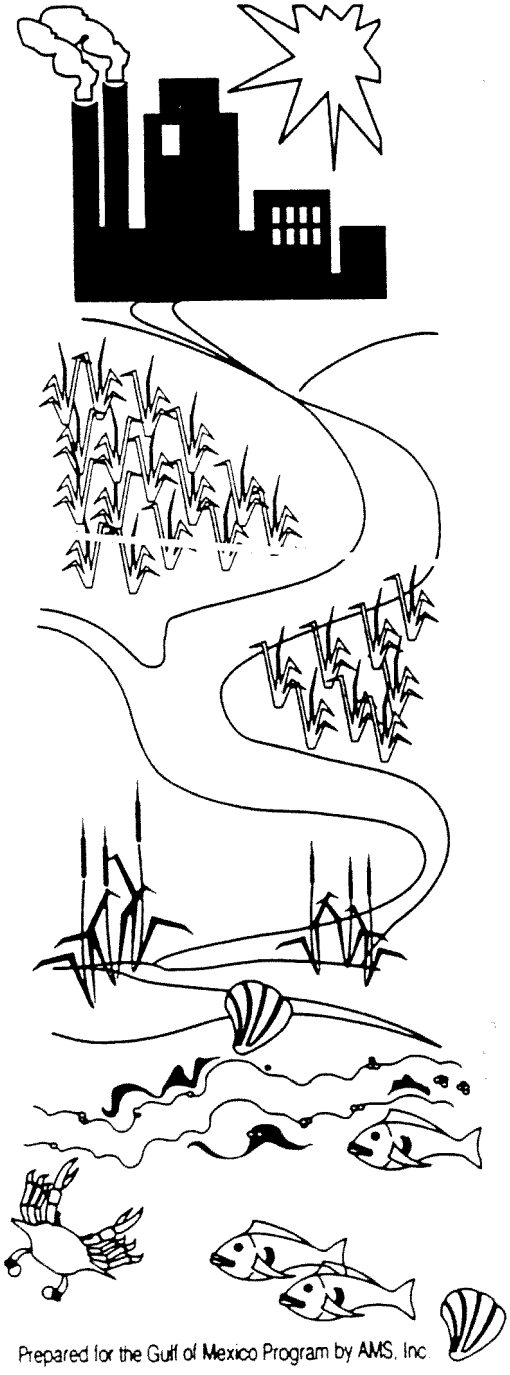
RESEARCH NEEDS FOR TOXIC SUBSTANCES AND PESTICIDES IN THE GULF OF MEXICO:



A STRATEGY

GULF OF MEXICO PROGRAM

Prepared for the Gulf of Mexico Program by AMS, Inc.

RESEARCH NEEDS FOR TOXIC SUBSTANCES AND PESTICIDES IN THE GULF OF MEXICO

EXECUTIVE SUMMARY

Although the Gulf of Mexico has been historically viewed as one of the most healthy and productive U.S. coastal environments, during recent decades there has been growing concern over decreasing environmental quality due to a variety of stressors. Human activities in the surrounding areas of the Gulf of Mexico, the Mississippi River basin, and other tributaries have introduced toxic substances and pesticides into coastal and offshore waters. Urban development, industrialization, farming, habitation, and recreation have all contributed to toxic loadings to the Gulf of Mexico. However, there are insufficient data to determine the role of toxic substances and pesticides in environmental degradation in the Gulf.

Recognizing these issues, the Gulf of Mexico Program established a Toxic Substances and Pesticides Committee to characterize the risks posed by toxic substances and pesticides, and to devise ways to prevent or mitigate contamination. The Committee includes representatives from industry, government, and academia.

The Toxic Substances and Pesticides Committee has developed an Action Agenda which summarizes information about toxic substances and pesticide sources and burdens in the Gulf of Mexico and identifies an initial set of activities needed to reduce toxic substance and pesticide inputs to Gulf waters. However, serious information gaps remain concerning contaminants and contaminant impacts. A priority activity identified in the action agenda was to conduct a workshop to identify research needed on the fate and effects of toxic substances and pesticides in the Gulf of Mexico. This research is critical to directing limited resources to the problems and areas of greatest concern.

This research needs workshop was convened on August 23-25 in Sarasota, Florida. Experts from academia, industry, and government participated in the workshop. Importantly, the group reached consensus on the most critical research needs for toxic substances and pesticides in the Gulf of Mexico. Because of the wide representation of this group, its recommendations constitute a research strategy for the entire Gulf community for the next 3 to 5 years. Future research (and funding for research) in the Gulf of Mexico should focus on and address those areas targeted in this Research Strategy.

After an introductory plenary session, workshop participants organized, according to their expertise, into three workgroups on toxic inorganics, toxic organics, and

pesticides. General research needs identified by the toxic inorganics workgroup included the establishment of baseline conditions, development of bioaccumulation and hydrogeologic models, standardization of assessment methods, development of metal speciation and bioavailability models, and development of quantitative techniques for integration of effects and exposure data. Major recommendations from the toxic organics group focused on the development of status indicators of healthy Gulf ecosystems, development of predictive and diagnostic tests for assessing ecological effects, assessment of available data on anthropogenic inputs, and development of a site-specific quality criteria for target pollutants in estuarine ecosystems. The pesticides workgroup concentrated on broad-based research needs related to the development and validation of hydrodynamic and ecological models, the identification of problem pesticides, the interpretation and application of tissue residue data, and the understanding of repeated short-term exposure events in the Gulf. Overall, recommendations from these three groups can be categorized into the following themes: characterization of exposure, characterization of effects, fundamental research, continuous chemical and biological monitoring, and risk reduction and pollution prevention. These themes represent the building blocks of an ecological risk assessment.

Table 1 provides an overview of the workgroup recommendations, which are grouped according to contaminant type. Related research needs for other contaminant groups are cross-referenced, and applicable themes are also noted on the recommendations listed in the table. The following codes are utilized in the table:

Cross References:	T	=	Toxic Organics
	O	=	Toxic Inorganics
	P	=	Pesticides

Themes:	A	=	Characterization of Ecological Effects
	B	=	Characterization of Exposure
	C	=	Fundamental Research
	D	=	Continuous Chemical and Biological Monitoring
	E	=	Risk Reduction and Pollution Prevention

Table 1. *Overview of Strategic Research Needs*

Summary Table			
Name of Strategic Research Need		Cross Reference	Theme
Toxic Inorganics (I)			
1.	Critical Review of Existing Chemical, Biological, and Physical Data	P1,P2,O4	B
2.	Standardization of Methods used in Gulf Wide Assessments	P8,O7,O1	A
3.	Establishment of Background or Reference Conditions	O1	C
4.	Development of Quantitative Techniques for Integrating Exposure and Effects Data	P1	B,E
5.	Development of a Toxics Budget for the Gulf		D
6.	Development and Validation of Effects Evaluation Techniques	O2,O3,P7,P11	A
7.	Mechanistic Research on Speciation and Bioavailability	P4	C
8.	Development of Trophic Level Bioaccumulation Models for the Gulf of Mexico Food Chains	O4,P1,P11	B
9.	Development of Hydrogeologic Models of Chemical and Biotic Transport Dynamics at Appropriate Scales of Resolution	O4,P1,P4	B
Toxic Organics (O)			
1.	Criteria for Healthy Gulf Ecosystems	I2,I3	C
2.	Predictive Ecological Effects Tests Battery	I6,P7	A
3.	Diagnostic Ecological Effects Tests Battery	I6	A
4.	Assessment of Loading/Ambient Data and Modeling Needs	I1,I8,I9,P1,P2,P4	B
5.	Atmospheric Deposition of Toxic Substances and Pesticides		B,C
6.	Development of Site-Specific Water Quality Criteria for Organic Toxicants in the Gulf	P7	E
7.	Development of Continuous and/or Integrated Sampling and Analysis Systems for Toxic Organic Compounds in the Gulf of Mexico	I2,P8	D
Pesticides (P)			
1.	Develop and Validate Estuarine Ecosystem Models	I1,I4,I8,I9,O4	B
2.	Update Contaminants Database for Tissue Residues, Sediments and Water	I1,O4	B
3.	Assess the Ecological Significance of Repeated, Acute Inputs of Pesticides in the Gulf of Mexico		A,C
4.	Understanding the Transport and Bioavailability of Pesticides Used in the Gulf of Mexico	I7,I9,O4	B,C
5.	Development and Implementation of Pesticide BMPs for the Gulf of Mexico		E
6.	Identify Which Pesticides are Causing Ecological/Health Effects and Where the Impacts are Most Significant		A
7.	Development of Standard Toxicological Test Methods Using Representative Endemic Species	I6,O2,O6	A,D,C
8.	Standardization of Analytical Methods and QA/QC	I2,O7	A,B
9.	Understanding of Chemical Contaminant Effects on Marine Mammals and Top Carnivores in the Gulf of Mexico		A
10.	Development and Evaluation of Remediation Strategies for Contaminated Habitats		E
11.	Development of an Ecosystem Water Quality Risk Based Approach for Risk Assessment Using Archived Tissue Contaminant Data	I6,I8	B,E

ORGANIZATIONS PARTICIPATING IN WORKSHOP

These research priorities will be returned to the environmental research community to help focus research activities. That community was represented by the following organizations at the workshop:

ABC Labs
Brookhaven National Laboratory
Ciba-Geigy, Inc.
Exxon Biomedical Sciences Inc.
Florida Department of Agriculture
Florida Department of Environmental Protection
Florida Institute of Technology
Gulf Coast Research Laboratory
Gulf of Mexico Program
International Paper Company
Louisiana State University
Mote Marine Laboratory
National Marine Fisheries Service
Occidental Chemical Corporation
Shell Development Company
Skidaway Institute
Texas Parks & Wildlife Department
U.S. Army Corps of Engineers
U.S. Environmental Protection Agency
U.S. Fish & Wildlife Service
U.S. Food and Drug Administration
Union Carbide
University of Mississippi
University of North Texas

INTRODUCTION

Goal of the Workshop

The goal of the workshop was to identify and rank research needs on the loading, fate, and effects of toxic substances and pesticides in water, sediment, air, and biota of the Gulf of Mexico. The ultimate goal is to establish a toxic substances and pesticides information base to be used for comparative ecological risk assessment in the Gulf of Mexico.

Gulf of Mexico Program

The Gulf of Mexico Program was formed to pioneer a broad geographic focus in order to address major environmental issues in the Gulf before the damage is irreversible or too costly to correct. The Program is a cooperative partnership among federal, state, and local government agencies and organizations, as well as with people and groups who use the Gulf. Regions IV and VI of the United States Environmental Protection Agency (USEPA), which share jurisdiction over the five Gulf Coast States (Alabama, Florida, Louisiana, Mississippi, and Texas), initiated the Program in August 1988. The goals of the Gulf of Mexico Program are to:

- protect, restore, and enhance the coastal and marine waters of the Gulf of Mexico and its coastal natural habitats;
- sustain living resources;
- protect human health and the food supply; and
- ensure the recreational use of Gulf shores, beaches, and waters—in ways consistent with the economic well being of the region.

Toxic Substances and Pesticides Committee

During the early stages of Program development, eight priority environmental problems were identified and the following Committees were established to address each of these problems: Marine Debris, Public Health, Habitat Degradation, Coastal & Shoreline Erosion, Nutrient Enrichment, Toxic Substances & Pesticides, Freshwater Inflow, and Living Aquatic Resources. There are important linkages

among the various Committees, and the Gulf of Mexico Program works to coordinate and integrate activities among them.

To respond to the threats posed by toxic contamination, the Toxic Substances and Pesticides Committee was charged with characterizing toxic substance and pesticide contamination and devising ways to prevent or mitigate this contamination and its impacts. The Toxic Substances and Pesticides Committee has been meeting for more than four years to review information and data collected by citizens and scientists, identify problem areas, discuss actions that can resolve the problems, and evaluate methods for achieving and monitoring results. Its long-term goal is to reduce and, where possible, eliminate adverse ecological impacts from toxic substances and pesticides in the Gulf of Mexico system. (Appendix D lists previous publications of the Committee.)

This Committee has developed an Action Agenda that summarizes information known about toxic substances and pesticide sources, burdens, and effects in the Gulf of Mexico, and specifies the primary activities needed to reduce toxic substance and pesticide loadings to Gulf waters. One of these primary activities in this Action Agenda is to conduct a workshop to identify research needed to fully evaluate the fate and effects of toxic substances and pesticides in the Gulf of Mexico. There are significant gaps in the understanding of sources and amounts of toxic substances and pesticides discharged into the Gulf and its tributaries and the fate and effects of these toxicants. This information is critical to conducting an ecological risk assessment for the Gulf, which will help target actions and resources on the most significant threats.

Research Needs Workshop

To meet the Action Agenda requirement, the Committee convened a workshop on August 23-25, 1993 at the Mote Marine Laboratory in Sarasota, Florida to identify strategic research needs and develop a planning document for use by the entire Gulf research community. Approximately 40 experts from government, academia, and industry participated in this effort (see Appendix A for a list of participants) .

The goals of the workshop were to identify and rank research needs on the fate and effects of toxic substances and pesticides in water, sediment, air and biota of the Gulf of Mexico and to provide a five-year Research Strategy for the Gulf community. The identified research will stimulate establishment of a toxic substances and pesticides information base to be used for comparative ecological risk assessment of the Gulf of Mexico. Comparative risk assessment uses the paradigm of comparing the risks associated with various activities relative to the resource and identifying the

probability that impacts will occur with specific activities and to what extent. Comparative risks may include other Gulf of Mexico Priority problems such as marine debris, nutrients, etc. Comparative risk assessment will allow agencies to focus limited resources on the most serious environmental problems affecting the Gulf of Mexico.

To achieve workshop goals, three objectives were identified:

- Bring federal, state and local agency program and resource managers together with industry representatives and research scientists to review the current information base relative to toxic substances and pesticides in the Gulf.

- Identify additional research activities needed to address information gaps regarding toxic substances and pesticides in the Gulf.

- Recommend Priority research activities that will address identified needs.

A steering committee was formed to help facilitate the organization and operation of the workshop. Prior to the workshop, the participants were provided with the reports describing the Action Agenda for Toxic Substances and Pesticides and a summary of what is known about the relative loadings and potential importance of specific chemicals to the Gulf.

At the workshop, a plenary session was devoted to introducing the charge of the workshop and summarizing existing information on chemical inputs and biological resources at risk. An example risk assessment study was presented along with a discussion of ecological risk assessment to focus the group on the approaches to be taken in the break-out sessions for developing the research strategy. Participants then organized, depending on their expertise, into working groups on toxic inorganic chemicals, toxic organic chemicals, and pesticides for individual research issue development. Through a consensus building process, the working groups then discussed current gaps in research and information relating to their topic area and recommended specific strategic research activities. The groups also ranked these research activities according to three levels of priority, reflecting the inherent sequential order necessary for completing them.

In addition to many topic-specific research needs, the groups also identified several overall cross-cutting research needs for the Gulf of Mexico. Future research and funding for research in the Gulf should focus on those areas targeted in this Research Strategy. This Research Strategy will be revised and updated to ensure that it remains consistent with the evolving needs of the Gulf of Mexico Program.

This document provides a brief overview of the threats of toxic substances and pesticides in the Gulf of Mexico, listing specific research needs under three types of contaminants: toxic inorganics, toxic organics, and pesticides. Each research need is described in depth along with a detailed justification of its importance and suggested initiation activities. Although *all* research needs identified in the strategy are considered high priority, the working groups ranked their recommendations into three categories: Priority 1, Priority 2, and Priority 3. These rankings reflect the fact that some activities need to be completed before others can be initiated (*i.e.*, Priority 1 recommendations should be completed first).

The *Synthesis and Conclusions* section summarizes cross-cutting issues that broadly describe the workshop recommendations and affect all types of toxic substances and pesticides research in the Gulf of Mexico. It is not coincidental that these issues represent fundamental building blocks for an ecological risk assessment for the Gulf of Mexico.

Figure 1. ***Gulf of Mexico Structured Partnership***

DEFINITIONS AND BACKGROUND

As defined by the Gulf of Mexico Program Toxic Substances and Pesticides Committee and for the purposes of this workshop, the following definitions apply: (See The Toxic Substances and Pesticides Action Agenda for the Gulf of Mexico, 1993)

Toxic substances (including pesticides) are materials—either synthesized by humans or present in Gulf of Mexico waters—that are capable of producing an adverse effect in a biological system or seriously injuring ecosystem structure or function. It should be noted that human and other pathogens were excluded from consideration by the Toxic Substances and Pesticides Committee because these issues are being addressed by the Public Health Committee. Many research needs identified in this document will, however, provide information that can be used to assess the human health effects of pesticides and toxic substances in the Gulf.

A **pesticide**, broadly defined, is any agent used to kill or control undesired insects, weeds, rodents, fungi, bacteria, or other organisms. Thus, the term "pesticides" includes insecticides, herbicides, rodenticides, fungicides, nematicides, and arachnicides, as well as disinfectants, fumigants, and plant growth regulators. For the purposes of this document, the term "pesticide" refers to chemical agents only; biological agents are not addressed as part of this Research Strategy.

Toxic substance and pesticide contamination can be a serious problem in coastal environments. While concerns about discharges of toxic substances in the Gulf of Mexico are growing because of the increased concentration of industrial activities, data are insufficient to determine the role of toxic substances and pesticides in environmental degradation in the Gulf.

Inputs of Toxic Substances and Pesticides

Sources and amount of toxic substances and pesticides discharged directly into the Gulf of Mexico are available through a variety of national and regional data bases and other sources. Information about direct and indirect discharges to the Gulf from upland watersheds and airsheds is not as easily accessible. USEPA's Toxic Release Inventory (TRI) is a computerized data base containing public information on the annual releases and transfers of approximately 320 toxic chemicals reported by U.S.

manufacturing facilities to USEPA and the states. Since 1987, federal law has required facilities to report the amount of both routine and accidental releases of the 320 listed chemicals to the air, water, and soil, and the amount contained in wastes transferred off-site. Some 695 facilities report this data within the 68 counties that border the Gulf. According to 1989 TRI data, all five Gulf Coast States are listed in the top 20 states nationally for total chemical emissions to the environment. Four Gulf States (Alabama, Mississippi, Louisiana and Texas) were among the top five states with the largest surface water discharges of chemicals. Other less identifiable sources of pollutants enter rivers, estuaries, and coastal areas from runoff and atmospheric deposition. Many of these nonpoint sources contribute chemicals and pesticides, as well as other material, to the receiving waters of the Gulf of Mexico. Although pollutant input estimates are critical to understanding the overall risks of toxic substances and pesticides, they cannot be used alone to target contaminated areas.

Comparable data are not currently available to address the fate and effects of these discharges on the aquatic environment. A toxicant entering the marine environment may remain in the water column or move into the sediment, biota, or atmosphere. Several predictive fate models exist, but need to be refined and validated to incorporate parameters such as flushing rates. Models for predicting effects are not as available. Nevertheless, it is clear that toxic contamination may cause a slow, subtle poisoning of water, soil, and aquatic resources that is fairly invisible to beach users, boaters, or casual observers of Gulf waters.

Consequences for Living Resources

The toxic effects of chemical contaminants to aquatic organisms are dependent on several factors, such as the bioavailability and persistence of specific contaminants, and the interference of contaminants with metabolic processes (Capuzzo and Moore, 1986). The responses of organisms to toxic chemicals can be exhibited at four levels of biological organization: 1) biochemical and cellular; 2) organismal, including the integration of physiological, biochemical and behavioral responses; 3) population, including alterations in population dynamics; and 4) community, resulting in alterations in community structure and dynamics (Capuzzo and Moore, 1986). One of the least understood problems is the effect of sub-lethal concentrations of toxic materials on ecosystem function.

Signs of increasing degradation and contamination from toxic substances and pesticides in the Gulf of Mexico include the following examples:

- In a USEPA study of three Gulf Coast estuaries, sampling stations near heavily industrialized sites yielded larger numbers of diseased fish and oysters when compared to more distant sampling stations (USEPA, 1990b).

- Biscayne Bay (Florida), Mississippi Sound, and Galveston Bay (Texas) have been reported (Overstreet, 1986) to contain striped mullet with mesenchymal neoplasms; sciaenid and other fishes with lymphocystis; fish with ulcers, red sores, fin erosion, and granulomata; crustaceans with shell disease; and other "pollution-associated" diseases.

- According to NOAA National Status and Trends Mussel Watch data, mercury is generally enriched in Florida sites, where 12 of 25 of the sites sampled are well above average. The oysters from Old Tampa Bay and Lavaca Bay are especially high in mercury (USDOC, 1987).

- In some locations in Texas, where oysters are known to be contaminated with mercury, harvesting has been limited because of the potential of a human health threat.

- The brown pelican became locally extinct in the northern Gulf because the presence of the pesticide DDT in large quantities inhibited the pelican's ability to reproduce (USEPA, 1991b; USEPA, 1990a). Regulatory controls have supported the recovery of this species in many areas; however, the brown pelican remains endangered in Texas.

- Total DDT is the most abundant chlorinated pesticide found in Gulf oysters. The regional distribution of total DDT shows that four of the five highest concentrations are associated with major river outfalls including the Brazos, Mississippi, Mobile, and Choctawatchee rivers. There are also relatively high total DDT concentrations at St. Andrew's Bay and Panama City, although there are no major rivers nearby. Polycyclic aromatic hydrocarbons (PAHs) are also highest in these regions. DDTs associated with soils may be transported downstream and collect in estuaries. This process provides a plausible explanation of the higher total DDT associated with major river outfalls. There are somewhat higher concentrations near areas of higher population density (*i.e.*, Galveston Bay, Mobile Bay, etc.) (Wade *et al.*, 1991).

- PCBs have been detected in all oyster samples analyzed in NOAA's National Status and Trends (NS & T) Program. The highest regional concentration is from St. Andrew's Bay.

- Moderately elevated concentrations of sediment pesticides and PCBs appear along the central Louisiana coast (possibly associated with Mississippi River discharge) and at isolated stations in Matagorda Bay and Galveston Bay (Texas). High concentrations of chlorinated hydrocarbons are observed along the Mississippi-northern Florida coast and at sampling stations in Tampa Bay. The most abundant chlorinated hydrocarbons in Gulf of Mexico oysters are PCBs, DDTs, chlordanes, and dieldrin. Overall, the geographical trends in organochlorine contaminant load in oysters follow those observed in sediments (Texas A & M Research Foundation, 1989).

Ecological Risk Assessment (USEPA, *Framework for Ecological Risk Assessment, 1992.*)

Quantifying the sources and understanding the fate and effects of contaminants are essential for evaluating the risks posed to the Gulf of Mexico. These data on contaminants and affected resources can be organized and analyzed through the process of ecological risk assessment.

Risk is essentially the probability of harm. Risk is the chance (probability) that the exposure of toxic chemicals or pesticides will result in an adverse effect over the lifetime of an organism or ecosystem.

Ecological risk assessment is defined as a process that evaluates the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors. Ecological risk assessments evaluate ecological effects caused by human activities and natural phenomena. The term "stressor" is used to describe any chemical, physical, or biological factor that can induce adverse effects on individuals, populations, communities, or ecosystems.

The framework is conceptually similar to the approach used for human health risk assessment, but it is distinctive in its emphasis in three areas. First, ecological risk assessment can consider effects beyond those on individuals of a single species and may examine a community or ecosystem. Second, there is no single set of ecological values to be protected that can be generally applied. Rather, these values are selected from a number of possibilities based on both scientific and policy considerations.

Finally, there is an increasing awareness of the need for ecological risk assessments to consider nonchemical as well as chemical stressors.

The risk assessment framework consists of three major phases: problem formulation, analysis, and risk characterization. *Problem formulation* is a planning and scoping process that establishes the goals, breadth, and focus of the risk assessment. Its end product is a conceptual model that identifies the environmental values to be protected (the assessment endpoints), the data needed, and the analyses to be used. It is where the problem is laid out and a strategy is designed to obtain the types and amount of exposure and effects data to perform risk assessment.

The *analysis* phase develops profiles of environmental exposure and the effects of the stressor. The exposure profile characterizes the ecosystems in which the stressor may occur as well as the biota that may be exposed. It also describes the magnitude and spatial and temporal patterns of exposure. The ecological effects profile summarizes data on the effects of the stressor and relates them to the assessment endpoints.

Risk characterization integrates the exposure and effects profiles. Risks can be estimated using a variety of techniques including comparing individual exposure and effects values, comparing the distributions of exposure and effects, or using simulation models. Risk can be expressed as a qualitative or quantitative estimate, depending on available data. In this step, the assessor also:

- describes the risks in terms of the assessment endpoint;
- discusses the ecological significance of the effects;
- summarizes overall confidence in the assessment; and
- discusses the results with the risk manager.

In order to conduct a comparative ecological risk assessment for the Gulf, many preliminary steps must be taken. (See Figure 2).

Figure 2. ***Risk Assessment Diagram***

The results of a risk assessment hinge on many factors, including the estimated uncertainty of the results; social perceptions of risk; the population at risk; values such as commerce, recreation, endangered species and supporting habitat, and regulatory requirements. Interpretations are called risk management. Risk management translates the scientifically obtained results of risk assessment into a social decision regarding appropriate actions to reduce the risk (Pastorok *et al.*, date unknown). Risk management must also try to consider combinations or interactions of chemicals—potential impact of more than one toxicant. Due to the inherent uncertainty associated with risk assessment and management, the most logical and productive area in which to focus limited resources is pollution prevention or source reduction which incorporates process modification, closed loop recycling, and product substitution.

Figure 3 represents a framework for understanding the various components of a risk assessment. The columns represent the three stages of risk assessment-problem formulation, analysis, and risk management and cross-constituent analysis. The rows describe different procedural steps and tools needed to assist in the risk assessment. Currently, a comprehensive ecological risk assessment or characterization can not be conducted for the Gulf of Mexico because there is a lack of information needed to fully carry out many of these preliminary steps. The primary goal of the Research Needs Workshop was to determine the most critical research needed to fill these gaps. Ultimately, a comparative ecological risk assessment can be conducted focusing Gulf of Mexico resources on high priority problems.

Figure 3. ***Risk Assessment Matrix***

TOXIC INORGANICS - STRATEGIC RESEARCH NEEDS

Overview

For the purposes of this workshop, the discussion of inorganic contaminants was confined to metals only. Although the workshop participants acknowledge that other inorganic constituents can represent potential pollutants in the Gulf of Mexico system (*e.g.*, salinity, nutrients, radionuclides), they made recommendations exclusively on trace metals for two reasons. First, other GOMP committees are addressing nutrient and salinity issues. Second, metals are perceived to be the greatest problem in the Gulf by a wide audience.

General needs identified by the workgroup included the establishment of baseline conditions, development of bioaccumulation and hydrogeologic models, standardization of historical data, validation of current assessment and evaluation techniques, and development of quantitative techniques for overall risk assessment.

Workgroup Participants:

Bill Adams (Chair)	ABC Labs
Denny Buckler (Co)	U.S. Fish and Wildlife Service
Fred Calder	Florida Department of Environmental Protection
Kellie Dixon	Mote Marine Laboratory
Mike Lewis	U.S. EPA
Sonny Mayer	U.S. EPA—Gulf Breeze
Simone Metz	Florida Institute of Technology
Bill Walker	Gulf Coast Research Laboratory
Herb Windom	Skidaway Institute
Parley Winger	U.S. Fish & Wildlife Service
Steve Wolfe	Florida Department of Environmental Protection

Strategic Research Needs:

Priority Level 1

1. Critical Review of Existing Chemical, Biological and Physical Data
2. Standardization of Methods Used in Gulf Wide Assessments
3. Establishment of Background or Reference Conditions
4. Development of Quantitative Techniques for Integrating Exposure and Effects Data

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Priority Level 2

5. Development of a Toxics Budget for the Gulf
6. Development and Validation of Effects Evaluation Techniques
7. Mechanistic Research on Speciation and Bioavailability
8. Development of Trophic Level Bioaccumulation Models for Gulf of Mexico Food Chains

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Priority Level 3

9. Development of Hydrogeologic Models of Chemical and Biotic Transport Dynamics at Appropriate Scales of Resolution

1. Critical Review of Existing Chemical, Biological and Physical Data

Research/Information Needs:

There is a need for data suitable to assess Gulf of Mexico-wide and sub-regional metal levels in sediments and organisms and to assess biological effects associated with specific contaminant loadings in the Gulf and its coastal systems.

Rationale:

A data base with known comparability in measurements based on proper documentation is essential to identifying contaminant levels with confidence and securing informed public support for environmental restoration and pollution prevention.

A variety of procedures have been employed to generate metal values. The following problems are associated with the existing data base:

- Concentrations of metals are based on either partial digestion (acid leach) or total digestion. Biological samples in many instances have not had the contents of the digestive track eliminated prior to sample treatment and often lack documentation of organism size and tissue type.

- Procedures do not attain sufficiently similar precision and accuracy in measurements to allow comparison. In addition, contaminant measurements are not always accompanied by proper QA/QC documentation to allow evaluation.

- Metal data are not accompanied by sufficient background information to allow for assessing the extent and severity of contamination.

Initiation Activities:

To address this issue, a science review working group should be established to develop criteria for evaluating chemical and biological data on the Gulf of Mexico and to provide guidance and assistance in the compilation and evaluation of existing data.

Existing compilations could be used for this review. These include: EPA Region IV Sediment Quality Inventory, Gulf of Mexico Sediment Quality Inventory and the Biological Effects Data Base for Sediments (BEDS). Recommendations for further work in the Gulf of Mexico should be made following the evaluation of the data base Either gaps created as a result of the evaluation or existing gaps need to be addressed. The recommendations should also cover the need for background metal data.

Priority Level: 1

2. Standardization of Methods Used in Gulf Wide Assessments

Research/Information Needs:

There needs to be an outline of criteria to generate scientifically valid data and an accompanying QA/QC plan that will allow data comparison.

Rationale:

Historical metal concentration data for sediments and tissues from most regions include results of analyses using a variety of sample digestion techniques and analytical methodologies. Many of these techniques and methodologies do not produce comparable or valid results. For example, metal concentrations based on the analyses of sediments using partial digestion techniques do not compare with those based on total digestion. In addition, partial digestion techniques fail to provide aluminum data necessary for normalizing data and for distinguishing between metal sources (*i.e.*, natural versus anthropogenic). Furthermore, standard reference materials (*i.e.*, NIST or NRC standards) are only certified for *total* metal content, thus only results for total analyses can be easily validated. The primary difficulties associated with trace metal data for biological samples is data generated using non-depurated (lack of elimination of digestive track contents) samples and lack of consistency in organism size and stage of development. Therefore, to assure that future data produced for the Gulf of Mexico are consistent and valid, there is a need to adopt standardized methodologies and establish a regional analytical quality assurance program.

Initiation Activities:

To address this issue, the Technical Steering Committee for the Gulf of Mexico Program should establish an independent science review group to initiate the following steps:

- Establish consensus on methodologies to assess biota and sediments.

- Organize a QA program that incorporates all regional scientists that are working within Gulf of Mexico program activities.
- Establish a quality assurance program that includes sponsoring workshops that bring together scientists to discuss ways of improving comparability of results and intercalibration exercises, coordinating with other groups working on QA improvements, and establishing a permanent QA committee to periodically review data quality and make recommendations for improvements.

Priority Level: 1

3. Establishment of Background or Reference Conditions

Research/Information Needs:

There is a need to develop methods for the determination of natural vs. anthropogenic stressors and for the establishment of baseline chemical and biological values.

Rationale:

For the protection and management of Gulf of Mexico resources, it is imperative to not only be able to determine the level, extent, or impact of contaminants, but to also be able to determine whether these levels exceed "normal" or background levels or effects. At present this can not be done effectively. This is necessary in order to provide a "yardstick" with which to make value judgments about the quality of the environment and to characterize the significance of impacts or potential impacts.

A significant body of knowledge exists regarding the presence of metals in a variety of biotic and abiotic compartments of the Gulf ecosystem. Similarly, a wide array of test methods are available for measuring biological responses in the plant and animal components of the Gulf. Information on normal values for environmental responses, as well as the variability associated with those responses, will enhance our ability to make decisions regarding the significance of environmental stressors.

Initiation Activities:

To address this issue, laboratory and field studies will need to be designed to establish normal or baseline values for chemical residues and biological responses. An initial component of the process will be the development of definitive criteria for identification and selection of appropriate reference or control sites for wetland, estuarine, and marine habitats. At these sites, samples of biotic and abiotic compartments can be taken over a sufficient period of time from which to determine both mean baseline values and estimates of the inherent and seasonal variability associated with those parameters. With this information in hand, more meaningful interpretation of existing data on contaminant presence and biological responses in other areas of the Gulf can be made.

Unimpacted areas from the various habitats of the Gulf of Mexico should be sampled to establish baseline concentrations of contaminants, community/population parameters, and toxicological effects. The initial activity would be discrete, relatively short term projects. However, continued input would be expected from ongoing monitoring and research activities. Because of the pivotal nature of this research need, baseline information on the chemical, biological, and toxicological components of the system should be collected as quickly as possible.

Priority Level: 1

4. Development of Quantitative Techniques for Integrating Exposure and Effects Data

Research/Information Needs:

There is a need for the development of quantitative techniques for integrating exposure and effects data.

Rationale:

To achieve a system-wide approach to the Gulf of Mexico, comparative risk assessments are necessary to characterize the relative importance of various stressors and identify sites of concern and resources at risk. This will require development and validation of estuarine assessment protocols, but even more importantly, it will require the development of quantitative and probabilistic analysis techniques for integrating exposure and effects data.

At present, ecological risk assessments involve generation of large amounts of data on exposure and effects that are derived under strict QA/QC conditions. Rather than analyzing all data in an integrated fashion, a simple quotient method requiring small amounts of the data is used to develop an estimate of risk. The quotient method involves dividing the no-effect concentration for the most sensitive species by the predicted environmental exposure concentration that aquatic organisms may encounter. An estimate of risk or a safety factor may then be applied to the value.

The existing approach increases the uncertainty of the risk assessment. Techniques are needed that will use all of the data to allow for modeling multi-scenarios of stressor impact and analysis and integration of disparate data sets. These techniques will provide probabilistic risk assessments with reduced uncertainty, widely applicable analytical approaches for comparative risk assessments, and more flexible and complete data management systems, including GIS applications.

Initiation Activities:

The first step required is to create a technical group to determine what analyses, information, and management capabilities would be expected from such a

system. This could be accomplished near-term through a workshop setting. The existing data will be used to develop and validate the system.

Priority Level: 1

5. Development of a Toxics Budget for the Gulf

Research/Information Needs:

There is a need to develop a refined toxics budget for the Gulf that recognizes contributions from extreme events.

Rationale:

While first order estimates of toxics budgets for the Gulf or tributary loadings exist, the data and loading estimates that have been produced with data of questionable quality (or of limited utility) may be insufficient for identifying the contributions of extreme events.

A unified source inventory is currently incomplete for all of the Gulf of Mexico watersheds. The amounts and components of chemical spills and the relative mobility of the species typically are not included. There is inadequate collated information to estimate the relationships between sources--surface water discharges and atmospheric deposition--and the eventual loadings to the Gulf.

It should be emphasized that atmospheric deposition of toxicants is poorly quantified compared to other sources. The variation in deposition from nearshore to mid-Gulf is unknown. The toxics budget should include information on the amounts of inorganics contained in groundwater and produced waters (released with drilling muds on-site during oil and gas drilling activities) which contain substantial quantities of metals and other toxicants.

Central American and Caribbean loading of toxics to the Gulf is presently inadequately quantified. The relatively poor levels of treatment for sewage and industrial effluents, the use of U. S. prohibited pesticides, and the substantial mining interests in the Central American region may represent a large fraction of metal contributions to the Gulf.

Initiation Activities:

An initial project to address this research need would include the following tasks: list potential pathways, acquire any existing data pertinent to loading rates, identify the quality of each data set, identify Gulf-specific information still lacking, and incorporate best estimates from data in other regions as applicable. The proportion of contributions during extreme events should also be addressed. This effort is viewed as a short term effort, parameters of which may be revisited as additional information becomes available. Depending on the utility of information from other regions, short term projects may be identified to provide estimates for all pathways.

Priority Level: 2

6. Development and Validation of Effects Evaluation Techniques

Research/Information Needs:

There is a need for the development of ecological effects evaluation techniques to be used Gulf-wide to ensure comparability of results. Although these standards should not stifle creativity, there should be a minimum data set required for all evaluations.

Rationale:

The ecological health of the Gulf of Mexico and its associated estuaries is relatively unknown, although there are indications that it may be declining. Assessment techniques and protocols have been reported to analyze the flora and fauna in this region, but they have not been evaluated for relevance and utility. These assessment techniques are needed to more accurately determine the ecological condition of the Gulf and to ensure that its economic and recreational importance is maintained. Development of effects evaluation techniques and their validation contains two major components: evaluation of specific endpoints as indicators and the validation of assessment protocols. We need to maximize the efficiency of data gathering by determining endpoints that are appropriate to specific ecosystems of interest. The relative sensitivities and ecological relevance of various biomarkers, tissue burdens, and community parameters currently are not clear. Many estuarine assessment protocols developed for the Gulf are conceptual in nature, and much of the baseline data are from laboratory studies. It is not clear if these assessment paradigms are appropriate and effective for assessing effects in complex estuarine ecosystems, especially the Gulf.

Initiation Activities:

We suggest that current broad-scale assessment programs conducted by NOAA, USFWS, and USEPA in the Gulf of Mexico should be used as the focal point for future protocol development and endpoint evaluation. Sampling and analytical activities are being completed in multiple estuaries in the Gulf including Back Bay of Biloxi, MS and Pensacola and Escambia Bays, FL. Techniques and approaches utilized in these individual studies, and those conducted by NOAA and USFWS, could

be immediately evaluated and assessed relative to results generated. The techniques could also be consolidated into a consensus protocol to be validated in additional Gulf-estuarine systems. A multiyear effort could begin immediately with a team of 8-10 research personnel. Sufficient analytical chemical support will also be needed to timely process samples of sediment, water, and biota. By building on efforts already underway, the probability of success in the relatively near term is high.

This effort will help establish baseline conditions for a healthy Gulf ecosystem Assessment activities at suspected impacted sites will necessarily require simultaneous assessment of reference areas, thereby providing information for the reference site database.

Priority Level: 2

7. Mechanistic Research on Speciation and Bioavailability

Research/Information Needs:

There is a need to understand toxicity changes as a result of the molecular speciation of toxicants induced by surrounding physical-chemical conditions.

Rationale:

The toxicity of many ionic (and nonionic) toxicants may vary widely as a result of other physical-chemical factors (*e.g.*, pH, alkalinity, hardness, salinity, and sediment grain-size, AVS content, and iron oxide/manganese oxide surfaces).

Some of this variability is caused by altered toxicant species and bioavailability. For example, competition among available ions at effect sites (*e.g.*, heavy metal ions competing with "nutrient" metal ions at uptake channels in gill membranes) may occur. Some variability is caused by changes in speciation of the molecules resulting from altered equilibria because of the presence of other ions (*e.g.*, silver's shift from Ag^+ to AgCl, AgCl2, and AgCl3 as the surrounding salinity increases). Some variability is also likely from presently unknown factors.

While the speciation in water of many metals can be modeled using the EPA MINTEQ or other similar programs, the toxicity changes from this speciation may be enormous, and are generally poorly understood. Most toxicity testing, particularly of metals, has been performed in the absence of understanding the molecular species to which the organisms were exposed.

Initiation Activities:

- Where the speciation knowledge and the available water chemistry data during bioassays are sufficient, toxicity test results should be analyzed in light of the exposure to molecular species.
- These results should then be compiled to provide information on toxicity of molecular species.
- Any research funded out of the Gulf of Mexico program should be required to consider these factors in experimental design.

- Estimated time to complete the projects would be one year.

Priority Level: 2

8. Development of Trophic Level Bioaccumulation Models for Gulf of Mexico Food Chains

Research/Information Needs:

There is a need to better understand bioaccumulation of organic and inorganic contaminants in the Gulf of Mexico food chains to perform ecological risk assessments.

Rationale:

The concept of trophic level transfer of contaminants is based on the recognition that contaminants can be taken up by aquatic organisms from water and/or sediments and passed on to consumer organisms. The contaminant of interest may be maintained as a body burden (residue) by organisms at several trophic levels and passed on to successively higher trophic levels resulting in trophic transfer. Trophic transfer involves contaminant uptake, metabolism, and depuration. The transfer of contaminants from one trophic level to the next may or may not result in successively higher concentrations of chemicals from one level to the next (biomagnification) depending on the physical/chemical properties of the contaminant.

Trophic transfer is an important process that results in the transport and transformation of metals within and outside of the Gulf system. Trophic transfer also broadens exposure pathways. This process provides a direct means of exposure of higher order organisms (including wildlife and humans) to contaminants contained in the Gulf.

Ideally, quality data would be obtained on key metals for the Gulf (mercury, cadmium, copper, zinc, and arsenic) for well-known food web systems. The data would be modeled using food web models and would be extrapolated to food webs other than those studied. Transfer coefficients would be developed and exposure would be based on food consumption quantified for various components of the food web. These data would then fit into an overall assessment of exposure for various aquatic organisms in the Gulf.

Initiation Activities:

- Review existing metals data on Gulf organism tissue levels. Select a specific site (estuary) within the Gulf to focus research activities. Construct appropriate food chain models for the selected site. Model the data and derive transfer coefficients, derive exposure estimates for key species, evaluate other pertinent metals related trophic transfer information and identify data gaps. This project is a short term project and could be completed in one year.

- Fill data gaps and expand the data set to include trophic transfer models for multiple estuaries and off-shore areas. This would be a long term project.

Priority Level: 2

9. Development of Hydrogeologic Models for Sediment and of Chemical Transport Dynamics at Appropriate Scales of Resolution

Research/Information Needs:

There is a need for information that would allow modeling of toxicant fate as a result of hydraulic flow, sediment movement, and biological transport mechanisms.

Rationale:

To perform a risk assessment, it is necessary to understand the movement of toxicants into and through the Gulf of Mexico and its coastal waters and tributaries. This requires an understanding of surface-water circulation patterns, ground-water flow to the coasts, movements of sediments, and transport from the movement of and cycling through the biota (*e.g.*, migration, bloom uptake and deposition). Sediment transport includes suspended sediments and bed-load from rivers, as well as resuspension (*e.g.*, resulting from storms and dredging) and subsequent transport in coastal waters.

Some estuaries already have circulation models; however, many are two-dimensional models that are relatively crude and insufficient for present needs. Open Gulf of Mexico circulation has been studied on a large scale to the exclusion of small-scale variations. This is because the physical oceanographers performing the studies are not to determine environmental effects.

The ability to model the mass transport of toxics through these mechanisms will contribute greatly to documenting and predicting effects, identifying areas of potential problems, and in interpreting results of other studies. This understanding needs to be on a scale pertinent to its intended use. The appropriate scale for a particular use may include general Gulf of Mexico current patterns, longshore coastal transport, or within-estuary circulation with greatest emphasis on near-shore movements.

Initiation Activities:

- Survey status of circulation modeling in Gulf of Mexico estuaries and any near shore information.

- Identify modeling methods that yield best results for toxicant-transport purposes.
- Prioritize locations where modeling is most needed to address current problems and contract for their creation.
- Estimated time for completion would be one year for these projects.

Priority Level: 3

TOXIC ORGANICS - STRATEGIC RESEARCH NEEDS

Overview

Protection and management of ecological resources in the northern Gulf of Mexico require an understanding of the effects and impacts of anthropogenic activities independent of natural ecosystem variations. Comprehensive systematic and standardized methods to access anthropogenic impacts in general, and toxic impacts in specific, have not been developed and/or widely applied in the Gulf. Major research needs include:

- healthy Gulf ecosystem status indicators,
- predictive ecological effects tests, and
- diagnostic ecological effects tests for detection of the specific causes of measured impacts.

In addition to these tests, assessment of available data on anthropogenic inputs, including atmospheric deposition and ambient concentrations, are needed. Advanced chemical analytical methods, including continuous and integrating sampling and analysis methods and data treatment procedures, together with site-specific estuarine/ecosystem sediment and water quality criteria for target pollutants, need development.

Workgroup Participants:

Ed Overton (Chair)	Louisiana State University
Linda Anderson-Carnahan (Co)	U.S. EPA, Region IV
Scott Carr	U.S. Fish & Wildlife Service
Nicholas Casseri	Occidental Chemical Corporation
Dick Conway	Union Carbide
Carol Daniels	U.S. EPA - Environmental Research Laboratory
Thomas Deardoff	International Paper Company
Robert Dickey	U.S. Food & Drug Administration
Phil Dorn	Shell Development Corporation
Seymour Holtzman	Brookhaven National Laboratory
Julia Lytle	Gulf Coast Research Laboratory

Ray Wilhour U.S. EPA - Gulf Breeze
Lloyd Wise Gulf of Mexico Program

Strategic Research Needs:

Priority Level 1

1. Criteria for Healthy Gulf Ecosystems
2. Predictive Ecological Effects Tests Battery
3. Diagnostic Ecological Effects Tests Battery

Priority Level 2

4. Assessment of Loading/Ambient Data and Modeling Needs
5. Atmospheric Deposition of Toxicants and Pesticides in the Gulf of Mexico
6. Development of Site-Specific Water Quality Criteria for Organic Toxicants

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Priority Level 3

7. Development of Continuous and/or Integrative Sampling and Analysis Systems for Toxic Organic Compounds in the Gulf of Mexico

1. Criteria for Healthy Gulf Ecosystems

Research/Information Needs:

There is a need for a suite of measurements and/or parameters that define the normal stability and variability observed in healthy Gulf ecosystems. The measurements of ecosystem health will be used to describe a normal system and identify healthy systems representative of broad regions of the Gulf of Mexico. These parameters should be:

- few in number and readily quantifiable,
- able to measure community and ecosystem health status,
- sensitive to stress, and
- able integrate change over time.

Rationale:

These "standardized" assessment tests are required to:

- identify and describe a healthy estuary for monitoring/research reference;
- classify estuaries as healthy, stressed, and degraded;
- identify changes in health status over time to assess effectiveness of control strategies (or the need to implement control strategies);
- provide early warning signals of declining systems; and
- compare Gulf-wide research and monitoring results;

The regionally representative "healthy ecosystems/estuaries" will be valuable as an indexing function in coordinating assessment activities throughout the Gulf of Mexico. A critical examination of EMAP, REMAP, and Walker's Biloxi Bay Study are needed to standardize a suite of measures and/or criteria to describe a healthy ecosystem. The applicability of these indicators Gulf-wide needs to be determined and modified, where appropriate, to accommodate regional differences.

Initiation Activities:

- Regional workshop to evaluate current monitoring strategies and expansion needs.

- Utilize Biloxi workshop as a template.
- $ 1-2 million per year for each of 3-5 years.

Priority Level: 1

2. Predictive Ecological Effects Tests Battery

Research/Information Needs:

There is a need for the identification, development, validation, and calibration of a suite of tests (*e.g.*, laboratory toxicity tests or *in situ* tests with animals and plants utilizing sublethal end points, etc.) with sensitive life stages of indicator species to identify and predict ecosystem problems in the Gulf of Mexico.

Rationale:

Contaminants entering an estuary from point or non-point sources may effect organisms directly in the water column, be concentrated in the surface microlayer, or be adsorbed to particulates. Sensitive stages of biota may be exposed to contaminates via any of these compartments. Because the majority of persistent contaminants and their degradation products entering estuaries eventually become associated with sediments and are deposited in estuaries, it is critical that a suite of tests contain sediment assays. Sediments may represent an integrated accumulation of contaminant inputs to an ecosystem. However, it is not generally practical to predict which sediment samples may be toxic on the basis of analytical chemistry information alone. A suite of toxicity tests capable of detecting deleterious effects in water, surface microlayer, and sediment samples are needed to assess potential contaminant problems in the bays and estuaries of the Gulf of Mexico. These tests should be compatible with diagnostic approaches (*e.g.*, toxicity identification evaluations) for evaluating the causes of any observed biological effects.

Initiation Activities:

Priority Level: 1

3. Diagnostic Ecological Effects Tests Battery

Research/Information Needs:

There is a need to identify and develop a battery of diagnostic tests to determine the stressors causing the observed biological impacts in I and II (*i.e.*, stressor characterization/evaluation/confirmation techniques).

Rationale:

In order to adequately assess the state of the Gulf of Mexico, there is a need to supplement chemical specific analyses and single species toxicity test results with population/ecosystem level health data. However, when population/ecosystem level assessments indicate a problem with the health of an estuary, the source(s) of the impact may not be clear cut. Unlike the case of single species toxicity tests for which toxicant identification evaluation methods have been and continue to be developed, no such techniques exist to determine which of the many potential stressors present in an estuary are causing the observed population/ecosystem effects. The battery of diagnostic tests developed should have the ability to distinguish between effects caused by toxic organic and inorganic chemicals, physical insults, biological stressors, etc. This battery could include biomarkers, post-mortem examinations, marine sediment toxicant identification evaluations, and single species tests coupled with chemical assays. They should focus on the specific impact observed.

Initiation Activities:

A detailed workplan needs to be developed as an initial step. The concept of how a battery of tests could diagnose the cause of several types of observed ecosystem problems would first be examined in a paper study. This approach is analogous to the tests used by medical practitioners to diagnose and establish causal relationships between problems and stressors in humans. The paper study would be followed by identification of an array of existing diagnostic ecological tests that may be useful such as EPA's Toxicant Identification Evaluation procedures. Gaps in existing techniques would be identified as methods development needs. The resulting workplan should include a thoughtful rationale, identification of the most promising

existing tests to evaluate first, test development needs, and a schedule for needed laboratory and field work to apply/revise/validate the diagnostic test battery.

Priority Level: 1

4. Assessment of Loading/Ambient Data and Modeling Needs

Research/Information Needs:

There exists a need to re-assess available data, qualify its uses, and target improvements and gaps. This also includes model development and use.

Rationale:

Gulf of Mexico-specific ecosystem-based toxics data are needed for predictive assessment, problem identification and resolution, and resource allocation. Mechanisms for flagging the data for various uses based on its quality and development of assessment and data QA/QC protocols (not necessarily totally standardized but equitable) need to be incorporated into existing databases. Selection of critical input parameters for use in existing models and development of appropriate Gulf-specific models that integrate toxic loading, ambient information, and exposure and fate data are fundamental requirements for effective toxic management and regulatory activities.

Initiation Activities:

An initial step in re-assessing existing data would be the screening of Gulf data from various sources and identification of obvious data gaps.

Priority Level: 2

5. Atmospheric Deposition of Toxic Substances and Pesticides

Research/Information Needs:

There is a need to develop information and methodologies which predict the magnitude and effects of atmospheric deposition of toxic organic compounds into the northern Gulf of Mexico.

Rationale:

The magnitude of TRI-reported toxic chemical emissions to air greatly exceeds the magnitude of discharges directly to water, and recent studies have indicated that atmospheric transport of toxic organic compounds from (primarily) point and fugitive sources may be a significant mechanism of toxics input to water bodies, both via direct deposition to water and deposition to land followed by runoff. Because of their proximity to industrial and municipal point sources, Gulf of Mexico waters are potentially at risk from airborne toxics input. This potential risk requires further evaluation, including the effects of inputs to the surface microlayer on pelagic organisms.

Initiation Activities:

The mechanism of assessment will include:

- examination of existing atmospheric deposition data;
- examination of models used to predict atmospheric transport, fates, and deposition to water bodies;
- selection of one or more models, including an assessment of the potential for field validation of the model; and
- utilization of the model(s) to predict deposition of toxics to Gulf waters.

Air toxics release information from industry-provided TRI data, from recently collected MACT studies data, and from state air toxics release submissions will be utilized. The scale of the study will be determined after the model has been examined and selected; it may be necessary to limit the first exercise to one or several specific

Gulf water bodies, thus demonstrating the technique and providing an assessment of the significance of this input to Gulf waters.

The activity is expected to require one to two years at a cost of $100,000 - 250,000 to achieve the first deliverable (*i.e.*, the first report on atmospheric deposition to a chosen water body). (A preliminary screening of the study to assess the magnitude of the atmospheric deposition effect and the feasibility of more comprehensive effort would cost from $50,000 to $100,000.) Assessment of the magnitude of the atmospheric deposition effect and the feasibility of more comprehensive efforts would cost from $50,000 to $100,000.

Priority Level: 2

6. Development of Site-Specific Water Quality Criteria for Organic Toxicants in the Gulf

Research/Information Needs:

There is a need to develop site-specific ambient water quality criteria for toxicants in the Gulf of Mexico. Ambient water quality criteria for marine systems are only available for a limited number of toxic pollutants. Little data are available for marine species in the Gulf of Mexico, nor are there validations of protection offered by national saltwater criteria in the Gulf of Mexico.

Rationale:

USEPA ambient water quality criteria are developed for nationwide applications. Many of the existing criteria, however, apply only to freshwater environments. The Gulf of Mexico's contiguous coastline is dominated by estuarine conditions with varying salinities and organisms. Organic chemical toxicity is not only a function of species sensitivity, but it is also a function of physical and chemical factors present in receiving waters. The use of existing freshwater criteria for NPDES discharge limitations can be inappropriate. There is a need to develop ambient water quality criteria for the Gulf of Mexico for a different suite of resident/surrogate species that are reflective of the diverse saline environments of the Gulf. Site-specific criteria would be compared to a "toxicity test battery" and validated in an estuarine ecosystem to determine comparative differences between the three levels of test complexity according to EPA national guidance. This would result in the ability to predict estuarine impacts from organic chemical pollution.

This work should focus on development of ambient criteria for those organic chemicals identified as high Priority for the Gulf of Mexico because of release once fate is considered, lack of a relevant data set using national guidelines, and perceived lack of data on specific chemicals.

Test data development would proceed with selection of relevant species for commercial interests, recreational interests, ecological interests, esthetic significance, and range of occurrence. Specific effects of physical and chemical modification of the control water would be included to evaluate the role of salinity, dissolved organic

carbons, solids, pH, temperature, and pulse exposures that would result from a significant storm event.

Initiation Activities:

This activity would cost approximately $200,000 per year for each of 5 years.

Priority Level: 2

7. Development of Continuous and/or Integrated Sampling and Analysis Systems for Toxic Organic Compounds in the Gulf of Mexico

Research/Information Needs:

There is a need to develop continuous, integrated environmental sampling and analysis systems for toxic organic compounds in the Gulf of Mexico.

Rationale:

The input and disposition of toxic organic compounds in the Gulf environment is non-homogeneous. A multitude of methods for sampling and analysis exist for a wide variety of known target compounds. These methods are largely time-consuming, costly, and laboratory-based. There is a need for accumulative and real-time sampling techniques, and cost effective, field deployable and analytically versatile instrumentation for continuous environmental monitoring programs. Analytical data from proposed instrumentation programs should be presented in a format useful to environmental managers. Further, it is implicit and essential that methods and instrumentation development comply with appropriate QA/QC controls.

Initiation Activities:

- Assess current technological capabilities in both commercial and federal sectors.
- Fund selective and promising research.
- Set up guidelines for commercial development incentives.

Priority Level: 3

PESTICIDES - STRATEGIC RESEARCH NEEDS

Overview

Ecological harm to the Gulf of Mexico and its resources can result from pesticide usage and consequent runoff into the Gulf system. Successful comparative assessments of the risks of various pesticides and pesticide usage practices hinge largely on the existence of an adequate information base.

To address current information gaps, the pesticides workgroup identified a variety of strategic research needs for the next five years. These needs fall into the following major categories:

- Modeling
- Chemistry
- Management Practices
- Loading/Fate/Inputs
- Toxicity (*e.g.*, Ecological, Human, Methods)
- Impacts/Field Effects

Some broad needs identified included the development and validation of models, the identification of problem pesticides, the interpretation and application of tissue residue data, and the understanding of repeated short-term events in the Gulf. Essentially, research in these areas would help fill information voids related to pesticide inputs, management, and outputs. In turn, this new information would help the Gulf community identify and select management options designed to reduce risks to this vital ecosystem. Figure 4 provides an overview of this concept.

Figure 4: ***PESTICIDE Flow Diagram***

Workgroup Participants:

Jim Clark (Chair)	Exxon Biomedical Sciences, Inc.
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Greg Cramer	U.S. FDA
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Tom Dillon	U.S. Army Corps of Engineers
Roxanne Dow	Florida Department of Environmental Protection
Catherine Fox	U.S. EPA - Office of Water
Mike Jahncke	DOC/NOAA/NMFS
"Smiley" Nava	Texas Parks and Wildlife Department
Rich Pierce	Mote Marine Laboratory
Geoff Scott	NMFS, Charleston
Darryl Smith	Florida Department of Agriculture

Strategic Research Needs:

Priority Level 1

1. Develop and Validate Estuarine Ecosystem Models
2. Update and Verify Contaminants Database for Tissue Residues, Sediments and Water
3. Assess the Ecological Significance of Repeated, Acute Inputs of Pesticides in the Gulf of Mexico
4. Understanding the Transport and Bioavailability of Pesticides Used in the Gulf of Mexico
5. Development and Implementation of Pesticide BMPs for the Gulf of Mexico

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Priority Level 2

6. Identify Which Pesticides are Causing Ecological/Health Effects and Where the Impacts are Most Significant
7. Development of Standard Toxicological Test Methods Using Representative Endemic Species
8. Standardization of Analytical Methods and QA/QC Criteria

Priority Level 3

9. Understanding of Chemical Contaminant Effects on Marine Mammals and Top Carnivores in the Gulf of Mexico
10. Development and Evaluation of Remediation Strategies for Contaminated Habitats
11. Development of an Ecosystem Water Quality Risk Based Approach for Risk Assessment Using Archived Tissue Contaminant Data

1. Develop and Validate Estuarine Ecosystem Models

Research/Information Needs:

An empirical understanding of the hydrologic dynamics apparent in estuarine systems as they relate to the fate and dissipation of pesticides has not at present been achieved. Therefore, the development and validation of an eco-model for estuarine ecosystems is an important research need. Albeit trophic interactions and top predator integration of primary energy sources have been studied to some degree, efforts to mathematically incorporate these data into practical computer models of exposure and effect have not been completed. Estuarine eco-models would be helpful in estimating impacts to non-target organisms by:

- estimating degradation times ($t_{1/2}$) in various components of the ecosystem (*i.e.*, intertidal zones, sediments, pore waters, interstitial sediments, etc.),
- determining the dissipation and fate of pesticides,
- estimating the effects of dilution and exchange on the bioavailability of pesticides,
- providing more realistic exposure concentrations for estimating toxicological effects, and
- linking acute and chronic effects on single species to population, community and ecosystem effects.

Rationale:

One feature unique to the Gulf of Mexico is the tremendous influx of freshwater via the Mississippi River. This feature would require special considerations for estuarine ecosystem modeling due to the inconsistent hydrologic dynamics of the Mississippi river drainage. Models for this ecosystem must specifically consider factors such as marked nutrient loads, high sediment loads, diverse and often low salinity ranges, and semi-diurnal tides. Additionally, pest control relating to fire ants, golf courses, coastal residential developments, aquatic weeds, mosquito control, and marine fouling create unique impact issues for the Gulf region.

A key component of assessing the potential impacts of pesticides on non-target organisms is the ability to estimate the risk of chemicals to biota and to quantify ecosystem effects. Risk is a factor of hazard, or general toxicity of a pesticide, and

exposure, which is a determination of how, where, and in what quantity non-target organisms are exposed to pesticides. While numerous models are available to estimate pesticide input and fate for freshwater ecosystems, comparable computer models have not been developed for estuarine systems.

The lack of a suitable computer model of estuarine dynamics has been a serious limitation of regulatory risk assessments. Modeling information is critical for adequately protecting susceptible estuarine species, which is based on better predictive capabilities for pesticide input, dissipation, and bioavailability. Utilization of this information will, in turn, lead to sound management practices. A significant effort to validate and calibrate new models will be needed to establish confidence in the predicted outcomes, by correlating field toxicity data with laboratory generated data.

Initiation Activities:

The resources needed to accomplish this goal would include, but not be limited to:

- Experienced mathematical modeling experts.
- Access to National/International databases via Local Area Networks (LAN) or similar information transfer systems.
- A team of experienced estuarine ecologists to include a marine hydrologist, planktologist, invertebrate biologist, phycologist, microbiologist, fishery biologist, ecologist, marine mammologist, and environmental toxicologists.
- Availability of research vessels equipped with on-board facilities for chemical, biological, and hydrological analyses.

Priority Level: 1

2. Update and Verify Contaminants Database for Tissue Residues, Sediments and Water

Research/Information Needs:

There is a paucity of reliable, quality environmental monitoring data available Gulf-wide or for many estuaries, bays, and sub-systems. Therefore, there is a need to update as well as verify currently available pesticide contaminant databases for tissues, sediments, and waters of the Gulf of Mexico.

Rationale:

Historically, data available in contaminant databases often lacks appropriate documentation of quality assurance and quality control. Furthermore, the data often are flawed by poorly designed and inadequate sampling programs or are biased based on the original sampling program needs. In view of these considerations, there is a need to update as well as verify currently available pesticide contaminant databases for tissues, sediments, and waters of the Gulf of Mexico. A comprehensive pesticide contaminant database for the Gulf of Mexico will assist in comparison of clean, minimally impacted (or controlled) areas with "contaminated" sites with similar attributes and/or natural resources. Such a database will be useful in sound management decisions regarding prioritization of impacted areas, mitigation and/or remediation strategies. The widespread availability of such a database is critically important to ensure parody and consistency among the management agencies bordering the Gulf of Mexico.

Initiation Activities:

Acquire and update as well as verify existing pesticide contaminant databases. Data without appropriate quality control quality assurance documentation should be utilized with caution in comparison to data acquired from a fully supported environmental monitoring program.

Priority Level: 1

3. Assess the Ecological Significance of Repeated, Acute Inputs of Pesticides in the Gulf of Mexico

Research/Information Needs:

The ecotoxicological significance of pulsed inputs of pesticides into estuarine ecosystems of the Gulf of Mexico is unknown, although this is the most likely exposure regime following pesticide runoff events. While existing data may provide estimates of individual, singe pulse events, the cumulative impact of repeated pesticide inputs from multiple pesticide uses is unknown.

Rationale:

Non point source runoff or spray drift during application of pesticides near estuarine ecosystems may result in repeated, acute, or chronic exposures of endemic aquatic organisms to multiple chemicals. The standard laboratory tests used for estimating chemical toxicity typically use continuous exposures over extended time periods (1 to 10 days) to characterize chemical hazards. This provides a great deal of uncertainty in predicting or evaluating field effects from laboratory data. Documentation of the toxicity resulting from single pulsed exposures at field sites are rare, while data on repeated pulses and exposure-effect data are lacking. Present hazard and risk assessments are inadequate to address the realistic, repeated, pulsed pesticide exposures, particularly where repeated exposure may result in an increased sensitivity to pesticides. Additionally, aquatic organisms are exposed to multiple pesticides (herbicides, insecticides, fungicides) as well as dynamic physicochemical conditions (salinity, dissolved oxygen, turbidity). For example, low salinity can enhance the toxicity of pesticides and other contaminants. Alternatively, particulates found in runoff may serve as binding sites, and reduce the bioavailability of some pesticides. Studies are needed to address issues such as:

- identification of effects of repeated, pulse exposures to pesticides on key indicator organisms (fish, shellfish, crustaceans);
- evaluation of the effects of exposures to multiple pesticides;
- quantification of the interaction of water quality factors such as dissolved oxygen, salinity, turbidity, and the toxicity or bioavailability of pesticides;
- linkages of site specific studies of pesticide impacts with regional resource evaluations; and

- ecological assessments to derive ecotoxicological hazard/risk assessment models with spatial characterization of regional impacts from pesticides in Gulf of Mexico habitats.

Ecotoxicological effects of realistic exposure regimes could then be linked to regional models of pesticide loading and watershed transport to coastal habitats, providing predictive management and assessment tools for assessment and mitigation of potential pesticide impacts. Contaminant assessments of sediments and biota and surveys of populations and communities in coastal habitats may be used to validate and characterize the cumulative impacts of pesticides. A tiered approach should be used which would begin by characterizing the land-estuarine interface followed by subsequent characterization of estuarine nearshore and offshore interfaces.

A program directed at such an effort would provide accurate assessments of the toxicity of pesticides under realistic field exposure regimes. In addition, the degree to which chemical by chemical assessments accurately predict impacts of multiple chemical exposures could be evaluated. Uncertainty in existing risk assessment approaches could be addressed by establishing relationships between dynamic water quality parameters and pulse, multi-chemical exposures.

Initiation Activities:

Remote, continuous, real-time monitoring and sampling equipment for water during pulse exposure events. Appropriate support staff and facilities, including field crews, analytical chemistry and toxicological testing.

Priority Level: 1

4. Understanding the Transport and Bioavailability of Pesticides Used in the Gulf of Mexico

Research/Information Needs:

Pesticides may reach coastal waters of the Gulf of Mexico as a result of surface runoff, atmospheric deposition, groundwater seepage, and direct application. The extent to which pesticides are transported to coastal waters, their chemical form, and their degree of bioavailability need to be evaluated.

Rationale:

An assessment of pesticide use in coastal areas of the U. S. by NOAA has concluded that the amounts and types of pesticides used in the Gulf of Mexico, place the Gulf at highest risk from pesticides among all coastal U. S. waters. The close proximity of large agricultural areas to rich aquatic resources combined with a year-round growing season and high rainfall result in a high potential for adverse ecological impacts of pesticides on the Gulf of Mexico. There are also many other uses of pesticides in the Gulf region that are not fully quantified, such as mosquito control, aquatic weed control, marine-anti fouling compounds and termite and fire ant control. Research is needed to document the amount and chemical form of these compounds entering the Gulf system.

Loadings to coastal waters are influenced by diverse hydrologic dynamics, climate, soil types, and various physico-chemical parameters. In addition, the persistence and environmental partitioning characteristics of individual pesticides vary widely. Consequently, site-specific use and field data need to be developed to determine actual loadings to the Gulf of Mexico.

These data would improve current ecosystem models used to predict environmental loading and risk assessment, lead to improved environmental management, and help focus limited resources on pesticides most likely to result in ecological impact. Further, they would provide pertinent information to address a variety of public health concerns.

Modern society has become very dependent upon a wide variety of pesticides in agriculture, consumer products and non-agricultural uses (*e.g.*, mosquito abatement,

weed control, etc.). While these compounds are commonly used, there is concern that they cause many environmental "insults" with little actual knowledge of the effects mechanisms. Not all pesticides are equally toxic or persistent, nor does mere use automatically mean there is a negative effect on aquatic resources. For example, although the National Academy of Sciences has concluded that pesticide contaminated seafood presents a low human health risk except in certain site-specific areas, the public, nevertheless, is fearful that seafood is contaminated. Because the Gulf of Mexico supplies so much of the nations seafood, this concern must be addressed.

Initiation Activities:

Priority Level: 1

5. Development and Implementation of Pesticide BMPs for the Gulf of Mexico

Research/Information Needs:

There is a need for the development and implementation of pesticide management approaches to reduce inputs into the Gulf of Mexico--a pollution prevention approach.

Rationale:

Pesticides have been known to cause a number of environmental problems in the Gulf of Mexico. These include fill kills and shell fish contamination. In addition, other unidentified impacts may be associated with pesticides because of their modes of action and widespread distribution.

Data indicate a relatively large potential for pesticide inputs for the Gulf of Mexico from a variety of sources. These include point and non-point sources, such as agricultural and residential uses, mosquito control, marine anti-fouling, fire ant control, golf course uses, waste water treatment facilities, and transport from distant locations (aerial deposition, Mississippi River inflow). The relatively long growing season and mild climate of the Gulf Coast also increases the use of pesticides throughout the year. Some of these uses may introduce pesticides into the Gulf of Mexico with relatively long residual times.

Although mitigation programs are being developed or are currently in use for specific pesticide applications, many uses have no such programs. Some programs being used are:

- herbicide best management practices (BMP)
- state water management programs
- reduced application rates
- new application techniques
- integrated pest management programs (IPM)
- impoundment or boundary areas

Consideration of these techniques and the unique characteristics of the Gulf Coast use patterns and loadings can be used to develop additional innovative ways to reduce pesticide transport into the Gulf of Mexico.

Initiation Activities:

The development of a comprehensive database on pesticide loading into the Gulf of Mexico would be necessary. Development of this information would require contacts and coordination with a number of federal and state agencies, pesticide manufacturers , and user groups. In order to further prioritize management efforts, the data of Pait (Pait et al, 1992 and Pait, Farrow, Lowe, and Pacheco, 1989) which ranked pesticides used in the Gulf of Mexico region according to characteristics which can influence their environmental impact should be used. Characteristics included acute and chronic toxicity, bioaccumulation potential, and persistence. This ranking, coupled with the current loading information, would provide the Priority targets for initiation of management programs.

An evaluation of current pesticide management techniques would provide those methods with the greatest opportunity to reduce transport into the Gulf of Mexico. New techniques also could be developed to address those uses and sources unique to the Gulf Coast. Recommendations would then be provided to appropriate regulatory and user groups for implementation. The effectiveness of these management techniques could be monitored in future pesticide loadings into the Gulf of Mexico.

Priority Level: 1

6. Identify Which Pesticides are Causing Ecological/Health Effects and Where the Impacts are Most Significant

Research/Information Needs:

There is a need to identify not only which pesticides are causing ecological (and/or human health) impacts in Gulf of Mexico estuaries, but also where the most significant impacts are occurring.

Rationale:

Due to the large amount of agricultural land use, climate, and relatively long growing season, large amounts of pesticides have been applied in areas which drain into the Gulf estuaries. In addition, chemical characterization of estuarine sediments by federal, state, academic, and other agencies have indicated the presence of high concentrations of persistent pesticides (chlordane, dieldrin, endrin) in certain estuaries, *i.e.*, Laguna Madre, TX, and Calcacieu Lake, LA. Additional studies in these and other Gulf estuaries have demonstrated significant biological impacts as well as elevated residues of pesticides in tissues and sediments. Many sediment quality and biological assessment methodologies have recently been developed which have had only limited success in linking historically contaminated sediments and tissue residues with ecologically relevant effects. There is a need to review, evaluate, and incorporate various approaches for data interpretation--particularly sediment and tissue residue information--in order to establish cause and effect relationships.

The overall goal of this effort is to identify specific pesticides responsible for detrimental ecological and human health effects. Potentially impacted areas can be prioritized by ranking the degree and extent of pesticide contamination reported through a detailed evaluation of sediment chemistry and biological effects data (both new and historical). This important effort is needed to identify areas of concern and implement effective management strategies which reduce and/or eliminate sources and their resulting impacts on the ecological systems of the Gulf of Mexico.

Initiation Activities:

Acquisition and review of existing information will be necessary to identify potential areas and pesticides of concern, as well as for the identification of data gaps. To avoid duplication of effort, to maximize use of the information collected, and to minimize potential differences in data interpretation, federal and state agencies, industry, environmental groups, academia, and the public will be involved.

Priority Level: 2

7. Development of Standard Toxicological Test Methods Using Representative Endemic Species

Research/Information Needs:

Establishing cause and effect relationships for pesticides requires the ability to detect detrimental biological impacts. This is accomplished through the use of standard test methodologies with ecologically relevant endpoints that are responsive to acute and chronic pesticide exposure.

Rationale:

Many standardized biological test methods are available which utilize various species and examine numerous biological endpoints (*i.e.*, growth, reproduction, physiological indices). For example, mysids and menidia are widely used in acute and chronic toxicity tests. The question becomes whether such tests are representative of the more susceptible, site-specific endemic species and whether the biological endpoints examined are indicative of ecologically relevant effects.

To address this problem, there is a need to develop short-term (10 day or less) toxicity tests for susceptible life stages of representative endemic species that can be used in combination with standard test organisms or bioindicator tests. The standard test organisms provide a normalizing assessment for Gulf-wide comparisons, where as community-specific test organisms provide site-specific information.

Biological indices (*e.g.*, growth, reproduction, biochemical, physiological indices) to be examined should provide a linkage with relevant ecological endpoints and be protective of ecosystem health. Specific attention should be given to *in situ* methodologies to address issues related to multivariable environmental exposure conditions. Highest Priority research needs for biological methods development are in the category of short-term tests to detect sublethal effects, resulting from both acute or chronic exposures, with specific attention given to pulsed exposures to pesticides.

Initiation Activities:

Research needs include methodologies for appropriate use of biological effects endpoints, approaches for evaluating the representativeness of selected species in site specific hazard assessments, and approaches for quantifying exposure-response relationships for ecological risk assessment. Validated methods such as these, specifically designed for the unique Gulf of Mexico coastal ecosystems, will allow prediction and assessment of current and future pesticide impacts.

Priority Level: 2

8. Standardization of Analytical Methods and QA/QC Criteria

Research/Information Needs:

Because quantitative environmental chemistry is an ever-changing science, methods used to analyze environmental samples for pesticide residues are continually changing. New methods may overcome inaccuracies or interferences in older analytical methods, making previous data suspect or unreliable. In order to retain and utilize as much historic data as possible, methods comparisons and minimum data quality standards must be developed. There is a research need for the following activities:

- Develop uniform criteria for pesticide analyses in different matrices.
- Develop a QA/QC protocol to be used for cross comparison of data derived from different methods.
- Prioritize sample matrices to be analyzed (tissue, whole body, viscera)
- Develop prioritized screening methods:
  - low to high sensitivity
  - compound specific *vs.* broad spectrum
  - tiered approach
  - biological variables; life stage, sex, age, lipids
  - methods for various levels of analyst skill, analysis cost
- Basic research leading to improved methods:
  - selectivity, verification of compound ID
  - sensitivity in various matrices
  - cost effectiveness, speed
  - multi component analyses
  - *in situ*, real time analyses
  - remote transmission and electronic data processing
  - computerized QA/QC to ensure data quality targets

Rationale:

Assessing the fate and effects of pesticides in the Gulf of Mexico requires intercomparable analyses among numerous laboratories. A wide variety of acceptable methodologies are in use for pesticide analyses in various matrices (water, sediment, tissue). Differences in protocol and analytical capabilities among these methods lead to nonreproducible or noncomparable results.

Even though various agencies have adopted standard methods to address this problem and various protocols do exist (*e.g.*, AOAC, EPA-500/600, EPA-SW-846, ASTM), a performance-based protocol is needed as a means to cut across differing methodologies.

The appropriate method may vary depending on the desired end product for the specific analytical problem to be addressed.

- compound specific (Qualitative *vs.* Quantitative)
- rapid screening
- desired sensitivity
- specific matrix
- level of ecological impact to be assessed (tiered approach)
- ancillary data (DO, temperature, salinity, sex, tissue, collection site, season, time, etc.)
- level of analytical sophistication required

To assure high quality and intercomparison of data, standard protocol must be followed. Establishing performance-based QA/QC procedures would allow data derived from different methodologies to be compared based on the performance of the analysts and not the method use. This protocol also would allow new methods developed to address speciation, bioavailability, partitioning, transport, etc. to be evaluated and used to resolve emerging issues.

The high cost of sample collection and analysis can be off set by the use of volunteer groups or other professionals of opportunity such as farmers, fishermen, scuba divers, school groups and volunteers. Strict training and QA/QC protocol designed for such data collection methods must be established and implemented for data collected in this manner to be of use.

Additional research needs to be directed toward simplified methods for analysis of new, unique chemical pesticides such as glyphosate (herbicide) which require special and costly analytical methods. Development of rapid screening methods encompassing broad classes of pesticides should be considered a high Priority, as should the development of proper QA/QC protocol to establish reproducible levels of detection, precision, and accuracy.

Initiation Activities:

- Standard reference pesticides in reference matrices

- Interfaces between ecologists and biologists
- Field sampling and sample transport/storage protocol
- Analytical instrumentation (various levels) protocol

Priority Level: 2

9. Understanding of Chemical Contaminant Effects on Marine Mammals and Top Carnivores in the Gulf of Mexico

Research/Information Needs:

Marine mammals, sea turtles and other protected species are high visibility, valued resources that often represent top carnivores or long-lived species in the Gulf. These species are not routinely considered in ecological assessments of pesticide impacts. Data are lacking on toxicity of chemical contaminants or related biochemical/physiological biomarkers of stress or exposure. The existing data gaps may presently limit the effective management of these species in the Gulf of Mexico.

Rationale:

Protected species such as marine mammals (*e.g.*, bottle nose dolphin) and sea turtles (*e.g.*, Kemps Ridley) are unique species to the Gulf of Mexico. There are several threatened or endangered species in these groups, because of the declining or unstable populations. Additionally, many of these species are long-lived or top carnivores, and may integrate contaminant exposures in marine ecosystems. Because these are highly valued, high visibility species in the public, special considerations may be warranted in environmental assessments of contaminant impacts.

Enhanced understanding of the exposure and dose-response relationships for these species is necessary to ensure that current pesticide management practices provide sufficient protection for threatened species. Research is needed to identify baseline physiological/biochemical conditions and effects of pesticides which can be used as biomarkers. Results of these efforts would be used to determine the role, if any, of pesticides in the effective management and protection of these unique organisms.

Identification of anthropogenic pollution sources and pollutant bioaccumulated by marine mammals or turtles may provide an effective integrated predictor of potential impacts for top trophic level species. Linkages between contaminant levels in the lower food chain may compliment predictive assessments used to evaluate health risks from consumption of contaminated seafood. Additionally, by building a chemical contaminant and physiological/biochemical biomarker database for the bottlenose dolphin, environmental managers would have requisite information to better predict overall biodiversity with respect to the health of threatened or protected species. A

final product would be a better information base to assist environmental scientists in diagnosing unusual mortality or morbidity events for these species.

Initiation Activities:

- Necessary items would include: boats for live capture operations; emergency care/rehabilitation facilities; trained, experienced veterinarians to oversee the live capture and sampling operations; interactions and consultations with marine mammals commissions for approval of live capture operations; interactions with national environmental organizations and state marine mammal stranding networks; and facilities to conduct contaminant physiological and biochemical analyses.

- Improved data and knowledge base on chemical contaminants and physiological/biochemical parameters in endangered and threatened species.

- Interactions and linkage of these data with the ongoing network of rescue and stranding programs.

- Protection of the biodiversity within the Gulf of Mexico.

Priority Level: 3

10. Development and Evaluation of Remediation Strategies for Contaminated Habitats

Research/Information Needs:

Monitoring programs in The Gulf have indicated the presence of persistent pesticides in sediment habitats of highly productive areas. In order to ensure complete ecological recovery and minimize potential food chain contamination problems, these areas must be remediated to acceptable background levels. There are several technical and political hurdles that must be overcome in order to develop and implement a remediation strategy.

- One of the research needs is to determine what agency or program (federal, state, or private industry) would be responsible for developing these strategies.

- There is a need to evaluate the feasibility of using the remedial approaches developed and tested in the ARCS (Assessment and Remediation of Contaminated Sediments) in the Great Lakes.

- There is also the potential for the utilization of biological, chemical, physical, or a combination approach for clean-up of pesticide-laden sediments.

Rationale:

The clean-up, restoration, and recovery of habitats or resources contaminated by pesticides may require one or more of the following:

- adaptations of existing remediation technologies used for water, soil, or sediments contaminated by more conventional pollutants (*i.e.*, petroleum hydrocarbons, creosotes, metals);
- development of novel treatment technologies that utilize specific pesticide degradation techniques; and/or
- techniques adapted for minimal habitat disruption.

The Gulf of Mexico contains extensive coastal areas that result in sediment trapping such as wetlands, submerged sea grass beds, or mud flats. Given the high degree of biological productivity associated with these depositional habitats, remediation

technologies that reduce pesticide concentrations, mobility, or bioavailability, the use of *in sita* approaches may be preferred over more intrusive methods. Given the long growing season and warm water temperatures that prevail in the gulf, biologically based remediation may be particularly effective in degrading pesticide residues.

As a result of high pesticide use practices and the historical use of organochlorine pesticides in the gulf, there are many sediments and watersheds that have detectable residues of persistent and bioaccumulative pesticides. In addition to habitats with historically contaminated sediments, watersheds feeding Gulf estuaries continue to deliver contaminated sediments and soils. Remediation strategies will be needed to deal with these continual sources as well as in-place contamination.

Initiation Activities:

Priority Level: 3

11. Development of an Ecosystem Water Quality Risk Based Approach for Risk Assessment Using Archived Tissue Contaminant Data

Research/Information Needs:

Current resource monitoring data provide information on contaminant levels which may be applied to human health hazard/risk management, but current techniques do not exist to predict resource impacts to estuarine and marine organisms in the Gulf of Mexico.

Rationale:

Chemical contaminant levels in fishery organism (molluscan, shellfish, crustacean and fin fish) constitute the largest data record for the Gulf of Mexico. While chemical contaminant levels in fishery organism are extremely important in terms of identifying potential human health hazards/risks, they are not predictive of potential ecological impacts. Derivation of "average" in stream water concentrations may be predicted from existing chemical contaminant residue data in aquatic resources by dividing these values by published bioconcentration factors (BCFs) for each reported chemical residue value. These derived "average in stream water concentrations" may then be divided by existing EPA water quality criteria to develop individual and cumulative ecological risk estimates. Both acute and chronic ecological risk may be predicted by this method. The margin of safety between the published EPA acute or chronic water quality criteria, and the estimated ecological risk estimates may swerve as a predictor of the potential assimilative capacity for a given geographical area. When these data are linked with modeling and loading estimates (which may indicate a 1-2 order of magnitude increase above average conditions), site-specific estimates of habitat vulnerability to nonpoint source runoff may be assessed and evaluated. Identification of water quality risk unique to Gulf may be learned. This may be of particular importance in Gulf of Mexico habitats jointly influenced by pesticide runoff and oil exploration activities, which may cumulatively impact water quality.

Initiation Activities:

Data on contaminant levels in estuarine/marine organisms and literature reviews to develop published BCF criteria are requisite resources needed. Limited field studies would be needed to validate derived water quality criteria estimates.

The products would be:

- water quality-based risk assessment estimates of ecosystem health and
- a method for identifying and evaluating cumulative impacts.

Water quality criteria based on reduced bioaccumulation and food chain effects would provide a degree of protection that takes into account the long growing season along The Gulf and the Potential for extended inputs or exposures. A similar approach has been proposed for the Great Lakes Region, but the degree of protection offered by importing those regional criteria is not known.

Priority Level: 3

SYNTHESIS AND CONCLUSIONS

The purpose of this workshop was to identify the data and information gaps that, when filled, will enable the Gulf of Mexico Program to complete a comprehensive ecological risk assessment for the Gulf of Mexico with regard to toxic substances and pesticides. The previous sections have summarized the major research needs required for better understanding toxic inorganic, toxic organic, and pesticide contamination in the Gulf. These additional research projects will provide essential information for assessing risks in the Gulf of Mexico. Throughout the workshop, however, several themes emerged from all three workgroups. These areas represent fundamental building blocks for an ecological risk assessment. These themes are:

- characterization of exposure
- characterization of ecological effects
- pollution prevention and risk reduction
- fundamental research
- continuous chemical and biological monitoring

Characterization of Exposure

Characterization of exposure is part of the second phase of ecological risk assessment. After problem formulation (the first step of ecological risk assessment), the analysis phase develops profiles of environmental exposure and the effects of the stressor. The exposure profile characterizes the ecosystems in which the stressor may occur as well as the biota that may be exposed. It also describes the magnitude and spatial and temporal patterns of exposure. The workgroups identified two areas of exposure assessment that in their current state were too inadequate to use in a risk assessment for the Gulf of Mexico: historical information verification and the development of fate and transport models.

Data Review

In order to ensure that historical data on toxic and pesticide loadings and ambient concentrations can be used in exposure assessments, data must be verified through a rigorous data review. Although there are significant data on inputs and contaminant levels found in water, sediments, and biota tissue (*e.g.*, NOAA Status and Trends, STORET), all workgroups expressed concern over the reliability of these data. A

wide range of procedures--QA/QC, sampling, technical, and analytical--have been used for all the various data sources available, making it extraordinarily difficult, if not impossible, to normalize these values and compare them to each other, and across estuaries. Data contained in some data bases do not contain an assessment of the reliability of that data. In addition, many data bases do not currently reflect state of the art analytical methods. All groups critically recommended review of existing data bases to determine whether data should be used in exposure assessments.

Fate and Transport Modeling

Contaminant transport in the Gulf of Mexico is subject to, and can be dominated by, extreme and episodic events, such as floods and hurricanes, as well as routine physical/chemical phenomena such as volitilization, sedimentation, and photosynthesis. Any attempt to understand the fate and transport of toxic substances and pesticides must consider these events as well as the influences of the wider Caribbean. All three working groups recommended that hydrogeologic/fate and transport models at various scales of resolution be developed that would include not only these extreme events, but also inputs and effects of the wider Gulf of Mexico region.

Characterization of Ecological Effects

Characterization of effects is also part of the analysis component of ecological risk assessment. This phase defines the quantitative and qualitative relationships between a stressor and an organism response. The assessment summarizes data on the effects of the stressor and relates them to the assessment endpoints. Estuarine ecosystems are subject to a complex and dynamic array of physical, chemical, and biological interactions. Scientists only have limited understanding of how toxic stressors influence these interactions and how disturbances at one level of biological organization are expressed at other levels. They have a limited capability to compare or predict effects from one species to another and have limited quantitative approaches for dealing with population, community, or ecosystem comparisons. Assessments should be extended from single-species approaches for site-specific and media-specific (*e.g.*, effluent, water column, sediment, biota) situations to a fundamental, quantitative understanding of exposure-response relationships for larger ecological units, such as estuaries.

Risk assessment techniques have been used in the past to evaluate the impact or potential impact of contaminants on coastal environments. A formal process of risk

assessment or risk analysis is currently used by regulatory agencies to assess such impacts on human health. And now, regulatory agencies are beginning to see the need to use a more formal ecological risk assessment process to determine impact on ecosystems, particularly estuarine systems. For example, EPA's Risk Assessment Forum is currently testing their ecological risk assessment framework in a New England estuary.

Preliminary procedures to assess ecosystem condition are presently available. Current broad-scale assessment programs conducted by NOAA, NMFS, and USEPA in the Gulf of Mexico provide a focus for future protocol development and endpoint evaluation. These protocols should then be validated in multiple environments in the Gulf. The need for developing additional techniques is not as great as the need to organize existing procedures into general guidelines and protocols applicable across a variety of Gulf of Mexico estuarine systems. The appropriate assessment design must include spatial, temporal, and historical considerations and must be configured around specific testable hypotheses and validated ecological models rather than random sampling for no directed purpose. The design must be generic to the degree that site-specific modifications can be implemented. A tiered approach would help ensure that the strategy meets budget, time, and personnel constraints.

Fundamental Research

Fundamental research is necessary to establish the foundation for each phase of ecological risk assessment. Each panel identified a number of specific items that need additional fundamental research. Some of these needs were unique to the panel's particular contaminant category (*e.g.*, inorganic, pesticide, organic), while others applied to all chemical classes. Within the area of inorganic contaminants, there is a continuing need for additional basic research into the fundamental processes that drive chemical speciation and ultimately influence metal bioavailability and toxicity. For pesticides and organics, there is a need for fundamental research to evaluate the resilience of aquatic plant and animal communities that are repeatedly challenged by episodic inputs and a need for a better understanding of the processes that govern the dynamics of trophic level chemical transfer.

Continuous Chemical and Biological Monitoring

Cutting across the range of contaminant classes was the need for identification of baseline values for the biological, chemical, and physical parameters that will be used to assess the health of the Gulf ecosystem. Inherent to the process is the identification

of unaffected habitats from which to obtain "normal" or background values. A logical approach would be to emulate the establishment of Long Term Ecological Research Sites (LTERs) along the Gulf of Mexico as developed by the National Science Foundation (*e.g.*, Hubbard Brook, NH). These areas could be used for comprehensive evaluation of baseline values that are representative of ecosystem health.

Current monitoring and assessment approaches in the Gulf of Mexico depend on collection, analysis, and reporting of discrete samples of water, sediment, and biota. Time lags of months and years are not uncommon before collected data are examined to assess environmental problems. These methods are time consuming, costly, and can fail to yield results because the inputs of toxic substances and pesticides are diverse and dynamic. It was the consensus of the workshop participants that the Gulf of Mexico Program represents a unique opportunity to nurture research and development capabilities for versatile and field deployable analytical methods and instrumentation to support multi-compound monitoring programs.

The Gulf of Mexico area includes research community agencies and laboratories that have developed sophisticated technologies with potential applications to real time environmental monitoring. For example, NASA has developed a host of active and passive remote sensing technologies which could potentially evaluate physical, chemical, and biological properties of the bays and estuaries of the Gulf of Mexico on a real-time basis. The Department of Defense's remote sensing capabilities and acoustical sensing, in combination with pattern recognition algorithms, may have direct applications to assessing ecological health. Advances in microelectronic telemetry and data storage and analysis make the use of living organisms as biosensors of the environment a feasible option. Because this type of instrumentation depends on the technological capabilities of university, commercial, and government facilities, workshop participants recommended that the Gulf of Mexico Program establish, nurture, and promote the development of technologies leading to the capability to monitor environmental quality on a continual basis.

Reducing Risk: Pollution Prevention

The input of toxic substances and pesticides into the Gulf of Mexico and the continued persistence of in-place materials are an important element of ecological risk. Altering toxic chemical and pesticide use practices could help reduce that ecological risk. This change may result in reduced application rates, formulations, or changing chemicals for pesticide applications. Changes in processes and treatments preventing a continued discharge of organic or inorganic chemicals may reduce ecological risk

from these materials. Due to the inherent uncertainty associated with risk assessment and management, all the workgroups agreed that one of the most logical areas to focus is pollution prevention.

Best Management Practices (BMP) can be implemented to reduce chemical input into the Gulf by changing application rates, constructing buffer zones with wetlands to prevent runoff, and altering application times and chemicals. Risk reduction can be accomplished by using pesticides with high degradation rates and high potency at low concentrations, requiring less material input.

Control of point source discharges of toxic chemicals may be altered using best available technologies to minimize wastes and limit mass emissions of toxic contaminants. It was a consensus recommendation of the workshop participants that regulatory agencies should extend incentives for pollution prevention, such as reducing loadings or the decreased discharge of significant chemicals. Industries may institute process, raw material, or housekeeping changes when there is an incentive for these offsets.

Conclusions

Although many of the workshop recommendations focus on fundamental research on the fate and effects of toxic substances and pesticides, participants recognized the need for research on tools that will eventually integrate this information.

Risk assessment requires integration of information about stressors and effects. Ecological resources in the Gulf of Mexico contend with a variety of natural and anthropogenic stressors. Although considerable information exists regarding the spatial and temporal distribution of stressors in the Gulf of Mexico, understanding the relative impacts of these stressors requires decision support tools. Scientists and resource managers should develop and utilize expert systems containing data based on stressor distribution over space and time, distribution of ecological resources along the Gulf of Mexico, and hydrological and ecological models at various scales of resolution. These expert systems or interactive data bases should allow for the integration of multiple data layers in a geographic context. Development of a GIS capability supporting the comparative risk assessment goal of the Gulf of Mexico Program was a consensus recommendation of the workshop.

Figure 5 arrays the recommendations contained in this Research Strategy in a ecological risk assessment framework. This is to provide both a context for understanding the role of the recommendations in risk assessment and a tool for

highlighting any remaining barriers or gaps that impede completion of an ecological risk assessment for the Gulf of Mexico.

The columns represent the three phases of risk assessment. The rows represent procedural steps and tools that are used to complete the risk assessment. Although the risk assessment process is iterative, this diagram is intended to depict a general process framework. Within this framework, workshop themes--highlighted in bold italics on the matrix--have touched upon both procedural tools and risk assessment stages.

Many of the recommended research activities are placed appropriately in the risk assessment paradigm. These activities typically cover more than one step in the risk assessment process and more than one analytical tool. These placements are not placed rigorously in all of these areas, but rather are arrayed to depict the general areas covered.

Major overall workshop recommendations included: assessment of existing data for proper QA/QC, standardized methods, and gaps; development of standard methodologies and assessment tools, including remote monitoring tools; development of Gulf-specific models; and establishment of baselines and criteria for healthy Gulf ecosystems. Specific needs identified by the toxic inorganics workgroup included the establishment of development of bioaccumulation and hydrogeologic models, development of metal speciation and bioavailability models, and development of quantitative techniques for integration of effects and exposure data. Specific needs identified by the toxic organics group focused on development of predictive and diagnostic ecological effects tests, assessment of available data on anthropogenic inputs, and development of a site-specific estuarine/ecosystem quality criteria for target pollutants. The pesticides workgroup specifically targeted the identification of problem pesticides, the interpretation and application of tissue residue data, and the understanding of repeated short-term exposure events in the Gulf.

Ideally, these recommended research activities, when coupled with existing knowledge, will provide a complete framework within which to initiate an ecological risk assessment for the Gulf of Mexico.

Figure 5. ***Risk Assessment Framework***

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Dickey	Robert	U.S. Food & Drug Administration
Dickson	Gary	Ciba Geigy, Inc.
Dickson	Ken	University of North Texas
Dillon	Tom	U.S. Army Corps of Engineers
Dixon	Kellie	Mote Marine Laboratory
Dorn	Phil	Shell Development Company
Dow	Roxanne	Florida Department of Environmental Protection
Duke	Belinda	Gulf of Mexico Program - Public Education
Fox	Catherine	U.S. EPA - Office of Water
Heimlich	John	AMS
Henry	Mike	Recorder, Mote Marine Laboratory
Holtzman	Seymour	Brookhaven National Laboratory
Jahncke	Mike	DOC/NOAA/NMFS
Lewis	Mike	U.S. EPA
Lytle	Julia	Gulf Coast Research Laboratory
Mayer	Sonny	U.S. EPA, Gulf Breeze
McCaffrey	Bruce	AMS
Metz	Simone	Florida Institute of Technology
Nava	"Smiley"	Texas Department of Parks & Wildlife
Overton	Ed	Louisiana State University
Pierce	Rich	Mote Marine Laboratory
Rossomando	Marybeth	AMS
Scott	Geoff	National Marine Fisheries Service, Charleston
Sherblom	Paul	Recorder, Mote Marine Laboratory
Smith	Darryl	Florida Department of Agriculture
Walker	Bill	Gulf Coast Research Lab
Wilhour	Ray	EPA - Gulf Breeze
Windom	Herb	Skidaway Institute
Winger	Parley	U.S. Fish & Wildlife Service
Wise	Lloyd	Gulf of Mexico Program
Wolfe	Steve	Florida Department of Environmental Protection

APPENDIX B: WORKGROUPS

PESTICIDES

Jim Clark (Chair)	Exxon Biomedical Sciences, Inc.
Bill Benson (Co)	University of Mississippi
Tom Bailey	EPA
Greg Cramer	U.S. FDA
Gary Dickson	Ciba Geigy, Inc.
Tom Dillon	U.S. Army Corps of Engineers
Roxanne Dow	Florida DEP
Catherine Fox	EPA - Office of Water
Mike Jahncke	DOC/NOAA/NMFS
"Smiley" Nava	TX Department of Parks & Wildlife
Rich Pierce	Mote Marine Laboratory
Geoff Scott	NMFS, Charleston
Darryl Smith	FL Department of Agriculture
Mike Henry	Recorder, Mote Marine Lab
John Heimlich	AMS

TOXIC INORGANICS

Bill Adams (Chair)	ABC Labs
Denny Buckler (Co)	U.S. Fish and Wildlife
Fred Calder	Florida DEP
Kellie Dixon	Mote Marine Laboratory
Mike Lewis	EPA
Sonny Mayer	EPA - Gulf Breeze
Simone Metz	FL Institute of Technology
Bill Walker	Gulf Coast Research Lab
Herb Windom	Skidaway Institute
Parley Winger	U.S. Fish & Wildlife Service
Steve Wolfe	Florida DEP
Kim Allen	Recorder, Mote Marine Lab
Marybeth Rossomando	AMS

TOXIC ORGANICS

Ed Overton (Chair)	Louisiana State University
Linda Anderson-Carnahan (Co)	EPA, Region 4
Scott Carr	U.S. Fish & Wildlife
Nicholas Casseri	Occidental Chemical Corporation
Dick Conway	Union Carbide
Carol Daniels	EPA - Gulf Breeze
Thomas Deardoff	International Paper Company
Robert Dickey	Food & Drug Administration
Phil Dorn	Shell Development Company
Seymour Holtzman	Brookhaven Research Laboratory
Julia Lytle	Gulf Coast Research Laboratory
Ray Wilhour	EPA - Gulf Breeze
Lloyd Wise	Gulf of Mexico Program
Paul Sherblom	Recorder, Mote Marine Laboratory
Bruce McCaffrey	AMS

SYNTHESIS & SUMMARY

Ken Dickson (Chair)	University of North Texas
Phil Dorn (Co)	Shell Development Company
Bill Benson	University of Mississippi
Denny Buckler	U.S. Fish and Wildlife
Sonny Mayer	EPA - Gulf Breeze
Rich Pierce	Mote Marine Laboratory
Bill Walker	Gulf Coast Research Lab
Ray Wilhour	EPA - Gulf Breeze
Bruce McCaffrey	AMS
Marybeth Rossomando	AMS

APPENDIX C: WORKSHOP AGENDA

WORKSHOP ON RESEARCH NEEDS FOR TOXIC SUBSTANCES IN THE GULF OF MEXICO

AGENDA

Monday - August 23

11:00 - 1:00	**REGISTRATION** - Mote Conference Center	
1:00	**PLENARY SESSION**	
	Introductions:	Richard Pierce, *Conference Chairman, Director of Research, Mote*
1:15	Welcome:	Kumar Mahadevan, *Exec. Director, Mote; GOM Regional Marine Research Program*
1:30	Keynote Speaker:	Lloyd Wise, *Deputy Director EPA Gulf of Mexico Program*
2:00	Overview, Toxicants:	Ray Wilhour, *Deputy Laboratory Director; Subcommittee EPA, Gulf Breeze Environmental Research Lab.*
2:15	Chemicals, What Where When:	Catherine Fox, *EPA, Risk Assessment and Management*
2:45	BREAK	
3:00	Research Case Study:	Seymour Holtzman, *Brookhaven National Assessment: Radionuclides and Formation Waters*
3:30	Living Aquatic Resources at Risk:	Geoffrey Scott, *NOAA NMFS Charleston Lab*
4:00	Comparative Risk Assessment:	Ken Dickson, *University of North Texas*
4:30	Workshop Goals:	Ken Dickson, *Workshop Facilitator*
5:00	Plenary Session Ends	
6:30	Social and Buffet Dinner, Mote Chickee.	

Tuesday - August 24

8:00	Continental Breakfast at Mote
8:30	Convene three Working Sessions
10:15	BREAK
10:30	Plenary Session Review
12:00	Lunch (Provided)
1:30	Reconvene Working Sessions
4:30	End day's Working Sessions: Synth. & Summ. Comm. review progress
7:30 - 9:30	Evening Working Sessions

Wednesday - August 25

8:00	Continental Breakfast at Mote
8:30	Reconvene Working Sessions for final recommendations
10:15	BREAK
10:30	Final Plenary Session to present Working Session's recommendations
12:00	Workshop Ends
1:30 - 4:30	Synthesis and Summary Committee, Session Chairs & Consultant

APPENDIX D: ADDITIONAL PUBLICATIONS

Other Gulf of Mexico Program Toxic Substances and Pesticides Committee Publications

"Impact of Toxic Substances and Pesticides on Nearshore Gulf of Mexico: A Preliminary Comparison (Toxicity Indices) of Twenty-Five Estuarine Drainage Systems Based on Releases of Toxics From Industrial and Municipal Sites and Pesticide Run-Off From Agricultural Operations in 1989"; by Jeri Brecken-Folse and Maureen G. Babikow, Technical Resources, Inc., and Dr. T.W. Duke, Consultant, under contract to USEPA Gulf Breeze, FL.

"Estuarine Assessment and Contaminant Problem Identification"; NOAA Technical Memorandum NMFS-SEFSC-, Summary of a workshop held in Biloxi, MS, April 23-25, 1991. Mayer, F. L., Thomas W. Duke, and William W. Walker (eds.). 1992.

"Evaluation of Gulf of Mexico Sediment Inventory"; by Jeri Brecken-Folse and Maureen G. Babikow, Technical Resources, Inc., and Dr. T.W. Duke, Consultant, under contract to USEPA Gulf Breeze, FL. Draft 1993.

"Gulf of Mexico Toxic Substances and Characterization Report"; by John Brabeck and Jeri Brecken-Folse.

"Proceedings of the Workshop on Toxics and Pesticides Action Plans", F. L. Mayer and P. Bass, Toxic Substances and Pesticides Subcommittee, Gulf of Mexico Program. 1990.

"Proceedings of the Workshop on Toxics and Pesticides Monitoring Data for Regulatory Purposes", F. L. Mayer and R. R. Dow, Toxic Substances and Pesticides Subcommittee, Gulf of Mexico Program, 1989.

"Proceedings of the First Meeting", F. L. Mayer and R. R. Dow, Toxic Substances and Pesticides Subcommittee, Gulf of Mexico Program, 1989.

"Proposed Action Items Beginning FY91", F. L. Mayer and P. Bass, Toxic Substances and Pesticides Subcommittee, Gulf of Mexico Program, 1990.

The above documents are available from:

The Gulf of Mexico Program Office
Bldg 1103, Room 202
Stennis Space Center, MS 39529-6000