



Research & Development Priorities: Oil Spill Workshop
March 16 – 19th, 2009

Coastal Response Research Center

National Oceanic and Atmospheric Administration

Coastal Response Research Center

FORWARD

The Coastal Response Research Center, a partnership between the National Oceanic and Atmospheric Administration (NOAA) Office of Response and Restoration (ORR) and the University of New Hampshire (UNH), develops new approaches to spill response and restoration through research and synthesis of information. The Center's mission requires it to serve as a hub for research, development, and technology transfer to the oil spill community. To better guide future response and restoration efforts, the Center and ORR co-hosted a workshop to identify research needs that could change response and restoration practices and improve protection strategies and recovery trajectories for NOAA trust resources. The workshop participants were asked to focus on 8 areas identified by the organizing committee as important: Spill response during disasters, Response Technologies, Acquisition, Synthesis and Management of information, Human dimensions, ecological monitoring and recovery following spills, Biofuels, ecological effects of oil spills, and environmental forensics.

The workshop, entitled "Research & Development Priorities: Oil Spill Workshop", was held in March 2009 at the University of New Hampshire (Durham, NH). This report provides a summary of discussions that occurred at the workshop, and a final summary of R&D needs identified by participants as a priority. Participants represented a broad spectrum of constituencies and expertise including governmental agencies, industry, and non-governmental organizations. This report is designed to serve as a resource for responders and government entities, and to aid in allocation of funding to improve the efficiency and efficacy of response to spills in the coastal environment.

We hope you learn from reading the report and exploring the topics. If you have any comments about it, please contact the Center. We look forward to many more similar endeavors during the coming years where the Center can be of service to the response and restoration communities, helping to protect coastal ecosystems.

Sincerely,

Nancy E. Kinner, Ph.D.
UNH Co-Director
Professor of Civil/Environmental Engineering

Amy A. Merten, Ph.D.
NOAA Co-Director
Environmental Scientist

INTRODUCTION

In 2003 the Coastal Response Research Center (CRRC), a partnership between the University of New Hampshire (UNH) and the National Oceanographic and Atmospheric Administration (NOAA), held a workshop titled "Research and Development Priorities: Oil Spill Workshop" in order to assess the current state of knowledge and identify priority research needs. CRRC used these findings to focus their research efforts over the following five years, and through partnerships and subcontracts was able to address some of the research needs identified in the 2003 workshop.

In order to gain a better understanding of the evolving needs of spill response, CRRC hosted a second Research and Development (R&D) priorities meeting in March, 2009. The scope of this workshop was expanded to include spill response during disasters, response technologies, acquisition, synthesis and management of information, human dimensions, ecological monitoring and recovery during spills, biofuels, ecological effects of oil spills, and environmental forensics. As with the 2003 meeting, the goal of the 2009 meeting was to identify top research priorities within the response and restoration community in order to better focus future research efforts to address these needs.

I. WORKSHOP ORGANIZATION AND STRUCTURE

The workshop, held at the University of New Hampshire March 17-19, 2009 consisted of four plenary sessions where participants discussed and prioritized research needs, developed research plans, and identified potential impediments. Participants were chosen by a high-level organizing committee, and represented many interests, including the U.S. Coast Guard (USCG), NOAA, U.S. EPA, Minerals Management Service (MMS), Industry, state and local agencies, academia, and NGOs. The workshop agenda (Appendix A), participants (Appendix B), and discussion topics were identified and developed by an organizing committee comprised of members of government, academia and industry.

Workshop participants were divided into eight groups representing areas the organizing committee (OC) felt significant research needs existed. Groups included: (1) Spill response during disasters; (2) Response technologies; (3) Acquisition, synthesis and management of information; (4) Human dimensions; (5) Ecological monitoring during spills; (6) Biofuels; (7) Ecological effects of spills; and (8) Environmental forensics. Each group contained a notetaker, responsible for recording key points of discussion, and a group lead, responsible for keeping the group on topic and focused. The group lead was also responsible for summarizing the discussion and research needs to be included in this report. Group F: Biofuels failed to provide a summary of their proceedings, and therefore was not included in this report.

II. Group Reports

A. Spill Response During Disaster

Group A addressed spill response issues that are encountered during natural (e.g., earthquakes, hurricanes, floods) or anthropogenic (e.g., terrorist attacks) disasters resulting in nearshore and offshore oil spills. Planning and implementation gaps and health and safety issues were the primary focus, however methodologies for assessments were also addressed. Group members included:

David Fritz, BP America
William Conner, NOAA, National Ocean Service
Dennis Hwang, University of Hawaii Sea Grant College Program
Anthony Lloyd, U.S. Coast Guard
Jimmy Martinez , Texas General Land Office

The group approached the topic by identifying issues and making suggestions pertaining to ten distinct issues associated with oil spills caused by disasters, including: (1) preparedness; (2) assessment; (3) access to facilities; (4) logistics; (5) human aspects; (6) health and safety; (7) data management; (8) response structures; (9) response measurement; and (10) debris. A wide range of disasters were considered as the group collaborated including floods, hurricanes, earthquakes, tsunamis, tornados, massive toxic gas releases, and volcanic activity. The group identified issues in each topic and suggested improvements.

Preparedness
Federal, state, local agencies, industry, emergency responders, and the general public need to be better prepared to carry out their duties during disasters. Responders from outside of the affected area may need additional training and guidance in order to respond, due to their unfamiliarity with the area. To improve general preparedness, response plans need to be coordinated and aligned. Plans are needed for handling wildlife and pets. Also, critical facilities, such as oil refineries, need to have hazard risk assessments performed and conduct mitigation actions based on the assessments.

Assessment
It is difficult to assess contamination of a wide area. The ability to set spill response priorities based on assessment findings needs improvement. This includes spill response occurring within the context of larger disaster response priorities. Government agencies need a quicker process to fund the assessment and start the response properly and in a timely manner. A process should be developed for assessing the types of debris and who is responsible for debris removal.

Access to facilities
During a large scale disaster access to facilities may be compromised. Industry may not be able to physically get to their facilities, and getting resources to remote

locations may be difficult or impossible. Local law enforcement may restrict access to critical infrastructure. Methods for credentialing emerging response workers need to be established in each state that will let responses bypass local checkpoints.

Logistics

Overall logistics are essential to these types of spill responses because they will be conducted and coordinated within a large disaster response effort. Feeding and lodging of responders and volunteers may be difficult. Rapid training of under-qualified personnel may be needed. Resources may need to be shared during a large response. Government agencies may appropriate response equipment from other groups.

Human Dimensions

The perception of the public, volunteers, and other responders is important. Social science should be used to address human dimension in all areas related to disasters. Spill impacts on neighborhoods (e.g., Murphy Oil, Coffeyville) need to be considered. Sociological aspects need to be incorporated into preparedness, response, recovery, and restoration efforts.

Health and Safety

The welfare of responders may be at greater risk because of conditions caused by the large scale disaster. Worker fatigue needs to be addressed. Dangerous wildlife (e.g., snakes, alligators) may need to be handled.

Data Management

Massive amounts of information will require processing and distribution after the events. Common data management schemes to promote data sharing at various command levels need to be developed. Communication among the various response teams needs to be better. Use of GIS systems to track the situation and deployment of resources needs to be encouraged.

Response Structures

Multiple response structures and organizations exist that can benefit from an integrated approach. Unifying the various command structures is needed. Competition between Federal Government and State Government response organizations need to be addressed and resolved.

Measuring Response

Tools to measure response effectiveness are needed. In addition to actual response activities, public perception will have to be measured. Objective post-disaster evaluations (i.e., preparedness, plans, response) are needed. Eliminating duplication of efforts is needed.

Debris

The combined effect of oil spills and disasters are likely to result in significant amounts of debris. Debris type needs to be categorized. Restoration after debris removal needs to be considered.

Recommendation

After discussing the issues the group recommended the development of a response guidebook that would provide guidance for oil spill and hazardous material response within a major disaster response. The guidebook should be able to augment existing response protocols and would be applicable to all hazards and will benefit preparedness, response, restoration, and recovery.

The objectives of the guidebook are to give procedures that address the issues identified and to provide response organizations the ability to unify and eliminate duplication efforts, including:

- Establishment of proper communication channels
- Descriptions of common data management schemes that promote data sharing at various command levels
- Resource management, in particular getting resources to remote locations and sharing of resources during a large response
- Guidance on setting response priorities based on assessment findings (within the context of larger disaster response priorities)
- Procedural information for funding the assessment
- Guidance on the assessment process for determining the types of debris and who is responsible for removal
- Guidance on assessment and plan development for handling dangerous wildlife and pets
- Plans for rapid training for response workers and volunteers, including methods for feeding and lodging

A broad range of response organizations needs to be involved in the preparation of the guidebook. The group believes that the agencies represented on the National Response Team (NRT) can lead the effort to create the document. It should incorporate information from other groups including data and social findings. The final product will need periodic updates. The potential impediments that may need to be addressed include the difficulty in assessing wide area contamination; control of access by local law enforcement; and the appropriation of response equipment by other agencies.

The group decided that the project is technically feasible and easy to put into practice and likely to significantly improve the basis for a broad range of decisions related to the recovery of resources. The group suggested that the research effort will likely require one to three years and will have a total cost between $150,000 and $250,000.

B. Response Technology

Group B addressed planning, implementation and effectiveness issues for response several response technologies, including: bioremediation, surface washing agents, solidifiers, sorbents, dispersants, and in-situ burning. Gaps in preparing and maintaining methods and technologies, keeping personnel trained in operating the equipment, and operations during spills were also covered. The group focused on hardware and methodologies. Group members included:

Kurt Hansen, U.S. Coast Guard
Tom Coolbaugh, ExxonMobil Research & Engineering
Brent Koza, Texas General Land Office
Ken Lee, Fisheries & Ocean Canada, Centre for Offshore Oil & Gas Environmental Research
Debbie Payton, NOAA, Emergency Response Division
Scott Pegau, Oil Spill Recovery Institute
Makram Suidan, University of Cincinnati

Over 55 topics were identified by the group during the initial brain-storming session in the areas of mechanical response, surface washing agents, herding, solidifiers, sorbents, bioremediation, dispersants, natural attenuation and *in situ* burning. Since CRRC held a workshop which specifically addressed submerged oil in 2007, it was not included in discussions. In addition, because of upcoming workshops and efforts by the National Academy of Sciences, cold climate/Arctic topics were removed as a specific topic.

The group reduced the initial list of 55 topics to the 14 that were seen as most important, and identified them as either high priority, medium priority, or low priority. High priority topics included: (1) bioremediation; (2) chemical dispersants; (3) *In situ* burning ; (4) physical dispersion, and reducing waste of sorbents. Medium priority topics included: (5) evaluation of solidifiers; (6) evaluation of surface washing agents; (7) intervention vs. natural attenuation; (8) evaluation of skimmers in ice; (9) solidifier procedures; and (10) surface washing agent procedures. Low priority topics included: (11) herding compilation; (12) modeling skimmers; and (13) recovery of biofuels.

<u>Bioremediation</u>
Research is needed to increase the knowledge on feasibility of bioremediation on a wider range of applications than currently exist. These applications include use in cold water, cleanup of multiple oil types (e.g. light and viscous), effectiveness when combined with other treatment types, and the impact of oxygen delivery. The objectives are to conduct field trials to evaluate alternatives and to develop operational guidelines.

Research will be required for: (1) multiple oil types and substrates; (2) nutrient requirements and delivery; (3) the differences between marine and fresh water (role of sulfate); (4) evaluation of toxicity and eutrophication issues; (5) identifying monitoring protocols and endpoints. Potential impediments to research include the political and public perception of the disadvantages of introducing foreign materials and/or "bugs", expensive field trials, and the need for long term monitoring. An enhancement to efforts is that it is considered green technology by some.

Chemical Dispersion

Research is needed to understand the long-term fate of chemically dispersed oil, including the long term effects of biodegradation, photo-oxidation, dissolution, etc. The objective of the research is to understand behavior and environmental impact of chemically dispersed oil.

The research will require meso-scale and, full-scale field trials that include tracking and monitoring techniques. Other guidelines include investigating cold water environments, and multiple oil (including heavy) and dispersant types. Potential impediments to research are public perception and politics, the difficulty of control and the limited scope, and the expensive field trials.

In Situ Burning

Guidelines and standards should be developed for the use of *in situ* burning in ice environments. They should take into account air monitoring and air quality requirements, carbon footprint, and research recovery and disposal of residue.

Potential impediments are ignition issues, narrow operational windows, negative perception of residue, and safety of operations. Several ongoing studies (e.g. the SINTEF Joint Industry Program (JIP)) may enhance current research.

Physical Dispersion

Research is needed to understand enhanced dispersion based on the addition of oil mineral aggregate (OMA). The objectives are to evaluate feasibility as an alternative oil spill counter measure based on the addition of mixing energy with the addition of mineral fines, and to understand behavior and environmental impacts of naturally, versus OMA, dispersed oil.

Guidelines and requirements for research include: testing for suitability in cold water and ice environments; use of both mesocosms and field trials; use of multiple oil and mineral fine types; tracking and monitoring techniques; and the influence of the combination of OMA and chemical dispersants. Potential impediments to research include expense of field trials, public perception and politics, and the difficulties of controlling and limiting scope of the research to ensure reasonable success.

Reduce Waste of Sorbents

The amount of waste that must be disposed of after use of sorbents is large. This research would evaluate technologies that could be used in the field to allow recovery of oil and possibly reuse of sorbents to ultimately reduce the waste of sorbent materials. The objective of the research is to develop equipment amenable to recycling and recovery.

The research effort should consider all materials associated with sorbents (i.e., booms, pads, snares, etc.) and include both natural and synthetic materials. The reuse process should result in acceptable recovery and any method should be field portable.

Evaluation of Solidifiers

There were two research topics identified for solidifiers: (1) development of evaluation methods and (2) procedures for their use. Evaluations will determine solidifier properties and appropriate uses. The overarching research goal is to develop protocols for evaluating efficacy and toxicity for solidifiers.

Evaluation procedures and protocols should: Evaluate potential ecological impacts; consider development of an ASTM procedure; and consider reuse of products and recovered oil. The research effort should consider the full range of products. Challenges to implementation include: full-scale field tests that will encourage acceptance may be difficult to conduct; insuring that the application procedures can be used for all existing and future commercial products.

Evaluate Surface Washing Agents

There were two research topics identified for surface washing agent: (1) development of evaluation methods and (2) procedures for their use. At this time no guidelines are available for evaluation of, or use of, surface washing agent. Protocols and procedures need to be developed to examine the efficacy of surface washing agent under a range of conditions, as well as determination of realistic application methods to ensure peak performance.

Evaluations should: use commercially available test equipment; examine effectiveness on a range of substrates and test conditions, evaluate biological impacts, and create an ASTM method for standardization. Other challenges include realistic scale tests that will increase usefulness and acceptance may be difficult to implement, and insuring that the procedures can be used for all existing and future commercial products.

Intervention vs. Natural Attenuation

It is unclear what the actual natural dispersion rates are for oil. Understanding the trade off options between the uses of physical or chemical treatments versus natural attenuation can have significant impacts on safety, time, cost, and the environment. In natural attenuation, the concentrations in the water column are lower, but the oil remains in there for a longer time. In contrast, when intervention is chosen as a response strategy, initial concentrations are often much higher, but decrease quickly. The objective of this research priority is to develop monitoring protocols for environmental effects that can provide the framework for interpretation of data and decision making when evaluating trade-offs between chemical or physical dispersion and doing nothing during a response.

Field trials and spills of opportunity should be considered when evaluating guidelines. In addition, consideration should be given to employing a limited response to future spills in order to collect data on natural attenuation. A long term effort could help understand behavior and thus help modelers build better models, however the cost of a long term effort may be discouraging. Another possible impediment is that public and political perception may preclude doing nothing during a response.

Skimmers in Ice

Research is needed to develop and evaluate the use of skimmers in broken ice and slush. The objectives of the research would be to develop equipment (i.e., skimmers), response protocols and procedures, as well as well as evaluate the efficacy of the skimmers when used in ice conditions. Research would be crucial for the "shoulder" seasons when ice coverage varies from 10-90% as it builds up in the fall and then as it breaks up later in the spring/summer.

Efforts should focus on making protocols and procedures as practical as possible, and include field performance testing. These efforts should also include deployment and operational issues, in addition to efficacy. It should include vessel requirements, skimmer requirements, training needs and specified directions for operation.

Compilation of Herding Research

An effort should be made to compile the research done on chemical herders and evaluate knowledge gaps. The overarching objective of the research would be to identify and characterize chemical herders and their potential areas of use. Currently, only one out-of-date formulation is being researched. A review of previous efforts and chemicals could provide additional insights. Challenges include the perception of toxicity that could reduce use; however, showing large benefits may encourage use.

Modeling Skimmers

Skimmer and boom efficiency is usually based on the size of the pump and the size of the opening and assumes that the oil will easily flow towards the skimmer as it gets sucking in. However, under many scenarios, the skimmer or vessel system moves into the oil. A better method for modeling recovery encounter rates needs to be developed. A model should be developed that takes into account environmental factors and identifies limits of surface skimming. It should also be possible to incorporate the model into existing oil behavior models. Ultimately the models will help develop better tools that can be used for planning and execution of surface recovery.

Concerns that industry and government will interpret model results as an end use and ultimately hold parties accountable may impede research. Configurations and scenarios for the model should start simple and state all assumptions. Users should be supplied with education, training, and planning guidelines. Requirements of interaction between manufacturers may slow progress therefore researchers should consider equipment and configurations in the Coast Guard inventory first (e.g. CG buoy tender system). Promoting network exchange of knowledge and technology (journals, workshop proceedings, websites, etc.) may also encourage using the new model.

Recovery of Biofuels

Little is known about the efficacy of oil recovery techniques when used on alternative fuels and their byproducts. Research needs to be done to gain an understanding of the behavior and recovery of biofuels, feedstock, and byproducts in marine environments, and the efficacy of typical recovery strategies. Emerging products and applications may increase the number of solutions needed. The research should include numerous recovery techniques, including mechanical, chemical and biological methods.

C. Acquisition Synthesis and Management of Information

Group C focused on practices and methodologies for accessing and using remote-sensing data, real-time observational data systems, electronic data collection via field surveys, and geographical information systems (GIS) to improve oil spill preparedness, response, assessment, and restoration decision-making. These include: identification of research needs for hardware and software development for data collection, management, synthesis and interpretation; and hardware, software, and infrastructure requirements/methodologies to fully exploit web-based products and services. Group C members included:

Amy Merten, NOAA
Toby Garfield, San Francisco State University
David Gisclair, Louisiana Oil Spill Coordinator's Office
John Kelley, NOAA, nowCOAST
Richard Knudsen, FL Fish & Wildlife Conservation Commission
Sankaran KrishnaRajm, Environment Canada
Tom Lippman, UNH, Center for Coastal & Ocean Mapping

Problems were addressed by discussing how data should be synthesized from collection to processing and eventually to presentation and use. As particular details were evaluated, such as what type of qualitative data should be prioritized and specific limitations of collection techniques, the general topic was identified as too broad. Therefore on the second day the group broke into two smaller groups. One analyzed the needs for data acquisition, dealing primarily with physical challenges involving hardware and conditions in the field. This group dealt mainly with ocean and water column measurement issues. The second group dealt with shoreline issues including the management of data and product delivery for the Unified Command and for general preparedness. Data ownership was discussed frequently. Data collected during a spill event is often sensitive and possibly confidential, and ownership and release of data may be controversial.

Data Acquisition (pre-spill)

Proper data management prior to a spill would increase the effectiveness of response efforts especially during the critical hours immediately after the event. Pre-spill data ranges from geographic locations to local expertise and established response protocol. It should be formatted and standardized so that it is immediately available and useful if a spill event occurs. The group discussed three specific priorities for managing pre-spill data; update the ESI, develop a risk index, and develop a training curriculum.

Update ESI

The Environmental Sensitivity Indexes are in need of update, in many cases they are over 20 years old. Older data may be of limited use in places where significant development, subsidence, or significant changes in water levels have occurred. The maps should identify Resources at Risk (RAR), shoreline, biological, and socio-economic sensitivities. Gaps in knowledge and data access need to be identified. Significant inland areas, rivers, and lakes should be included and a schedule for future updates developed. Data acquisition standards should promote national and international integration and use a format that is compatible across GIS and web platforms. Considering other agencies that may already have the information may enhance the effort if the resources to extract information from varying national and international data sets are available.

Create Risk Index

Creating Risk Index Atlases are a way to present information that is unique to local communities. The maps should include; geographical data such as facilities, tank farms, and shipping lanes; local expertise such as climatology and important contact information; and procedural data such as available technologies and responsibilities. The objective of the maps is to use GIS framework to better assess risks. Some of the information has already been gathered by homeland security because each region is supposed to have a risk assessment, however, they may be reluctant to share the information.

Develop Training Protocol

To fully take advantage of existing and emerging technologies and models for oil spill response, a training protocol will need to be established that continually update the skill sets of responders. The curriculum will train the trainers who in turn train responders. The protocol will define roles and responsibilities based on job titles as well as standards for field collection techniques and output products. The curriculum and prep exercises should be designed with ease of training and particular technologies in mind.

Data Acquisition (post-spill)

Post-spill observational data is collected by tools and responders after an event has occurred. Technology is essential to observational data collection therefore a serious evaluation of technologies should be conducted. Examples include limitations of HF RADAR at distances or battery drain during cold weather climates. Availability of technologies should be catalogued beforehand such as the sources of satellite data, schedules, and capabilities. Challenges in observational data collection vary depending on environment. The subgroup that discussed research and development for data collection in water broke priorities into 3 categories defined by water column depth. The depths are: shallow (10^0 meters,) intermediate (10^1 meters,) and deep ($10^2 – 10^4$ meters.) Research and development priorities along the shoreline were discussed by the other subgroup separately.

Observational Data Collection (various water depths)

The objectives in improving observational data collection are to develop methodologies, instrumentation, dataflow and procedures for providing the necessary environmental data to the SCC and ICC in real time. At deep depths the data will enable successful in-water recovery. In intermediate depths the data will enable successful in-water oil recovery and predict landfall. The data in shallow depths will help predict oil movement along shore, re-suspension, and transport. Guidelines for all depths involve evaluating existing instrumentation and data flow to determine present capabilities. Then identify emerging technologies that need to be incorporated into spill response. Databases need to be developed to handle the rapid cascade of information coming from technologies and it should be required that data and metadata follow a common format (DIF and DMAC compatible). Technical limitations were identified as a potential impediment because either current instrumentation is not presently capable of providing required information as in the case of certain biological and chemical sensors, or available technology is sufficient but does not have coverage in a particular area for example the limited coverage of HF Radar and the National Buoy Network. The legal status of incorporating data into models and the decision making process may also be a potential impediment. Improved collection of certain observational data would result in improvements to oil spill response. For shallow water, high resolution bathymetry, surface waves, and winds for example are needed to initialize a model for near-shore and inner shelf circulation for making predictions about transport and dispersal. Bathymetry is needed to develop modeling capability (most preferably in high risk regions ahead of time), or preparing for model applications when incidents occur, and therefore is a research need. It would be of value to improve bathymetric observational techniques, particularly in shallow water where common methodologies are not applicable or impractical. Observational data collection has a broader application as technologies put in place or utilized for oil spill incidence response could be added to present observational networks. Additionally, present observational systems could provide useful data to oil spill responders. Research needs relating to on-shore data collection were discussed by the larger subgroup. The objective is to use data from the field to accurately assess the level of shoreline oiling and status of clean-up activities for planning and operations. Recommendations for cleaning specific shoreline types should be created so that after a spill has occurred decision makers can quickly develop clean up recommendations. Clean up recommendations should then be written in a common format that organizers will become familiar with, allowing for quicker deployment of appropriate groups. Improvements should incorporate existing efforts and formats such as the Natural Resource Damage Assessment (NRDA) process, NOAA's Marine Debris program, and Arcpad. As new technologies are developed, convenient open source and modular formatting should be implemented.

Data Processing

Data processing must allow for the integration of information collected from the field instantly with pre-spill data. Methods, procedures, and standards should be established so that agreements aren't being negotiated during valuable time after a spill event. Data processing in models or GIS and other platforms must be able to handle massive amounts (terabytes) of dataflow shortly after a spill. The sub group discussing post-spill data collection in various water column depths identified the needs for advanced data-assimilation models. The subgroup that discussed pre-spill data acquisition identified needs regarding integrating data from different sources into a single GIS system. Lastly, together the subgroups discussed the advantages of data acquisition from hardware handled by automated processing. The conversation established the need for an "extract/translate/load" mechanism.

Computer Models

Proper computer models fill gaps in circulation knowledge in order to best inform the SCC and ICC on expected transport and fate of oil. Evaluations of old models must be conducted using a standardized quality assurance and control system that identifies capabilities. New 4D numerical circulation models should be developed with foreign substance transport forecast capability that puts oil on the map quickly. The models should use single management platforms that are real-time and remotely accessible.

Models have a wider application for use such as Marine Protected Areas selection, homeland security, fisheries, water quality, etc. The development of new models should be guided by the significance of data types such as wind, waves, depths, etc. Rapid access to observational data and joint centers with academic institutions for model operations must be established for convenient assimilation. Bathymetry and boundary conditions should identify the models domain. The models must be implemented and tested beforehand as well as the legal issues associated with using or incorporating results from models identified.

Incorporation of Data

The subgroup that discussed pre-spill data acquisition determined that a workshop is required to identify and discuss integration of data from multiple sources and formats into a single web based GIS system. The rights of data will also be discussed at length such as sources, ownership, and the availability for agencies to share. The workshop will develop protocol for how to ingest data from new and local sources, share base maps, keep data updated, and will establish who is responsible for keeping data updated. Other questions were identified by the group that should be addressed during the GIS workshop since it will pertain to integrating information. These include how to acquire and integrate new technologies from academia without dealing with red tape, how to geo-reference research, how to make data dynamic (auto-updating), and how to retrieve information from NOAA and non-NOAA sources, including: Department of Homeland Security (DHS), Fish and Wildlife Services (FWS), and other local sources that already exist. It was noted that certain information has to be approved by NOAA before it is usable and there should be a method developed to streamline the approval process.

Extract/Translate/Load

To make data more immediately useful, a method to rapidly acquire data from hardware should be developed. The method would extract information from any hardware used to collect observational data then translate it into a GIS compatible format and load it into the appropriate GIS tool in use by responders and decision makers. Rather than ask technology developers to update old hardware and manufacture software adhering to new standards, a software program can be developed to translate all existing formats. The software would operate the way device drivers do with Windows®. The program would store a list of potential devices that produce any type of info that is useful to GIS systems. When output is sent to the ETL program it would determine what device it is coming from by data characteristics. A unique driver would then be loaded to convert the data into a format appropriate for the GIS system.

The benefit of a software system is that standards don't have to be enforced. They can be written for the oil response community and pertain only to GIS software and not equipment. Manufacturers may be encouraged to develop drivers because the ETL system would provide the connectivity to the widely used GIS programs therefore promoting their product. For hardware that already exists in the field, drivers can be developed by software engineers just as they are for many electronics today.

Data presentation involves the output that decision makers will use after data has been collected and processed. Establishing a global protocol for the delivery of maps and readings can make available significant amounts of invaluable time after a spill event. Such a protocol would eliminate the learning required before responders can use information coming from unfamiliar sources as well as the eliminate explanations required for decision makers to communicate about differing platforms. The basic need is for product delivery to follow a standardized format. The objective is to create a standardized output for product delivery. The standards should be easily adoptable with open-source development. The organizational framework and terminology should apply to all groups. Cartographic standards would include definitions for line colors, thicknesses, and types, and established hatch patterns for polygons. Inter-agency coordination issues are a potential obstacle but collaborative standards development may promote updating older information.

In conclusion, research and development in data management will create a clear and concise synergistic matrix of emergency response that is easily referred to for identifying processes, needs, and progress. The matrix should be refined continually with regards to acquisition and synthesis methods, information management and delivery, and preparedness education. Technologies being developed for the response community should involve concerted collaboration and easily adoptable standards and formats that assist in communication between multiple agencies. Proper data management will improve oil spill preparedness, response, assessment, and restoration decision-making.

D. Human Dimensions

Group D focused on: minimizing social impacts during a spill event and subsequent response activities; strategies to address the long-term socio-economic effects a spill might have on a region's culture and vitality; incorporating social science research; methodologies; and initiatives into its individual and collective response plans.

Group members included:

Doug Helton, NOAA, Emergency Response Division
David Chapman, Stratus Consulting
David Kaiser, NOAA, Office of Ocean & Coastal Resource Management
Scott Knoche, U.S. Coast Guard National Pollution Funds Ctr
Fabienne Lord, Social Environmental Research Institute

Related Workshops
The group noted that a more comprehensive workshop addressing Human Dimensions of Oil Spill Response was held at the University of New Hampshire in June of 2006. The human dimensions field is broad, and touches a number of governmental interests and academic disciplines, including the communication sciences, ethics, cultural studies, anthropology, economics, psychology, sociology, political science, and other social and behavioral sciences. The 2006 workshop had over 40 participants and included a wide-ranging list of disciplines, state and federal agencies, and other organizations, and produced a broad set of research and development goals. The 2009 meeting included representatives from only 2 federal agencies (USCG and NOAA), and two technical disciplines (economics and sociology)

The 2009 workgroup members note that all of the priorities developed during the 2006 workshop are still relevant today, but some priorities have grown in significance given recent spill events (e.g., volunteer issues during the *Cosco Busan* spill). Other human dimension issues identified in 2006, including risk communication, environmental ethics, valuing natural resources, and the social impacts of spills on communities and subsistence peoples, all are still active research needs.

Summary Issues and R&D Needs
Almost every spill affects humans in the short and long term. Spill impacts to humans are both through affected natural resources and impacts to community well being. Potential impacts to community well being must be considered on the same

plane as natural resource and physical impacts at the preparedness, response, restoration, and recovery stages. The failure to consider community well being may lead to an ineffective pollution response and increase societal losses. Effectively incorporating these human dimensions will require expanding the components of effective planning and response, including:

Discussion and Recommendations

The Human Dimensions Working Group agreed that the 2006 Human Dimensions Workshop was still an effective blueprint and that specific research was needed under each of the four components (Preparedness, Response, Restoration, and Recovery). The Working Group felt that a broader set of federal, state, and tribal governments, industry, NGOs, and academic researchers would be needed to define further research and development needs.

The workgroup also discussed how to improve the applicability of human dimensions research on oil spills and natural disasters, including how to improve the RFP process to generate operationally useful research. Several of the workgroup members were concerned that there is too broad a gap between researchers and practitioners in this field.

The group members strongly recommend that human dimensions be a much more substantial element of response plans, protocols, and training. Many response managers come from the maritime industry, or have a background in engineering or the natural and physical sciences, and may under-appreciate the importance of human dimensions, despite the broad recognition within the response community that the success of a spill response was largely dependent on effective community and stakeholder involvement in oil spill planning, communication, response and restoration. However, given limited R&D funds, there will always be a tension over how much effort, money, and research to dedicate to human dimensions issues.

Specific R&D recommendations focused on guidelines/guidance documents for incorporation of human dimensions into local, regional and national spill response plans, including:

1) General:
   a) What would a human dimensions plan for spills entail? What categories of information would be needed?
   b) What would a training program on human dimensions for responders look like? Is there a model curriculum?
   c) How do we capture the human dimensions issues and lessons learned from past spills?
   d) Defining Human Dimension indicators and metrics

2) Spill Prevention
   a) Can human dimensions research assist with the reduction of incidents through human error?

b) Is there another body of on-going research on human error in other fields (e.g., aircraft and industrial accidents), that should be incorporated?

3) Local Knowledge:
   a) We know that lack of engagement of local experts and ignoring local knowledge is a common point of failure- even if the response is technically successful.
   b) How to balance desire for local "experts" to feel engaged with other response goals?
   c) Are there other ways to engage local knowledge?

4) Assessment Issues
   a) How do you measure "well being" in a community**?**
   b) Tool and processes to identify what's important to a community – culturally, socially
   c) Tools to better understand how individuals and communities will react to spills.

5) Restoration and Recovery:
   a) Post spill assessment and recovery. Are there indicators of how a community will heal?
   b) How do you compensate for cultural use losses? Are there better ways to compensate impacted parties?

6) Community Resilience:
   a) What makes a community resilient?
   b) What are the key human/social indicators and pre-incident planning and data needs for understanding of communities? What needs to be monitored? Are the existing data sources from Census and other routine assessments that would serve as basic indicators of how a community may respond to a spill?
   c) Why does one incident generate huge public interest and outcry while another similar incident receives low attention?
   d) Why are there such strong regional differences in attitudes and concerns?
   e) How to deal with impacted people, particularly addressing subsistence users and other groups that have unique relationships with resources

7) Communications:
   a) Assessment of risk communication messages associated with oil spills.
   b) Managing and modifying public and media expectations on what is realistically achievable and what is a good response.
   c) Communications plans improvements and guidelines for better communicating with public, volunteers, etc. about progress of response, cleanup

8) Volunteers:
   a) Systematic appraisal of 'lessons learned' from past oil spills– including use and management of volunteers.

b) Can social science research help responders better understand volunteer motivations and needs, in order to develop productive, appropriate and fulfilling roles for volunteers?

9) Organization Cultures:
   a) Studies of organizational culture and its influence on preparedness, response, and restoration
   b) What are the sociological impediments to specific response technologies, such as dispersant use?

E. Ecological Monitoring and Recovery Following Spills

Group E discussed the understanding of long-term ecological recovery following oil spills, and monitoring methods and endpoints that are able to cost-, time-, and ecologically-effectively capture environmental services that track natural resource services. Several questions were addressed, including: what ecological factors affect recovery rates? What ecological 'metrics' can be applied using common assessment tools (e.g., Habitat Equivalency Analysis) that will help resource managers develop restoration projects that best compensate for lost resources? Group members included:

Dan Hahn, NOAA, Assessment & Restoration Division
Mark Curry, Industrial Economics, Inc
Moonkoo Kim, KORDI, South Sea Research Institute
Francois Merlin, CEDRE
Veronica Varela, U.S. Fish & Wildlife Service

Oil spills have the potential to impact a diverse array of habitat types and organisms. Depending on the severity of the spill, impacts may be easily observed or require special studies to determine impacts. The initial injury is just one component of the total injury to habitat and organisms following a spill. The duration and trajectory of recovery for the injured habitat and organisms is also important yet long term monitoring of recovery is seldom done.

Both in measuring the initial injury and the recovery, it is important to know the baseline conditions for the affected habitats and populations. These may vary regionally, seasonally, or along other natural gradients such as salinity. Although prevalent in the literature, comprehensive summaries of production, structure, and function of various habitat types are often not available to those conducting an injury assessment.

After examining the issue of ecological monitoring and recovery from a number of angles, the panel developed a list of 11 topic areas for research. This list ranges from broad research topics such as "recovery rates for injured habitats," and, "sand beach synthesis," to much more specific questions such as, "avian embryonic mortality."

Recovery Rates for Injured Habitats

Injury assessments require estimates of the severity and duration of spill impacts, while restoration planning requires data on the trajectory of service gains. Little information exists that tracks services over long periods of time and for long-lived species. Assessment efforts are hampered by the lack of long-term trajectory data. Research should characterize recovery rates, including the development of recovery trajectories, for injured habitats over long periods, ranging from 5 to 20 years, with a focus on biological structure and integrity or bio-geochemical processes. Proposals should focus on locations that were previously monitored, either during a spill, or as a restoration site, and develop repeat measures of previously examined endpoints (again, with a focus on biological structure and integrity or bio-geochemical processes). Key habitats include marshes, stream banks, and sediment replacement sites. The limited inventory of restored sites with monitoring data may impede the research effort.

Background Birds

The rate at which birds beach due to natural mortality is poorly characterized, but is an important consideration for determining spill-related avian mortality. Existing data sources are not adequate for estimating beaching rates at time scales relevant to oil spills (e.g. monthly surveys). Research should define the rate at which birds naturally beach in the absence of oil. Studies must consider regional and seasonal variation and designs must be statistically based.

Long-Term Viability of Oiled Birds

Little is known about the fate of birds that are oiled and not captured during a spill, or oiled birds that are rehabilitated and released. Research should evaluate survival and/or the reproductive success of oiled birds following a spill. The study should track birds that were oiled during a spill for periods up to 18 months after a spill. The research should also consider variations in regions, guilds, and degree of oiling should be considered to the extent possible. The difficulty of tracking oiled, non-rehabilitated birds may impede the research effort.

Mudflat Recovery

Oil often persists in mudflats due to sediment accretion, sequestration in burrows, and limited cleanup. The effects of these long-term exposures are poorly understood. Research should focus on developing a model for mudflat recovery as a function of relevant physical, geochemical, and biological processes (i.e., microbial degradation and bioturbation), with consideration for sequestered oil (especially oil retained in burrows). The research should establish the degree and duration of oil retention as a function of bioturbation, and other physical (e.g. grain size, agitation, tidal and runoff exchange) and geochemical factors. The research must consider sorbed oil and bulk oil that is buried or sequestered in burrows. Additional research will be needed to establish the biological component of the model.

Sand Beach Synthesis

Sand beaches are often extensively oiled and subjected to extensive cleanup, including habitat replacement. Regional estimates of productivity and toxicological effects are needed to accurately estimate biological impacts and the length of the recovery period. Research should focus on compiling and synthesizing existing information for sand beaches regarding productivity, species diversity, and community structure, and the effects of oil on these parameters, including recovery time with consideration for regional variation.

Particular interest should be paid to infauna, meiofauna, and periphyton. Research efforts may be enhanced by substantial existing literature relating to the topic, but it may be geographically limited. Following the synthesis, research gaps should be identified.

Oiled Bird Assessment Tool

Externally oiled birds are frequently observed, but not recovered during spills. Establishing the relationship between external oiling and the bird's fate (acute, chronic, and sub-lethal) could be used to expedite injury assessments of oiled birds and to inform spill response efforts. The research should consider variations in regions, guilds, oil type/origin, and degree of oiling to the extent possible. Potential impediments for this effort include numerous challenges for field studies.

Rocky/cobble synthesis

Rocky/cobble habitats, rocky outcrops, and rip-rap are often extensively oiled and subjected to extensive cleanup, including habitat replacement. Regional estimates of productivity and toxicological effects are needed to accurately estimate the length of the recovery period. Research should focus on compiling and synthesizing existing information regarding productivity, species diversity, and community structure; the effects of oil on these parameters, including recovery for rocky/cobble habitats with consideration for regional variation.

Particular interest should be paid to benthos, infauna, and epifauna. Research efforts may be enhanced by substantial existing literature relating to the topic, but it may be geographically limited. Following the synthesis, research gaps should be identified, with emphasis on latitudinal differences.

Bird Toxicology

Little is known about the basic toxicological effect of oil on birds. Research should explore the toxicological effects of ingestion, inhalation, and food web accumulation on avian mortality and reproduction. Studies must consider bird species impacted by coastal oil spills. Field and laboratory studies will be considered. The research should also consider variations in regions, guilds, and degree of oiling.

Sand Beach Recovery

Recovery of sand beach habitat and the associated biological organisms after an oil spill is poorly understood. Research should develop a model for sand beach recovery as a function of relevant physical, geochemical, and biological processes. It will establish the degree and duration of oil retention as a function of grain size, agitation, tidal and runoff exchange, and other physical and geochemical factors. Additional research will be needed to establish biological components of the model.

Mudflat Synthesis

Mudflats are highly productive habitats and are very difficult to clean following an oil spill. Often, oil remains in and on mudflats over extended periods of time. Research is needed to quantify the severity and duration of oil spill impacts on mudflats. Research should focus on compiling and synthesizing existing information regarding productivity, species diversity, and community structure; the effects of oil spills on these parameters, including time for recovery with consideration of regional variation. Particular interest should be paid to infauna. Research efforts may be enhanced by substantial existing literature relating to the topic, but it may be geographically limited. Following the synthesis, research gaps should be identified.

Avian Embryonic Toxicology

Little is known about basic embryonic toxicology of oil, particularly for species likely affected by coastal oil spills. Research should explore the toxicological effects (acute and sublethal) of embryonic oil exposure via external oiling of the egg. Studies must consider bird species impacted by coastal oil spills. Field and laboratory studies will be considered. The research should consider variations in regions, guilds, and degree of oiling should be considered to the extent possible.

F. Biofuels

Note: No summary received from this group.

G. Ecological Effects of Oil Spills

Understanding the long-term effects of residual oil is essential for developing appropriate emergency response and remedial actions, assessing risks, for determining short and longer term environmental impacts, and assessment of resource recovery following an oil spill. Given the wide array of spilled oils, the numbers of unique ecosystems and receptor species, and complex ecosystem interactions, opportunities for meaningful research on longer term effects of residual oil in the environment are numerous. The ecological effects workgroup discussed the many directions that ecological effects research could go in, and evaluated past research and potential future research needs and developed the following ranked list of prioritized research needs. Group members included:

Lisa DiPinto, NOAA, Assessment & Restoration Division
Jim Clark, ExxonMobil Research & Engineering
Tracy Collier, NOAA, National Marine Fisheries Service
Letitia Grenier, San Francisco Estuary Institute
Peter Hodson, Queen's University
Won Joon Shim, KORDI, South Sea Research Institute
Mike Sowby, California Oil Spill Prevention & Response
Andy Tirpak, Texas Parks & Wildlife Department

Toxicology

This topic was ranked as the workgroup's highest priority as toxicological considerations were considered to be the fundamental drivers for effects both in the short and long term. Given the wide array of spilled oils and the immense numbers of unique ecosystems and receptor species, calls for more research to simply develop more dose response relationships will not be taken seriously. There is already an abundance of data on acute effects, but too little understanding of chronic and sublethal effects that contribute to long term injury to ecosystems.

Research that will help assess the risk to aquatic species from oil include the nature of acute and chronic toxic effects in different aquatic species, particularly the embryonic stages of highly valued species of fish and birds. Long-term exposure scenarios of weathered oil can be used to assess chronic toxicity in a realistic way. Effects on population structure and productivity of lethal and sublethal embryo toxicity, and the duration of these effects following a spill should be developed. Interactions that need to be researched include life history traits with sensitivity to oil toxicity (why are some species more affected than others by spilled oil?), the interactions among exposure time, concentration, embryonic stage of development, and among multiple environmental stressors (e.g. natural pathogens) with toxicity under the highly variable exposure scenarios of an oil spill.

Research that will aid in monitoring the most appropriate chemicals and ecological responses following a spill include the unresolved complex mixture that is slowly being dissected by chemists, and that includes the numerous alkyl PAH that may be responsible for the chronic toxicity of oil to embryonic fish, and the long-term fate and bioavailability of these compounds as oil weathers and changes its physical and chemical state. Structure-activity relationships should be researched that will allow the modeling of the behavior, fate, and effects of closely-related alkyl PAH. In addition, the effects of major ecosystem variables (e.g., temperature, salinity; ecosystem type) on short and long-term fate and effects of alkyl PAH should be developed. Finally, the modifying effects of different clean-up technologies on short and long-term fate and effects of alkyl PAH should be developed.

Retroactive Assessment of Oiled Sites

Looking retroactively at oiled sites can give real-time data to resource managers and responders that can be used to refine models and can better inform response, cleanup and natural resource damage assessment (NRDA) decisions. Objectives include collecting information that can be used to validate cleanup decisions (i.e., "how clean is clean?"), and assess longer term ecological effects from various cleanup approaches. Information is needed to validate assumptions about resource injury and recovery such as ecological recovery rates, degree of injury, area affected, etc. Results from this research can also help identify unexpected ecological outcomes, both positive and negative. Studies that monitor multiple oiled sites of different 'ages', and/or monitoring a single site over time to validate assumptions about recovery rates, degree of injury, contaminant levels, toxicity, impacts and/or success of cleanup processes would be considered as high priorities in this research category. Additionally, a comprehensive synthesis of past research on retroactive spill monitoring would be valuable to help frame future research. Data collected could be compared among different habitat types and geographic areas. Issues with scale, habitat complexity/uniqueness, the wide array of oil properties should be factored into any research program. Ongoing litigation issues at many oiled sites could present challenges to researchers at some sites of interest.

Communication Tool Development

Getting and keeping the response and assessment community connected with local scientific expertise and data has proven challenging, especially maintaining these data and relationships over the long term and after the response is completed. An objective of this group would be to developing communication tools that facilitate information management and sharing among diverse stakeholder groups. These tools would support maintenance of local and regional data in a commonly accessible platform. This would result in better response and assessments through more effective dissemination and incorporation of local knowledge and scientific results. Results of these tools will benefit interests beyond oil spill communities, andcould be applied to accommodate interests of diverse stakeholders for other regional ecological issues.

Assessment methods for oiled fringing marsh

Marshes, in addition to being a highly productive and ecologically valuable habitat, are one of the most commonly oiled habitats. Often following a spill, oiled marsh is characterized by having higher levels of residual on fringing and edge marsh, with less or no visible oiling persisting into the marsh interior. This results in a large overall area of affected marsh, but a smaller actual 'footprint' of visibly oiled marsh over the entire affected area. Considering the high faunal use of fringe marsh for both feeding and ingress/egress and the potential for marsh erosion resulting from injured fringing marsh vegetation, objectives of this research are to assess impacts to marshes affected by edge oiling, and to better define assumptions about degree of injury and recovery rates. Factors to consider include seasonality, specific flora and fauna categories, and assessment of sensitivity of stressed versus unstressed marshes. Use of retroactive assessment opportunities, ongoing marsh studies or a spill of opportunity research arrangement could facilitate access to oiled sites.

Assessment of effects of volatile plumes on exposed resources

This category is relevant for evaluation of scenarios where there is a highly volatile component, such as with pipeline releases or with *in situ* burns and potential for associated effects from combustion products. There is an overall lack of basic toxicological information for many potentially affected species. Objectives include improved understanding of plume composition, magnitude and dispersion rates, and to determine the link between plume exposure and impacts to resources. Exposure routes, duration and associated toxicity on mobile, sessile or small home range species should be evaluated, including the potential for plume avoidance. Habitat considerations (e.g., open area versus wooded area) should be considered, and research could include both lab and field based experiments. There will be challenges associated with capturing information on short-term volatile events, but perhaps methods used for tracking information about forest fires could be considered in design.

Quantitative approach to assessing ecological tradeoffs during spill response
Spill countermeasure resources are limited during a response, and decisions about allocation of resources, and use of various response methods, require understanding of the relative value and/or ecological significance of resources affected by response decisions. To date, the most commonly used fate and effects models applied are proprietary. An objective of this research would be the development of integrated ecosystem models to understand and weigh tradeoffs associated with response decisions to enhance assessment of resource impacts. Weighing the ecological effects associated with spill response methods such as using dispersants, shoreline cleaning agents, burning versus natural attenuation would be better informed through enhanced modeling that can incorporate interactions between exposure times, concentrations and effects on various receptor life stages and habitats. Data, including information and analysis of socioeconomic factors have been collected, but have not been incorporated into a spill specific integrated ecosystem assessment approach, that can frame questions about functions and services at the systems level. Evaluation of impacts using common assessment tools (e.g., habitat equivalency analysis, resource equivalency analysis), use of bird/wildlife modeling and toxicity assessments, and life history attributes and toxicant properties could be considered in ecosystem models that would assist resource managers in determining where recovery and restoration is feasible, areas that are hard to clean, areas that will struggle to recover, etc.

H. Environmental Forensics

Oil spills frequently occur in industrialized areas where there are numerous sources of PAHs, beyond those resulting from the specific incident (e.g., runoff, pyrogenic sources, oily wastes, natural seeps). Group H focused on forensics, or chemical fingerprinting to determine the source and extent of oil resulting from an incident. Identification of the source is important for clean-up, assessment, recovery monitoring, and associated liability issues. Research needs for this topic focused on analytical and interpretive methods to advance existing approaches to chemical fingerprinting of spilled oil in the environment. Group members included:

Bob Haddad, NOAA, Assessment & Restoration Division
Wayne Gronlund, U.S. Coast Guard
Scott Stout, Newfields
Mike Unger, Virginia Institute of Marine Science
Alison Watts, University of New Hampshire

Four major research needs within the field of spill forensics were identified during this workshop. The four priorities, listed in order of importance are:

Identification of new and evaluation of existing analytical techniques
New analytical techniques need to be developed to better characterize known and new compounds of forensic interest (e.g., biofuels). Improvements for analytical

techniques could be made with individual PAH isomers, NSO compounds, finding new target analytes for weathered petroleum, and distillate fuels.

New techniques in chemical data analysis
A more quantitative approach to correlate sample to source needs to be developed to enable a more defensible argument, and should include greater differentiation in background contamination levels. Statistical or numerical data analysis can maximize the usefulness and minimize the uncertainty/bias with existing methods. Integration of other field's approaches and established methods (e.g., statistics, data processing) will be good models to look at.

Advances in field monitoring techniques
Improvements in the collection of chemical data in terms of quantity, ease, and usefulness are necessary to advance field monitoring techniques. Background levels should be continually monitored, and during post spill operations, information should be gathered at different temporal scales. Short term (real time) monitoring should be conducted to identify the spatial and temporal extent of chronic and acute exposure. This will inform and validate modeling. Long term monitoring of residual contaminants in the environment will help identify the source(s) and observe long-term recovery. Also, development of alternative monitoring techniques such as passive monitoring (SPME) in different media (e.g., water columns, sediments) will help advance the field of environmental forensics.

Chemical fingerprinting in biological matrices
Correlation of spilled oil (regardless of the degree of weathering) to residues in biological matrices will assist in establishing a direct link to exposure levels. Oil needs to be evaluated at multiple weathering states. There are multiple exposure pathways for organisms (e.g., sediments, biological), and these pathways need to be further evaluated. The different life stages of species needs to be examined, specifically sensitive stages (e.g., larval). The laboratory results on these subjects need to be transferred to the field for validation.

III. Conclusion

As the response and restoration of the April, 2010 explosion of the Deepwater Horizon drill rig has illustrated, there remains a significant number of unknowns with respect to the response and restoration of oil in the environment. Clearly, more R&D is needed to gain a better understanding of the many aspects of oil spill response and restoration. The research needs identified in this report are not exhaustive, however represent the most critical immediate research needs in order to improve the response and restoration of oil releases in the environment.

APPENDIX A

Research & Development Priorities:
Oil Spill Workshop

March 16 - 19, 2009
University of New Hampshire
Durham, NH USA

Monday, March 16

Arrival and Check-in at the Holiday Inn Express

19:00 Organizing Committee Meeting in 320 Gregg Hall

Tuesday, March 17

08:15 *Continental Breakfast in DeMeritt Hall*

08:45 Welcome and Introductions
Nancy E. Kinner, UNH Co-Director, CRRC
Amy A. Merten, NOAA Co-Director, CRRC
Taylor Eighmy, Vice President for Research, UNH
Robert Haddad, Office of Response & Restoration, NOAA
Anthony Lloyd, U.S. Coast Guard
James Clark, ExxonMobil

09:15 Background and Workshop Goals/Outcomes
Amy Merten, NOAA Co-Director, CRRC

09:30 Participant Introductions
Jon Hockman, Workshop Facilitator

10:00 Workshop Structure & Logistics
Jon Hockman, Workshop Facilitator

10:15 *Break*

10:30 Plenary Session I: Setting the Stage (5 minutes each)

A. Spill Response During Disasters (David Fritz)
B. Response Technologies (Kurt Hansen)
C. Acquisition, Synthesis & Management of Information (Amy Merten)
D. Human Dimensions (Doug Helton)
E. Ecological Monitoring & Recovery Following Spills (Dan Hahn)
F. BioFuels (Bruce Hollebone)
G. Ecological Effects of Oil Spills (Lisa DiPinto)
H. Environmental Forensics (Bob Haddad)

12:00 *Lunch*

Tuesday, March 17 (continued)

13:45	**Breakout Session I** Breakout Discussion Groups
15:30	**Plenary Session II: Group Reports (10 minutes each)**
17:00	**Adjourn**
18:30	Shuttle to *Dinner at the Kinner Home*

Wednesday, March 18

08:30	*Continental Breakfast in DeMeritt Hall*
09:00	**Overview and Review/ Recalibrate** Jon Hockman, Workshop Facilitator
09:15	**Breakout Session II** Breakout Discussion Groups
12:00	*Lunch*
12:45	**Breakout Session III** Breakout Discussion Groups
15:00	**Plenary Session III: Group Reports**
16:45	**Adjourn**
18:30	**Shuttle to** *Dinner at Riverworks Restaurant & Tavern in Newmarket, NH*

Thursday, March 19

08:30	*Continental Breakfast in DeMeritt Hall*
09:00	**Plenary Session IV: Synthesis and Next Steps** Jon Hockman, Workshop Facilitator
11:00	**Closing Remarks** Jon Hockman, Workshop Facilitator

APPENDIX B

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Oil Spill Workshop

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Durham, NH USA

David Chapman
Stratus Consulting
dchapman@stratusconsulting.com

Jim Clark **
ExxonMobil Research & Engineering
jim.r.clark@exxonmobil.com

Tracy Collier
NOAA, National Marine Fisheries Service
tracy.k.collier@noaa.gov

William Conner
NOAA, National Ocean Service
william.conner@noaa.gov

Tom Coolbaugh
ExxonMobil Research & Engineering
thomas.s.coolbaugh@exxonmobil.com

Mark Curry
Industrial Economics, Inc
curry@indecon.com

Lisa DiPinto **
NOAA, Assessment & Restoration Division
lisa.dipinto@noaa.gov

Dave Fritz **
BP America
fritzde@bp.com

Newell "Toby" Garfield
San Francisco State University
garfield@sfsu.edu

David Gisclair
Louisiana Oil Spill Coordinator's Office
david.gisclair@la.gov

Letitia Grenier
San Francisco Estuary Institute
letitia@sfei.org

Wayne Gronlund
U.S. Coast Guard
wayne.r.gronlund@uscg.mil

Robert Haddad
NOAA, Assessment & Restoration Division
bob.haddad@noaa.gov

Daniel Hahn
NOAA, Assessment & Restoration Division
daniel.hahn@noaa.gov

Kurt Hansen **
U.S. Coast Guard Research & Development Center
kurt.a.hansen@uscg.mil

Doug Helton
NOAA, Emergency Response Division
doug.helton@noaa.gov

Jon Hockman **
OLA Consulting, Facilitator
jhockman@theD3group.com

Marc Hodges
American Petroleum Institute
hodgesm@api.org

Peter Hodson
Queen's University
pvh@queensu.ca

Bruce Hollebone
Environment Canada
Science & Technology Branch
bruce.hollebone@ec.gc.ca

Alex Hunt
ITOPF
alexhunt@ITOPF.com

Dennis Hwang
University of Hawaii Sea Grant College Program
djh@roplaw.com

** Designates Organizing Committee

The Coastal Response Research Center
at the University of New Hampshire

ExxonMobil
Research and Engineering

David Kaiser
NOAA, Office of Ocean & Coastal Resource Management
david.kaiser@noaa.gov

John Kelley
NOAA, nowCOAST
john.kelley@noaa.gov

Moonkoo Kim
KORDI, South Sea Research Institute
mkim@kordi.re.kr

Jeffrey Kimble
U.S. EPA, Region 5
kimble.jeffrey@epa.gov

Nancy Kinner **
UNH, Coastal Response Research Center
nancy.kinner@unh.edu

Scott Knoche
U.S. Coast Guard
National Pollution Funds Ctr
scott.d.knoche@uscg.mil

Richard Knudsen
FL Fish & Wildlife Conservation Commission
richard.knudsen@myfwc.com

Brent Koza
Texas General Land Office
brent.koza@glo.state.tx.us

Sankaran KrishnaRaj
Environment Canada
sankaran.krishnaraj@ec.gc.ca

Ken Lee
Fisheries & Ocean Canada
Centre for Offshore Oil & Gas Environmental Research
leek@dfo-mpo.gc.ca

Steve Lehmann
NOAA, Emergency Response Division
steve.lehmann@noaa.gov

Tom Lippmann
UNH, Center for Coastal & Ocean Mapping
lippmann@ccom.unh.edu

Anthony Lloyd
U. S. Coast Guard
anthony.s.lloyd@uscg.mil

Fabienne Lord
Social Environmental Research Institute
fyh2@cisunix.unh.edu

Jimmy Martinez
Texas General Land Office
jimmy.a.martinez@glo.state.tx.us

Latarsha McQueen
U.S. Coast Guard
latarsha.s.mcqueen@uscg.mil

Francois Merlin
CEDRE
francois.merlin@cedre.fr

Amy Merten **
NOAA, Coastal Response Research Center
amy.merten@noaa.gov

Debbie Payton
NOAA, Emergency Response Division
debbie.payton@noaa.gov

Scott Pegau **
Oil Spill Recovery Institute
wspegau@pwssc.gen.ak.us

Chris Reddy
Woods Hole Oceanographic Institution
creddy@whoi.edu

Won Joon Shim
KORDI, South Sea Research Institute
wjshim@kordi.re.kr

Mike Sowby **
California Oil Spill Prevention & Response
msowby@ospr.dfg.ca.gov

Scott Stout
Newfields
sstout@newfields.com

** Designates Organizing Committee

Makram Suidan
University of Cincinnati
makram.suidan@uc.edu

Andy Tirpak
Texas Parks & Wildlife Department
andy.tirpak@tpwd.state.tx.us

Mike Unger
Virginia Institute of Marine Science
munger@vims.edu

Veronica Varela
U.S. Fish & Wildlife Service
veronica_varela@fws.gov

Al Venosa **
U.S. EPA
venosa.albert@epamail.epa.gov

Alison Watts
UNH, Stormwater Center
alison.watts@unh.edu

Greg Wilson
U.S. EPA
wilson.gregory@epa.gov

CRRC Staff

Kristin Bailey-McCarthy
Coastal Response Research Center
kristin.bailey-mccarthy@unh.edu

Joseph Cunningham
Coastal Response Research Center
joseph.cunningham@unh.edu

Kathy Mandsager
Coastal Response Research Center
kathy.mandsager@unh.edu

Kimberly Newman
Coastal Response Research Center
kim.newman@unh.edu

Recorders

Heather Ballestero
University of New Hampshire

Bill Boonazian
University of New Hampshire

Jarod Cournoyer
University of New Hampshire

David Gaylord
University of New Hampshire

Marcel Kozlowski
University of New Hampshire

Jennifer Morris
University of New Hampshire

Organizing Committee Members Not In Attendance

Buzz Martin **
Texas General Land Office
buzz.martin@glo.state.tx.us

Don Davis **
Louisiana Applied and Educational Oil Spill Research and Development Program
don.lsu.davis@gmail.com

Joseph Mullin **
U.S. Minerals Management Service
joseph.mullin@mms.gov

** Designates Organizing Committee

APPENDIX C

Research & Development Priorities:
Oil Spill Workshop

March 16 - 19, 2009
University of New Hampshire
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Spill Response During Disasters
This topic will address issues that are encountered during natural (e.g., earthquakes, hurricanes, floods) or anthropogenic (e.g., accidents) disasters resulting in nearshore and offshore oil spills. Planning and implementation gaps and health and safety issues will be the primary focus. Methodologies for assessments will also be addressed.

Response Technologies
This topic will address planning, implementation and effectiveness issues for response including: bioremediation, surface washing agents, solidifiers, sorbents, dispersants, and in-situ burning. Gaps in preparing and maintaining methods and technologies, keeping personnel trained in operating the equipment, and operations during spills will be covered. The focus will be on hardware and methodologies.

Acquisition, Synthesis and Management of Information
This theme will focus on practices and methodologies for accessing and using remote-sensing data, real-time observational data systems, electronic data collection via field surveys, and geographical information systems (GIS) to improve oil spill preparedness, response, assessment, and restoration decision-making. This will include: identification of research needs for hardware and software development for data collection, management, synthesis and interpretation; and hardware, software, and infrastructure requirements/methodologies to fully exploit web-based products and services.

Human Dimensions
Reducing social impact is paramount for any spill. This topic will address several questions. How does the response community minimize social impacts during a spill event and subsequent response activities? What strategies are used to address the long-term socio-economic effects a spill might have on a region's culture and vitality? How does the response community translate and incorporate social science research, methodologies, and initiatives into its individual and collective response plans? Where does social science research "fit" into the spill management structure, from trajectory models on one side of the ledger to hands-on interaction with individuals that possess the best "local knowledge" of potential human impacts on the other?

Ecological Monitoring and Recovery Following Spills
Understanding long-term ecological recovery following oil spills informs decisions from response to restoration. What monitoring methods/endpoints are able to cost-, time-, and ecologically-effectively capture environmental services that track natural resource services flowing from impacted habitats? Several questions will be addressed. What ecological factors affect recovery rates? What ecological 'metrics' can be applied using common assessment tools (e.g., Habitat Equivalency Analysis) that will help resource managers develop restoration projects that best compensate for lost resources?

BioFuels

Biofuels have hardly been discussed with respect to spill issues. Little is known about first generation biofuel blends, including ethanol/gasoline blends (e.g., E85) and biodiesel blends (e.g., B100, B20), in terms of spill response technologies and determination of fate and effects after a spill. In addition, the fate and effects of second generation biofuels (e.g., biobutanol, hydrotreated vegetable oils); crude oil fractions replacing nitrogen, oxygen, and sulfur with hydrogen; and synfuels (e.g., produced by the Fischer-Tropsch (FT) process) on the environment are unknown. Possible impacts of biofuel blends and synfuels on infrastructure (e.g., storage and dispensing equipment, materials compatibility with metals and gaskets) could lead to more spills if such materials are breached. Waste conversion to energy and processes such as algaeculture (which can produce orders of magnitude more oil per acre than vegetable oil crops)—may also have impacts during spills in the environment. Safety of production and water preservation through closed loop processes will also be discussed.

Ecological Effects of Oil Spills

This topic focuses on long-term effects of residual oil in the environment. What level and types of adverse effects result when oil remains? How much does residual oil matter? The impacts of an oil spill may be magnified, at least locally, by the clean-up technologies used and the effort placed on removing oil from the environment. Steps should be taken to develop a process to select clean-up endpoints, incorporating ecological, toxicological, legal and socio-economic criteria, that is protective without being over invasive (i.e., How Clean is Clean?). R&D projects to retroactively monitor sites of past incidents, in commonly encountered oiled ecosystems (nearshore and offshore environments) will be the focus. Ecological effects beyond species levels, and impacts on resources through effects on competition, predation and habitat function will be prioritized.

Environmental Forensics

Oil spills frequently occur in industrialized areas where there are numerous sources of PAHs, beyond those resulting from the specific incident (e.g., runoff, pyrogenic sources, oily wastes, natural seeps). Chemical fingerprinting to determine the source and extent of oil resulting from an incident are important for clean-up, assessment, recovery monitoring, and associated liability issues. Research needs for this topic will focus on analytical and interpretive methods to advance existing approaches to chemical fingerprinting of spilled oil in the environment.

APPENDIX D

Research & Development Priorities:
Oil Spill Workshop

March 16 - 19, 2009
University of New Hampshire
Durham, NH USA

A. **Spill Response During Disasters**
(Room 352)

Dave Fritz, Group Lead
Jennifer Morris, Recorder
William Conner
Dennis Hwang
Anthony Lloyd
Jimmy Martinez

B. **Response Technologies**
(Room 253)

Kurt Hansen, Group Lead
Bill Boornazian, Recorder
Tom Coolbaugh
Brent Koza
Ken Lee
Debbie Payton
Scott Pegau (via skype)
Makram Suidan

C. **Acquisition, Synthesis and Management of Information**
(Room 112)

Amy Merten, Group Lead
David Gaylord, Recorder
Toby Garfield
David Gisclair
John Kelley
Richard Knudsen (via skype)
Sankaran KrishnaRaj
Tom Lippmann

D. **Human Dimensions**
(Second Floor Lobby)

Doug Helton, Group Lead
Kimberly Newman, Recorder
David Chapman
David Kaiser
Scott Knoche
Fabienne Lord

E. **Ecological Monitoring & Recovery Following Spills**
(Room 238)

Dan Hahn, Group Lead
Marcel Kozlowski, Recorder
Mark Curry
Alex Hunt
Moonkoo Kim
Francois Merlin
Veronica Varela

F. **BioFuels**
(Room 251)

Bruce Hollebone, Group Lead
Joseph Cunningham, Recorder
Marc Hodges
Jeff Kimble
Steve Lehmann
Latarsha McQueen
Chris Reddy
Al Venosa
Greg Wilson

G. **Ecological Effects of Oil Spills**
(Room 240)

Lisa DiPinto, Group Lead
Jarod Cournoyer, Recorder
Jim Clark
Tracy Collier
Letitia Grenier
Peter Hodson
Won Joon Shim
Andy Tirpak
Mike Sowby (via skype)

H. **Environmental Forensics**
(Room 239)

Bob Haddad, Group Lead
Heather Ballestero, Recorder
Wayne Gronlund
Scott Stout
Mike Unger
Alison Watts