Testimony
Before The Committee On Commerce, Science and Transportation
United States Senate
May 18, 2010

Potential Impacts of the Deepwater Horizon Oil Spill on Marine and Coastal Ecosystems

Deborah French McCay, PhD
Director of Impact Assessment Services
Applied Science Associates, Inc., South Kingstown, RI

Introduction and Experience

I am a scientist and environmental consultant based in Rhode Island, where I am a principal of the small consulting firm Applied Science Associates, Inc. (ASA, South Kingstown, RI). I received a bachelor's degree in Zoology from Rutgers University in 1974 and a Ph.D. in Biological Oceanography from the University of Rhode Island in 1984. I joined ASA in 1984, where I specialize in scientific assessments of oil and chemical releases, i.e., the transport and fate of oil; exposure to and bioaccumulation of pollutants by biological organisms; and toxic and other effects on individual animals, populations and aquatic ecosystems.

Since 1984, I have worked with the federal government and several states in developing and applying quantitative methods for assessing oil spill impacts. I was the principal investigator in developing computer models for federal regulations in assessing natural resource damages from spills (under CERCLA and the Oil Pollution Act, OPA). I have been involved in hundreds of natural resource damage assessment cases for oil and chemical spills, assisting federal and state governments as a technical expert. I have published scores of technical reports and manuscripts in peer-reviewed journals, and served on national and international committees evaluating oil spill risks and impacts. I am an internationally recognized expert in assessing oil spill fate and biological effects, as well as in computer modeling, that is to say quantitative estimation of oil spill impacts using computer programs employing equations based on physical/chemical and biological processes. I will be happy to provide any technical background material you might need related to my work and experience. My Curriculum Vitae is attached to this testimony.

General Behavior and Fate of Oil

Oils and petroleum products are generally lighter (less dense) than seawater, and so oil floats to the surface unless it is dispersed into the water directly or by turbulence. Floating oil tends to form slicks when fresh, which thin out over time to sheens, as well as collect into thick aggregations at wind rows and current convergences. The oil weathers and degrades when exposed to air and sun, such that the more volatile components evaporate off and the oil becomes tarry and sticky. Some oils form mousse, in which water becomes incorporated into the oil, making it thicker and more viscous. Eventually, floating oil breaks up into weathered tar balls, which may be transported great distances by currents. If winds are on-shore, oil will come ashore and strand on beaches and in wetlands.

If oil is dispersed in the water, it is in the form of small oil droplets or tar balls. The smaller are these particles of oil, the more readily they are dispersed throughout the water column. Oil may be dispersed from the water surface by natural turbulence from breaking waves. If dispersant is applied to oil on the water surface, this dispersion process is enhanced. Dispersants are soap-like surfactant mixtures, composed of compounds that coat the oil surface and encourage it to break into smaller particles.

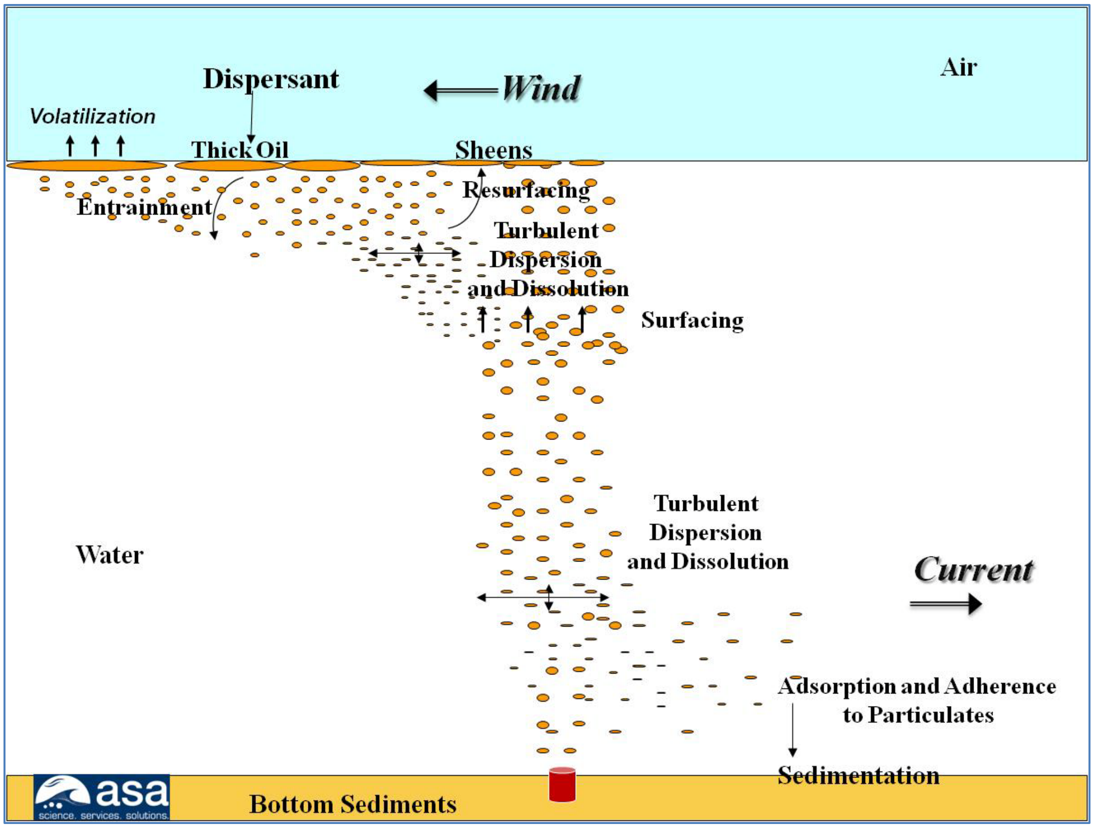
Crude oils and petroleum products are composed of thousands of chemicals. In general, the hydrocarbon compounds found in crude oil are characterized by their structure. These compounds include straight-chain hydrocarbons and aromatics; aromatics include at least one benzene ring. Understanding these different compounds and their structures is important for understanding the fate and biological effects of releases of crude oil or products derived from it.

Most of the compounds in oil are not soluble in water. However, the low molecular weight aromatic compounds (such as the one-ring compounds benzene, toluene, ethylbenzene and xylenes (BTEX); and the polynuclear aromatic hydrocarbons (PAHs)) are both volatile (so evaporate from the water surface) and soluble in water. Benzene rings are very stable, and therefore persistent in the environment, and can have toxic effects on organisms. Because the BTEX and PAHs are at least semi-soluble, they can be taken up into the tissues of aquatic organisms, where they can disrupt (or poison) cellular functions. For this reason, scientists evaluate exposure of aquatic biota to these BTEX and PAH compounds derived from spilled oil, as well as the toxic effects of such exposures.

The BTEX and PAHs also are volatile, and so the evaporate off relatively rapidly when oil is exposed to the atmosphere. In addition, the smaller non-aromatic compounds (e.g., pentane, hexane, octane, etc.) evaporate rapidly. Thus, over time the oil contains less and less of both the volatile and soluble compounds, leaving a residual heavier material that can become sticky and tar-like.

Eventually oil hydrocarbons are degraded by sunlight and microbial processes (bacterial degradation), whether in the water, in bottom sediments or on shorelines. Degradation rates are generally slow, and in conditions of low oxygen, degradation can take decades because oxygen is consumed in, and so needed for, the degradation process. The largest compounds are very slow to degrade, which is why they make good road materials – they remain tarry and asphalt-like for years.

Important oil movements and processes involved in a sub-sea oil release are depicted in the cartoon figure below.



Important oil movements and processes involved in a sub-sea oil release.

<u>Biological Impacts of Spills</u>

The potential biological impacts of oil include:

- Surface smothering/coating exposure to floating and stranded oil, affecting
  - Shoreline habitats (salt marshes, mangroves, sea grasses, oyster flats)
  - Wildlife (birds, marine mammals, sea turtles)
  - Aquatic organisms inhabiting the sea surface (called neuston)
- Toxicity from uptake of dissolved components (aromatics)
  - Fish
  - Shellfish and other invertebrates
  - Plankton, including fish and shellfish eggs and larvae
- Subsurface suspended oil droplets
  - Fish
  - Shellfish and other invertebrates
  - Plankton, including fish and shellfish eggs and larvae

Oil can kill marine organisms, reduce their fitness through sublethal effects, and disrupt the structure and function of marine communities and ecosystems. While such effects have been unambiguously established in laboratory studies and after well-studied spills, determining the subtler long-term effects on populations, communities and ecosystems at low doses and in the presence of other contaminants poses significant scientific challenges. Because of the high natural variability of aquatic populations, it is extremely difficult to measure the changes from before to after a spill. Thus, scientists use a variety of types of information, including past experience from other spills, field measurements, analyses of samples taken for chemistry or to count organisms, experimental tests, and biological data to estimate the impacts of a spill. We often combine such information with computer model calculations to quantify the impact.

In general, the most vulnerable species to oil spills are birds and fur-bearing marine mammals. These animals depend on their feathers or fur to maintain body heat and keep their skin relatively dry. They preen daily, and so will ingest toxic components present in oil that covers any portion of their bodies. Sea turtles, all species of which are threatened or endangered, are also highly susceptible to oil's effects.

Shoreline habitats are very vulnerable to oil exposure. Oil stranding in wetlands or other shoreline habitats can coat small animals and plants, suffocating them. The toxic components can also impact the organisms inhabiting the habitats. These habitats require years to decades to recover from lethal-levels of oil exposure.

Because fish and invertebrates are for the most part under the water surface, and much of the oil is not soluble, their exposure to oil hydrocarbons is subject to (1) the degree to which the oil is mixed by turbulence or other means (i.e., dispersed) into the water column; (2) the degree to which the dispersed oil still contains the toxic compounds (which otherwise evaporate); and (3) the rate of dissolution of soluble aromatics into the water. Oil dispersion rate is highest in storm conditions and when large amounts of dispersants are applied to the oil. Mortality is a function of duration of exposure – the longer the duration of exposure, the lower the effects concentration. Thus, a situation where oil is largely dispersed into the water while fresh is that where the highest impacts to fish and invertebrates would be expected.

Socioeconomic Impacts of Spills

There are many potential socioeconomic impacts that result from large oil spills, including fisheries losses, lost recreation use of beaches and waterways for boating-related activities, impacts on national parks and other protected areas, lost tourism-related business, commercial shipping disruptions, and so on. As a marine biologist, I am focusing on the biological impacts in my testimony; however, the potential for socioeconomic impacts needs consideration as well.

Previous Spills as Case Examples – *Exxon Valdez* Oil Spill (March 1989)

The *Exxon Valdez* oil spill involved 11 million gallons of crude oil. As is well understood, hundreds of thousands of seabirds and thousands of marine mammals (mostly sea otters) were oiled and killed by this spill. This large impact was due both to the nature of the Alaskan crude oil (a viscous persistent type) and the high densities of seabirds and marine mammals present in the affected area. The impacts to fish and invertebrates in open waters were relatively low in comparison because of the slow rate of dispersion into the water just after the release (winds were light at the time of the spill) and the large volume of Prince William Sound that facilitated dilution. However, impacts on and near shorelines to salmon reproduction and other resources were also considerable.

The socioeconomic impacts of the spill were largely related to disruptions to the fishing industry and subsistence uses of natural resources. The local indigenous peoples utilize nearshore and shoreline shellfish as food sources, and hold natural resources as sacred. In addition many Alaskans and Americans in general consider Alaska to be pristine, and so were outraged by the oil's impacts.

Previous Spills as Case Examples – *North Cape* Oil Spill (January 1996)

In January 19-20, 1996, during a severe winter storm, the barge *North Cape* spilled 828,000 gallons of home heating oil (No. 2 fuel oil) into the surf zone on the south coast of Rhode Island. Most of the oil was mixed into the water column by the heavy surf, resulting in high concentrations of the toxic components (PAHs) in the shallow water near the beach. It was evident that there was significant injury to marine aquatic organisms caused by the spill, in that large numbers of lobsters, surf clams, other invertebrates, and fish washed up on the beaches.

Because of the large numbers of highly valued lobsters affected, field sampling was performed to estimate the impact. Impacts to other marine organisms were estimated using computer modeling of oil fates and toxicological effects. The model assumptions and input data were based on existing literature and site-specific information.

While about 2400 birds were oiled in the *North Cape* spill, it was estimated that 9 million lobsters were killed, along with billions of smaller invertebrates and thousands of fish. The spill was so devastating to the local shellfish and fish populations because fresh highly-toxic oil was completely dispersed naturally into shallow water near shore by high waves.

The socioeconomic impacts of the spill were primarily related to disruptions to the fishing industry. To my knowledge, there were no claims by native Americans made against the spiller. The light oil evaporated and degraded quickly, well before the summer tourist season, so impacts on recreational uses and tourism were minimal.

Previous Spills as Case Examples – Ixtoc Oil Spill

The largest spill in history was the Ixtoc blowout which began in June 1979 in Mexican waters of the Bay of Campeche. The well was not completely brought under control until late March 1980. The spill rate was estimated to be about 30,000 bbl[1]/day for 5 ½ months until November, and then about 4,000 bbl/day for another 4 months. The impacts of this spill remain largely unknown. Shoreline-related impacts were observed to birds, sea turtles and invertebrates. However, the impact on fish and shellfish was not estimated. Because of the very large amounts of oil released in relatively shallow waters, it is likely that impacts to shrimp, other shellfish and fish in the Bay of Campeche and southern Gulf of Mexico were highly significant. The socioeconomic impacts of the spill are not documented, but likely included large disruptions of the local fisheries.

---

[1] 1 bbl (barrel) = 42 US gallons; estimates vary widely and the release may have been up to 50,000 bbl/day..

Potential Impacts of the Deepwater Horizon Oil Spill

Natural resources of the Gulf of Mexico (e.g., birds, sea turtles, marine mammals, fish, shellfish, plankton; and a wide variety of habitats along the shoreline and at the sea bottom, such as salt marshes and submerged aquatic vegetation) are currently being exposed to and impacted by oil from the Deepwater Horizon oil spill; as well as potentially by other materials being added to the marine environment during the response that might be toxic or change biological or chemical conditions. In addition there will be impacts on water quality near beaches, shellfish (e.g., oyster) beds, and fishery nursery grounds.

The open water environment, the ongoing release of oil and the ongoing response efforts all contribute to complex, constantly-changing exposure conditions for biological resources in the offshore and near-shore environments of the northeastern Gulf of Mexico. Contributing factors to the complexity of the situation include:

1. Characteristics of released oil and other materials, which change with time due to weathering and response activities; also, there may be changes in the released material at the discharge site due to changes in materials leaving the well;
2. Volume and duration of the continued release of oil, with the oil release rate varying in time;
3. Location and nature of the release (i.e., while burning at the sea surface, from various pipe breaks on the sea floor);
4. Physical oceanographic conditions (currents, temperature, etc.), which vary in space and time;
5. Weather (winds, light exposure, air temperature), affecting the oil’s chemistry;
6. Response effectiveness to stop or slow the release of oil, as well as changes in the location, nature, and volume of the release;
7. Dispersant type, application methods (i.e., injected versus aerial or boat), volumes, effectiveness, locations and timing;
8. Exposure scenarios for biological resources (i.e. exposure duration, species, life history stages involved);
9. Location of critical habitats (live bottom, deep water corals, cold seeps; fishing grounds); and
10. Impacts of oil hydrocarbon/dispersant/contaminant mixes over time, resulting from short duration and long exposures, delayed and indirect impacts, etc.

The socioeconomic impacts of the spill will include disruption of fisheries and dependant businesses, effects on tourism and recreational uses, and potentially changes in oil industry practices.

The purpose of using dispersants on the oil is to lessen the potential impact to wildlife (birds, mammals, and sea turtles) and shoreline habitats. However, to some degree there is a tradeoff, in that the contamination in the water is increased by dispersant application. The objective is to achieve a net environmental benefit: to disperse the oil sufficiently to reduce the impact to wildlife and shorelines, but to do so in deep water where the dilution potential is high to minimize adverse effects on fisheries resources.

Natural Resource Damage Assessment Process

I am involved with the response to the Deepwater Horizon Oil Spill, specifically in evaluating the impact of the spill for the purposes of Natural Resource Damage Assessment (NRDA). NRDA is the process where the federal and state government agencies who are trustees for specific resources on behalf of the public may make damage claims against the responsible party. Under federal regulations of the Oil Pollution Act (OPA) of 1990, the polluter pays for restoration and replacement of services provided by natural resources. The damages are the cost of the restoration. The procedure involves assessment of an adverse impact, known as the injury, and then planning a restoration activity that is sufficient to replace the losses, including consideration of the time for recovery.

Injury Assessment

The goal of injury assessment is to determine the nature, degree, and extent of any injuries to natural resources and services. This information is necessary to provide a technical basis for evaluating the need for, type of, and scale of restoration actions. Under the OPA regulations, injury is defined as an observable or measurable adverse change in a natural resource or impairment of a natural resource service. Government trustees determine whether there is:

- Exposure, a pathway, and an adverse change to a natural resource or service as a result of an actual discharge; or
- An injury to a natural resource or impairment of a natural resource service as a result of response actions or a substantial threat of a discharge.

To proceed with restoration planning, trustees quantify the degree, and spatial and temporal extent of injuries. Injuries are quantified by comparing the condition of the injured natural resources or services to baseline, as necessary.

> “Baseline means the condition of the natural resources and services that would have existed had the incident not occurred. Baseline data may be estimated using historical data, reference data, control data, or data on incremental changes (e.g., number of dead animals), alone or in combination, as appropriate.” (OPA regulations at § 990.30).
>
> “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.” (OPA regulations at § 990.30).

The Appropriate Scale of Restoration

The basic concept underlying restoration project scaling is that restoration is to be of sufficient scale to produce resources and services of the same type and quality and/or of comparable value to those that were lost. The loss is quantified from the time of injury until the resources and services return to the level they would have been at in the absence of the impact. Services include ecological and human uses of the resources. The approach used is that the restoration project is scaled to compensate for the direct kill, indirect effects and lost services from the time of the start of the incident into the future until recovery is complete.

For example, to scale a compensatory fish or shellfish restocking program, the equivalent number of eggs, larvae, or animals at the age they are stocked, is needed. The lost individuals will be replaced once that equivalent number of eggs/animals is stocked and the animals have gone through their normal life cycle to the age of the impacted animals they are to replace. The number killed by age class may be translated into an equivalent number at any age to be stocked using an age- or size-specific survival schedule.

If it is not feasible to replace a species with individuals of the same species, other options are available for restoration, such as habitat restoration or protection projects. Salt marsh and seagrass bed restoration projects are frequently considered options as compensation for injuries to marine resources. The challenge is to determine an appropriate scale for the project to be compensatory (i.e., equivalent to the loss). The approach often used is to calculate the net (e.g., fish) production gain per unit of created (or preserved) habitat. The scale of the newly-created or enhanced habitat is made such that the new production produced by created habitat is equivalent to the loss.

Protection and enhancement projects are often used for restoring wildlife. For example, seabird and sea turtle nest sites might be protected from human disturbance or predation. In addition, during the spill response, extensive efforts are made to clean and rehabilitate oiled wildlife.

Restoration should not be arbitrary in scale or punitive, but should be proportional to the loss. Biological science is able to provide quantitative information that helps make this compensatory damage assessment possible. However, sufficient field- and experimental-based data are needed to make both the injury and restoration scaling assessments.

Preassessment Phase Activities

At the present time, the trustees are gathering data with which to plan for and quantify injury. The focus is on collection of ephemeral data, i.e., information that might be missed or lost if not gathered at the time of the event. The ephemeral data collections are being made in cooperation with scientists assisting the responsible party, such that as much information as possible is collected with minimal duplication of effort and maximum mutual benefit. We are organized in technical working groups to plan and execute this data collection effort. Thousands of federal and state scientists, as well as consultants and contractors, are engaged in this effort 24/7 to ensure we get the best information possible with which to assess the spill’s impacts. Clearly this monumental effort needs support from the federal government, such that a good scientific analysis of the spill’s impacts can be made.

Attachment: CV for Dr. Deborah French McCay

Deborah P. French McCay, Ph.D. **Modeling: Pollutant Fates & Effects;**
ASA Principal **Biological Systems**

EDUCATION

Ph.D., Biological Oceanography, Graduate School of Oceanography, University of Rhode Island, 1984

A.B., Zoology, Rutgers College, 1974

QUALIFICATIONS

Dr. French McCay (formerly Dr. French) specializes in quantitative assessments and modeling of aquatic ecosystems and populations, pollutant transport and fates, and biological response to pollutants. Her population modeling work includes models for plankton, benthic invertebrates, fisheries, birds and mammals. She has developed water quality, food web and ecosystem models for freshwater, marine and wetland ecosystems. She is an expert in modeling oil and chemical fates and effects, toxicity, exposure and the bioaccumulation of pollutants by biota, along with the effects of this contamination. These models have been used for impact, risk, and natural resource damage assessments, as well as for studies of the biological systems. She has provided expert testimony in hearings regarding environmental risk and impact assessments. Dr. French McCay is a Principal at Applied Science Associates.

EXPERTISE

- Environmental/ecological risk and impact assessments
- Assessment and modeling of the impacts of pollutants, dredging, and other disturbances on aquatic biota, wildlife and ecosystems
- Oil and chemical fates and biological effects modeling
- Aquatic toxicology: modeling of exposure, uptake, depuration, bioaccumulation, toxicity
- Biological oceanography
- Analysis and modeling of plankton and nutrient dynamics, water quality, eutrophication
- Food web and ecosystems modeling
- Analysis and modeling of fishery species early life history stages: transport, behavior and movements, entrainment, and impingement
- Population modeling of fish, shellfish, birds, mammals and reptiles
- Modeling of animal migrations and interactions with pollutants, dredging, and development
- Marine, estuarine, freshwater and wetland biology and ecosystem analysis
- Biological and environmental data analysis
- Natural resource damage assessment: pollutant fates, exposure pathways, injury quantification, compensatory restoration scaling
- Support for permitting: effluents, (CWA) NPDES/316b, dredging, development, (NEPA) EIS, spill risk assessment; for power plants, ports and terminals, marinas, transportation companies
- Expert testimony
- Current OSHA HAZWOPPER Certification

EXPERIENCE RELATED TO OIL AND CHEMICAL SPILL ASSESSMENTS

Applied Science Associates, Inc. **1984 to present**

Oil and Chemical Spill Fate, Impact and Natural Resource Damage Assessment

- Principal investigator/project manager for the Natural Resource Damage Assessment Model for Coastal and Marine Environments (NRDAM/CME) and the Natural Resource Damage Assessment Model for Great Lakes Environments (NRDAM/GLE) which are used in "Type A" assessments of damages due to spills of toxic substances under US regulations (Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980 and of oils under the Oil Pollution Act of 1990 (OPA)).
- Developed biological effects model components of the NRDAM/CME, NRDAM/GLE, and ASA's derivative model SIMAP, which estimate pollutant-induced losses in productivity, fisheries yield and wildlife.
- Developed aquatic toxicity model and supporting toxicological database such that mortality is a function of concentration, time and temperature of exposure; this toxicity model forms part of the NRDAM/CME, NRDAM/GLE and other model systems (e.g., SIMAP, CHEMMAP) developed by Applied Science Associates, Inc.
- Principal developer of the physical fates model component of the NRDAM/CME, NRDAM/GLE, and ASA's derivative models SIMAP and CHEMMAP, which estimate oil and chemical distribution and concentrations over time after a spill.
- Developed the restoration model components of the NRDAM/CME and NRDAM/GLE, which determine appropriate restoration actions and approximates costs.
- Principal Investigator in the development of biological databases for fishery species and wildlife by habitat and season for 77 coastal, 11 Great Lakes and 10 inland freshwater biological provinces of the United States. These data support the NRDA models.
- Principal Investigator in the development of a Primary Restoration Guidance Manual which evaluates feasibility, effectiveness and success, and costs of restoration of wetland and aquatic natural resources. This supports NOAA's OPA NRDA regulations.
- Provided technical support and modeling to federal and state trustees to estimate fates, injuries and natural resource damages resulting from spills:
  - *World Prodigy* oil spill in Narragansett Bay, June 1989 (modeled fates, injuries, damages); the damage assessment was used by the R.I. Attorney General's office to successfully negotiate a settlement with the responsible party.
  - *Vista Bella* Oil Spill of 6 March 1991 in Caribbean Sea
  - Bouchard oil spill, August 1993, at the entrance to Tampa Bay. Provided technical support to federal public trustees in developing a natural resource damages claim (modeled fates and injuries)
  - Caustic soda spill, Barge *Cynthia M*, March 1994 (modeled fates and injuries)
  - *Morris J. Berman* No.6 fuel oil spill, January 1994, in San Juan, Puerto Rico.
  - *North Cape* oil spill, January 1996, in Rhode Island – provided technical support, modeling of fates and injuries, restoration scaling, Chair of Technical Working Group assessing injuries and restoration alternatives for marine resources
  - May 1997 Lake Barre, Louisiana, oil pipeline break (modeled fates, injuries; restoration scaling)
  - September 1997 Platform Irene, California, oil pipeline break (modeled fates and injuries)
  - November 1997 *Kure* spill in Humboldt Bay, California for State Natural Resource Trustees (modeled trajectory and fate)
  - Alafia River phosphoric acid spill of December 1997 (injury quantification and restoration scaling)
  - September 1998 *Command* spill off San Francisco, California

    - for State Natural Resource Trustees (modeled trajectory and fate)
    - February 1999 *New Carissa* spill in Oregon (modeled fates and injuries)
    - Chalk Point (Pepco) oil spill in the Patuxent River, MD, April 2000 (injury quantification and restoration scaling)
    - *Penn* oil spill in Narragansett Bay, July 2000 (modeled fates and injuries)
    - November 2000 *Westchester* oil spill in the Mississippi River (modeled fates and injuries)
    - 23 oil spill cases in Florida (injury quantification and restoration scaling); for State Natural Resource Trustees who successfully submitted claims to the National Pollution Fund Center (USCG OPA fund)
    - *Ever Reach* Spill of 30 September 2002 in Charleston Harbor, SC
    - April 2003 Bouchard 120 oil spill in Buzzards Bay, Massachusetts
    - Mosaic acidic process water release of September 2004 in Hillsborough Bay, FL
    - Citgo Refinery Spill of 21 June 2006 in the Calcasieu River, Louisiana
    - Several on-going spill cases (still confidential)
- Provides technical support to NOAA's Office of Response & Restoration / Assessment & Restoration Division and state trustees in on-going natural resource damage assessment cases.
- Provided training to federal and state trustees, industry, and private parties on use of modeling for NRDA, impact and risk assessment.

Modeling and Analysis of Pollutant Fates and Effects, Ecological Risk Assessment

- Project Manager and model developer for ASA's spill fates and biological effects model systems: SIMAP for oil spills and CHEMMAP for chemical spills. These models are used for impact and risk assessment, as well as natural resource damage assessment.
- Developer of Orimulsion fates model in ASA's SIMAP model system. Used this model to perform an ecological risk assessment for the importation of Orimulsion into Tampa Bay, Florida, as compared to the present risk using No. 6 fuel oil, and testified in permit hearings (client: Florida Power and Light). Model also used for an ecological risk assessment for permit applications by a power plant in New Brunswick Canada for conversion from No. 6 fuel oil to Orimulsion.
- Used modeling to estimate impacts resulting from hypothetical spills of the cargo of a ship carrying hazardous wastes to be incinerated at sea; applied to several coastal areas (Gulf of Mexico and North Atlantic) and 10 possible wastes; analyzed worst-case and most- likely scenarios and performed sensitivity analysis.
- Project Manager for oil modeling analysis as part of the development of the Environmental Impact Assessment for the El Segundo Marine Technical Lease Renewal.
- Assessment of potential oil spill impacts and natural resource damages for oil platform spills off the coast of Florida, involving conditional probability (trajectory) modeling and worst case analysis. Testified in permit hearings for Coastal Petroleum.
- Principal investigator for modeling fates and ecological risks of discharges associated with the use of chemical products used in deep water oil and gas operations in the Gulf of Mexico (MMS project, as subcontractor to A.D. Little).
- Principal investigator for modeling analysis of potential spills resulting from groundings in San Francisco Bay in an ecological risk assessment and cost analysis for natural resource damages, response costs and socioeconomic costs (client: Army Corps of Engineers, San Francisco District).
- Principal investigator for modeling analysis of potential spill impacts and costs in Washington state waters as part of a cost-benefit analysis for the Washington Department of Ecology's rulemaking regarding spill response requirements
- Principal investigator for modeling of spills in US waters with and without dispersant use, for use in an Programmatic Environmental Impact Statement,
  US Coast Guard rulemaking on response equipment regulations

- Principal investigator for preparation of an Environmental Assessment of hazardous material spill response equipment regulations, a US Coast Guard rulemaking under OPA90

Modeling of Wildlife Population Dynamics and Movements for Impact Assessment

- Developed a population model and a seasonal migration model for the northern fur seal; differences by age and sex were incorporated in the models; analyzed the impact of entanglement in discarded plastics on the northern fur seal population.
- Utilized northern fur seal population and migration models along with an oil spill trajectory model to estimate impacts on the northern fur seal population.
- Bioenergetics modeling to evaluate fish consumption by cormorants and its impact on fish populations in the Narragansett Bay estuary

Fisheries Modeling and Impact Assessment

- Developed population and fisheries model with spatial resolution for eggs, larvae, juvenile and adults; an associated transport model used to distribute eggs and larvae.
- Applied the spatially-resolved population and fisheries model to sea scallops and Atlantic cod on Georges Bank; used this model to estimate potential impacts of off-shore oil development on the populations and fisheries.
- Developed a model system LARVMAP, which simulates active (directional swimming or sinking) and passive (by currents) movements of eggs, larvae, ichthyoplankton and other life stages of aquatic biota; used for evaluating potential impacts of spills, development, entrainment and impingement
- Assessed potential impacts of the entrainment of ichthyoplankton as a result of seawater heating from regasification facilities, and impacts from pipeline and LNG terminal construction and operation, for Environmental Impact Statements for proposed LNG projects: two off the coast of Louisiana in the Gulf of Mexico, one in Mount Hope Bay, Massachusetts.

Expert Testimony and Hearing Experience (Oil Spill Related)

- Testified in Florida permit hearings for Florida Power and Light (1995-1997) as an expert in oil spill modeling, regarding the modeling of the fates and effects of potential oil and Orimulsion spills.
- Testified in Florida permit hearings for Coastal Petroleum (1997) as an expert in oil modeling and natural resource damage assessment, on the assessment of potential oil spill natural resource damages resulting from oil platform spills off the coast of Florida.

National Academy of Sciences, National Research Council

- 2008 Provided technical information on oil spill consequence analysis to the Committee on Risk of Oil Spills in the Aleutian Islands: A Study to Design a Comprehensive Risk Assessment
- 2002 Member of Committee to Review the Oil Spill Recovery Institute's Arctic and Subarctic Research Programs
- 2001 Provided technical information and text inserts on oil spill modeling to the Committee on Oil in the Sea III
- 2001 Provided technical information and model simulations to the Committee on Spills of Emulsified Fuels: Risk and Response
- 1999 Provided technical information and model simulations to the Committee on Environmental Performance of Tanker Designs in Collision and Grounding

SELECTED PUBLICATIONS RELATED TO OIL AND CHEMICAL SPILL ASSESSMENTS

Articles in Journals and Books

French McCay, D., N. Whittier, M. Ward, and C. Santos, 2006. Spill hazard evaluation for chemicals shipped in bulk using modeling. Environmental Modelling & Software 21(2):158-171.

French McCay, D.P., 2004. Oil spill impact modeling: Development and validation. Environmental Toxicology and Chemistry 23(10): 2441-2456.

French McCay, D. P. and T. Isaji, 2004. Evaluation of the consequences of chemical spills using modeling: Chemicals used in deepwater oil and gas operations. Environmental Modelling & Software 19(7-8):629-644.

French McCay, D., N. Whittier, S. Sankaranarayanan, J. Jennings, and D. S. Etkin, 2004. Estimation of potential impacts and natural resource damages of oil. J. Hazardous Materials 107/1-2:11-25.

French McCay, D.P., M. Gibson, J.S. Cobb, 2003. Scaling restoration of American lobsters: combined demographic and discounting model for an exploited species. Mar Ecol Prog Ser 264:177-196.

French McCay, D.P., C.H. Peterson, J.T. DeAlteris and J. Catena, 2003. Restoration that targets function as opposed to structure: replacing lost bivalve production and filtration. Mar Ecol Prog Ser 264:197-212.

French McCay, D.P., and J.J. Rowe, 2003. Habitat restoration as mitigation for lost production at multiple trophic levels. Mar Ecol Prog Ser 264:235-249.

French McCay, D.P., 2003. Development and Application of Damage Assessment Modeling: Example Assessment for the *North Cape* Oil Spill. Marine Pollution Bulletin, Volume 47, Issues 9-12, September-December 2003, pp. 341-359.

French McCay, D.P., 2002. Development and application of an oil toxicity and exposure model, OilToxEx. Environmental Toxicology and Chemistry 21(10): 2080-2094.

French, D.P., 2000. Modelling Oil and Chemical Spill Impacts. Sea Technology 42(4): 43-49, April 2001

French, D.P., 2000. Modelling Oil Spill Impacts. In: State of the Art in Oil Modelling and Processes, R. Garcia-Martinez and C. Brebbia (eds.), WIT Press, Ashurst Lodge, Ashurst, Southampton, UK, 2001.

French, D.P., 1998. Evolution of oil trajectory, fate and impact assessment models. p. 73-86 In: Oil and Hydrocarbon Spills, Modelling, Analysis and Control, R. Garcia-Martinez and C. A. Brebbia (eds.), Computational Mechanics Publications, Ashurst Lodge, Ashurst, Southampton, UK, 2001.

French, D.P. and M. Reed, 1994. Integrated Environmental Impact Model and GIS for Oil and Chemical spills. P. 197-198 In: GIS and Environmental Modeling: Progress and Research Issues, Michael F. Goodchild, Louis T. Steyaert, Bradley O. Parks, Carol Johnston, David Maidment, Michael Crane, and Sandi Glendinning, Editors, GIS World Books, Fort Collins, CO, 1996.

French, D.P. and T. Smayda, 1993. Temperature regulated responses of nitrogen-limited *Heterosigma akashiwo*, with relevance to its blooms. P.

Lessus, G. Arzul, E. Erard, P. Gentien, and C. Marcaillou, Eds., Harmful Marine Algal Blooms, Technique et Documentation, Lavoisier, Intercept. Ltd.

French, D.P., 1991. Estimation of exposure and resulting mortality of aquatic biota following spills of toxic substances using a numerical model, *Aquatic Toxicology and Risk Assessment: Fourteenth Volume*, ASTM STP 1124, (M.A. Mayes and M.G. Barron, Eds.) American Society for Testing and Materials, Philadelphia, 1991, pp. 35-47.

French, D.P., 1990. Utilizing numerical models to assess natural resource damages from the oil spills: The *World Prodigy* case. Marine Technology Society Journal 24(4):16-22.

French, D.P. and M. Reed, 1990. Potential impact of entanglement in marine debris on the population dynamics of the northern fur seal, *Callorhinus ursinus*. p. 431-452 In: R.S. Shomura and M.L. Godfrey (eds.) Proceedings of the Second International Conference on Marine Debris, April 2-7, 1989, Honolulu, Hawaii.

Feng, S., M. Reed and D.P. French, 1989. The chemical data base for the natural resource damage assessment model system. Oil and Chemical Pollution 5:165-193.

French, D.P. and F.W. French, III, 1989. The biological effects component of the natural resource damage assessment model system. Oil and Chemical Pollution 5:125-163.

French, D.P., M. Reed, J. Calambokidis and J. Cubbage, 1989. A simulation model of seasonal migration and daily movements of the northern fur seal, *Callorhinus ursinus*. Ecological Modelling 48:193-219.

Reed, M., D.P. French, J. Calambokidis and J. Cubbage, 1989. Simulation modelling of the effects of oil spills on population dynamics of northern fur seals. Ecological Modelling 49:49-71.

Reed, M., D.P. French and K. Jayko, 1987. Simulation of marine ecosystem effects due to PCB waste incineration in the Gulf of Mexico. Ecological Modeling 38:213-242.

Reed, M., K. Jayko, D.P. French, M. Spaulding, T. Isaji and J. Rosen, 1986. A model system for estimating fate and effects of pollutants in marine ecosystems: Application and sensitivity analyses. Rapp. P.-v. Reun. Cons. Int. Explor. Mer. 186:80-103.

French, D.P., 1984. Nutrient and temperature-limited continuous culture of the phytoplankton species *Skeletonema costatum* (Greville) Cleve, *Asterionella glacialis* Castracane and *Olisthodiscus luteus* Carter, and modeling of their seasonal succession in Narragansett Bay, R.I., Ph.D. Thesis, University of Rhode Island, Kingston, R.I.

French, D.P., M.J. Furnas and T.J. Smayda, 1983. Diel changes in nitrite concentration in the chlorophyll maximum in the Gulf of Mexico. Deep-Sea Research 30:797-722.

Technical Reports

French McCay, D., Dagmar Schmidt Etkin, CJ Beegle-Krause, J. Rowe, Colin Moore and Keith Michel, 2008. Final Report, Oil Spill Risk Analysis Review, Submitted to: State of Washington Joint Legislative Audit and Review Committee, Olympia WA, ASA Report 2008-099, November 3, 2008, 42p. plus appendices.

French McCay, D., J. Rowe, S. Sankaranarayanan, and M. Schroeder, 2007. CITGO Refinery Spill of 21 June 2006 in Calcasieu River, Louisiana: Inputs for Modeling of Physical Fates and Biological Injuries to Subtidal Aquatic Organisms. Draft Report to National Ocean Service NOAA, Office of

Response & Restoration/Assessment & Restoration Division, Baton Rouge, LA, ASA Report 2006-181, June 4, 2007.

Payne, J.R., French-McCay, D.P, C. Mueller, K. Jayko, B. Longval, M. Schroeder, E. Terrill, M. Carter, M. Otero, S.Y. Kim, W. Middleton, A. Chen, W. Nordhausen, R. Lewis, M. Lampinen, T. Evans, C. Ohlmann, 2007. Evaluation of Field-Collected Drifter and In Situ Fluorescence Data Measuring Subsurface Dye Plume Advection/Dispersion and Comparisons to High-Frequency Radar-Observation System Data for Dispersed Oil Transport Modeling. Final Report Submitted to the NOAA/UNH Coastal Response Research Center. NOAA Grant Number(s): NA04NOS4190063 (CFDA No. 11-419). Project Number: 06-084, May 11, 2007, 96p plus 8 appendices.

French-McCay, D.P., J.J. Rowe, N. Whittier, R. Asch, S. Sankaranarayanan, A. Borowik, C. Suárez, and D. S. Etkin, 2006. Evaluation of the Consequences of Various Response Options Using Modeling of Fate, Effects and NRDA costs for Oil Spills into Washington Waters, Phase II: Draft Report (29 Volumes), submitted to Washington Department of Ecology, Lacey, WA, February 2006.

Etkin, D.S. and D. French-McCay, 2005. Summary of Response Modeling Assumptions and Results For Washington State Oil Spill Scenarios Phases I and II. Submitted to Washington Department of Ecology, Lacey, WA, October 2005.

French McCay, D, J. Rowe, N. Whittier, S. Sankaranarayanan, C. Suàrez, and D. Schmidt Etkin, 2005b. Evaluation of the Consequences of Various Response Options Using Modeling of Fate, Effects and NRDA costs for Oil Spills into Washington Waters. Phase I, Final Report (26 volumes), Submitted to Washington Department of Ecology, Lacey, WA, November 2005.

French McCay, D.P., Jill Rowe, Matthew Ward, and Dennis Forsythe, 2005. Revised Report: M/V Ever Reach Spill of 30 September 2002 in Charleston Harbor, SC: Modeling of Physical Fates and Biological Injuries. Prepared under contract to NOAA Damage Assessment Center, Silver Spring, MD, October 4, 2005.

French McCay, D.P., 2005. Revised Report for Trustees: M/V Ever Reach Spill of 30 September 2002 in Charleston Harbor, SC: Restoration Scaling for Bird Injuries. Prepared under contract to NOAA Damage Assessment Center, Silver Spring, MD, October 4, 2005.

French McCay, D., D. Aurand, J. Michel, R. Unsworth, N. Whittier, C. Lord, C. Dalton, R. Levine, J. Rowe, S. Sankaranarayanan, H-S. Kim, R. Piovesan and M. Hitchings, 2004. Oil Spills Fate and Effects Modeling for Alternative Response Scenarios. Final Report to US Department of Transportation, Cambridge, MA and US Coast Guard, Washington, DC, submitted by Applied Science Associates, Narragansett, RI, USA, March 2004, 6 volumes.

French McCay, D., J. J. Rowe, and N. Whittier, 2003a. Final Report, Estimation of Natural Resource Damages for 23 Florida Cases Using Modeling of Physical Fates and Biological Injuries. (23 volumes). Prepared for Florida Department of Environmental Protection, May 2003.

French McCay, D., J. J. Rowe, N. Whittier, S. Subbayya, W. Saunders, C. Dalton, and D.S. Etkin 2003. Bio-Economic Modeling for Oil Spills from Tanker/Freighter Groundings on Rock Pinnacles in San Francisco Bay. Final report prepared for US Army Corps of Engineers – San Francisco District, Dept. of the Army, Sacramento, CA, Contract No. DACW07-01-R-0001, May 2003, 7 volumes.

French McCay, D., and J. Jennings, 2002. Chalk Point Oil Spill of April 7, 2000 in Patuxent River, MD: Modeling of the Fates and Acute Biological Effects of the Spilled Oil on the Water Column. Final report prepared for Research Planning Inc., Columbia, SC, for submission to NOAA Damage Assessment Center, Silver Spring, MD, April 2002, 36p plus appendices.

French McCay, D., N. Whittier, T. Isaji and W. Saunders, 2002. Assessment of the potential impacts and NRDA costs for oil spills in the James River. Final report prepared for Research Planning, Inc., Columbian, SC, for submission to Maritime Administration, South Atlantic Region, Department of Transportation, Norfolk, Virginia, February 2002, 84p plus appendices.

French McCay, D., C. Galagan and N. Whittier, 2001. Florida mystery spill of August 2000: modeling of physical fates and biological injuries. Final Report prepared for NOAA Damage Assessment Center, October 2001, 35p. plus appendices.

French McCay, D. and C. Galagan, 2001. *M/T Westchester* spill in the Mississippi River, November 2000: modeling of physical fates and biological injuries. Final Report prepared for Industrial Economics, Inc., September 2001, 35p. plus appendices.

French McCay, D. and J. Payne, 2001. Final report, computer simulations: Spatial and temporal movement of spilled oil. Final report prepared Tetra Tech EM, Reston, VA, for submission to U.S. EPA, Office of Research and Development, National Exposure Research Laboratory, Ecosystems Research Division, Athens, Georgia, Sept. 2001.

French McCay, D., 2001. *T/B.Penn* spill of July 2000 in Narragansett Bay: Modeling of physical fates and biological injuries. Final report prepared for Stephen Morin, RI Department Environmental Management. Providence, Rhode Island, May 2001, 36p. plus appendices.

Boehm, P., D. Turton, A. Raval, D. Caudle, D. French, N. Rabelais, R. Spies, and J. Johnson, 2001. Deepwater program: Literature review, environmental risks of chemical products used in Gulf of Mexico deepwater oil & gas operations, Final report to US Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, February 20001, OCS Study MMS 2001-011, 326p plus appendices.

French McCay, D.P., 2001. Development and application of an oil toxicity and exposure model, OilToxEx. Final report to NOAA Damage Assessment Center, Silver Spring, MD, January 2001, 50p plus appendices.

French D. P., 2000. Habitat productivity analysis to compensate for injuries resulting from the December 1997 process water spill into the Alafia River. Submitted to NOAA Damage Assessment Center Silver Springs MD. ASA project 99-176.

French, D., T. Isaji, K. Jayko, C. Galagan, D. Field, 2000. Draft final report, *M/V Kure* spill pathway analysis: Trajectory modeling. Prepared for the California Department of Fish and Game, Sacramento, CA.

French, D. and T. Isaji, 2000. Spill pathway analysis: Trajectory modeling of the September 1998 spill in the San Francisco southern traffic lane. Prepared for Office of Spill Prevention and Response, California Department of Fish and Game, Sacramento, California.

French, D., 1999. Restoration scaling for marine and salt pond shellfish injuries resulting from the *North Cape* oil spill: With updated surf clam injury. Prepared for Industrial Economics, Incorporated, 2067 Massachusetts Avenue, Cambridge, MA 02140 and NOAA Damage Assessment Center. NOAA Contract: 50-DSNC-7-900032. ASA project #98-10.

French, D. 1999. Pre-assessment NRDA analysis: Preliminary modeling of the fates and effects of oil released from the *M/V New Carissa* in February-March 1999. Prepared for Industrial Economics, Incorporated, 2067 Massachusetts Avenue, Cambridge, MA 02140 and NOAA Damage Assessment Center. NOAA Contract: 50-DSNC-7-900032.

French, D., 1999. Restoration scaling for injuries resulting from the *North Cape* oil spill. Prepared for Industrial Economics, Incorporated, 2067 Massachusetts Avenue, Cambridge, MA 02140 and NOAA Damage Assessment Center. NOAA Contract 50-DSNC-7-90032.

French, D., 1999. North Cape oil spill: Synthesis of injury quantification and restoration scaling for lobsters. Prepared for Industrial Economics, Incorporated, 2067 Massachusetts Avenue, Cambridge, MA 02140 and NOAA Damage Assessment Center. NOAA Contract 50-DSNC-7-90032.

French, D., H. Schuttenberg, C. Galagan, and E. Howlett, 1999. Trajectory and risk analysis for FPL plants and terminals using the spill impact model analysis package (SIMAP). Report to Florida Power & Light, 700 Universe Boulevard, Juno Beach, FL 33408

French, D.P., 1998. Scaling injuries resulting from the December 1997 process water spill into the Alafia River. Prepared for Industrial Economics, Inc., Cambridge, MA 02140.

French, D.P., 1998. The natural resource damage assessment model for California (NRDAM/CAL). Technical documentation, February 1998.

French, D.P., 1998. Modeling of the torch/platform Irene pipeline spill. Report to NOAA Damage Assessment Center, Rapid Assessment Program, Silver Springs, MD, NOAA Contract 50-DSNC-7-90032, March 12, 1998.

French, D.P., 1998. Modeling of the fates and effects of the Lake Barre pipeline release of May 1997. Report to NOAA Damage Assessment Center, Silver Springs, MD, NOAA Contract: 50-DSNC-7-90032, September 9, 1998.

French, D.P. and H. Rines, 1998. Estimation of losses in the salt ponds resulting from water column and sediment acute toxicity from the *North Cape* oil spill. Report to NOAA Damage Assessment Center, Silver Springs, MD, September 1998.

French, D.P., 1998. Updated estimate of injuries to marine communities resulting from the *North Cape* oil spill based on modeling of fates and effects. Report to NOAA Damage Assessment Center, Silver Spring, MD, September 1998.

French, D.P., 1998. Restoration scaling for injuries resulting from the *North Cape* oil spill. Report to NOAA Damage Assessment Center, Silver Spring, MD, Contract: 50-DSNC-7-90032, August 1998.

French, D.P., 1998. *North Cape* oil spill: Synthesis of injury quantification and restoration scaling for lobsters. Report to NOAA Damage Assessment Center, Silver Springs, MD, August 31, 1998.

French, D.P. and H. Rines, 1998. Determining the window of opportunity for water column sampling: surface oil spills. Report to NOAA Damage Assessment Center, Rapid Assessment Program. NOAA Contract: 50-DSNC-7-90032, Silver Springs, MD, January 22, 1998.

French, D. P., 1998. Estimate of Injuries to marine communities resulting from the *North Cape* oil spill based on modeling of fates and effects. Report to NOAA Damage Assessment Center, Silver Spring, MD, January 1998.

French, D.P. and H. Rines, Tampa Bay Oil Spill Damage Assessment: Water Column Injury, Report to National Oceanic and Atmospheric Administration, Damage Assessment Center, April 15, 1997.

French, D.P. and C. Galagan, 1997. Oil spill trajectories and analysis of maximum credible natural resource damages resulting from platform spills in the Gulf of Mexico offshore of Apalachicola Bay. Report to: Coastal Petroleum, PO Box 10468, Tallahassee, FL 32302, September 4, 1997.

French, D.P., M. Reed, K. Jayko, S. Feng, H. Rines, S. Pavignano, T. Isaji, S. Puckett, A. Keller, F. W. French III, D. Gifford, J. McCue, G. Brown, E. MacDonald, J. Quirk, S. Natzke, R. Bishop, M. Welsh, M. Phillips and B.S. Ingram, 1996. The CERCLA type A natural resource damage assessment model for coastal and marine environments (NRDAM/CME), Technical Documentation, Vol. I-V. Final report, submitted to the Office of Environmental Policy and Compliance, U.S. Dept. of the Interior, Washington, DC, April, 1996, Contract No. 14-0001-91-C-11.

Reed, M., D.P. French, S.Feng, F.W. French III, E. Howlett, K, Jayko, W.Knauss, J. McCue, S. Pavignano, S. Puckett, H. Rines, R.Bishop, M. Welsh, and J. Press, 1996. The CERCLA type a natural resource damage assessment model for the Great Lakes environments (NRDAM/GLE), Vol. I-III. Final report, submitted to Office of Environmental Policy and Compliance, U.S. Department of the Interior, Washington, DC, by Applied Science Associates, Inc., Narragansett, RI, April 1996, Contract No. 14-01-0001-88-C-27.

French, D.P., and Rines, H., 1995. Rap manual support document: Preliminary assessment of chemical spills. Submitted to National Oceanic and Atmospheric Administration, Damage Assessment Center, Silver Spring, MD, ASA # 95-01.

French, D.P., and Rines, H., 1995. Considerations and methods for performing mass balance calculations for oil spills. Submitted to: National Oceanic and Atmospheric Administration, Damage Assessment Center, Silver Spring, MD, ASA # 95-01.

French, D.P., S. Pavignano, A. Keller, D. Gifford, S. Puckett, S. Feng, M. Reed, M. Welsh and R. Bishop, 1993. Compensation formula for natural resource damage assessments under OPA: Oil spills into inland (freshwater) waters. Report to the National Oceanic and Atmospheric Administration, Rockville, MD, March 1993.

French, D.P., M. Reed, S. Puckett, S. Pavignano, H. Rines, A. Keller, D. Gifford, F.W. French III, S. Feng, C. Turner, G. Brown, E. MacDonald, J. Quirk, S. Natzke and B.S. Ingram, 1993. Compensation formula for natural resource damage assessments under OPA: Oil spills into estuarine and marine environments. Report to National Oceanic and Atmospheric Administration, Rockville, MD, March 1993.

French, D.P., H. Rines, D. Gifford, A. Keller, S. Pavignano, G. Brown, B. Ingram, E. MacDonald, J. Quirk, S. Natzke, and K. Finkelstein, 1993. Final report: Restoration guidance document for natural resource injury as a result of discharges of oil. Report to National Oceanic and Atmospheric Administration, Office of General Council, Damage Assessment Regulations Team, February, 1994, submitted by EG&G Washington Analytical Services Center with Applied Science Associates, Contract No. 50-DSNC-8-00139, ASA 92-65.

French, D.P., H. Rines, D. Mendelsohn, J. Boothroyd, C. Galagan, M. Harlin, A. Keller, G. Klein-MacPhee, S. Pratt, A. Ross, M. Gould, and L. Gould, 1991. Habitat inventory/resource mapping for Narragansett Bay and associated coastline. Atlas, ASA 89-33, June 1991.

French, D.P., J.J. Opaluch and T.A. Grigalunas, 1990. World Prodigy oil spill damage assessment using the CERCLA Type A Model (NRDAM/CME). Report to the Rhode Island Department of the Attorney General, Providence, R.I., August 1990, 30 p. plus appendices.

French, D.P., S. Hurlbut, E. Anderson and M. Reed, 1989. Simulation of effects of potential oil spills on Georges Bank scallop and cod. Final report prepared for Texaco Canada Resources Ltd., Calgary, Alberta, Canada, March 1989, 229 p. plus appendices.

Conference Proceedings

French-McCay, D.P, and E. Graham, 2010. Guidance for Dispersant Decision Making: Potential for Impacts on Aquatic Biota. In: Proceedings of the 33rd AMOP Technical Seminar on Environmental Contamination and Response, Emergencies Science Division, Environment Canada, Ottawa, ON, Canada.

French-McCay, D.P, 2009. State-of-the-Art and Research Needs for Oil Spill Impact Assessment Modeling. In: Proceedings of the 32nd AMOP Technical Seminar on Environmental Contamination and Response, Emergencies Science Division, Environment Canada, Ottawa, ON, Canada, pp. 601-653.

French-McCay, D.P, CJ Beegle-Krause, J. Rowe, W. Rodriguez, and D. S. Etkin, 2009. Oil Spill Risk Assessment – Relative Impact Indices by Oil Type and Location. In: Proceedings of the 32nd AMOP Technical Seminar on Environmental Contamination and Response, Emergencies Science Division, Environment Canada, Ottawa, ON, Canada, pp. 655-681.

French-McCay, D.P, N. Whittier, and J.R. Payne, 2008. Evaluating Chemical Spill Risks to Aquatic Biota Using Modeling. In: Proceedings of the 31th AMOP Technical Seminar on Environmental Contamination and Response, Emergencies Science Division, Environment Canada, Ottawa, ON, Canada, pp. 243-272.

French-McCay, D.P, J. Rowe and D.S. Etkin, 2008. Transport and Impacts of Oil Spills in San Francisco Bay – Implications for Response. In: Proceedings of the 31th AMOP Technical Seminar on Environmental Contamination and Response, Emergencies Science Division, Environment Canada, Ottawa, ON, Canada, pp. 159-176.

French-McCay, D.P., 2008. Modeling as a Scientific Tool in NRDA for Oil and Chemical Spills. Paper 396, Proceedings of the 2008 International Oil Spill Conference, American Petroleum Institute, Washington, D.C.

French-McCay, D.P., C. Mueller, J. Payne, E. Terrill, M. Otero, S.Y. Kim, M. Carter, W. Nordhausen, M. Lampinen, B. Longval, M. Schroeder, K. Jayko, and C. Ohlmann, 2008. Dispersed Oil Transport Modeling Calibrated by Field-Collected Data Measuring Fluorescein Dye Dispersion. Paper 393, Proceedings of the 2008 International Oil Spill Conference, American Petroleum Institute, Washington, D.C.

French-McCay, D.P, C. Mueller, K. Jayko, B. Longval, M. Schroeder, J.R. Payne, E. Terrill, M. Carter, M. Otero, S. Y. Kim, W. Nordhausen, M. Lampinen, and C. Ohlmann, 2007. Evaluation of Field-Collected Data Measuring Fluorescein Dye Movements and Dispersion for Dispersed Oil Transport Modeling. In Proceedings of the 30th Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Emergencies Science Division, Environment Canada, Ottawa, ON, Canada, pp.713-754.

Payne, J.R., E. Terrill, M. Carter, M. Otero, W. Middleton, A. Chen, French-McCay, D.P, C. Mueller, K. Jayko, W. Nordhausen, R. Lewis, M. Lampinen, T. Evans, C. Ohlmann, G. L. Via, H. Ruiz-Santana, M. Maly, B. Willoughby, C. Varela, P. Lynch and P. Sanchez, 2007.

Evaluation of Field-Collected Drifter and Subsurface Fluorescein Dye Concentration Data and Comparisons to High Frequency Radar Surface Current Mapping Data for Dispersed Oil Transport Modeling. In Proceedings of the 30th Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Emergencies Science Division, Environment Canada, Ottawa, ON, Canada, pp.681-711.

D.S. Etkin, J. J. Rowe, S. Sankaranarayanan, D.P. French-McCay, and J. Reichert 2007. Using Current Analysis to Determine Efficacy of Pre-Booming Operations. In Proceedings of the 30th Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Emergencies Science Division, Environment Canada, Ottawa, ON, Canada, pp. xxx-xxx.

D.S. Etkin, French-McCay, D.P, and J. J. Rowe, 2007. Using Analytical Models to Assess the Benefits of Oil Spill Response technology. In Proceedings of the 30th Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Emergencies Science Division, Environment Canada, Ottawa, ON, Canada, pp.657-680.

French-McCay, D.P, J. J. Rowe, W. Nordhausen, and J.R. Payne, 2006. Modeling Potential Impacts of Effective Dispersant Use on Aquatic Biota. In Proceedings of the 29th Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Emergencies Science Division, Environment Canada, Ottawa, ON, Canada, pp.855-878.

French-McCay, D.P, J. J. Rowe, S. Sankaranarayanan, and D.S. Etkin, 2006. Data Needs to Reliably Hindcast a Spill's Impact: The PEPCO Pipeline Spill of April 2000 as Case Example. In Proceedings of the 29th Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Emergencies Science Division, Environment Canada, Ottawa, ON, Canada, pp.827-853.

Etkin, D.S., D. French McCay, and J. Rowe. 2006. Modeling to evaluate effectiveness of variations in spill response strategy. In Proceedings of the 29th Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Emergencies Science Division, Environment Canada, Ottawa, ON, Canada, pp.879-892.

French-McCay, D.P, N. Whittier, D. Aurand, C. Dalton, J. J. Rowe, S. Sankaranarayanan, and H.-S. Kim, 2005. Use of Probabilistic Trajectory and Impact Modeling to Assess Consequences of Oil Spills with Various Response Strategies. In Proceedings of the 28th Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Emergencies Science Division, Environment Canada, Ottawa, ON, Canada, pp. 253-271.

French-McCay, D.P, N. Whittier, D. Aurand, C. Dalton, J. J. Rowe, S. Sankaranarayanan, 2005. Modeling fates and impacts of hypothetical oil spills in Delaware, Florida, Texas, California, and Alaska waters, varying response options including use of dispersants. Proceedings, 2005 International Oil Spill Conference, Paper 399, Miami, Florida, American Petroleum Institute, Washington, DC.

French-McCay, D.P, J. J. Rowe, N. Whittier, S. Sankaranarayanan, D. S. Etkin, and L. Pilkey-Jarvis, 2005. Evaluation of the Consequences of Various Response Options Using Modeling of Fate, Effects and NRDA Costs of Oil Spills into Washington Waters. Proceedings, 2005 International Oil Spill Conference, Paper 395, Miami, Florida, American Petroleum Institute, Washington, DC.

French McCay, D.P., and J.J. Rowe, 2004. Validation of the SIMAP Oil Spill Model Using Historical Oil Spill Cases. In *Proceedings of the 27th Arctic and Marine Oil Spill Program (AMOP) Technical Seminar*, Emergencies Science Division, Environment Canada, Ottawa, ON, Canada, pp. 421-452.

French McCay, D. and N. Whittier, 2003. Modeling Assessment of Potential Fates and Exposure for Orimulsion and Heavy Fuel Oil Spills. In: *Proceedings, International Oil Spill*

Conference, April 2003, Paper 157, American Petroleum Institute, Washington, DC.

French McCay, D., N. Whittier, S. Sankaranarayanan, J. Jennings, and D. S. Etkin, 2002. Modeling Fates and Impacts for Bio-Economic Analysis of Hypothetical Oil Spill Scenarios in San Francisco Bay. In *Proceedings of the 25th Arctic and Marine Oil Spill Program (AMOP) Technical Seminar*, Emergencies Science Division, Environment Canada, Ottawa, ON, Canada, p. 1051-1074.

French McCay, D. James R. Payne, 2001. Model of oil fate and water concentrations with and without application of dispersants. *Proceedings of the 2001 24th Arctic and Marine Oil Spill Program (AMOP) Technical Seminar*, June 12-14, 2001, Environment Canada, pp.611-645.

French McCay, D. P. 2001. Chemical spill model (CHEMMAP) for forecasts/hindcasts and environment risk assessment. *Proceedings of the 2001 24th Arctic and Marine Oil Spill Program (AMOP) Technical Seminar*, June 12-14, 2001, Environment Canada, pp.825-846.

French, D., H. Schuttenberg, T. Isaji, 1999. Probabilities of oil exceeding thresholds of concern: Examples from an evaluation for Florida Power & Light. In: *Proceedings of the 22nd Arctic and Marine Oil Spill Program (AMOP) Technical Seminar*, June 2-4, 1999, Environment Canada, pp. 243-270.

French, D.P. and H. Rines, 1997. Validation and use of spill impact modeling for impact assessment. In: *Proceedings of the 1997 International Oil Spill Conference*, American Petroleum Institute, Fort Lauderdale, Florida, Publication No. 4651, pp. 829-834, 1997.