The Impact of the Deepwater Horizon Oil Spill on Louisiana's Coastal Wetlands

by Jeff Lange

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Wetlands are some of the most dynamic, valuable, and sensitive ecosystems on the planet; and Louisiana's coastal marshes are no exception. While Louisiana currently has approximately 3 million acres of wetlands, this area has been shrinking continually over the past century, losing 734,000 acres of coastal wetlands between 1956 and 2004 alone.[1]

Birds are some of the most visible casualties of an oil spill due to their susceptibility to the physical interference of oil.

This is largely due to human impact, but natural events have played a role as well. Sea-level rise, subsidence, sediment deprivation, saltwater intrusion, herbivory, the dredging of oil and gas canals, navigation canals, and shoreline erosion have all contributed to the loss of coastal wetlands in Louisiana. While it is commonly accepted that all of these factors have an impact on wetland health, it is difficult to determine each factor's individual impact, due to the interconnected nature of each of these considerations, and the relatively long timeline over which wetland losses are measured.

Characteristics of Southern Louisiana Crude

The oil contaminating the Gulf is a sweet crude oil, classified as MS252. This oil is relatively easily degraded by micro-organisms, and is less toxic than most crude oils, due to the low concentrations of polyaromatic hydrocarbons (PAHs). MS252 contains average levels of volatile organic compounds (VOCs), but these are of little concern to coastal environments in the case of the *Deepwater Horizon* spill, as VOCs evaporate quickly, and only exist in significant quantities in recently spilled oil.

With concern to the marshes, the most harm will be a result of the physical properties of the oil. MS252 will eventually mix with water to form a water-in-oil emulsion. The emulsified oil has a sticky consistency, and is aptly called "mousse." Wind and tidal forces hasten the transformation of crude into mousse, as does the passage of the oil from the sea floor to the surface, a 5,000-foot journey. Emulsion reduces biodegradability and makes the crude oil more dangerous physically.

Wind and tides will continue to weather the mousse, breaking it into smaller and smaller pieces, until the mousse eventually forms tarballs, which are small, hard black pellets very resistant to further degradation. Tarballs may soften in the sun, collect sediment and sink, or travel great distances before settling. Tarballs still contain PAHs, and may cause harm to birds and animals that ingest them.[2]

Economic Impacts

The economic impact of coastal marshes contamination has the potential to be very significant. Marshes play a major role in Louisiana's economy. Attention to coastal wetlands has increased significantly since hurricane Katrina, but they are still in dire shape. These marshes are important because they help to diminish the strength of a hurricane before it reaches more populous areas. The value of coastal wetlands is immeasurable in this capacity, both in the sense that it prevents vast amounts of damage, and in the sense that it's impossible to calculate the value that the wetlands provide with concern to coastal protection with a high degree of accuracy.

Louisiana is known for its picturesque marshes, which are part of the reason Louisiana is known as "The Sportsman's Paradise." Marshes are the ecological foundation of Louisiana's economy and culture. Many residents utilize the marshes for recreational purposes. Damaged marshes will result in decreased revenue to the state through loss of licensure and permit fees. Tourism revenue will also be diminished as the marshes degrade and disappear. As marshes lose their beauty and recreational value, property values will drop as well, if any land remains at all.

The petroleum and seafood industries are both fundamental parts of Louisiana's economy. The marshes are home to shrimp, oyster, crab, and fish nurseries. Contamination of these nurseries has the potential to decimate the industry. Even if the nurseries are unharmed by the oil, perception may keep consumers from purchasing seafood. Louisiana, and New Orleans in particular, is known for its seafood restaurants. Any harm done to the seafood industry will echo through the restaurant and tourism industries as well.

Biological Impacts

Flora

Algae. Counter-intuitively, algae populations often increase after a wetland is contaminated by petroleum. Algal growth can be attributed to the addition of nitrogen to the system, although the oil itself is not the source of the nutrient. The presence of oil encourages aerobic, nitrogen-fixing bacteria. The increase of nitrogen, in turn, creates an environment capable of forming large crops of algae in an area that was previously nitrogen-limited.[3] Nutrients are also often added to an ecosystem following oil contamination in an effort to hasten biodegradation. This too may promote elevated algal growth.

Algae are an important part of the ecosystem, providing sustenance for a variety of species. However, artificially elevated populations of algae, as often occur in the case of petroleum contamination, can be detrimental to a system. The abundance of algae increases the amount of suspended solids in the water, blocking sunlight and killing other plants. As the algal growth begins to subside, oxygen levels in the water will drop, potentially causing mass fish kills.

Macrophytes. Marcophytes, or aquatic plant-life larger than algae, are the backbone of shallow-water ecosystems. The recovery of coastal wetlands depends most heavily on the recovery of the system's plant-life. Susceptibility to oil contamination varies from species to species. Floating vascular plants tend to be the most susceptible. Perennial plants, on the other hand, may be negligibly or minimally affected by the contamination, depending on the season. The variance in susceptibility from species to species leads to decreased biodiversity, with the more resilient plants emerging as the dominant species post-recovery.

The detrimental effects to Macrophytes may be physical or chemical. Much of the damage to plant-life is due to oil blocking sunlight and inhibiting photosynthesis. The extent of physical damage depends largely on the physical properties of the oil, namely density and viscosity.

Biophysically, cell membranes may be damaged by hydrocarbon molecules that have penetrated the cell wall, which leads to the leakage of cell contents.[3] The toxic components of the oil can also have detrimental biochemical effects, namely the inhibition of a plant's enzyme reactions due to polyaromatic hydrocarbons. The toxic effects of oil depend largely on the solubility of the oil's toxic components, and its physical properties related to tissue penetration, such as surface tension and viscosity.

Macrophytes also experience sublethal effects, such as growth inhibition. Studies show that reduction of biomass post contamination can be unpredictable, and varies species to species.[3]

Floating Vascular Plants. Floating vascular plants are among the flora most sensitive to oil's toxic components, as they are immersed in the contaminated water. Because of this, the effect on floating vascular flora is largely dependent on the residence time of the oil in the water. There have been cases where high survival rates have been recorded in areas of heavy spillage with swiftly running water. In contrast, there have also been studies showing the complete death of floating vascular species in contaminated areas with standing water.[3] The flow of water through Louisiana wetlands varies, although lack of flow is a noted problem in many areas for reasons unrelated to oil contamination.

Marsh Grass. Grass is extremely important to marsh systems, as it is the organism most instrumental in creating marshes. Grass begins to grow on tidal flats that form at the high-tide line. The grasses provide increased stability to the flats, and accelerate the rate of sedimentation due to the baffling effect they create. Marsh grass also is the primary source of shelter in marshes (aside from the water).

Marsh grasses are relatively hardy in relation to other wetland flora. They cannot survive a complete coating of oil, but will usually be able to persevere if partially coated. There have even been studies showing an increase in grass crop.[4] This is likely the result of the grass becoming the dominant species after other flora are weakened or die off due to contamination. Furthermore, grasses may even return intact if they are cut or burned as a remediation effort, as long as their roots are unharmed.

Fauna

Microorganisms. Populations of individual species of microorganisms are not of large concern, as populations may fluctuate within a relatively small timeframe as a function of the marsh's current conditions. In fact, some microorganisms thrive in petroleum-contaminated conditions, and are actively cultivated in order to aid in the degradation process. The role of microorganisms in remediation will be discussed in further detail in the remediation section.

Invertebrates. Invertebrates are a key part of the food chain. Any impact on this class of organism will have great implications for the rest of the ecosystem. More toxic refined oils may be lethal to invertebrate populations, but the concentration of toxic components found in crude oil is generally not high enough to kill off most species of invertebrates. However, the less toxic crude oil will still have a number of nonlethal impacts.

The metabolisms of invertebrates often slow down after exposure to oil; studies have found cases of decreased respiration and reduced ingestion or food assimilation.[3] Ironically, exposure to oil has been known to slow the metabolism of invertebrates, often leading to increased lifespan.

It has been suggested that there is a link between slowed metabolism and the reduced reproductive effectiveness of exposed invertebrates. Growth rates of invertebrates slow due to a decreased number of broods, higher abortion rates, defective offspring, and impaired moulting.[3] So, while the individual organism may live longer, exposure to contaminants is still detrimental as a whole.

Fish. Fish are among the most sensitive vertebrate species concerning oil exposure. This is logical, as fish are continually immersed in water, and if that water is contaminated, they are constantly absorbing the toxic chemicals that have dissolved in the water.

Fish are subject to many sublethal effects as well. Numerous studies have documented the damage to fish gills when exposed to crude oil.[3] Damage to eye lenses and to the digestive organs has also been documented, as well as loss of muscular and tactile control.

As with many other types of organisms, developmental and reproductive functions are often impaired when exposed to oil. The hatchability rate of eggs may decrease, or the hatching process may be lengthened. Developmental abnormalities are also observed, such as lack of body pigment, insufficient yolk sacs, kyphosis, eye defects, and reduced growth rates.[3]

There is also some concern that the presence of oil may exacerbate the existing problem of hypoxia, leading to massive fish kills. A layer of oil between the water surface and the air may decrease the natural dissolution of oxygen, and bacteria feeding on the oil may further reduce dissolved oxygen levels.[5] Furthermore, algal growth—the root of the problem—is often found to increase after an oil spill.

Amphibians. Amphibians and fish have similar susceptibilities to oil contamination, as they both absorb water and the toxins it contains. Not all amphibians spend their entire lifetime in the water, but they all spend at least a portion of their day submerged. Comparatively few studies have been performed on amphibians due to low commercial impact, but amphibians exhibit many of the same symptoms as fish. The rate of reproduction falls, and the quality of offspring usually declines. Cases

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of decreased visual function or blindness have been observed as well.[3]

Birds. Birds are some of the most visible casualties of an oil spill due to their susceptibility to the physical interference of oil. Feathers lose their insulative properties when coated with oil, which may lead to hypothermia. Additionally, birds with coated feathers also lose their ability to fly, which may interfere with their ability to obtain food, evade predators, or migrate.

While the physical effects of oil are more damaging to birds than the toxic effects, this does not suggest that there are no toxic effects. Birds may accidentally ingest oil, limiting the intestine's ability to absorb water, causing birds to die of dehydration.[3] Ingestion of oil can also lead to infertility or decreased hatch rates. Birds may ingest harmful components of oil either directly or through eating other exposed animals. As animals higher on the food chain, birds are particularly susceptible to bioaccumulation and biomagnifications. Egg exposure to oil can decrease hatch rates and increase the occurrence of birth defects as well.[3]

Mammals. Like birds, mammals are harmed mostly by the physical interference of oil. Oil increases the thermal conductance of fur, often leading to hypothermia. In this way, mammals that rely on their fur the most for warmth are the most susceptible. This is not to say that the toxins found in oil have no effect on mammals, but the large majority of harm is due to physical effects.

Recommendations

Many consider the costs of spill response too great to take action for the sake of biological impact reduction alone. Oil is, after all, a natural product; decaying organic matter subject to anaerobic conditions. Oil frequently occurs naturally in aquatic environments, albeit in small quantities. Furthermore, the concentration of hydrocarbons continually released into waterways by chronic, land-based sources is not largely dissimilar to the concentrations found at the sites of oil spills.[6] Some maintain that the detrimental impact of a spill occurs over a relatively short time, as little as 1–3 years,[4] and that the most affected populations are those at the extremes of their range of acceptable habitats.[3]

Of course, a comparison of hydrocarbons discounts the physical impacts of an oil spill. The physical impacts, more so than the chemical, are the reason cleanup efforts are conducted. It is the emotional and economic impacts of the spill that make people take action. A bird, coated in oil, thrashing about and unable to fly is a very visually stirring image. Birds are a fundamental part of the ecosystem, but they get a disproportionate amount of attention. Few pay much thought to the invertebrates dying unseen in the sediment, even if their demise will later harm birds and other larger animals higher up in the food chain.

It is the damage to industry that is the real motivator: the reduction of amenity value to beaches and preserves, the further degradation of a coastal protection buffer. Biological impact concerns people largely because of its economic ramifications, namely the fear of food contamination and the implementation of fishing bans. These are the primary concerns, and if none are at risk, then the de facto plan is to do nothing.

This is not to say, however, that the advantages of a do nothing plan are merely economic. Many times, the impact of cleanup efforts may be more damaging than the oil itself. Marshes are particularly sensitive to human impacts, and particularly resilient to oil contamination. A healthy marsh can typically recover within a few years.

Unfortunately, Louisiana's coastal wetlands were in poor shape before contamination, and will not recover to the fullest possible extent unaided. Skimmers and booms work best in open water, and usually cannot be used in marsh areas. However, many of the damaged coastal marshes have open water areas due to salt water intrusion or other factors. Booms and skimmers should be used in these areas, while taking care not to harm vegetated areas.

In the vegetation portion of the marsh, it is important to conduct all cleanup efforts from inside a boat; walking on the marsh will offset any benefit provided by remediation efforts. Contaminated debris or dead organic material should be removed, as long as it is not part of a nesting area. Sorbent material is placed on the shoreline, soaking up nearby oil and acting as a barrier between the vegetation and the oil.

Cutting or burning marsh grasses is often recommended, with the intent of decreasing wildlife exposure to soiled vegetation. In this instance, cutting or burning of marsh grass should be avoided. The marsh was already retreating prior to contamination, and special care must be paid to not further contribute to the erosion of the wetlands. In most of Louisiana's coastal marshes, the additional benefit to wildlife by cutting or burning is not worth the risk of further erosion.

A low-pressure, warm water wash is often used to remove oil from vegetation. This may or may not be an effective remediation technique for this spill. The emulsified oil found in the marshes is relatively viscous, reducing the effectiveness of this technique. A higher pressure wash may be used to consolidate slicks in areas too confined for boom use. A skimmer or vacuum is used to collect the concentrated slick.

After all other appropriate remediation measures have been exhausted, a favorable environment for biodegradation should be cultivated. As mentioned earlier, there are likely already hydrocarbon-degrading microorganisms present in the marshes naturally. Their populations will now grow, but may still be limited by nutrient availability. If native microorganisms are not sufficient, foreign microorganism populations may be added to aid the biodegradation process as well.

Special care must be paid to the amounts of nutrients added. Nutrient addition can help speed the rate of microbial degradation, and aid the growth of plants stressed by contaminants, but it must be carefully measured. If overly large amounts of nutrients are added, algal blooms may form, inducing hypoxia and massive fish kills.

While animals higher on the food chain tend to get the most attention, it must be logic, not emotion, which guides remediation efforts. The highest priority must be given to those lowest on the food chain—the foundation of the ecosystem, not the apex. Of course, in a more literal sense, the plants that give form to the marshes are the true foundation. The marshes are not only in danger of dying out, but also of drifting away into oblivion. And oblivion for the marshes, means oblivion for coastal Louisiana.

Educational Benefit

To determine the impact of oil intrusion into wetlands, one must look at the problem from multiple perspectives. Politics, biology, economics, sociology, and environmental science all come into play. As an engineer, this study helped me recognize the nature of the problem in a more holistic way. Often, engineers get so focused on the details, they fail to see the "big picture," but the interplay between the different disciplines is fundamentally important, especially in large-scale disasters such as the *Deepwater Horizon* oil spill. As engineers, we must increasingly broaden our awareness beyond what is traditionally considered to be within the realm of engineering in order to provide the optimal solution. **em**

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