




Research & Development Priorities: Oil Spill Workshop
Durham, New Hampshire
November 4-6, 2003

Sponsoring Agencies:	National Oceanic and Atmospheric Administration University of New Hampshire
Report Issued:	April 6, 2004

UNIVERSITY OF NEW HAMPSHIRE

Introduction

Eight thousand oil and chemical spills were reported in U. S. waters in 2001. These spills, whether catastrophic or chronic, can have major environmental impacts, cause substantial disruption of recreational and commercial activities and have unexpected short and long term social, as well as economic, consequences. NOAA has conducted spill research since the T/V *Argo Merchant* ran aground off the Nantucket shoals in 1976. This research is in support of NOAA's role, as described in the National Oil and Hazardous Substances Pollution Contingency Plan, in providing technical and scientific support to the Coast Guard to mitigate the effects of spills on natural resources, as well as meeting NOAA's natural resource trustee responsibilities. As the Federal trustee for marine resources, NOAA is required by the Oil Pollution Act of 1990 (OPA) to act for the protection of those resources threatened or injured by the release of oil or other hazardous substances and to restore any injured resources to what they would be but for the release. Fulfillment of these responsibilities requires information on the interaction between the released material and natural resources; OPA directs NOAA, as well as the other trustee agencies to develop this information through research.

As funding for spill R&D has declined in recent years, partnerships among the relevant federal and state agencies, industry and academia have increased in importance. In order to encourage thinking about spill R&D, develop some agreement on research needs and foster partnerships, NOAA and the University of New Hampshire (UNH) hosted a three day workshop to identify applied science needs that could improve decision making across the continuum of oil spill preparedness, response and recovery. The focus of this work was on oil spills due to their frequency and effects on NOAA resources. It is anticipated, however, that many aspects of this work will be applicable to spills of other hazards in similar environments. The emphasis was on research that could change response and restoration practices and improve protection strategies and recovery trajectories for NOAA trust resources.

The workshop was held on UNH's Durham campus on November 4-6, 2003. A diverse group of more than 30 experts in the areas of spill process, response techniques, and habitat restoration participated in the workshop (see Appendix 1 for a list of workshop participants). The group included scientists from NOAA, U.S. Coast Guard, U.S. EPA, U.S. Minerals Management Service, state agencies, the private sector and academia. The goals of the workshop were to identify the gaps in knowledge of spill response and restoration and determine the best approach for addressing these gaps.

Discussion Categories

Insights gained during the workshop will be the foundation for a NOAA R&D strategic plan and a road map for funding decisions for the next five years. To take advantage of everyone's expertise during the workshop, small groups were formed to identify the R&D needs within each of six categories. The groups were asked to consider approaches to meet these needs and then prioritize them in terms of short- and long-term research objectives, cost effectiveness and ability to apply the results in response and restoration actions.

Six general discussion categories were considered during the workshop. The categories, described to workshop participants prior to the workshop in background material (Appendix 2), are:

Fate and Transport of Released Materials. Understanding fate and transport of oil allows a more precise evaluation of the consequences of response alternatives. Specific needs include:

- Resolving uncertainties about the short and long-term processes and rates affecting the properties of spilled oil in coastal environments.
- Improving our abilities to understand, measure, and model oil spill processes (including evaporation, emulsification and dispersion) in real-time or near real-time during oil spills.

Effects of Spills and Spill Response on Organisms. The short and long-term effects that environmentally realistic exposures and response activities may have on organisms remain a topic of primary importance. Questions of relative sensitivity, acute and chronic endpoints, exposure regimes, and chemically and naturally dispersed oil are some of the topics of interest. Metrics below the organismal level must have a direct link to individual level endpoints such as growth, reproduction, and mortality.

Effects of Spills and Spill Response on Habitats. Changes in the structure and function of habitats and communities resulting from the mortality or impairment of key species are an emerging field of study. These changes may cascade through a community as the result of a change in predator-prey relationships, changes in breeding schedules, loss of biogenically structured habitat etc.

Social and Economic Concerns and Needs. In spills affecting areas and habitats with high associated human use, it is not uncommon for the value of lost use to exceed the values/restoration costs associated with ecological injuries. Thus, it is critical to develop sound estimates of human use values (e.g. beach-going, hunting, recreational fishing, etc.) that can be adapted for spills of differing extent, severity and location. R&D efforts should also address the development of values and scaling approaches for regionally critical but less-studied human uses, such as wildlife and scenic viewing. Efforts should not focus exclusively on development of monetary values, but also address development of stated preference methodologies that allow direct tradeoffs across differing attributes of restoration projects. Another priority research area is quantifying users' value tradeoffs between different types of habitats, in order to better understand when cross-habitat restoration alternatives may be acceptable in addressing the effects of a spill.

Quantitative Metrics for Use in Injury Determination and Restoration. The metric used to quantify changes in the environment after a spill fundamentally affects the bottom line of whether impact and recovery have occurred. The ideal metric would be ecologically relevant, sensitive, cost-effective to implement, widely available and provide information of statistical significance and known uncertainty suitable for scaling and monitoring restoration. That is, this metric would be capable not only of clearly indicating a change from baseline but would also provide defensible, numerical information about magnitude of this change. In addition, it would be sufficiently sensitive that it could also be used to monitor recovery after restoration or remediation and indicate the success (or lack thereof) of these actions.

Restoration Methods. As a Natural Resource Trustee, NOAA must restore resources injured or lost due to oil spills. Methods to do this, however, are only slowly being developed. A primary goal for restoration is to minimize the need for dramatic restoration methods by improving predictive capabilities in correlating response technologies with restoration costs. The lack of reasonable and cost effective methods for the restoration of an injured resource can impact our ability to justify the inclusion of that resource in the damage assessment. All restoration methods or technologies need to prescribe scientifically defensible and measurable metrics to assess the success of the research methods.

Each of five breakout groups (A-E) had the opportunity to discuss each category and develop a list of research topics that might fill identified knowledge gaps. The groups were asked to rank each topic they suggested based on technical feasibility, potential impact on resource recovery decisions, time required to complete and cost. Groups were also asked to complete a description of each topic they proposed so that their thoughts could be captured for further NOAA use after the workshop (e.g., D7 – Better Understanding and Estimates of Non-Market Value of Resources/Use Loss from Spills). At the conclusion of the workshop, a total of 84 topics had been discussed during the small group meetings (see Appendix 3 for the list of generated topics), a portion of which had also been the focus of whole group discussions. Some topic titles listed in Appendix 3 have been modified to better reflect the topic descriptions provided.

Research Topic Synthesis

Although topic prioritization was a key point of discussion during the workshop, post workshop topic reviews have focused on evaluating the topics without regard to their initial ranking. As many of the topics overlap or are similar, they have been grouped into themes (see Appendix 4 for the workshop themes and relevant topics). The themes include:

- Physical Transport Forecasting
- Oil Weathering: Data Development and Modeling
- Ecosystem Services: Identification and Valuation
- Communication: Public and Stakeholder Participation in Response and Restoration
- Restoration Review
- Chronic Effects of Oil:

    1. Individual
    2. Habitat
- Methods and Techniques
- New Tools for Restoration and Recovery
- Others

A synthesis has been prepared for each theme. Each synthesis includes a statement regarding the theme, some specific research needs identified during the workshop, potential R&D outcomes, and a list of the relevant topic titles. These syntheses were developed to help in redefining areas of need. Syntheses are provided in Appendix 5.

Workshop Outcome

The Workshop offered a rare opportunity for the people involved in spill response to discuss the state of this art with their colleagues in an informal setting. The formation of new partnerships in areas of shared interest is already underway. NOAA will use the research areas and topics identified in this Workshop as the framework for a cooperative strategy to meet R&D needs in spill response and restoration and will continue to foster partnerships with other Federal agencies, industry, non-governmental organizations (NGOs) and other interested parties.

Appendix 1

Workshop Attendance List
Group Assignments

Workshop Attendance List

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Appendix 2

Background Material

NOAA/UNH R&D Workshop
Background Material

NOAA and the University of New Hampshire (UNH) will convene an oil spill R&D workshop in Durham, NH, November 4 – 6, 2003. The workshop will bring together thirty experts from academia, federal and state government, and industry to identify applied research needs and priorities to improve decision making throughout the oil spill continuum, i.e., preparedness, active response, and subsequent restoration activities. The following information is provided as a starting point for workshop dialogue.

Background

Eight thousand oil and chemical spills were reported in the U.S. during 2001. Spills into our coastal waters, whether catastrophic or chronic, can have major environmental impacts and cause substantial disruption of recreational and commercial activities. As people have seen from recent events like the *T/V Erika* in France and the *T/V Prestige* in Spain, marine spills are difficult to prevent, contain, and clean up. The impacts of these spills are economic and social as well as environmental. For example, it is estimated that the losses to fishing and aquaculture resulting from the *T/V Prestige* spill will total between $87 and $272 million.

NOAA has conducted spill research since the *T/V Argo Merchant* sank off the Nantucket shoals in 1976. Under the National Oil and Hazardous Substances Pollution Contingency Plan, NOAA provides technical and scientific support to the Coast Guard for spill prevention, preparedness and response to mitigate the effects of spills on the environment. NOAA is also identified as a trustee for living marine resources in the Oil Pollution Act of 1990 (OPA). As such, NOAA is required to act for the protection of those resources threatened or injured by the release of oil or other hazardous substances, and to restore injured resources to their state in the absence of the release.

Fulfillment of NOAA's responsibilities requires information on the characteristics of the interaction between the released material and natural resources. NOAA's primary areas of interest include coastal and marine regions and extend to estuaries, rivers and lakes that provide habitat for trust resources. OPA directs NOAA, among other federal agencies, to conduct research in these areas to mitigate the impact of releases on the NOAA trust resources. The Office of Response and Restoration (OR&R) has actively developed operationally relevant data and information to forecast the movement of surface and subsurface oil and chemical spills, as well as the physical, chemical and toxicological changes in the released material. OR&R monitors the influence of various response options, (*e.g.*, mechanical, *in situ* burning, dispersant use, and bioremediation) on the rate of recovery of impacted resources to their state prior to the release and subsequent response. Currently, OR&R uses this information to evaluate short- and long-term effects on resources and to develop response strategies that increase the rate and magnitude of recovery. Other areas of research interest include metrics to quantify injury and restoration in oiled habitats and restoration scaling.

Historically, funding for oil spill R&D has resembled a "feast or famine" cycle. After a major incident, public interest results in a short-term infusion of cash. This cyclical nature of funding seems to hold true for the private as well as the public sectors. The last major funding cycle in the US followed the grounding of the *T/V Exxon Valdez* and resulted in the passage of OPA and a comprehensive program of oil pollution research, technology development and implementation among the Federal agencies. While the actual funding appropriated for this ambitious effort never approached the authorized levels, NOAA, the Minerals Management Service, U.S. Coast Guard, and the Environmental Protection Agency continue to support limited research activities.

The private sector responded similarly with the formation of the Marine Spill Response Corporation (MSRC), which funded approximately $30 million worth of R&D activities from 1990 to 1995 then discontinued funding as research money declined. The American Petroleum Institute continues to conduct some private sector funded research.

In early 2003, the National Research Council (NRC) published "Oil in the Sea: Inputs, Fates and Effects" which identified specific research, development and monitoring needs relevant to NOAA responsibilities, and provided a catalyst for comprehensively examining NOAA's R&D requirements. To help establish R&D priorities, NOAA and the University of New Hampshire are hosting a workshop to identify applied science needs that will improve decision making across the continuum of oil spill preparedness, response and recovery. The initial focus of this work is on oil spills due to their frequency and effects on NOAA resources. We anticipate that many aspects of this work will be applicable to spills of other hazards in similar environments. The emphasis will be on research that could change response and restoration practices and improve protection strategies and recovery trajectories for NOAA trust resources.

We have identified six general topic areas for consideration during the workshop. These topics, and potentially others, will provide an initial point of discussion.

Fate and Transport of Released Materials. Understanding fate and transport of oil allows a more precise evaluation of the consequences of response alternatives. Specific needs include:

- Resolving uncertainties about the short and long-term processes and rates affecting the properties of spilled oil in coastal environments. This includes the effect of physical and chemical weathering on transport and biological impacts.
- Improving our abilities to understand, measure, and model oil spill processes (including evaporation, emulsification and dispersion) in real-time or near real-time during oil spills. For example investigating the fate of naturally or chemically dispersed oil in shallow or poorly mixed waters, including estuaries and embayments.

Effects of Spills and Spill Response on Organisms. The short and long-term effects that environmentally realistic exposures and response activities may have on organisms remain a topic of primary importance. Questions of relative sensitivity, acute and chronic endpoints, exposure regimes, and chemically and naturally dispersed oil are some of the topics of interest. Metrics below the organismal level must have a direct link to individual level endpoints such as growth, reproduction, and mortality. Such parameters will improve our ability to recommend response strategies, minimize future impacts, reduce restoration requirements and quantify performance.

Effects of Spills and Spill Response on Habitats. Oil and response impacts can occur at larger scales than the organism level. They can also affect functional aspects at the habitat level. For example, an oil spill may affect marsh plants by either killing them outright or impairing growth or reproduction. An oil spill may also affect marsh habitat by reducing cover or food items for wildlife and other occupants or by changing the structure of the plant community in such a fashion as to make it less desirable.

Habitats defined in other NOAA programs include:

> Salt marshes, tidal flats, mangroves, sand beaches, gravel shorelines rocky shorelines, seagrass beds, algal beds, muddy bottoms, oyster reefs, sand bottoms, coral reefs, hard/live bottoms, coastal shelf, estuaries.

Social and Economic Concerns and Needs. In spills affecting areas and habitats with high associated human use, it is not uncommon for the value of lost use to exceed the values/restoration costs associated with ecological injuries. Thus, it is critical to develop sound estimates of human use values (e.g. beach-going, hunting, recreational fishing, etc.) that can be adapted for spills of differing extent, severity and location. R&D efforts should also address the development of values and scaling approaches for regionally critical but less-studied human uses, such as wildlife and scenic viewing. Efforts should not focus exclusively on development of monetary values, but also address development of stated preference methodologies that allow direct tradeoffs across differing attributes of restoration projects. Another priority research area is quantifying users' value tradeoffs between different types of habitats, in order to better understand when cross-habitat restoration alternatives may be acceptable in addressing the effects of a spill.

Quantitative Metrics for Use in Injury Determination and Restoration. The metric used to quantify changes in the environment after a spill fundamentally affects the bottom line of whether impact and recovery have occurred. The ideal metric would be ecologically relevant, sensitive; cost-effective to implement; widely available and provide information of statistical significance and known uncertainty suitable for scaling and monitoring restoration. That is, this metric would be capable not only of clearly indicating a change from baseline but would also provide defensible, numerical information about magnitude of this change. In addition, it would be sufficiently sensitive that it could also be used to monitor recovery after restoration or remediation and indicate the success (or lack thereof) of these actions.

Current metrics used for injury identification and quantification are a varied lot, ranging from mortality counts to rates of nutrient cycling. Some are more useful for some types of injuries and resources than others. For example, in a marsh impacted by an oil spill a metric such as change in percent vegetative cover can be easily and consistently measured and correlated with both visual and chemical measurements of oil concentration. If the impact is not too severe, the metric will return to baseline in a reasonable time frame. However, oil may remain buried in the sediments for decades and other metrics, e.g. rate of nutrient cycling and percent underground biomass, may still be depressed, leading to questions as to whether or not the resource has completely recovered.

Restoration Methods. OPA requires NOAA to restore resources injured or lost due to oil spills, including impacts from response technologies, to what they would have been in the absence of the release. Methods to do this, however, have only been considered since the passage of OPA. A primary goal for restoration is to minimize the need for dramatic restoration methods by improving predictive capabilities in correlating response technologies with restoration costs. The lack of reasonable and cost-effective methods for the restoration of an injured resource can impact our ability to justify the inclusion of that resource in the damage assessment. Therefore, preventative approaches and primary restoration techniques are of interest. R&D topics should focus on the most vulnerable habitat types (e.g., mangroves, corals, salt marsh, and other quiescent environments). All restoration methods or technologies need to prescribe scientifically defensible and measurable metrics to assess the success of the research methods.

Workshop Outcomes:

Insights gained during the UNH/NOAA workshop will be the foundation for NOAA's Spill Response R&D strategic plan and a road map for funding decisions for the next five years. To take advantage of everyone's expertise during the workshop, small groups will be formed to identify the R&D needs within each of the above categories. The groups will be asked to consider approaches to meet these needs, and then prioritize needs in terms of short- and long-term research objectives, cost effectiveness and ability to apply the results in response and restoration actions.

In early 2004, we will provide the first draft of the R&D strategy to workshop participants for review and comment. We will solicit input from stakeholders including Federal and state governments, industry and non-governmental organizations. We will consider input through a variety of peer-review mechanisms including hosting future workshops, participating in appropriate conferences, and other venues. The final strategy will provide the basis for future research funded through our cooperative relationship with the University of New Hampshire Environmental Research Group.

Definitions:

To provide a common and consistent basis for discussions, the definitions used throughout the workshop will be those from the OPA Natural Resource Damage Assessment regulations. That is:

- **Baseline** means the condition of the natural resources and services that would have existed had the incident not occurred.
- **Damages** mean the value in dollars of the restoration needed to restore the injured or lost resources and services.
- **Injury** means an observable or measurable adverse change in a natural resource or impairment of a natural resource service, Injury may occur directly or indirectly to a natural resource and/or service. Injury incorporates the terms “destruction,” “loss,” and “loss of use’ as provided in OPA.
- **Recovery** means the return of injured natural resources and services to baseline.
- **Restoration** means any action (or alternative), or combination of actions (or alternatives), to restore, rehabilitate, replace, or acquire the equivalent of injured natural resources and services.
- **Services** mean the functions performed by a natural resource for the benefit of another natural resource and/or the public.

Appendix 3

Workshop Topics

ID	Title	Description
Fate and Transport		
C1	Model Enhancements (Shoreline and Near Shore Interaction, 3D Models)	We grouped several subject areas related to improving the performance of physical transport models into this one category: I.e., accommodation of different oil types, oil interactions with suspended particulates, 3-D capabilities, differential spatial scales, calibration and validation in the field, and intercomparisons with other existing modeling environments.
A1	Protocols for Modeling (2D/3D, Integration of Real Time Data)	Define data/method needs to improve trajectory modeling, 2D, 3D (surface and subsurface), real time comparison/validation, integrate surface and fate modeling. Include checklists of monitoring needs. Develop standards to validate models. More site specific models.
B1	Deep Water Blowout Models	Deep Water Blowouts - Droplet size, fate of dissolvables: How thick on surfacing: Deep wells are associated with high flow rates (profitable), but a blowout may take 60-90 days to control. Issue #1 - droplet size (droplets: small rises slow, large rises fast) and oil density. Issue #2 - what happens to dissolvable components (f[sfc/vol ratio]) which is tied to droplet size as well? Issue #3 - how thick is oil upon surfacing; when will it coalesce? Not much faith in current models. LA - 90% of wells are deep wells off the coast; huge issue - not only where it comes up but where it goes (i.e., what resources are threatened and where).
B4	Strategic Planning Models (Stochastic Predictions)	Strategic Plan Models (Climatology): Develop statistics for strategically planning for different risks, their location, and therefore who has what voice at the table. Develop stats for risk profiles and pre-position equipment. Makes a case for cross-walking with other NOAA LO to bring in climatological assessments. Which requires improved knowledge of net advection; atmosphere/ocean linkage. This would improve understanding of variability of spill behavior.
C5	Life History of Oil in Shoreline Habitats	Basically, fate of stranded oil, or Life History of Shoreline Oiling. Bundling of several questions and considerations related to subsurface (i.e., buried) oil and other interactions with substrate & particles along the shoreline: How did it get there? How to get rid of it? Should you get rid of it? How to find it and quantify it? How long will it last? Influence of different habitats, characteristics of the forces of nature that will re-expose subsurface oil.

ID	Title	Description
D1	Long Term Fate of Oil in Water Column and Subtidal Environments	Long term fate of oil that does not remain on the surface of water or stranded on intertidal environments. Includes fate of naturally/chemically dispersed oil with fine suspended or bottom sediments (Key factor involved is stickiness or adhesive properties of the oil and the grain size and composition of the sediment including organic and mineral content). Encompasses processes moving oil from shore habitats back to near shore surface and subtidal environments. Degradation of oil after it is adhered to sediments, both chemical and biological.
E1	Fate and Transport of Chemically Dispersed Oil	Focus on the long term. Look at solubility, micells, tar balls, photolysis, and biodegradability. Plug into models. EPA may co-fund (Albert Venosa is doing work in this area).
E2	Effect of Habitat Type on Fate and Transport Processes	Upon grounding, how do the physical and biological interactions at the grounding site affect degradation/persistence/toxicity? May involve a literature review. Could involve small study sites or spills of opportunity. Mecocosm work may be useful too.
E3	Synthesis of Fate/Transport Processes	Directed Synthesis and Sensitivity Analysis of Spreading, Advection, Evaporation, Mixing…to Improve Forecast: Take Alan's list, literature search and do sensitivity analyses on fate/transport processes, to improve trajectory analysis/transport models (hind casting needed) on spills. Some lab work. See long term fate weathering workshop.
E4	Develop Linkages to Incorporate Observing System Data	Linkage to Systems of Observation: F/T models and trajectory people need instant access to real time data on ocean "state" (easy access, good useable data in proper forum) linkage. Encourage liaison.
A2	Emulsification Models	Limitation in mass balance models.
B3	Near Real Time Tactical Forecasting	Near Real-Time Tactical Forecasting with New Technology: Include an assessment of the feasibility of mapping circulation in the path of spills with such equipment as drift buoys, LIDAR, Doppler radar, mapping technologies, etc.; to provide a better forecast of currents at improved spatial and temporal scales.
C3	Life History of an Oil Spill Droplet in the Water Column	Big Picture perspective and Deep Thinking. We considered many of the physical and biological processes that could influence the fate of oil in the water column, including the role of response actions, and decided that the most useful concept to frame the sum of these was to view the research as defining the Life History of an Oil Droplet. This would integrate physical parameters, degradation processes, vertical and horizontal transport mechanisms, and the influence of response into a more relevant package of results.

ID	Title	Description
D2	Emulsification Process Studies	Fate of oil as it relates to emulsification. Properties of oil that impact emulsification - oil properties including stickiness and density, sea state, temperature, and wave energy. Emulsification research needed at conceptual and laboratory scales. Important to applied modeling used to predict appropriate response actions; existing predictive tools are not very accurate. Will it emulsify, how quickly will it emulsify, how much will it emulsify?
A3	Evaporation Models	Evaporation modeling with wider range of temperature, wind speed, etc.
B2	Circulation Models for Convergence/Divergence Processes	Convergence Sites (circulation models): Identify location, intensity, frequency of convergence zones both as sentinels for otherwise undetectable oil (highly dispersed; convergence sites collect oil); but also as a high risk site for biota.
C2	Forecasting Oil Transport and Fate Including Stranding	Big Picture Thinking: We defined the broad category of Forecasting to include a number of different potential research program activities. These included: near shore and/or shoreline characteristics influencing the movement and stranding of oil, data on oil movement, spatial resolution, the role of models and remote sensing to improve forecasts, and special considerations for oil in/under ice.
C4	Practical Approaches to Detect Oil	Development, improvement, or validation of oil detection capabilities. Most of these are related to remote sensing, i.e., open water, nighttime, or under ice. However, also included in our grouping are other detection approaches such as reliable portable detectors of oil on the shoreline for beach surveys.
Habitat Effects		
A7	Low-Level Residual Oil Across Species and Habitats	1) Validate 1 ppb for sublethal effects for same habitat/organism and other habitat types. 2) What does this mean if it is true? 3) What is the mode of toxicity? 4) What does background mean? Norwegians and Auke Bay studies.
A8	Validate Habitat-Specific Cleanup	Verify 1 ppb and what does this mean? Validate J. Michel and B. Benggio paper. Late 1990s 1) Based on geomorphology 2) Qualitative vs. quantitative 3) Do we need to be more quantitative and biologically oriented? Use new information. 4) How clean does the intertidal need to be? Revisiting paper, incorporating 1 ppb, how does this change how we approach how clean is clean? Validate assumptions that were made; does this still work? Based on Net environmental benefit. Critical review.
D5	Classification and Understanding Initial Loss of Services and Process of Recovery of Key Habitats	Developing conceptual models of service loss and recovery from key habitats. Develop information necessary to parameterize recovery models. Key habitats include: Structurally vulnerable habitats such as mangroves, sand beach/mud flats, salt marshes/seagrass beds, tundra shorelines; Very sensitive habitats like coral reefs and other hard bottom habitats. Need to understand both degraded and pristine environments for understanding initial loss of services.

ID	Title	Description
E10	Effect of Habitat Type on Fate and Transformation	Intertidal and shallow subtidal habitats (cobbles, pebbles, sands, mud, mussel beds, mangroves and marshes). How does habitat dictate rates and extent of degradation and transformation? Bioavailability and ecotoxicity effects on biota. Would involve biologists, toxicologists, and geochemists. Upon grounding, how do the physical and biological interactions at the grounding site affect degradation/persistence/toxicity? May involve a literature review. Could involve small study sites or spills of opportunity. Mesocosm work may be useful too. Will influence response decisions and need for restoration.
B10	Washing Agent Effects on Habitats	What are the consequences across communities and latitudes (temperature regimes, salinities); issues of recovery of post-washing effluent. Key is the effect of washing agents on habitats and ecosystems, especially protected and economically valuable species inhabiting these habitats, and food webs. Another avenue would be examination of bacterial communities for bioremediation; particularly deep water communities in place of washing agents.
C9	Spatial and Temporal Scale Differences	The methodology will provide a basis to plan data collection and analysis on habitat impacts using small scale (<km) sampling strategies in order to more fully capture the diversity of biota present along shorelines. Currently, there is a mismatch between the information conveyed in typical ESI databases (km scale characterizations) and real world, small scale or transiently important biota in near shore or shoreline habitats. Data will be collected on smaller scale temporal, spatial extent (shoreline-lateral and near shore depth). Understanding the diversity of communities will affect characterization of sensitivity and vulnerability, as well as assisting in understanding the rates and scale of recovery.
C10	Effect of Dispersed and Undispersed Oil on Different Habitats in Different Regions	Effects of dispersed oil plumes and non-dispersed floating oil coming into shoreline or near shore habitats needs to be evaluated over a variety of habitat types (rocky intertidal, soft bottoms, eel grass, kelp, stratified estuaries, etc). Research should address habitats by region (arctic, tropical, and in between). Efforts would be focused on response and recovery issues controlled by the fate of the oil. Studies would be focused on response of the habitat structure and function to exposure of the oil.
C11	Source-Sink Info for Different Habitats	Apply life-history strategies to characterize source-sink. Apply circulation studies to look at distributions.
C12	Retrospective Analysis of Response Actions in Sensitive Habitats	Efforts will be focused on retrospective assessment of impacts of foot traffic and equipment deployed for shoreline, near shore response and clean-up efforts. By conducting detailed NEBA and cost benefit analysis of the various approaches and their impacts, we can gain insights into best practices for response, quantify incentives for development of new, less intrusive equipment or new, more effective response alternative. Research will involve development and quantitative basis for recommending best practices, using regional approaches.

ID	Title	Description
D6	Long-Term Fate of Oil in Key Habitats of Concern	Key habitats include: Structurally vulnerable habitats such as mangroves, sand beach/mud flats, salt marshes/seagrass beds, tundra shorelines; Very sensitive habitats like coral reefs and other hard bottom habitats. Chemical, physical (photooxidation) and biological weathering of oil in habitat. What is long term oil budget in the habitat? Links to D1 project. How does residual oil affect habitat function?
B11	Habitat Recovery Rates	Encourage input of information on habitat recovery strategies into remediation/spill response actions. This topic crosses most NOAA trust resources (sessile). This understanding is a driver in the restoration process - but weakness is that this needs to be actively fit into the remediation/spill response action. Important: Need partnership between folks experienced in the remediation/response action and the recovery dynamics of injured ecosystems.
E11	Ecosystem-Based Approach to Understanding Oil Ecotoxicology	Incorporate better understanding of trophic and habitat linkages among organisms, into models (food web, habitat dependency) looking at cascading indirect effects. Two ways: (1) change in abundance of predator/prey/habitat and (2) transfer of contaminants through consumption. Spills of opportunity studies. Philosophy change within NOAA - may be longer term view. Relate to ecotoxicity risk assessment modeling.
B9	Mangrove Restoration and Recovery Rates	Although limited geographically, they are vulnerable and difficult to access in terms of cleaning - and cleaning might make things worse. Some species are more susceptible than others. Recovery rates may be poorly understood. Questions about level of contamination that must be reached before effective restoration can occur. Questions about restoration stock availability. Little information in the US - and only a few instances abroad (Panama, Australia, Kuwait). Recovery rates X contamination X spp X remediation. Revisiting restoration sites with emphasis on contaminated, vs. mechanically disturbed sites needs to be evaluated; collate extant reports/data.
E12	Synthesis of Oil in Ice Habitats	Directed synthesis. Develop response guide, develop restoration guide. OCSEAP is a source. International literature (e.g., Canadian and Norwegian) works need to be examined.
B8	Natural Seeps	Natural Seeps: Examination of bacterial communities for bioremediation; particularly deep water communities. Also, what is the role of natural seeps in the contribution to deepwater ecology and food webs? High partnership opportunities with OE, Industry, MMS. Has high potential for natural laboratory for understanding effects of oil on deepwater habitats.
Organism Effects		
E6	Data Synthesis of Short Term Acute Exposure to Dispersed Oil or Dispersant	Pull together existing data in a format useful for making response decisions for chemical counter measures, identify gaps, may lead to new R&D. Make a guidance document.

ID	Title	Description
A4	Effects of Dispersed Oil on Species of Concern	Dispersed oil (chemically and naturally) - long term, chronic exposure/effects of dispersed oil. Exposures to - inverts/herring, anadromous fish (age/time of year), corals, local issues/spp. -- metrics of effects suborganismal to individual level, reproduction, fecundity, lifespan, biomarkers. Develop assay for measuring, like Microtox --> but more "sensitive" --> expand CROSERF. Bioavailability issues, enhanced biodegradation, etc.
B6	Chronic Effects of Low Oil Concentrations	Focus heretofore has been on acute effects. Long-term exposure issues, low concentrations of dispersed oil with focus on vulnerable ontogenetic stages. Need to come out of lab and establish a causative, not merely correlative link between oil and effects on organisms.
C6	Long-Term Effects of Short-Term and Long-Term Exposures	Testing will involve a range of environmentally relevant exposure scenarios (mode and duration of exposure) for species of interest over a variety of geographic regions. Tests will involve short-term and long term exposure duration and impacts on organisms studies for survival, growth and reproductive endpoints. Testing could begin with existing database on short-term exposure, acute effects used for dispersant studies, and expand to assessment of long-term biological impacts from these shore-term exposures, compared to long-term exposures. It will be necessary to develop a robust database representative of species from numerous geographic areas and exposure regimes form various response technologies.
C7	Defining Baseline of Natural Variability in Organisms and Communities	There are existing sampling strategies used by various state or federal resource agencies to characterize the health of local populations or communities. This research would evaluate various ongoing strategies and other alternatives to characterize pre-spill conditions and the nature of variance over time and space for endpoints relevant to individual organisms to community metrics. Focus would be species of significance due to environmental relevance (keystone species) or those of importance defined by commercial interest or ecological importance.
C8	Physical Effects of Dispersed Oil in Biological Matrices (Feather, Fur, Epidermis, Algal Surfaces)	Tests would involve adhesion studies of physically and chemically dispersed oil to fur, feathers and other biological substrates of interest with a focus on how adhesion changes over time (hours to days). The data would be developed with an eye to determine when dispersed oil droplets began to adhere to substrates similar to physically dispersed oil, and when sorption becomes a means of enhanced exposure.

ID	Title	Description
C23	Species and Life Stage Sensitivities	A common technique in ecological risk assessment is utilization of species sensitivity distributions to evaluate potential impacts from a range of exposure scenarios. This work will focus on evaluations of data for a wide range of species representative of various phylogenetic units and life history stages. The focus will be on determining where we are getting data on potential impacts on organisms using environmentally relevant characterizations of the range so species exposed and the life stages exposed. Part of the research will be to determine if the current environmental toxicology focus on developing data for the most sensitive species, most sensitive life stage are providing an adequate basis to characterize the potential ecological impact of exposure to oil spills.
D3	Quantitative Sublethal Effects on Organisms (Indicators, Definition of Injury)	What are the relevant endpoints -growth, behavior, inhibit reproduction, physiological aberrations? What are appropriate organisms to use as indicators for different habitats? Long term consequences of short term exposures and also risk from residual oiling? Research needed on what is the link between elevated body burden in an organism and injury to the organism. Much work to be done in the lab.
B5	Effects of Dispersed Oil on Species of Concern	Effect of dispersed oil on organisms. How is highly dispersed material utilized by organisms, effects on respiration, how is it taken up, what are the end-products, what is the effect on benthic primary production? What are the effects outside of State waters - particularly on deep water food webs? Shift focus from toxicological studies to ecosystem effects/food web issues.
B7	Cascading System Effects as a Result of Organism Impacts	Cascade effects on organisms: selective removal of key member (with particular emphasis on susceptible ontogenetic stages); otherwise unanticipated effects of a spp leads to larger scale loss of other services. Creates opportunity for invasive species, loss of related ecosystem services. Fits in with concepts of ecosystem engineers.
E5	Long-Term Chronic Exposure (Dispersed and Undispersed Oil)	Long Term Chronic Exposure Both Directly and Indirectly Through Food Chains: The focus will be on fish eggs (direct), bottom-feeding birds/mammals (benthic foragers) (indirect), and the development and reproductive impairments (genetic effects, maternal effects).
E8	Effects of Oil on Foraminifera and Other Microbenthic Indicator Species	Foraminifera and Other Microbenthos as Indicator Species: See Dave Scott. Dalhousie University work as lead.
E9	Analytical Methods and Identification of Specific Compounds of Interest	Analytical Methods and Compounds of Interest: What is in the TPH hump? Does TPH hump mislead? Who are the bad actors? How does composition of compound change over time? Garbage in, garbage out.
A5	Metrics of Effects (Biomarkers, Impacts of Response Actions)	Metrics of effects suborganismal to individual level, reproduction, fecundity, lifespan, biomarkers. Develop assay for measuring, like Microtox - but more "sensitive". Effects of response actions on protected/endangered spp.

ID	Title	Description
E7	Effects of Oil on Reptiles	Effects of Oil on Turtles and Reptiles: Need info on acute toxicity to oil, effects of chronic exposure, value of rehabilitation.
Quantitative Metrics		
B13	Applying Performance Metrics to Evaluate Response Effectiveness (Metric Vetting)	Part of the issue is getting a handle on what metrics are in play so as to help those in the response process understand and respond to public perception. A balance is required to obtain scientific rigor and objective assessments and involve/satisfy and educate stakeholders. Contemplate a workshop to sort out important metrics (strategic solutions by geographic region/stakeholder group); product is guidance manual and more focused research agenda. Objective would be to seek a metric that is satisfies stakeholders but provides scientific defensibility. Also, explore the tradeoff of metric selection among popular (informed) opinions and those that serve to accurately represent ecosystem responses. One goal would be to develop a metric assessment protocol (via workshop?) that answers whether a metric relates to a desirable characteristic. An end product would be the establishment of regional metrics that are scientifically valid and have been vetted with the stakeholders.
A12	Wildlife Multipliers (Phase 1-Controling Factors/Confidence Limits, Phase 2-Protocol)	What are the controlling factors and confidence limits in determining wildlife multipliers for injury assessment? Protocols for randomized search and recovery of oiled wildlife (dead and alive). Statistical rigor in assessment, national standard. Can you do this in different regions?
A14	Methods to Differentiate Between Spill Effects and Natural Variability/Stressors	Detect oil effects vs. natural stressors. Beach profiles, prespill measurements, community structure and function.
C17	Develop Conceptual Models of Ecosystems	We consider this activity to be the first step in a process for defining and refining metrics for use in impact assessment and restoration. This would entail listing systems/habitats of interest and referring to the literature to define functional relationships among major components, keystone species, etc. This is a necessary predecessor to exploring potential metrics for measuring health and impact, because the exercise will determine key areas of vulnerability, appropriate definitions of baseline, interactions among components, potential for cascading impacts from disturbance, and relevant endpoints to quantify condition. Example from the opening talks is Mark Fonseca's seagrass experience, in which more refined understanding of how Halophile behaved as an opportunistic species resulted in the realization that it was below-ground biomass that was more relevant for reflecting that system's recovery as opposed to above-ground biomass.

ID	Title	Description
C19	In Situ Instrumentation and Materials for Defining Exposure Over Time	This activity would support development and field validation of in situ instrumentation or synthetic materials that could be used to monitor exposure (presence) of specific contaminants of interest over time. These materials would provide a readily available, consistent, cost-effective means of measuring environmental concentrations and thus could be deployed to determine baseline conditions, areas of impact, and areas meeting cleanup or recovery criteria.
D9	Defining and Measuring the End Point of Recovery	What components of a habitat are most closely associated with services that the habitat provides to the ecosystem, specifically with respect to those functions that would be adversely affected by an oil spill? The next question is how to measure those components. How do you account for the natural variability inherent in the habitat absent the spill? Might involve sub-organism level measures in addition to or instead of population or habitat level measures. Reference sites important but sometimes difficult to find. Establish reference sites prespill to get a baseline data pattern, especially if spatial reference sites will be hard to find in the event of a spill. Area of investigation is to develop methods of investigation to define the end point of recovery after a spill in the absence of reference sites or site specific prespill data. Is definition of recovery the recovery of all oiled shorelines from that spill or is it recovery of the particular sensitive shoreline habitats that were damaged by the spill? A comprehensive retrospective analysis of restoration/recovery success of previously done restoration sites. What is the "no effect level" of oil contamination in a habitat? Area to fund, a workshop that would address the issue of reference sites: How do you choose? What if none can be found? How do you define reference sites? How do you define/design a recovery study from the point of view of reference sites?
E16	Measures of Microbial Services	What are measures of microbial services: Measures of carbon metabolism; S, N, P cycling; community structure. Signatures for pre-spill impacted community, recovery community. PCR/DGGE/Probes; Fatty acid profiles (FAME). Stable isotopes.
A13	Identifying Toxicologically-Relevant Analytes by Habitat and Organism	Standard suite of parameters to measure. Toxicologically relevant analytes. GRP for chemical, biological sampling. By habitat and organism. Right now, can't compare.
C18	Research into Robust Markers Diagnostic of Petroleum Impacts, Validated	Second step in the process for defining or improving metrics for injury assessment and restoration: research into robust diagnostic markers of petroleum impacts, including validation. This will not be an easy or straightforward task, and we believe that a logical first step would be to request a workshop of experts to canvass what techniques are available and appropriate to satisfy NOAA expectations and requirements. Workshop would be used to focus and frame RFPs for actual research.
E18	Metrics for Trophic Modification and Augmentation	Fate of carbon, trace through food web 13C/12C (N too?). Look at ratio as a tracer.

ID	Title	Description
E17	Sensitive Indicator Species for Injury and Recovery	Need new organisms/tests for damage assessment. Existing may not be sensitive enough. Are we looking at the right ones? Interpret whole community. Questioning whether we are using current ones correctly. Environmental toxicity tests like microtox. Space/time.
Restoration Methods		
B14	Evaluation and Forecasting of Restoration Success	Develop ways to accrue this information and winnow out the non-workable and evaluate trade-offs. Search for cost-effective synergisms (e.g. bird stakes), revisit sites. Synthesis with site visits of types of restoration efforts with overlapping objectives across time since implementation. Forecasting restoration success: fill the gap between restoration techniques and forecasting success based on environmental conditions; improve site selection for off-site selection; (i.e.: does this method work at this site under these conditions?). Use output from retrospective analyses. Use to re-route efforts to more effective use of resources. Create a decision protocol/model of site selection and methods match up.
D10	Evaluating Success, Potential Negative Impact, Total Cost of Restoration Projects	What are the comparative success, possible adverse effects, and total cost of restoration methods that have been applied already for each give habitat? Outcome could be a matrix that shows the cost compared to success of restoration methods for specific habitats. This would require a retrospective analysis -follow up - existing restoration projects that have been implemented for both spill and non spill projects. Should consider whether a specific restoration approach improves on "no action" alternative? Investigate developing a Bayesian approach to decisions for selection of restoration methods, incorporate new information in an iterative approach for subsequent decisions. Bayesian approach includes accumulating new information based on lessons learned from previous decisions.
A9	Advanced Response Technologies	Near shore use of advanced response technology. 1) Studies to address use of dispersants in near shore, "better" use of shoreline cleaners vs. mechanical damage. 2) Test variety of shoreline cleaners. Approach: mesocosm, but not "shoe-string" budget.
C20	Metrics for Restoration Performance	There is a recognized need for relevant metrics for restoration performance (success/failure) in an oil spill setting. We suggest beginning the task with the fairly robust literature on restoration evaluation in wetland and salt marsh habitats, expand, extrapolate, and generalize.
C22	Past Restoration Retrospective: Case Studies in Different Habitats	This effort would guide the development of recommended restoration practices by habitat types and geographic location, possibly selecting a series of previous spill or grounding restoration efforts as case studies and following up as necessary to determine level of long-term success (may involve field visits). Also would canvass the literature to examine restoration for other contaminant situations (i.e., other chemicals, hazardous waste sites, etc.).

ID	Title	Description
B15	Out-of-Kind Tradeoffs for Restoration Actions	Evaluate the cost/benefit of alternative measures that prevent subsequent events vs. direct application of resources to the injuries themselves (e.g. meteorological station to provide wind data to guide ship traffic in restricted environment; channel markers to prevent groundings). Consider including maintenance costs of these out-of-kind tradeoffs. Retrospective analysis to guide implementation of this evaluation in future projects.
B16	Comparative Analysis of Restoration Technology	Emphasize vetting new restoration tools in this context and examining limitations of applications across permitting agencies at the same time. Apply multiple techniques at common sites to reduce contribution of among-site variability to get at variation contributed by techniques themselves; emphasize designed field experiments from scratch in an agricultural-like context.
A10	Post Auditing of Marsh Restoration - As a Pilot Project (NRDA, COE)	Use GRPs, standardize for pre-NRDA assessment, "preinjury assessment". Demonstration project to see if GRPs are compatible for pre-NRDAs. Use statistical analysis to determine hot cost areas.
C21	Bivalve Restoration: Removal, Holding, Replanting	This effort would evaluate the viability of fairly intrusive restoration approaches to bivalve communities of ecological and economic concern. The approach would involve temporary relocation of communities, holding nearby to simulate depuration period (no oil would be involved in this methods-testing exercise), disturbance of donor sediments to simulate either tilling or replacement, then re-placement of original bivalve community on cleaned area. Survival/viability of bivalves would be followed over time. Begin with mussel beds in Alaska; expand to other oyster or clam resources in other parts of the country.
D11	Investigating Non-Traditional Restoration Methods	Such as projects that prevent injury from occurring. Examples include improving aids to navigation or putting oil booms, preventing predation of sensitive species that will prevent spills from hitting sensitive habitats. Also might include emergency restoration actions that could be taken during a response.
E19	Synergistic Restoration (Multiple Restoration Methods and Pairing Habitats)	Evaluate degree to which pairing multiple restoration methods of different types may provide greater benefits (e.g., pairing salt marsh and oyster reef). Landscape scale. Used for more than one injury. Augment compensatory restoration. Build for interaction. Corridors. Pilot project. Monitor and analyze.
E21	Restoration Lessons Learned	Net benefit of restoration vs. natural attenuation? Compare to practice. Case histories. Evaluating success. Learn from mistakes. Synthesis.
E22	Characterization of Recovery Trajectories/Curves in Various Habitats	For natural attenuation and restored action.
E23	Keystone Species	Basic research on population abundances for keystone species (e.g., mangroves, corals). How do we keep communities together?
Socioeconomic Concerns		

ID	Title	Description
C14	Understanding Tolerance of Ecological Risk	Need to get better handle on factors that shape and form and individual's tolerance of the ecological disturbance that is a fact of life when an oil spill happens. What shapes or forms their acceptance of various response strategies, acceptance of what is clean enough for response/recovery? Why and what leads to outrage or acceptance among outcomes of oil reaching or impacting various parts of the local environment, or environments remote from the area but of interest? Have to address individual's sense of fairness and justice. What is appropriate for specifics of a situation? Level of punishment differs on who is responsible.
C15	Graphic Communication of Spill Tradeoffs	There are various types of information involved in assessing and communicating tradeoffs. Need to address impacts, recovery, trade offs, ecology and technical limitations. Need to address a variety of audiences and regional perspectives (technical, public, native Americans, etc.).
C16	Communication Plans for Differing Audiences	Research will involve a combination of studies from case histories, current state of the practice, assessing information needs from various perspectives. Implementation of results should include training sessions, guideline documents, and good examples of practices. There should be existing literatures to build on from other topics, but done with an eye to the specific nature of information needs, individual behavior and temperaments surrounding oil spill events. Topics should start with NOAA ICS strategies and forms, but move on to meeting public and stakeholder expectations.
D7	Better Understanding and Estimates of Non-Market Value of Resources/Use Loss from Spills	Better understanding and estimates of non market values of resources/use loss from spills: a) Better understanding of subsistence uses, values, restoration alternatives and regional variation; b) Better understanding of how the public trades off restoration attributes; c) Better quantification of diminished (vs. lost) use values; d) Development of value estimates transferable to small spills.

ID	Title	Description
B12	Developing Estimates of Human Use Value	Developing Estimates of Human Use Values: This begs an evaluation that links site vulnerability/susceptibility issues (perhaps via links to Near Real Time Tactical Forecasting) to associated lost human services and values. This is another path of impact evaluation that is different from HEA (which does not have human values). This contingency planning calls for quantification of values of lost services, including intangibles, socioeconomic cascade, and consequences of resource redirection associated with a catastrophic, temporary event, not just lost infrastructure. Comparative analysis might be done among baseline conditions vs. acute event situation (scenario gaming). Perform an Ecological Assessment. Include social scientists in the proposal evaluations, not just the cleanup/remediation process. Develop a protocol that captures human use values for non-infrastructural losses/changes in response to a wide range of spill scenarios across various geographic locations, that leads to increased public satisfaction with the choice and consequences of actions of decision makers (dislocation and perceptual minimization during the cleanup/remediation process). Support outreach and extension support. Consider Environmental Psychology/Perception: No question that the perception of damage causes damage to become an issue - even if none can be scientifically documented (e.g., the high pressure steam washing example). Elicit stakeholder values. How would you evaluate trade-offs? Implement Environmental Assessments. Disaster Conference: 1) If you want to know what is going on, the press is not a useful outlet; 2) Level of cooperation or public sentiment is dependent upon the real/perceived RP (e.g., natural event responses vs. large, corporate vilification). This leads to identification of a need to effectively communicate simple truths.
D8	Informing Public and Decision-Makers about the Consequences of Spills	Informing the public and decision makers about the consequences of spills and response options. Scientists communicating with a public, whose perception is at odds with scientific information. Public perception of consequences of spills. Public confidence in experts conducting response operations. Public perception of the value of habitats and individual organisms. Public perception of what is an adequate cleanup. Public perception of what is pristine. Public perception about the tradeoffs inherent in response and restoration alternatives. Research is to investigate the basis of public perception and then to develop effective communication methods before during and after spills occur so that public is well informed. Need to do this for both the interested public and decision makers.
E13	Ecosystem Services Evaluation	What are important services? How to incorporate ecosystem-level services? How to value in loss assessment? How to value in restoration plan/efficacy? Not necessarily human services.
E14	Communication	Communication and Perception: Outreach of public. Stakeholder buy in. Consensus building. How clean is clean? Tainting? Examples: Perception problems from fisheries closure. How to do this better? Public service. Generate a decision making/governance framework.

ID	Title	Description
E15	Subsistence Use Valuation	How to value a lifestyle, heritage. Less traditional "cost structure". Used in damage assessment. Use in response planning. Use in EIS. Use in RA.
E20	Non-Point Source Pollution Policy Issue	Non-point source oil may account for majority of hydrocarbons in coastal environment (see NAS, NRC). This may be outside NOAA's mandate. NOAA's expertise in this area may be applied to help. Bigger problem than spills? Apply this to developing programs. Add to OPA (include NRC conclusions).
C13	Communicating Tradeoffs of Dispersants and other Alternative Technologies	Efforts would focus on communication of hazard tradeoffs and NEBA from dispersants. Deciding who can work this issue credibly, building on lessons learned from previous efforts. Try to identify factors that influence a group's willingness to accept dispersants: how to best address their issues? Determine risk acceptance/risk tolerance factors for these environmental issues. Develop plans and tools to communicate results of existing technical studies and risk assessments, develop strategies and protocols that would be appropriate to get stakeholder ideas and buy in. Need to have regional approaches, also can address In-situ burning, bioremediation and other technologies.

Appendix 4

Workshop Themes

Workshop Themes

1. **Physical Transport Forecasting**
    - A1 – Protocols for Modeling (2D/3D, integration of real time data)
    - B1 – Deep Water Blowout Models
    - B2 – Circulation Models for Convergence/Divergence Processes
    - B3 – Near Real Time Tactical Forecasting
    - C1 – Model Enhancements (Shoreline and near shore interaction, 3D models)
    - C2 – Forecasting Oil Transport and Fate, Including Stranding
    - C4 – Practical Approaches to Detect Oil
    - E1 – Fate and Transport of Chemically Dispersed Oil
    - E3 – Synthesis of Fate/Transport Processes
    - E4 – Develop Linkages to Incorporate Observing System Data

2. **Oil Weathering: Data Development and Modeling**
    - A2 – Emulsification Models
    - A3 – Evaporation Models
    - C3 – Life History of an Oil Spill Droplet in the Water Column
    - C5 – Life History of an Oil in Shoreline Habitats
    - C11 – Source-Sink Info for Different Habitats
    - D1 – Long Term Fate of Oil in Water Column and Subtidal Environments
    - D2 – Emulsification Process Studies
    - D6 – Long Term Fate of Oil in Key Habitats of Concern
    - E2 – Effect of Habitat Type on Fate and Transport Processes
    - E10 – Effect of Habitat Type on Fate and Transformation
    - E12 – Synthesis of Oil in Ice Habitats
    - E18 – Metrics for Trophic Modification and Augmentation

3. **Ecosystem Services: Identification and Valuation**
    - B12 – Developing Estimates of Human Use Values
    - B15 – Out of Kind Tradeoffs for Restoration Actions
    - D5 – Classification and Understanding Initial Loss of Services and Process of Recovery of Key Habitats
    - D7 – Non-Market Value of Resources/Use Loss from Spills
    - E13 – Ecosystem Services Evaluation
    - E15 – Subsistence Use Valuation

4. **Communication: Public and Stakeholder Participation in Response and Restoration**
    - B13 – Applying Performance Metrics to Evaluate Response Effectiveness (“Metric Vetting”)
    - C13 – Communicating Tradeoffs of Dispersants and other Alternative Technologies
    - C14 – Understanding Tolerance of Ecological Risk
    - C15 – Graphic Communication of Spill Tradeoffs
    - C16 – Communication Plans for Differing Audiences
    - D8 – Informing Public and Decision Makers about the Consequences of Spills

- E14 – Communication

5. **Restoration Review**
    - A10 – Post Auditing of Marsh Restoration – As a Pilot Project
    - B14 – Evaluation and Forecasting of Restoration Success
    - B16 – Comparative Analysis of Restoration Technology
    - C20 – Metrics for Restoration Performance
    - C21 – Bivalve Restoration: Removal, Holding, Replanting
    - C22 – Past Restoration Retrospective: Case Studies in Different Habitats
    - D10 – Evaluating Success, Potential Negative Impact, Total Cost of Restoration Projects
    - E21 – Restoration Lessons Learned

6. **Chronic Effects of Oil**

    Part 1: Individual
    - ➢ A7 – Low-Level Residual Oil Across Species and Habitats
    - B6 – Chronic Effects of Low Oil Concentrations
    - C6 – Long-Term Effects of Short-Term and Long-Term Exposures
    - C23 – Species and Life Stage Sensitivities
    - D3 – Quantitative Sublethal Effects on Organisms (Indicators, Definition of Injury)
    - E7 – Effects of Oil on Reptiles
    - E8 – Effects of Oil on Foraminifera and Other Microbenthic Indicator Species

    Part 2: Habitat
    - A8 – Validate Habitat-Specific Cleanup Endpoints and Recommendations (J. Michel & B. Benggio paper)
    - B7 – Cascading System Effects as a Result of Organism Impacts
    - B9 – Mangrove Restoration and Recovery Rates
    - B10 – Washing Agent Effects on Habitats
    - B11 – Habitat Recovery Rates
    - C12 – Retrospective Analysis of Response Actions in Sensitive Habitats
    - D5 – Classification and Understanding Initial Loss of Services and Process of Recovery of Key Habitats
    - E10 – Effect of Habitat Type on Fate and Transformation
    - E11 – Ecosystem-Based Approach to Understanding Oil Ecotoxicology
    - E20 – Non-Point Source Pollution Policy Issue
    - E22 – Characterization of Recovery Trajectories/Curves in Various Habitats

7. **Methods and Techniques**
    - A5 – Metrics of Effects (Biomarkers, Impacts of Response Actions)
    - A13 – Identifying Toxicologically-Relevant Analytes by Habitat and Organism
    - C18 – Research into Robust Markers Diagnostic of Petroleum Impacts, Validated
    - C19 – In Situ Instrumentation and Materials for Defining Exposure Over Time
    - E9 – Analytical Methods and Identification of Specific Compounds of Interest

8. New Tools for Restoration and Recovery

- A9 - Advanced Response Technologies
- A14 – Methods to Differentiate Between Spill Effects and Natural Variability/Stressors
- C7 – Defining Baseline of Natural Variability in Organisms and Communities
- C9 – Spatial and Temporal Scale Differences
- C17 – Develop Conceptual Models of Ecosystems
- D9 – Defining and Measuring the Endpoint of Recovery
- D11 – Investigating Non-Traditional Restoration Methods
- E17 – Sensitive Indicator Species for Injury and Recovery
- E19 – Synergistic Restoration (Multiple Restoration Methods and Pairing Habitats)
- E23 – Keystone Species

9. Others

Dispersed Oil: The upcoming NAS publication on dispersed oil should help in defining need(s) for data and information on the transport, fate and effects of chemically dispersed oil, as opposed to naturally dispersed oil. This topic would include:

- A4 – Effects of Dispersed Oil on Species of Concern
- C8 – Physical Effects of Dispersed Oil in Biological Matrices (Feathers, Fur, Epidermis, Algal Surfaces)
- C10 – Effect of Dispersed and Undispersed Oil on Different Habitats in Different Regions
- E1 – Fate and Transport of Chemically Dispersed Oil
- E6 – Data Synthesis of Short Term Acute Exposure to Dispersed Oil or Dispersant

Additional Topics:

- A12 – Wildlife Multipliers
- B8 – Natural Seeps

Appendix 5

Workshop Theme Syntheses

Physical Transport Forecasting

R&D Statement:

During major spills in U.S. waters, NOAA is responsible for providing spill fate and transport modeling expertise to the U.S. Coast Guard. In addition, NOAA is often called to participate in modeling efforts in regions outside U.S. waters. The successful improvement, development and application of physical transport models are NOAA priorities.

The ability to accurately forecast the trajectory of spilled oil and other hazardous materials is a vital tool in spill response. This ability both guides the spill response and provides data and information to update the restoration. Consequently, there is a clear need to tie forecasting in with systems of observation, including real time observations from platforms such as *in situ* sensors and satellites. Transport models will increasingly become site specific and require enhancements to improve sensitivity to oil type, oil interactions and transformation, 3D spatial resolution and scaling (especially under ice and in energetic near shore environs), and refinement by calibration and validation. Finally, the coupling of transport forecasting requires proper coupling with the myriad fate processes that affect oil (see for example the synthesis on Oil Weathering).

Some specific research needs, as identified during the Workshop include: sensitivity analyses of fate and transport processes, validation of current models, deep water releases, 3-dimensional capabilities, improved circulation information, use of innovative technologies to improve forecasting, improved access to real time data for fate and transport modelers, improved understanding of near shore/shoreline processes and better oil detection methods.

Possible NOAA Outcomes:

NOAA is interested in applying advances in 2D/3D process capabilities to the General NOAA Oil Modeling Environment (GNOME) and Automated Data Inquiry for Oil Spills (ADIOS2) models. Improved strategic planning, tactical planning, and post-spill assessment will be made possible with such advancements.

R&D Workshop Topic References:

A1 – Protocols for Modeling (2D/3D, Integration of Real Time Data)
B1 – Deep Water Blowout Models
B2 – Circulation Models for Convergence/Divergence Processes
B3 – Near Real Time Tactical Forecasting
C1 – Model Enhancements (Shoreline and Near Shore Interaction, 3D Models)
C2 – Forecasting Oil Transport and Fate Including Stranding
C4 – Practical Approaches to Detect Oil
E1 – Fate and Transport of Chemically Dispersed Oil
E3 – Synthesis of Fate/Transport Processes
E4 – Develop Linkages to Incorporate Observing System Data

Oil Weathering: Data Development and Modeling

R&D Statement:

Following the release of oil into the marine environment, physical, chemical, and biological processes begin transforming (i.e. weathering) the released material. Weathering will change the physical and chemical characteristics of the oil and determine the kind and magnitude of the oil's impact on natural resources. The rate of weathering depends on the characteristics of the released material and the specific environmental conditions at the time and place of release (e.g., temperature, wind speed, hydraulic energy, suspended particulate material). The weathering work done to date has focused on floating oil in an open water environment, leaving questions as to the effects of nearshore processes, e.g. turbulence, interaction with suspended particulate material, on these processes. In addition, once the oil comes ashore or is deposited, weathering processes and rates may be profoundly affected. Developing a better understanding of oil weathering processes and rates and improving the ability to model and predict them are NOAA priorities.

Research needs identified during the Workshop include: examination of the affects of a grounding site on oil degradation, persistence and toxicity; development of a response and restoration synthesis for oil in ice habitats; examination of the chemical, physical and biological weathering of oil in structurally vulnerable habitats, including mangroves, sand beaches, mud flats, salt marshes, sea grass beds, tundra shorelines, and coral reefs; examination of stranded, buried, and particle-associated oil, including adhesive properties, grain size, and potential for re-exposure; examination of trophic modification using carbon tracers; and improved model performance with regard to weathering activity, to include extended ranges of temperature, wind speed, etc., for a variety of habitats and released materials.

Because controlled releases of petroleum products are not practicable under most circumstances, fate and weathering studies are generally restricted to spills of opportunity and laboratory-scaled studies. Natural seeps and sites of historical spills, such as Prince William Sound, AK, also offer opportunities for research, specifically of the long term fate and weathering of released petroleum.

Possible NOAA Outcomes:

Advances in modeling capabilities of weathering may be applied to NOAA's Automated Data Inquiry for Oil Spills (ADIOS2) model, as appropriate. There is interest in habitat-specific fate modeling. Improved predictions will enable NOAA and U.S. Coast Guard to more precisely determine appropriate response actions in order to reduce the overall impact to natural resources.

R&D Workshop Topic References:

A2 – Emulsification Models
A3 – Evaporation Models
C3 – Life History of an Oil Spill Droplet in the Water Column
C5 – Life History of Oil in Shoreline Habitats

C11 – Source-Sink Info for Different Habitats
D1 – Long Term Fate of Oil in Water Column and Subtidal Environments
D2 – Emulsification Process Studies
D6 – Long-Term Fate of Oil in Key Habitats of Concern
E2 – Effect of Habitat Type on Fate and Transport Processes
E10 – Effect of Habitat Type on Fate and Transformation
E12 – Synthesis of Oil in Ice Habitats
E18 – Metrics for Trophic Modification and Augmentation

Ecosystem Services: Identification and Valuation

R&D Statement:

The value of the goods and services provided to society by healthy ecosystems is just becoming realized. A spill may disrupt the flow of those services through injury to the ecosystem components. For example, the 1996 *North Cape* oil spill at Moonstone Beach, Rhode Island resulted in the release of more than 800,000 gallons of home heating oil and a significant reduction in the number of lobster, clams, fish, seabirds and other invertebrates. This spill closed the commercial fin fishery and shellfish fishery for months with severe effects on the local economy.

In order to initiate the recovery process following a spill, it is important to understand not only what has been lost, but also what can be regained through the different response/restoration options. Conceptual models for services lost are needed. Parameterized services recovery models can be used in decision making. Human use valuation estimation (both market and non-market assessments), including subsistence use impacts, can help define recovery models. Wildlife injury assessment multipliers are needed for service loss estimations. Assessing the tradeoffs of various response plans will be the first step in the recovery process. The assessment of lost values and the consideration of viable recovery options in response to environmental spills are NOAA priorities.

Some specific research needs identified during the Workshop include: evaluation of out-of-kind tradeoffs for restoration actions (e.g., the cost/benefit of measures that prevent subsequent events vs. direct application of resources to injuries); examination of how value is assigned to important services (e.g., human as well as non-human use services) in loss assessments; development of conceptual models for service loss and recovery from a variety of habitats; quantification of values of lost services; and examination of how the public trades off restoration attributes.

Possible NOAA Outcomes:

NOAA is interested in developing a greater understanding of assessing the values of lost services, both human and non-human use, as well as the myriad of restoration tradeoffs. One potential product of this research might be the development of a protocol for assessing loss values based on a range of spill scenarios in a variety of habitats or locations.

R&D Workshop Topic References:

B12 – Developing Estimates of Human Use Value
B15 – Out-of-Kind Tradeoffs for Restoration Actions
D5 – Classification and Understanding Initial Loss of Services and Process of Recovery of Key Habitats
D7 – Better Understanding and Estimates of Non-Market Value of Resources/Use Loss from Spills
E13 – Ecosystem Services Evaluation
E15 – Subsistence Use Valuation

Communication: Public and Stakeholder Participation in Response and Restoration

R&D Statement:

Effective communication with the public, private industry and stakeholders prior to and in the aftermath of an environmental incident is an important part of a successful response and restoration. Growing realization of the importance of communication in meeting trustee responsibilities during and after spill response reveals a need for developing better tools and techniques for this process. The promotion of effective communication before, during and after a spill is considered a NOAA priority.

Public and stakeholder expectations and concerns are very high during any environmental disturbance. However, the level of public understanding of the risk, response and outcome varies widely. Effective dialogue about spill prevention, first response planning efforts, response strategies, relative risks and trade-offs of response strategies, injury assessments, and subsequent restoration alternatives requires an informed public and an iterative dialogue. Techniques are needed to identify and initiate this dialogue. Techniques are also needed to communicate outcomes from this involvement.

Some specific research needs, as identified during the Workshop include: an examination of factors that shape public understanding, especially of ecological disturbances; development of an array of scientifically defensible metrics that include public and stakeholder input and understanding for use during a response; development of a public and stakeholder metric assessment protocol; assessment of information needs during environmental events to assess impacts, tradeoffs, etc.; examination and assessment of various regional perspectives; and examination of public understanding regarding alternative remedial technologies (e.g., dispersants, in-situ burning, bioremediation).

Possible R&D Outcomes:

NOAA is interested in developing tools to engage the public and stakeholders in the planning and decision-making process, assess factors that shape their opinions and preferred decisions, and quantify their input. Strategies for effective outreach and education about planning and decision making are needed. Procedures for engagement, particularly to regional audiences or targeted stakeholder groups, are also needed. New ways of information depiction and portrayal will be required.

R&D Workshop Topic References:

B13 – Applying Performance Metrics to Evaluate Response Effectiveness
C13 – Communicating Tradeoffs of Dispersants and Other Alternative Technologies
C14 – Understanding Tolerance of Ecological Risk
C15 – Graphic Communication of Spill Tradeoffs
C16 – Communication Plans for Differing Audiences
D8 – Informing Public and Decision Makers about the Consequences of Spills
E14 – Communication

Restoration Review

R&D Statement:

The Oil Pollution Act of 1990 (OPA) requires that designated natural resource trustees restore natural resources injured as a result of a release of oil or a hazardous substance to what it would be but for the release. Since 1990, NOAA has settled more than two dozen damage assessment cases and initiated restoration for a wide variety of injured resources. Interest in the restoration method(s) used and the success of these methods is high.

NOAA recognizes the importance of learning from past restoration experiences. The review and evaluation of past restoration projects and the advancement of metrics to evaluate restoration performances and innovative restoration techniques are NOAA priorities. The return of ecosystem services must be placed into contextual framework bounded by "do nothing alternatives" or intrusive restorations. What is the net benefit of restoration versus natural attenuation? What are the net benefits of restoration schemes? Expert systems involving causative models for restoration principles and expert knowledge can be used to establish a Bayesian belief network framework. Inferential methods may be employed in these frameworks to evaluate various types of habitat loss information and improve restoration decision making. Pre-injury assessments may also be useful in decision making. Restoration practices by habitat type may be of benefit, especially for critical and sensitive habitats.

Some specific research needs identified during the Workshop include: evaluation of restoration projects already in progress or completed (compare successes, adverse effects, and total cost for each habitat type) and confirmation that the restoration improved on the "no action" alternative; development of a decision protocol to match sites in need of restoration with methods deemed viable for those specific habitats and site characteristics; application and comparison of multiple restoration techniques at the same test site; development of a success/failure metric for restoration performance; and evaluation and application of innovative restoration approaches (e.g., intrusive restoration approach for bivalve community).

Possible NOAA Outcomes:

NOAA is interested in the continued application and assessment of restoration techniques suitable for use in areas impacted by petroleum (or petroleum products). With continued examination of innovative restoration methods, more effective techniques of habitat renewal will continue to be discovered. NOAA is interested in the development of a matrix or protocol which would identify potential restoration methods for a variety of habitats and site characteristics.

R&D Workshop Topic References:

A10 – Post Auditing of Marsh Restoration – As a Pilot Project
B14 – Evaluation and Forecasting of Restoration Success
B16 – Comparative Analysis of Restoration Technology
C20 – Metrics for Restoration Performance
C21 – Bivalve Restoration: Removal, Holding, Replanting
C22 – Past Restoration Retrospective: Case Studies in Different Habitats
D10 – Evaluating Success, Potential Negative Impact, Total Cost of Restoration Projects
E21 – Restoration Lessons Learned

Chronic Effects of Oil: Part 1 – Individual

R&D Statement:

Early studies on the effects of oil released into the marine environment were standard, short term (96 hour), acute exposures, examining the effects of different compounds and oils on marine organisms. While these data provided information on the relative toxicity of various oils and their components, as well as the sensitivity of various test species, it provides little information on the results of non-standard exposure regimes (e.g. greater than 96 hours or varying concentrations over this period or end points other than mortality). Measurements of the concentrations of oil in the water column during field, laboratory and mesocosm experiments indicate that most water column organisms will not be exposed to a constant concentration for 96 hours but to varying concentrations over a shorter period of time. There is little information available on either lethal or sublethal effects of this sort of exposure regime. In addition, the long term monitoring performed in Prince William Sound after the *Exxon Valdez* supports a hypothesis that oil, as mixture of compounds, may have multiple modes of action. That is, not just acute mortality as a result of narcosis but also hormonal disruption, and perhaps genotoxicity, modulated through the Ah receptor. This second mechanism would operate at exposure levels orders of magnitude lower than the presently accepted clean up levels. Data and information from these non-standard exposures are needed to set protective cleanup levels and make responsible decisions regarding cleanup. NOAA recognizes the need to develop this information and has set this as a research priority.

Research focused at the individual level should utilize non-standard exposures with both fresh and weathered oil and consider sublethal as well as lethal endpoints. Relevant end points may include hormonal changes, inhibition of reproduction, changes in fertility or fecundity, hatching/swim up success, etc. Part of this research should be to determine if the current focus on the most sensitive species and the most sensitive life stages provides a basis to characterize potential ecological impact of exposure to oil spills. An examination of the effects of oil on indicator species as well as special species of interest (e.g., endangered species, reptiles) is also encouraged.

Some specific research needs identified during the Workshop include: evaluation of the chronic effects of low concentrations (parts per billion) of oil; evaluation and validation of 1 ppb for sublethal effects across a variety of species; evaluation of long-term effects (e.g., survival, growth, and reproductive end points) of both short- and long-term exposure scenarios; evaluation of species and life stage sensitivities and quantitative examination of sublethal effects on organisms.

Possible NOAA Outcomes:

NOAA is interested in the development of a database containing information from a range of exposure scenarios for species of interest over a variety of geographic regions. Such a database would become a valuable reference in the aftermath of a petroleum spill. In addition, assays and methodologies and their assessments that provide better understanding of the low level, chronic, and sublethal effects of spilled oil on organisms and biogenically structured habitats will aid in the establishment future clean up endpoints.

R&D Workshop Topic References:

A7 **–** Low Level Residual Oil across Species and Habitats
B6 **–** Chronic Effects of Low Oil Concentrations
C6 **–** Long-Term Effects of Short-Term and Long-Term Exposures
C23 **–** Species and Life Stage Sensitivities
D3 **–** Quantitative Sublethal Effects on Organisms (Indicators, Definition of Injury)
E7 **–** Effects of Oil on Reptiles
E8 **–** Effects of Oil on Foraminifera and Other Microbenthic Indicator Species

Chronic Effects of Oil: Part 2 – Habitat

R&D Statement:

Oil spills into coastal waters whether acute or chronic, can have major environmental impacts and cause substantial disruption of recreational and commercial activities through the loss or change in ecosystem components. Historically, studies on the effects of oil have been to determine the acute toxicity of oil and its components on single species and their life stages. With the data coming out of long term studies on the effects of the *Exxon Valdez*, it is becoming evident that single species acute toxicity is not the only mechanism by which spilled oil impacts ecosystems. A loss or change in the structure or function of biogenic habitats such as mussel or sea grass beds can have cascading effects through suddenly appearing in unexpected components of the system (e.g., decreased reproduction in harlequin ducks). Alternatively, the acute mortality of a major predator can also cascade through a system as the result of a change in predator/prey relationships (e.g. sea urchins, Laminaria and sea otters). These complex relationships affect both our ability to: assess the extent of a potential or real injury, develop and implement the most effective restoration, and to predict when the impacted system has recovered (Peterson et. al., 2003).

Research focused at the habitat level should emphasize the fate of oil in key habitats, the effect of response actions on various habitats, cascade effects, recovery trajectories and clean up goals. Research focused on a broad range of habitats, with an emphasis on sensitive and/or vulnerable habitats is encouraged. Detailed net environmental benefit analysis and cost benefit analysis should be conducted. Research would benefit from the implementation of long-term monitoring programs at spill sites and a partnership between experts in remediation/response and recovery dynamics of injured ecosystems.

Some specific research needs, as identified during the Workshop include: validation of habitat-specific cleanup endpoints, particularly the guidelines developed by Michel and Benggio (1999); development of conceptual model of service loss and recovery from key habitats; examination of how habitat type effects the rate and extent of degradation and transformation; examination of the effect of washing agents on habitats and ecosystems, especially protected and economically valuable habitats; examination of cascading system effects; retrospective analysis of response actions in sensitive habitats; and examination of trophic and habitat linkages among organisms and incorporation of understanding into models looking at cascading indirect effects.

Possible NOAA Outcomes:

NOAA is interested in the development of a database containing contamination, response and restoration data for various habitats of interest. This database would become a valuable reference in the aftermath of a petroleum spill and could be coupled with the database suggested for exposure scenarios (see Chronic Effects of Oil: Part 1 – Individual). The goal of this work will be to develop a more comprehensive body of knowledge regarding habitat exposure, vulnerabilities, recovery, and restoration following an encounter with petroleum.

R&D Workshop Topic References:

A8 – Validate Habitat-Specific Cleanup Endpoints and Recommendations
B7 – Cascading System Effects as a Result of Organism Impacts
B9 – Mangrove Restoration and Recovery Rates
B10 – Washing Agent Effects on Habitats
B11 – Habitat Recovery Rates
C12 – Retrospective Analysis of Response Actions in Sensitive Habitats
D5 – Classification and Understanding Initial Loss of Services and Process of Recovery of Key Habitats
E10 – Effect of Habitat Type on Fate and Transformation
E11 – Ecosystem-Based Approach to Understanding Oil Eco-toxicology
E20 – Non-Point Source Pollution Policy Issue
E22 – Characterization of Recovery Trajectories/Curves in Various Habitats

Reference:

Michel, J. and B. Benggio, 1999. Guidelines for Selecting Appropriate Cleanup Endpoints at Oil Spills. Presented at the 1999 International Oil Spill Conference, Seattle, USA, 8-11 March 1999.

Peterson, C.H., S.D. Rice, J.W. Short, D. Esler, J.L. Bodkin, B.E.,Ballachey and D. B. Irons, 2003. Long-Term Ecosystem Response to the ExxonValdez Oil Spill. Science 302:2082-2086.

Methods and Techniques

R&D Statement:

Increased understanding of the potential impacts of oil on ecosystem structure and function has highlighted the need for new methods and techniques to quantitatively measure chronic exposure and indicate both potential and real injury to the exposed organisms. Some of this need may be met by increased interest in the analytical chemistry of "oil". Previous work has focused on the acute toxicity of the water soluble, low molecular weight, volatile compounds. These compounds however are rapidly lost through evaporation, leaving the less well characterized higher molecular weight aromatics and other compounds that may be produced by microbial degradation or photo oxidation. The ability to identify and quantify these compounds, in long-term field situations as well as controlled laboratory experiments, is a first step in determining the long term impacts of input of petroleum hydrocarbons in to the environment. A second and equally necessary step is the development of sensitive, quantitative, early indicators of changes in metabolic processes in chronically exposed organisms. Together, this information will be a major factor in determining clean up levels.

Some specific research needs, as identified during the Workshop include: development and field validation of *in situ* instrumentation to monitor exposure from specific contamination; identification of a standard suite of toxicologically-relevant parameters by habitat and organism; evaluation of the state of knowledge regarding petroleum impact diagnostics; and development and/or improvement of metrics for injury assessment.

Possible NOAA Outcomes:

NOAA is interested in the development of markers and metrics to be used as diagnostic tools in evaluating the long-term impacts/effects of response actions and decisions.

R&D Workshop Topic References:

A5 **–** Metrics of Effects (Biomarkers, Impacts of Response Actions)
A13 **–** Identifying Toxicologically-Relevant Analytes by Habitat and Organism
C18 **–** Research into Robust Markers Diagnostic of Petroleum Impacts, Validated
C19 **–** In-Situ Instrumentation and Materials for Defining Exposure Over Time
E9 **–** Analytical Methods and Identification of Specific Compounds of Interest

New Tools for Restoration and Recovery

R&D Statement:

NOAA has set as a priority the investigation of innovative approaches to response, restoration, and recovery from environmental spill events. While there are undoubtedly a wide variety of approaches to post-spill site response, restoration, and recovery for any given spill scenario, the need for inventive new ideas remains. Given the opportunity to "think outside the box" regarding seemingly standard methods, researchers are often able to uncover new facets to their problems which result in insights and new solutions. Some important questions that might lead to new discoveries include how do we differentiate between spill effects and natural, baseline variability in populations that might be induced by natural stressors? What lessons can be learned by spatial and temporal scaling of restoration methods and recovery assessments? Are there better conceptual models of ecosystems than the ones that are presently used? How can further basic research on keystone and sensitive species be translated into practice? How can non-traditional restoration practices be identified? Are there ways to explore synergistic restorations that address multiple problems or enhance restoration through syntrophy? What are the best methods to project recovery trajectories and for defining and measuring recovery end points?

Some specific research needs, as identified during the Workshop include: investigation of non-traditional restoration methods; examination and evaluation of innovative response technologies; evaluation of alternatives to characterize pre-spill conditions; examination of shoreline diversity using small scale spatial and temporal differences; comparison of natural stressors vs. effects of petroleum contamination; examination and evaluation of current and innovative tests for damage assessment; comparison of recovery trajectories for various habitats, considering natural attenuation vs. restorative actions; evaluation of cost/benefit in using multiple restoration methods; and examination of past restoration/recovery successes in an effort to define potential recovery end points for various post-spill circumstances.

Possible NOAA Outcomes:

NOAA is interested in expanding the National Estuary Restoration Inventory (NERI), an online database of restoration projects, as well as receiving public comments pertaining to the inventory.

R&D Workshop Topic References:

A9 – Advanced Response Technologies
A14 – Methods to Differentiate Between Spill Effects and Natural Variability/Stressors
C7 – Defining Baseline of Natural Variability in Organisms and Communities
C9 – Spatial and Temporal Scale Differences
C17 – Develop Conceptual Models of Ecosystems
D9 – Defining and Measuring the End Point of Recovery
D11 – Investigating Non-Traditional Restoration Methods
E17 – Sensitive Indicator Species for Injury and Recovery

E19 – Synergistic Restoration (Multiple Restoration Methods and Pairing Habitats)
E23 – Keystone Species