can be located. The DOI system is implemented through a federation of registration agencies coordinated by the *International DOI Foundation* (IDF), which manages the system. The DOI system has been developed and implemented in a range of publishing applications since 2000; by late 2009 approximately 43 million DOI names had been assigned by some 4,000 organizations (Wikipedia). This also allows the data repository in the portal to be included in the *DataCite*, an international consortium aimed, among others, at establishing easier access to scientific research data.

CoNGER will design, develop and deploy a single focal point for communication and data acquisition and access through a CMS, the *CoNGER Data Portal* or CDP. Various types of data in various formats are expected to be collected and processed in this multi-disciplinary and multi-institutional endeavor. The design of the system will be based largely on user requirements that are classified broadly as (Figure D1):

- Generating Scientists: Consortium scientists responsible for generating and releasing all appropriate data to the central repository.
- Consuming / Verifying Scientists: Consortium scientists collaborating closely with Generating Scientist in validating the data before publication.
- Data Manager: Identified for each Task in the consortium, is responsible to curate data and to check quality of the data. He ensures the appropriate metadata has been created and is properly associated before releasing the data by moving into the *released* space. Data will be released as soon as the data manager can validate that it is accurate and metadata is provided. He and his

team may derive new data by processing or filtering to create thumbnail images or data subsets, but the original data will always be available from the GRI-AU.

- Public: May view and download all public data but will be required to complete free registration to facilitate the auditing of data uses/access.

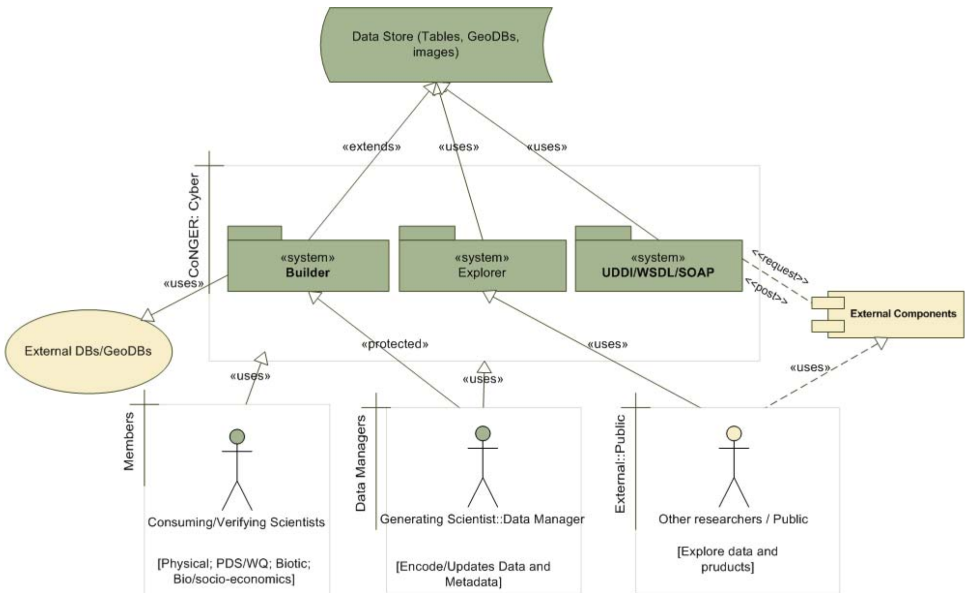


Figure D1. Use case schematic diagram of the CoNGER Data Portal (CDP).

CoNGER will strike the appropriate balance between validating data and releasing it quickly to the public. Data will be kept in two repositories (Figure D2): one named *for review* providing access to consortium members and the other named *released* providing access to the general public. The consortium will establish a data release policy with the GRI-AU and the CDP will abide by its policy. Modifications to this policy will be announced via the public portal and to registered users, and will not be retroactively applied to data already collected. To answer one of the RFP questions, yes, CoNGER agrees with the database approach presented in the RFP.

It is the *Generating Scientist* responsibility to release all appropriate data immediately by placing in the *for review* space. Measured and modeled data become appropriate to be released as soon as they are validated, as indicated in point 21 of the management plan. However, data generated by models under development will not be released even to the *for review* space. Moreover, personal data, data that leads to the identification of an individual will not be stored in the central repository. All data requiring *Institutional Review Board* (IRB) certification will reside with the IRB certified scientist.

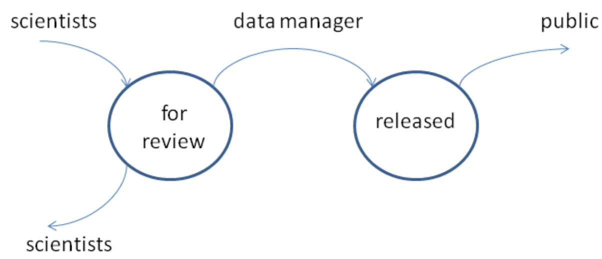


Figure D2. Data flow in the CDP central repository. Data are recorded in "review" space for validation before posting on the "release" space for public use.

The codes and data on the CDP will be backed-up regularly. CoNGER will provide alternate server facilities at another physical location to mirror the primary CoNGER server in its entirety to minimize system downtime. The alternate server will be activated in cases where the primary server is unavailable either because of planned maintenance or unplanned events such as system failures.

A data management sub-task has been included in all the original-data-producing tasks in order to highlight the requirement for an active data management effort throughout the project.

Management Plan for Consortium

The Consortium of the Northern Gulf Ecosystem Research (CoNGER) project is a transdisciplinary research effort among multiple institutions at various locations across the Gulf region. To build upon existing strengths and to proactively address challenges, the CoNGER management team draws on research about academic collaboration that identifies conditions and governance practices that contribute to scientists' efforts to successfully engage in collaborative work (Bukvova, 2010; Cummings and Kiesler, 2007; Heinze and Kuhlmann, 2008; Stokols, et al., 2008; Wray, 2006).

Managing a multi-institution, multi-location and transdisciplinary research effort is a complex task that requires substantial management skill and diplomacy. The Northern Gulf Institute (NGI), a consortium of five universities that serves as the core of this consortium, is nationally recognized for its successful management of collaborative research for multiple clients over the past five years. An independent NOAA Science Advisory Board review rated NGI as "outstanding" after an extensive review of its management and administrative processes and of its science and education programs, giving accolades such as, "NGI has established a proven track record for successful collaboration …" (NOAA Science Panel Review, 2010) and that the administrative team, " … has experience in grants management, demonstrated excellent communication skills, and interact well as a team" (NOAA Administrative Review, 2010). The NGI management team, joined by the Harte Institute for Gulf of Mexico Studies (HRI), Cooperative Institute for Marine and Atmospheric Studies (CIMAS), University of Louisiana, Lafayette (ULL), and U. S. Army Corps of Engineers Engineer Research and Development Center (ERDC) will apply its established expertise in combination with widely accepted management models (e.g., Gray and Walters (1998); Katz and Martin, 1995; Boardman and Corley, 2008 and others) to manage research for the Gulf of Mexico Research Initiative (GRI).

The CoNGER management and research teams have readiness factors that are early indicators for successful collaborative research outcomes. A key antecedent indicator for effective collaboration productivity is a shared history of working together on prior projects. The CoNGER research leads and teams have demonstrated success in functioning in interdisciplinary and multi-institutional teams and have established trust, network ties, and existing communication channels that allow them to focus on the integration of their work for transformative outcomes. Mindful of the potential for group-think and reliance on familiar, yet potentially ineffective strategies, the CoNGER management and research teams include a designed mix of recognized, successful, and established teams with new members who bring additional expertise, insight, and experience. Additional readiness factors for successful collaborations include the availability of shared research and meeting space and electronic connectivity – to include cyber-infrastructure – among members

Another early indicator of successful outcomes from collaborative research is commitment to team research and the active participation of researchers in project planning and implementation. CoNGER lead researchers have been actively involved in the development of CoNGER teams, goals, and plans from the onset of this project and will continue involvement in formative evaluation for adjustments for the duration of this project. Administrators at member institutions have provided formal agreement for involvement in this CoNGER project.

This Management Plan presents the structure and procedures proposed to effectively manage the CoNGER project. The text is aligned with the GRI Request for Proposal Evaluation Criteria and with requirements in the GRI Master Research Agreement (MRA).

## Organizational Structure and Responsibilities

All CoNGER activities will be governed by applicable state and Federal laws and regulations, by professional standards set forth by the National Academy of Sciences, and by member research institutions' Offices of Regulatory Compliance, including safety procedures, laboratory protocols, and environmental safeguards.

Management of the Consortium's research will be accomplished through the organizational structure and procedures described below and shown in the organizational chart shown in Figure M1. When referenced with the Narrative Description of Research, this chart depicts the plan for integration across institutions, projects and Co-Principal Investigators. This chart shows how research tasks (as opposed to independent projects) are coordinated within the consortium and distributed by expertise across institutions.

The CoNGER Steering Committee (CSC) serves as a board of directors with one voting representative from each primary institution plus a Chairman. The CSC meets twice per year and decides policy and strategic research direction. Members, some of which are playing substantial technical roles, are Co-Principal Investigators with the Director. CSC Members are:

- Steven Lohrenz, University of Massachusetts-Dartmouth
- Larry McKinney, Harte Research Institute
- Robert Twilley, University of Louisiana, Lafayette
- Susan Welsh, Louisiana State University
- Stephan Howden, University of Southern Mississippi
- John Harding, Northern Gulf Institute
- Edmond Russo, Engineer Research and Development Center, Mississippi
- Robert Moorhead, Mississippi State University
- Just Cebrian, Dauphin Island Sea Lab, Alabama
- Felicia Coleman, Florida State University
- Peter Ortner, Cooperative Institute for Marine and Atmospheric Studies
- Steve Bartell, E2 Consulting Engineers
- Director: William H. McAnally, Director, CoNGER

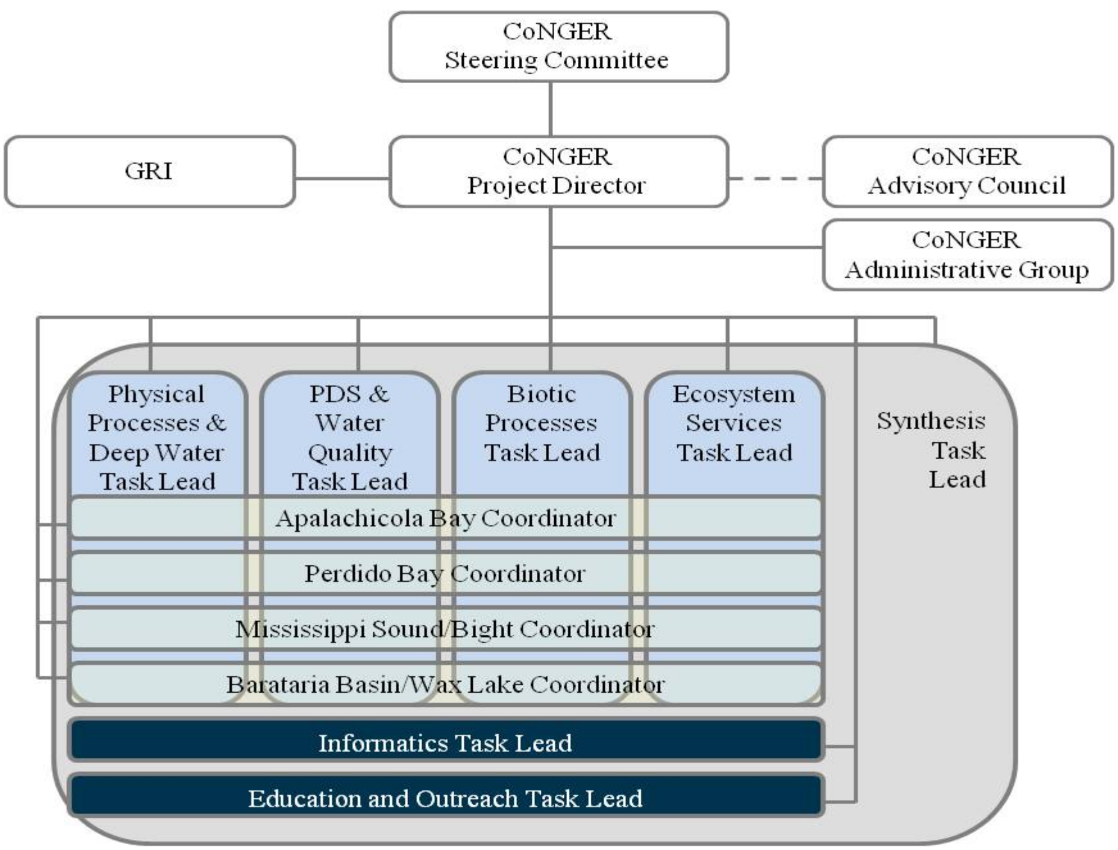


Figure M1. CoNGER Organization Chart

In order to prevent the appearance of conflicts of interest, members of the CSC will abstain from voting on items involving funding of their institution and technical direction for efforts which they lead. A further provision is to include Dr. Steven Lohrenz on both the CSC and the Advisory Council, chairing the latter. Dr. Lohrenz's deep understanding of the Gulf of Mexico, familiarity with the strengths of all the Gulf institutions, and present position as Dean of the School for Marine Science and Technology at the University of Massachusetts - Dartmouth make him uniquely suited to provide candid and impartial counsel to the consortium.

Project Director is William McAnally, who has over 40 years experience in research and development, the last 25 of which was spent in formulating, organizing, and managing large, interdisciplinary research programs. He will fulfill duties described in section 4.5 of the GRI MRA which include the following: supervise the tasks, monitor progress and expenditures, ensure coordination, advise the CSC as a non-voting member, convene the Advisory Council, and communicate with the GRI. He will exercise reprogramming authority for grant funds, with the consent of the GRI Administrative Unit, based on task performance and unforeseen events.

The CoNGER Advisory Council will serve as outside reviewers of research results and advise the Director on science and engineering issues, meeting semi-annually. The following have been invited to serve on the CoNGER Advisory Council:

- Chair: Steven Lohrenz, University of Massachusetts-Dartmouth (agreed to serve)
- LaDon Swann, Alabama-Mississippi Sea Grant
- Steve Wolfe, Florida Department of Environmental Protection
- Cynthia Suchman, National Science Foundation CAMEO Program
- Trudy Fisher, Mississippi Department of Environmental Quality
- Ryan Fikes, Gulf of Mexico Foundation
- Jack Gerard, American Petroleum Institute

The Administrative Group will be led by Jennifer Easley, Business Manager at Mississippi State University and head of the NGI Administrative Group. She will manage the grant finances, including confirmation of approved overhead rates, work with member institutions to simplify contract and administrative procedures, and advise the Project Director on all administrative issues. The Project Director and Administrative Group will fulfill responsibilities or provide support to Task Leads and Site Coordinators to fulfill responsibilities as described in section 4.3 of the GRI MRA. Maggie Dannreuther, Coordinator at the NGI Program Office, will assist the Director and Administrative Group in program analysis for internal process improvement and performance progress. The NGI Administrative Group will provide clerical/secretarial support to facilitate meetings and minutes reports and with travel and event coordination. NGI IT support will supplement member institutions' IT teams for cyber-infrastructure use and for web and video conference meetings.

Each Task, shown as a column or row in the organization chart above, is led by a senior scientist/engineer with extensive experience in, and deep knowledge of, the subject matter of the Task. Task Leaders will manage and report the work of their tasks and coordinate with the other Task Leaders and Site Coordinators to ensure mutual success. See the Narrative Description of the Research for a listing of those Task Leaders.

Each of four representative ecosystems (sites) will be examined by all the Tasks and those efforts will be coordinated by a senior researcher with extensive experience in that ecosystem. These Site Coordinators will oversee data collection, ensure that all appropriate data are available to the Tasks, and that findings are grounded in a deep understanding of the site's characteristics. See the Narrative Description of the Research for a listing of the Site Coordinators.

The CoNGER management and research teams have established working relationships and experience in dealing with issues regarding conflicts, personnel, safety requirements, subcontracts, reporting requirements, and adherence to contracted requirements. Involvement of key participants in the development and planning process allowed for proactively identifying and resolving issues. Experienced professionals comprise the CoNGER teams which contribute to a high-level of mutual respect and comfort to discuss different opinions and perspectives and provide an atmosphere conducive for satisfactory handing of issues. The Director and Administrative Group will actively seek internal feedback for continual process improvement and effective communication. For issues that arise during the course of this project that are not satisfactorily addressed at the most immediate level, the CoNGER Director will apply standard organizational mediation and resolution techniques. If issue persists, the CoNGER Director will seek direction and, if necessary, involvement from members of the CSC.

As a result of developing the consortium using the GRI MRI and RFP, the CoNGER Director and CSC do not anticipate any limitations imposed by CoNGER policy, rules, or regulations that would affect the operation of the GRI. Individual members of the CSC will notify the consortium if limitations arise from member institutions for immediate resolution. The CoNGER Director will apprise the GRI administrative unit of such limitations and subsequent actions.

The CoNGER Director, CSC, Task Leads, and Site Coordinators have reviewed and approved the research timeline and milestones (see Section 4b).

Administrators at member institutions have advised that appropriate facilities (see Section 5 Facilities, Equipment, Ship Time, and Other Resources) are available for the duration of this project. The CoNGER management and research teams anticipate transformative research outcomes that advance knowledge for selected GRI themes. These outcomes provide high value and cost effectiveness as the consortium leverages strengths, capabilities, capacity, and resources to an extent that could not be realized by any institution acting alone.

**Procedures**

The overall technical approach, including the Tasks, has been devised in a process directed by the CSC, which adopted the Conceptual Earth Ecosystem Model created by a working group of senior and mid-career researchers currently working on oil spill research funded in part by BP grants to the states. Details of the Tasks were then created by Task team members selected as the best candidates to accomplish each task.

Execution of the Tasks will be performed by virtual teams, listed in the Technical Description and linked by cyber-infrastructure created in part by an NSF EPSCoR Phase 2 grant to the Northern Gulf – Coastal Hazards Collaboratory, directed by Dr. Twilley, a member of the CSC.

The Teams will have joint office space set aside for them at the MSU Science and Technology Center that houses the NGI Program Office at Stennis Space Center, Mississippi, for periods of work in which the virtual teams become physical teams. The use of these resources leverages existing research and development efforts.

Each project participant will continue reporting under their existing supervisory structure at their respective institutions. The CoNGER Director will inform supervisors at individual institutions about participants' activities through the CSC representative, using information from Task leaders and colleagues' reviews on team performance. Academic integrity will be fully supported as expressed by the individual institutions' regulations. The CoNGER will also allow team members who disagree with their team's conclusions to offer the equivalent of a "minority opinion" to the CSC.

Funding requirements are generated at the task level, then aggregated separately for each institution and approved by the CSC representative for that institution. Each institutional submission has been signed by the senior administrators responsible for funded research (usually Vice-President for Research or equivalent and Sponsored Programs Director or equivalent) in order to insure institutional support and commitment to the project. This commitment to team research is a key antecedent condition for successful collaborative research.

Initial sub-awards to the institutions will be 50 percent of the estimated year 1 expenses. Each individual institution will bill NGI monthly; and at the end of 5 months, the remaining year 1 amount will be awarded if fiscal and technical performance has been satisfactory. Succeeding years' funding will be processed in the same manner, contingent upon continued GRI funding of the project. The CoNGER Director will notify leads of tasks and the CSC representatives about performance that is less than satisfactory. Funding for continued unsatisfactory performance will be withdrawn and reprogrammed at the direction of the CSC and concurrence of GRI.

Technical progress will be monitored by the Director through (a) day-to-day interactions with project staff; (b) biweekly web-conferences with the Co-PIs and other key individuals during the first 6 months, moving to monthly web-conferences thereafter; (c) quarterly written progress reports using the established NGI format (addressing progress, issues encountered, percent complete/date of completion on milestones; and plans for the following quarter) plus, specific to this proposal, an explicit statement of how the progress contributes to GRI themes and goals; and (d) annual meetings of all participants.

All Co-PIs have agreed to responsibility for required input to the GRI database and web site, described in the attached Data Management Plan; publications (as described in the Intellectual Property and Publications Policy in Appendix 3 of the GRI MRA); and presentations at the project's annual meeting are basic requirements for participation in the project, part of the conditions of the award, and required deliverables.

Quality assurance and quality control (QA/QC) procedures will follow the standards established for each branch of science, engineering, or management involved in a particular task. With one exception, they are too diverse across disciplines to be easily summarized here, but will all follow the Deming-Shewhart cycle of Plan-Do-Check-Adjust (Deming, 1986) and ISO (2003) concepts for projects. The exception is numerical modeling, for which the QA/QC process will follow the widely accepted Best Modeling Practice guidelines (Van Waveren, et al.) and EPA (2002) modeling guidelines.

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