Excerpt from Anderson, *et.al* 2014

Understanding and Properly Interpreting the 2010 *Deepwater Horizon* Blowout

by NCEAS Gulf Oil Spill EcoTox Working Group

Sean Anderson, Charles Peterson, Gary Cherr, Richard Ambrose, Shelly Anghera, Steve Bay, Michael Blum, Rob Condon, Thomas Dean, Jeffrey Duncan, Greg Eckert, Monty Graham, Michael Guzy, Stephanie Hampton, Roger Helm, Michael Hooper, Amanda Joye, John Lambrinos, Bruce Mate, Douglas Meffert, Sean Powers, Christopher Reddy, Ponisseril Sonasundaran, Robert Spies, Caz Taylor, Ronald Tjeerdema, and Joseph Torres.

Abstract

The *Deepwater Horizon* oil release of 2010 presented a mixture of unique and familiar environmental challenges to marine scientists, government and industry responders, and policy makers. Intensive dispersant application at the wellhead 1544 m below the surface and on the surface helped create an oil-dispersant mix of toxicants at depth, reducing the mass of floating mousse to an unknown degree. This response decision was a trade-off, limiting the amounts of floating oil transported to shore over the first five months following the blow-out, and thereby protecting sensitive coastal organisms and habitats, including marshes where persistence can extend for decades, at the expense of unknown chronic impacts on pelagic organisms out of sight beneath the sea surface. Properly interpreting the ecotoxicology of the *Deepwater Horizon* blowout is a challenge and involves a clear questioning of basic assumptions accumulated over the past several decades of oil spills. In this chapter we briefly review the historic spills that have shaped our views and then propose a new conceptual model for the fate, transport, and exposure pathways for ecological effects of a marine oil spill that unifies our previous understanding of historic spills with our still-unfolding understanding of the *Deepwater Horizon* oil spill across the Gulf of Mexico. *Deepwater Horizon*–induced ecosystem level impacts may and likely will take years to become fully revealed. We argue that a complete understanding of resrouces impacted by the *Deepwater Horizon* blowout must include a robust assessment of deep benthic and midwater communities in the Gulf of Mexico. Impact assessment for the *Deepwater Horizon* blowout is challenged by the dearth or complete absence of long-term ecological monitoring data necessary to define pre-impact, baseline conditions across the Northern Gulf of Mexico, particularly for midwater and deep sea communities. Targeted advances in deep water pelagic environmental science are critically needed to keep pace with engineering developments that open new ocean depths to risks of spilled oil.

Introduction

The Gulf of Mexico *Deepwater Horizon* Oil Blowout[1] initiated a previously-unknown category of marine pollution. The massive spatial and temporal scales of this release, combined with the ultra-deep water[2] location of the wellhead yielded a pollution event dramatically more complex than our prior understanding of the toxicology of oil spills suggested.

Piecemeal deconstruction of this complex, large-scale event has fostered an incorrect understanding of the mechanisms of exposure, patterns of oil dispersal, persistence of oil, and ultimately the acute and chronic effects of this spill upon the populations and communities of the Gulf of Mexico. Complete understanding of the ecotoxicology of this and any similar future blowouts requires both a new conceptual model of deep sea hydrocarbon release, fate, and transport and ultimately a new interdisciplinary approach to quantifying the impacts of such exposure upon marine and coastal ecosystems across all depths and realms.

While a complete understanding of the impacts of this disaster is years or decades away, this chapter serves as an initial orientation to the *Deepwater Horizon* event and an introduction to the subsequent chapters in this volume.

Background

Significant Past Marine Oil Spills

Free petroleum has been a component of the world's oceans for hundreds of millions of years, primarily entering into the marine environment through slow-release

---

[1] Note that the *Deepwater Horizon* event is properly characterized as a wellhead "blowout" and not a "spill." An oil *spill* refers to the release of a contained volume of oil such as from the rupturing of a tanker's hold or breaking open of a storage tank. A *blowout* occurs when a tapped subsurface reservoir of unknown volume freely and uncontrollably releases those hydrocarbons. It is important to note the difference, particularly from a policy and management perspective. As evidenced by the *Deepwater Horizon* event, the management of a *spill* is initially focused on containment only whereas management of a *blowout* must initially have dual foci of capping and containment. A *blowout* is therefore a much more difficult beast to deal with given that the scale of the catastrophe is unknown and ever-expanding. Acknowledging this important semantic distinction, we will use both terms in this chapter. While *blowout* is the preferred term, we have found most audiences prefer the colloquial *spill* moniker and so have accepted its use in even technical writings about this disaster.

[2] The drilling industry and regulatory agencies have revised their depth classifications over time reflecting technical advances. In 2010, the former Minerals Management Service defined depths below 400 m (1,312 ft) as *deep water* and depths below 1,600 m (5,249 ft) as *ultra-deep water (Nixon et al. 2009)*

seeps in coastal shelf regions with fractured or discontinuous stratigraphies. Oil spills have gone hand in hand with human oil extraction, and posed significant health and environmental risks for well over a century. For example, the largest accidental oil spill to date, the Lakeview Gusher (near Bakersfield, California), occurred a century before the *Deepwater Horizon* near the dawn of our petroleum age when bores were drilled manually. That 1910 terrestrial blowout ultimately released an estimated 1.5 million m^3 (9.4 million barrels, or 190% of the release of the *Deepwater Horizon*) over 544 days, creating a series of oil lakes as deep as 30 m before the majority of the oil volatized or seeped into underlying sediments (West Kern County Oil Museum 2011).

Hundreds of oil spills occur each year in United States waters, with most of these relatively small in both spatial extent and duration (National Research Council 2003). While large spills from both extraction and transportation occur on a relatively frequent basis, some spills have had a disproportionate influence upon our conceptualization of the nature of oil spills, our resulting management responses to these events, and the aggregate ecological impacts. As such these have had a direct bearing on our subsequent management and expectations of the *Deepwater Horizon* Blowout.

Below we briefly review some of the spills that we feel have most influenced our thinking about marine spills ecotoxicology (Table 1).

1967 Torrey Canyon Spill

The world's first supertanker *Torrey Canyon* ran aground upon the Seven Stones offshore reef on March 18, 1967 as Captain Pastrengo Rugiati attempted to shorten the ship's arrival time in Wales via a shortcut (BBC Newswire 1967b, Petrow 1969). Within 12 hours of the grounding, the British Navy and local firefighters began spraying dispersants (more appropriately described as detergents, mainly BP1002) upon the expanding slick, applying approximately 75 m^3 over the first three days (9,500 m^3 would ultimately be used at sea and upon intertidal shores) onto the accumulating surface slick then comprised of an estimated 30,000 m^3 of oil (Smith 1968). By day six the hull broke apart after refloating attempts had both failed and claimed the life of a Dutch salvage team leader (Axford 2012). Prime Minister Harold Wilson ordered the military to bomb the fractured hull to sink it and burn the surface slick as the Cornish coast was becoming heavily oiled (BBC Newswire 1967a, Lewis 1967). This proved difficult and was complicated by both roughening seas and the fact a quarter of the 161 bombs and 16 rockets dropped over three days by British warplanes missed their conspicuous, stationary target (Barkham 2010). Ultimately the military resorted to directly dumping 1,500 m^3 of napalm and 44.5 m^3 of aviation fuel over the wreck site to get that localized slick to ignite and burn consistently (Staff 1978). Fourteen thousand m^3 of oil were ultimately released and comprised a surface slick covering 700 km^2 at its peak, which killed an estimated 15,000 sea birds (Smith 1968) and 90% of the sardine (*Sardina pilchardus*) eggs in the region (Spooner 1969). As with the *Deepwater Horizon* four decades later, unseasonable offshore winds kept the majority of the oil off of British shores such that only about 15% of the spilled oil grounded across roughly 240 km (although only about 80 km were heavily oiled) of British coastline (Smith 1968). The French coastal zone received more of the released oil. Both coastlines were covered with mixtures of weathered and emulsified crude. The French interdictions were more successful at minimizing oil upon their famous tourist beaches by applying 3,000 tons of powdered Craie de Champagne (naturally occurring chalk containing stearic acid) onto the surface slick as it reached their nearshore waters (Smith 1968).

In response to the heavy coastal oiling, the British deployed even more dispersant, ultimately applying the majority of the 9,500 m^3 used in the overall response within the coastal zone (Smith 1968). This coastal application utilized often famously ineffectual techniques such as burying drums of dispersant, pouring dispersants directly onto beach sands en masse, or dropping whole dispersant barrels over cliffs (M'Gonigle and Zacher 1979, Barkham 2010). These first generation "dispersants" were essentially engine degreasers, created and applied with little or no concern for any toxicological impacts upon natural systems. In the prescient words of the Guardian's science reporter Anthony Tucker in 1967, "There may be little point in spending many millions of pounds simply to convert an unpleasant but visible marine poison into another kind of poison that is insidious and entirely unknown in its effects" (quoted in Barkham 2010). The 1968 post-spill report by the Marine Biological Association of the United Kingdom (Smith 1968) found the use of such dispersants magnified the toxicity by making spilled oil more bioavailable than untreated oil, rendering the management decision to use dispersant "largely ineffective, uneconomic, and wasteful of effort", suggesting that a safer route would have been to follow the French lead. Local intertidal populations bore the brunt of the spill impacts, with the highest mortality among sessile invertebrates, mobile herbivores, and macroalgae in areas where dispersants were most heavily applied (O'Sullivan and Richardson 1967, Smith 1968). While recolonization by opportunistic algae began in the months following the initial impact, significant differences in intertidal community composition, elevational distributions and reduced species richness persisted for more than a decade, with the greatest differences in detergent-treated regions (Southward and Southward 1978). The *Torrey Canyon* spill provided our first modern case study of the effects spilled oil on the marine ecosystem (see Southward and Southward 1978, Hawkins and Hartnoll 1983, Southward and Southward 1988, Hawkins and Southward 1992, Raffaelli and Hawkins 1999, Hawkins 2012).

Salvaged coastal oil was deposited directly into an open air pit approximately 100 m from the shoreline of Guernsey (now known locally as the Torrey Canyon Quarry) where the pooled oil continues to kill alighting birds and wildlife to this day (Barkham 2010). Throughout the immediate spill response the government and responders were soon painted as either bumbling or (at best) ineffectual (M'Gonigle and Zacher 1979). In the wake of the immediate impact, the drawn-out legal attempts to deflect responsibility by all potentially responsible parties spurred major reforms of international maritime libel statues (Okidi 2010). The *Torrey Canyon* Spill marked the advent of long-term monitoring with robust modern statistical approaches on impacted communities (e.g., Schmitt and Osenberg 1996). It was also the first marine spill wherein researchers and managers would conclude the proposed management was worse than the "baseline" oiling and was therefore directly responsible for stimulating development of second generation dispersants wherein the ecotoxicology of the dispersants themselves was explored prior to use in a real-world management situation.

1969 Santa Barbara Blowout

One of the most influential oil spills occurred on January 29, 1969 approximately 10 km off of the coast of Summerland (just south of the city of Santa Barbara), California. While nearing the completion of drilling a fifth well, Union Oil's Platform A suffered a catastrophic failure (National Oceanic and Atmospheric Administration 1992). Insufficient borehole casings led to multiple ruptures along the adjacent seafloor. This fostered an unrestricted release of oil and gas into the Santa Barbara Channel for 11 days, with subsequent fissures opening up and oil ultimately leaking into the marine environment from associated seafloor cracks for at least a year (albeit at a much reduced flow rate). Somewhere between 13,000 and 16,000 m^3 of oil was released, making it the then-largest marine oil spill in US waters (Table 1; Straughan 1971a, Nicholson 1972).

The importance of the Santa Barbara blowout to our conceptualization of spilled marine oil cannot be underestimated. Climactic and oceanic conditions for most of the first three days of the spill kept the primary slick offshore, but a large winter storm then brought the oil onto mainland beaches (Kolpack 1971). The high visibility and popularity of the beaches in the area, disingenuous industry claims of successfully curtailing the spill despite ample evidence to the contrary across newspaper front pages and on evening newscasts, continual re-oiling of previously cleaned shoreline, proximity to the nation's film and broadcast epicenter, an eventual visit by the President of the United States, and deep-seated public outrage over the growing disaster set the stage for this oil spill to write the iconic story line of all future oil spills (Easton 1972, Corwin 1989, Nash 1989, Nash 2001). Included in this narrative that now dominates perceptions are conspicuously oiled marine vertebrates that volunteers from the public valiantly strive to clean, rudimentary industry and governmental technologies to sop up oil deposited along the coastline, fishery closures that idled fishing fleets, decimation of the regional coastal-dependent economies, a general inability of regulators and industry to correctly predict or characterize the fate and transport of the oil, and non-existent processes to robustly characterize the impacts of the spill or offer up effective mitigation for the associated impacts. This was the first test of the recently-passed National Pollution Contingency Plan and effectively put the federal government in the driver's seat of response coordinator. Numerous regulatory responses to this spill greatly improved our capacity to respond to future spills (e.g., Clean Seas), exert greater regulatory controls over such offshore production (e.g., the California Coastal Commission), and mandate improved contingency plans, which include conceptually modeling such oil spills to help think through what a future spill might look like and who might be affected (e.g., Environmental Impact Reviews). No new oil leases in California state waters have been granted since this spill. The Santa Barbara Oil Spill was a major influence upon the nascent Environmental Movement and helped usher in our foundational federal laws of modern ecological protection (i.e. NEPA, Clean Water Act, Clean Air Act; Nash 1989, Nash 2001).

Much effort has been devoted to understanding why the Santa Barbara oil did not cause larger impacts. While oil roamed over roughly the same amount of coastline (about 200 km, from Pismo Beach to Ventura) as *Torrey Canyon* oil two years before, oil groundings were most concentrated close to the well (Kolpack 1971, Straughan 1971a). Oil was coming ashore onto the campus of University of California Santa Barbara and therefore stimulated a rapid, initially *ad hoc* inventorying and assessment of the biological impacts of this event by a wide cross-section of local marine researchers and amounted to our first assessment of oil fate and effects post-*Torrey Canyon* (Kolpack 1971, Straughan 1971a). Given the high profile nature of the spill and the relative intensity of post-spill biological monitoring, many were therefore surprised by the findings of minimal apparent acute impacts from the blowout. As a group, only several thousand seabirds seabirds and very localized populations of sessile intertidal invertebrates appeared to show consistent signs of acute mortality (Straughan 1971b). To explain this apparent lack of impact, the Straughan (1971a) report set up a series of hypotheses that have generally guided our thinking since.

Straughan (1971b) reasoned that aspects of the physical environment ameliorated potential impacts. First and foremost were the winter storms that both helped break-up and degrade oil and created stresses of their own (that winter had the highest rainfall in two decades) which made distinguishing oil effects from low salinity, *etc*. effects difficult. Secondly, those storms created conditions where oil was constantly moving over and through the coastal environment, in effect reducing site-attached organisms' exposure time to oil. Next this hypothesis postulates that many species in the Santa Barbara channel had an inherent physiological (chiefly prokaryotes) or behavioral (mobile animals) protection from hydrocarbon exposure/toxicity owing to their evolution in this oil seep-rich region wherein some level of background oiling has been occurring for millions of years. Lastly, and perhaps most importantly was the rather cautious nature of the interpretation of data and the benefit of the doubt that was given. As virtually no baseline monitoring data existed pre-spill, Straughan and her colleagues were hard pressed to even document any post-spill differences in ecological conditions and were reluctant to attribute any apparent observed differences to the spill (Straughan 1971a, Fauchald 1972). This lack of pre-spill ecological data and robust statistical methods to interpret impact led to the conclusion that little acute (and by extension chronic) toxicity occurred. The frequent caveats and qualitative statements throughout the report about the lack of tools to conduct a robust analysis (insuring what we might now term statistical power) were largely ignored. It was widely concluded that the Santa Barbara Oil Spill had little ecological impact (e.g., Squire 1992, Epstein 2010). In light of the *Deepwater Horizon* blowout, it is also important to note that in this and other concurrent explorations of the effects of the Santa Barbara spill, subtidal benthic and pelagic communities were largely ignored (save for offshore fish trawls, some grab sampling of benthic infauna that proved problematic, and limited nearshore kelp bed surveys) and having oil sink out of surface waters was generally considered an improvement from an ecotoxicological perspective. All aspects of this oil spill model have been directly applied to our initial interpretations of the *Deepwater Horizon*, although this Straughan model has become so deeply engrained into our ecotoxicologists assumptions that few cite her work as the ultimate source.

1979 Ixtoc I Blowout

On June 3, 1979 in Caribbean Mexico's Bay of Campeche, the Pemex semi-submersible exploratory drilling rig Sedco 135F experienced a drilling mud failure while drilling an exploratory well 80 km offshore (National Oceanic and Atmospheric Administration 1992). Diminishing drill mud pressure allowed a methane kick to proceed up the bore and blowout the well. A complete failure of an in-place blowout preventer left the company with no ability to stem the flow and oil flowed for more than 10 months, releasing approximately 580,000 m^3 of oil into the Gulf of Mexico before a new relief well could intercept and cut off the original wellbore (Anderson et al. 1982). A variety of surface-lowered and diver-deployed containment structures failed to stem the flow. Nearly 493 sorties of aerial tankers applied about 5,600 m^3 of dispersants (Corexit 9527) across a wide area of the sea surface in Mexican waters, but were disallowed in U.S. Territorial Waters (Lindblom et al. 1981).

Despite the relatively shallow and near-shore location of this well, few readily apparent impacts were seen on local shores as most of the slick was transported northward away from the Mexican shore and into the Gulf of Mexico (Jernelöv and Olof 1981). The application of dispersants to the sea surface soon commenced and became widely viewed as an effective tool with which to attack such spills (e.g., Lindblom et al. 1981, Walker and Henne 1991, Walker et al. 1999). No dispersants were used in U.S. territorial waters as federal managers deemed their value limited given the highly weatherized state of most oil (weeks at sea) by the time oil reached the American shores (National Oceanic and Atmospheric Administration 1992). The general lack of robust marine science/environmental monitoring capacity (Hooper 1981), the apparent lack of interest in impact assessment by Mexican authorities (with the possible exception of interest in impacts to local fisherfolks; Editorial Board 1980, Vargas 2010), and the fact that the vast majority of the oil went "out of sight, out of mind" led to only limited documentation of the long-term consequences of this spill and any unintended impacts of the dispersant (Energy Resrouces Co. Inc. 1982, Lewbel 1985). For example, in a representative description of minimal ecological impact from released hydrocarbons, Jernelöv and Olof (1981) simply note "…[t]he rest of the oil, about 120,000 metric tons or 25 percent, sank to the bottom of the Gulf" with no other comment or research to support a no effective impact assessment. The most sustained and robust investigations were conducted upon coastlines and coastal-dwelling species (i.e. birds and infauna) along the Texas shoreline (Tunnell and Chapman 1980, Tunnell and Dokken 1980, Kindinger 1981, Tunnell et al. 1981, Tunnell et al. 1982), an area that received but a small fraction (perhaps 1%; Jernelöv and Olof 1981) of the overall released hydrocarbons. *Deepwater Horizon* response efforts largely paralleled those for *Ixtoc I*, particularly in the initial weeks of the spill (Vargas 2010).

In addition to little of evidence for any negative (or positive) impacts of sustained dispersant use and implicit acceptance of the Straughan model for oil spills, another notable outcomes of the *Ixtoc I* spill emerged from the time-lag preceding surface oiling of the Texas coast. As nearly two months elapsed between the onset of the blowout and landfall (National Oceanic and Atmospheric Administration 1992) of the weatherized oil upon the American coastline, federal responders realized the importance of coastline mapping relative to oil sensitivity. The resulting mapping/classification project produced the first Environmental Sensitivity Index (ESI) for coastal oiling. Proximately, this helped optimize the deployment of oil-containing-booms Longer-term, it helped cement the notion that littoral communities are the most vulnerable ecological communities and that future spill mitigation planning should de-emphasize concern for pelagic/benthic communities (e.g., Cooper and McLaughlin 1998, Pincinato et al. 2009).

1989 Exxon Valdez Oil Spill

By early 1989, the Trans-Alaska Pipeline System had been bringing oil from Alaska's North Slope and Prudhoe Bay down to the marine shipping terminal at Valdez for more than 12 years. So routine had the shipping of oil from this facility become that an inebriated Captain Jeffrey Hazelwood abandoned the bridge of the *Exxon Valdez* supertanker soon after leaving port and allowed the autopilot to run the vessel aground on Bligh Reef on the early morning of March 24, 1989 in Alaska's Prince William Sound (Alaska Oil Spill Commission 1990). Over the course of the next 3 days the vast majority of the tanker's hold spilled between 42,000 and 120,000 m^3 of crude oil into the sound, with perhaps 25% of that oil subsequently escaping into the northern Gulf of Alaska (Exxon Valdez Oil Spill Trustee Council 1994).

The oil largely disappeared from the surface of the ocean within a matter of weeks, but the crenulated shoreline of Prince William Sound and the Gulf of Alaska, dominated by cobble and boulders, received large amounts of oil that persisted on the intertidal surfaces for several years and for up to 20 years or more below that surface where protected from surface wave energy (Bodkin et al. 2012). Little of the oil reached the bottom of Prince William Sound, except in the shallow subtidal areas immediately off oiled beaches.

Major impacts of the spill occurred to birds and mammals on the surface of the ocean (e.g., common murres and sea otters) and to plants and animals living in or utilizing the intertidal areas for spawning (De Vogelaere and Foster 1994, Houghton et al. 1997, van Tamelen et al. 1997). Little damage was documented to midwater animals and little or none of the oil was found bellow 20 m depths (Rice et al. 2003). Work done after the spill documented the sublethal effects of low parts-per-billion exposure to polynuclear aromatic hydrocarbons (PAHs) to the young stages of pink salmon (Rice et al. 2001) and herring (Carls et al. 2002) and revised our expectations of toxicity of these compounds following oil spills. Research more than two decades post-spill is still illuminating which species and populations have recovered (e.g. Harlequin Ducks; Esler and Iverson 2010) and which still manifest sublethal impacts (e.g. otters; Bodkin et al. 2012). Consequently, *Exxon Valdez* has becomes the world's best studied oil spill. The *Exxon Valdez* Trustee Council, which oversees and authorizes most of this work, has emphasized peer-review at all stages and has importantly funded work that has focused on understanding the totality of the coastal ecosystem and hence allowed insights which would not have been possible under the previous, traditional approaches to impact assessment. Without this body of work we would have been unable to understand the unexpected persistence of subsurface oil and the degree to which sublethal chronic exposures have continued to affect populations and communities (Peterson et al. 2003b).

Without this body of work we would have been unable to understand, for example, the causal relationship between the 1989 spill and the subsequent reductions of pink salmon and herring stocks years later (Rice et al. 2001, Carls et al. 2002). Long-term impacts continue to unfold and the *Exxon Valdez* has become a new model for ecotoxicological assessment. It also represents the model upon which the 1990 Oil Pollution Act was based and which now guides the present Natural Resource Damage Assessment process following oil spills (Johnson 2011).

Literature Cited

AFP Staff. 2010. US oil production, shipping unaffected by spill so far. Agence France-Presse Wire Service. Agence France-Presse.

Alaska Oil Spill Commission. 1990. Spill: The wreck of the Exxon Valdez Final Report.

Anderson, S., P. Boehm, D. Fiest, H. R., C. Lewbel, D. Pilson, and A. Wait. 1982. IXTOC Oil Spill Damage Assessment Study. Minerals Management Service.

Austin, D., B. Carriker, T. M. J. P. T. Priest, and A. G. Pulsipher. 2004. History of the Offshore Oil and Gas Industry in Southern Louisiana Interim Report Volume I: Papers on the Evolving Offshore Industry. OCS MMS 2004-049, U.S. Department of the Interior, Baton Rouge, Louisiana.

Axford, D. N. 2012. The Breaking-up of the oil tanker Torrey Canyon.

Barkham, P. 2010. Oil spills: Legacy of the Torrey Canyon. The Guardian, London, England.

BBC Newswire. 1967a. Bombs rain down on Torrey Canyon. BBC Hourly News Summary.

BBC Newswire. 1967b. Supertanker Torrey Canyon hits rocks.

Bodkin, J. L., B. E. Ballachey, H. A. Coletti, G. G. Esslinger, K. A. Kloecker, S. D. Rice, J. A. Reed, and D. H. Monson. 2012. Long-term effects of the ‘Exxon Valdez’ oil spill: sea otter foraging in the intertidal as a pathway of exposure to lingering oil. Marine Ecology Progress Series **447**:273-287.

Boufadel, M. C., Y. Sharifi, B. Van Aken, B. A. Wrenn, and K. Lee. 2010. Nutrient and Oxygen Concentrations within the Sediments of an Alaskan Beach Polluted with the Exxon Valdez Oil Spill. Environmental Science & Technology **44**:7418-7424.

Bowman, T. D., P. F. Schempf, and J. A. Bernatowicz. 1995. Bald Eagle Survival and Population Dynamics in Alaska after the "Exxon Valdez" Oil Spill. The Journal of Wildlife Management **59**:317-324.

Briggs, J. C. 1974. Marine Zoogeography. McGraw Hill, New York, New York.

Brooks, J. M., C. Fisher, H. Roberts, B. Bernard, I. MacDonald, R. Carney, S. Joye, E. Cordes, G. Wolff, and E. Goehring. 2008. Investigations of Chemosynthetic Communities on the Lower Continental Slope of the Gulf of Mexico: Interim Report 1. OCS MMS 2008-009, Department of the Interior.

Bureau of Ocean Energy Management, R. a. E. 2010. History of Offshore Oil and Gas Development in the Gulf of Mexico.

Bureau of Ocean Energy Management Regulation and Enforcement. 2011. Well Information and Data Available in ASCII Files for Downloading. Bureau of Ocean Energy Management Regulation and Enforcement.

California Academy of Sciences. 2012. Scientists find higher concentrations of heavy metals in post-spill oysters from Gulf of Mexico.*in* C. A. o. Sciences, editor. California Academy of Sciences, San Francisco, California.

Camilli, R., C. M. Reddy, D. R. Yoerger, B. A. S. Van Mooy, M. V. Jakuba, J. C. Kinsey, C. P. McIntyre, S. P. Sylva, and J. V. Maloney. 2010. Tracking Hydrocarbon Plume Transport and Biodegradation at Deepwater Horizon. Science **330**:201-204.

Carls, M. G., G. D. Marty, and J. E. Hose. 2002. Synthesis of the toxicological impacts of the Exxon Valdez oil spill on Pacific herring (Clupea pallasi) in Prince William

Sound, Alaska, U.S.A. Canadian Journal of Fisheries and Aquatic Sciences **59**:153-172.

CBS/Associated Press. 2010. BP's Spill Contingency Plans Vastly Inadequate. CBS News. CBS.

Chapman, P. M. and J. D. Morgan. 1983. Sediment bioassays with oyster larvae. Bulletin of Environmental Contamination and Toxicology **31**:438-444.

Cooper, J. A. G. and S. McLaughlin. 1998. Contemporary Multidisciplinary Approaches to Coastal Classification and Environmental Risk Analysis. Journal of Coastal Research **14**:512-524.

Cordes, E. E., M. P. McGinley, E. L. Podowski, E. L. Becker, S. Lessard-Pilon, S. T. Viada, and C. R. Fisher. 2008. Coral communities of the deep Gulf of Mexico. Deep Sea Research Part I: Oceanographic Research Papers **55**:777-787.

Corwin, M. 1989. The Oil SPill Heard 'Round The Country. Page I23 Los Angeles Times, Los Angeles, California.

CSA International, I. 2007. Characterization of Northern Gulf of Mexico Deepwater Hard-Bottom Communities with Emphasis on *Lophelia* Coral. OCS MMS 2007-044, U.S. Department of the Interior.

Culbertson, J. B., I. Valiela, E. E. Peacock, C. M. Reddy, A. Carter, and R. VanderKruik. 2007. Long-term biological effects of petroleum residues on fiddler crabs in salt marshes. Marine Pollution Bulletin **54**:955-962.

Culbertson, J. B., I. Valiela, M. Pickart, E. E. Peacock, and C. M. Reddy. 2008. Long-term consequences of residual petroleum on salt marsh grass. Journal of Applied Ecology **45**:1284-1292.

Darnell, R. M. and R. E. Defenbaugh. 1990. Gulf of Mexico: Environmental Overview and History of Environmental Research. American Zoologist **30**:3-6.

Dauvin, J.-C. and F. Gentil. 1990. Conditions of the peracarid populations of subtidal communities in Northern Brittany ten years after the Amoco Cadiz oil spill. Marine Pollution Bulletin **21**:123-130.

De Vogelaere, A. P. and M. S. Foster. 1994. Damage and Recovery in Intertidal Fucus Gardneri Assemblages Following the 'Exxon Valdez' Oil Spill. Marine Ecology Progress Series **106**:263-271.

Deepwater Horizon Study Group. 2011. Final Report on the Investigation of the Macondo Well Blowout. Center for Catastrophic Risk Management, University of California Berkeley.

Defenbaugh, R. E. 1990. The Gulf of Mexico: A Management Perspective. American Zoologist **30**:7-13.

Easton, R. O. 1972. Black tide: the Santa Barbara oil spill and its consequences. Delacorte Press.

Editorial Board. 1980. The Lessons of Ixtoc I. Page 22 New York Times, New York, New York.

Elmgren, R., S. Hansson, U. Larsson, B. Sundelin, and P. D. Boehm. 1983. The “Tsesis” oil spill: Acute and long-term impact on the benthos. Marine Biology **73**:51-65.

Energy Resrouces Co. Inc. 1982. Ixtoc Oil Spill Assessment Final Report. AA851-CTO-71, Bureau of Land Management.

Enticknap, B. 2002. Trawling the North Pacific: Understanding the Effects of Bottom Trawl Fisheries on Alaska's Living Seafloor. Alaska Marine Conservation Council.

Environmental Protection Agency. 2010. EPA and NOAA Press Conference Call on Dispersant Use and Approval.

Epstein, A. 2010. Obama Follows Nixon on Oil Spills. Wall Street Journal.

Esler, D. and S. A. Iverson. 2010. Female Harlequin Duck Winter Survival 11 to 14 Years After the Exxon Valdez Oil Spill. Journal of Wildlife Management **74**:471-478.

Exxon Valdez Oil Spill Trustee Council. 1994. Final Environmental Impact Statement for the Exxon Valdez Oil Spill Restoration Plan.

Fauchald, K. 1972. A survey of the Benthos off Santa Barbara following the January 1969 Oil Spill. CalCOFI Report.

Fautin, D., P. Dalton, L. S. Incze, J.-A. C. Leong, C. Pautzke, A. Rosenberg, P. Sandifer, G. Sedberry, J. W. Tunnell, Jr., I. Abbott, R. E. Brainard, M. Brodeur, L. G. Eldredge, M. Feldman, F. Moretzsohn, P. S. Vroom, M. Wainstein, and N. Wolff. 2010. An Overview of Marine Biodiversity in United States Waters. PLoS ONE **5**:e11914.

Geraci, J. R. and D. J. St. Aubin. 1988. Synthesis of effects of oil on marine mammals. OCS MMS 88-0049, Minerals Management Service, Ventura, California.

Giarrusso, C. C., E. Pugliese Carratelli, and G. Spulsi. 2001. On the effects of wave drift on the dispersion of floating pollutants. Ocean Engineering **28**:1339-1348.

Gower, J. F. R. and S. A. King. 2011. Distribution of floating Sargassum in the Gulf of Mexico and the Atlantic Ocean mapped using MERIS. Int. J. Remote Sens. **32**:1917-1929.

Grabowski, J. H. and C. H. Peterson. 2007. Restoring oyster reefs to recover ecosystem services. Pages 281-298 *in* K. Cuddington, J. E. Byers, W. G. Wilson, and A. Hastings, editors. Ecosystem engineers. Elsevier Academic Press.

Graham, B., W. K. Reilly, F. Beinecke, D. F. Boesch, T. D. Garcia, C. A. Murray, and F. Ulmer. 2011. Deep Water: The Gulf Oil Disaster And The Future Of Offshore Drilling - Report to the President (BP Oil Spill Commission Report). BP Oil Spill Commission.

Graham, W. M., R. H. Condon, R. H. Carmichael, I. D'Ambra, H. K. Patterson, L. J. Linn, and F. J. H. Jr. 2010. Oil carbon entered the coastal planktonic food web during the Deepwater Horizon oil spill. Environmental Research Letters **5**:045301.

Gulf of Mexico Sea Grant Programs. 2010. Fish Stocks in the Gulf of Mexico Fact Sheet. Page 3 *in* U. S. D. o. Commerce, editor. National Oceanic and Atmospheric Administration.

Hawkins, S. J. 2012. Marine conservation in a rapidly changing world. Aquatic Conservation: Marine and Freshwater Ecosystems **22**:281-287.

Hawkins, S. J. and R. G. Hartnoll. 1983. Changes in a rocky shore community: An evaluation of monitoring. Marine Environmental Research **9**:131-181.

Hawkins, S. J. and A. J. Southward. 1992. The Torrey Canyon oil spill: Recovery of the rocky shore communities. Pages 583-631 *in* G. W. Thayer, editor. Restoring the Nation's Marine Environment. Maryland Sea Grant, College Park, MD.

Hazen, T. C., E. A. Dubinsky, T. Z. DeSantis, G. L. Andersen, Y. M. Piceno, N. Singh, J. K. Jansson, A. Probst, S. E. Borglin, J. L. Fortney, W. T. Stringfellow, M. Bill, M. S. Conrad, L. M. Tom, K. L. Chavarria, T. R. Alusi, R. Lamendella, D. C. Joyner, C. Spier, J. Baelum, M. Auer, M. L. Zemla, R. Chakraborty, E. L. Sonnenthal, P. D'haeseleer, H.-Y. N. Holman, S. Osman, Z. Lu, J. D. V. Nostrand, Y. Deng, J. Zhou, and O. U. Mason. 2010. Deep-sea oil plume enriches indigenous oil-degrading bacteria. Science **330**:204-208.

Helguero, G. 2010. U.S. confirms underwater oil plume from Deepwater Horizon well. International Business Times.

Hoffmayer, E. R., J. S. Franks, B. H. Comyns, J. R. Hendon, and R. S. Waller. 2005. Larval and juvenile fishes associated with pelagic Sargassum in the northcentral Gulf of Mexico. Pages 259–270 *in* Proceedings of the Gulf and Caribbean Fisheries Institute.

Hooper, C. H. 1981. IXTOC I Oil Spill: The Federal Scientific Response. Report, National Oceanic and Atmospheric Administration, Boulder, Colorado.

Houghton, J. P., R. H. Gilmour, D. C. Lees, W. B. Driskell, S. C. Lindstrom, and A. Mearns. 1997. Prince William Sound intertidal biota seven years later: has it recovered? Pages 679-686 *in* International Oil Spill Conference. American Petroleum Institute, Washington D.C.

Hu, X., W.-J. Cai, Y. Wang, X. Guo, and S. Luo. 2011. Geochemical environments of continental shelf-upper slope sediments in the northern Gulf of Mexico. Palaeogeography, Palaeoclimatology, Palaeoecology **312**:265-277.

Jackson, J. B. C., J. D. Cubit, B. D. Keller, V. Batista, K. Burns, H. M. Caffey, R. L. Caldwell, S. D. Garrity, C. D. Getter, C. Gonzalez, H. M. Guzman, K. W. Kaufmann, A. H. Knap, S. C. Levings, M. J. Marshall, R. Steger, R. C. Thompson, and E. Wei. 1989. Ecological Effects of a Major Oil Spill on Panamanian Coastal Marine Communities. Science **243**:37-44.

Jernelöv, A. and L. Olof. 1981. Ixtoc I: A Case Study of the World's Largest Oil Spill. Ambio **10**:299-306.

Johansen, Ø., H. Rye, and C. Cooper. 2003. DeepSpill—Field study of a simulated oil and gas blowout in deep water. Spill Science Technology Bulletin **8**:433-443.

Johnson, C. C. 2011. The Oil Pollution Act of 1990: A Long Time Coming. Fordham Environmental Law Review **2**:58-77.

Joye, S., I. MacDonald, I. Leifer, and V. Asper. 2011. Magnitude and oxidation potential of hydrocarbon gases released from the BP blowout. Nature Geoscience **4**:160-164.

Kessler, J. D., D. L. Valentine, M. C. Redmond, M. Du, E. W. Chan, S. D. Mendes, E. W. Quiroz, C. J. Villanueva, S. S. Shusta, L. M. Werra, S. A. Yvon-Lewis, and T. C. Weber. 2011. A Persistent Oxygen Anomaly Reveals the Fate of Spilled Methane in the Deep Gulf of Mexico. Science.

Kindinger, M. E. 1981. Impact of the Ixtoc I oil spill on the community structure of intertidal and subtidal infauna along south Texas beaches. Corpus Christi State University.

Kolpack, R. L., editor. 1971. Biological and Oceanographical Survey of the Santa Barbara Channel Oil Spill 1969-1970: Volume II. Sea Grant, University of Southern California.

Law, R. J., C. A. Kelly, K. L. Graham, R. J. Woodhead, P. E. J. Dyrynda, and E. A. Dyrynda. 1997. Hydrocarbons and PAH in fish and shellfish from southwest Wales following the Sea Empress oil spill in 1996. Pages 205-211 *in* International Oil Spill Conference, Fort Lauderdale, Florida.

Lenihan, H. S., C. H. Peterson, J. E. Byers, J. H. Grabowski, W. T. Gordon, and D. R. Colby. 2001. Cascading of Habitat Degradation: Oyster Reefs Invaded by Refugee Fishes Escaping Stress. Ecological Applications **11**:764-782.

Lewbel, G. S. 1985. Strengths and weaknesses of damage assessment programs: the IXTOC-I and Burmah Agate oil spills and the benthic macroinfauna of the Texas continental shelf. Texas Journal of Science **37**:269-310.

Lewis, A. 1967. British Jets Drop Bombs, Napalm and Rockets on Stranded Tanker in New Effort to Burn Oil Cargo. New York Times.

Lindblom, G. P., B. D. Emery, and I. M. A. G. Lara. 1981. Aerial application of dispersants at the Ixtoc I Spill. Pages 259-262 *in* Oil Spill Conference.

Lowther, A. 2011. Fisheries of the United States 2010. Current Fishery Statistics No. 2010, National Marine Fisheries Service, Silver Spring, Maryland.

Lustgarten, A. 2010a. Chemicals Meant To Break Up BP Oil Spill Present New Environmental Concerns. ProPublica. ProPublica, New York.

Lustgarten, A. 2010b. Years of Internal BP Probes Warned That Neglect Could Lead to Accidents. ProPublica. ProPublica, New York.

M'Gonigle, R. M. and M. W. Zacher. 1979. Pollution, Politics, and International Law: Tankers at Sea. University of California Press, Berkeley, California.

MBARI. 2010. Data Report: NOAA Ship Gordon Gunter cruise GU-10-02, Gulf of Mexico June 2-3, 2010 operations of the MBARI AUV Dorado. Monterey Bay Aquarium Research Institute, Moss Landing, California.

McNutt, M., R. Camilli, G. Guthrie, P. Hsieh, V. Labson, B. Lehr, D. Maclay, A. Ratzel, and M. Sogge. 2011. Assessment of Flow Rate Estimates for the Deepwater Horizon / Macondo Well Oil Spill. Page 30 *in* I. S. G. Flow Rate Technical Group report to the National Incident Command, editor.

Millennium Ecosystem Assessment. 2005. Ecosystems and Human Well-Being: Wetlands and Water Synthesis. World Resources Institute, Washington, D.C.

Minerals Management Service. 2002. Summary of offshore petroleum operations in the Gulf of Mexico OCS Region. U.S. Department of the Interior, New Orleans, Louisiana.

Nash, R. 1989. Experiencing the Santa Barbara Oil Spill and Energizing Effect Upon the Environmental Movement in California.*in* S. Anderson, editor., University of California Santa Barbara.

Nash, R. F. 2001. Wilderness and the American Mind. 4th edition. Yale University Press.

National Oceanic and Atmospheric Administration. 1992. Oil spill case histories: 1967-1991 Summaries of significant U.S. and international spills. HMRAD 92-11, Hazardous Materials Response and Assessment Division, Seattle, Washington.

National OIl Spill Commission. 2011. Stopping the Spill: The Five-Month Effort to Kill the Macondo Well. National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, Washinton, D.C.

National Research Council. 1985. Oil in the Sea:Inputs, Fates, and Effects. The National Academies Press.

National Research Council. 2003. Oil in the Sea III: Inputs, Fates, and Effects. National Academies Press, Washington, D.C.

National Science Foundation. 2008. Proposal and Award Policies and Procedures Guide: Part I - Proposal Preparation & Submission Guidelines Grant Proposal Guidelines. National Science Foundation.

Nicholson, N. 1972. The Santa Barbara Oil Spills in Perspective. CalCOFI Report **16**:130-149.

Nixon, L. D., N. K. Shepard, C. M. Bohannon, T. M. Montgomery, E. G. Kazanis, and M. P. Gravois. 2009. Deepwater Gulf of Mexico 2009: Interim Report of 2008 Highlights. Page 87 *in* M. M. Service, editor.

NMFS Fisheries Statistics Division. 2011. Annual Commercial Landing Statistics. National Marine Fisheries Service.

O'Sullivan, A. J. and A. J. Richardson. 1967. The Torrey Canyon disaster and intertidal marine life. Nature **214**:448-541.

Okidi, C. O. 2010. International legal responses to threats to marine biodiversity from pollution. Pages 1-31 *in* 8th Annual Colloquium of IUCN Academy of Environmental Law, Ghent University, Belgium.

Pagès, F., H. E. González, M. Ramón, M. Sobarzo, and J. M. Gili. 2001. Gelatinous zooplankton assemblages associated with water masses in the Humboldt Current System, and potential predatory impact by Bassia bassensis (Siphonophora: Calycophorae). Marine Ecology Progress Series **210**:13-24.

Paine, R. T., J. L. Ruesink, A. Sun, E. L. Soulanilee, M. J. Wonham, C. D. G. Harley, D. R. Brumbaugh, and D. L. Secord. 1996. Trouble on oiled waters: lessons from the Exxon Valdez oil spill. Annual Review of Ecology and Systematics **27**:197-235.

Pequegnat, W. E. 1983. The Ecological communities of the continental slope and adjacent regimes of the northern Gulf of Mexico. OCS MMS 1983-11, Minerals Management Service, Metairie, Louisiana.

Peterson, C. H. 2001. The "Exxon Valdez" oil spill in Alaska: Acute, indirect and chronic effects on the ecosystem. Pages 1-103 Advances in Marine Biology. Academic Press.

Peterson, C. H., S. S. Anderson, G. N. Cherr, R. F. Ambrose, S. Anghera, S. Bay, M. Blum, R. Condon, T. A. Dean, M. Graham, M. Guzy, S. Hampton, S. Joye, J. Lambrinos, B. Mate, D. Meffert, S. P. Powers, P. Somasundaran, R. B. Spies, C. M. Taylor, R. Tjeerdema, and E. E. Adams. 2012. A Tale of Two Spills: Novel Science and Policy Implications of an Emerging New Oil Spill Model. BioScience **62**:461-469.

Peterson, C. H., J. H. Grabowski, and S. P. Powers. 2003a. Estimated enhancement of fish production resulting from restoring oyster reef habitat: quantitative valuation. Marine Ecology Progress Series **264**:249-264.

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

Petrow, R. 1969. What Really Caused the Torrey Canyon Disaster? Pages 114-119, 226 Popular Mechanics.

Pincinato, F. L., P. S. Riedel, and J. C. C. Milanelli. 2009. Modelling an expert GIS system based on knowledge to evaluate oil spill environmental sensitivity. Ocean & Coastal Management **52**:479-486.

Rabalais, N. N., B. A. McKee, D. J. Reed, and J.C. Means. 1993. Fate and Effects of Produced Water Discharged in Coastal Louisiana, Gulf of Mexico, USA. Pages 355-369 *in* J. P. Ray and F. R. Englehart, editors. Produced Water: Technological/Environmental Issues and Solutions. Plenum Press, New York, New York.

Raffaelli, D. and S. Hawkins. 1999. Intertidal Ecology. 2nd edition. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Rand, G. M., editor. 1995. Fundamentals of Aquatic Toxicology: Effects, Environmental Fate, and Risk Assessment. 2 edition. Taylor and Francis, Washington, D.C.

Reddy, C. M., J. S. Arey, J. S. Seewald, S. P. Sylva, K. L. Lemkau, R. K. Nelson, C. A. Carmichael, C. P. McIntyre, J. Fenwick, G. T. Ventura, B. A. S. Van Mooy, and R. Camilli. 2011. Composition and fate of gas and oil released to the water column during the Deepwater Horizon oil spill. Proceedings of the National Academy of Sciences.

Resnick-Ault, J. and K. Klimasinska. 2010. Transocean Oil-Drilling Rig Sinks in Gulf of Mexico. Bloomberg New Service.

Rezak, R. 1972. Carbonate Sediments o the Gulf of Mexico. Texas A&M Oceanographic Studies **3**:263-280.

Rezak, R., T. J. Bright, and D. W. McGrail. 1983. Reefs and Banks of the Northwestern Gulf of Mexico: Their Geological, Biological, and Physical Dynamics. 83-1-T, Minterals Management Service.

Rezak, R., T. J. Bright, and D. W. McGrail. 1985. Reefs and Banks of the Northwestern Gulf of Mexico. John Wiley & Sons, New York, New York.

Rice, S. D., M. G. Carls, R. A. Heintz, and J. W. Short. 2003. Comment on “hydrocarbon composition and toxicity of sediments following the Exxon valdez oil spill in Prince William Sound, Alaska, USA”. Environmental Toxicology and Chemistry **22**:2539-2540.

Rice, S. D., R. B. Spies, D. A. Wolfe, and B. A. Wright, editors. 1996. Proceedings of the "Exxon Valdez" Oil Spill Symposium. American Fisheries Society, Bethesda, Maryland.

Rice, S. D., R. E. Thomas, R. A. Heintz, A. C. Wertheimer, M. L. Murphy, M. G. Carls, J. W. Short, and A. Moles. 2001. Synthesis of long-term impacts to pink salmon following the Exxon Valdez oil spill: persistence, toxicity, sensitivity, and controversy. 99329, Exxon Valdez Trustee Council.

Rigzone. 2012. Offshore Rig Day Rates. Dice Holdings, Inc.

Robertson, C. and L. Robbins. 2010. Oil Rig Sinks in the Gulf of Mexico. The New York Times, New York.

Sabatès, A., J. M. Gili, and F. Pagès. 1989. Relationship between zooplankton distribution, geographic characteristics and hydrographic patterns off the Catalan coast (Western Mediterranean). Marine Biology **103**:153-159.

Schmitt, R. J. and C. W. Osenberg, editors. 1996. Detecting Ecological Impacts: Concepts and Applications in Coastal Habitats. Academic Press, San Diego.

Secretaria de Energia. 2008. Sistema de Informacion Energetica: Informacion Estadistica. Secretaria de Energia Mexico City, Mexico.

Short, J. W., M. R. Lindeberg, P. M. Harris, J. M. Maselko, J. J. Pella, and S. D. Rice. 2003. Estimate of Oil Persisting on the Beaches of Prince William Sound 12 Years after the Exxon Valdez Oil Spill. Environmental Science & Technology **38**:19-25.

Silliman, B. R., J. van de Koppel, M. W. McCoy, J. Diller, G. N. Kasozi, K. Earl, P. N. Adams, and A. R. Zimmerman. 2012. Degradation and resilience in Louisiana salt marshes after the BP–Deepwater Horizon oil spill. Proceedings of the National Academy of Sciences.

Skytruth. 2011. Over 28,000 Abandoned Wells in the Gulf of Mexico. Skytruth Blog. Skytruth, Florida.

Smith, J. E., editor. 1968. Torrey Canyon pollution and marine life: A report by the Plymouth Laboratory of the Marine Biological Association of the United Kingdom. Marine Biological Association of the United Kingdom, Cambridge, England.

Socolofsky, S. A. and E. E. Adams. 2002. Multi-phase plumes in uniform and stratified crossflow. Journal of Hydraulic Research **40**:661-672.

Socolofsky, S. A., E. E. Adams, and C. R. Sherwood. 2011. Formation dynamics of subsurface hydrocarbon intrusions following the Deepwater Horizon blowout. Geophys. Res. Lett. **38**:L09602.

Southward, A. J. and E. C. Southward. 1978. Recolonization of Rocky Shores in Cornwall after use of toxic dispersants to clean up the *Torrey Canyon* spill. Journal of the Fisheries Research Board of Canada **35**:682-706.

Southward, A. J. and E. C. Southward. 1988. Disappearance of the warm-water hermit crab *Clibanarius erythropus* from south-west Britain. Journal of the Marine Biological Association of the United Kingdom **68**:409-412.

Spooner, M. 1969. Some ecological effects of marine oil pollution. Pages 313-316 *in* Proceedings of the Joint Conference for Preventing and Controlling Oil Spills, New York, New York.

Squire, J. L. J. 1992. Effects of the Santa Barbara, Calif., oil spill on the apparent abundance of Pelagic fishery. Marine Fisheries Review **54**:7.

Staff. 1978. The ecological disaster caused by the stricken Torrey Canyon. Look and Learn.

Staff. 2010. NOAA confirms USF oil plume research. Tampa Bay Business Journal, Tampa Bay Florida.

Straughan, D., editor. 1971a. Biological and Oceanographical Survey of the Santa Barbara Channel Oil Spill 1969-1970: Volume I Bacteria and Bacteriology. Sea Grant, University of Southern California.

Straughan, D. 1971b. What has been the efect of the spill on the ecology in the Santa Barbara Channel? Pages 401-426 *in* D. Straughan, editor. Biological and Oceanographical Survey of the Santa Barbara Channel Oil Spill 1969-1970: Volume I Bacteria and Bacteriology. Sea Grant.

Teal, J. M. and R. W. Howarth. 1984. Oil spill studies: A review of ecological effects. Environmental Management **8**:27-43.

Tunnell, J. W. J. and B. R. Chapman. 1980. Environmental effects of Ixtox I oil spill on south Texas barrier islands.*in* Congreson sobre problemas ambientales de Mexico. Instituto Politecnico Macional, Mexico.

Tunnell, J. W. J., B. R. Chapman, M. E. Kindinger, and Q. R. Dokken. 1982. Environmental Impact of Ixtoc I Oil Spill on South Texas Sandy Beaches: Infauna and Shorebirds. Page 142 *in* International Symposium on Ixtoc-I.

Tunnell, J. W. J., E. A. Chavez, and K. Withers, editors. 2007. Coral Reefs of the Southern Gulf of Mexico. Texas A&M University Press, College Station, TX.

Tunnell, J. W. J. and Q. R. Dokken. 1980. Observations on Ixtoc I oil impact of southwestern Gulf of Mexico coral reefs.*in* Congreson sobre problemas ambientales de Mexico.

Tunnell, J. W. J., Q. R. Dokken, and M. E. Kindinger. 1981. Effects of the Ixtoc I oil spill on the intertidal and subtidal infaunal populations along lower Texas coast barrier island beaches. Pages 467-475 *in* Oil Spill Conference. American Petroleum Institute, Washington, D.C.

Tunnell, J. W. J. and F. W. Judd, editors. 2001. The Laguna Madre of Texas and Tamaulipas. Texas A&M University Press, College Station, Texas.

U.S. Geological Survey. 2000. Seagrasses in Northern Gulf of Mexico: An Ecosystem in Trouble. Factsheet USGS Factsheet FS-017-00, USGS National Wetland Reserach Center, Lafayette, Louisiana.

Upton, H. F. 2011. The Deepwater Horizon Oil Spill and the Gulf of Mexico Fishing Industry. CRS 7-5700 R41640, Congresional Research Service.

Valentine, D. L., J. D. Kessler, M. C. Redmond, S. D. Mendes, M. B. Heintz, C. Farwell, L. Hu, F. S. Kinnaman, S. Yvon-Lewis, M. Du, E. W. Chan, F. G. Tigreros, and C. J. Villanueva. 2010. Propane Respiration Jump-Starts Microbial Response to a Deep Oil Spill. Science **330**:208-211.

Valentine, D. L., I. Mezic, S. Macesic, N. Crnjaric-Zic, S. Ivic, P. J. Hogan, V. A. Fonoberov, and S. Loire. 2012. Dynamic autoinoculation and the microbial ecology of a deep water hydrocarbon irruption. Proc Natl Acad Sci U S A.

van Tamelen, P. G., M. S. Stekoll, and L. Deysher. 1997. Recovery processes of the brown alga *Fucus gardneri* following the 'Exxon Valdez' oil spill: Settlement and recruitment. Marine Ecology Progress Series **160**:265-277.

Vargas, R. A. 2010. 1979's Ixtoc oil well blowout in Gulf of Mexico has startling parallels to current disaster. The Times-Picayune, New Orleans, Louisiana.

Walker, A. H. and D. R. Henne. 1991. The Region III Regional Response Team Technical Symposium on Dispersants: An Interactive, Educational Approach to Enlightened Decision Making.*in* Proceedings of the 1991 International Oil Spill Conference. American Petroleum Institute, San Diego, CA.

Walker, A. H., D. K. Scholz, J. H. Kucklick, and R. G. Pond. 1999. Government and Industry Partnering: Nationwide Progress in Pre-authorization Agreements since 1994.*in* International Oil Spill Conference. American Petroleum Institute, Seattle, Washington.

Wang, M. 2010a. After 3 Weeks, BP Handed Over Samples Requested By Scientists. ProPublica. ProPublica Blog, New York.

Wang, M. 2010b. Top BP Exec Still Says Spill Flow Rate Doesn’t Matter. ProPublica. ProPublica Blog, New York.

Wells, H. W. 1961. The Fauna of Oyster Beds, with Special Reference to the Salinity Factor. Ecological Monographs **31**:239-266.

Wells, P. G., J. N. Butler, and J. S. Hughes, editors. 1995. Exxon Valdez Oil Spill: Fate and Effects in Alaskan Waters. American Society of Testing and Materials, Philadelphia, PA.

Wells, R. J. D. and J. R. Rooker. 2009. Feeding ecology of pelagic fish larvae and juveniles in slope waters of the Gulf of Mexico. Journal of Fish Biology **75**:1719-1732.

West Kern County Oil Museum. 2011. The Lakeview Gusher. Page Exhibit, 1168 Wood Street, Taft, CA.

White, H. K., P.-Y. Hsing, W. Cho, T. M. Shank, E. E. Cordes, A. M. Quattrini, R. K. Nelson, R. Camilli, A. W. J. Demopoulos, C. R. German, J. M. Brooks, H. H. Roberts, W. Shedd, C. M. Reddy, and C. R. Fisher. 2012. Impact of the Deepwater Horizon oil spill on a deep-water coral community in the Gulf of Mexico. Proceedings of the National Academy of Sciences.

Wolfe, D. A., M. J. Hameedi, J. A. Galt, G. Watabayashi, J. Short, C. O'Claire, S. Rice, J. Michel, J. R. Payne, J. Braddock, S. Hanna, and D. Sale. 1994. The Fate of the Oil Spilled from the Exxon Valdez. Environmental Science & Technology **28**:560A-568A.