The Effects of Oil on the Aquatic

On April 20, 2010, an explosion aboard the Deepwater Horizon oil rig, located 43 miles off the southeast coast of Venice, LA, led to a leak that was 5,000 feet below the water surface and took more than three months to fix. During this time, more than 200 million gallons of light, sweet crude oil spilled into the Gulf of Mexico. Over 600 miles of coastline were contaminated and more than 1 million gallons of dispersants were used.

The fishing industry has a strong cultural and economic presence in Louisiana and the Gulf Coast region. The millions of gallons of oil that entered the Gulf as a result of this spill challenge the future existence of the industry. When a foreign substance enters an environment, it is inevitable that there will be effects throughout the ecosystem. The concern surrounding the Deepwater Horizon spill is the amount of oil that was released. How will the biggest oil spill in history affect the underwater species and can it make its way up the food chain to threaten human health?

**Background on the Effects of Oil on Aquatic Species**

Fish are exposed to oil in the water column via their gills and take up the toxins through their mouths as food. Though this has little impact on the ecosystem as a whole, studies have uncovered a physiological change in fish that has become integral in studying the effects of oil in the ecosystem. Fish in oil-polluted water have shown an increase in an enzyme called Cytochrome P4501A (CYP1A), which is found in the liver for the purpose of detoxifying blood. Humans have a similar enzyme that is present when they ingest known drugs and pollutants. The concentration of the enzyme increases with increasing oil pollution, and in turn, decreases as pollutant levels decrease, leaving the adult fish unharmed. This makes it an ideal tool in measuring the persistence of oil components in water.¹

The discovery of the CYP1A enzyme has also led to the understanding of how oil is harmful. Oil, which is made up of hydrogen and carbon chains, becomes weathered and evaporates leaving the toxic rings called polycyclic aromatic hydrocarbons (PAHs) that enter the water column. These compounds are toxic to humans and have been found to cause infertility in lab studies with mice.

After the Exxon Valdez oil spill in 1989, elevated concentrations of PAHs caused a decrease in the hatch rate of salmon eggs, by causing distress to the eggs in their sensitive developmental stages. This scenario also showed that the PAH-exposed...
Ecosystem and Food Chain as a Whole

eggs that did develop fully to adulthood were slower and had a reduced chance of survival (when compared to eggs that were not exposed to oil pollution).

The reproductive dysfunction caused by the increased PAH levels could have effects on an ecosystem, but adult fish remain unharmed due to their ability to metabolize the toxin. This eliminated the possibility of causing health concerns to organisms high on the food chain, including humans.²

Bivalves are less complex organisms that do not have the ability to metabolize PAHs in the environment or to move from a contaminated area. All bivalves, including oysters, take up the PAHs that are in the water column. Their bodies cannot process the compounds, so the harmful pollutants accumulate in their tissues. PAHs are made up of anywhere between two and six benzene rings linked together. Smaller, lower molecular weight PAHs with fewer rings are more soluble; they are taken up by organisms in the water column readily, but are relatively harmless. The larger molecular weight PAHs with four or more rings are fat-soluble.³

When ingested by the bivalves, the molecules are stored in the tissue because they are hydrophobic and lipid-soluble. This is dangerous for oysters, which burrow, because they are in direct contact with the PAHs trapped in the sediment.

The PAHs build up in the oysters’ tissue and remain toxic as the oyster continues to function normally. This occurred to oysters found at Prince William Sound, Alaska. It took more than a decade to uncover the link between the accumulation of PAHs in oysters to the increase in mortality rates of the otters that fed there. Scientists assumed the initial decrease in sea otter populations were related to the oil spill itself. But, decades later, the mortality rate continued to increase and the new offspring, otters that had never exposed to the oil, were not surviving. A little over one hundred miles from this site is Montague Island, an area that did not get polluted with oil and, in turn, was not having the same problems with the otter populations. It was concluded by comparing the levels of CYP1A enzyme that Prince William Sound otters were still being exposed to high levels of PAHs, decades later, with little to no visible oil left. Research showed that the PAHs accumulated in oysters were poisoning the otters that fed on them.

Impact on the Gulf Coast Oyster Fisheries

Louisiana is a national leader in oyster production; testing the safety of the oysters is a necessity. Initially, NOAA set up a five-mile buffer zone around the oil slick in Mississippi and Louisiana to protect the seafood from the spreading oil. By May 6, 2010, officials had tested 6,930 finfish, shrimp, and oysters in the laboratory, with all organisms testing negative for high levels of hydrocarbons. NOAA maps tracking the location of the spill movement are shown in Figure 1.
Nearshore Surface Oil Forecast
Deepwater Horizon MC252

NOAA/NOS/OR&R
Nearshore

Estimate for: 1200 CDT, Sunday, 7/04/10
Date Prepared: 2100 CDT, Thursday, 7/01/10

This forecast is based on the NWS spot forecast from Thursday, July 1 PM. Currents were obtained from several models (NOAA Gulf of Mexico, West Florida Shelf/USF, TGLO/TAMU, NAVO/NRL) and HFR measurements. The model was initialized from Wednesday-Thursday satellite imagery analysis (NOAA/NESDIS). The leading edge may contain tarballs that are not readily observable from the imagery (hence not included in the model initialization). Oil near bay inlets could be brought into that bay by local tidal currents.

Mississippi Canyon 252 Incident Location

Forecast location for oil on 4-July-10 at 1200 CDT

The offshore forecast has been temporarily stopped due to small amounts of oil offshore, the absence of recent observations confirming significant amounts of oil in offshore areas, and the large separation between the loop current complex and the oil slick. Forecasts will resume if the threat returns.

Winds are forecast to continue to have an onshore component (predominantly SE) through next week, with speeds from 5 to 15 kts. These onshore winds will continue to move the northern edge of the slick northwest threatening the barrier islands of Mississippi/Alabama and the Florida Panhandle west of Freeport, FL. The Chandeleur Islands, Breton Sound and the Mississippi Delta also continue to be threatened by shoreline contacts. To the west of the Delta, these winds may bring oil ashore between Barataria Bay and Caillou Bay – any remaining floating oil may be moved quickly to the west due to the development of a strong westward coastal current in this region.

Next Forecast: July 2nd PM

Figure 1. NOAA tracked the approximate location of the oil movement. This map shows that many of the oyster beds on the Louisiana coast would be affected by the oil spill. Source: NOAA.
NOAA is no stranger to testing bivalve quality. The organization started the Mussel Watch Program in 1986 with the purpose of monitoring the quality of the water by testing bivalves that grow all over the coast of the United States. In the Gulf Coast region, including the Louisiana coast, the Eastern Oyster (*Crassostrea virginica*) is monitored. NOAA tests for 104 different compounds, including trace metals and organic contaminants such as PAHs. In the report with the data from 1986 to 2005, the Gulf Coast had some of the “cleanest” oysters. Tests taken just after the spill did not show elevated PAH levels, but government organizations are taking precautions to ensure the oysters continue to be safe.4

The Gulf Coast oyster season was scheduled to open on November 15, 2010, but remained closed for public oyster seed ground east of the Mississippi. This decision was made in order to rebuild the natural resources for future use. Researchers from Louisiana State University and Auburn University came up with a way to grow oysters suspended in the water column instead of on the reefs on the water bottom. Although this project was developed before the Deepwater Horizon spill, it gives hope to the future of producing healthy oysters.5

The U.S. Food and Drug Administration (FDA) is actively testing and observing the seafood and closing harvest waters that could have been exposed to oil to ensure there is no possibility of eating contaminated oysters.

The Louisiana Department of Wildlife and Fisheries (LDWF) is in charge of monitoring the size and health of the oysters on an area of 1.7 million acres of public water bottoms. Throughout the public oyster farms Louisiana has coastal study areas to get an estimate of the amount of oysters produced and health of the sites. Annually, researchers go to each of the areas and count the number of oyster seeds and adult oysters that are present and assess the spat production. In 2010, samples were taken between June and July, after the *Deepwater Horizon* spill.6 Findings are displayed in Table 1.

Today, attempts to clean up the shoreline are still occurring, and have been successful in removing much of the oil along the Gulf Coast. Mechanical and manual techniques were being used to clean the beaches. Attempts were made to sift, till, recover, and relocate the sand that was contaminated with oil, and teams walked along the beach looking for any sign of oil mats. Much oil was recovered, but as of March 2011, there is still oil that persists in the sand. This oil is located in the sediment and has been categorized as Supratidal Buried Oil (SBO), Small Surface Residual Balls (SSRB), or Surf Zone Submerged Oil Mats (SOM). Because of their locations these oil types are particularly

<table>
<thead>
<tr>
<th>CSA</th>
<th>Location</th>
<th>Area of Water Bottom (acres)</th>
<th>Farms</th>
<th>Oyster Seeds (Barrels)</th>
<th>Oiled</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSA I</td>
<td>MS Sound, Lake Borgne, Chandeleu Sound</td>
<td>690,000</td>
<td>Lake Borgne</td>
<td>120,199</td>
<td>Oiled, due to Hurricane Alex</td>
</tr>
<tr>
<td>CSA II</td>
<td>South of MRGO</td>
<td>300,000</td>
<td>Lake Fortuna, Machias, Bay Long, Bay Gardene</td>
<td>105,836</td>
<td>Oiled, numerous oil sheens</td>
</tr>
<tr>
<td>CSA III</td>
<td>Barataria Bay Estuary</td>
<td>8,000</td>
<td>Hackberry, Barriatria Bay, Little Lake Public</td>
<td>5,019</td>
<td>Heavily oiled</td>
</tr>
<tr>
<td>CSA IV</td>
<td>Terrebone and Lafourche Parishes</td>
<td>~77</td>
<td>Lake Tambour, Lake Chein, Lake Felicity, Deep Lake</td>
<td>2,021.3</td>
<td>No oil data</td>
</tr>
<tr>
<td>CSA V</td>
<td>Southwest Terrebonne Parish(Seed reservation)</td>
<td>12,331</td>
<td>Sister Lake, Lake Junop, Lake Merchant</td>
<td>154,340</td>
<td>Unofficial oil sightings in Sister Lake</td>
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<tr>
<td>CSA VI</td>
<td>Vermillion, east and West Cote Blanche</td>
<td>541,787</td>
<td>Atchafalaya public oyster seed ground</td>
<td>~0</td>
<td>Oiled, closures due to oiling May 8</td>
</tr>
<tr>
<td>CSA VII</td>
<td>Cakcasieu and Mermentau river Basins</td>
<td>58,260</td>
<td>Area 29, Area 30</td>
<td>307,264</td>
<td>No oil data</td>
</tr>
</tbody>
</table>

Table 1. Summary of all the coastal study areas (CSAs) of the Louisiana Department of Wildlife and Fisheries, including number of larval oysters and oil data.
It is certain that the coast of Louisiana will feel the environmental effects for years to come.

As researchers continue to find ways to clean the oil from the sediment, protecting human health becomes the foremost concern. All seafood is thoroughly tested for PAH contamination by multiple government groups and private facilities. FDA and NOAA are particularly committed to making sure oysters and seafood remain safe to eat and are developing new technology to make testing more feasible. One technology that is promising is using a liquid chromatography that is detected by fluorescence spectroscopy. PAHs can be detected at very low concentrations using these methods to get more accurate data as to contamination in seafood. This new fluorescence spectroscopy technique is quicker than methods that are currently being used; innovations such as this are important in getting accurate data to protect human health. The government recognizes that testing food quality will continue to be paramount in dealing with the after effects of this oil spill, with BP promising $48 million to Louisiana’s seafood and tourism industry specifically allotted to seafood quality testing.

**Summary/Outlook**

Fisheries in Louisiana are of major cultural and economic importance. Although it would be impossible to predict the specific effects this oil spill will have on the Gulf Coast, we have models of how oil spills in the past have shaped the ecology of the area. We know the aquatic ecosystem is very dynamic and can acclimate itself well to environmental changes, but the uncertainty comes from the amount of oil that entered the water. An oil spill this large is unprecedented, and coupled with the unusually large amount of chemical dispersants added, will be sure to have long-lasting effects. The harmful PAHs that enter the environment have to go somewhere, now we see what cannot be broken down by microbes are taken up by fish, bivalves, algae, and other organisms in the ecosystem. The problem lies in the fact that those PAH compounds are still hazardous to human health. They can be stored in the tissues of bivalves and work their way up the food chain. This is particularly significant in Louisiana, which over the past decade accounted for an average of 24% of the nation’s total oyster landings.

With a spill of this magnitude it is impossible to predict exactly what the future holds, but it is certain that the coast of Louisiana will feel the environmental effects for years to come.

Fixing what was caused by the spilled oil is a long and expensive process, but the best way to protect human health is to continue to test the PAH concentrations. Current tests that show PAH levels are not necessarily indicative of oyster contamination in the future. These tests were run on adult oysters that did not grow in the PAH infected waters, and oysters in their larval stage that are most sensitive when exposed to the contamination. This is partly due to the fact that larval oysters are exposed to the PAHs in the water column, as well as the phytoplankton food source that can accumulate smaller, water soluble PAHs.

Louisiana’s choice not to open oyster season was a tough economic call, but a good one with respect to public health. The state’s fear is for the long-term future of the industry and farming now will jeopardize the forthcoming production. Waiting one year might not make much of a difference in oyster contamination, unless the oil can be removed from the sediment, which is very persistent. In smaller spills, the oil is metabolized by organisms in the water column, but very few microbes have the ability to do this in the anaerobic sediment. Once the sediment reaches the beaches or seafloor, it persists for decades. The oil in the sediment challenges the industry even more with respect to oyster harvesting practices. Currently, oysters are dredged using chain nets that scrape the seafloor with the oyster beds. This re-suspends the sediment and any pollutants that maybe there. This never-ending cycle proves bleak for the oyster industry as it operates now.

The best line of defense in protecting the environment would be to prevent disasters such as this, to take a proactive approach in assuring that oil...
practices are done safely and respectfully. Technological advances to clean the oil that is in the sediment are a necessity in removing it from the environment for good. Until then, scientists and engineers should approach this situation with caution and accept the situation for what it is.

The underwater ecosystem is forever changed from what it used to be, and, as this dynamic system change, what we once accepted to be fact will change as well. Events manipulate the development of large-scale ecosystems and populations will evolve to these environmental changes; scientists and researchers should do the same. Researchers should be open minded about what is happening, and while these underwater populations fight to find an equilibrium, we as humans need to alter our behavior to protect our health. Eventually, the ecosystems will become stable again, but until then we need to continue to proceed cautiously.

References