Impacts of crude oil on the physiology of estuarine fish: The Deepwater Horizon oil spill

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Shoreline Oiling Data

1,770 km of shoreline were oiled

790 km of Louisiana shoreline were oiled
Genomic and physiological footprint of the Deepwater Horizon oil spill on resident marsh fishes

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Gulf killifish (*Fundulus grandis*)

- Most abundant vertebrate in coastal marshes of the Gulf of Mexico
- Easily reared in the laboratory
- Adults produce transparent embryos
- Model organism for studying the effects of environmental stressors

Photo: A. Whitehead
1. What are the physiological and molecular impacts of oil exposure at different stages of fish development?

2. What is the geographical and temporal extent of oiling in the field?

3. How does exposure history affect the sensitivity of fish to DWH oil?
Sample Site for Gulf Killifish Monitoring

- Grande Terre (GT), Louisiana
- Bay St. Louis (BSL) and Belle Fontaine Point (BFP), Mississippi
- Bayou La Batre (BLB), Fort Morgan (FMA) and Upper Mobile Bay (MB), Alabama

PNAS (2012) 50: 20298-20302
Timing of Gulf Killifish Monitoring
• Note: GT was the only location that oil made landfall (between June 9-14, 2010).

• Extremely high concentrations of oil constituents in the sediment.
Track marsh fish health before, during DWH oil exposure, and during recovery period

- Method: Measured tissue-specific changes in gene expression in field-collected fish.
Genome Expression: Microarray

Provides relative increase and decrease in gene expression.

http://bitesizebio.com/7206/introduction-to-dna-microarrays/
Oil exposed GT fish showed divergent gene expression in livers

AHR ligand regulated genes were differentially expressed

PNAS (2012) 50: 20298-20302
Aryl-hydrocarbon Receptor (AhR): Biomarkers of Exposure
AhR-mediated CYP1A Protein Expression in Gulf Killifish Gills

Dark red stain = CYP1A protein in gills from fish collected in situ
Blue stain = hematoxylin (nuclei)

PNAS (2012) 50: 20298-20302
HYPOTHESIS: Exposure to toxic components of oil

Dark red stain = CYP1A protein from fish collected in situ
Blue stain = hematoxylin (nuclei)

PNAS (2012) 50: 20298-20302
Genome Expression Response in Livers of Field-Collected Gulf Killifish

**Reproduction**

- Genes important for the development of the egg and yolk turned **OFF** coincident with timing/location of oiling.

*PNAS (2012) 50: 20298-20302*
Genome Expression Response in Livers of Field-Collected Gulf Killifish

Reproduction

Ligand (PAH)-activated AHR

Inc. Ubiquitin-ligase activity

Increased degradation of sex steroid receptors

Suppression of sex hormone induced gene expression

Dioxin receptor is a ligand-dependent E3 ubiquitin ligase

PNAS (2012) 50: 20298-20302
HYPOTHESIS: Compromised reproduction (altered estrogen signaling)
Genome Expression Response in Livers of Field-Collected Gulf Killifish

Cardiovascular

- Genes important for **cardiovascular development and function** differs in oiled population.
HYPOTHESIS: Altered cardiac physiology
• Altered gene expression indicates hydrocarbon exposure took place in Louisiana marsh fish collected in Grand Terre, LA.

• Gene expression data suggest potential for **reduced reproductive capacity** and **alterations in cardiovascular physiology**.
Multitissue Molecular, Genomic, and Developmental Effects of the Deepwater Horizon Oil Spill on Resident Gulf Killifish (*Fundulus grandis*)

Benjamin Dubansky,*† Andrew Whitehead,‡ Jeffrey T. Miller,‡ Charles D. Rice,§ and Fernando Galvez†
Gulf Killifish Embryo Exposures to Field-Collected Sediments

Salt Water & “Clean” Sediment

Salt Water & Oiled Sediment

EST (2013) 47: 5047-5082
Heavily oiled sediment resulted in lower embryonic heart rates.
Decreased Hatching

Heavily oiled sediment resulted in decreased hatch.

Increasing Oil Concentration

![Graph showing increased oil concentration and decreased hatching rate.](chart.png)
Increased Time-to-Hatch

Heavily oiled sediment resulted in increased time to hatch.

Increasing Oil Concentration

Percentage Hatch

Days Post Fertilization

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Developmental Abnormalities

Elongated Heart and Improper Folding

Pericardial Edema
Craniofacial Deformities

Hemorrhage

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Study Conclusions

- Exposure to oiled field-collected sediments increases time-to-hatch and reduces the percent hatch of killifish embryos.

- DWH oil leads to teratogenic effects and affects cardiovascular fitness.
Characterizing Long-term Effects

Sublethal exposure to crude oil during embryonic development alters cardiac morphology and reduces aerobic capacity in adult fish

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Exposure to high concentrations of crude oil produces a lethal syndrome of heart failure in fish embryos. Mortality is caused by cardiotoxic polycyclic aromatic hydrocarbons (PAHs), ubiquitous components of petroleum. Here, we show that transient embryonic exposure to very low concentrations of oil causes toxicity that is sublethal, delayed, and not counteracted by the protective effects of cytochrome P450 induction. Nearly a year after embryonic oil exposure, adult zebrafish showed subtle changes in heart shape and a significant reduction in swimming performance, indicative of reduced cardiac output. These delayed physiological impacts on cardiovascular performance at later life stages provide a potential mechanism linking reduced individual survival to population-level ecosystem responses of fish species to chronic, low-level oil pollution.
Lawsuit alleges BP ignored, undersold health risks for workers cleaning up oil spill
Summary

• Oil exposure following DWH spill resulted in:
  • altered expression of genes important for **reproduction** and **cardiovascular fitness**.

• Embryonic exposures to oil rich sediment resulted in:
  • **declined hatching success**, **increased time-to-hatch**, and **increased incidence of developmental abnormalities**.

• It is important to further understand the **long-term, multigenerational effects** of crude oil exposure.
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