



# OIL SPILL SCIENCE

## SEA GRANT PROGRAMS OF THE GULF OF MEXICO

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

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



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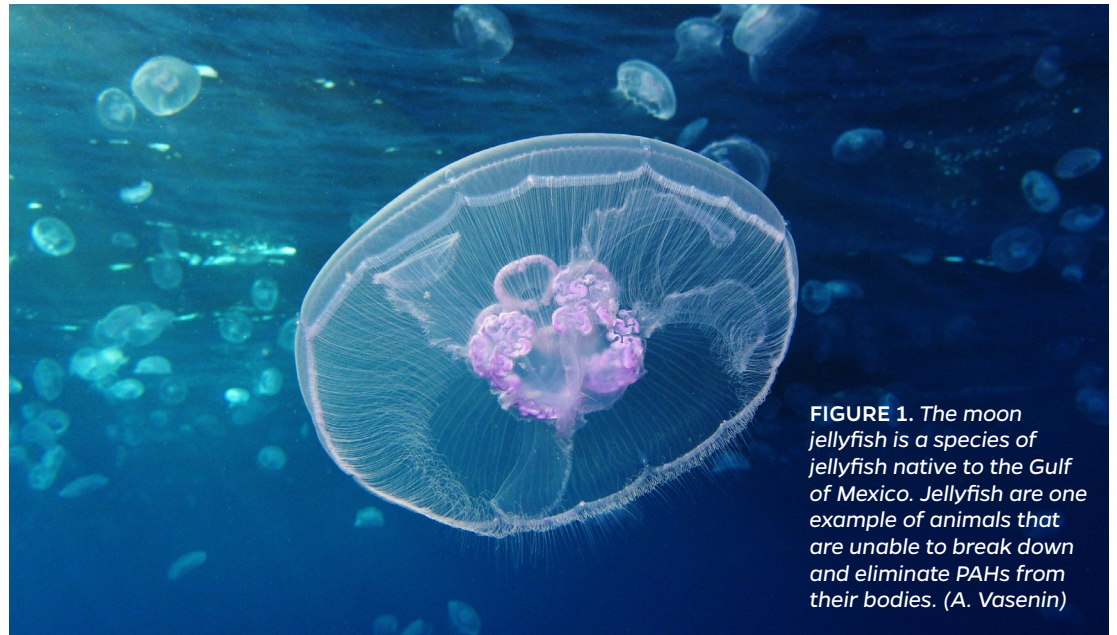


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## RESPONSES OF AQUATIC ANIMALS IN THE GULF OF MEXICO TO OIL AND DISPERSANTS

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As the Deepwater Horizon (DWH) oil spill unfolded, concern grew over the potential impacts of oil and chemical dispersants to aquatic animals. Scientists are able to use biological markers to detect if an animal was exposed to oil. Research indicates that the fate of oil-based compounds in exposed animals depends greatly upon the age and species, as well as environmental conditions.



**FIGURE 1.** The moon jellyfish is a species of jellyfish native to the Gulf of Mexico. Jellyfish are one example of animals that are unable to break down and eliminate PAHs from their bodies. (A. Vasenin)

In April 2010, the Deepwater Horizon oil rig caught fire and sank off the coast of Louisiana. Over the next 87 days the Deepwater Horizon oil spill released approximately 200 million gallons of oil from the Macondo well. Oil spill responders applied chemical dispersants **Corexit 9500** and **9527**. These dispersants were used to increase the natural breakdown of oil, reduce the number of oiled

animals and limit on-shore oiling. Funding agencies like the Gulf of Mexico Research Initiative (GoMRI) sponsor research to better understand the responses of marine and coastal animals to oil-dispersant mixtures. This outreach publication summarizes research results related to the effects of oil and dispersants on aquatic animals that live in the Gulf of Mexico (Figure 1).

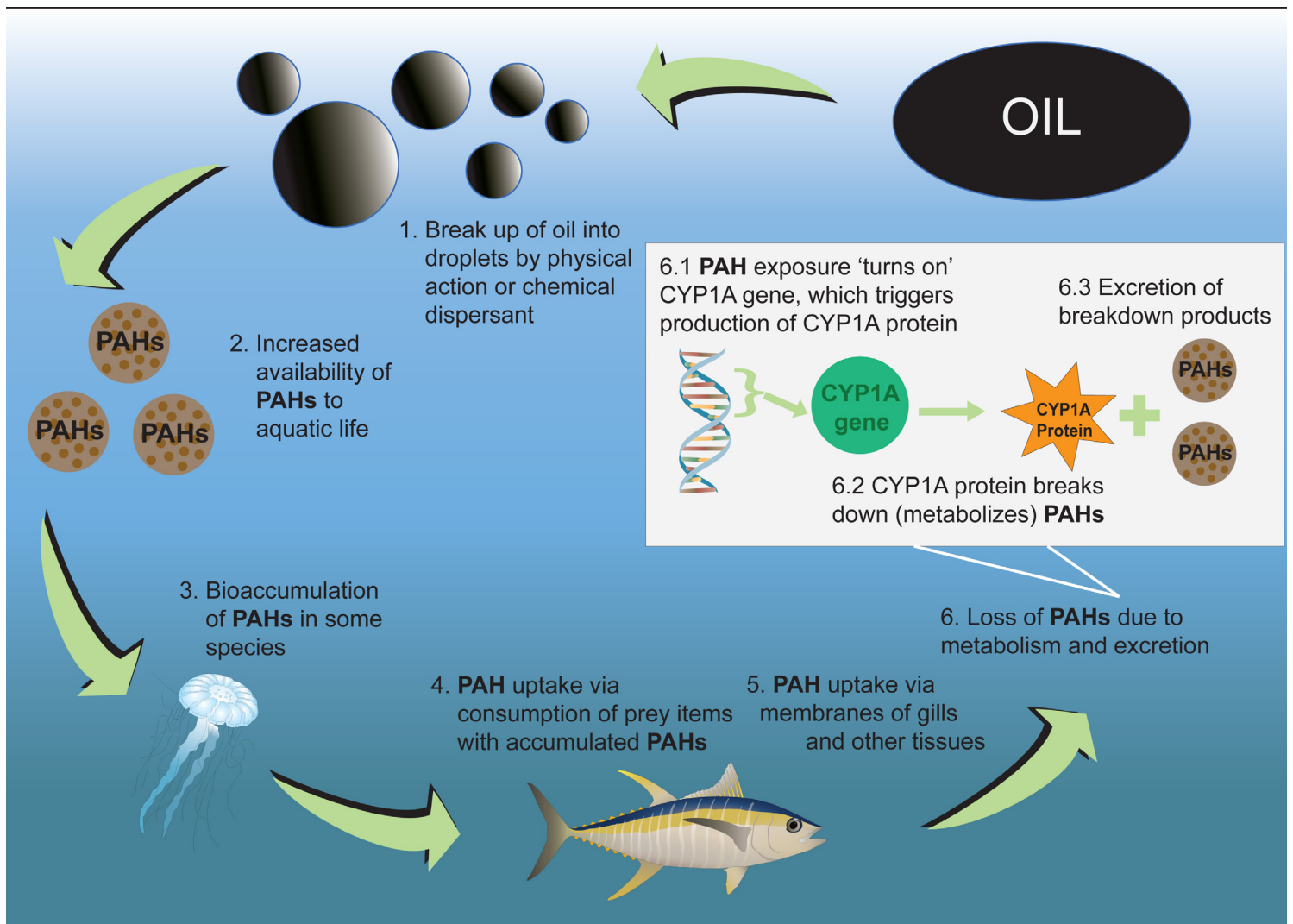
## Polycyclic Aromatic Hydrocarbons (PAHS)

Crude oil is a mixture of thousands of compounds. **Alkanes** (such as methane and ethane) are usually the most abundant compounds in oil and have relatively low toxicity. **Polycyclic aromatic hydrocarbons (PAHs)** are also present in crude oil. PAHs are found in oil<sup>1</sup> and tar. They are formed in burning of gas, oil, coal, wood, and charring of animal fat. Dispersants break up oil slicks into relatively small oil droplets that bacteria can more readily degrade. While applying dispersants to oil increases the rate at which oil droplets diffuse into the water column<sup>2</sup>, dispersants also increase concentration of PAHs in the water.<sup>3</sup> PAHs cause concern because they can remain in the environment for a long period of time. Some of them cause

mutations, developmental problems<sup>4</sup>, and/or cancer in wildlife and humans.<sup>5</sup>

## Physiological Responses

Animals respond to chemicals like PAHs from oil in several ways. Chemicals that are not easily broken down are often stored (a process known as **bioaccumulation**) in the body's tissues. Chemicals that bioaccumulate in the body have the potential to be passed to predators higher in the food chain or passed from a mother to her young. A mother passes the PAHs to her eggs<sup>6,7</sup> through the **glycolipoprotein** that will form the egg yolk.<sup>8,9</sup> If these eggs hatch then the offspring from the eggs will have elevated PAH levels.



**FIGURE 2.** Diagram of possible ways polycyclic aromatic hydrocarbons (PAHs) from oil enter aquatic animals and animal responses (i.e., uptake, bioaccumulation, metabolism, excretion). Image credit: Florida Sea Grant/Anna Hinkeldey with contributions from D. Tracey, J. Thomas, T.Saxby (IAN-UMCES Image Library).

Some animals can break down foreign chemicals such as PAHs using their body's metabolism processes (Figure 2). Metabolism occurs when the animal's body activates or inactivates certain genes through gene expression. CYP1A is an important gene that enables animals to breakdown PAHs and other foreign compounds.<sup>10,11,12,13,14</sup> Some of these breakdown products are easily excreted. This process prevents foreign chemicals from being stored in the animal's tissues. Other breakdown products are more toxic and can cause cancer in the animal. Scientists study changes in CYP1A expression levels in animals to determine if they have encountered a toxic substance like oil. Scientists are able to confidently estimate oil exposure by doing experiments in the lab and comparing the lab results with the results collected in the field.

### Four Key findings related to aquatic animal responses to Corexit and oil mixtures

#### Some animals accumulate PAHs

Many aquatic animals cannot breakdown and remove PAHs once these compounds enter their bodies. This causes PAHs to accumulate in their tissues.<sup>15</sup> Copepods are aquatic animals related to insects and are about the size of a pinhead (Figure 3). Copepods accumulate PAHs when exposed to oil. However, they are also able to release some PAHs in their waste.<sup>16</sup> Levels of PAHs in jellyfish (Figure 1) exposed to oil are 1.4-3.1 times higher than in jellyfish not exposed to oil. PAH levels in jellyfish also increase with level of oil exposure.<sup>17</sup> The PAHs can travel through the food web when other animals eat the contaminated copepods, copepod waste, or jellyfish.

Scientists monitoring wild Gulf coast coquina clams found that levels of PAHs in the clams were variable the year after DWH.<sup>18</sup> The variability may have been due to the patchy distribution of the oil that came to shore. PAH levels in the clams were higher than the PAH levels in the surrounding sands. This suggests that the clams accumulate PAHs in their tissues. PAH levels in the

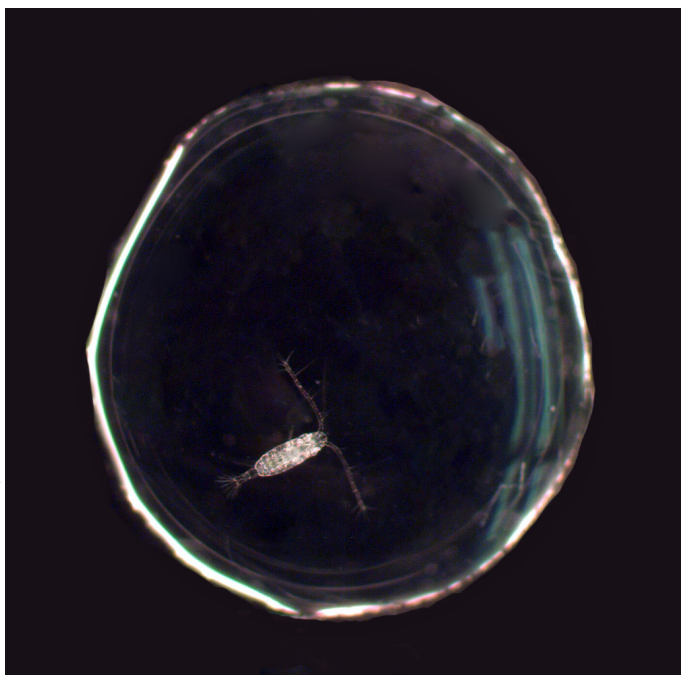
clams declined during the two years after the spill. This indicates that PAH levels were declining at the beach locations where the clams were tested.

Clams and their relatives (e.g. oysters, mussels) tend to be stationary. They are also relatively slow at breaking down and excreting foreign chemicals. This causes these animals to bioaccumulate foreign compounds in their tissues.<sup>19</sup> These factors make this group of animals good indicators of environmental pollution. For more than twenty years NOAA's Mussel Watch program has tested the tissues of oysters and mussels to monitor the presence of foreign chemicals (e.g., PAHs, metals) in the environment.<sup>20</sup> Post-DWH, GoMRI-funded scientists collected wild oyster samples (Figure 4). They compared them to samples the Mussel Watch program had previously collected in the Gulf.<sup>21</sup> PAH levels were similar to those found during the ten years before the DWH oil spill. Other GoMRI-funded scientists tested oysters from Mississippi and Alabama. Samples were taken during and after the DWH oil spill to determine if oysters accumulated oil in their shells. They found no measurable traces of oil-based compounds in the oyster shells.<sup>22</sup>

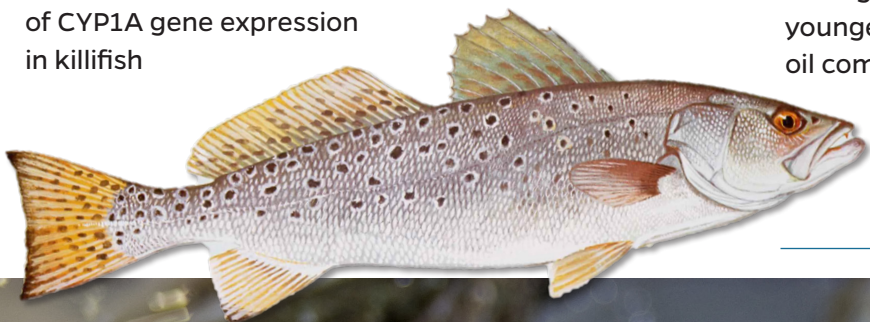
#### Fish break down oil-based compounds in their bodies – and that can be used to detect exposure to oil.

Fish are able to breakdown and eliminate PAHs from their bodies by expressing the CYP1A gene. Scientists

**FIGURE 3.** Copepods are tiny crustaceans that live in the water column of estuaries and the ocean. Copepods are typically a couple of millimeters (mm) in length (a dime is 1.35 mm thick). Pictured is a copepod in a water droplet. Copepods serve as an important food source for many larger animals. (M. Finiguerra, University of Connecticut)



can determine if a specific area has been oiled by examining Gulf killifish (Figure 5). This fish will turn up CYP1A gene expression if they experience oil. Gulf killifish do not travel far from their homes. So if a killifish has high levels of CYP1A gene expression then it is likely that the area had oil. Grand Terre, Louisiana, is a location that was heavily oiled from the DWH oil spill. Fish collected in Grand Terre after the DWH oil spill had higher levels of CYP1A gene expression than fish collected from that location before the oil came to shore or fish from locations that did not have oil.<sup>23</sup> In August 2011, more than a year after the well was capped, scientists still found higher levels of CYP1A gene expression in killifish



sampled from Grand Terre than in killifish from unoiled locations.<sup>24</sup> The elevated levels indicate that oil and/or oil components remained in Grand Terre for at least one year after the DWH oil spill.

### Effects differ based on stage of life and environmental conditions

An animal's response to oil and dispersant may change with age. Newly hatched spotted sea trout (Figure 6) exhibited stress from chemically dispersed oil while slightly older juvenile spotted sea trout did not.<sup>4</sup> The skin of newly hatched fish allows more chemicals to pass through it than the skin of older fish. This may make younger fish more sensitive to chemically dispersed oil compared to older fish.

**FIGURE 6.** Adult spotted sea trout, like the one pictured here, are recreational sport fish. GoMRI-funded scientists are studying the young of this species. Image Credit: Raver Duane (U.S. Fish and Wildlife Service)

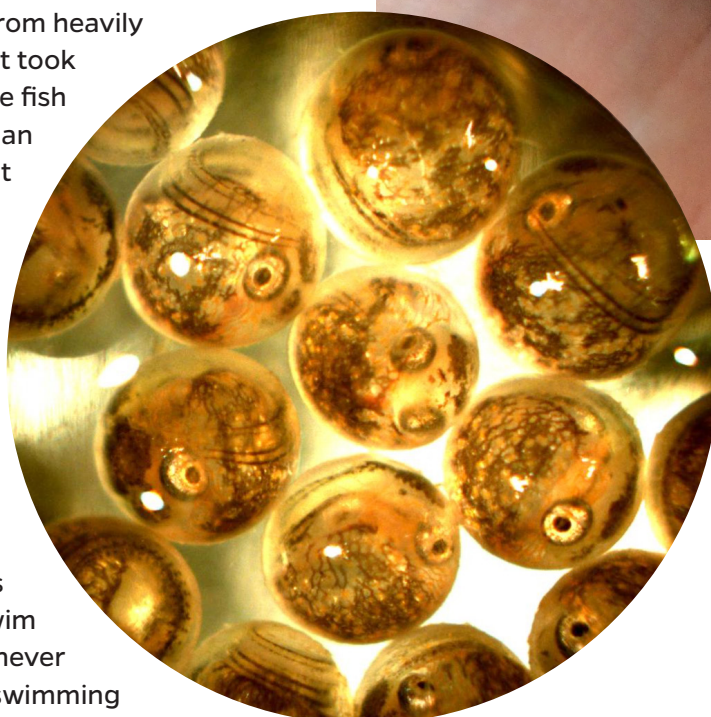


**FIGURE 4.** Shellfish, like oysters, are filter-feeders. This means they filter the surrounding waters to extract their food. (Florida Sea Grant)

Environmental factors can influence the impacts of oil and dispersants on animal health too. These factors include the amount of salt in the water (**salinity**) and ultraviolet rays from sunlight. Animals living in salt marshes encounter a wide range of salinities. The salinity in a marsh can change within hours due to tides and weather events. Oil and dispersant mixtures at low salinities were more toxic to Gulf killifish than the mixtures at higher salinities.<sup>3</sup> Scientists concluded that the fish were either more sensitive at low salinities or less capable of breaking down PAHs in low salinity environments. Long-term exposure to PAHs can make some fish and their offspring tolerant to PAHs.<sup>25</sup> However, when fish spend energy becoming more resistant to PAHs they can become more sensitive to other environmental factors like UV light and low oxygen. Finally, in some cases, other environmental stressors can affect animals more than PAHs or oil exposure. For example, salinity has a greater impact on the reproductive health of oysters than oil exposure.<sup>26</sup> Scientists continue to explore the relationships between environmental factors and aquatic animal health.

### Oil exposure can impair vital development and bodily function

Oiled sediments and PAHs impact the ability of fish eggs to hatch, the development of the fish and how well the fish functions. Few killifish eggs hatched when exposed to sediments from heavily oiled areas. If they did hatch, it took longer for them to hatch.<sup>24</sup> The fish that did hatch were smaller than expected and developed heart problems. Heart problems included reduced heart rate and the development of a fluid filling the sac surrounding the heart. These heart problems might be due to PAHs changing the normal function of the heart tissue.<sup>27</sup> Mahi-mahi (Figure 7) juveniles exposed to PAHs or hatched from eggs exposed to PAHs could not swim as fast as juveniles that were never exposed to PAHs.<sup>28</sup> Reduced swimming



**FIGURE 5.** Killifish are a species of fish that are common to the marshes of the Gulf coast. GoMRI-funded scientists are studying both the developing young and adult fish of this species to better understand the impacts of oil and dispersants on aquatic life. (C.C. Green, LSU AgCenter).

speed could translate into fewer young surviving into adulthood, leading to reduced reproduction rates and population levels.

The energy needed to break down foreign chemicals (i.e., PAHs and dispersants) can come at the cost of

growth. For example, both newly hatched and juvenile spotted sea trout exposed to either dispersant or PAHs were significantly smaller than unexposed individuals.<sup>4</sup> This indicates that the fishes' bodies used energy to breakdown the dispersant and PAHs instead of putting



**FIGURE 7.** Mahi-mahi are large, predatory fish that spawn in the Gulf of Mexico. The adult form of the species (pictured here) is popular in recreational fishing circles. The young of the species are studied by GoMRI-funded scientists (J. Weiss)

that energy toward growth. However, these effects do not appear to be permanent in juveniles. Within several weeks after exposure, the body size of the juveniles exposed to dispersants and PAHs became similar to individuals who had never been exposed to these chemicals.

To learn more about the research being conducted on the Deepwater Horizon spill, visit the Gulf of Mexico Research Initiative website at [www.gulfresearchinitiative.org](http://www.gulfresearchinitiative.org). Visit the Sea Grant oil spill outreach program website at: <http://gulfseagrant.org/oilspilloutreach> to view other publications related to this theme.

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## SUGGESTED CITATION

Maung-Douglass, E.S., Graham, L., Hale, C., Sempier, S., Swann, L., and Wilson, M. (2015). Oil Spill Science: Responses of Aquatic Animals in the Gulf of Mexico to Oil and Dispersants. GOMSG-G-15-001.

## GLOSSARY

**Alkanes** - A group of compounds composed of hydrogen and carbon. Have carbon atoms in chains linked by single bonds and that have the general formula  $C_n H_{2n+2}$ . Occur naturally in petroleum and natural gas, and include methane, propane and butane.

**Bioaccumulation** - The accumulation or build-up of chemicals in the tissues of an organism. In the aquatic world, the bioaccumulated chemical can enter an organism via several methods, including their food, gills, and other tissue membranes.

**Corexit** - A modern dispersant approved for use in US waters that was used to minimize the presence of surface oil slicks during the Deepwater Horizon oil spill

**CYP1A** - Gene that helps the body metabolize, or breakdown, foreign chemicals (e.g., PAHs).

**Gene(s)** - Unit of DNA that codes for a trait in an organism (e.g., coloration, size, stress response). Passed from parent to child.

**Gene expression** - A gene that is expressed is 'turned on' or 'turned off'. Expression can also be turned up or down, similar to a volume knob on a stereo, producing a response within the body.

**Glycolipoprotein** - A molecule that has the properties of sugar, lipid (fat), and protein (e.g., vitellogenin, the protein that that will form an egg's yolk).

**Metabolism** - The breakdown of chemicals by the body (e.g., metabolism of foreign chemicals).

### Polycyclic aromatic hydrocarbon (PAH)

A group of hydrocarbons commonly found in oil, tar, burned wood and animal fats. More than 100 PAHs exist and some are known to cause cancer, birth defects, mutations, or death.

**Salinity** - The average concentration of dissolved salts in a body of water.

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

GOMSG-G-15-001