Impacts, Perception, and Policy Implications of the Deepwater Horizon Oil and Gas Disaster

by Elliott A. Norse and John Amos

Elliott A. Norse is President, Marine Conservation Biology Institute, Bellevue, Washington.
John Amos is President, SkyTruth, Shepherdstown, West Virginia.

I. Background

In many places, truth is what economic interests or government say it is, and the media and legal institutions are their facilitators. But countries with a robust nongovernmental sector have made the decision to welcome (or at least tolerate) unblinking, independent scrutiny as a way to create both more just societies and more effective economies and governments. When disseminated publicly, the analyses of skilled nongovernmental observers can provide crucial perspective and a useful reality check on powerful economic interests and government. As scientists (JA is a geologist; EAN is a marine biologist) who worked on aspects of oil and gas drilling for the industry and the federal government, respectively, and now, as chief executive officers of small environmental nonprofit organizations, we offer this Article on what is seen as the greatest environmental catastrophe in U.S. history. Our purpose is to help people remember this very recent past, and thereby avoid being condemned to repeat it. Because this event is so recent, almost none of the work we cite has appeared in the peer-reviewed scientific literature.

A. How It Happened

In the early months of 2010, a technological marvel floated in the Gulf of Mexico, 50 miles off the Louisiana coast. She was the Deepwater Horizon, drilling the first oil well in the newly discovered Macondo Oilfield. Known as a Mobile Offshore Drilling Unit, this semisubmersible rig was built in South Korea in 2001. It was 400 feet long, 250 feet wide, and stood 14 stories tall.[1] Designed to withstand heavy weather and operate in the extreme deepwater frontier environments targeted by the global offshore oil industry, it had just set a record at the end of 2009: drilling a well nearly seven miles into the earth, in water 4,000 feet deep, continuing a long string of record-setting achievements for its owners, Transocean, and the rig's client, BP.[2] But on April 20, something went terribly wrong.

At about 10 p.m., a series of explosions ripped through the rig, killing 11 workers and injuring 17 others. Intense fire spread rapidly, and the survivors evacuated, some jumping off the deck and plunging nearly 80 feet into the dark Gulf waters below. Fire raged unabated for nearly two days, as emergency teams raced to the site and poured seawater on the blaze. But despite their efforts, the rig listed heav-

Authors' Note: During an environmental trauma of this magnitude, when emotions are running high and information is scarce, scattered, and sometimes contradictory, it is especially encouraging that good people have come forward with observations, data, analysis, and funding when it is needed most.

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Finally, we thank our wise and patient spouses, Amy Mathews Amos and Irene Norse, for enduring our obsession with absorbing the copious information on OCS oil and gas, critiquing our ideas, and allowing us to devote the long hours needed to understand this momentous event.

1. Offshore-Technology.com, Macondo Prospect, http://www.offshore-technology.com/projects/macondoprospect/ (last visited Sept. 24, 2010).
2. Transocean, Deepwater Horizon Drills World's Deepest Oil & Gas Well, http://www.deepwater.com/fw/main/IDeepwater-Horizon-i-Drills-Worlds-Deepest-Oil-and-Gas-Well-419C151.html (last visited Sept. 24, 2010).

ily to one side, and on April 22—Earth Day—the Deepwater Horizon slipped beneath the waves and plunged to the muddy seafloor 5,000 feet below.

At first, the only sign of its passing was a thin slick of oil spread across the water, dotted with workboats and response vessels searching vainly for the 11 lost crew members. The U.S. Coast Guard reported that the well the Deepwater Horizon had been drilling for BP was not leaking any oil or gas. But soon thick, orange-brown crude oil began emerging at the ocean's surface. Assurances that the "leak" rate was manageable soon gave way to the realization that a major oil blowout or gusher was happening. By the time the well was finally killed more than 12 weeks later, the nation had experienced the world's worst unintentional oil spill, with government scientists estimating that 205 million gallons (4.9 million barrels) of oil had spewed from the leaking well, affecting an area at least the size of Oklahoma and fouling over 600 miles of beaches and wetlands spread across five states.

Multiple industry and government investigations, including a panel appointed by President Barack Obama, are now working to reveal the cascade of technical breakdowns and human decisions that led to the blowout and uncontrolled release of oil and natural gas. We anticipate that these investigations will produce many detailed technical and management prescriptions for improving the safety and reliability of offshore drilling and the effectiveness of response activities to contain and remediate future spills, and determining where these operations can or cannot be conducted safely.

We write this as the well is capped, the static kill has stopped the gushing, and oil on the sea surface is becoming scarce. Now, while the images and smell of oil in the marshes are still fresh, and while tourism businesses look at forlorn beaches and field biologists make plans for post-hoc impact evaluation, is a good time for us to offer some thoughts on what happened, how understanding is shaped by perception, what the impacts were, and what we must do to avoid a similar blot on America's environment. This is an event we do not want to repeat, an uncommon opportunity that invites us to reexamine our ideas about the roles of scientists and fishermen, salt marshes and open seas, the private and public sectors, and decisionmaking from afar versus locally.

The best teachers help us learn that the most important step in arriving at the right answers is to ask the right questions. That is not easy, because humans pay more attention to things that (1) are sudden, (2) are visible, and (3) touch our emotions, compared with those that are not. Some key aspects of this disaster were undoubtedly sudden, visible, and moving; others that demand close attention were not.

The nearly three months from the blowout to the capping of the well may be perceived as a sudden, concentrated event. But it followed decades of diffuse, accumulated decisions and actions by the oil and gas industry, government agencies responsible for regulating Outer Continental Shelf (OCS) oil and gas operations, and people in the region. Here, we pay special attention to what happened far from shore and in the Gulf's depths. These impacts might be less visible and emotionally moving to many people, but are nonetheless crucial to the health of the Gulf and the people who depend on it.

This Article concludes with a few key conclusions and recommendations by EAN.

B. The Name for This Event

First, a little housekeeping is in order. What should we call this event?

Names matter because—so often—we remember little of the past but a name. Names set off chains of associations in people's minds. As of this writing, the United States has not settled on a name for this event. We hear "BP Oil Spill," "Gulf of Mexico Oil Spill," and variations on these modified by other terms. But, we would argue, these are not the right names.

One reason is that "spill" has rather innocuous implications, of harmless minor accidents, calling for the need to forget and move on, as in "Don't cry over spilled milk." But the highly pressurized petroleum that jetted into the Gulf of Mexico for some 80 days was not as innocuous as milk, and the quantity was more like 3.3 billion glasses. This fatal event was truly a disaster, and it was not just oil that spewed out of the well: untold quantities of natural gas (mainly methane (CH_4)) were also released into the deep ocean. For these reasons, what is arguably the worst environmental event in U.S. history is more accurately termed the "BP/Deepwater Horizon Oil and Gas Disaster."

C. Relevant Precedents

The BP/Deepwater Horizon Oil and Gas Disaster came after major North American well blowouts in 1969 in the Santa Barbara Channel and 1979 off Yucatan. But the oil and gas industry repeatedly assured us that these events had become irrelevant: Improved technology had now made OCS operations so blowout-proof that decisionmakers and the public need not worry. Despite these assurances, a disastrous blowout occurred in 2009, in Australia's Montara Oilfield, located in the Timor Sea between northwest Australia and Indonesia. It was an eerie foreshadowing of the BP/Deepwater Horizon Oil and Gas Disaster. A major international offshore drilling company based in Norway but with operations worldwide, including in the Gulf of Mexico, was working at an oil platform 150 miles offshore in water 260 feet deep. The platform and drill rig were less than two years old. While drilling a new well, a previously completed well suddenly "blew out," ejecting a spray of natural gas and crude oil into the air and water. The platform and rig were evacuated, fortunately with no loss of life. The oil company and Australian government determined that the best course of action

was to drill a relief well. The main cleanup activity to address the rapidly spreading oil slick was repeated application of chemical dispersants from low-flying aircraft.

Ultimately, the gusher of oil and natural gas continued unabated for more than 10 weeks before the relief well finally succeeded in killing the blowout, culminating in a fire that raged for two days, totally destroyed the drill rig and caused major damage to the platform. Estimates of the amount of oil spilled range from 1.2 to 9.2 million gallons. The amount of CH_4 released is unknown. As with BP's Macondo Well in the Gulf, cementing problems have been implicated as a contributing cause to the blowout of the Montara Well.

Montara showed that OCS operations conducted by well-respected multinational companies continue to risk blowouts, and that stopping a wild well is by no means easy, even in warm, relatively shallow waters. The fact that BP was drilling in water 5,000 feet deep dramatically reduced its ability to respond quickly and effectively, although the event occurred in the world's biggest offshore oil patch. JA testified[3] about the Montara spill, and warned of other ongoing risks posed by OCS drilling, to the U.S. Senate Committee on Energy and Natural Resources five months *before* the Deepwater Horizon blowout.

Moreover, the agency that was then charged with OCS oil and gas leasing, the U.S. Department of the Interior's (DOI's) Minerals Management Service (MMS), had participated in Project Deep Spill,[4] which showed that, in comparison with releases in shallow waters, oil and gas behave differently under the cold, high-pressure conditions in the deep sea.

II. How an Experienced Analyst Taught a Newbie to Look at OCS Drilling

Some lessons are unforgettable. In 1978, EAN began his first full-time marine biology position: providing scientific justification for the U.S. Environmental Protection Agency (EPA) to issue national pollution discharge elimination system permits for offshore oil and gas drilling (mainly in the Gulf of Mexico). After introducing EAN to his new colleagues in the Ocean Programs Branch, the Branch Chief handed EAN the DOI's *Draft Environmental Impact Statement for Outer Continental Shelf Lease Sale 49* (proposing leasing off the Mid-Atlantic states), then said:

> I want you to evaluate this EIS carefully. You won't find it difficult to critique what's in it. But you need to pay special attention to information that's *not* there. What's missing is often far more important than what's visible.

His wisdom echoed the ancient Turkish Nasreddin Hodja parable whose modern recounting goes: A drunk in a parking lot looks for his lost keys, not in the darkness where he had dropped them, but under a streetlight . . . because that's where he can see. People tend to consider important what our senses perceive. But to understand the impacts of an oil gusher originating in the Gulf of Mexico's cold, black depths, we need to look far from the shore and beneath the sea surface.

III. What We Saw

A. *Satellite Imagery and Oil Slick Detection*

SkyTruth has repeatedly seen that satellite imagery and other remote-sensing datasets are useful for detecting and monitoring pollution at sea caused by offshore oil and gas development. In 2005, SkyTruth called attention to extensive oil slicks in the Gulf of Mexico after Hurricane Katrina, a Category 5 storm at one point, damaged hundreds of pipelines and destroyed more than 100 platforms.[5] A few years later, SkyTruth published aerial survey imagery from the National Oceanic and Atmospheric Administration (NOAA) showing spills along the Texas coast resulting from Hurricane Ike,[6] and in 2009, SkyTruth conducted continuous monitoring of the Montara Well blowout and 10-week-long oil spill in the Timor Sea.[7]

But satellite images have limitations. Systems like the Moderate-Resolution Imaging Spectroradiometer (MODIS) instrument, carried on the National Aeronautics and Space Administration's (NASA's) Aqua and Terra satellites, measure visible to infrared wavelengths of light. Such systems rely on the sun for illumination, and are impeded by clouds, fog, dust, and haze. They are also affected by the angle of the sun relative to the position of the satellite as it passes overhead. Certain conditions of illumination geometry and sea-state create a pattern of "sunglint" over the target area that can reveal the presence of oil slicks and sheen (very thin slicks), but those favorable conditions are not always met. For these reasons, satellite images are not uniformly suitable for mapping the full extent of large oil spill events at sea.[8]

The use of radar imaging satellites helps fill some of the gaps in coverage left by visible-infrared sensors. Imaging radars create their own illumination of the target, beaming radar energy down to the ground as they pass overhead and measuring the radar energy that bounces back up to the sen-

3. *Full Committee Hearing: To Receive Testimony on Environmental Stewardship Policies Related to Offshore Energy Production Before the Senate Comm. on Energy & Natural Resources*, 111th Cong., 1st Sess. (2009) (statement of John Amos), *available at* http://energy.senate.gov/public/index.cfm?FuseAction=Hearings.Hearing&Hearing_ID=c129bd12-a00d-67c6-dbdc-78a685496298.
4. *Project Deep Spill Promoting Rapid Response*, 2(3) MMS Ocean Sci. (Mary Boatman ed., 2006), *available at* http://www.gomr.mms.gov/homepg/regulate/environ/ocean_science/mms_ocean_05_may_jun.pdf.
5. SkyTruth, *Hurricane Katrina—Gulf of Mexico Oil Spills*, Dec. 12, 2007, http://blog.skytruth.org/2007/12/hurricane-katrina-gulf-of-mexico-oil.html. Press Release, MMS, MMS Updates Hurricanes Katrina and Rita Damage (May 1, 2006), http://www.boemre.gov/ooc/press/2006/press0501.htm.
6. SkyTruth, *AP: Hurricane Ike Environmental Toll Apparent*, Oct. 8, 2008, http://blog.skytruth.org/2008/10/ap-hurricane-ike-environmental-toll.html.
7. SkyTruth, *Timor Sea Drilling Spill—Cumulative Impact,* Feb. 8, 2010, http://blog.skytruth.org/2010/02/timor-sea-drilling-spill-cumulative.html.
8. For more information, see examples and excellent discussions by NASA at Rebecca Lindsey, *Gulf of Mexico Oil Slick Images: Frequently Asked Questions*, July 21, 2010, http://earthobservatory.nasa.gov/Features/OilSlick/ and Mike Carlowicz. *Scientists Find Black Gold Amidst Overlooked Data*, Feb. 18, 2009, http://www.nasa.gov/topics/earth/features/oilslick.html.

sor. This long-wavelength microwave energy is able to penetrate clouds, dust, haze, fog, and all but the heaviest tropical rainfall or hail, day or night, reliably imaging the earth's surface. Because they are sensitive to the "roughness" of the ocean surface, radar images can provide excellent detection of even very thin oil slicks and sheen, which tend to smooth the ocean's surface. But other factors can create smooth patches on the ocean, including very calm wind conditions, heavy rain, coastal upwelling, and the presence of oily surfactants emanating from phytoplankton blooms, coral spawn, and other natural sources.[9] High sea-state conditions due to strong surface winds can mechanically disaggregate oil slicks and overwhelm the tendency of the oil to smooth the ocean's surface. Confident delineation of human-caused oil slicks therefore depends on the analyst's experience, understanding of the context of the oil spill and characteristics of the target area, knowledge of wind and weather conditions when the images are acquired, and familiarity with the particular features of the radar sensor.[10]

Throughout the duration of the BP/Deepwater Horizon Oil and Gas Disaster, from April through August 2010, SkyTruth acquired satellite images collected on a daily basis from two main sources. Visible-infrared images were downloaded from the MODIS Rapid Response website[11] operated by NASA. Radar images and visible-infrared images from a variety of non-U.S. orbiting sensors were collected from the Center for Southeastern Tropical Advanced Remote Sensing (CSTARS) facility operated by the University of Miami.[12] SkyTruth performed standard image processing techniques to map-rectify and enhance the brightness, contrast, and color balance in the images, and overlay other geographic information, including the location of the Macondo Well, NOAA weather stations and buoys, coastline, state, and country boundaries, coastal cities, and other useful information. SkyTruth manually delineated oil slicks and sheen, and produced and published simple image maps on the SkyTruth blog[13] and image gallery.[14]

Below, we describe nine significant observations and conclusions made by SkyTruth using imagery in combination with other sources of information and analysis, in chronological order. Our most important observations were that initial government and industry estimates of the daily spill rate were far too low, and that a government report suggesting most of the spilled oil had dissipated by early August was overly optimistic and relied on unsupported assumptions. Throughout the spill and in its aftermath, SkyTruth's analysis of satellite imagery provided timely and credible information that in key instances differed from official statements by industry and government sources.

1. Spill Overwhelms Response Capability; Slick Grows Rapidly

At about 7:30 a.m. EDT on April 21, 2010, JA saw an *ABC News* report that there had been an explosion and fire aboard the Deepwater Horizon rig. He alerted colleagues at NASA and inquired about their plans to collect satellite imagery over the site. The following day, Earth Day, the rig sank and the fire was extinguished. An oil slick appeared at the site, and the Coast Guard stated the Macondo Well could be leaking as much as 336,000 gallons (8,000 barrels) per day.[15] The Coast Guard made assurances they could keep any oil from coming ashore, and BP announced it had vessels on scene that could skim up to 7.2 million gallons (171,000 barrels) of oil per day from the surface.[16]

Official estimates of the spill rate varied dramatically. On April 23, SkyTruth alerted colleagues at Florida State University and the CSTARS satellite imaging facility operated by the University of Miami about the potential for a major oil spill, although the Coast Guard believed that no oil was leaking from either the sunken rig or the Macondo wellhead at the seafloor.[17] The following day, the Coast Guard discovered that the well was indeed leaking at the seafloor, at a rate they estimated to be 42,000 gallons (1,000 barrels) per day,[18] comfortably within the level of the response capability that both BP and the Coast Guard had claimed a few days into the incident.

However, the size of the oil slick at the Gulf's surface expanded rapidly as efforts to activate the blowout preventer on the wellhead to shut off the flow of oil and natural gas repeatedly failed. SkyTruth began acquiring visible-infrared satellite images from the MODIS sensors on two NASA-operated satellites.[19] Two images taken April 21 showed long smoke plumes from the rig, still burning at that time, and evidence that the rig was adrift and moving to the east at

9. Michele Vespe et al., *Perspectives on Oil Spill Detection Using Synthetic Aperture Radar, in* Oceanography From Space: Revisited 132 (Vittorio Barale et al. eds., 2010).
10. Fanny Girard-Ardhuin et al., *Oil Slick Detection by SAR Imagery: Potential and Limitation*, Proceedings of the Marine Technology and Ocean Science Conference OCEANS2003 (Sept. 22-26, 2003), *available at* http://public.enst-bretagne.fr/~mercierg/articles/Ocean2003.pdf. Werner Alpers & Heidi A. Espedal, *Oils and Surfactants*, *in* Synthetic Aperture Radar Marine User's Manual (Christopher R. Jackson & John R. Apel eds., 2004), *available at* http://www.sarusersmanual.com/ManualPDF/NOAASARManual_CH11_pg263-276.pdf.
11. NASA, *MODIS Rapid Response System*, http://rapidfire.sci.gsfc.nasa.gov (last visited Sept. 10, 2010).
12. Center for Southeastern Tropical Advanced Remote Sensing, *CSTARS Birds Eye View*, https://www.cstars.miami.edu (last visited Sept. 10, 2010).
13. SkyTruth, *Blog*, http://blog.skytruth.org (last visited Sept. 10, 2010).
14. SkyTruth Flickr, *Deepwater Horizon Blowout—April 2010*, http://www.flickr.com/photos/skytruth/sets/72157623909364472/with/4842693548 (last visited Sept. 10, 2010).
15. CNN Wire Staff, *Oil Slick Spreads From Sunken Rig*, CNN.com, Apr. 22, 2010, http://www.cnn.com/2010/US/04/22/oil.rig.explosion/index.html?hpt=T2.
16. Matthew Tresaugue, *Crews Fear Oil Rig Will Spill 336,000 Gallons a Day*, Hous. Chron., Apr. 22, 2010, *available at* http://www.chron.com/disp/story.mpl/business/deepwaterhorizon/6971824.html.
17. Associated Press, *Coast Guard: No Oil Leak From Sunken Rig Off Louisiana*, Apr. 23, 2010, *available at* http://www.foxnews.com/us/2010/04/23/missing-workers-feared-dead-gulf-rig-sinks/.
18. Brett Clanton, *Oil May Spew for Months After Rig Blast*, Hous. Chron., Apr. 29, 2010, *available at* http://www.chron.com/disp/story.mpl/business/deepwaterhorizon/6974381.html.
19. NASA, *MODIS Rapid Response System*, http://rapidfire.sci.gsfc.nasa.gov (last visited Sept. 10, 2010).

more than one mile per hour.[20] An image from April 25[21] showed obvious oil slicks and sheen covering more than 800 square miles. Most disturbing was another satellite image from that day taken by the Advanced Land Imager from the Earth Observing (EO)-1 satellite.[22] This was the first public image that showed a portion of the growing oil slick in great detail (Figure 1). Several of the skimmer vessels, working around the edges of the slick to collect oil from the surface, are plainly visible. The scale of the response effort appears to be overwhelmed by the magnitude of the slick. The next good image SkyTruth obtained, taken on April 27,[23] showed the slick had nearly tripled in size in just two days.

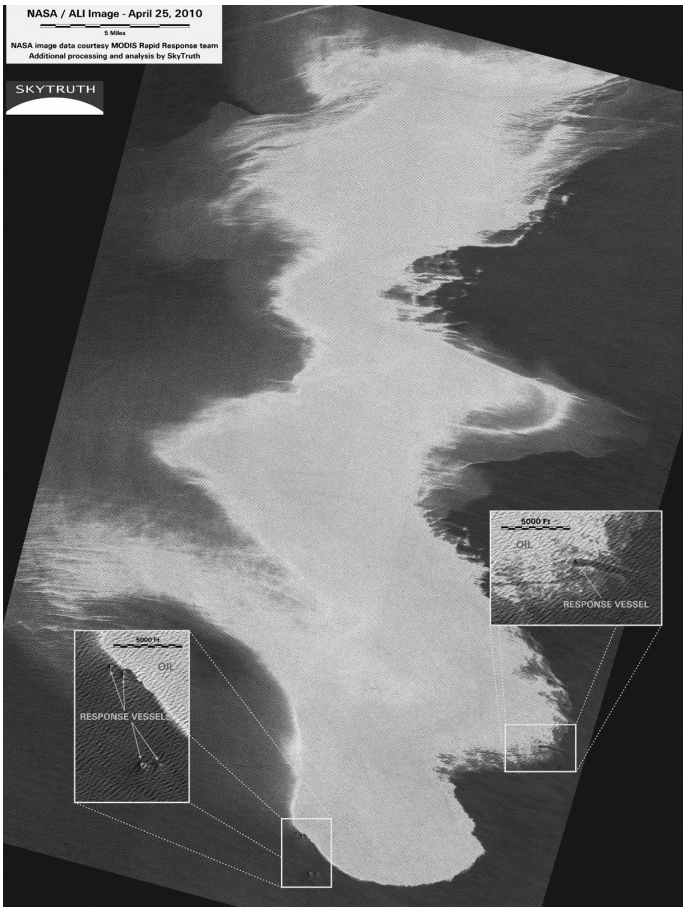

Figure 1. Satellite image taken by the Advanced Land Imager on April 25, 2010, showing some of the oil slicks and sheen (bright areas) resulting from the Deepwater Horizon blowout in the Gulf of Mexico. Slicks extend well beyond the image to the northeast (upper right). Insets show several response vessels working on the periphery of the slick.

On April 29, despite the earlier Coast Guard assurances, oil began to come ashore on the Mississippi Delta.[24] By May 1, satellite imagery showed the slick had reached 2,600 square miles,[25] and SkyTruth got our first radar satellite image from CSTARS to supplement the visible-infrared imagery.[26]

2. Spill Much Worse Than Reported; Spill Quickly Surpasses *Exxon Valdez* as Worst U.S. Oil Spill

The Coast Guard and BP maintained that the spill rate from the leaking Macondo Well was only 42,000 gallons (1,000 barrels) per day, despite obvious indications that the response capacity brought to bear was being quickly overwhelmed. On April 27, SkyTruth and Dr. Ian MacDonald of Florida State University calculated that the spill rate had to be much higher: 210,000 gallons (5,000 barrels) per day at an absolute minimum to generate a slick covering 2,233 square miles in just seven days. Based on statements made that same day by a BP executive about the thickness of the oil slick,[27] we concluded the rate was more likely on the order of 840,000 gallons (20,000 barrels) per day, and more than six million gallons of oil had already been released into the Gulf during the first week of the spill.[28]

The day after we published our estimate, NOAA weighed in on the rate of the spill, claiming it was 210,000 gallons (5,000 barrels) per day.[29] BP objected, but ultimately accepted that estimate, and it remained the official spill-rate figure for the next four weeks.

SkyTruth published a refined estimate from Dr. MacDonald on May 1[30] that was based on a Coast Guard map of the oil slick, compiled from observations made during low-altitude reconnaissance overflights. At a rate of 1.1 million gallons (26,500 barrels) per day, SkyTruth predicted that the previous worst oil spill in U.S. history, the *Exxon Valdez* disaster, was surpassed that day.

Possibly due in part to pressure from SkyTruth, other scientists, and the media calling on BP and the federal government to defend the 5,000 barrel per day spill-rate estimate, on May 19, the federal government convened a panel of scientists designated the Flow Rate Technical

20. SkyTruth Flickr, *Deepwater Horizon Blowout—April 2010*, http://www.flickr.com/photos/skytruth/sets/72157623909364472/detail/ (last visited Sept. 10, 2010).
21. SkyTruth Flickr, *Deepwater Horizon Oil Spill—MODIS/Aqua Detail (with interpretation) (April 25, 2010)*, http://www.flickr.com/photos/skytruth/4554456919/in/set-72157623909364472/ (last visited Sept. 10, 2010).
22. SkyTruth Flickr, *Deepwater Horizon Oil Spill—Advanced Land Imager (ALI) (April 25, 2010)*, http://www.flickr.com/photos/skytruth/4557813199/in/set-72157623909364472/ (last visited Sept. 10, 2010).
23. SkyTruth Flickr, *Deepwater Horizon Oil Spill—MODIS/Terra Detail (with interpretation) (April 27, 2010)*, http://www.flickr.com/photos/skytruth/4559143710/in/set-72157623909364472/ (last visited Sept. 10, 2010).
24. SkyTruth, *Gulf Spill—Oil Is Hitting the Shore*, Apr. 29, 2010, http://blog.skytruth.org/2010/04/gulf-spill-oil-is-hitting-shore.html.
25. SkyTruth Flickr, *Deepwater Horizon Oil Spill—MODIS/Terra Detail (with interpretation) (May 1, 2010)*, http://www.flickr.com/photos/skytruth/4569237958/in/set-72157623909364472 (last visited Sept. 10, 2010).
26. SkyTruth Flickr, *Deepwater Horizon Oil Spill—MODIS/Terra and TerraSAR-X (TSX) Images (May 1, 2010)*, http://www.flickr.com/photos/skytruth/4589189833/in/set-72157623909364472 (last visited Sept. 10, 2010).
27. Noah Brenner et al., *Coast Guard May Burn Off Oil Spill*, Upstreamonline.com, Apr. 27, 2010, http://www.upstreamonline.com/live/article213244.ece?WT.mc_id=rechargenews_rss.
28. SkyTruth, *Gulf Oil Spill Rate Must Be Much Higher Than Stated—6 Million Gallons So Far?,* Apr. 27, 2010, http://blog.skytruth.org/2010/04/gulf-oil-spill-rate-must-be-much-higher.html.
29. CNN.com, *Oil Spill From Rig Explosion at 5,000 Barrels a Day*, Apr. 28, 2010, http://www.cnn.com/2010/US/04/28/louisiana.oil.rig.fire/index.html#.
30. SkyTruth, *Gulf Oil Spill—New Calculation*—Exxon Valdez *Surpassed Today,* May 1, 2010, http://blog.skytruth.org/2010/05/gulf-oil-spill-new-spill-rate.html.

Group (FRTG), tasked with producing scientifically robust estimates of the spill rate. A May 22 op-ed in the *New York Times* by Dr. MacDonald,[31] JA, and others presented the case for why accurate spill estimates are both possible and necessary. On May 27, the FRTG issued an interim report,[32] estimating that the likely spill rate was in the range of 504,000-798,000 gallons (12,000-19,000 barrels) per day. Some members of the panel independently spoke out and explained those estimates were based on incomplete data and only addressed the likely *minimum* rate of flow,[33] and consequentially the probable spill rate was much higher. Indeed, as the FRTG gained access to better data, the estimates increased significantly. On June 10, the estimate was raised[34] to 840,000-1.7 million gallons (20,000-40,000 barrels) per day, and on June 15, the estimate was upped again[35] to 1.5-2.5 million gallons (35,000-60,000 barrels) per day.

Finally, on August 2, the FRTG announced[36] that the initial spill rate from the leaking Macondo Well was 2.6 million gallons (62,000 barrels) per day, and that the amount of oil spewed into the Gulf over the duration of the spill totaled 172.2 million gallons (4.1 million barrels),[37] exceeding the Ixtoc-1 blowout and spill in the Gulf of Mexico in 1979 and ranking as the worst unintentional oil spill in history.[38]

3. Slick Entrained in Loop Current, Approaches Florida Straits

A strong surface current in the eastern Gulf of Mexico, called the Loop Current, acts like an ocean conveyor belt, transporting water through the Gulf and out into the Atlantic Ocean.[39] Many observers voiced concern that the oil spilling into the Gulf would move through the Florida Straits and into the Gulf Stream, potentially reaching the eastern seaboard from Florida to North Carolina, and beyond. On June 3, scientists at the University Center for Atmospheric Research in Boulder, Colorado, released a supercomputer simulation that strengthened these concerns, and said that ocean currents were likely to carry oil along the Atlantic Coast.[40]

On May 17, SkyTruth published a MODIS image (Figure 2) showing that the oil slick was indeed being entrained in the Loop Current.[41] Analysts at The Weather Channel concurred, as did the NOAA Administrator the following day.[42] Images on subsequent days confirmed our analysis, and on May 27, SkyTruth tentatively identified a thin sheen of oil entering the Florida Straits.[43] We know of no water-sampling data collected from the area confirming that oil from the spill reached the straits or the Gulf Stream.

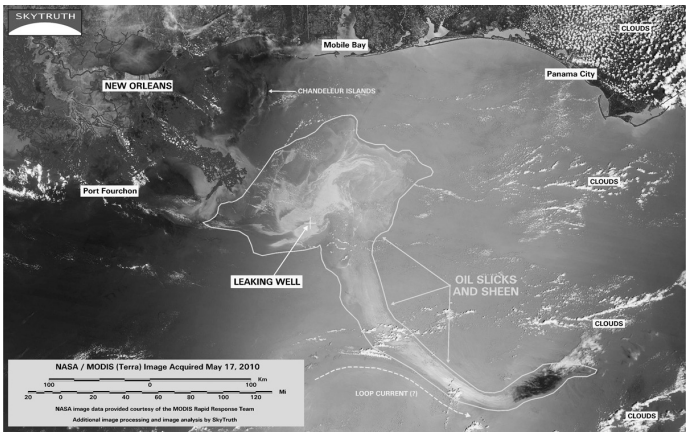

Figure 2. MODIS satellite image taken May 17, 2010, shows oil slick being entrained in the Loop Current, with a broad conveyor-belt-like extension of the slick sweeping in a gentle arc to the Southeast and reaching 222 miles (357 km) from the location of the leaking well. Slick and sheen covers 10,170 square miles (26,341 km^2).

4. Oil Makes Landfall in Alabama

Our analysis of a radar satellite image taken June 3 indicated oil reaching the shoreline of Alabama for the first time.[44] Other analysts, using the same image, suggested

31. Ian R. MacDonald et al., *The Measure of a Disaster*, N.Y. Times, May 21, 2010, *available at* http://www.nytimes.com/2010/05/22/opinion/22macdonald.html.
32. Marcia McNutt, U.S. Geological Survey (USGS), Summary Preliminary Report From the Flow Rate Technical Group (June 10, 2010), *available at* http://www.doi.gov/deepwaterhorizon/loader.cfm?csModule=security/getfile&PageID=33972.
33. Gregory Boyce, *Scientists From the Flow Rate Technical Group Dispute BP's Oil Containment Claims*, Examiner.com (June 9, 2010), http://www.examiner.com/progressive-in-new-orleans/scientists-from-the-flow-rate-technical-group-dispute-bp-s-oil-containment-claims.
34. Press Release, Deepwater Horizon Unified Command, Admiral Allen; Dr. McNutt Provide Updates on Progress of Scientific Teams Analyzing Flow Rates From BP's Well (June 10, 2010), http://www.deepwaterhorizonresponse.com/go/doc/2931/627011/.
35. CNN.com, *Oil Estimate Raised to 35,000-60,000 Barrels a Day* (June 15, 2010), http://www.cnn.com/2010/US/06/15/oil.spill.disaster/index.html.
36. Press Release, Deepwater Horizon Unified Command, U.S. Scientific Teams Refine Estimates of Oil Flow From BP's Well Prior to Capping (Aug. 2, 2010), http://www.deepwaterhorizonresponse.com/go/doc/2931/840475/.
37. SkyTruth, *BP/Gulf Oil Spill—How Big? Just Got Bigger, Again* (Aug. 3, 2010), http://blog.skytruth.org/2010/08/bp-gulf-oil-spill-how-big-just-got.html.
38. Joel Achenbach & David A. Fahrenthold, *Oil Spill Dumped 4.9 Million Barrels Into Gulf of Mexico, Latest Measure Shows*, Wash. Post (Aug. 3, 2010), *available at* http://www.washingtonpost.com/wp-dyn/content/article/2010/08/02/AR2010080204695.html?hpid=topnews.
39. Joanna Gyory et al., The Loop Current in Ocean Surface Currents, *available at* http://oceancurrents.rsmas.miami.edu/atlantic/loop-current.html (last visited Aug. 19, 2010).
40. Press Release, University Corporation for Atmospheric Research, Ocean Currents Likely to Carry Oil Along Atlantic Coast (June 3, 2010), http://www2.ucar.edu/news/ocean-currents-likely-to-carry-oil-spill-along-atlantic-coast.
41. SkyTruth, BP/Gulf Oil Spill—Slick Now Entrained in Loop Currents? (May 17, 2010), http://blog.skytruth.org/2010/05/bp-gulf-oil-spill-slick-now-entrained.html.
42. Paul Voosen, *NOAA: Oil Tendril "Likely" Headed Into Loop Current*, N.Y. Times (May 18, 2010), *available at* http://www.nytimes.com/gwire/2010/05/18/18greenwire-noaa-oil-tendril-likely-headed-into-loop-curre-32417.html.
43. SkyTruth, BP/Gulf Oil Spill—Moving Toward Florida Straits (May 29, 2010), http://blog.skytruth.org/2010/05/bp-gulf-oil-spill-moving-toward-florida.html.
44. SkyTruth, BP/Gulf Oil Spill—Landfall in Alabama? (June 3, 2010), http://blog.skytruth.org/2010/06/bp-gulf-oil-spill-landfall-in-alabama.html.

that oil slicks clearly extended into areas that remained open for fishing.[45]

5. Unrelated Leak Detected

The Deepwater Horizon disaster created a unique opportunity: a large area of active offshore oil and gas production was being repeatedly blanketed by satellite images taken from a variety of orbiting systems. SkyTruth noticed a small, persistent oil slick that was not related to the Macondo spill. Overlaying GIS data from the MMS, SkyTruth correlated this slick with a known oil platform location and published our findings on June 3.[46] Two days later, a professional photographer flew over the site and shot photos and a video that showed an obvious oil slick next to a semisubmersible drill rig.[47] SkyTruth learned that this rig was working to plug 26 abandoned wells that had been damaged by Hurricane Ivan and leaking since 2004.[48]

Intrigued by this discovery, the *Associated Press* published a story on July 27 revealing the presence of 27,000 abandoned oil and gas wells in the Gulf of Mexico.[49] It's not uncommon for abandoned wells on land to leak, requiring replugging and reabandonment, but federal agencies do not routinely inspect abandoned offshore wells to assess potential problems.

6. Oil Slick Peaks, Spans Most of Northeastern Gulf, Comes Ashore in Five States

Throughout May and June, satellite images showed the oil slick generally increasing in size, although SkyTruth noted significant day-to-day fluctuations that we attribute[50] to cleanup and containment activity, weather and sea-state conditions, and variability in imaging conditions that affected the ability of satellite images to reveal the full extent of oil slicks and sheen.

On June 25 and 26, MODIS images (Figure 3) showed slicks and sheen ominously spread across more than 24,000 square miles of the northeastern Gulf of Mexico—an area the size of West Virginia—clearly affecting hundreds of miles of beaches and marshes from Louisiana to Florida.[51] Later reports of tar balls coming ashore on Texas beaches[52] added a fifth state to those experiencing direct impacts from this spill.

This was the peak size of the spill that SkyTruth could observe at the Gulf's surface. In coming days, tropical storms Alex and Bonnie brought strong winds, large waves, and heavy rain that helped dissipate the slicks.

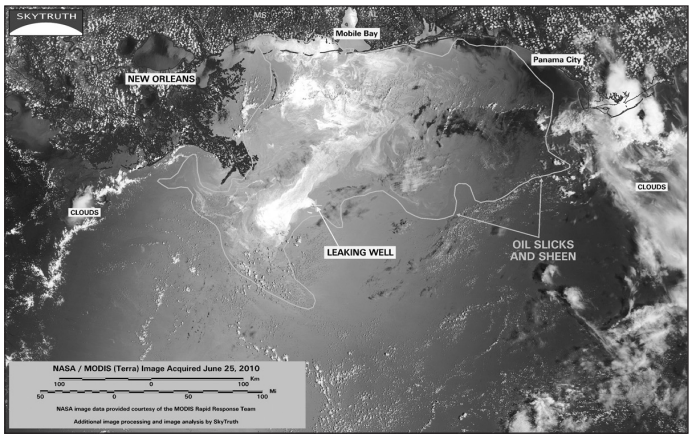

Figure 3. This MODIS satellite image shows oil slick and sheen covering 24,453 square miles on June 25, 2010. Freshly upwelling oil is apparent at the site of the leaking Macondo Well, and is moving west in the immediate vicinity of the well.

7. Macondo Fully Capped, Oil Slick Recedes[53]

BP experimented with various methods and tools for capturing the flow of oil and gas from the well so it could be diverted to ships at the surface for collection and disposal. The first containment device, a large metal and concrete box deployed in early May, failed almost immediately.[54] A smaller containment cap, known as the "top hat," was built and lowered to the seafloor but never deployed.[55] BP opted instead to insert a small-diameter pipe into the leak to siphon some of the oil and gas to a surface vessel[56]; this worked, ultimately capturing a small percentage of the overall flow.[57]

In early June, a second containment cap was built and deployed. The Low Marine Riser Package (LMRP) was a better-engineered device that succeeded in diverting a sig-

45. Brad Johnson, *Breaking: Oil Haw Spread Into Florida Waters Open to Fishing*, The Wonk Room (June 3, 2010), http://wonkroom.thinkprogress.org/2010/06/03/open-for-fishing-in-oil/.
46. SkyTruth, BP/Gulf Oil Spill—Time to Get Serious About Routine Satellite Monitoring (June 3, 2010), http://blog.skytruth.org/2010/06/gulf-of-mexico-time-to-get-serious.html.
47. SkyTruth, Routine Gulf Monitoring—Here's Why We Need It (June 6, 2010), http://blog.skytruth.org/2010/06/routine-gulf-monitoring-heres-why-we.html.
48. SkyTruth, Leaking Well at Platform 23051 Location—New Images (June 18, 2010), http://blog.skytruth.org/2010/06/leaking-well-at-platform-23051-location.html.
49. Associated Press, *27,000 Abandoned Oil and Gas Wells in Gulf of Mexico Ignored by Government, Industry*, Times-Picayune (July 7, 2010), *available at* http://www.nola.com/news/gulf-oil-spill/index.ssf/2010/07/27000_abandoned_oil_and_gas_we.html.
50. SkyTruth, Satellite Imaging of Oil Slicks—A Primer (July 21, 2010), http://blog.skytruth.org/2010/07/satellite-imaging-of-oil-slicks-primer.html.
51. SkyTruth, BP/Gulf Oil Spill—Satellite Images Show Oil Impact From Gulfport to Destin (June 27, 2010), http://blog.skytruth.org/2010/06/bp-gulf-oil-spill-satellite-images-show.html.
52. T.J. Aulds & Nick Cenegy, *Oil on Bolivar, Galveston Beaches From BP Spill*, Galveston Co. Daily News (July 6, 2010), *available at* http://www.galvnews.com/story/160958.
53. SkyTruth, BP/Gulf Oil Spill—The Slick Is Dissipating (July 27, 2010), http://blog.skytruth.org/2010/07/bp-gulf-oil-spill-slick-is-dissipating.html.
54. CBS/Associated Press, *BP Exec: Oil Leak Containment Box "Didn't Work,"* CBS News (May 8, 2010), *available at* http://www.cbsnews.com/stories/2010/05/08/national/main6469495.shtml.
55. Brian Baskin, *BP Prepares to Lower "Top Hat" on Oil Leak*, Wall St. J. (May 12, 2010), *available at* http://online.wsj.com/article/NA_WSJ_PUB:SB10001424052748703339304575240721758211174.html.
56. George Altman, *BP Favors Insertion Tube Over "Top Hat" to Stop Gulf Oil Leak*, Press-Reg. (May 14, 2010), *available at* http://blog.al.com/live/2010/05/bp_favors_insertion_tube_over.html.
57. Associated Press, *BP Says Insertion Tube Not Working as Well as Before*, Times-Picayune (May 23, 2010), *available at* http://www.nola.com/news/gulf-oil-spill/index.ssf/2010/05/bp_says_insertion_tube_not_wor.html.

nificant amount of oil and gas to surface vessels.[58] A tight-fitting cap was added to the system on July 12,[59] and valves in the cap that allowed oil and gas to flow into the water were gradually closed. Satellite images analyzed by SkyTruth confirmed the effects of this reduced spill rate: MODIS and radar satellite images taken on July 11, 12, and 14 showed a much smaller area of oil slicks and sheen than in previous images, spanning about 3,800 square miles.[60]

On July 15, all flow of oil and gas from the Macondo Well was finally stopped.[61] Tropical Depression Bonnie tracked directly over the spill site on July 24,[62] dispersing some of the oil slick. Satellite images on July 26 revealed widely scattered patches of oil.[63] Oily sheen covered almost 11,000 square miles again on July 28,[64] but subsequent visible-infrared and radar images indicated a progressive reduction of oil floating on the Gulf's surface over the next two weeks. This was not unexpected: with no new oil leaking from the Macondo Well, oil slicks at the surface would be steadily diminished by evaporation, photolysis, biodegradation, natural dispersal, and the efforts of cleanup crews.

On August 5, the well was plugged from the top with cement.[65] The final operation to permanently kill the well—injecting cement into the bottom via a relief well—is expected to occur before the end of August.

8. Cumulative Observed Surface Extent > Oklahoma (68,000 square miles)

Satellite observations of the surface oil slicks and sheen from April 25 through July 16 showed that, at one time or another, 68,000 square miles of Gulf waters were covered with oil—an area about the size of Oklahoma.[66] That does not include the distribution of hydrocarbons that we could not see, suspended in the water column, dissolved in the water, or driven beneath the surface by the application of chemical dispersants. Ocean currents at depth potentially transported that material in different directions than oil at the surface, making it likely that the total area of the Gulf that was directly impacted by oil and natural gas from this spill is larger than the cumulative oil-slick footprint determined from satellite image analysis (Figure 4).

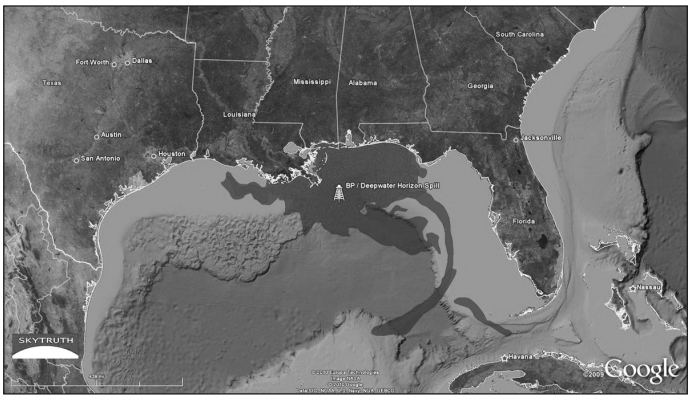

Figure 4. Graphic showing the cumulative oil-slick footprint for the BP/Deepwater Horizon oil spill, created by overlaying all of the oil slicks mapped by SkyTruth on satellite images taken between April 25 and July 16, 2010.

9. Government Assessment of Oil Fate Overly Optimistic

On August 4, NOAA and the U.S. Geological Survey (USGS) reported[67] that a total of 205.8 million gallons (4.9 million barrels) of oil gushed from the Macondo Well over 85 days before it was completely shut off on July 15. Subtracting 33.6 million gallons (800,000 barrels) of oil that was kept out of the water by direct capture at the wellhead yields a total spill of 172.2 million gallons (4.1 million barrels) of oil directly into Gulf waters.

The NOAA/USGS report included a pie chart (Figure 5) that suggested three-fourths of the spilled oil was dispersed or destroyed, leading White House Office of Energy and Climate Change Policy Director Carol Browner to conclude "more than three-quarters of the oil is gone. The vast majority of the oil is gone."[68]

How much of the oil, injected at high pressure into frigid water 5,000 feet deep and treated at the wellhead with chemical dispersants,[69] never reached the surface? The NOAA/USGS report does not directly address this question. The SkyTruth-MacDonald-estimated spill rate of 1.1 million gallons (26,500 barrels) per day[70] was based entirely on the

58. Bryan Walsh, *BP Makes Progress on Spill, Less on Restoring Trust*, Time (June 7, 2010), *available at* http://www.time.com/time/nation/article/0,8599,1994657,00.html.
59. Jaquetta White, *Tests of New Containment Cap to Determine Whether It Can Hold Oil in Place*, Times-Picayune (July 12, 2010), *available at* http://www.nola.com/news/gulf-oil-spill/index.ssf/2010/07/tests_of_new_containment_cap_t.html.
60. SkyTruth, BP/Gulf Oil Spill—Stopped (For Good?) (July 16, 2010), http://blog.skytruth.org/2010/07/bp-gulf-oil-spill-stopped-for-good.html.
61. Campbell Robertson & Henry Fountain, *BP Says Oil Flow Has Stopped as Cap Is Tested*, N.Y. Times (July 15, 2010), *available at* http://www.nytimes.com/2010/07/16/us/16spill.html?_r=1.
62. SkyTruth, BP/Gulf Oil Spill—What Did Bonnie Do? (July 26, 2010), http://blog.skytruth.org/2010/07/bp-gulf-oil-spill-what-did-bonnie-do.html.
63. SkyTruth, BP/Gulf Oil Spill—The Slick Is Dissipating (July 27, 2010), http://blog.skytruth.org/2010/07/bp-gulf-oil-spill-slick-is-dissipating.html.
64. SkyTruth, BP/Gulf Oil Spill—Curb Your Enthusiasm, Part 2 (July 29, 2010), http://blog.skytruth.org/2010/07/bp-gulf-oil-spill-curb-your-enthusiasm_29.html.
65. Kimberly Quillen, *BP Working to Cure, Dry Cement It Pumped Into Macondo Well in the Gulf of Mexico*, Times-Picayune (Aug. 6, 2010), *available at* http://www.nola.com/news/gulf-oil-spill/index.ssf/2010/08/bp_working_to_cure_dry_cement.html.
66. SkyTruth, BP/Gulf Oil Spill—68,000 Square Miles of Direct Impact (July 27, 2010), http://blog.skytruth.org/2010/07/bp-gulf-oil-spill-68000-square-miles-of.html.
67. Jane Lubchenco et al., Deepwater Horizon/BP Oil Budget: What Happened to the Oil? (Aug. 3, 2010), http://www.deepwaterhorizonresponse.com/posted/2931/Oil_Budget_description_8_3_FINAL.844091.pdf.
68. David A. Fahrenthold, *Scientists Question Government Team's Report of Shrinking Gulf Oil Spill*, Wash. Post (Aug. 5, 2010), *available at* http://www.washingtonpost.com/wp-dyn/content/article/2010/08/04/AR2010080407082.html.
69. Steve Gelsi, *BP to Increase Dispersants Under Water to Break Up Spill*, MarketWatch.com (May 4, 2010), http://www.marketwatch.com/story/bp-to-increase-dispersants-to-break-up-oil-spill-2010-05-04.
70. SkyTruth, Gulf Oil Spill—New Spill Calculation—*Exxon Valdez* Surpassed Today (May 1, 2010), http://blog.skytruth.org/2010/05/gulf-oil-spill-new-spill-rate.html.

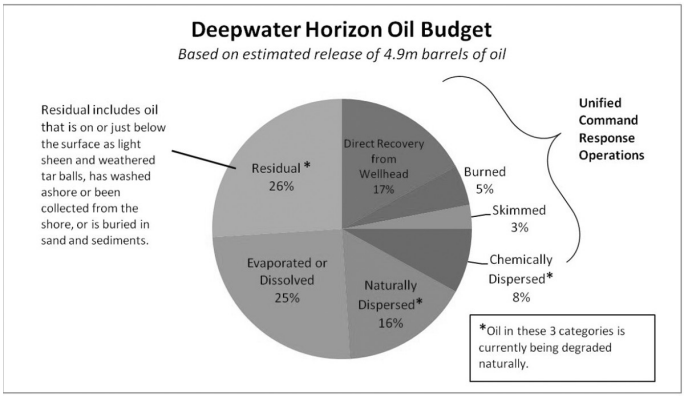

Figure 5. Status of 4.9 million gallons of oil spilled from BP's Macondo Well according to NOAA/USGS report released August 4, 2010.

Source: Jane Lubchenco et al., Deepwater Horizon/BP Oil Budget: What Happened to the Oil? (Aug. 3, 2010), http://www.deepwaterhorizonresponse.com/posted/2931/Oil_Budget_description_8_3_FINAL.844091.pdf.

oil we could see and measure at the ocean's surface. This estimate is 43% of the 2,604,000 gallons (62,000 barrels) per-day rate that scientists later estimated for the early days of this disaster. But surely some of the "missing oil" in our estimate was consumed in the fire that raged on the Deepwater Horizon rig before it sank on April 22 (the government estimates start the "spill clock" on April 22). Assuming 36 hours of flow from the well was completely consumed in the fire, SkyTruth's estimated daily flow rate increases to 1.4 million gallons (34,500 barrels) per day, about 56% of the most recent government estimate. No oil was being diverted from the well at that time, and skimming operations probably were not collecting much at that point, but dispersants were being used to break up the slick.

This suggests 44% of the oil that leaked from the well remained underwater (or was driven back underwater by dispersants), out of sight of satellite images and Coast Guard observers. Given a total spill of 172.2 million gallons, extrapolation from that first week leads to the conclusion that 76 million gallons may have lingered beneath the surface. NOAA is assuming rapid biodegradation of the dispersed and dissolved oil, which may be reasonable in relative terms, i.e., biodegradation in the warm shallows of the Gulf of Mexico progresses more quickly than in the frigid Arctic Ocean, for example. But with no data provided on the actual rates of biodegradation at various depths, there is no way to determine confidently how much oil had naturally biodegraded by early August. At best, one can say that 25% of the total amount of oil released from the well has been accounted for by direct recovery from the wellhead, and by burning and skimming at the surface. Evaporation, biodegradation, and other natural processes are attacking the remainder, but at unknown rates and with unknown efficacy.

IV. What We Did Not See

Humans are among the most visual of animals; perhaps 90% of what we learn comes via our eyes.[71] To oyster farmers and recreational fishermen, to tourist hoteliers and longtime residents, the oil that came ashore or floated on the sea surface provides an indelible impression of the BP/Deepwater Horizon Oil and Gas Disaster. But it is a misleading impression for reasons that merit thoughtful analysis.

The Macondo Oilfield's light crude (and most crude oil) is largely insoluble in seawater, and is less dense, so it tends to rise in coherent clumps to the sea surface. To observers, including the media, it was tempting to assume that we saw the full extent of this event. That is wrong, because of (1) the great pressure that jetted the oil-gas mixture into the cold Gulf bottom waters, (2) the unprecedented use of at least 1.8 million gallons of chemical dispersant, which was sprayed on the oil slicks at the surface and injected directly into the stream of oil and gas gushing from the wellhead nearly a mile deep,[72] and (perhaps) (3) the fact that the oil was mixed with a large amount of CH_4 and other hydrocarbons that form a slushy hydrate at low temperatures and high pressures but become gaseous at warmer temperatures and lower pressures in shallower waters. These factors undoubtedly dispersed the oil-gas mixture more than other (shallower) blowouts, tanker spills, or undersea pipeline leaks. The National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling established by President Obama, and other investigations now underway, will need to get clear answers to the following questions:

1. How Much Oil Never Reached the Sea Surface?

SkyTruth's estimate of the spill rate, based entirely on the oil we could see at the ocean's surface, is only 56% of the most recent government estimate of the Macondo Well's flow rate in the early days of the disaster (see details of this analysis in the preceding section). This suggests that perhaps 44% of the oil released during the spill remained underwater—a total of 76 million gallons (1.8 million barrels).

Undoubtedly, some of this has been oxidized completely or partly by bacteria, but there are as yet no credible estimates of the rates of biodegradation, or what the byproducts of that breakdown might be. Therefore, how much remains below the surface is unclear, but the discovery of extensive undersea plumes of oil particles[73] at depths of 1,300-4,600 feet suggests that what remains may be a very substantial sum of oil.

71. D.B. Reuben et al., *The Aging Driver*, 36 J. Am. Geriatrics Soc'y 1135 (1988).
72. Mark Sappenfield, *New Gulf Oil Spill Mystery: How Much Dispersant Did BP Use?*, Christian Sci. Monitor (Aug. 1, 2010), *available at* http://www.csmonitor.com/Environment/2010/0801/New-Gulf-oil-spill-mystery-How-much-dispersant-did-BP-use.
73. Stephen Thompson, *USF Scientists Underwater Oil Definitely From BP Spill*, Tampa Trib. (July 23, 2010), *available at* http://www2.tbo.com/content/2010/jul/23/231735/usf-scientists-link-underwater-oil-plumes-bp-spill/. Justin Gillis, *Giant Plus of Oil Forming Under the Gulf*, N.Y. Times (May 15, 2010), *available at* http://www.nytimes.com/2010/05/16/us/16oil.html.

2. *What Are the Forms and Effects of Oil (and Gas) That Did Not Reach the Surface?*

Although thick, more or less continuous layers of oil, archipelagoes of tar balls, or thin sheens were the visible surface manifestations of the BP/Deepwater Horizon Oil and Gas Disaster, it is likely that a sizeable fraction of oil was distributed at depth as droplets, some too small to see with the unaided eye. The purpose of applying chemical dispersants is to break up oil into smaller particles, increasing the surface area but also causing the oil to lose buoyancy and sink.[74] Aside from the toxicity of the dispersant alone, this could have effects including:

(a) Toxicity of the dispersant-oil mixture, which could be substantially greater or less than that of oil or dispersant alone.

(b) Dramatic reduction in visibility of oil slicks on the sea surface, perhaps because of substantial reduction in the amount of oil that reaches the sea surface.

(c) The presence of "plumes" containing small droplets of oil at various depths below the surface.[75] The undersea plumes are particularly important because the lifetime of droplets in the cold depths of the Gulf, especially where oxygen might be a limiting factor, could be much greater than the lifetime of similar-sized droplets in warm surface waters, where evaporation and photodegradation can occur and bacterial degradation is much faster. Even hundreds of kilometers from the wellhead, species living below the surface could be exposed to oil droplets and their breakdown products for weeks, months, or years. Lacking substantial, robust, verifiable data to the contrary, the most prudent course is to assume that there is still a significant amount of oil persisting below the surface of the Gulf.

(d) Reduction in dissolved oxygen due to aerobic degradation of oil by bacteria.

Before oil droplets degrade to harmlessness, they can collide with marine animals and adhere to their surfaces (including their gill surfaces). Or, marine animals can ingest oil droplets. Many pelagic (water column) species in the depths and others dwelling on the deep seafloor, e.g., siphonophores, ahermatypic corals, sabellid polychaetes, bivalves, copepods, crinoids, salps, and fishes such as bristlemouths in the genus *Cyclothone*, perhaps the world's most abundant vertebrates, are specifically adapted to gathering and consuming small suspended particles.

Furthermore, bacterial oxidation of oil requires dissolved oxygen, which is in short supply in very large areas of the Gulf of Mexico, thanks largely to dramatically increased nutrient inputs from agriculture and municipalities throughout the Mississippi River Watershed, which empties into the Gulf. The resulting "dead zones"[76] were a growing problem even before the BP/Deepwater Horizon Oil and Gas Disaster.

The large amount of CH_4 released from the Macondo Well could exacerbate this problem in the Gulf ecosystem. Some scientists have estimated that as much as 40% of the flow from the Macondo Well was natural gas, mostly CH_4 that dissolved rather than floating to the surface and escaping into the atmosphere.[77] At 80 cubic meters of CH_4 per barrel of oil, with a total spill of 4.1 million barrels of oil, we calculate 328 million cubic meters of CH_4 were injected into the Gulf. Researchers from Texas A&M University, the University of Georgia, and the University of California-Santa Barbara have measured levels of dissolved CH_4 thousands of times above normal, thousands of feet below the surface.[78] The microbial degradation of CH_4 will consume oxygen from the water, possibly slowing biodegradation of the oil, particularly at deeper levels, and leading to the formation of additional oxygen-deficient dead zones devoid of fishes and the marine mammals that eat them.

3. *How Applicable Are Acute Toxicity Tests on Estuarine Animals to Critical Deep-Sea Ecosystem Processes?*

As Susan Shaw notes,[79] the tests[80] done on the Macondo Oilfield's oil and on the dispersants that were injected at depth into the oil-gas mixture and sprayed on the sea surface used only a few test species, e.g., the estuarine mysid crustacean *Americamysis bahia* and the inland silverside fish *Menidia beryllina*. The populations of these animals must be especially "tough" (resistant to environmental changes and resilient, or able to rebound afterwards) to withstand the highly variable conditions in estuaries. Moreover, the acute toxicity tests EPA scientists did (48-hour and 96-hour Lethal Concentration 50 tests, which some ecotoxicologists

74. National Research Council Report, *Oil Spill Dispersants: Efficacy and Effects Report in Brief* (2005), *available at* http://dels.nas.edu/resources/static-assets/materials-based-on-reports/special-products/oil_spill_dispersants_key_findings_final.pdf.

75. National Research Council Report. Press Release, Woods Hole Oceanographic Institute, WHOI Scientists Map and Confirm Origin of Large, Underwater Hydrocarbon Plume in Gulf (Aug. 19, 2010), http://www.whoi.edu/page.do?pid=7545&tid=282&cid=79926&ct=162.

76. Nancy N. Rabalais, *The Potential for Nutrient Overenrichment to Diminish Marine Biodiversity*, *in* Marine Conservation Biology: The Science of Maintaining the Sea's Biodiversity (Elliott Norse & Larry Crowder eds., 2005).

77. David Valentine, *Measure Methane to Quantify the Oil Spill*, 465 Nature 421 (2010).

78. *Id.* Chuck Hopkinson, *Outcome/Guidance From Georgia Sea Grant Program: Current Status of BP Oil Spill* (2010), *available at* http://uga.edu/aboutUGA/joye_pkit/GeorgiaSeaGrant_OilSpillReport8-16.pdf. Associated Press, *Gulf Gas: BP Oil Spill Increases Methane in Gulf Waters*, Christian Sci. Monitor (June 18, 2010), *available at* http://www.csmonitor.com/From-the-news-wires/2010/0618/Gulf-gas-BP-oil-spill-increases-methane-in-Gulf-waters.

79. Susan D. Shaw, *What the EPA Dispersant Tests Fail to Tell Us* (Aug. 13, 2010), *available at* http://www.meriresearch.org/Portals/0/Documents/Susan%20Shaw%20Statement%20Re%20EPA%20Report%20August%2013.pdf.

80. Michael J. Hemmer et al., U.S. EPA, *Comparative Toxicity of Eight Oil Dispersant Products on Two Gulf of Mexico Aquatic Test Species* (June 30, 2010), *available at* http://www.epa.gov/bpspill/reports/ComparativeToxTest.Final.6.30.10.pdf. Michael J. Hemmer et al., U.S. EPA, *Comparative Toxicity of Louisiana Sweet Crude Oil (LSC) and Chemically Dispersed LSC to Two Gulf of Mexico Aquatic Test Species* (July 31, 2010), *available at* http://www.epa.gov/bpspill/reports/phase2dispersant-toxtest.pdf.

lovingly call "kill 'em and count 'em" tests) are the least sensitive of all tests for assessing impacts on organisms and their ecosystems. It is likely that thousands of species of deep-sea Gulf of Mexico marine organisms are more vulnerable than *Americamysis* and *Menidia*, and that more ecologically sophisticated, longer term toxicology tests using more sensitive indicators of population health would provide much more appropriate input into post-hoc impact assessments. It is truly unfortunate that such data were unavailable *before* the responsible government agencies decided to allow deep-sea drilling to begin.

Moreover, although the Gulf of Mexico has natural hydrocarbon seeps, the nature and magnitude of this blowout and all that was done deliberately to disperse the oil makes it very unlikely that most Gulf organisms have had anywhere near as much oil exposure during evolutionary history as they have lately experienced.

4. What Are the Real Impacts on Deep-Sea Species?

Anyone with a heart was moved to see oiled birds dying on shore and on the sea surface. The media showed many heroic people devoting their time and money to save oiled birds. But nobody has been working to save *Lophelia* corals and many other species in deep-sea ecosystems that are out-of-sight and—for most people—out-of-mind. There is reason for concern: There is a news story telling that tests using a shallow-water (presumably less-sensitive) Gulf of Mexico coral, *Porites astreoides*, showed that their planula larvae failed to attach to suitable substrates at realistic concentrations of oil-dispersant (Corexit 9500A) mix.[81] Marine ecologists usually find that deep-sea species have far slower growth than warm-blooded animals (such as brown pelicans, *Pelecanus occidentalis*) and less-familiar species that live in warm and shallow waters (such as *Porites astreoides*). We would therefore expect that in animals having slower growth and lower population resilience, such as deep-sea *Lophelia* corals, population-level impacts of oil and dispersant could be much worse, even if they do not have characteristics that touch the emotions of so many people, namely warm blood and backbones. Moreover, scientists can probably model recovery rates of brown pelicans reasonably accurately. But how quickly can the Gulf's ancient deep-sea corals or its suspension-feeding fishes recover? It would have been wise to get some data *before* we drilled in their habitats. We still need such data to chart their recovery.

5. To Disperse or Not to Disperse? That Is the Question

One of the most important questions raised by the BP/Deepwater Horizon Oil and Gas Disaster is whether the oil should deliberately have been dispersed, or rather concentrated, skimmed, and disposed of. The strategy of dispersing oil has at least two apparent bases: Increasing the surface-to-volume ratio of the oil to increase its exposure to evaporation and bacterial degradation, and decreasing the visual impact of the oil. If oil reaches the surface (a big *if* for oil dispersed a mile deep), evaporation might well be faster for small droplets than for more concentrated mats of oil. There is little doubt that bacterial degradation is faster with smaller droplets. But we worry that the profoundly important decision to disperse the oil was based primarily on concern for visual impacts on the shoreline.

One consequence of an effort to minimize oil making landfall could be dramatically increased impacts below the surface and dramatically reduced effectiveness of skimming and other response efforts at the surface that require oil to be concentrated. Among the many questions about the BP/Deepwater Horizon Oil and Gas Disaster that need to be answered, this is surely one of the highest priorities.

6. How Complete Was the Body Count?

The U.S. Fish and Wildlife Service (FWS) has kept a record of animals collected (dead and alive) in what they consider Deepwater Horizon impact areas.[82] As all people who are experienced with wildlife population studies on land or in the sea will admit, these numbers also may be misleading. TV newswatchers, web surfers, and readers of newspapers were appalled by tragic photos of oiled brown pelicans, northern gannets (*Morus bassanus*), and laughing gulls (*Leucophaeus atricilla*), and of corpses of loggerhead sea turtles (*Caretta caretta*) and bottlenose dolphins (*Tursiops truncatus*). But not all dead animals float, not all floating corpses come ashore, and not all that float or come ashore are seen and recorded. It is likely that the real number of deaths was many times greater than the birds (4,080 as of this writing),[83] sea turtles (525), and marine mammals (72) that the FWS recorded. Because some Gulf of Mexico populations, e.g., Kemp's Ridley (*Lepidochelys kempii*) and loggerhead sea turtles, were already endangered or threatened before the blowout, the BP/Deepwater Horizon Oil and Gas Disaster might threaten their recovery or even their continued existence.

Moreover, the population size of these animals is known with greater certainty than many other marine species (fishes, crabs, bivalves) that were in harm's way. It will probably be relatively easy to estimate impacts on a handful of sessile, shallow-dwelling, commercially important invertebrate species such as Atlantic oysters (*Crassostrea virginica*). But there are probably no reliable population estimates for the vast majority of Gulf of Mexico species. Moreover, oysters and many marine invertebrates and fishes in this area have eggs or larvae that float near the sea surface; it is unlikely that anyone will be able to estimate how the spill affected the propagules of entire year classes of these species. Veteran

81. Sujata Gupta, *Oil Spill Dispersant Could Damage Coral Populations*, New Scientist (Aug. 3, 2010), *available at* http://www.newscientist.com/article/dn19260-oil-spill-dispersant-could-damage-coral-populations.html?DCMP=OTC-rss&nsref=environment.

82. U.S. FWS, Deepwater Horizon Response Consolidated Fish and Wildlife Collection Report (Aug. 13, 2010), http://www.fws.gov/home/dhoilspill/pdfs/collection_08132010.pdf.

83. *Id.*

crustacean biologist Harriet Perry from Gulf Coast Research Laboratory in Ocean Springs, Mississippi, has found many blue crab (*Callinectes sapidus*) megalopa larvae containing oil droplets.[84] If larval mortality causes year-class failure to important commercially and recreationally fished animals such as blue crabs, redfish (*Sciaenops ocellatus*), or northern bluefin tunas (*Thunnus thynnus*), and these species become far less abundant in years to come, as well they might, scientists are unlikely to have data needed to "prove" definitively that the BP/Deepwater Horizon Oil and Gas Disaster was to blame.

7. Do Numbers of Less-Known Species Really Matter?

Endangered and commercially important species are the ones whose population trends people pay most attention to. But in any ecosystem such as the Gulf of Mexico, numbers of all species and key rates always matter, just as numbers of people, jobs, productivity, and spending do in economic systems. Adults of many ocean animals might avoid direct effects of oiling, but can be profoundly affected by the oil's effects on their food. Unless scientists are funded to look for them, we may see unwelcome changes in the numbers, or may miss them entirely. But overlooking such food-web impacts on these species will not mean that the BP/Deepwater Horizon Oil and Gas Disaster was not a disaster for them too.

There is probably no reason to worry about extinction of striped hermit crabs (*Clibanarius vittatus*), fiddler crabs (*Uca spp.*), and legions of less visible species that live in the latticework of peat and mud in marsh grass and black mangrove (*Avicennia germinans*) ecosystems. But their abundance, although often overlooked by people who focus on larger, more charismatic or commercially important wildlife, is crucial because these animals play crucial food-web and biogeochemical roles in estuarine intertidal and shallow subtidal zones of the Gulf of Mexico, and are likely to have been especially heavily impacted by oil that came ashore. Substantial population declines could have harmful effects on oiled wetlands for a long, long time to come. Marine scientists are even less likely to have good data on species that dwell in the depths of the Gulf.

8. Can We Feel at Least Small Consolation Because Some Species Will Become More Abundant?

Ecologists and economists know that every disaster generates winners along with losers, so we should also be prepared for major increases (population outbreaks) in some species. Short-lived ones, such as eastern saltmarsh mosquitoes (*Ochlerotatus sollicitans*) whose populations are normally kept in check by saltmarsh fishes, might become more abundant at some point after the well is killed. So might species that have protective anatomy and physiology, such as marsh periwinkles (*Littorina irrorata*), which can close their opercula and, so, wait out short bouts of unfavorable conditions, even while populations of other species, including commercially important ones, imperiled ones, and other ecologically important ones, are severely diminished. Indeed, a major oil release is likely to have a variety of ecosystem effects, some of which we will see in months, years, and decades to come, and many others of which are likely to escape our notice while, nonetheless, harming human interests. Given the scarcity of baseline information this time, and the crucial importance of such information, we would be wise and cost-effective to have sufficient information to forecast the full spectrum of likely impacts before the next deep-sea blowout happens, whether in the Gulf of Mexico or elsewhere.

V. So There Won't Be a Next Time: Conclusions and Recommendations

Before the oil stopped jetting into the Gulf, great numbers of people were taking on the heroic task of picking up oil that had come ashore to help coastal ecosystems and human communities recover to a semblance of their pre-disaster condition. We wish all who are doing so great success in healing the wounds the Gulf region and our country has suffered. This final section looks ahead in a different way, with the purpose of helping decisionmakers shape policies to ensure that such a disaster never happens again in the Gulf or anywhere else Americans can exert control over events. Because SkyTruth's purpose is to offer images and interpretation of events, rather than policy guidance, the policy conclusions and recommendations below are the Marine Conservation Biology Institute's alone.

A. Conclusions

1. One-Off or Inevitable?

There are some interests who might want the public to think that the BP/Deepwater Horizon Oil and Gas Disaster was a "one-off," a highly improbable or unique accident that could never possibly happen again. But the weight of evidence combined with the appalling cost of such "accidents" should remind all of us of Rita Mae Brown's insight in her 1983 book *Sudden Death:* "Insanity is doing the same thing over and over again but expecting different results." The BP/Deepwater Horizon Oil and Gas Disaster was hardly an unimaginable accident; it was the unintended but forewarned and perhaps inevitable result of a cascading chain of deliberate decisions made by the industry, state and local governments, businesses, ordinary citizens, and elected officials living in the region.

84. John Flesher, *Oiled Crabs Stoke Fears Spill Is Tainting Food Web*, Associated Press (Aug. 9, 2010), http://customwire.ap.org/dynamic/stories/U/US_GULF_OIL_SPILL_BLUE_CRABS?SITE=AP&SECTION=HOME&TEMPLATE=DEFAULT&CTIME=2010-08-09-22-11-34.

2. Can Technology Alone Prevent Disasters?

One of the costliest benefits gained from the BP/Deepwater Horizon Oil and Gas Disaster is a clear new understanding of our incapacity to remedy a massive deep-sea blowout, and, more broadly, of the importance of prevention in hostile marine environments rather than post-disaster remediation. Moreover, it is clear that we relied too much on technology for prevention. When the Deepwater Horizon's "fail-safe" blowout preventer failed to work as promised, there was no backup plan, so BP improvised, repeatedly and often ineffectually, at enormous cost to the marshes and fishes, fishermen, and tourist-dependent businesses. A blowout preventer that works some of the time is as useful as a parachute that works some of the time: It might be better *not* to have one because it creates a false sense of security. The ecology, economy, and culture of the Gulf and other regions where the United States might contemplate drilling are too important to have equipment that is unreliable, that is not maintained to the highest standards of readiness, or is not the best available technology (for example, remotely activated kill mechanisms on blowout preventers). In the months to come, these and other factors will be identified, by multiple ongoing investigations, as flaws that helped to bring us this disaster.

The BP/Deepwater Horizon Oil and Gas Disaster occurred within the borders of the world's greatest concentration of OCS oil and gas operations, and hence near a lot of specialized infrastructure, such as equipment and personnel. Despite this fortuitous setting, the relentless gusher of oil rapidly overwhelmed an all-out effort to contain it and avoid catastrophic damage. Other places where offshore drilling is being considered might not have anywhere near the amount of dedicated resources, or—for that matter—alternative resources (such as thousands of shrimp boats) that can be repurposed to assist oil spill response. This tells any thoughtful policy analyst that future drilling, especially in hostile environments, requires:

a. dramatic improvements in preventive, containment, and cleanup technologies;

b. universal, diligent application and continual improvement of those technologies;

c. infrastructure capacity sufficient to handle the worst plausible accident scenario; and

d. much-improved government and independent oversight of OCS oil and gas operations.

Indeed, unless we can have a very high degree of assurance that these four conditions are met in every case, everywhere there is a proposal to drill for oil and gas, any thoughtful observer must ask: Should we really be drilling there?

3. Can We Drill Safely in New Oil and Gas Provinces?

Drilling in the ocean is inherently risky because our ancestors gave up gills and evolved lungs, making doing things underwater difficult and dangerous, especially a mile deep. The risk of disaster increases as operating conditions become more hostile. The deep sea in the Gulf of Mexico and a few other places, e.g., off Brazil, is the most hostile place for conducting offshore oil and gas operations at present. The Arctic Ocean will be an even more hostile environment for drilling and producing oil and gas, with the risk of experiencing catastrophic impacts from a major spill commensurately greater.

4. How Did Regulatory Capture Contribute to This Disaster?

Agencies that have overseen oil and gas drilling, particularly the MMS of the DOI (now reorganized and renamed as the Bureau of Ocean Energy Management (BOEM)) saw their jobs as facilitating (or at least not impeding) the operations of private companies extracting resources in federal waters owned by the American people, even in deep waters where there was inadequate capacity to deal with a major accident.[85] These agencies failed to meet their primary responsibility of safeguarding the public interest. How much of the inadequate governmental oversight owed to the phenomenon of "regulatory capture"[86] and how much to inadequate funding of regulatory agencies for performing their responsibilities is, as yet, unclear. But we are reminded of the wisdom of Adm. Hyman Rickover, the father of our nuclear Navy, who insisted on designing and implementing stringent safety systems and procedures onboard U.S. nuclear submarines to make them "sailor-proof." Our Navy was wise to insist on these rigorous safety standards. With so much at stake in the Gulf of Mexico, the MMS should have done the same.

5. Why Was There So Much Confusion About Rates of Oil Release and the Fate of the Released Oil?

Critical questions raised by the Deepwater Horizon disaster went unanswered for weeks, and, in some cases, have yet to be answered. According to BP and the Coast Guard, there was no way to accurately estimate the rate of oil and gas gushing from the leaking well into the sea, an important number to know for appropriately scaling and designing the cleanup response for future spills, and for engineering novel technologies and approaches to containing or diverting the flow of hydrocarbons.[87] Reports of large underwater plumes of dispersed oil were initially discounted, then later confirmed, by government agencies. Controversy surrounded and still surrounds the decision to allow aerial and subsea application of chemical dispersants that have toxic effects of their own, and change the behavior and fate of oil in unknown ways.

85. Jason DeParle, *Minerals Service Had a Mandate to Produce Results*, N.Y. Times (Aug. 7, 2010), *available at* http://www.nytimes.com/2010/08/08/us/08mms.html?hp=&pagewanted=all.
86. Toni Makkai & John Braithwaite, *In and Out of the Revolving Door: Making Sense of Regulatory Capture*, 12 J. Pub. Pol'y 61 (1992).
87. MacDonald et al., *supra* note 31.

In early August, a federal government report[88] suggested that "most" of the oil spilled into the Gulf had dissipated or been destroyed. Some scientists at academic institutions strongly challenged this report, criticizing the government's unsupported assumptions about rates of evaporation and biodegradation of oil at and beneath the sea surface.[89] In addition to questions about the full surface and subsurface extent of the spill and its impacts, many questions remain about the breakdown pathway of hydrocarbons remaining in the environment and the long-term ecosystem, economic, and social impacts.

6. How Can Citizens and Responsible Government Officials See What Is Happening in the Oil Patch?

Roughly 25,000 miles of active oil and gas pipeline on the seafloor in the Gulf of Mexico connect 3,600 production platforms and tens of thousands of actively producing wells to coastal storage, processing, and distribution facilities. Much of this infrastructure is getting old: Drilling began offshore in the Gulf in the 1940s. A recent investigation revealed that 27,000 oil and gas wells on the Gulf seafloor[90] have been abandoned, and that many abandoned wells onshore have been inadequately plugged resulting in leaks and expensive replugging procedures. There is no reason to believe that inadequately safeguarded abandoned wells occur only onshore. During ongoing monitoring of the BP/Deepwater Horizon Oil and Gas Disaster, SkyTruth serendipitously detected an unrelated chronic leak from hurricane-damaged wells.[91] In late July, a barge collided with an abandoned well in the shallow coastal waters of Louisiana, causing an uncontrolled blowout.[92] These facts and incidents prompt a few questions:

a. How much chronic, day-to-day pollution is associated with offshore drilling and production?

b. Who is doing the necessary oversight to minimize this pollution?

c. How effective is this oversight?

d. As our vast offshore infrastructure of platforms and pipelines ages, can we effectively identify small chronic problems before they turn into big problems?

Satellite observations can play a crucial role in addressing these questions.

88. Lubchenco et al., *supra* note 67.

89. Hopkinson, *supra* note 78. Craig Pittman, *USF Scientists Find Oil Spill Damage to Critical Marine Life*, St. Petersburg Times (Aug. 18, 2010), *available at* http://www.tampabay.com/news/education/college/article1115706.ece.

90. Jeff Donn & Mitch Weiss, *Gulf Awash in 27,000 Abandoned Wells*, MSNBC.com (July 7, 2010), http://www.msnbc.msn.com/id/38113914/ns/disaster_in_the_gulf/.

91. SkyTruth, Leaking Well at Platform 23051 Location—New Images (June 18, 2010), http://blog.skytruth.org/2010/06/leaking-well-at-platform-23051-location.html.

92. SkyTruth, Barataria Bay, Louisiana—Abandoned Well Blowout (Aug. 2, 2010), http://blog.skytruth.org/2010/08/barataria-bay-louisiana-abandoned-well.html.

7. Did Scientists Know Enough About the Open-Ocean and Deep-Sea Ecology of the Gulf?

All "sides" on this issue, and most of all, the American people, benefit from scientific information that can be generated and made available only if scientists have adequate resources to do needed research. Science plays a unique role in offshore oil drilling, in part because scientists are the only people outside the oil and gas industry who have the tools to see what is happening in the deep sea. Inadequate understanding of biodiversity and ecosystem processes in the Gulf of Mexico, especially in the deep sea where drilling is increasingly occurring, greatly impedes informed public discourse on deep-sea drilling. Discussions with our colleagues reveal that government support for marine science has steadily declined in the Gulf region, resulting in a loss of seaworthy research vessels, skilled technicians and crews, and specialized equipment. Reversing this loss and maintaining the marine science infrastructure are critical to improve our nation's ability to respond effectively and appropriately to future spills, and to make better decisions about when and where we allow drilling to occur. Continuing to starve the marine sciences, particularly marine biology, creates the risk that we will be no better prepared for the next OCS disaster. The resource constraints that have limited pre-disaster and subsequent scientific observations have undermined informed decision-making. Many of these questions could have been, and may yet be, answered by a swift, aggressive mobilization of science resources throughout the Gulf region. Determining the long-term effects of the spill on ecosystems and human communities will require a sustained science effort.

8. Did the American People Know Enough to Take the Risk of Drilling a Mile Deep in the Gulf and in Other Hostile Areas?

The United States has not had an informed, transparent, robust national dialogue on the benefits and risks of drilling for oil under extreme, hostile conditions. The public did not appear to appreciate that oil released a mile deep or under ice during polar storms is not as easy to deal with as a release in more benign conditions. It is quite possible that not having had that national dialogue was a major reason why we had the BP/Deepwater Horizon Oil and Gas Disaster. Americans (including our elected officials) need to be informed enough to decide (1) where we will and will not drill for oil and gas, (2) how much we must devote to the science of understanding baseline conditions, environmental consequences of successful oil and gas operations, and what plausible disasters could do, and (3) how much the industry must invest beforehand as insurance to mitigate impacts and compensate injured parties in the event of another disaster. An informed national dialogue is especially important in view of proposed expansion of OCS oil and gas operations into new regions, some of which would happen in new, unprecedented conditions.

9. Would Coastal and Marine Spatial Planning Have Prevented This Disaster?

Ten months before the blowout in BP's Macondo Oilfield, the Obama Administration began the process of establishing a new National Ocean Policy using Coastal and Marine Spatial Planning (CMSP) to be carried out primarily at the regional level, e.g., the Gulf of Mexico, to maintain the integrity of marine ecosystems and to reduce conflicts among citizens and various ocean users.[93] Had this policy been in place years ago, the Gulf of Mexico regional planning council might have decided that drilling in the Macondo Oilfield is incompatible with other values in the region. Whether or not it did so, there would have been more effective official and citizen scrutiny of the drilling plans, including national oversight by the newly formed National Ocean Council, which constitutes a major policy step forward for both regional empowerment and coordinated interagency national oversight. And although CMSP might not have stopped the blowout from occurring, one major benefit would have been the trust and greatly improved lines of communication among federal, state and local governments, scientists, and the diverse stakeholders in the Gulf. The chaos that was so plainly evident during the BP/Deepwater Horizon Oil and Gas Disaster, and consequently, impacts, would have been greatly reduced if such lines of communication had been in place, so the response would have been much faster, better-coordinated, and more effective.

B. Recommendations

1. No Drilling Without an Adequate Backup Plan

Each drilling plan must include detailed, credible assurance that harm to the ecosystem, society, and economy is minimized both from normal OCS operations in federal waters and in the event of an accident, such as the blowout that started the BP/Deepwater Horizon Oil and Gas Disaster. To safeguard the interests of the American people, our federal government must never allow drilling unless and until a comprehensive, workable, immediately implementable backup plan is approved and in effect. Although this approval should come from the BOEM, it must be fully integrated into and fully consistent with approved regional coastal and marine spatial plans and implemented by all responsible agencies in ways that are fully consistent with these regional plans.

This will ensure that the United States will never again be taken by surprise or overwhelmed by events beyond our control, because we will have anticipated all plausible scenarios and developed workable, effective ways to deal with them if even the rarest plausible and most difficult-to-remedy event happens. And it will ensure that, in U.S. waters, no one will ever again have to beg for understanding because it is so very difficult to remedy an accident in the oceans, whether shallow or deep, in the Gulf of Mexico, or in new oil and gas provinces, and especially in the most hostile of all places to drill, the Arctic Ocean. Our government must never again say "yes" if there is no trustworthy backup plan.

2. Implement Routine Satellite Monitoring of OCS Oil and Gas Operations

As SkyTruth and others demonstrated throughout the BP/Deepwater Horizon Oil and Gas Disaster, satellite imagery has proven value for collecting unique information in response to catastrophic spills, and offers the ability to detect and assess the frequency and significance of smaller, chronic pollution events. Therefore, we recommend that the federal government institute a program of routine, comprehensive satellite image monitoring to detect and assess pollution problems wherever offshore drilling occurs or is being contemplated, in both state and federal waters. The cost for such a program, covering oil and gas infrastructure in the Gulf of Mexico, would likely fall in the range of $3-4 million per year. This could be funded by offshore operators, their insurers, government agencies, and revenues collected from lease sales and petroleum production. The design, implementation, and results of a monitoring program should be publicly transparent, and should engage active participation by the academic and nongovernmental organization communities.

3. Develop, Launch, and Operate Civilian Radar Imaging System

For our highly visual species, seeing is believing. For all those who want to ensure that OCS operations are not causing unobserved spills, radar satellite imagery is a vital tool for offshore monitoring and has many other practical applications. Currently, the United States does not operate or have plans to deploy any civilian radar imaging satellites, leaving our nation dependent on foreign-operated satellite systems for monitoring and disaster response in our own coastal waters. The United States should develop and implement a civilian radar imaging satellite program.

4. Fill Crucial Information Gaps by Providing Sustained Federal Funding for Marine Biological Research, Particularly Research Relevant to Conservation

The Administration's 2012 budget request should ask the U.S. Congress to double funding for marine biological research in general, through the National Science Foundation, NOAA, the FWS, the USGS, and EPA, especially for (1) assessing the distributions and vulnerability of deep-sea species, (2) determining the toxicity of various kinds of untreated oil and oil that have been dispersed, and (3) examining ecosystem dynamics and resilience in the Gulf of Mexico and in any other area where offshore oil and gas is under active con-

93. The White House Council on Environmental Quality, Final Recommendations of the Interagency Ocean Policy Task Force (July 19, 2010).

sideration. Indeed, the availability of a coherent, up-to-date ecosystem assessment that is publicly available should be a required precondition for any new drilling in U.S. waters. Among institutions to ensure that this information is generated and evaluated: the United States should provide at least $54 million per year to establish 10 academic Centers of Excellence in Marine Conservation Biology, two in the Gulf of Mexico and one each in the other eight U.S. marine bioregions outlined by the Council on Environmental Quality.[94] These centers should be jointly chosen and overseen by the National Science Foundation and NOAA, which annually should receive $2 million each to do so. The centers should each receive $5 million per year for at least 10 years, to serve as places for research and graduate/postdoctoral training in marine conservation biology and immediately relevant fields.

5. Fully Implement Ecosystem-Based Coastal and Marine Spatial Planning as a Means of Evaluating Oil and Gas Operations Beforehand, and Ensure That All Management of OCS Operations Is Fully Integrated Into and Consistent With Approved Plans

OCS oil and gas operations and the well-being of our oceans and coastal communities are far too important to depend on the approval of one agency operating independently of other federal, state, tribal and local agencies, scientists, and stakeholders. And even the best, publicly informed decision-making process can succeed only if we insist on gathering, analyzing, and making publicly available the full spectrum of spatial and temporal ecological, sociological, and economic information relevant to impacts of routine OCS operations and unplanned events. Informed by the best available science and other sources of information, ecosystem-based CMSP and its effective implementation by the BOEM and other responsible federal, state, tribal, and local government agencies in the region, subjected to diligent national oversight from the National Ocean Council, will, in combination, ensure to the maximum extent practicable that OCS operations are safe and consistent with achievement of other goals articulated in the National Ocean Policy.

94. *Id.*