FIVE YEARS & COUNTING

GULF WILDLIFE IN THE AFTERMATH OF THE DEEPWATER HORIZON DISASTER

NATIONAL WILDLIFE FEDERATION

Jim Kavanagh

On April 20, 2010, the Deepwater Horizon oil rig exploded,

killing 11 men and unleashing a torrent of oil and natural gas from BP's Macondo wellhead into the Gulf of Mexico. By the time the well was capped on July 15, 2010, an estimated 134 million gallons of crude oil and four million pounds of gas had escaped into Gulf waters.[1]

Five years later, scientists are still investigating the effects of the disaster on the Gulf ecosystem. Much of this research has not yet been made public, as it is part of the federal government's case against BP and the other companies responsible for the disaster.

The National Wildlife Federation has closely monitored the research that has become available for evidence of the spill's effects on wildlife and habitats. This is our fifth annual report highlighting these impacts. This year, new research allows us to include a total of twenty species of wildlife or wildlife groups in this report—although many more species were likely affected.

Summary

- In 2014, dolphins on the Louisiana coast were found dead at four times historic rates, and there is increasing evidence that these ongoing dolphin deaths are connected to the 2010 oil disaster.
- Between 27,000 and 65,000 Kemp's ridley sea turtles are estimated to have died in 2010, and the annual numbers of Kemp's ridley nests have declined in the years since the spill.
- Twelve percent of the brown pelicans and 32 percent of the laughing gulls in the northern Gulf are estimated to have died as a result of the BP oil spill.
- Oil and dispersant compounds have been found in the eggs of white pelicans nesting in three states—Minnesota, Iowa and Illinois.
- Exposure to oil has been shown to cause abnormal development in many species of fish, including mahi-mahi, Gulf killifish and bluefin and yellowfin tuna.
- Spotted seatrout, also known as speckled trout, spawned less frequently in 2011 in both Louisiana and Mississippi than in previous years.
- Both 2010 and 2011 had the lowest numbers of juvenile red snapper seen in the eastern Gulf fishery since 1994.
- Coral colonies in five separate locations in the Gulf—three in the deep sea and two in shallower waters—are showing significant oil damage.
- Sperm whales are spending less time foraging in the area around the wellhead.
- Oil has been found in sediments deep in the Gulf of Mexico, in a 1,200-square-mile area surrounding the wellhead.

Given the significant quantity of oil remaining on the floor of the Gulf and the unprecedented large-scale use of dispersants during the spill, it will be years or even decades before the full impact of the Deepwater Horizon disaster is known. It is clear that robust scientific monitoring of the Gulf ecosystem and its wildlife populations must continue—and that restoration of degraded ecosystems should begin as soon as possible.

ECOSYSTEM IMPACTS

The Gulf of Mexico, with its sandy beaches, lush wetlands and deep water corals, is a vast system that teems with life. The waters, beaches, marshes and upland areas of this ecosystem support an incredible amount of wildlife—birds, fish, marine mammals and countless others. These diverse habitats also support a robust economy that includes tourism and recreational and commercial fishing, among other activities.

The explosion of the Deepwater Horizon drilling rig precipitated the largest marine oil spill in U.S. history. This event was unprecedented in many ways: the large volume of oil and natural gas that was discharged, the three-month time period between the blowout and when the well was finally capped, the depth of the well and the sheer area and number of habitats over which the oil was ultimately found.[2] The crude oil that was released into the Gulf is a mix of compounds, including polycyclic aromatic hydrocarbons (PAH) that are known to cause toxic effects in birds, fish, and other wildlife.[3] In marine environments, discharged oil spreads and undergoes weathering.[4]

In an effort to break up the oil into smaller droplets, nearly two million gallons of chemical dispersants were discharged into the Gulf in 2010. Two dispersants, Corexit 9500 and Corexit 9527, were applied to the oil, both at the surface, to break up oil slicks, and directly at the wellhead, to try to prevent their formation.[5] Notably, dispersants do not reduce the amount of oil in the environment; they simply break the oil into fine droplets. Dispersants are intended to reduce the likelihood that birds and other wildlife may be oiled or that an oil slick will contaminate beaches and coastal marshes. However, the fine droplet size of dispersed oil increases the likelihood that fish, coral, and other organisms in the water column will be exposed to the harmful compounds in oil.[6] There are also indications that dispersants can remain in the environment for years.

Deep Water

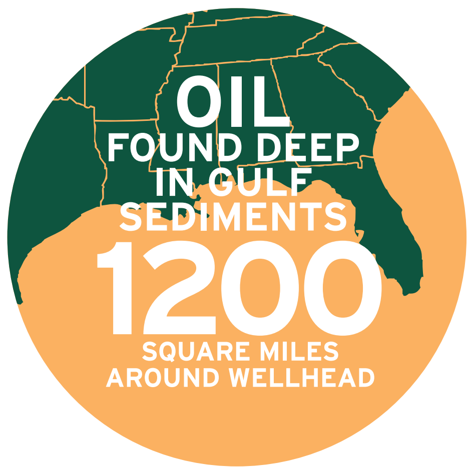
The disaster began nearly a mile below the surface of the Gulf. Much of the oil eventually rose to the surface, where it formed extensive oil slicks and was mixed and dispersed by ocean currents.[8] The dispersants Corexit 9527 and Corexit 9500 were applied in unprecedented quantities in deep-sea waters near the wellhead in an effort to prevent the formation of oil slicks.[9] In addition to oil, nearly four million pounds of natural gases, including methane, propane, ethane and butane, were discharged into the deep Gulf.[10,11]

In June 2010, long before the well was capped, a 21-mile plume of oil and gas mixed with water was found 3,500 feet below the surface of the Gulf.[12] Shallower plumes of oil and gas were found at depths of 80 feet, 869 feet and 2,800 feet.[13] The application of dispersants

in the deep water may have increased the retention of oil in the water column.[14] While there is evidence that microbes living in the deep Gulf quickly began breaking down the methane and propane gases trapped within the huge plumes, the fate of much of the oil has until recently been uncertain.[15,16]

Recent studies from two research groups have found evidence of significant oil contamination in bottom sediments in the Gulf. While these studies used different methods, they had similar results, suggesting that between 80,000 and 600,000 barrels of oil released into the environment during the oil spill were deposited on the sea floor. This oil remains in sediments deep in the Gulf in a 1,200-square-mile area surrounding the wellhead.[17,18]

In the cold depths of the Gulf, oil is likely to take a long time to break down. Therefore, the large area of oil contamination may have far-reaching and long-lasting implications for bottom-dwelling fish, corals, crabs, worms and other organisms. Reductions in abundance and diversity of benthic organisms have been observed at moderate to severe levels in an area roughly 57 square miles around the wellhead.[19] In studies of shallow-water oil spills, bottom-dwelling communities have taken years to decades to recover.[20] Recovery of the bottom-dwelling communities in the deepwater environment may take decades or longer to recover, and loss of deep-sea benthic biodiversity has been linked to reduced ecosystem functioning.[21,22]



Coastal Marshes

The coastal wetlands of the Gulf provide vital habitat for countless fish, birds and other wildlife.[23] Coastal wetlands also improve water quality by filtering out nutrients and sediment, provide storm protection for coastal communities, and support recreational opportunities.

Thirty-nine percent of the coastal wetlands in the continental U.S. are located along the Gulf of Mexico. These wetlands are suffering disproportionate losses, however, due to erosion, storms, sea level rise and other factors. Between 2004 and 2009, 71 percent of the coastal wetland loss in the U.S. took place along the Gulf Coast.[24] This wetland loss is especially rapid in Louisiana, where an area the size of a football field becomes open water every hour on average.[25]

Coastal marshes were greatly damaged by the 2010 oil spill. Ultimately, 490 miles of coastal wetlands had some of degree of visible oiling, the vast majority in

Louisiana. In May 2013, three years after the spill, more than 80 miles of marsh shoreline in Louisiana remained visibly oiled.[26,27]

Oil from the Deepwater Horizon event reached marsh shorelines during the spring and summer. Oil exposure during the growing season is more likely to kill vegetation both above ground and at the roots.[28] Studies conducted in Barataria Bay, Louisiana found that heavy oiling of marsh edges led to plant death, accelerating erosion and marsh loss. This increased rate of erosion lasted at least 18 months, if not longer.[29,30] In addition, the weakening of the marsh soils and loss of root systems below the surface could lead to increased loss of oil-exposed wetlands in the face of future sea level rise.[31]

Oil from the spill particularly contaminated marshes in Barataria Bay and Terrebonne Bay in Louisiana. One study found that concentrations of PAHs—which can cause toxic effects in many fish, birds and other wildlife—were on average 186 times higher than pre-spill conditions in these two bays, and that these concentrations could take decades to return to baseline levels. Results from this study also suggested that storm events could distribute oil into previously unoiled wetlands.[32]

The long-term effects of the oiling of Gulf marshes are still unclear and may take decades to unfold. The persistence of toxic hydrocarbons and accelerated marsh erosion threaten the multitude of birds, fish and other wildlife that depend on this habitat as well as the overall health of the Gulf Coast ecosystem.

Beaches

The Gulf Coast's iconic sandy beaches are not just prime real estate for sunbathing, fishing, building sandcastles, and other recreational activities. They also provide critical nesting and foraging habitat for many sea turtles and birds, including the piping plover and the endangered Kemp's ridley sea turtle.[33,34,35]

Despite attempts to protect beaches and barrier islands with floating oil-containment booms, a form of emulsified oil that scientists call "viscous mousse" began to wash up on Gulf shores in May and June of 2010.[36,37] Visible oiling was observed on more than 550 miles of beach shoreline in the months immediately after the spill, and even three years later, oil was still observed on nearly 300 miles of beach shoreline.[38] While some of the oil mousse washed up on beaches, a portion mixed with sand near the shore and formed large submerged oil mats.[39]

Cleanup efforts on impacted beaches involved excavation and sifting of contaminated sand to remove the oil. Although this method was successful in removing the larger pieces of consolidated oil fragments from the beach, it also helped distribute smaller remnants of oil over a larger area of the treated beach.[40]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The submerged oil mats that formed in the near-shore area became partially buried, making them difficult to locate and remove. These submerged mats are likely the principal source of the sandy oil balls that have littered many beaches in the region after storms.[41,42] Recent studies of beach shoreline in Alabama suggest that these sandy tar balls are likely to continue washing up for years to come on Gulf Coast beaches, and could pose a risk to organisms living on or near those beaches.[43,44,45]

WILDLIFE IMPACTS

The Gulf of Mexico is home to more than 15,000 species of wildlife that live in a variety of habitats, from coastal estuaries to the deep sea floor. These species and their habitats are often interconnected in intricate ways. The common loon winters on the productive wetlands of the Gulf, before traveling back to Canada to breed. Species of shrimp need both the inland bays and offshore habitats to complete their life cycles. Couple these connections with the intricate food webs of the ecosystem and it makes for a highly dynamic Gulf of Mexico.

As described earlier in this report, the Deepwater Horizon oil spill affected multiple habitat types throughout the Gulf region. The wildlife that use those habitats have likewise been affected, sometimes in ways that cascade through the food web. This section of the report describes what we know so far about how the Deepwater Horizon oil spill has affected twenty species of wildlife or wildlife groups.

ATLANTIC BLUEFIN TUNA

The Atlantic bluefin tuna is one of the largest fish in the Gulf, averaging 6.5 feet long and 550 pounds. A single fish can sell for tens of thousands of dollars. Considered one of the greatest big game fish in the world, the western Atlantic bluefin tuna population has declined by 82 percent from the 1970s, primarily due to overfishing.[46]


Flickr: Aziz Saltik

A recent comprehensive laboratory study found that a chemical in Deepwater Horizon oil can cause irregular heartbeats in bluefin and yellowfin tuna that can lead to heart attacks, or even death. The researchers exposed tuna embryos and larvae to concentrations of Deepwater Horizon oil similar to what may have been found in the Gulf in 2010. The resulting heartbeat changes significantly altered the development of other organs. The researchers suggest that many other vertebrate species in the Gulf could have been similarly affected.[47]

The study above was done in the laboratory, but could have significant implications for fish in the wild. Atlantic bluefin tuna breed in only two places: the Mediterranean Sea and the Gulf of Mexico. The Deepwater Horizon rig exploded while the April-May breeding season was underway in the northern Gulf. Tuna eggs float in the upper water column; it is therefore likely that some larval fish were exposed to oil from the spill.[48]

Estimates on how many tuna larvae may have been exposed to oil vary. NOAA researchers have estimated that the figure could be as high 20 percent.[49] A different team of scientists concluded that less than 12 percent of larval bluefin tuna were located within contaminated waters.[50]

For a species already in peril, any reduction in the population can be a major impediment to recovery. In 2011, NOAA identified Atlantic bluefin tuna as a "species of concern." It will be important to understand the spill's impacts on the bluefin tuna population to appropriately manage the fishery while protecting the species.

BLUE CRAB

The Deepwater Horizon spill occurred during the blue crab spawning season, when female crabs were migrating out of protected estuaries into the deeper waters of the Gulf to release their eggs. Scientists observed oiled larvae in 2010, but the extent of the impact is not known.[51] One estimate is that 40 percent of offshore larval grounds across the north-central Gulf were exposed to oil.[52]

Commercial crabbers in multiple locations across the Gulf reported a drop in blue crab populations in the years after the spill, particularly in 2013.[53,54,55] Blue crab harvests have been approximately 20 percent lower between 2011 and 2014 than they were in the ten years prior to 2010.[56] However, commercial harvests of blue crabs fluctuate annually due to a variety of factors and have been declining for decades.

One study found that oil and dispersants can compromise the integrity of a crustacean's protective layer—known as the epicuticle—leading to the development of lesions.[57] There are anecdotal reports of such lesions on blue crabs as recently as 2013. Similar lesions and deformities were found on other crustaceans in the immediate aftermath of the disaster, but scientists lack baseline data for comparison.[58]

Some research suggests a relatively low level of larval mortality in 2010,[59] while a separate study found that younger blue crabs were sensitive only to high concentrations of oil and dispersant.[60]

Oiled marshes may also be continuing to affect blue crab populations and distribution. Preliminary research results indicates that fewer larval crabs may be settling in marshes known to have been oiled.[61]


Jason Williams

Blue crabs are a staple food source for a wide variety of Gulf creatures—everything from Kemp's ridley sea turtles to whooping cranes. The blue crab's critical place in the Gulf food web means that any prolonged changes in its populations could have wider repercussions. A deeper understanding of any impacts from the oil spill is needed.

BOTTLENOSE DOLPHIN

As top-level predators, bottlenose dolphins play an important role in the Gulf ecosystem. Gulf bottlenose dolphins include coastal populations that migrate into bays, estuaries and river mouths, as well as offshore populations that live in the open sea along the continental shelf.[62]

Since the spill began, approximately 1,000 bottlenose dolphins have been found dead in an area stretching from the Florida panhandle to the Texas-Louisiana border. In 2014, dolphins were found dead at more than twice historic rates in this area. However, these deaths were not evenly distributed—places that received less oil did not have particularly elevated numbers of dolphin deaths in 2014, while dolphins in heavily-oiled Louisiana were found dead at four times historic rates.[63]

A study conducted in 2011 found that dolphins in Louisiana's Barataria Bay had symptoms consistent with oil exposure—such as unusual lung masses, adrenal problems and tooth loss. Nearly half the

Lisa Comer

dolphins examined were very ill; 17 percent of the dolphins were not expected to survive. The study also concluded that the health effects would likely reduce the dolphins' ability to reproduce.[64]

A more recent, separate study found that dead dolphins were recovered in larger numbers in heavily oiled places such as Barataria Bay. This study also found that the deaths of a cluster of dolphins during the months before the Deepwater Horizon exploded were likely caused by extended exposure to fresh water and unusually cold weather.[65]

This is by far the longest period of above-average deaths in the past two decades and it includes the greatest number of stranded dolphins ever found in the Gulf of Mexico. NOAA has determined that there is no evidence that the two most common causes of previous dolphin deaths—morbillivirus and red tide—are a factor in the current mortalities.[66] The agency is actively investigating the role of the Deepwater Horizon event in these ongoing deaths.

BROWN PELICAN

The practice of hunting birds for feathers and food in the early 20th century greatly reduced brown pelican populations. These losses were compounded by extensive use of the insecticide DDT in the 1950s and 1960s, which caused widespread reproductive failure.[67] The banning of DDT in 1972 initiated recovery efforts, and was complemented by relocating birds from the Atlantic coast to Louisiana. The brown pelican's dramatic recovery led to its removal from the federal endangered species list in late 2009, just months before the spill.

In the summer of 2010, brown pelicans covered in oil became the iconic image of the disaster. In the year after the spill, several hundred brown pelicans were collected from the oiled area, and scientists thought this represented only a small fraction of the birds affected by oil.[68]

A recent study looked at these carcass counts and used modeling techniques to estimate that as many as 12 percent of the brown pelicans in the northern Gulf of Mexico population were killed as a result of the oil.[69] A separate team of researchers looking at the age structures of brown pelican populations on Louisiana barrier islands in 2011 were not able to make any significant connections to oil-related deaths, but noted that their research may not be conclusive.[70]

William Osterloh

Birds such as the brown pelican can ingest oil while cleaning their feathers or by consuming contaminated food. Oil exposure can lead to long-term physiological, metabolic, developmental or behavioral effects, which can in turn lead to reduced survival or reproduction.[71]

An additional significant threat to brown pelican populations is the ongoing erosion of coastal barrier islands and marsh habitat. This erosion was significantly accelerated in places affected by oil.[72]

The federal government has been studying the oil spill's potential impacts on the brown pelican as part of the Natural Resources Damage Assessment investigation. The results of this research are not yet publicly available.

COMMON LOON

Most common loons migrate a thousand miles or more to the Gulf Coast for the winter. During their winter stay, they molt their wing feathers, leaving them flightless for as long as six weeks. Some loons are observed during the summer along the Gulf Coast, but most migrate north by early-to-mid April. Recent studies tracking common loon migration found that loons wintering off the Louisiana coast traveled as far as Saskatchewan, Canada during the breeding season.[73]

Loons eat mostly fish and spend their lives on the water, going onto land only to nest and mate. This leaves loons particularly vulnerable to direct exposure to oil from polluted water as well as to indirect exposure from eating oil-contaminated fish. Long-lived top predators, loons are indicators of overall ecosystem health.

Oil contains polycyclic aromatic hydrocarbons (PAH), which are known to compromise immune and hormonal systems and cause a range of other health problems in birds.[74] Scientists discovered that the frequency and concentrations of PAHs in common loons near Barataria Bay, Louisiana increased between 2011 and 2012, but overall concentrations remained relatively low.[75]

In 2013, however, many loons had PAH levels high enough to cause harm. Researchers also found indications of weathered oil, which contains heavier PAHs that are more toxic to wildlife. This increase may indicate that these oil compounds are making their way up the food chain.[76,77]

Oil can affect birds in a variety of ways, and exposure to oil is not necessarily fatal. Instead, repeated exposure to oil within and between seasons may have sub-lethal effects, such as diminished health and reproductive fitness.[78] It remains to be seen if these levels of PAHs will have adverse impacts on loon health, reproduction and survival.

Charles Robertson

CORAL

Diverse coral colonies provide a foundation for an assortment of marine life including brittlestars, fish and many other organisms.[79] Unfortunately, coral colonies in at least five separate locations in the Gulf—three in the deep sea and two in shallower waters—are showing signs of oil damage.

Despite the challenges inherent in exploring the deep waters of the Gulf, scientists have discovered three deep-sea coral communities impacted by the oil. At one site less than four miles south of the wellhead, more than 90 percent of the corals showed signs of impact.[80] At a site seven miles southwest of the well, nearly half of the corals were damaged, and marine life associated with the coral showed signs of impact. This site was under a documented oil plume from the spill and the petroleum material found on the coral matched oil from the spill.[81] In addition, a sign of coral stress known as hydroid colonization increased at this site over time.[82] The discovery of a third affected site nearly 14 miles southeast of the wellhead, and in 50 percent deeper waters, expanded the known area of impact.[83]

Corals in shallower waters were affected as well. Preliminary analysis of underwater video footage shows that two coral reefs in the oiled area—Roughtongue Reef and Alabama Alps Reef—also had significantly elevated rates of damage after the Deepwater Horizon event.[84]

A separate team found that fish populations declined dramatically on these same two reefs in the aftermath of the spill.[85]

The long-term impact of the spill on affected reefs remains unclear. In a laboratory study, coral larvae that had been exposed to oil, a chemical dispersant, and an oil/dispersant mixture all had lower survival rates than control larvae in clean seawater. This study could have implications for the recovery of impacted coral reefs.[86] Because corals grow very slowly, recovery of dead and damaged corals to pre-spill conditions could take centuries.[87]

EASTERN OYSTER

Oysters are not just a treat for seafood lovers. An adult oyster can filter as much as 50 gallons of water per day, and oyster reefs provide important foraging and refuge habitat for many economically important species of fish and shellfish, including redfish, shrimp and blue crabs.

Oysters live in estuaries—coastal water bodies where fresh water from rivers mixes with saltier Gulf waters. Oyster reefs have been declining for many years across the Gulf's estuaries for a multitude of reasons, including overharvesting, dredging and changes in the way rivers are managed. Despite this decades-long decline, the Gulf Coast still produces about two-thirds of the nation's oyster harvest.[88]

According to a federal report published in 2013, oyster eggs, sperm and larvae were exposed to oil and dispersants during the 2010 oil spill. PAHs can be lethal to oyster gametes, embryos, larvae, juveniles and adults. They can also have sub-lethal effects, such as reduced reproductive success.[89,90] Oysters are vulnerable to oil contamination because they are unable to move away from oiled areas.

The 2013 federal report also noted that intertidal adult oysters were exposed to oil droplets and oil on sediments suspended in the water,[91] although a study done months after the spill found that oyster reefs in oiled areas had PAH levels that were not expected to cause negative impacts on oyster health.[92]

In the fall of 2010, even after the well was capped, oyster larvae were rare or absent in many of the water samples collected across the northern Gulf. Oyster spat recruitment (the settling of oyster larvae onto a hard substrate) was also extremely low or zero in 2010 over large areas of subtidal oyster habitat along the northern Gulf Coast. There was also low spat recruitment through the spring and fall of 2011 and the fall of 2012.[93]

In portions of Louisiana, oysters experienced particularly high mortality and low spat recruitment. This mortality may have been related to oil and to extensive exposure to fresh water. The reduction in recruitment in the years after the spill may be related to lasting effects of the oil, the absence of adult oysters, low salinity, or other factors that are not yet completely understood.[94]


Kathy Reeves

Oyster harvests in the northern Gulf have been markedly low for the past four years.[95] Between 2011 and 2014, average annual oyster harvests declined unevenly in Louisiana, Mississippi and Alabama when compared with the decade prior to the spill.[96] However, commercial oyster harvests vary widely from year to year for a multitude of reasons.

FORAMINIFERA

There are nearly 1,000 species of microorganisms known as foraminifera in the Gulf of Mexico.[97] These small marine creatures are part of the marine food web, serving as a food source for marine snails, sand dollars and fish. Previous research has shown that these sediment-dwelling microorganisms are sensitive to oil damage.[98]

Rapid accumulation of oiled sediment on the Gulf floor between late 2010 and early 2011 contributed to a dramatic die-off of foraminifera.[99,100,101] Researchers found a significant difference in community structure and abundance during and after the *Deepwater Horizon* event at sites located from 100 to 1,200 meters deep in the Desoto Canyon, nearly 60 miles south-southwest of Pensacola, Florida.[102]

Similar research found an 80-to-93 percent decline in the density of foraminifera 35-to-69 miles from the wellhead in late 2010 and 2011. The same scientists also calculated that following the disaster, carbon from petroleum comprises two percent of the carbon in foraminifera shells.[103,104]

Deep sea foraminifera had not recovered in diversity a year and a half after the spill. How long the oiled sediments on the Gulf floor will affect these organisms in heavily oiled areas is unknown.[105]

GULF KILLIFISH

Gulf killifish, also known as bull minnows or cockahoe, play an important role in the Gulf food web and are a common bait fish for anglers. These larger minnows are prey for many sport fish, such as flounder, speckled trout and red snapper. The species lives in coastal wetlands across the Gulf.

This species has been extensively studied in the aftermath of the disaster because of its abundance, sensitivity to pollution, and importance in the Gulf food chain. Oil exposure can alter the killifish's cellular functions, which can lead to developmental abnormalities, decreased hatching success, and decreased embryo and larval survival.[106]

In 2012, Louisiana State University researchers compared the gill tissue of killifish in an oiled marsh to those in an oil-free marsh. Killifish residing in oiled marshes of Louisiana showed evidence of effects even at low levels of oil exposure, including altered regulation of genes associated with blood and blood vessel maintenance.[107,108]

In 2013, scientists released a study that found that killifish embryos exposed to oiled sediments collected more than a year after the spill exhibited effects significant enough to have an impact at a population level, including reduced hatch rates, smaller size at hatch and reduced heart rates.[109,110]

By mimicking field conditions in the lab, scientists last year were able to confirm biological effects of oil exposure. This new research indicates that native killifish were exposed to relatively high concentrations of toxic components in weathered oil from the Deepwater Horizon oil spill that are especially damaging to early life stages, including potential damage to DNA.[111,112]

In particular, toxic PAHs at peak oiling in shallow-marsh sediments of Barataria Bay, Louisiana were found to be sufficient to cause decreased heart rates and decreased hatching success in developing killifish. Exposure at these levels is also capable of causing sub-lethal impacts in adults, including DNA damage.[113,114]

Adult killifish were also used by scientists as a model species to assess the environmental impacts of chemical dispersants. Oil treated with dispersant was consistently more lethal than undispersed oil. Furthermore, they found that Corexit alone could kill fish within a week of exposure.[115]

Additional research has found that four common species of marsh fish, including the Gulf killifish, seem to be avoiding oiled areas. These behaviors, even at small scales, could be significant within marsh communities, leading to changes in food-web dynamics.[116]

INSECTS

More than 100 species of insects and other arthropods, like spiders, inhabit Gulf Coast marshes. Reaching densities as high as several thousand individuals per square meter, insects and other arthropods are an important food source for fish and birds. They also play a key role in nutrient cycling in marsh soils.[117]

Soil concentrations of some toxic compounds from oil increased a thousand-fold in the first three years after the spill, impacting insects and other marsh residents higher in the food chain.[118] Arthropod populations were suppressed by oil exposure even in seemingly unaffected stands of plants.[119] This sensitivity of arthropods to oil exposure makes them a good indicator of marsh health following environmental impacts.[120]

Arthropod communities in affected areas showed some signs of recovery within a year of the oil spill, as long as the host plants remained healthy.[121] However, there is concern that residual oil may continue to suppress arthropod populations for years to come. Preliminary results from Louisiana salt marshes in 2013 and 2014 found continued impacts on the arthropod community, and significant decreases in insect populations at contaminated sites.[122] Re-exposure to oil could take place via slow erosion of marsh shorelines or through disturbances such as coastal storms.

Researchers are currently taking a closer look at impacts on the acrobat ant, an important marsh insect that lives in colonies within marsh grass stems. These ants can serve as an indicator of food web changes in marshes. Preliminary results indicate continued impacts on acrobat ants in oiled sites through 2014.[123]

KEMP'S RIDLEY SEA TURTLE

The Kemp's ridley is the smallest sea turtle in the world and it lives and nests almost exclusively in the Gulf of Mexico. The species was on the brink of extinction in the late 1970s and into the 1980s, with only a few hundred breeding females remaining.[124] The Mexican and American governments have worked together for decades to monitor nesting beaches, halt consumption of turtle eggs, and limit incidental bycatch in shrimp trawls and other fishing gear.[125]

The result of this bi-national collaboration was a remarkable recovery for the species, at least through 2009. In the period before the spill, the number of nests was increasing at an exponential rate—about 15 to 18 percent annually.[126] In 2010, the number of nests dropped by 35 percent.[127] The number of annual nests recovered to pre-spill levels in 2011 and 2012 but fell again in 2013 and 2014.[128] The recovery of the Kemp's ridley, which once seemed inevitable, may now be in doubt.

More than three-quarters of the sea turtles found dead or stranded during the spill and for up to three years afterwards were Kemp's ridleys.[129] However, the recovered carcasses appear to be a small fraction of the total Kemp's ridleys affected. Large-scale federal aerial surveys conducted in 2010 indicated that tens of thousands of sea turtles were within the area of the Gulf that had surface oiling.[130] Modeling done for a recent stock assessment of the Kemp's ridley projected that somewhere between 27,000 and 65,000 Kemp's ridleys died in 2010. In contrast, in 2009 the estimated mortality was 15,000.[131]

Kemp's ridley foraging habitats overlap closely with the surface area oiled. Kemp's ridleys are omnivorous but they are known to feed largely on crabs. Scientists are currently trying determine whether the decrease in nests is due to increased mortality alone, or if adult females may be less healthy and therefore less able to reproduce.[132] This health effect could have been caused by exposure to oil or by a reduction in the available food supply, such as blue crabs. Preliminary studies indicate that the Kemp's changed foraging habitat in 2011 and 2012, but the significance of this change is not well understood.[133]

Laronna Doggett

Kemp's ridleys do not begin to reproduce until they are ten or 12 years of age. Therefore the full extent of impacts to the species may not be apparent for some time.[134] Ongoing Natural Resource Damage Assessment studies will likely yield further insight into impacts on the Kemp's ridley population.

LAUGHING GULL

The high-pitched sound of laughing gulls is as much a part of the soundscape of Gulf Coast beaches as the sound of crashing waves. Having faced serious population declines in the 19th century due to hunting and the feather trade, this species generally recovered well in the early 20th century.[135]

Found primarily in coastal areas near beaches, salt marshes, and estuaries, laughing gulls feed on crabs, shrimp, insects and fish. They breed in colonies, often by the thousands, building their nests on the ground, where eggs and subsequent hatchlings spend four-to-five weeks before taking their first flight.[136] Unfortunately, this nesting behavior put the laughing gull at the front lines for exposure as the oil came to shore.

Based in part on the number of laughing gull carcasses found, research models indicate that 32 percent of the northern Gulf's coastal population of laughing gulls were killed during the disaster. This translates to more than 730,000 individual birds. The study did not calculate how many laughing gulls might have died further offshore.[137]

The National Audubon Society's annual Christmas Bird Count survey revealed that laughing gulls in the five Gulf states declined by up to 64 percent between winter 2010 and the winters of 2011, 2012 and 2013.[138] This substantiates the losses predicted by the modeling study above.

LOGGERHEAD SEA TURTLE

Loggerhead sea turtles are found in temperate and tropical oceans throughout the world and are the most common species of sea turtle found in waters of the United States. However, the species is listed as threatened under the federal Endangered Species Act.

Many beaches where loggerheads nest were at risk of oiling during the summer of 2010. To minimize potential impacts, some 14,700 eggs were moved from the Gulf Coast to beaches along Florida's Atlantic Coast.[139] This action may have saved the hatchlings from entering oiled waters, or the eggs from being exposed to oiled


Jacqueline Orsulak

sand—loggerhead sea turtles eggs are known to absorb PAHs from oil, which can cause physiological and health impacts[140]—but the relocation was not without its own potential impacts. Sea turtles return to nest in the same general area where they hatched.[141] Therefore, it is unlikely that these turtles will return to nest on Gulf beaches when they reach reproductive age.

During 2010, a radio-tracking study revealed that one-third of foraging loggerheads remained in the oil spill area.[142,143] Hatchling and juvenile loggerheads live in Sargassum, but some of this valuable habitat was burned during the disaster response, in an effort to contain surface oil.[144] Studies on the overall status of loggerheads in the wake of the Gulf oil disaster are not available and are likely tied up in the federal government's ongoing investigation.

As loggerheads take some 12 to 30 years to reach sexual maturity,[145] it will be a least another decade before scientists understand whether the oil spill and the relocation of eggs had any significant impact on loggerhead populations in the Gulf.

MAHI-MAHI


Christopher Doherty

Mahi-mahi, also known as dolphinfish or dorado, is an economically important species in the northern Gulf. Like many fish, mahi-mahi produce fertilized eggs that float in the upper layers of the water column. Mahi-mahi were spawning at the time of the oil spill and it is therefore likely that their eggs and larvae were exposed to oil during 2010.

Larval or juvenile exposure to a chemical in oil from the Deepwater Horizon has been shown to cause significant developmental impacts in a number of fish species.[146] Similar research in mahi-mahi corroborates these findings. Embryonic or juvenile mahi-mahi briefly exposed to Deepwater Horizon oil were later unable to swim as fast as unexposed fish. The concentrations of oil in the study were designed to mimic conditions in affected areas of the Gulf.[147] This could translate into increased mortality, as slower fish would likely be less able to catch prey or avoid predators.

These studies could help explain "crude oil toxicity syndrome," which has been observed in a number of fish species, across both fresh and saltwater habitats.[148] Additional research has recently been funded that will look further into impacts in redfish and mahi-mahi.[149]

RED SNAPPER

Red snapper is one of the Gulf's signature sport fish, popular among both recreational and commercial fishermen and prized at markets and in restaurants. Due to this popularity, red snapper in the Gulf have been overfished since the early 1980s.[150] Efforts are in place to rebuild the populations in the Gulf.

Red snapper spend most of their lives offshore, and congregate around hard structures such as natural and artificial reefs. Fertilized snapper eggs float on the ocean surface and hatch within a day. In 2010, oil was on the water surface during red snapper spawning season, and much of the red snapper's range in the northern Gulf overlaps with the area of surface-oil distribution from the blowout.


Flickr: NOAA Photo Library

In the aftermath of the spill, a number of fish caught in the Gulf between eastern Louisiana and western Florida had unusual lesions or rotting fins. Lesions were most common in bottom-dwelling species, including red snapper, and were particularly common north of the wellhead. Results showed that the overall frequency of lesions had declined by about half by 2012.[151,152]

Researchers also examined the livers of red snapper and other fish in 2011 and 2012 and determined that they contained oil compounds with a strong resemblance to the oil from the Macondo well. These compounds in the fish livers declined between 2011 and 2012, suggesting that they came from a specific event—like the oil spill.[153]

Preliminary research indicates additional potential impacts of the spill on red snapper. An analysis of snapper populations in the Gulf done between 2011 and 2013 showed an unusual lack of younger snapper and point to a decline in red snapper growth rates after 2010.[154]

A 2013 stock assessment report, analyzing Southeast Area Monitoring and Assessment Program trawl survey data, found something similar. The study looked at the breakdown of ages of red snapper and found that 2010 and 2011 had the lowest numbers of juvenile fish seen in the eastern Gulf of Mexico fishery since 1994. This led the Gulf of Mexico Fishery Management Council to approve more conservative quotas in anticipation of lower numbers of these fish growing to adulthood.[155]

Related research calculated weight-at-age measurements and identified declines ranging from 11 to 16 percent for fish ages three, four and five in 2010. These results indicate a significant decline in fish growth in 2010, at the same time as the Deepwater Horizon oil spill. Growth rates later returned to normal.[156]

Scientists with the University of West Florida have also observed a significant decline in snapper and other reef fish after the spill. Small plankton-eating fish, such as damselfishes and cardinalfishes, declined most dramatically, but red snapper and other larger reef fish also declined.[157]

However, a study released by Auburn University in 2014 did not find the decline in juvenile fish suggested by the studies above—at least not on artificial reefs at four sites off the Alabama coast.[158] More research on red snapper will be necessary to guide management of this economically valuable species.

SARGASSUM

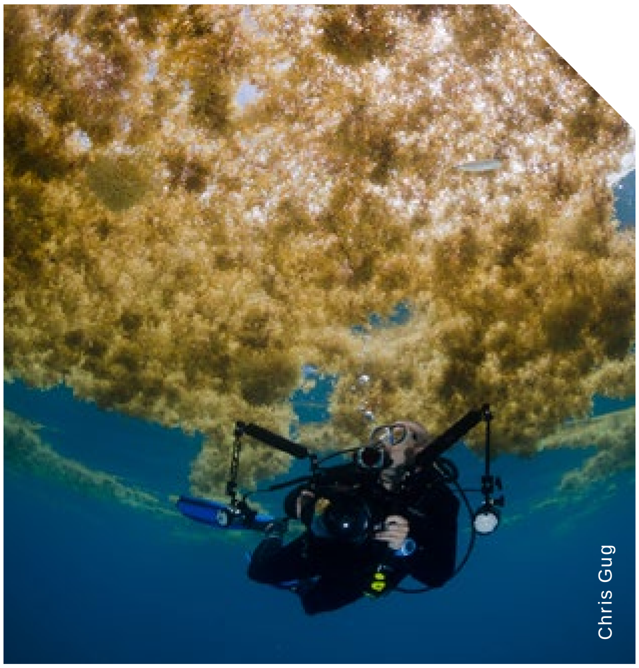
Sargassum, a species of brown algae often referred to as seaweed, floats in large mats on the sea surface. These mats can reach several acres in size and can extend up to 10 feet deep. Sargassum is widely dispersed across the Gulf, particularly off Texas and Louisiana.[159]

Collections of Sargassum serve as a diverse and productive floating offshore ecosystem. More than fifty-four species of fish are known to use Sargassum habitat for shelter, feeding, spawning and as nurseries for juveniles.[160,161] Sargassum also provides habitat for shrimp and crabs, as well as juvenile loggerhead, green, hawksbill and Kemp's ridley sea turtles.[162] In addition, a wide variety of birds forage in Sargassum.

Oil can directly coat Sargassum as well as the life in and around it. Aerial surveys conducted during and after the Deepwater Horizon oil spill documented that Sargassum communities were exposed to oil and dispersant but appear to have later rebounded, increasing four-fold between 2011 and 2012.[163]

Dispersant and dispersed oil had significant effects on the vertical position of Sargassum in the water column. The research suggests there were multiple pathways for oil-spill-related injury, including direct contamination at the surface, exposure of associated wildlife and reduced surface habitat due to Sargassum sinking after dispersant application.[164]

During the active-response phase of the disaster response some Sargassum mats were burned in an effort to eliminate surface oil. It is unknown how



Chris Gug

wildlife associated with Sargassum were impacted by the burning. Because of potential impacts to juvenile sea turtles, the National Wildlife Federation and others argued against this practice.[165]

Ongoing Natural Resource Damage Assessment studies may reveal the extent to which Sargassum was impacted in the oil spill area, as well as the extent to which it has recovered. Even if the Sargassum has returned to pre-spill abundance, long-lived animals that depend on Sargassum, such as sea turtles, could experience long-term impacts.

SEASIDE SPARROW

Lori Oberhofer

Seaside sparrows live only in coastal marshes, where they are common year-round residents that play an important ecological role in this ecosystem. Previous studies of seaside sparrows have demonstrated that the species can serve as a good indicator of the health of the wetlands where they live.[166]

Researchers compared seaside sparrows in unoiled areas to areas with moderate-to-heavy oiling and found a link between oil exposure and reduced abundance. Preliminary data from 2012 and 2013 indicated that nests on unoiled sites were significantly more likely to fledge than those on oiled sites.[167] In 2012 and 2013, seaside sparrows in Louisiana salt marshes were found to have reductions in overall abundance that may have been due to the redistribution of oil after Hurricane Isaac.[168,169]

Because these birds are not aquatic, any exposure to oil would likely come from incidental contact on the shore or from eating oil or insects and other creatures that have oil in their systems.[170] Separate studies have shown a significant decrease in the insect population in oiled marshes, which could be reducing prey availability for seaside sparrows.[171]

Oil from the Deepwater Horizon spill remains in some marshes, putting seaside sparrows at continued risk from direct oiling, contaminated or reduced food supplies, and continued habitat loss.

SPERM WHALE

Franco Banfi

Roughly 700 sperm whales live year-round in the Gulf's deep waters off the continental shelf. Even decades after commercial whaling was outlawed, this unique population—smaller than sperm whales outside the Gulf and with different vocalizations—remains endangered. The preferred range of sperm whales in the northern Gulf largely overlaps the area of surface oil contamination.[172] Capable of diving more than a mile deep, sperm whales could come into contact with oil not only on the surface, but throughout the entire water column and on the Gulf floor.

Sperm whales and several species of dolphins were seen in oiled waters during the time of the spill.[173] NOAA has estimated that thousands of marine mammals were exposed to oil during the Gulf oil disaster.[174] The agency is currently conducting a broad investigation of ongoing whale and dolphin deaths in the northern Gulf. This investigation includes five sperm whales.[175]

Researchers have found higher levels of DNA-damaging metals such as chromium and nickel in sperm whales in the Gulf of Mexico compared to sperm whales elsewhere in the world. These metals are present in oil from the spill and the results suggest exposure, particularly since whales closest to the wellhead showed the highest levels. Whales known to be full-time residents in the Gulf had higher levels than seasonal migrants. This study suggests that metal exposure is an important, yet understudied concern for the Deepwater Horizon oil spill.[176] Exposure to oil could have come via direct ingestion of contaminated waters, inhalation of aerosol particles, absorption through the skin, or consumption of contaminated prey. Further research identifying the pathways of exposure is warranted.

Little is known about the toxicity of dispersants or their long-term health effects in marine mammals. One recent study found that the two dispersants used in the Deepwater Horizon spill—Corexit 9500 and 9527—were both found to be damaging to sperm whale cells and DNA.[177] This outcome raises concerns around impacts of Corexit on reproduction, development, and potentially carcinogenesis in marine mammals and other species.

Furthermore, two separate teams of researchers have found that sperm whales are spending less time foraging in the area around the wellhead.[178,179] Prior to the spill, this general area was thought to have been a preferred sperm whale feeding ground. The long-term significance of this change is unclear, but one concern is that these whales are being forced into less suitable areas.

SPOTTED SEATROUT

The spotted seatrout, commonly known as speckled trout, is a commercially and recreationally important species that resides in estuaries in the northern Gulf of Mexico. These fish are considered an excellent indicator of habitat conditions, given the rapid rate at which they reach sexual maturity and their relatively long lifespan.[180]

Spotted seatrout are batch spawners, meaning that they shed eggs more than once during a spawning season, in this case from April through September. As a result, it is highly likely that their young were exposed to dispersed oil as either larvae or juveniles in 2010.[181]

Laboratory studies on larval and juvenile spotted seatrout exposed to dispersed oil showed no difference in mortality but demonstrated a significant decrease in growth rates after 96 hours of exposure.[182] Studies have shown that even slight changes to growth rates can potentially impact population structure.[183]

In 2011, researchers collected spotted seatrout less than one year old from Louisiana and Mississippi and compared their reproductive organs to those of seatrout collected pre-spill from the same areas. Results indicated that spotted seatrout from both states evidenced significant negative impacts on their reproductive potential when compared to previous years.[184]

Barbi Martinson

Interestingly, while female spotted seatrout in Mississippi exhibited development delays at the beginning of their reproductive season one year after the oil spill, as compared to pre-spill data, this did not appear to be true for spotted seatrout in Louisiana. However, dramatic reductions in spotted seatrout spawning frequency were also noted after the spill in both Louisiana and Mississippi, suggesting the potential for population impacts such as reduced recruitment into estuaries.[185]

Mark Matthews

WHITE PELICAN

American white pelicans nest in colonies of several hundred pairs on islands in remote inland lakes in North America, and they winter on the Pacific and Gulf Coasts. Most white pelicans were in their northern breeding grounds at the time of the spill.

Two years after the spill, however, researchers found evidence of oil and dispersant in the eggs of white pelicans nesting in Minnesota. Scientists made this discovery at Marsh Lake, which is home to the largest colony of white pelicans in North America. Petroleum compounds were present in 90 percent of the first batch of eggs tested. Nearly 80 percent of the eggs contained the chemical dispersant used during the Gulf oil spill.[186]

White pelicans could have been contaminated while wintering in the Gulf, either through direct contact with remaining oil and dispersant or by eating contaminated fish. Long-term increases in breeding pairs in Minnesota have occurred since 2004, but from 2011-2012 the breeding population has essentially stabilized.[187]

Scientists from the Minnesota Department of Natural Resources are continuing to investigate the impacts of these compounds, which have been known to cause cancer and birth defects and to disrupt embryo development in other species.[188,189]

Contaminated eggs have been found in two other states as well. In 2012, staff at the Upper Mississippi National Wildlife Refuge collected eggs that failed to hatch from pelican colonies in the Iowa and Illinois portions of the refuge.[190]

Population declines in migratory shorebirds and reduced breeding productivity may have an impact on ecosystems outside the Gulf region.[191] Therefore it is important to link wintering and breeding locations for migrant species in order to fully understand the impacts of the Gulf oil disaster.

RESTORING THE GULF OF MEXICO

The 2010 Deepwater Horizon oil spill focused the world's attention on the environmental and economic importance of the Gulf of Mexico. In addition to causing the tragic deaths of 11 men, the disaster closed vast areas of the Gulf to fishing, killed and injured countless marine mammals, shorebirds, sea turtles and other wildlife, and damaged the Gulf's delicate web of life in ways that are still unfolding.

This report describes what we know so far about how twenty wildlife species (or groups of species) are faring in the wake of the disaster. It may take years or even decades before the full impacts are known, and more research is clearly needed. In the meantime, restoration of the Gulf ecosystem must become a high priority for the nation.

In order to advance the restoration of the Gulf of Mexico and prevent a disaster of this magnitude from happening again, the following actions should be taken:

- The Department of Justice must hold the parties responsible for the Deepwater Horizon spill fully accountable for their violation of federal environmental laws, including the Clean Water Act and the Oil Pollution Act.
- Federal, state and local officials must direct the fines and penalties paid by the parties responsible for the Deepwater Horizon oil spill to ecological restoration efforts that will make the Gulf healthier and more resilient for people and wildlife.
- Any settlement of claims must include a reopener clause to hold the responsible parties accountable for damages that may be identified in the future.
- Congress and the Administration must reform oil and gas leasing practices and permitting requirements to better safeguard people, communities, wildlife and the environment.

In December 2014, the National Wildlife Federation released *Restoring the Gulf of Mexico for People and Wildlife: Recommended Projects and Priorities*. This report recommended to the RESTORE Council[192] for funding a suite of projects across the Gulf that would greatly enhance the health and productivity of the region. Our recommendations follow four principles aimed at creating tangible benefits for wildlife and for the millions of Americans who live, work and recreate along the Gulf coast.

- **Restore the Balance between Fresh and Salt Water:** Estuaries, where fresh water from rivers mixes with the saltier waters of the Gulf, are vital habitat for young fish, crabs, shrimp, oysters and most of the species of fish we eat. But over the past hundred years, most of the major rivers that flow into the Gulf of Mexico have been substantially altered in one way or another. Many rivers have been leveed, or dammed, or deepened and straightened by dredging, their seasonal cycles of flow altered, and their water diverted for cities, agriculture or navigation. Restoring the natural flows of fresh water and sediment into coastal estuaries will greatly benefit fish and wildlife both along the coast and in the deeper Gulf waters.

- **Restore Wetlands:** Wetlands play a critical role in the Gulf ecosystem—providing wildlife habitat, filtering pollutants and protecting communities from storms. Wetlands also support the commercial and recreational fishing industries. Wetlands and marshes across the Gulf Coast are at risk, but the problem is most pronounced in Louisiana's Mississippi River Delta. These wetlands are eroding or sinking at an alarming rate, in part because levees erected for flood control prevent the Mississippi River from building and sustaining land in its delta. Projects to strategically re-introduce sediment and fresh water from the Mississippi River into the delta could rebuild or protect as many as 300 square miles of wetlands by 2060.

- **Restore Oyster Reefs:** Estuaries like the Mississippi Sound and Pensacola Bay are estimated to have each lost more than 90 percent of their historical oyster reefs. Restoring oyster reefs along the Gulf Coast will improve water quality and clarity and create habitat for fish and wildlife—all while protecting shorelines from storms and erosion.

- **Protect Critical Landscapes:** The Gulf Coast's five states boast a rich diversity of habitat types: barrier islands, beaches, dunes, marshes, forested wetlands and coastal prairies, among others. With 86 percent of these lands in private hands, landowners can play an important role in the long-term recovery of the Gulf Coast—restoring marshes and long-leaf pine forests, supporting efforts to protect water quality, or just setting land aside for the benefit of wildlife. These private-landowner actions should be encouraged, and where appropriate, key parcels of coastal lands should be purchased and managed to protect their natural resource value and support the long-term health of the Gulf Coast.

The Gulf Coast's economy and way of life are deeply connected to the land and the water. The fines and penalties from the Gulf oil disaster have great potential to restore and protect a region that is vitally important to our nation's ecological, economic and cultural health. However, there is a real risk that some of these funds could be spent unwisely—even squandered on projects that would harm the very places the money was intended to benefit. The public can and should insist that all recovery dollars be spent on scientifically sound restoration projects that will ensure a healthy Gulf of Mexico for the wildlife and people who depend on it.

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