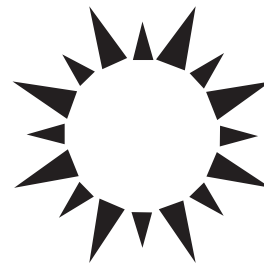


# Wetlands: Impacts of Energy Development in the Mississippi Delta



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## Glossary

**accretion** The upward growth of a sedimentary deposit due to settling of suspended sediments or *in situ* organic soil formation (due to root growth).

**benthos** Aquatic bottom-dwelling organisms; benthic is the adjective form (e.g., benthic animals).

**bioremediation** The addition of materials to a contaminated environment to cause an acceleration of the natural biodegradation processes.

**estuary** Any semi-enclosed coastal body of water that has a connection with the open sea and within which fresh water and salt water mix.

**impoundment** An enclosed wetland that is hydrologically isolated, either completely or partially, from the surrounding ecosystem; impoundment can be due to a combination of natural (e.g., beach ridge, natural levee ridge) and anthropogenic (e.g., road embankment, spoil bank) features.

**levee** A linear dike or embankment built along the bank of a channel, often to prevent inundation of lowlands by flooding.

**primary production** Total amount of organic matter newly formed during photosynthesis.

**produced water** By-product of the oil production process that is brought to the surface along with petroleum; produced water often contains high levels of salt, heavy metals, and hydrocarbons.

**relative sea level rise** A rise in sea level relative to that of the land due to a combination of eustatic sea

level rise (i.e., worldwide sea level rise due to global warming) and sinking of the land as a result of subsidence.

**subsidence** Sinking or settling of the land surface due to natural (compaction and consolidation of sediments) or artificial causes.

The Mississippi Delta encompasses the largest area of coastal wetlands in the United States and supports one of the most extensive developments of petroleum extraction of any coastal area in the world. This area has experienced ecological impacts from energy development related human activities since the early 1900s. The Louisiana coastal zone encompasses approximately 3.8 million ha (9.5 million acres). The zone includes water bodies, marsh (fresh, intermediate, brackish, and salt), forested wetlands, submerged aquatic vegetation, mudflats, beaches, and upland habitats on natural levees with forests, agriculture, and urban development. Marshes make up approximately 63% of the land area in the coastal zone, and coastal Louisiana contains approximately 60% of the estuaries and marshes in the Gulf of Mexico. Coastal wetlands are vital for protecting developed areas from storm surges, providing wildlife and fish habitat, and improving water quality. The coastal zone has experienced multiple ecological impacts due to human activities, including leveeing of the Mississippi River, large-scale wetland reclamation, water quality deterioration, pollution, and widespread disruption of hydrology. Oil and gas development has contributed significantly to these impacts.



TABLE 1

*Multiple Impacts of Energy Development inside Wetlands*

Stage	Short-term impacts	Long-term impacts
Exploration	Changes in marsh surface elevation Breaks in natural hydrological barriers Noise and commotion during exploration  Immediate loss of marsh vegetation Destruction of biota Changed habitat New migration pattern of aquatic organisms inside marsh	Changes in surface hydrology and drainage Saltwater intrusion Changes in plant growth, organic matter accumulation, and sediment distribution
Access to site	Direct conversion to open water Direct conversion to spoil bank habitat  Return of nutrients and toxins to marsh Noise and commotion during construction Immediate loss of marsh/shallow water habitat Changes in soil/water chemistry Destruction of biota Potential for interrupting fish spawning and feeding Potential negative impact on plant growth  Potential for disturbing avifauna nesting by noise	Increased wave action Changed water circulation and turnover; stagnant water Dredged canal deeper than natural channel Intercepted freshwater flow Saltwater intrusion Increased drainage of marsh Changes in surface hydrology and drainage Changes in sediment distribution Changes in interaction of surface/subsurface hydrology and sediment distribution
Drilling	Reduction in water quality Return of nutrients and toxins to surroundings Inhibition of rainfall penetration Noise and commotion during construction Increase in suspended solids Changes in soil/water chemistry Changes in plant growth Destruction of biota Potential for interrupting fish spawning and feeding Potential for disturbing avifauna nesting by noise	Alteration of surface hydrology and drainage Changes in subsurface hydrology and drainage Changes in sediment distribution Saltwater intrusion  Increased sediment release from discharges Anoxia Loss of marsh habitat Altered soil/water chemistry Possible negative influence on aquatic/benthic organisms Changes in mineral accretion and soil nutrition
Production	Noise and commotion during construction Flowlines in the marsh Pit construction; toxins to surroundings Changes in marsh elevation Reduction in water quality Saltwater disposal Oil spills Destruction of biota Potential for interrupting fish spawning and feeding Potential for disturbing avifauna nesting by noise	Noise of processing facilities Changes in surface hydrology and drainage Changes in subsurface hydrology and drainage Saltwater intrusion More saltwater species Anoxia Increased localized subsidence Loss of marsh habitat Altered soil/water chemistry Possible negative influence on aquatic/benthic organisms
Pipeline building	Direct conversion to open water Increased turbidity Loss of forested wetlands Noise and commotion during construction Increased susceptibility to storm damage	Changes in surface hydrology Bank erosion Compacted marsh surface Direct habitat conversion Indirect wetland loss

*continues*

Table 1 continued

Stage	Short-term impacts	Long-term impacts
Spill control	Formation of open water ponds	Changes in forest succession
	Disruption of natural surface drainage	Changes in plant species, composition, diversity, and percentage cover
	Release of nutrients and toxins	Shoreline bank stability
	Soil oxidation	
	Changes in plant species, composition, diversity, and percentage cover	
	Nesting disturbance	
	Changed habitat	
	Disturbance of fish spawning and feeding	
	Impacts on plant growth	
	Destruction/Disturbance of benthos	
	Interruption of tidal cycle	Loss of marsh habitat
	Direct conversion of marsh to open water	Injury to birds and wildlife
	Trampling of vegetation	
Immediate loss of marsh habitat		
Temporary interruption of aquatic organism migration and flux of matter		
Injury to birds and wildlife		
Disruption of avifauna nesting		
Cleanup	Potential disruption of substrate	Loss of marsh habitat
	Removal of vegetation	Injury to birds and wildlife
	Immediate loss of marsh habitat	
	Decrease in biological production	
	Destruction of vegetation and benthic organisms	
	Potential negative impact on plant growth	
Potential injury to wildlife		

produced inside the coastal zone and from the Outer Continental Shelf (OCS) disrupt natural hydrology. Fifth, spilled oils have an impact on wetland habitats. Sixth, spilled oil and produced water stress estuarine consumers by increasing turbidity, increasing salinity stress, introducing toxins, and so on. Finally, wetland loss decreases the value of the coastal zone as a nursery ground for estuarine consumers and the economic value to the human economy (Fig. 2).

This article reviews the multiple ecological impacts of oil- and gas-related impacts and synthesizes existing information to help researchers and managers understand how oil and gas development affects coastal wetland ecosystems in Louisiana, focusing on (1) plant physiology, (2) estuarine consumers (including the benthic community), and (3) hydrological disturbance and wetland loss.

## 2. IMPACTS ON PLANT PHYSIOLOGY

### 2.1 Impacts of Oil Spills

Wetland plants are subject to stresses from oil spilled during production and transportation (using tankers, pipelines, and tank trucks). Oil spills can have significant short- and long-term impacts on coastal ecosystems due to oil's physical effects and chemical toxicity, leading to decreased primary production, plant dieback, wildlife mortality, and marsh erosion. The mechanisms of these impacts are through (1) disruption of plant-water relationships, (2) direct impacts on plant metabolism, (3) toxicity to living cells, and (4) reduced oxygen exchange between the atmosphere and the soil. If leaves are coated with spilled oil, leaf stomata are blocked, oxygen diffusion to the roots decreases, and root oxygen stress



## 2.2 *In Situ* Burning

As a way in which to control oil spill impacts while minimizing physical damage to impacted wetlands, controlled *in situ* burning has been tested and used as an option to remove oil and gas condensate in contaminated wetlands. When water depth is sufficient (e.g., 10 cm) in damaged wetlands, *in situ* burning can be an efficient option because water on the surface will allow a successful burn of the above-ground vegetative component while absorbing heat produced by the fire and preventing root burning. However, flooding following *in situ* burning adversely affects plant growth in many species because the immediate reduction of plant cover decreases oxygen transportation to below-ground tissues. Full recovery of marsh vegetation from *in situ* burning reportedly takes 1 to 3 growing seasons. *In situ* burning generates atmospheric pollutants whose chemical components are a variety of gaseous sulfur (e.g., carbonyl sulfide, carbon disulfide) and carbon compounds (e.g., methane, carbon dioxide) and reduced alkylated naphthalene compounds from postburn oil.

## 2.3 Chemical Methods

Dispersants wash oil from surfaces such as rocks and vegetation. However, high doses (e.g., 0.3 L/m<sup>2</sup>) reduce total and above-ground biomass significantly, at least for a short time. Another problem in dispersant application is that it is not practicable for use in coastal wetlands because there is little water to dilute the dispersed oil inside wetlands. Application of cleansers (e.g., COREXIT 9580), another chemical method, does not disperse oil but rather allows oil to be washed from surfaces, such as soils and plants, and to be collected in adjacent open water areas by boats. Plants improve their survival, regeneration, and above-ground biomass growth because the application leads to a recovery of stomatal conductance, photosynthesis, and respiration. The effectiveness of the cleanser in cleaning up oil depends on oil type, delivery mode, timing, and amount of oil. Marsh plants (e.g., *S. lancifolia*, *Scirpus olneyi*, *Thpfa latifolia*) show different sensitivities to cleanser use. Cleanser application to brackish (*S. patens*) and fresh (*S. lancifolia*) marshes removes oil from marsh grasses and reduces the short-term impact of oil spills on gas exchange of the vegetation, but it still reportedly results in reduced above-ground biomass for the first growing season. Another problem in cleanser application is the

potential impact of cleanser toxicity on various organisms in wetlands. Finally, solidifiers, which are dry, granular, hydrophobic polymers, can be used for spilled oil removal. Solidifiers react with spilled oil to form a floating cohesive and solidified mass that is easily removable, leaving very little residue.

## 2.4 Bioremediation

Wetland plants have the potential to enhance the bioremediation process through diffusion of oxygen from the shoots to the roots and soil, and its effectiveness can be increased through applications of fertilizer, microbial products, or soil oxidants. Fertilizer may be applied to spilled oil in water bodies before it reaches the marsh or may be applied directly to marshes already contaminated with oil. Additions of soluble inorganic fertilizers stimulate microbial activity and prolong the period of active oil degradation. The microbial activities lead to degradation of toxic petroleum products into carbon dioxide and water. However, the effectiveness of bioremediation may be limited by marsh plant tolerance to oil-related stress, risk of eutrophication, and soil type. Nutrients added to marshes may be transported to adjacent water bodies, leading to algal growth. Fertilizer application is more effective in sandy soils than in mineral soils. In some cases, the best action may be to allow the marsh to recover on its own, using no cleanup techniques.

## 3. IMPACTS ON ESTUARINE CONSUMERS

Benthic and nekton species are key organisms, both ecologically and economically, in coastal and wetland systems. The benthic community is an important link in transferring contaminants from the sediment to higher trophic levels, and the benthic community structure is sensitive to petroleum hydrocarbon exposure. The ecological and biological impacts of energy development on coastal marshes and estuarine environments are broad and sometimes persistent, including mortality, growth inhibition, reduced production, altered metabolic systems, and tainted flesh in fish and shellfish. Oil and gas production and transportation in coastal wetlands in Louisiana have resulted in the accumulation of polycyclic aromatic hydrocarbons (PAHs) and heavy metals in impacted areas. These compounds cause ecological impacts, including alteration of aquatic











