OIL SPILL SCIENCE

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

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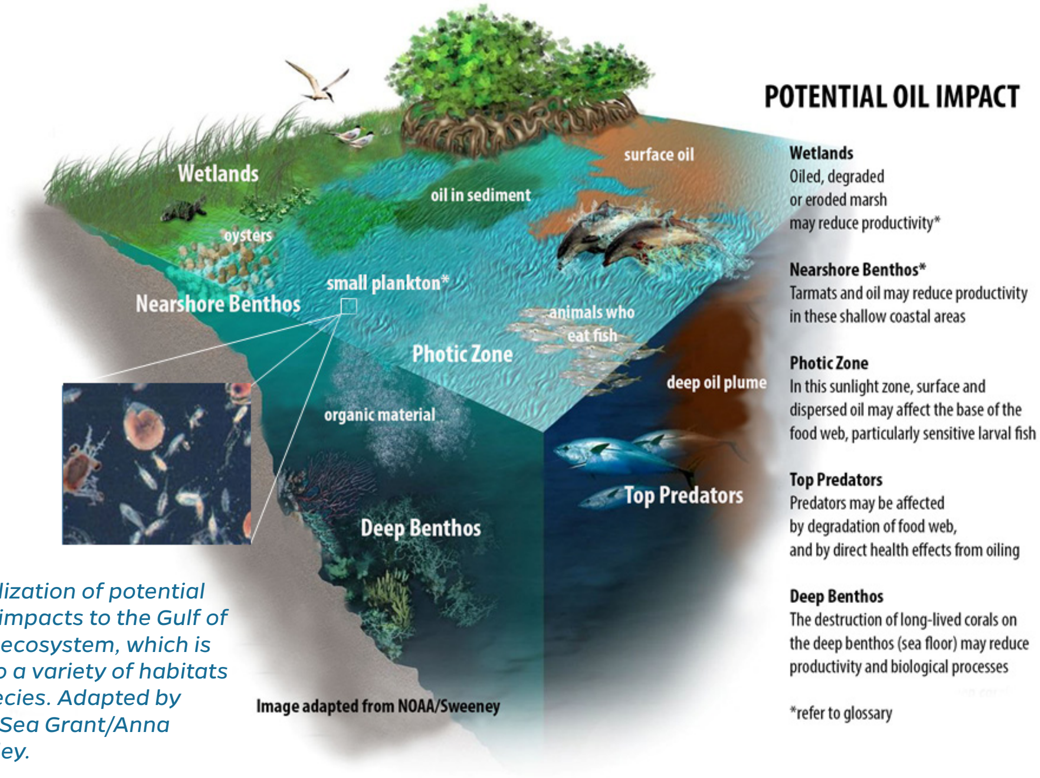
Scientists are studying aquatic ecosystems in order to fully understand the 2010 Deepwater Horizon oil spill's impact. Knowing how oil and dispersants might affect fisheries can help natural resource managers maintain healthy Gulf of Mexico ecosystems and protect the livelihoods of the people who depend on them. The following publication highlights some examples of the way species were affected by the spill.



A visualization of potential oil spill impacts to the Gulf of Mexico ecosystem, which is home to a variety of habitats and species. Adapted by Florida Sea Grant/Anna Hinkeldey.

INTRODUCTION

Oil is a mixture of many compounds. Some are known as **hydrocarbons**. These form from decomposed organic matter and occur in crude oil and natural gas. There are different types of hydrocarbons in oil. One type of hydrocarbon is a **polycyclic aromatic hydrocarbon** (**PAH**). Some PAHs can be harmful to living things.[1]

Emergency response teams sometimes use chemicals such as **dispersants** to reduce the effects of oil spills. Dispersants break up spilled oil into smaller droplets. These smaller dispersed oil droplets can become more available

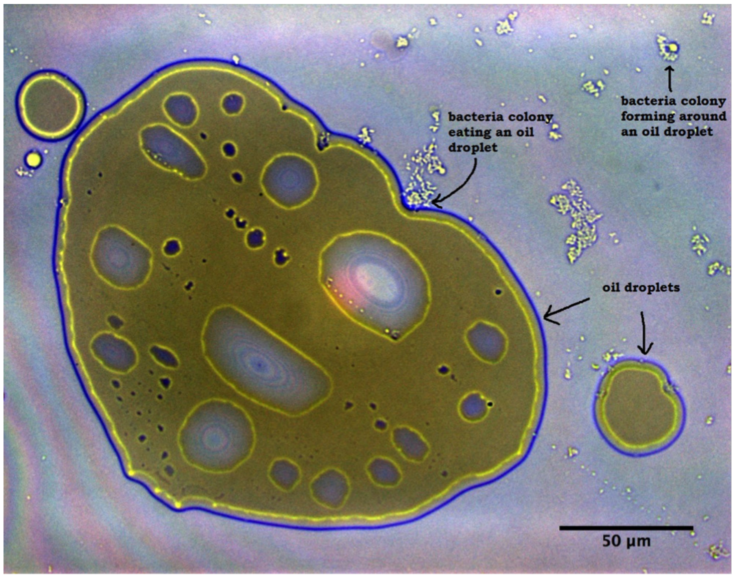


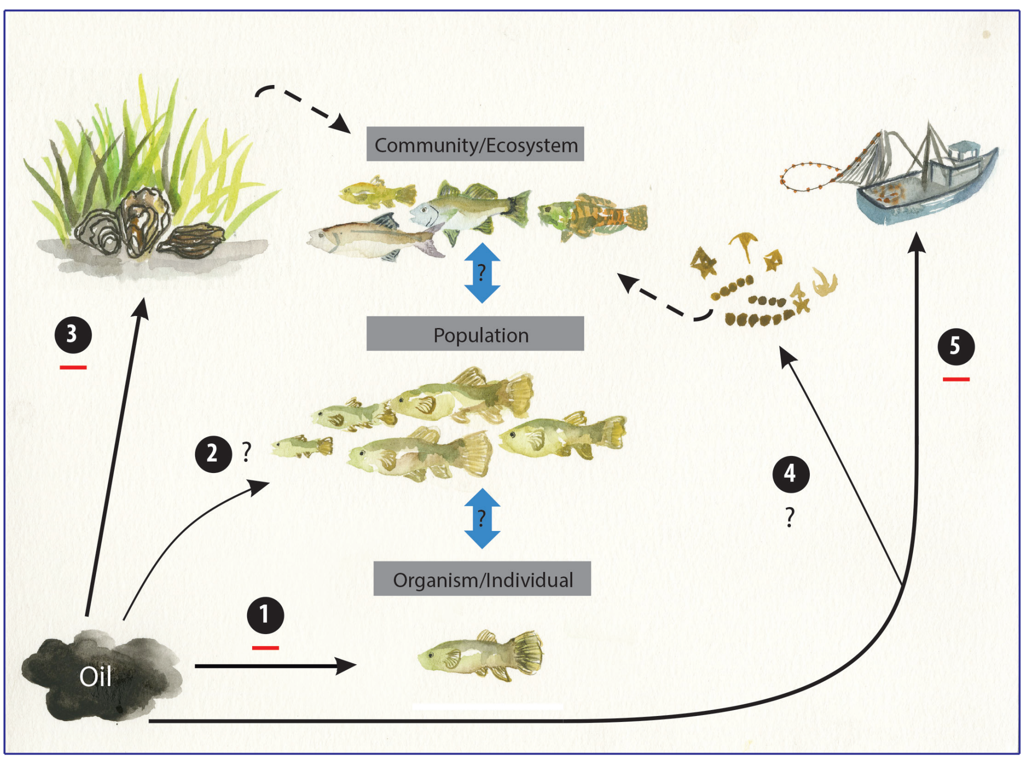
FIGURE 1. *A microscopic image of oil droplets being colonized and consumed by bacteria (a type of microbe)* **P. aeruginosa**. *As bacteria eat, the oil droplets change in size and consistency. Photo by DROPPS/Tagbo H.R. Niepa, adapted by Chris Hale*

to the Gulf's tiny aquatic **microbes.** These microbes consume oil and remove it from the ecosystem (Figure 1). Dispersants that are used on offshore oil spills can help prevent large quantities of spilled oil from drifting onto shorelines where cleaning up oil is challenging.

Individual creatures, entire **populations**, or **communities** of interacting organisms can be impacted by oil spills.[2] 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. This alters the **food chain** and could have consequences throughout an entire **food web**, including effects to the seafood that people eat.[2] When trying to understand how the oil spill affected **fisheries**, scientists conduct studies on three different levels:

1. The individual level, or how oil spills may impact a single living thing (like a fish).
2. The population level, or how oil spills may impact a group of living things of the same species.
3. The community-wide level, or how oil spills may impact many different kinds of living things in an area or habitat.

By dividing studies into these general levels, scientists can investigate impacts to the complex Gulf of Mexico ecosystem. Figure 2 portrays this approach, and the following sections highlight examples of impact studies that scientists have conducted since the spill.[3]



1. Physiological and developmental consequences
2. Potential mortality, especially for young fish
3. Habitat loss, degradation or alteration
4. Changes to base of food chain
5. Fishery closures

— : Established negative effects of oil
? : Effects of oil are unclear
↙ : Indicates direct (solid) and indirect (dashed) effects of oil (+ other stressors) on fishes

FIGURE 2. *Diagram of scientifically documented impacts from the Deepwater Horizon oil spill, organized by level: the organism or individual level, the population level, and the community or ecosystem level. See the figure key for symbol description. Adapted by Florida Sea Grant/Anna Hinkeldey/USF with permission from CWC/Joel Fodrie.*

INDIVIDUAL-LEVEL IMPACTS TO FISH

When an oil spill occurs, animals in ocean and coastal waters may be exposed to oil and dispersants in several ways. This exposure can impact their health. For example, fish breathe by passing oxygen-rich water across their gills. In doing so, oil-polluted water can make contact with the gills and cause damage. This makes **respiration** challenging.[4,5] Contaminants can also enter the bloodstream through the gills and then be delivered into the fish's other body parts, which can harm or kill them.[4] Fish can also be exposed to PAHs when they eat prey tainted with oil.[5] Additionally, bottom-dwelling fish and other animals could potentially be exposed to PAHs from contaminated sediments when their skin makes direct contact with the sea floor.[6]

The Deepwater Horizon oil spill negatively impacted the health of individual fish.

Gulf killifish are an abundant bait fish in the Gulf and tend to stay within a small area for their entire life. Killifish are regarded by scientists as a **sentinel species** whose presence or absence, abundance and relative well-being can indicate the general health of its environment.[3] Thus, scientists often test these fish to monitor oiled Gulf coastlines. Scientists have found that Gulf killifish experience negative effects to their **genes**, **enzymes**, gills, heart, blood vessels, and **embryos** when exposed to oil and dispersants.[4,7,8,9]

After the oil spill in 2010, numerous fishermen reported seeing skin lesions (sores) on offshore fish species like red snapper, yellowedge grouper, tilefish, and others.[6] These observations raised questions about the cause-and-effect relationship between the oil spill and fish health. Scientists verified that for a short time after the spill, fish were exposed to elevated levels of PAHs.[6] During that time there was also an increase in the occurrence of fish skin lesions.[6] However, scientists could not directly link DWH oil samples to the fish that had lesions. Through further testing, many other possible sources of contamination were eliminated as causing the lesions.[6] The frequency of lesioned fish in the northern Gulf has declined in the years since Deepwater Horizon oil spill (DWH).[6]

FIGURE 3. *The eye and lens of red grouper are being investigated along with lenses of other species for their potential use as a biomarker, or indicator, of environmental pollution. Photo: C-IMAGE/ Amy Wallace*

POPULATION IMPACTS

The DWH spill happened when many aquatic species were **spawning** in the Gulf. Eggs, embryos, and **larvae** were at risk of exposure to oil and dispersants.[11] Studies have shown negative impacts to individual fish.[4,6,7,8,9] Scientists want to know if those impacts carry over to entire populations of fish or other wildlife.

Impacts to populations of organisms are unclear, but science is revealing information important to resource managers.

*Scientists think that fish eyes could become **biomarkers** of environmental pollution.[10] A part of the eye known as the lens has been found to reveal information about an individual fish's life, such as where it has lived.[10] To figure out the connection between fish lenses and their habitats, scientists remove the eyes from captured fish. They then read certain parts of the eyes to look for chemical clues— similar to reading a tree's rings to learn its age. Scientists want to know if a fish that lived in a polluted area will have remnants of that pollution in its eyes. This idea is still being tested, and someday it might be possible to link fish to local contaminants by analyzing their eyes (Figure 3).[10]*

To determine the population level impact to red snapper, scientists observed population numbers of young red snapper using reefs.[11] Young red snapper normally move from coastal nursery areas to inshore and offshore reefs to continue growing. Therefore, scientists set up artificial reefs along coastal Alabama to count young red snapper for a year after the spill.[11] They could not link red snapper **recruitment** levels on those reefs to the oil spill.[11] However, at one study site they discovered that the presence of older and more territorial red snapper influenced how many younger red snapper lived near that particular site.[11] Low oxygen conditions also played a role in recruitment.[11] Factors like habitat preference, fish behavior, and environmental condition are important in assessing the impact of oil spills on fisheries and the Gulf ecosystem.

Blue crab is another vital fishery species that was spawning in the northern Gulf of Mexico when the DWH oil was spilling. Scientists had questions about the impact to blue crab larvae and how different groups of blue crabs were interacting with each other.[12] In nature, sub-populations (or smaller groupings) of a species usually live in different locations within a region. The individuals from these sub-populations move around in order to mate or find food. Blue crabs (and other creatures) benefit from interacting with one another because these connections help them survive if a disaster like an oil spill happens.[12] To better understand this **population connectivity**, scientists looked at blue crab **larval dispersal** and **larval settlement**. Field studies of the movement of large numbers of live, tiny, aquatic organisms like blue crab larvae are very challenging and costly.[12] Instead, scientists used computer models to make predictions about dispersal and settlement. 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 that survived oil exposure had settled in a particular area (east of the Mississippi River Delta).[12] This type of species-specific and location-specific population information can help managers make decisions about prioritizing resource protection activities during future spills.

Marine technicians set traps used to collect marsh-associated finfish and shellfish near Point-aux-Pins, AL. Photo: GoMRI/Ryan M. Moody

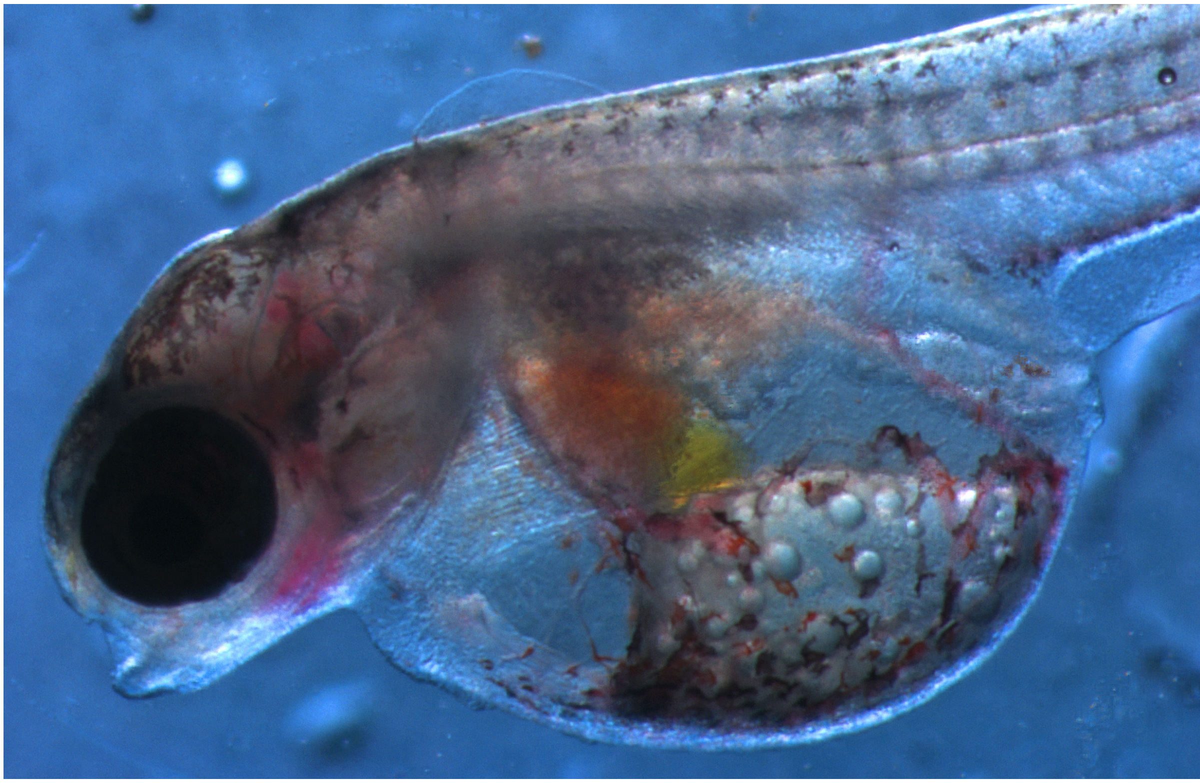
COMMUNITY-WIDE IMPACTS

Food web studies reveal shifts in diet and changes in communities.

Scientists can examine interactions between predators and prey to learn about oil spill impacts on aquatic communities. Exposure to contaminants could alter the **species composition** of food webs if species within the web change or decrease in numbers.[2] For instance, species that are sensitive to pollution can diminish in abundance 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 be altered. This could change the food web. Decades after the 1989 Exxon Valdez oil spill in Alaska, scientists continued to find oiled habitat and wildlife.[2] Over the years they documented changes in the structure of food webs as species numbers changed.[2]

Food web and community-wide impacts like those seen after the Exxon Valdez spill are a focus for many Gulf of Mexico scientists. Some are studying what fish are eating to gain clues about potential shifts in diet resulting from oil exposure. For example, a study found red snapper usually consume a variety of prey ranging from small **zooplankton** to fish and **decapods**.[13] In that study, the scientists demonstrated that red snapper diets change as the fish grow.[13]

They found that smaller red snapper consumed more fish prey.[13] Larger, more mature red snapper included smaller organisms such as zooplankton as a substantial portion of their diet.[13] After the DWH event, scientists found that adult red snapper shifted their diets away from zooplankton and increased their consumption of other animals like fish, squid, shrimp, and crabs.[14] Some scientists believe that the diet shift could be a result of the oil spill because plankton populations in certain parts of the Gulf of Mexico experienced a temporary die-off during the spill.[14] In the absence of zooplankton, larger red snapper had opportunistically fed on other prey.[14] Feeding ecology information like this is useful to scientists as well as decision makers working to protect natural resources and the livelihoods of people who depend on them.



The decrease and delay in hatching of Gulf killifish is associated with developmental defects that are characteristic of oil exposure. Photos: RECOVER/Ben Dubansky

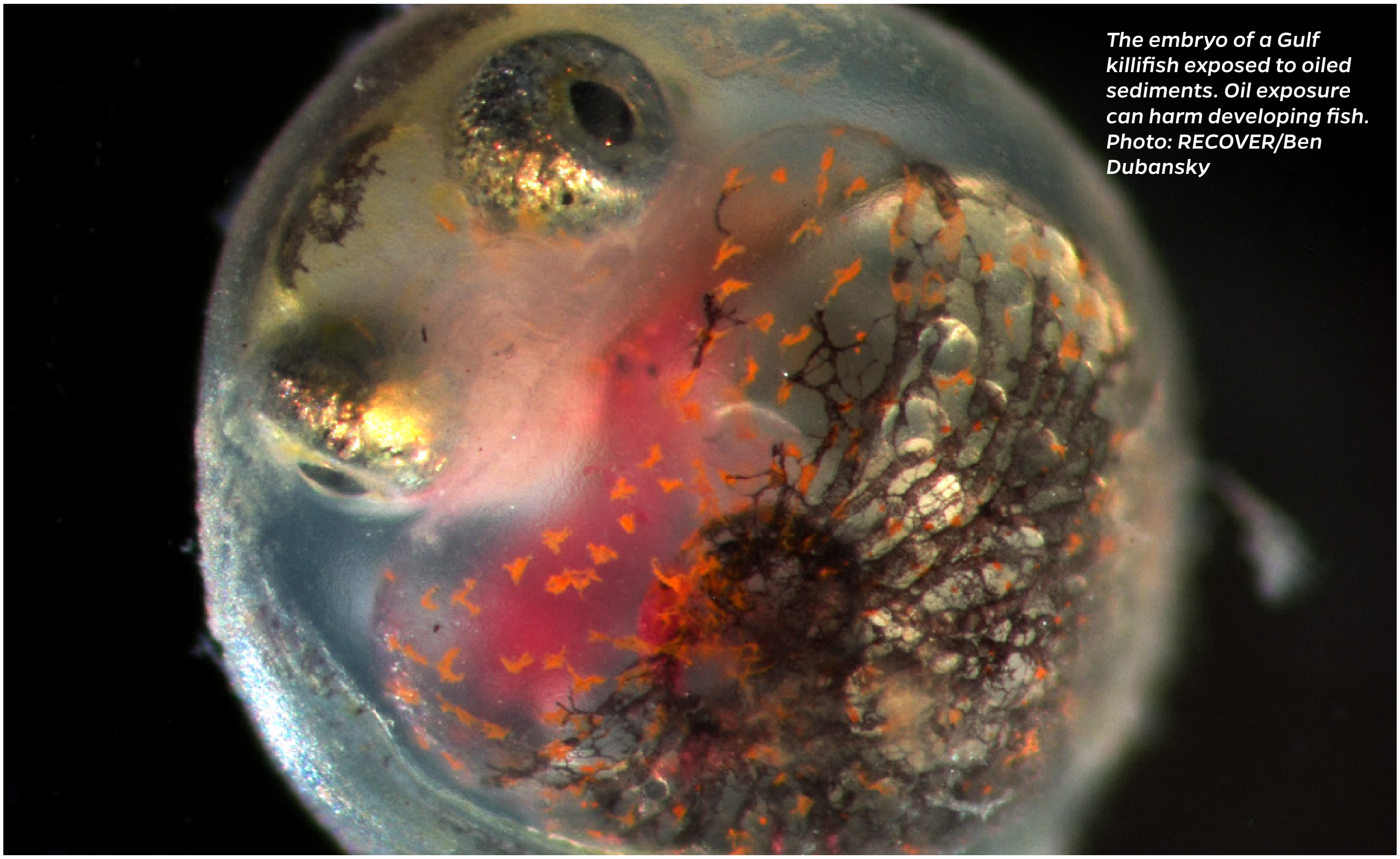
In addition to food web studies, the number of different species found living together in a habitat can also help determine if there were oil spill impacts on fisheries. Fisheries scientists do this by catching fish and counting them. They compare population numbers within communities over time to look for changes. Scientists compared fish abundance and the type of species present at oiled versus unoiled marshes of Louisiana.[15] They did not find any negative oil effects on type, abundance, or size of fish.[15] Similarly, in coastal Alabama, scientists collected animals that normally use both offshore and nearshore habitats throughout their life cycle to see if exposure to oil offshore would affect their success in recruitment to coastal waters.[16] 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 by 2012.[16] Overall, the research did not find evidence of negative impacts at the community level.[16]

FACTORS THAT INFLUENCE IMPACTS TO FISHERIES

Many factors must be considered when making conclusions about what affects fisheries. Some factors include fisheries management decisions, fishing effort, environmental conditions, and time of year.

> *Long-term studies that synthesize the various pieces of the puzzle will provide answers to ecosystem impact questions.*

A fishery closure is an example of a management action made during and after the DWH oil spill. Emergency managers closed large fishing areas of the Gulf and reopened them when seafood test results showed safe levels for eating.[17,18] The largest closure on June 2, 2010, was an area of 88,522 square miles, which is about 37 percent of the U.S. fishable waters in the Gulf of Mexico.[18] This fishing closure may have enabled some species to survive and reproduce because they were not being fished.[19,20] 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 communities of



The embryo of a Gulf killifish exposed to oiled sediments. Oil exposure can harm developing fish. Photo: RECOVER/Ben Dubansky

estuarine fish.[19] Mangrove snapper, pigfish, spotted sea trout, hard head catfish, and sheepshead are some of the species they caught in greater numbers after the oil spill compared to before.[19] Although many of those species spawned during the spill and their larvae were potentially exposed to oil-polluted water, the catch was still high after the spill compared to the four years before the spill.[19] This suggests that fishing closures may have enhanced spawning and allowed more young fish to survive, so any negative oil spill impacts would be difficult to determine[19], especially in such a short time frame. Similarly, other scientists monitoring shrimp found that brown and white shrimp abundances increased in estuaries that were oiled from the DWH spill.[20] One possibility for the increase could be that shrimp fishery closures gave shrimp more chances to reproduce and add to the population.[20] More time, and more sampling, is needed to make conclusions about management decisions impacting fisheries during and after the spill.

Some scientists use the three-tiered approach (they study individual, population, and community-wide impacts) to understand oil spill impacts in the Gulf of Mexico, both in the short and long term. Thus far, oil spill science has shown evidence of negative impacts to individual fish in the Gulf. There has not been conclusive evidence that those negative impacts expand to populations and communities in the Gulf, as some people would expect. Scientists continue to explore factors influencing these results. For example, most study sites have a history of oil exposure and completely unoiled locations in the Northern Gulf no longer exist, so populations of marsh fishes may be conditioned to PAH exposure and able to survive oil exposure.[15] Some scientists suggest that young transient animals, like the fish that spend their lives moving among estuaries, are better suited to cope with big disturbances like spills.[16] Clearly, more work is required to assess the full extent of the suite of impacts to fisheries, including oil spills.

For emerging GoMRI-funded science related to fisheries and oil spills, and to view more bulletins like this one, visit the program website at www.gulfseagrant.org/oilspilloutreach.

GLOSSARY

Aquatic ecosystems
Communities of organisms that live in the water and are dependent on each other and on their environment. The main types of aquatic ecosystems are marine, estuarine and freshwater ecosystems.

Benthos
The flora and fauna found on the bottom, or in the bottom sediments, of a sea, lake, or other body of water.

Biomarker
A measurable substance in an organism whose presence is indicative of some phenomenon such as disease, infection, or environmental exposure.

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

Decapod
A crustacean of the order *Decapoda*, such as a shrimp, crab, or lobster.

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

Embryo
An unborn or unhatched offspring in the process of development.

Enzyme
A substance produced by a living organism that acts as a catalyst to bring about a specific biochemical reaction, such as digestion of food or metabolism of a toxicant.

Fisheries
All of the activities involved in catching finfish, shellfish or seafood.

Food chain
A series of organisms each dependent upon the next as a source of food.

Food web
A system of interlocking and interdependent food chains, where numbers of predators and prey species keep each population in balance.

Gene
A sequence of DNA that encodes a protein. A gene is the basic unit of heredity that is passed from parent to offspring, outfitting the next generation with traits of the parents.

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.

Larvae
The immature form of an animal that undergoes physical changes during its life.

Larval dispersal
The spread of larvae from a spawning location to a settlement site.

Larval settlement
Settlement phase of some animals which begin life as free-swimming larvae and eventually settle to locations on or near the sea floor.

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.

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

Polycyclic aromatic hydrocarbons (PAHs)
A group of hydrocarbons commonly found in oil, tar, combustion of fossil fuels, burned wood and animal fats.

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

Population connectivity
The successful exchange of individuals between separated sub-populations.

Productivity
The rate that biomass or energy is generated in an ecosystem.

Recruitment
The addition of new individuals to a population by reproduction.

Respiration
The extraction of oxygen from the environment and resulting production of carbon dioxide.

Spawning
The release or deposit of eggs and sperm.

Species composition
All of the different organisms that make up a community within an ecosystem. This is important when trying to discover how an ecosystem works and how important different organisms are to an environment.

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

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