OIL SPILL SCIENCE

SEA GRANT PROGRAMS OF THE GULF OF MEXICO

CORALS AND OIL SPILLS

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The largest offshore spill in American history, 2010's Deepwater Horizon oil spill occurred deep in the ocean, spreading oil at depth and into shallow and coastal areas. Scientists have since discovered the spill injured some coral communities living in the Gulf of Mexico.

This sea fan, an octocoral, lives in the deep Gulf of Mexico. Its healthy branches are a home for other animals, including the brittle sea stars and squat lobsters seen here. (Ocean Exploration Trust and ECOGIG)

CORAL: ANIMAL, PLANT, OR ROCK?

Corals support a diverse ecosystem that is fundamental to the health of the ocean. Scientists and educators often describe coral communities as "cities under the sea" or "the rainforests of the sea." Healthy coral communities provide food, shelter, and habitat to thousands of creatures, from tiny **plankton** to larger **crustaceans**, **mollusks**, fish, reptiles, mammals, and even birds. Humans also depend on healthy coral communities for sources of medicine, food, livelihoods, recreation, and as protection from storm surge.[1]

What most people think of as "a coral" is really a colony of coral polyps — tiny, soft-bodied animals related to jellyfish and anemones.[2] Hundreds to thousands of polyps can live connected to each other, established as a coral branch or coral head. Corals begin life in the water as tiny, free-

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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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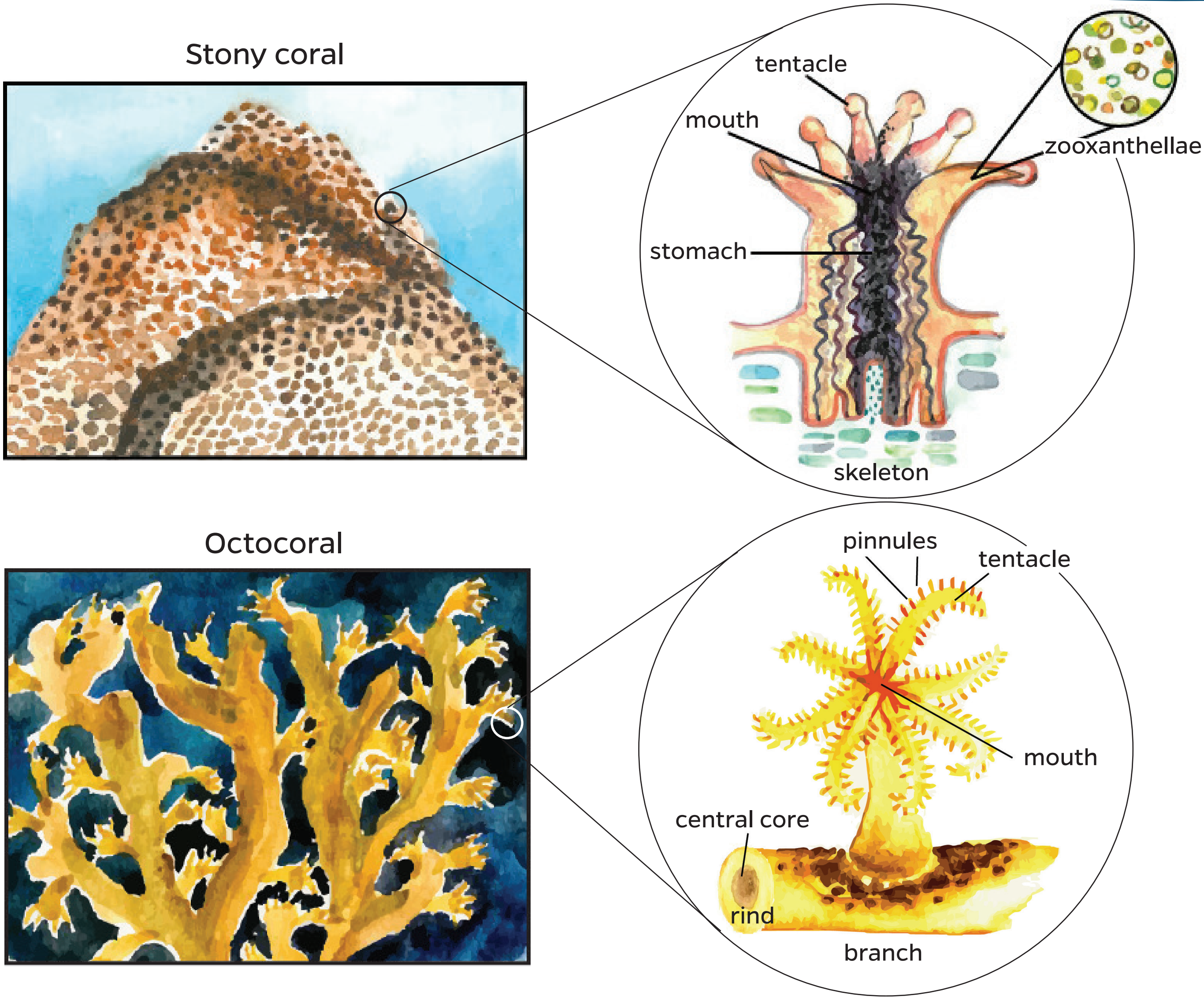


FIGURE 1. *Corals have polyps with tentacles for grabbing food from the water. Stony coral polyps have six tentacles and their polyps often have algae – zooxanthellae – living in their tissue to absorb sunlight for energy. Stony corals produce a limestone skeleton in which they live. Octocoral polyps have eight tentacles, and are often called "soft coral" because their structure is made of a more flexible material. (Florida Sea Grant/Anna Hinkeldey)*

swimming organisms, eventually settling on the seafloor or on other structures in the ocean to grow. Thousands of different types of corals exist in oceans around the world. Some coral species are mistaken for rocks because they are stony and hard; others are soft and branching like plants or blades of grass.[2]

Stony corals are reef-building corals and are often what people envision when thinking about coral reefs. The polyps of stony corals produce a hard, limestone skeleton that is the foundation for a mature coral reef ecosystem. Other types of corals do not form limestone skeletons. Instead, their polyps are housed in structures made from more flexible, horn-like protein material. These soft corals are called octocorals because their polyps have eight tentacles around their mouths, as compared to stony corals that have six. Octocorals, such as sea fans and sea plumes, attach to hard structures, like stony coral reefs or oil rigs, to live out their lives (Figure 1).[2]

Corals usually grow very slowly (from 0.1 to 4 inches a year) and can live for a long time — some are thousands of years old.[1,2] Scientists have identified corals in the Gulf of Mexico that are several hundred years old.[3]

Corals can be exposed to pollutants in the water either by direct contact (like when oil or oil products contact coral tissue), or indirectly through their feeding behavior.[4,5] Corals feed on live prey by extending the tentacles on their polyps into the surrounding water. The polyps capture small plankton that drift or swim by in the water, pulling the plankton into their mouths.[2] If corals eat contaminated food, they are then at risk for becoming contaminated.[4,5] Corals living in shallower depths also use sunlight for energy. Tiny algae living inside their polyp tissue transforms sunlight into nutrients useful to the coral.[2]

Corals anchor themselves to the ocean bottom, so they cannot move from threats or changes in the environment around them. One way they protect themselves from debris and other harmful substances is by producing a mucus. Scientists think this mucus plays many roles in a reef community, including helping corals to remove or “slough off” unwanted materials from their tissues. While the mucus production and sloughing can help, it takes a lot of the coral’s energy and does not always suffice against thick, heavy layers of oil or oil-soaked sediments.[2]

WERE CORALS IN THE GULF IMPACTED BY THE DEEPWATER HORIZON OIL SPILL?

The spill impacted important habitat for deep-sea octocoral and mid-depth communities, but not shallow coral reefs.

During the Deepwater Horizon (DWH) oil spill, the risk of coral exposure to spilled oil was high because the broken wellhead was close to hard-bottom habitat where deep-sea coral communities grow. Oil spilled at a depth of about 5,000 feet, and emergency responders injected **dispersants** into the leaking wellhead at this depth.[6] Although some dispersant-treated oil rose to the ocean surface, a large subsurface plume of oil formed in the water around 2,500 to 4,000 feet deep. Scientists estimated that the plume covered 400 to 700 square miles.[7] Meanwhile, at the ocean surface, natural weathering processes, burning of surface oil, and dispersant use on oil slicks caused much of the unrecovered oil and dispersants to sink to the ocean floor.[7,8]

Research conducted before and after the DWH spill has shown that oil exposure can harm corals in a variety of ways. Oil can reduce corals’ ability to reproduce and therefore may prevent growth of new colonies. Oil also negatively affects their early life stage development.[2] Oil on the seafloor can prevent coral larvae from settling there.[9] To understand how the DWH spill may have impacted corals in the Gulf of Mexico, scientists explored three general ocean zones where corals are known to live (Figure 2):

1. the deep-sea,
2. the mesophotic or “middle light” zone, and
3. the shallow-water zone.

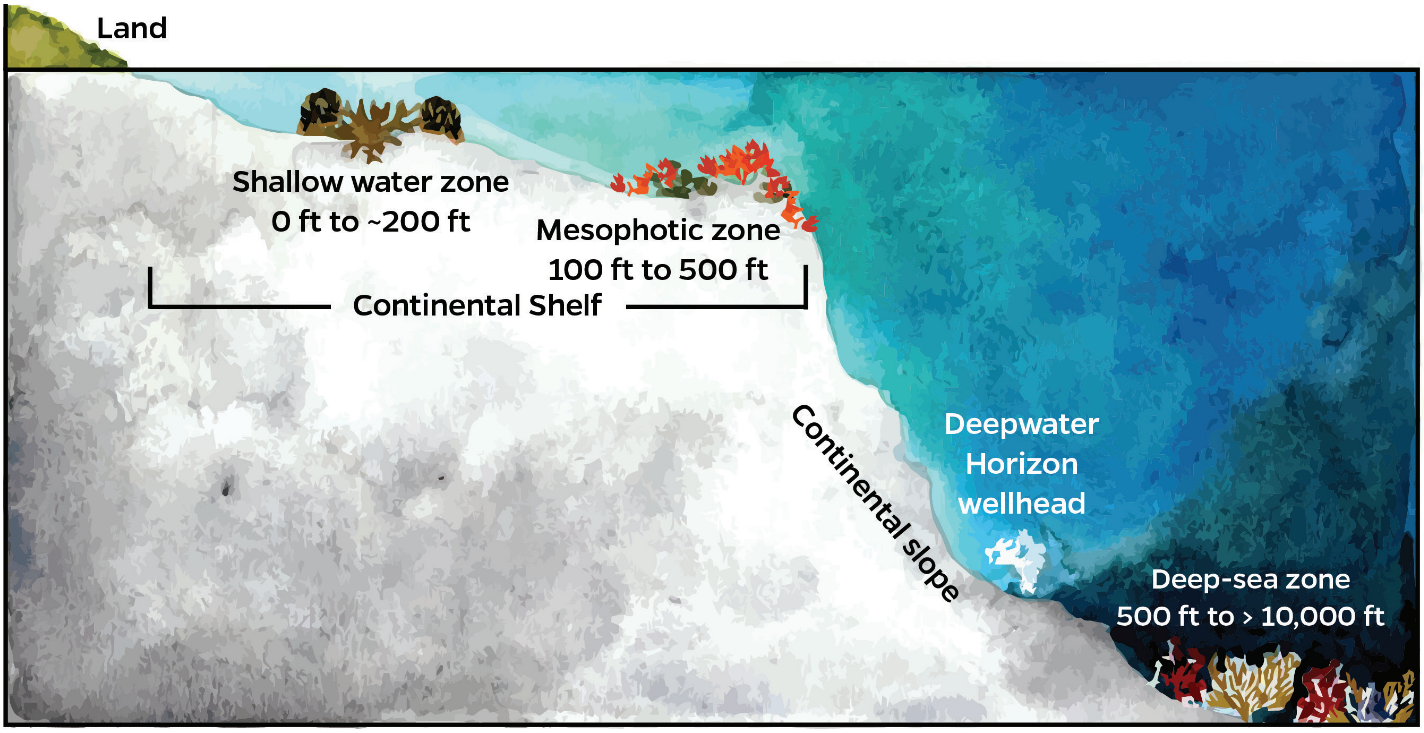


FIGURE 2. *The ocean bottom gradually slopes from the shore down to the deep sea. Corals can live in shallow, mesophotic, and deep-sea zones. The Deepwater Horizon oil spill harmed corals in the mesophotic and deep-sea areas.[7] (Florida Sea Grant/Anna Hinkeldey, adapted from NOAA)*

Deep-sea zone

The deep-sea zone begins at about 500 feet deep and extends to more than 10,000 feet deep. Nearly 95 percent of the Gulf of Mexico deep seafloor is soft-bottom mud, and the remaining areas consist of hard bottom. Soft coral communities live in these hard-bottom habitats but are limited by the availability of hard surfaces for attachment. Experts have identified more than 23,700 distinct hard-bottomed areas along the Gulf's seafloor. These areas are widely and patchily distributed in deep water, and not all support coral growth, making finding and sampling deep-sea coral a challenge for scientists.[6,8] Despite the difficulties in locating and studying deep-sea communities, scientists estimate that 770 square miles of ocean bottom surrounding the wellhead, including coral habitats, were impacted by the DWH oil spill.[7]

After the spill, scientists used **remotely operated vehicles (ROVs)** and **autonomous underwater vehicles (AUVs)** equipped with cameras to find and observe deep-sea corals in the Gulf of Mexico. In late 2010, one group of scientists located a coral community near the spill site.[10] These scientists found that more than half of the corals were covered in a flocculent ('floc') or clumped, brown material. The corals also showed signs of stress such as loss of the tissues that make up the coral polyps, and excess mucus production.[10] Scientists sampled the floc and determined that it contained a trace of both oil and dispersants from the DWH spill.[10,11] Scientists returned to check for any changes in coral health over time, as seen in Figure 3 .[12] They photographed these corals from 2010 through 2012. By March of 2011, most of the floc had disappeared and the corals seemed to be recovering. However, some tissue loss did not heal, and exposed portions of coral branches became colonized by stinging organisms called **hydroids**.[12] Eventually, scientists observed other changes to the coral community and associated animals — notably the lack of brittle sea stars — who commonly reside on healthy coral communities. By March 2012, scientists witnessed coral branch loss.[12] Because of these studies, scientists now look for hydroid colonization of deep-sea corals, as it has shown to be a reliable indicator of coral deterioration.[6] Scientists have yet to document recovery of deep-sea corals because of the challenges in studying them. Due to the slow rate of growth in the deep sea, it could take decades to hundreds of years to see recovery of corals there. Scientists will continue to study this deep sea coral community and others in the area for long-term changes and to establish better baseline data.[7,8]

Mesophotic zone

The mesophotic ('meso' means middle and 'photic' means light) zone, around 100 to 500 feet below the ocean's surface, is a lower-light environment. Both reef-building stony corals and soft octocorals live in this zone. Some corals here feed on plankton and some use sunlight for energy. The mesophotic zone is considered by some

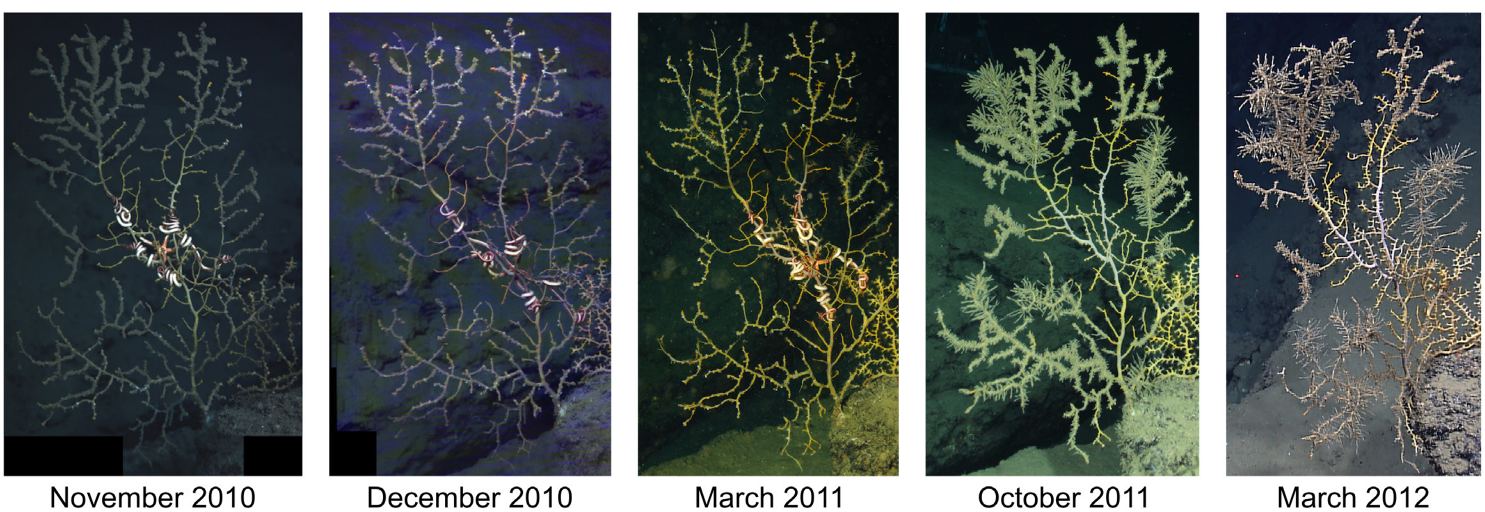


FIGURE 3. *Injuries to coral following the Deepwater Horizon oil spill progressed over time. In November 2010, scientists found clumped, brown material containing oil from Deepwater Horizon on the coral branches. By March 2011, most of the brown material had disappeared but the corals started losing tissue, and the brittle sea star that lived on this coral abandoned it. By October 2011, hydroids grew on the branches, a sign of coral deterioration. By March 2012, coral branch loss was apparent.[12] Scientists document other animals in a coral community, such as hydroids or sea stars, in order to gain better understanding of overall community health. (ECOGIG/Pen-Yuan Hsing)*

TABLE 1. *Below is a quick guide for trained personnel who respond to spills in shallow coral reef areas. Emergency responders must consider the environmental impact of each response method based on the type of oil that has spilled near coral communities.*
KEY: A = least harmful impact; B = some harmful impact; C = significant harmful impact; D = most harmful impact; n/a = not applicable.[15] *(Adapted from NOAA Office of Response and Restoration)*

Cleanup methods for shallow coral reefs	OIL TYPE				
	Gasoline products	Diesel-like products & light crudes	Medium crudes & intermediate products	Heavy crudes & residual products	Non-floating oil products
Natural recovery	A	A	A	A	B
Booming	n/a	B	B	B	n/a
Skimming	n/a	B	B	B	n/a
Manual oil removal/cleaning	n/a	n/a	B	B	B
Mechanical oil removal	n/a	n/a	n/a	D	D
Sorbents	n/a	A	A	A	B
Vacuum	n/a	n/a	B	B	B
Low-pressure, ambient water	B	B	B	C	C
Dispersants	n/a	C	C	C	n/a
In-situ burning	n/a	B	C	C	n/a

scientists to be a transition zone between the shallow and deep-sea zones. Recent research has shown that the area might be an important refuge for some corals living in the shallower zone.[13] Corals in the shallows are often threatened by impacts from warming sea temperatures, pollution, and coastal development. Scientists think mesophotic zone corals might help re-populate damaged coral reefs in shallower waters.[13,14]

DWH oil and dispersants likely affected corals in the mesophotic zone.[5,7] To determine the spill's impact, scientists compared the health of octocorals living below the surface oil slick to corals living further away from the spill area. Scientists evaluated these corals' health in 2010, 2011, and 2014 and compared their pre-spill condition using photographic data from as early as 1997. Scientists saw a severe decline in the condition of octocorals closer to the oil after the spill. Before the spill, records showed natural or non-spill related damage (such as coral predation and fishing activity) to around 10 percent of colonies, but by 2011, the spill had injured more than 50 percent of colonies. They described the injuries as eroded polyps, overgrowth of hydroids, residue on branches, discoloration, bare branches, and missing or broken branches.[5] Nearly all injured colonies declined in health over the next few years, so scientists suggest this means recovery of the damaged corals is unlikely.[5]

Shallow-water zone

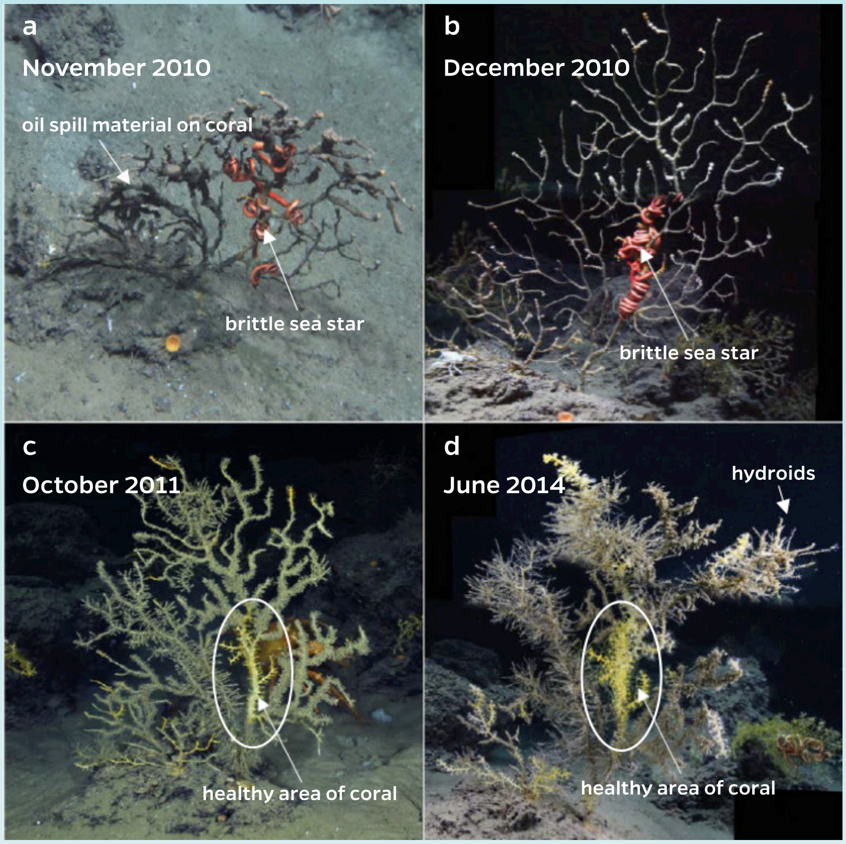
The shallow-water zone is generally considered to be from the surface to about 200 feet deep.[1,7] The mesophotic zone extends into or overlaps with the deeper end of the shallow-water zone. Corals in shallower areas tend to be the stony reef-building type, and they depend on warm, clear, clean water to receive sunlight for energy.[1] Octocorals also live in these shallow waters. As part of the spill assessment activities, scientists observed areas of rocky, shallow-water reefs in the northern and eastern Gulf of Mexico, offshore of Alabama and Florida. Scientists did not locate any shallow-water coral reefs impacted by oil and dispersants from the DWH oil spill, unlike the coral colonies in the deep-sea and mesophotic environments.[7]

TO DISPERSE OR NOT TO DISPERSE?

Emergency responders use a variety of approaches, including dispersants, to combat oil in areas containing corals, as seen in Table 1.[2,15] In 1989, the National Research Council published recommendations for dispersant use near shallow coral reefs.[2,16] These guidelines work in conjunction with local area **contingency plans** to help emergency personnel make spill response decisions. Dispersant use in areas where corals live is generally not recommended, though some situations may make it appropriate.[9] The DWH spill was the first time responders applied dispersants below the ocean's surface at such great depths and in such large amounts.

In order to study oil and dispersant effects in a more controlled setting, scientists have recently brought common deep-sea, cold-water corals into the laboratory. They tested how corals would react to different doses of DWH oil and dispersants. Though they did not exactly reproduce the conditions of the DWH oil spill, their goal was to understand the sensitivity of deep-sea corals to a range of oil and dispersant concentrations.[17] They reported that in the laboratory setting, corals showed more severe health declines in response to dispersant exposure than to oil alone.[17] Mixtures of oil and dispersant caused more severe effects than oil exposure by itself.[17] Additionally, they found that higher concentrations of dispersant, and of the oil and dispersant mixtures, resulted in more severe health impacts.[17]

However, laboratory results can be very different from what happens in real-life dispersed oil situations, especially considering the various environmental conditions and the many types of oil that can be spilled.[2,9,18] In other words, concentration levels of oil and dispersant, the length of exposure time, depth in the ocean, temperature of the ocean, and ocean and wind currents are just some of the factors influencing how oil and dispersants impact corals.[2] Previous studies about oil and dispersant effects have been inconsistent, and questions remain about how toxic oil and dispersants are to different coral species.[9,18] Therefore, scientists are conducting new experiments to establish a standardized baseline of toxicity levels for corals.[9] Updated toxicity information could help emergency responders and managers make more informed decisions about dispersing oil spilled near valuable coral communities.[9]



BRITTLE SEA STARS

Certain species of brittle sea star live entwined on the branches of deep-sea octocorals, using the coral as an anchor (a, b) so they can extend their arms into the water to gather passing food. Brittle sea stars may have protected some corals from oil and dispersant impacts during the Deepwater Horizon oil spill. Corals with attached brittle sea stars were more likely to recover in the years following the spill (c, d). Scientists think the sea stars may have prevented oil and dispersant materials from settling on the corals where they were living. The sea stars may have also prohibited hydroids from growing on the corals. This coral and sea star relationship is an example of resilience to stressors.[22] (adapted from ECOGIG/Fanny Girard)

CORAL RESTORATION

The **Natural Resource Damage Assessment (NRDA)** for the DWH spill includes recommendations to restore impacted natural resources. Scientists have established techniques for restoring shallow coral reefs, such as coral transplantation, but very few restoration methods exist for deeper habitats.[20] Some experts suggest that continued monitoring will improve understanding of mesophotic and deep-sea coral communities to inform better management. Cooperative management can help protect against multiple threats and provide a framework for monitoring, education, and outreach.[20]

For more oil spill science and information, visit ***gulfseagrant.org/oilspilloutreach.***

CORAL STRUGGLES

Corals all over the world face many threats. For example, excess carbon dioxide in the atmosphere is dangerous to corals. The oceans absorb excess carbon dioxide from the air, causing the water to become more acidic over time. Changes in ocean acidity make it more difficult for many corals to form skeletons, the foundation of reefs. Additionally, stress from changing ocean temperatures can cause coral bleaching. Coral bleaching happens when corals evict the algae living in their tissues, causing the coral to turn white. If conditions do not improve quickly enough, corals can die from bleaching, especially if they are already weak from disease or injury. Other threats, such as damage from fishing gear, energy exploration, and cable deployment can destroy coral communities. Some corals can live hundreds to thousands of years, but because they grow so slowly, it can take them hundreds of years to recover from damage. Faced with so many threats, many species of coral are under both domestic and international government protection.[1,2,7,19,21]

GLOSSARY

Autonomous Underwater Vehicles (AUVs) — Programmable robotic vehicles that can drift, drive, or glide through the ocean without being controlled by humans.

Contingency plans — Plans developed to enable responders to address incidents by helping to identify and coordinate the activities of the different government agencies and private organizations involved in a response.

Crustaceans — A large group of mostly aquatic animals (such as crabs, lobsters, and shrimps) with a body made of segments, a tough outer shell, two pairs of antennae, and limbs that are jointed.

Dispersants — Chemicals that are used during oil spill response efforts to break up oil slicks and limit floating oil from impacting sensitive ecosystems such as coastal habitats.

Hydroid — Colonies of hundreds of tiny, stinging organisms related to jellyfish and coral. They form into what looks like a feather or seaweed. They tend to attach to and colonize other creatures and structures.

Mollusks — Invertebrates with a soft and unsegmented body often enclosed in a shell, such as a snail, mussel, or squid.

Natural Resource Damage Assessment — The legal process used to determine the impacts of oil spills, hazardous waste sites, and ship groundings on natural resources and humans.

Plankton — Very small and microscopic organisms that drift or float in bodies of water. Consisting of algae, protozoans, diatoms, crustaceans, and the eggs and larval stages of animals, etc., they are an important part of food webs.

Remotely operated vehicle (ROV) — An underwater mobile device that is tethered to a ship. They are often used in deep-sea exploration where human access is not possible.

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SUGGESTED CITATION

Hale, C., Graham, L., Maung-Douglass, E., Sempier, S., Skelton,T., Swann, L., and Wilson, M. (2017). Corals and oil spills. TAMU-SG-17-505.

ACKNOWLEDGMENT

Special thanks to the many external reviewers who contributed to the betterment of this oil spill science outreach publication.

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This work was made possible in part by a grant from The Gulf of Mexico Research Initiative, and in part by the Sea Grant programs of Texas, Louisiana, Florida and Mississippi-Alabama. The statements, findings, conclusions and recommendations do not necessarily reflect the views of these organizations.

TAMU-SG-17-505 GOMSG-G-17-014