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IMPACTS FROM THE DEEPWATER HORIZON OIL SPILL ON GULF OF MEXICO FISHERIES

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Since 2010, scientists have studied marine ecosystems in the Gulf of Mexico to more fully understand the impacts from the Deepwater Horizon oil spill in the region. Knowing how oil and dispersants affect fisheries can help natural resource managers maintain healthy Gulf of Mexico ecosystems and protect the livelihoods of people who depend on them.

Fish, such as this sailfish, are studied, weighed, and measured throughout the Gulf of Mexico in order to provide further health information relating to the individual and population. (Texas Sea Grant/Tony Reisinger)

UNDERSTANDING OIL IMPACTS TO FISHERIES

Oil spills can impact individual animals, **populations**, or **communities** of interacting organisms in the marine environment.[1] For instance, if small fish die from exposure to oil, then other fish or birds that normally eat those small fish will have to find other food to eat. These changes can alter the **food web** and influence important seafood species.[1] Changes in population and communities

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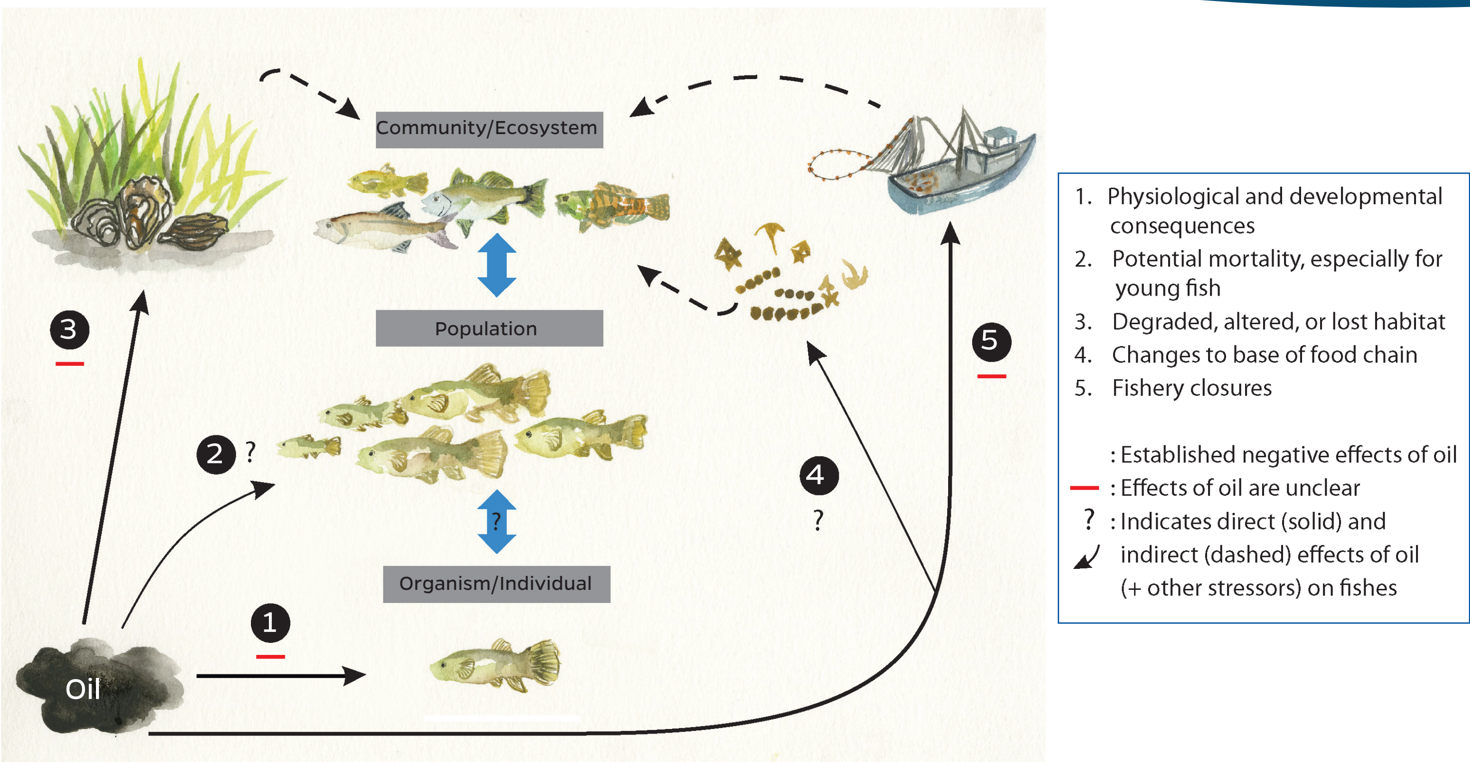

FIGURE 1. *Oil impacted multiple levels of fisheries at the individual level, the population level, and the community or ecosystem level. See the figure key for symbol description. (USF with permission from CWC/Joel Fodrie, adapted by Anna Hinkeldey)*

are often harder to detect but can be more relevant to the whole food web. When trying to understand how the Deepwater Horizon (DWH) oil spill affected fisheries in the Gulf of Mexico, scientists can conduct studies at three different levels:

1. The individual level, or how oil spills may impact a single living thing (such as an individual fish).
2. The population level, or how oil spills may impact a group of living things of the same species (such as a population of red snapper).
3. The community level, or how oil spills may impact many different species in an area or habitat (such as an entire reef fish community).

By dividing studies into these general levels, scientists can more easily investigate impacts of oil and **dispersants** on the complex Gulf of Mexico ecosystem (**Figure 1**).[2] Oil is a mixture of many compounds, including **hydrocarbons**. Some, though not all **polycyclic aromatic hydrocarbons (PAHs)**, can be harmful to living things.[3] Emergency response teams used dispersants, which also contain compounds that can be harmful, during the DWH oil spill to break up spilled oil into smaller droplets. These smaller droplets are then available to the Gulf's aquatic **microbes**. The microbes consume oil, breaking it down, and reduce impacts to other species and the amount of oil that would reach the coastline.[4]

Individual-level impacts to fish

When an oil spill occurs, animals in ocean and coastal waters may be exposed to oil and dispersants in the very rare instances, including DWH, when dispersants are used on an oil spill. The DWH spill was unusual in that large amounts of dispersants were applied both at the surface and underwater at the well head. Fish breathe by passing oxygen-rich water across their gills (**Figure 2**). In spill-impacted areas, oil-polluted water can come in contact and coat the gills, reducing how much oxygen the fish can absorb.[5,6] Contaminants can also enter the bloodstream through the gills and nose and then be delivered to other body parts, which can harm or kill fish.[5] Fish can be exposed to PAHs on their skin, scales, or when they eat other sea life tainted with oil.[6] Oil can impact individual fish differently due to variability in habitat, behavior, diet, and life stage.

Gulf killifish are an abundant fish in the Gulf, often used for bait, and tend to stay within a small area for their entire life. If that area is oiled, it can have an impact on individuals and possibly the entire local population. Scientists regard killifish as an **indicator species**,

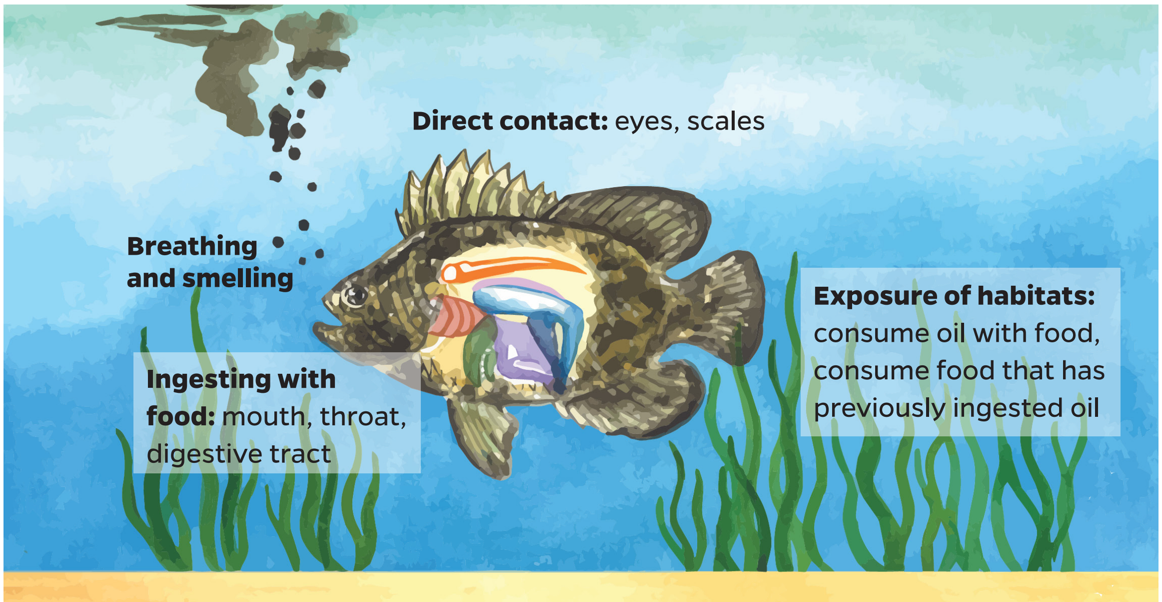

FIGURE 2. *Fish, like this tripletail, can encounter oil and other contaminants in multiple ways. (Anna Hinkeldey)*

meaning its presence or absence, abundance, and relative well-being can indicate the general health of its environment.[2] Scientists found that Gulf killifish in the field and laboratory experience negative effects to their **genes**, internal chemical reactions, gills, heart, blood vessels, and embryos when exposed to oil.[7-9]

Scientists collected 10 species of grouper—a recreationally and commercially important fish—over a period of six years to better understand the impacts of PAHs throughout the Gulf.[10] Initially the levels of PAHs decreased in the three years following the spill. However, levels rose after that period. This increase is likely due to resuspension of oil buried in the seafloor, natural oil seeps, and runoff from human sources (industry, river flow, etc.).[10] Scientists studying grouper are still unsure at what PAH concentration level exposed fish are no longer able to function.[10]

Effects of oil and dispersants vary depending on the species and life stage. Embryos and **larval** fish are very susceptible to oil because they often float and have a thin coating, similar to an egg sac, that can absorb chemicals when they come in contact with it.[11] In addition, other factors such as ultraviolet (UV) wavelengths from sunlight can further increase damage from exposure to oil. UV wavelengths break down and increase the toxicity of oil to larval fish more than droplets not exposed to UV light.[12] Potential effects from encountering UV-broken-down oil in the environment can include impacts to feeding and survival, delayed hatching, lowered reproduction rates, and changes in behavior that reduce time exposed to sunlight.[12]

The blue crab is another vital fishery species that spawns in the northern Gulf of Mexico. A study of oil effects on blue crab growth and development concluded that larval and juvenile crabs developed normally, but that oil-exposed juveniles took longer to enter each life stage.[13] Exposure to PAHs may also affect female crabs with eggs and developing embryos.[14] Laboratory studies comparing the effects of oil, three different dispersant types (Corexit 9527 and 9500, and MicroBlaze®), and a combination of oil and each of the dispersant types, determined that any oil and dispersant mixture was the most toxic to crabs, with Corexit 9527 having the greatest negative effects overall.[15] This toxicity is due to the increased amount of oil available in the water after it is dispersed. The use of the dispersant Corexit 9527 during the DWH spill was relatively limited compared with Corexit 9500, and future use will not occur as this specific formula is no longer manufactured. Depending on the concentrations of the oil and dispersant mixture used in laboratory tests, growth into the next life stage was reduced by an average of 37%.[15] This growth to the next life stage, like metamorphosis of a butterfly, is energy consuming and can contribute to young crabs' vulnerability to chemicals like oil and dispersants.[13,15]

As the result of a new, non-invasive PAH detection method that enabled scientists to test the mucus on a fish's skin without harming the fish, scientists now know more about how various species fare after oil exposure by looking at how genes in the mucus are altered.[16] Mahi-mahi exposed to PAH in laboratory studies caused damages to cardiac development because heart cells are not able to contract as well after they are exposed to oil. The mahi mahi embryos also showed reduced ability to swim, behavior changes, and overall decreases in health and survival.[16,17]

If oil contaminates the seafloor as it did during DHW, PAHs break down more slowly in oiled **sediments** in the seafloor than in the water.[18] Bottom-dwelling fish that live in or on top of the seafloor could potentially be exposed to oil and PAHs when their skin makes direct contact with the oiled seafloor, when they ingest contaminated sediment while burrowing, or when they ingest prey that also live near the seafloor. As a result, if the seafloor is contaminated, bottom-dwelling fish, such as flounder or golden tilefish, can be exposed to oil and oil-derived chemicals for longer periods of time and have longer-lasting impacts than fish who do not spend time on the sea floor.[18,19] Laboratory studies of southern flounder found that when they were exposed to high levels of PAHs, they spent more time swimming and avoiding laying on the bottom.[18] Scientists studying wild golden tilefish, a commercially important fish that burrows into the seafloor sediment, found increased levels of PAHs in their bodies that were persistent for years following the DWH. Although tilefish were able to break the oil down over time, the extra energy required to do so may have taken a toll on their body condition and energy storage.[19] Overall size and fat content are important indicators of survival and reproductive potential that may demonstrate the possibility of a population-level impact. These two examples show how fish behavior can be altered by the exposure and effects of an oil spill.

Individual-level impacts do or have the potential to increase fish death, lower reproductive output, and decrease growth, all factors that could lead to a population-level change if serious enough.

Population impacts

The DWH oil spill occurred at a time of year when many aquatic species from the Gulf were **spawning**. Eggs, embryos, and larvae were at risk of exposure to oil and dispersants, which could impact the next generation of the population (**Figure 3**).[20] Some studies have shown negative impacts to individual fish from DWH, and changes in some fish populations.[4] Even with limited data prior to DWH on open ocean and deeper depths, some fish and invertebrate species declined substantially since 2010 and have not yet recovered.[21] Further, one study documented an increased uptake of PAHs in migrating fishes associated with DWH.[22] Another study that used modeling to predict changes suggested the reef fish population decreased 25 to 50% and larger more mobile species decreased by 40 to 70%, depending on the species.[23] Other population behaviors, such as mating trends, can influence outcomes. Recovery of populations that can reproduce quickly can happen within 10 years; for other slower growing populations, it may take over 30 years to recover.[23] The Eastern oyster population, an important fisheries species, decreased substantially, particularly in coastal Louisiana where oil spill response actions flooded marshes with fresh water.[24] Scientists could not solely tie this reduction in population to oil exposure but to multiple factors, including the prolonged flow of diverted river water that responders used to keep oil away from nearshore areas.[22] After DWH the coastal fish and invertebrate community changed substantially in Barataria Bay favoring species with more freshwater connections.[21] Not all fishery populations declined after DWH. Scientists monitoring Gulf menhaden and shrimp (brown and white species) found that numbers increased in some oiled estuaries.[26,27]

Another question that interested scientists was how different groups of blue crabs interact with each other after the spill.[28] In nature, sub-populations (or smaller groupings) of a species usually live in different locations within a broader region like groups of neighbors in a

FIGURE 3. *Dr. Pasparakis observes changes in development of mahi-mahi embryos under a microscope. (Gulf of Mexico Research Initiative/DiNicola)*

Blue crabs like this one were extensively studied after the Deepwater Horizon. (Bree Yednock)

larger city. The individuals from these sub-populations move around in order to mate or find food. Due to the ability to feed, reproduce, and move from place to place, blue crabs and other creatures benefit from interacting with various sub-populations because these connections help the population survive if a disaster like an oil spill occurs.[28] To better understand this connectivity of sub-populations, scientists looked at where blue crab larvae traveled using computer models, a much more efficient and affordable way to study tiny organisms. They calculated that a portion of the Gulf blue crab population was exposed to oil during spawning time. They also determined that the blue crabs who survived oil exposure settled in a particular area east of the Mississippi River Delta.[28] These types of species-specific and location-specific population models can help resource managers make decisions about how to protect resources during future spills.

Oil exposure can cause behavioral changes to individuals and populations in addition to physical effects from contact with the chemicals in oil and dispersants, including impacts to the coordination of a group's movement. These changes can alter the ability to find food, reproduce, and avoid predators. A study that focused on the movement and coordination of a group of Gulf menhaden, a schooling type of fish, found that oil impacting just one fish disrupted group movement.[29]

Community-wide impacts

Exposure to contaminants can cause the population size of species that make up the food web to change.[1] For instance, species that are sensitive to pollution can diminish over time because they die or become unable to reproduce. If the number of a species decreases dramatically, then prey or predator population sizes could also be altered due to lack of food.

For instance, scientists collected fish in oil-affected seagrass meadows in the northern Gulf to assess the types of fish living there. Comparing catch numbers from 2006 through 2010, they found that the DWH oil spill did not negatively impact coastal wetland fish communities.[30] Mangrove snapper, pigfish, spotted seatrout, hardhead catfish, and sheepshead are some of the species they caught in greater numbers after the oil spill compared to before.[30] Other species, such as many commercially important shellfish species, recovered fairly quickly after the DWH spill.[31]

Some scientists study what fish are eating to gain clues about potential shifts in diet following oil exposure. Plankton, often small organisms that drift or float in bodies of water, are an important part of aquatic food webs. Some shifts in the plankton community after DWH varied by depth.[32] For example, studies have found red snapper usually consume a variety of prey ranging from swarms of **zooplankton** to fish and crustaceans, like shrimp and crabs.[33] Scientists found that larger, more mature red snapper include more small organisms like zooplankton in their diets.[33] After DWH, scientists found that adult red snapper diets shifted away from zooplankton and increased their consumption of other animals like fish, squid, shrimp, and crabs.[34] Information on how species change or adjusts their diet after oil exposure is useful to scientists as well as decision makers working to protect natural resources.

FISHERIES CLOSURES DECSISIONS AFTER THE DEEPWATER HORIZON SPILL

During DWH, emergency managers closed large fishing areas of the Gulf and reopened them when there was no visible sign of oil and chemical tests indicated safe PAH levels in seafood.[40,41] In June 2010 the largest area of closure was over 88,500 square miles, which is about 37% of U.S. fishable waters in the Gulf of Mexico.[41] Most fishing areas reopened within a year or two; however, the last one in Louisiana reopened in 2015. Models run to determine how DWH fishing closure orders affected fisheries found they had little influence on overall population sizes.[23]

In addition to food web studies, the number of species found in the same habitat can also help determine potential oil spill impacts on fisheries. Fisheries scientists do this by catching fish and counting them in their natural habitat. They then compare population numbers within communities over time to look for changes. Results of many studies indicate changes in the communities, although many factors could affect community changes besides the oil spill.[35]

Scientists documented the amount, type, and size of fish at oiled versus unoiled marshes in Louisiana and did not find any differences.[36] Similarly, in coastal Alabama scientists collected animals that normally live in both offshore and nearshore habitats throughout their life cycle to see if oil exposure affected how successfully they reproduce.[37] Although they did find a short-term drop in amounts of both blue crab and grass shrimp immediately after the spill, those numbers recovered to pre-spill levels within two years.[37]

FACTORS THAT INFLUENCE IMPACTS TO FISHERIES

Many factors must be considered when making conclusions about oil impacts to fisheries. Environmental conditions prior to a spill; how much oil a habitat received; the diversity of plants and animals, including microbes and algae; the quality of soil; and available food all play a role in the recovery of the fisheries of that area.[38] About 18 months after DWH, marsh plants began to grow back, leading the way for a reestablishment of other plants and small animal recovery at heavily oiled sites.[39] Scientists must understand specific impacts and the time it takes for areas to recover to help create restoration plans.[38]

Scientists use a three-tiered approach—individual, population, and community-wide impacts—to understand oil spill impacts on Gulf of Mexico fisheries. Field observations and laboratory studies have shown evidence of negative impacts to individual fish in the Gulf. Some species populations with impacted individuals have seen slight changes in population sizes—some for the better—but most are at similar population levels pre-spill.[4] Most study sites have a history of oil exposure before DWH due to natural seeps and other causes. Since completely unoiled locations in the northern Gulf do not exist, populations of marsh fishes may be conditioned to PAHs and therefore able to recover from oil exposure.[36] Some scientists suggest that young transient animals, like fish and crabs that spend their lives moving among estuaries, are better suited to cope with big disturbances like spills.[37] Scientists continue to explore factors influencing these results, including susceptibility, vulnerability, habitat alterations, climate change, and commercial harvest.

GLOSSARY

Community — A group of populations of plants and animals in a given place.

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.

Food web — A system of linked food chains within an ecological community.

Gene(s) — Unit of DNA, passed from parent to child, that codes for a trait in an organism (for example, coloration, size, stress response).

Hydrocarbon — A compound composed of carbon and hydrogen atoms. Most hydrocarbons naturally occur in crude oil and natural gas and are formed from decomposed organic matter.

Indicator species — A representative organism whose presence, absence, and change in population numbers or health status can help gauge the status or health of the whole system.

Larval/larvae — The immature form of an animal that undergoes physical changes during its life.

Microbes — Very tiny or microscopic organisms including bacteria, fungi, archaea, and protists. Some microbes (bacteria and archaea) are the oldest form of life on earth.

Polycyclic aromatic hydrocarbons (PAHs) — A chemical group found in many sources, including but not limited to oil, tar, ash, coal, car exhaust, chargrilled animal fats, and smoke from burning oil or wood.

Population — A group of individuals that interbreeds and inhabits a specific area.

Sediment(s) — Natural materials (including rocks, minerals, and remains of plants and animals) broken down by weathering and erosion, and then transported and deposited to a new location by wind, water, or ice and gravity.

Spawning — A group of individuals that interbreeds and inhabits a specific area.

Zooplankton — Small animals, and the immature stages of larger animals, drifting in oceans, seas, and bodies of fresh water.

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