DISASTERS

Scenario-Building for the Deepwater Horizon Oil Spill

Interdisciplinary science-based scenarios can assist responses to the Gulf oil spill and similar environmental crises.

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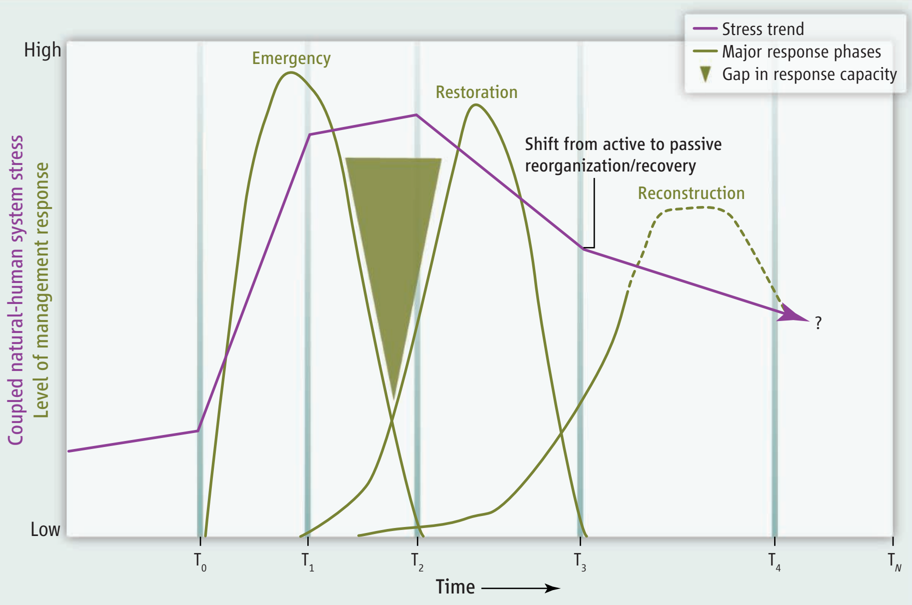
In May 2010, the U.S. Department of the Interior (DOI) established a Strategic Sciences Working Group (SSWG) to assess how the Deepwater Horizon (DH) oil spill may impact the ecology, economy, and people of the Gulf of Mexico (GOM). It included scientists from diverse disciplines and federal, academic, and nongovernmental organizations. The SSWG was not to conduct a scientific investigation, but to provide rapid scientific assessment of potential consequences of the spill that could provide usable knowledge to decision-makers.

Such teams are not common to formal government response efforts. Most scientific activity at early stages of the spill was tactical, e.g., documenting preimpact conditions, monitoring oil transport, assessing resource damage, and supporting technical decisions associated with oil containment. Interdisciplinary and comprehensive analyses of consequences were not integral to these tactical efforts. The SSWG was a strategic and experimental response initiated by DOI, novel to the DH spill for its combination of (i) independence from standard response structures [e.g., the Incident Command System (ICS) and Natural Resource Damage Assessment (NRDA)]; (ii) collaborative engagement of federal and nonfederal scientists; (iii) rapid scenario-building within a interdisciplinary framework; (iv) assignment of scientific uncertainties; and (v) potential application to mid- and long-term recovery. The SSWG assembled in Mobile, Alabama, within 36 hours of establishment and developed initial scenarios 23 to 28 May 2010. A full description of the methodology and scenario results is available in the group's first technical report (*1*).



Conceptual scenario framework. This shows system stress, time horizons, major management response phases, and the potential gap in response capacity. [Adapted from (*1*)]

Organizing Framework

During major incidents such as the DH oil spill, response time is critical, conditions change rapidly, quantitative models and/or their requisite data may be unavailable, and many key factors are unknown. Scenario-building, originally developed for the military (*2*) and adapted by large-scale firms and others, offers several advantages, particularly its capacity to systematically examine possible futures and cascading consequences that are complex and uncertain (*3*, *4*). Unlike quantitative modeling or risk assessment, scenarios identify alternative futures rather than predict new-state conditions. Limitations include constraints due to available expert opinion and lack of theory (*4*).

There are numerous approaches to constructing science-based scenarios (*3*). For the oil spill, the SSWG adapted and applied a specific, coupled natural-human systems model to identify key variables (*5*) and developed a conceptual framework adapted from the natural hazards literature to reflect the DH oil spill (*6*, *7*). Scenarios were not limited to discrete physical, chemical, biological, economic, and/or sociocultural consequences but included how these consequences interact in shaping possible trajectories of the overall system.

The scenario framework (see the figure) incorporates system stress over key time horizons through recovery. Baseline stress in the GOM was treated as increasing before the DH oil spill, due to nutrient loading, expansion of the seasonal hypoxic area, wetland loss, land subsidence, invasive species, climate change, fishing pressures, effects of past hurricane damage, and national and regional economic recession (*8*–*11*). At the time of the DH explosion (T_0; 20 April 2010), system stress began to rapidly accumulate. After oil flow containment (T_1; well shut-in occurred 15 July 2010) system stress may continue to rise due to lagged effects, e.g., landfall of previously released oil and/or chronic toxicity to sensitive ecosystem components. At T_2, system stress begins to decline because of a combination of reduced inputs of stressors, resilience in the coupled natural-human system, and emergency and recovery responses. Long-term recovery (T_3, T_4, to T_N) involves some reorganization of the system rather than full return to preexisting states (*12*); future baseline stress is largely unknown. Natural variability is overlaid on general stress trends (*13*).

Building the Scenarios

The SSWG rapid assessment involved establishing a matrix of alternative scenario param-

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eters, using parameter subsets to develop a detailed "chain of consequences," and assigning a level of uncertainty to each element in each chain. The SSWG developed four key parameters, based on expert opinion and data from ICS briefings: (i) estimated flow rate for DH oil release [5000; 12,000 to 19,000; 40,000; or 100,000 barrels (bbl)/day]; (ii) estimated time to containment of the oil release (40, 100, or 160 days); (iii) time horizons (T_1 to T_4, and T_N); and (iv) geographic and spatial units of interest (vertical life zones, major ecosystem types, sociopolitical and administrative units, and GOM biodiversity quadrants) (*14–17*). This approach allowed for adaptation to new information, such as revised flow-rate estimates or oil landfall data. Beginning with specific scenario parameters, group members examined variables in the coupled natural-human system model, developed chains of consequences, and integrated these into an overall scenario. Online literature searches and input from additional subject-matter experts were also used. The SSWG applied a scale of informal scientific certainty (*18*), well-suited to scenario-building, that allows for rapid refinement as new information becomes available. The SSWG established uncertainty levels for each cascading consequence. Where opinions diverged, the precautionary principle dictated assignment of the lower level of certainty.

A Recovery Scenario

Scenario S3, constructed 27 May 2010, was requested by the DOI Mobile Incident Command. It employed estimates by the ICS Flow Rate Technical Group released that morning (other scenarios used higher flow estimates), and oil landfall patterns reported for the previous 48 hours. S3 examined time horizons for short-term and long-term recovery (T_2 to T_4), assumed 12,000 to 19,000 bbl/day oil release, and 100 days to containment. Geographic focus was the littoral zone in the northwest biodiversity quadrant of the GOM, including Louisiana and Texas. Several highlights emerged, for example: (i) Delayed mortality of wetland flora is probable and could impair fisheries recovery and resistance to hurricane damage, with cascading consequences from rerelease of sequestered oil; (ii) rerelease of sequestered oil triggered by storms and hurricanes is reasonably certain to lead to a resumption of stress in the coupled natural-human system; (iii) recovery by oysters may be slow and is likely to result in long-term displacement of some oyster harvesters; (iv) delayed stress on cultural communities, e.g., Isleños, Acadians, and United Houma [Indian] Nation, is reasonably certain; (v) institutional adjustments related to regulation and reorganization of government systems are reasonably certain.

Applications to the DH Oil Spill

The SSWG scenarios provide decision-makers with possible intervention points (e.g., when mid-water contamination reaches critical levels and/or tax revenues begin to decline). Decision-makers can focus attention on key interventions likely to reduce negative impacts (e.g., rerelease of sequestered oil) and/or increase resilience and positive recovery responses (e.g., improved monitoring or targeted income support). The scenarios reveal potential surprises that might be initially overlooked by decision-makers (e.g., fishing closures leading to rebound of previously stressed fish populations or the impact of re-introducing compromised birds into migratory bird populations). The scenarios can identify potential new monitoring needs (e.g., advanced monitoring technologies for mid-water pollution, new protocols for monitoring rerelease of sequestered oil, and/or long-term monitoring for occupational exposure or financial stress). Such advances can support ongoing inventory and monitoring programs, inform modeling efforts, help develop future NRDA protocols, and contribute to incident command training. Chains of consequences with their approximate levels of scientific uncertainty can help prioritize research and policy needs by identifying important, but not yet well understood, relations (e.g., the relation between landfall hurricanes, oiling of marshland, and ecosystem stress).

A Strategic Sciences Approach

Science is only one of many inputs into policy during a complex event such as the DH oil spill. Beyond technical problem analyses (e.g., evaluating "kill" methods for shutting the DH well), the influence of a particular scientific assessment upon policy is partial, given the range of inputs, interests, and institutions involved.

Comparison of the DH spill with other regional disruptive events may be insightful. Three response phases following Hurricane Katrina were (i) emergency, (ii) restoration, and (iii) reconstruction (*19*). Although Hurricane Katrina and the DH oil spill differ in substantial ways (e.g., high loss of life and severe infrastructure damage), overlaying generalized response phases onto the scenario framework (see the figure) reveals a potential gap in capacity between emergency and recovery phases, which, for the DH oil spill, is likely a period of continued increase in system stress. Elements of the restoration phase should be initiated concurrently with the standing down of the emergency, so as to more quickly and effectively achieve recovery of the coupled natural-human system. Timely development and implementation of restoration plans are essential. Further SSWG scenario-building focused on recovery is currently under way [another SSWG session is scheduled 20 to 24 September in New Orleans, with updates available at (*20*)] and includes additional subject matter experts, decision-support tools, and refined scenario techniques. We believe there is a valuable role for this strategic approach to science and policy interaction as the federal government learns from the DH oil spill, plans and implements GOM recovery, and prepares for future environmental crises.

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21. The authors thank members of the DOI SSWG: C. Colten, S. Dalton, J. Grace, J. Eitel, J. Hay, G. Plumb, E. Widder, and R. Woita. Additional assistance, advice, and review were provided by A. Castle, J. Cross, J. Jarvis, J. McKendry, S. Kimball, B. Werkheiser, colleagues of SSWG members, and anonymous reviewers.

10.1126/science.1195382