



OIL SPILL SCIENCE

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The mission of Sea Grant is to enhance the practical use and conservation of coastal, marine and Great Lakes resources in order to create a sustainable economy and environment. There are 33 university-based Sea Grant programs throughout the coastal U.S. These programs are primarily supported by the National Oceanic and Atmospheric Administration and the states in which the programs are located.

In the immediate aftermath of the Deepwater Horizon spill, BP committed \$500 million over a 10-year period to create the Gulf of Mexico Research Initiative, or GoMRI. It is an independent research program that studies the effect of hydrocarbon releases on the environment and public health, as well as develops improved spill mitigation, oil detection, characterization, and remediation technologies. GoMRI is led by an independent and academic 20-member research board.

The Sea Grant oil spill science outreach team identifies the best available science from projects funded by GoMRI and others, and only shares peer-reviewed research results.



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FREQUENTLY ASKED QUESTIONS: OIL EDITION

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Products made from crude oil power our cars and homes, make up many personal care products, and even help transport us into outer space. This outreach publication explores a few basic aspects of this natural resource, including what it is, its production and consumption, and its detection and release into the environment.



Oil is sometimes released into the coastal and marine environments via natural seeps underwater, like the one shown here. (U.S. Geological Survey/Donna Schroeder)

WHAT IS OIL?

Oil is often referred to as a “fossil fuel.” As prehistoric marine life died, the decaying matter sank to the sea floor and became covered with sediment.¹ This process continued over millions of years, hardening the deeply buried sediments into rock. Heat transformed the plant and animal remains in the rocks into **crude oil** with a distinct chemical signature unique to the components it was made from as well as the geological conditions.

Crude oil is mainly composed of hydrogen and carbon compounds called hydrocarbons. Several different types of hydrocarbons are present in oil. **Alkanes** are the most abundant and have low chemical toxicity. Some types of alkanes are created by and present in both marine organisms and land plants and can enter the marine environment from those sources. **Polycyclic aromatic hydrocarbons (PAHs)** are another group

of hydrocarbons found in oil, but also occur in items such as coal, car exhaust, or in charred animal fat.² PAHs are typically less abundant in fresh oil than alkanes and can be highly toxic.

Multiple types of crude oil exist and each has its own properties.³ Heavy crude is thick and gooey due to large, carbon-based molecules and a higher percentage of compounds with oxygen, nitrogen, and sulfur atoms. In most cases, it floats on water despite its gooey nature. Light crude oil contains smaller, carbon-based molecules and flows more easily at room temperature.

Crude oil is also classified according to what other elements are present. One undesirable compound in crude oil is sulfur.³ Sour crude oil has a large amounts of sulfur, while sweet crude contains relatively low levels. Traces of nitrogen, oxygen, and metals may also be present in small quantities.^{4,5} Engineers remove these unwanted compounds through a process called

refining. Refining also breaks large molecules into smaller ones so the oil can be more easily utilized. The Deepwater Horizon Oil Spill (DWH) oil is called Macondo 252 (MC252) and is a light, sweet crude.

HOW IS OIL RELEASED INTO THE MARINE & NEARSHORE ENVIRONMENT?

Spots where oil naturally leaks into the aquatic environment and, less frequently, on land through cracks and faults in the earth are called **oil seeps**. Certain types of sea life have adapted to depend on these oil seeps as a source of food.⁶ Some microbes consume chemical compounds found in the oil to produce food for themselves and in turn nourish certain types of worms and clams.

More than 42 million gallons of crude oil enter the Gulf of Mexico each year from the region's more than 900 natural oil seeps (Figure 1).^{7,8} This is the equivalent to

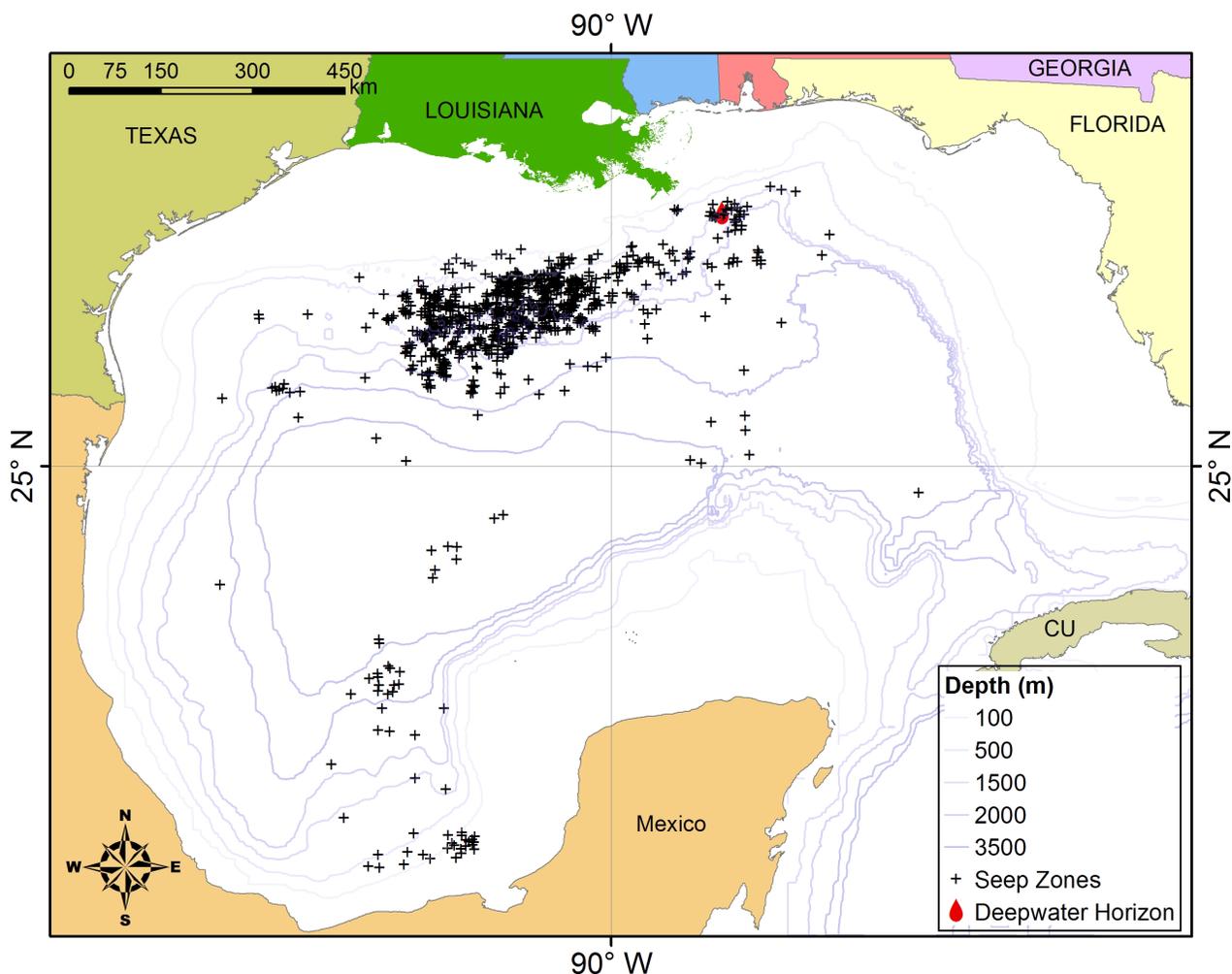


FIGURE 1. Over 900 natural oil seeps (mapped here) release more than 42 million gallons of oil into the Gulf of Mexico each year. This is about 24 percent of the volume of oil that entered the Gulf of Mexico during the Deepwater Horizon oil spill.⁸ (Reprinted from MacDonald et al., 2015)

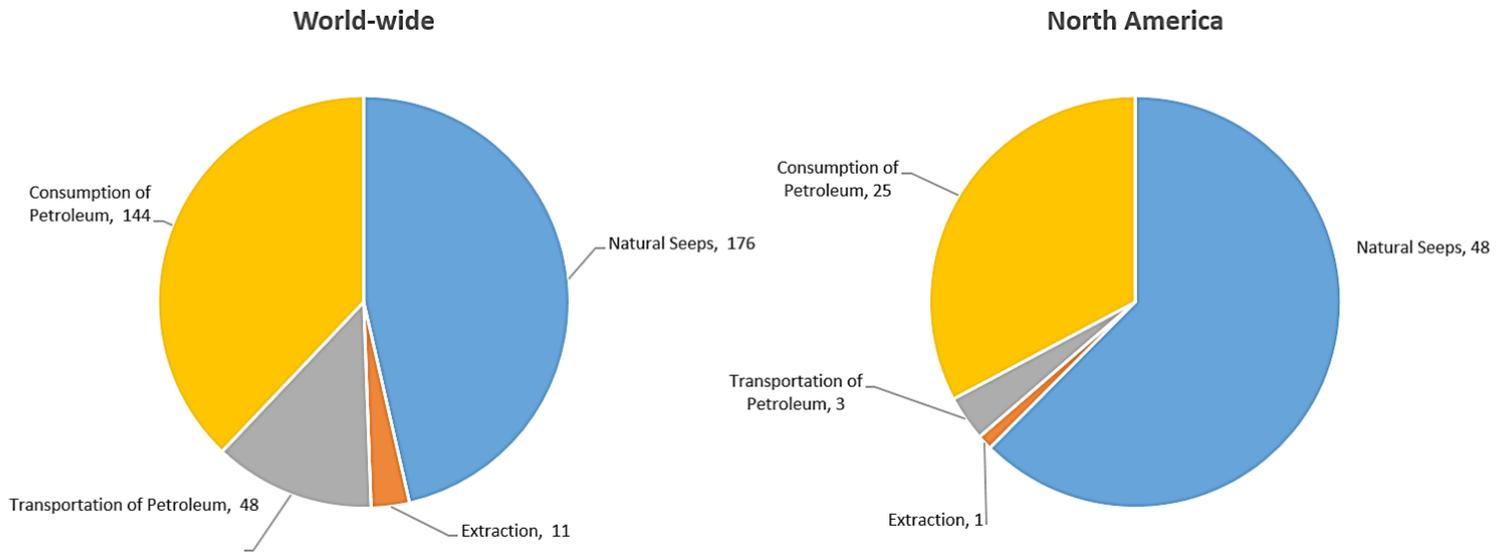


FIGURE 2. Petroleum enters the marine environment in multiple ways, including via natural seeps, operational discharges from oil consumption (e.g., from boat use and land-based runoff), accidental release of oil while in transport, and accidental release of oil during extraction. Relative contributions of each source (in millions of gallons) are shown here for North America and worldwide.¹⁰ (Data from the Ocean Sciences Board & Marine Board, 2003).

15 percent of the annual oil production in the United States.⁹ Natural oil seeps around the world release about 180 million gallons of crude oil each year, accounting for an estimated 47 percent of the crude oil entering the global marine environment annually.⁷

The remaining 53 percent of oil entering the marine environment makes its way there during operational discharges from production, transportation, and consumption of petroleum (Figure 2). This includes accidental release during activities such as drilling for or transporting oil.¹⁰ It is important to keep in mind that the chemical composition of these various sources can be different. These varying characteristics influence oil's long-term fate and effects.

WHO PRODUCES & USES OIL?

The United States produces an average of 273.8 million gallons of crude oil each day (2009-2014).⁹ Fifty-five percent of U.S. production comes from the Gulf of Mexico region, both land-based and offshore, and 39 percent of U.S. Gulf of Mexico's production comes from offshore. The next top domestic crude oil producers are North Dakota, California, and Alaska (Figure 3).⁹

U.S. crude oil production does not meet demand. Historically, the largest portion of the U.S. trade deficit was **petroleum**, a broad category that includes both

crude oil and products made from it (Figure 4).^{9,11} Petroleum accounted for approximately 10-66 percent of the national trade deficit between 2011 and 2015.¹¹ The United States utilized an average of 793.2 million gallons of petroleum per day during 2009-2014 (Figure 5).¹¹

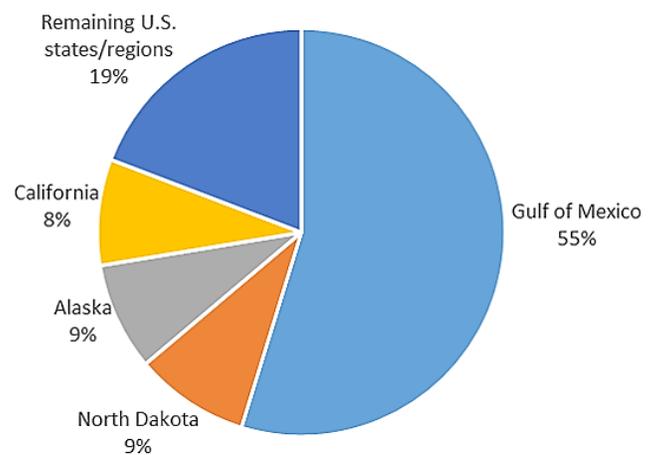


FIGURE 3. The Gulf of Mexico region is responsible for more than half of the crude oil production in the United States.¹² Shown here is the average percent of U.S. production of crude oil by states/region from 2009-2014 (273.8 million of gallons per day).¹² (Data from the U.S. Energy Information Administration, 2015).

The United States is the world's leading petroleum consumer.¹² The average American used 2.5 gallons of oil per day in 2014.⁹

DOES OIL BREAK DOWN?

Oil breaks down or **weathers** over time. Weathering occurs when oil goes through physical and chemical processes that cause it to “age.”¹³ Sunlight, heat, microbes, and oxygen can all trigger and dictate the weathering process.¹⁴⁻²¹ For example, warm water temperatures and microbes can break down many of the carbon-based compounds in oil within a couple of weeks to one month.¹⁹ Cold water conditions slow this process and it may take more than forty days.

Many factors influence the rate at which oil breaks down, including if it is mixed with dispersant.¹⁸ Emergency responders used the **dispersants Corexit 9500A** and **9527A** to minimize the amount of oil reaching the shore and especially low oxygen areas during DWH. Oil-degrading microbes are not abundant in low oxygen environments, such as muddy marshes or areas deep under the surface of sandy beaches.¹⁸ The use of dispersants enhances the breakdown of oil in water by allowing an oil slick to form small droplets more easily consumed by microbes.¹⁸

Weathered slicks can create solid residues that interact with other particles and sink to the ocean floor or wash ashore with the weathered slicks, common occurrences near seeps and after spills.²²⁻²⁵



FIGURE 4. How does society use oil? After the refining process, oil is used in a variety of ways, including transportation, heating, and everyday products. (Florida Sea Grant/Anna Hinkeldey)

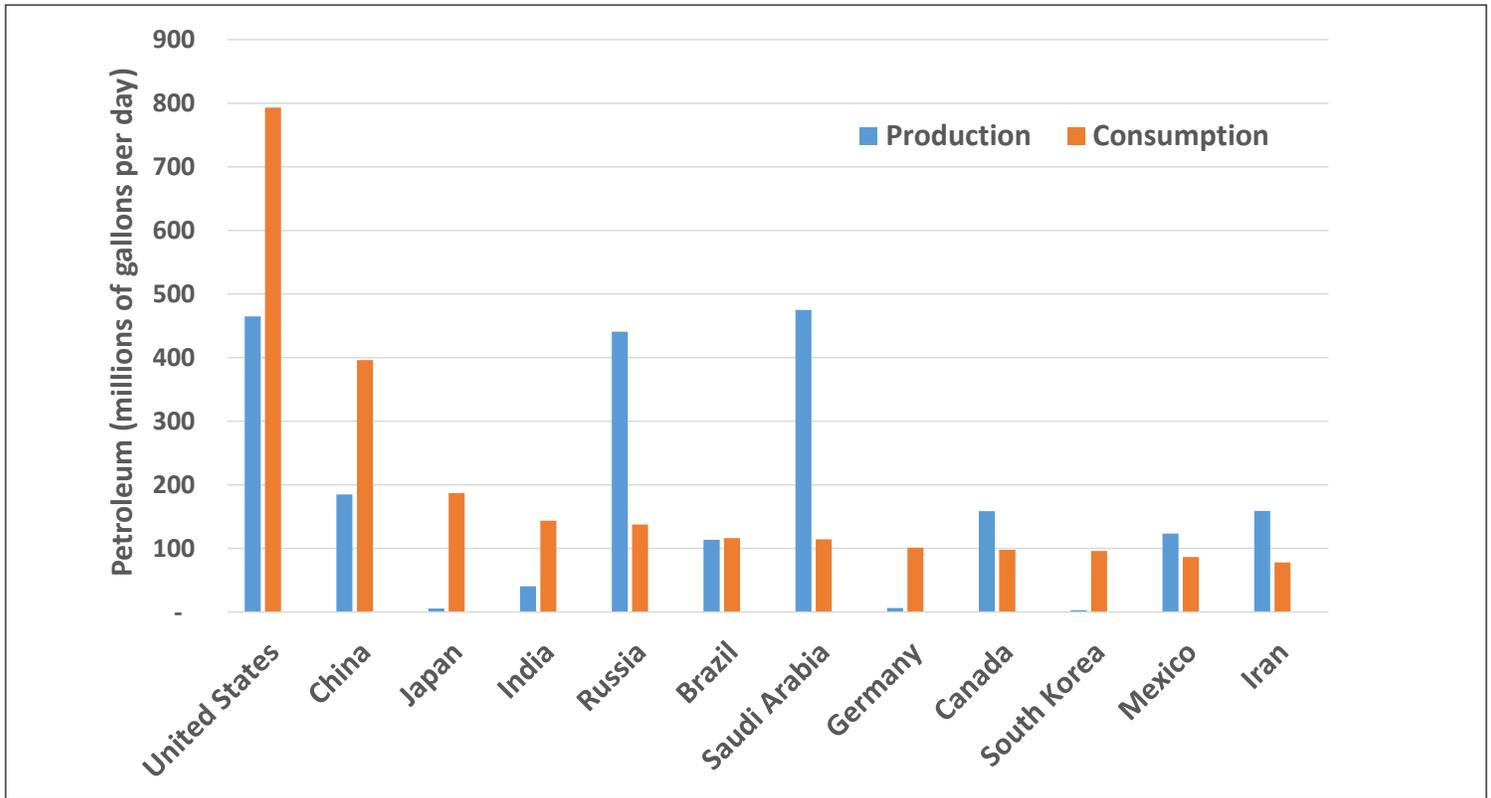


FIGURE 5. Petroleum is defined by the U.S. Energy Information Administration (U.S. EIA) as a broad category that includes natural gas, crude oil, and products made from crude oil. The U.S. is both a leading consumer and producer of petroleum (in millions of gallons per day from 2009 to 2014), with more than twice the consumption of China and others shown in this chart.¹² (Data from the U.S. Energy Information Administration, 2015)

The processes that create these solid residues are not fully understood.^{23,24} Recent research suggests that oxygen reacts with many of the chemicals in oil.^{14,20} The compounds produced from this reaction make up most of the mass of weathered oil.²⁰ Their chemical properties cause them to persist in the environment.¹⁴ More work is needed to increase understanding of the breakdown and ultimate fate of oil in the coastal environment.

HOW DO SCIENTISTS DETERMINE THE ORIGIN OF OIL FOUND IN THE ENVIRONMENT?

All oil has a chemical signature unique to its place of origin. Scientists use laboratory equipment to identify and compare the chemical signatures of oil from a spill to oil from known origins. Called **oil fingerprinting**, this process can help identify the source of oil. It is an invaluable tool since roughly half of the oil entering the coastal and marine environment worldwide comes from natural seeps (Figure 2).⁷ Scientists, emergency responders, and regulatory agencies need to identify oil's source to know if it is a natural or man-made issue.



Humans can extract crude oil from the earth with the help of sophisticated drilling platforms, like the one pictured here in the Gulf of Mexico. (Andyminicooper)

Matching oil's fingerprint to its source is not as easy as fingerprinting people. Weathering processes can change an oil's fingerprint.^{14,15,20} This decreases the confidence in locating a specific oil source. Scientists are continually

studying the many compounds in oil to understand what chemicals do not readily degrade so they can accurately identify oil's source for longer periods.²¹

A great example of oil fingerprinting in action occurred two years after the DWH disaster. GoMRI-funded scientists wanted to know if the Macondo site was leaking after a surface oil sheen appeared near the wellhead. Scientists compared the sheen's chemical makeup to samples of MC252 oil, samples from the capped wellhead area, and Macondo wreckage using cutting-edge fingerprinting technologies. The new method analyzed samples for compounds typically found in the drilling fluid lubricants used during oil extraction. These types of chemicals are not naturally

found in crude oil. Because the sheen's chemical signature included compounds that would normally be found in drilling fluid lubricant, the scientists determined the sheen was from the wreckage of the DWH drilling rig and not a leak from the wellhead.²⁶

To learn more about the research being conducted on the Deepwater Horizon spill, visit the Gulf of Mexico Research Initiative website at www.gulfresearchinitiative.org. Visit the Gulf Sea Grant program website at <http://gulfseagrant.org/oilspilloutreach> to view other publications that provide additional information on the chemistry of oil and oil's impact on aquatic organisms.



Crude oil has naturally occurring impurities that must be removed before the oil is ready to be made into useable products, such as gasoline. This process is called refining and it takes place at refineries, like the one pictured here. (Jim Bowen)

GLOSSARY

Alkanes — A group of compounds composed of hydrogen and carbon. These occur naturally in petroleum and natural gas, and include methane, propane, and butane. Some alkanes are produced by living organisms.

Corexit 9527A and 9500A — Dispersants approved for use in U.S. waters and those that were used to minimize the presence of surface oil slicks during the Deepwater Horizon oil spill.

Crude oil — Naturally occurring, unrefined oil. Crude oil is refined to produce a wide array of petroleum products (e.g., heating oils, gasoline, diesel, lubricants, asphalt, propane).

Dispersants — Chemicals that are used during oil spill response efforts to break up oil slicks to enhance the breakdown of oil. They can limit floating oil from impacting sensitive ecosystems such as coastal habitats.

Oil fingerprinting — A method that identifies sources of oil using a combination of sophisticated chemical techniques. It helps scientists trace spills to their source.

Oil seeps — Locations where oil and natural gas flow up naturally through cracks in the earth at a slow rate.

Petroleum — Broadly defined by the U.S. Energy Information Administration as a class of liquid hydrocarbon mixtures. Included are natural gas, crude oil, lease condensate, unfinished oils, refined products obtained from the processing of crude oil, and natural gas plant liquids. Volumes of finished petroleum products include non-hydrocarbon compounds, such as additives and detergents, after they have been blended into the products.

Polycyclic aromatic hydrocarbons (PAHs) — A group of hydrocarbons found in oil, tar, smoke from burning oil, coal, wood, (and ash from burning), car exhaust and cooked (e.g., grilled) animal fats.

Weather (-ing, -s) — A collection of physical and chemical processes which alter and break down oil. It includes processes such as oil spreading, evaporation, dispersing, biodegradation, and photooxidation. These processes are influenced by many factors (e.g., type of oil being weathered, temperature, bacteria present).

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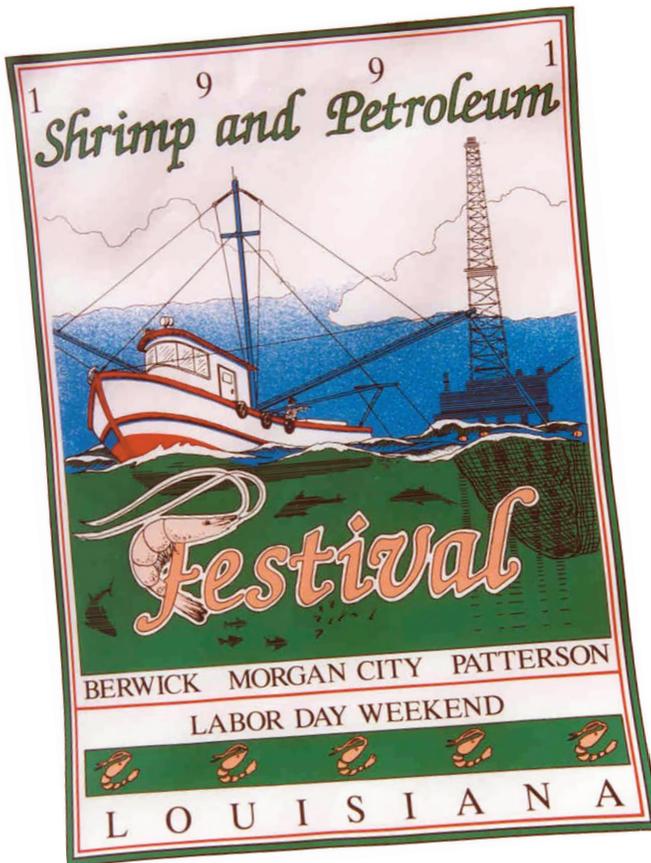
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Much of coastal Gulf of Mexico produces both seafood and petroleum, including crude oil. Louisiana holds an annual festival to celebrate both of these commodities. (Louis Dupuy)



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