# Office of Science

# Research Project Summary

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# Trophic Transfer of Oil Contaminants from Menhaden Fish: Will the Gulf Oil Spill Effect NJ?


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## *Abstract*

The Deepwater Horizon oil spill in the Gulf of Mexico in 2010 resulted in record amounts of oil and dispersants that potentially could be circulated far from the spill origin. Research was conducted to examine the possibility of transfer of oil compounds into the marine foodchain. Specifically, the pathway of oil uptake by menhaden in the Gulf of Mexico, a fish that migrates to waters off the coast of Virginia. In these waters predators, including striped bass and bluefish, feed on these fish and migrate north along the Atlantic Coast including New Jersey's waters. Polycyclic aromatic hydrocarbons (PAHs) were analyzed as the signature of the oil spill in menhaden oil from three locations (NJ, VA and LA). Other menhaden tissues were analyzed for PAHs from each of the three locations. The current health of menhaden were examined by histopathological examinations of several tissues. Trophic transfer of PAHs from menhaden into bluefish was also investigated to determine if it was feasible for distant oil spills to affect migratory fish in New Jersey's waters.


## Introduction

The Deepwater Horizon (DWH) oil spill in the Gulf of Mexico released record amounts of oil and dispersant in surface waters in 2010. This spill affected the coastal waters of Louisiana, Mississippi, Alabama and Florida. Due to the reported possibility of the oil entering the Gulf Stream and moving up the eastern Atlantic Coast, the State of New Jersey was concerned about the potential effects of the spill on state waters. One potential pathway was consumption of contaminated migratory fish. There are two species of menhaden, the yellowfin menhaden (*Brevoortia smithi*) and the gulf menhaden (*Brevoortia patronus*) that migrate from Louisiana to Virginia waters. The Atlantic menhaden (*Brevoortia tyrannus*) migrates between Virginia and New Jersey waters. Predators such as striped bass and bluefish, both common in NJ waters, migrate and spend time in Virginia/North Carolina coastal waters and feed on these menhaden species. These migratory patterns suggest a potential pathway for human exposure to oil contaminants (e.g., PAHs) via striped bass (*Morone saxatilis*) and bluefish (*Pomatomus saltatrix*) consumption and/or from omega-3 supplements from menhaden.

## Objectives

This project involved answering the following questions and objectives:

- Is there a distinctive chemical 'fingerprint' for the DWH oil that can be detected analytically in menhaden fish oil?
- Do PAH concentrations in recently exposed LA fish exceed urban background levels in fish from James River, VA and lower Delaware River?
- Objective: determine PAH levels in fish oil and other tissues from NJ, VA and LA menhaden;
- Objective: evaluate the current health of NJ and LA menhaden by histopathological examinations and determine if there is a relationship between tissue levels of oil contaminants; and
- Are the DWH contaminants in menhaden transferred to predatory fish? The objective was to assess the levels of trophic transfer of PAHs from menhaden fish oil to YOY bluefish.

The study was also designed to examine the levels of dispersant in fish; however this portion of the study was not performed due to the limitations imposed by the manufacturer on access to the product.

## Methods

Menhaden were collected from three States including Barataria Bay (BBLA; young of year) and Grand Isle, LA (large fish); James River, VA (JRVA; large fish); and Delaware River (young of year) and offshore locations in

NJ (e.g., MVNJ, large fish) in September and October 2010 with the assistance of the NJDEP Division of Fish and Wildlife, Louisiana Department of Wildlife, and William & Mary Virginia Institute of Marine Science. The LA locations had been impacted by the DWH oil spill in the months prior to collection of the fish. Larger menhaden were used for fish oil extraction, with smaller fish used for histopathology.

Two analytical methods were used to measure PAHs in fish oil and tissue: Gas Chromatography-Mass Spectrometry (GC-MS) and Fixed Emission Fluorescence Spectroscopy (FEFS) as indicated in Table 1.

The full report provides more details on the experimental study design and methods: (http://www.state.nj.us/dep/dsr/).

## Results

Analysis of the DWH oil indicated high concentrations of alkylated naphthalenes, fluorenes, and phenanthrenes; high molecular weight PAHs included alkylated pyrenes and chrysenes. However, extensive analytical work and methods could not discriminate a petroleum fingerprint for the DWH oil in fish oil or tissue. The GC/MS method only detected a small number of PAHs in the menhaden. The FEFS method resulted in detections of napthol (HNP), phenanthrol (HPN) and hydroxyprene-like (HPY) PAHs.

**Table 1. Summary of Results**

| Experiment/Analysis | Results |
|---|---|
| **Headspace Solid-Phase Microextraction (HS-SPME) with Gas Chromatography-Mass Spectrometry (GC-MS) analysis of Large Menhaden fish oil for PAHs** | • Detections of PAHs were low at all sites.<br>• Fluoranthrene and Pyrene concentrations were similar in NJ and LA fish; Anthracene higher in VA and NJ fish.<br>• A petroleum finger print could not be established. |
| **Fixed Emission Fluorescence Spectroscopy (FEFS) of Large Menhaden Fish Oil and Liver** | • PAH concentrations much higher in fish liver than fish oil.<br>• Liver: NJ and VA fish had higher concentrations than LA fish<br>• Fish Oil: LA fish had higher levels of naphthol-like PAHs than NJ and VA, and similar/lower levels of hydroxypyrene-like PAHs. High ratios of HNP/HPY indicative of petroleum exposure. |
| **GC-MS of Small Whole Body Menhaden** | • PAH concentrations low ng/mg in NJ and LA fish<br>• Most low molecular weight PAHs were alkylated phenanthrenes and were higher in NJ than LA fish<br>• High MW PAHs were only found in LA fish (which were large in size) |
| **FEFS of Small Menhaden GI Track Tissues** | • FEFS could not detect specific PAHs<br>• NJ and LA fish spectra looked similar<br>• High HNP/HPY ratio for LA fish similar to LA fish oil<br>• HNP-like and total PAHs similar for LA and NJ fish; inconsistent with histological results |
| **Histopathology on Small Menhaden** | • Prominent gill damage observed in LA fish<br>• Exposure to crude oil could affect the filter feeding ability of menhaden<br>• Liver necrosis, bile duct dilation and Cholangioma-like lesions detected in LA fish<br>• Small NJ menhaden were considered in good health |
| **Trophic Transfer of PAHs in fish oil to Silver Perch (24 hour exposure); Analysis by FEFS** | • PAHs detected in all tissues and individuals including control fish: GI track, liver, gill and bile (gall bladder)<br>• Fish accumulated PAHs from DWH crude oil and PAH spiked fish oil<br>• Tissues preferentially accumulated different PAHs<br>• No significant difference between treatments |
| **Trophic Transfer of PAHs in fish oil to Bluefish (24 hour exposure)** | • PAHs detected in all tissues including controls, indicating prior exposure<br>• Relative concentrations in bluefish tissues different than silver perch<br>• No significant difference between treatments; however, treatment effects were observed (i.e., PAHs distributed to spleen and gill) |
| **Trophic Transfer of PAHs in fish meal to Bluefish (96 hour exposure)** | • Bluefish absorbed PAHs from the JRVA menhaden fish meal; PAHs detected in all tissues including controls, indicating some level of prior exposure.<br>• Highest PAH levels detected in liver |

Histopathological analysis was conducted to determine if the oil spill caused any adverse effects on the LA fish, with the NJ fish used essentially as a reference location. Tissues processed for sectioning included gill, GI tract and liver.

Trophic or feeding studies were conducted on silver perch and bluefish using fish oil or fish meal. Fish oil was administered by gavage with a 24 hour exposure and fish meal (menhaden) was fed to bluefish daily for 96 hours.

However, the ratio of low to high molecular weight PAHs may be an indication of crude oil in LA fish. Table 2 indicates that the concentrations detected in large LA and NJ menhaden fish oil were relatively similar, with total PAHs of between 300 and 389 ppb.

PAHs were detected in all fish (oil and liver), with concentrations relatively low in all fish oil samples. PAHs were much higher in liver than fish oil; LA fish had lower levels of PAHs than NJ and VA menhaden. HNP-like

**Table 2. PAHs in large menhaden fish oil (µg/L) collected in fall 2010. Samples were from Barataria Bay, LA (BBLA), and NJ from the ships, Mt Vernon (MVNJ1) and Enterprise (EPNJ1).**

| PAH | BBLA (ppb) | MVNJ1 (ppb) | EPNJ1 (ppb) |
|---|---|---|---|
| **Naphthalene** | NQ | NQ | NQ |
| **Fluorene** | NQ | NQ | NQ |
| **Acenapthene** | ND | ND | ND |
| **Biphenylene** | ND | ND | ND |
| **Fluoranthene** | 182 | 185 | 184 |
| **Pyrene** | 69 | 71 | 10 |
| **Anthracene** | 91 | 133 | 106 |
| **Phenanthrene** | ND | ND | ND |
| **Benz(a)anthracene** | ND | ND | ND |
| **Chrysene** | ND | ND | ND |
| **Benzo(a)pyrene** | ND | ND | ND |
| **Benzo(k)fluoranthene** | ND | ND | ND |

PAHS were approximately 100x higher in liver than fish oil; HPY-like were approximately 10x higher in liver. The high HNP to HPY ratio in LA fish indicated recent petrogenic exposure (i.e., DWH oil), while the low ratio in NJ and VA fish indicated exposure of pyrogenic origin.

Young of year (YOY) whole body menhaden analysis results only found limited types of PAHs. FEFS results showed that DBNJ and BBLA fish had very similar fluorescence spectra. Similar to the adult menhaden, a higher HNP/HPY ratio in BBLA YOY was found as compared to DBNJ fish, indicating exposure to petroleum.

Small LA menhaden showed significant histological tissue damage including gill. NJ menhaden appeared to be in good health. See Table 3 and Figures 1 and 2.

**Table 3. Summary of Histological Lesions. Red text indicates effects particular evident in LA peanut menhaden.**

| Organ - Lesion | NJ Sites | LA Site | Comment |
|---|---|---|---|
| **Gill Hyperplasia** | +[1] | ++ to +++[2] | Response to continuous exposure |
| **Gill Lamellar Fusion** | ± | ++ to +++ | Response to past extensive exposure Permanent change |
| **Gill Wavy 2nd Lamellae** | --[3] | ++ to +++ | Response to past extensive exposure Permanent change |
| **Liver & Gallbladder** | + | ++ | Focal necrotic areas occurred in both locations but some LA fish had extensive necrosis Gallbladder involvement was present and ranged from dilation to Cholangioma-like lesions |
| **Epithelial Hyperplasia** | -- | + | Minor |
| **Kidney Hemosiderin** | + | +I | More was evident in the oiled area fish, but was present in both populations |
| **Parasitism** | + | + | Minor, no real difference |

The trophic transfer studies indicated that PAHs were detected in all tissues including controls, indicating prior exposure for all fish. There was no significant difference between treatments.

Results did show transport of PAHs from the GI tract into liver, spleen and gall bladder tissue. The relative concentrations in bluefish tissues were different than silver perch.

Additional detail on the individual studies and results can be found in Table 1 and the full report http://www.state.nj.us/dep/dsr/.

## Discussions and Conclusions

This project was designed to examine fish from three locations that included one directly affected by the DWH oil spill (LA), and two others (NJ and VA) where three menhaden species migrate and become prey for predatory fish. NJ and VA fish were also used as reference sites to examine the 'background' urban PAH signals for comparison with LA fish exposed to crude oil, as well as providing pre-oil spill data for New Jersey. This 'baseline' PAH data on NJ menhaden can be used to compare to tissue data from future oil spills.

The analytical methods did detect PAH compounds but could not determine a DWH oil fingerprint for any of the fish tissues or oil tested. However, there were some indications of differences in PAHs (e.g., ratios) between LA and NJ fish that indicated a petroleum source in the LA fish that could be useful.

The largest distinction was the marked differences in the histopathological observations between NJ and LA menhaden. The LA fish had a number of lesions and were similar to those observed from other oil spills for other fish species. Notable damage to gills of the LA fish appeared to be unique to this species. Other effects included liver necrosis, bile duct dilation and Cholangioma-like lesions in the LA fish. In comparison, NJ small menhaden appeared in overall good health and this data can also be used for comparison of impacts for a potential future spill in NJ waters.

Of ecological concern is that gill damage due to oil spills could result in effects to the filter feeding ability of these fish, a very important species (i.e., as prey) in the food chain. In addition, it has been reported that menhaden can filter approximately 4 gallons of water per minute and 2+ million gallons of water per year. A reduction in this filtering ability could potentially negatively affect water quality.

Figure 1. Gill lamellae showing little or no clubbing and other lesions in New Jersey menhaden compared to moderate lesions in the oil spill exposed menhaden. Note: No clubbing, lamellar fusion, erosion or wavy secondary lamellae in NJ menhaden. Note: gill hyperplasia (H), and wavy appearance (W) and erosion (E) in LA menhaden.

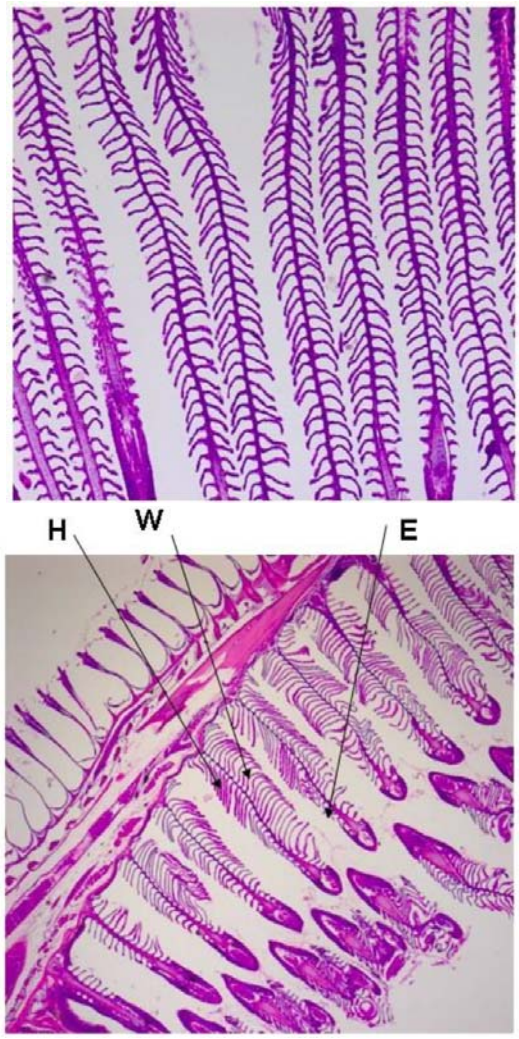
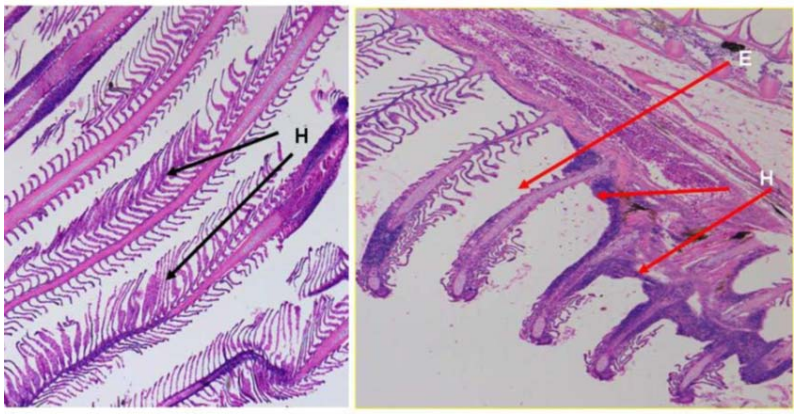



Figure 2. Higher magnification (40x) of hyperplasia (H) and erosion (E) of gill lamellae




The trophic transfer studies provided evidence of PAH accumulation by predators (e.g., bluefish fed menhaden). This is important as it indicates that fish can pick up oil contaminants from prey that spent time in other waters; for example an oil spill off N. Carolina or Virginia could affect migratory fish captured off NJ including targeted recreational species (striped bass and bluefish). However, based on the ability of fish species to metabolism PAHs, it would be expected that levels in the flesh (muscle) would be lower than other organs (liver) and would quickly approach background levels soon after the cessation of exposure to an oil spill.

Overall, this project provided valuable information that New Jersey can use in the aftermath of oil spills in the State's estuarine and marine waters to determine the impacts on valuable food chain species such as the menhaden and other commercially and recreationally important species.

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## RESEARCH PROJECT SUMMARY

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