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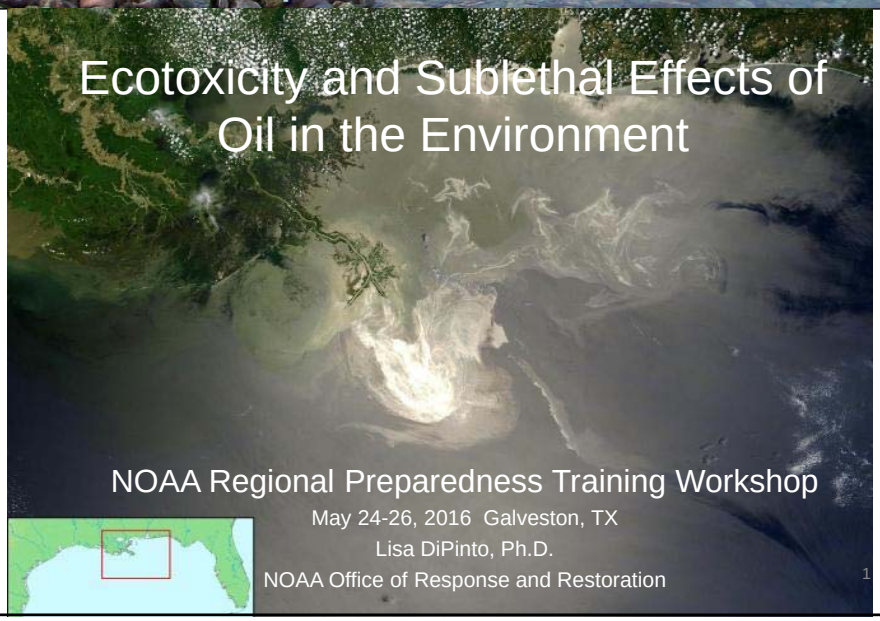

Ecotoxicity and Sublethal Effects of Oil in the Environment

NOAA Regional Preparedness Training Workshop

May 24-26, 2016 Galveston, TX

Lisa DiPinto, Ph.D.
NOAA Office of Response and Restoration

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Oil Toxicity Documented in Literature: Numerous Lab and Field Studies

- Fish
- Invertebrates
- Birds
- Mammals
- Reptiles
- Plants
- Plankton
- Bacteria

- Death
- Reduced growth rates
- Impaired early life stage development
- Tissue impacts (e.g., liver and skin lesions)
- Developmental abnormalities
- Cardiac damage
- Reproductive impairment
- Immune effects
- Cancer

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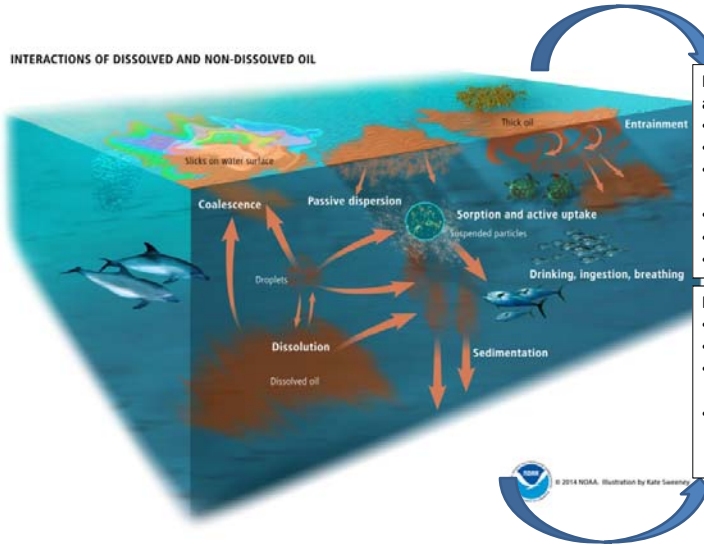
Assessment: What is considered an injury?

"Injury" includes adverse effects on:

- Survival, growth, and reproduction
- Health, physiology and biological condition
- Behavior
- Community composition
- Ecological processes and services
- Physical and chemical habitat quality or structure
- Public services, such as recreation

Oil Mixes, Disperses and Partitions in the Environment



Potential exposure-aquatic organisms:

- Oil in water
- Oil on water
- Droplets and particles
- Dispersant
- Diet
- Physical effects

Potential exposure:

- Multiple habitats
- Multiple species
- Multiple trophic levels
- Multiple life stages

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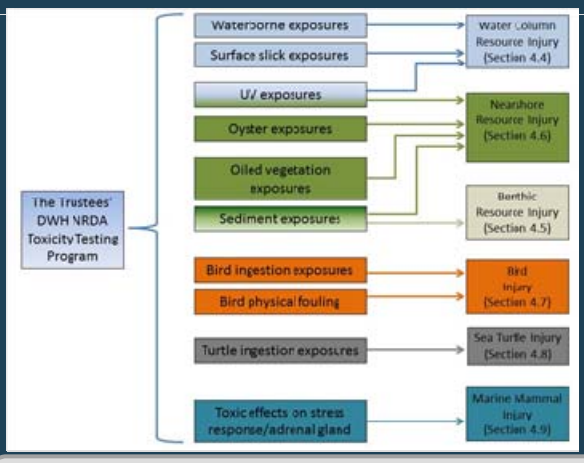
Deepwater Horizon Toxicity Program

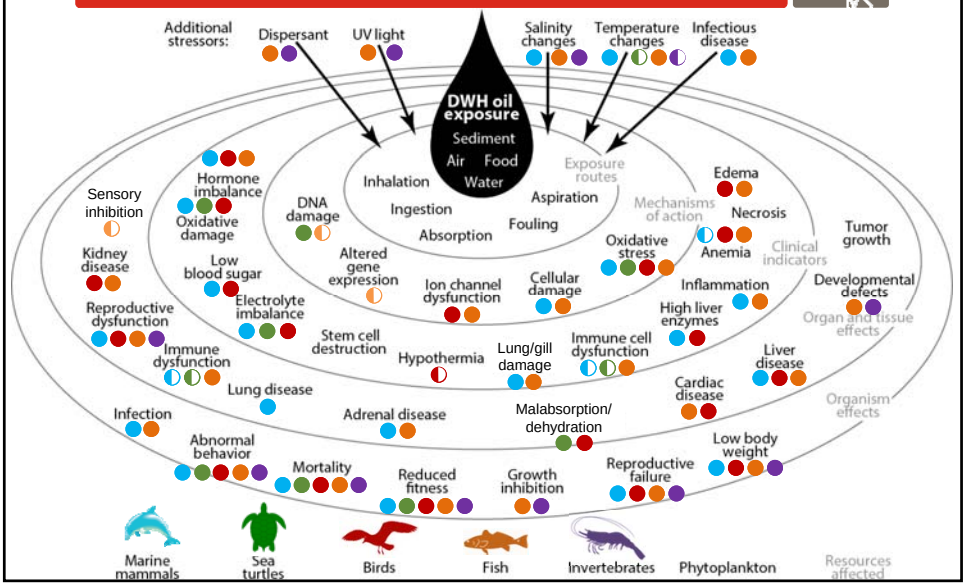


Tested 40 species including fish, invertebrates, plankton, 2 freshwater turtle species, birds, and a mammal adrenal cell line study

Toxicity Program Findings

- Adverse effects at sediment concentrations ~ 1 ppm (mg/kg) TPAH50 (*reporting LC20s*)
- Adverse effects at water concentrations ~ 1 ppb (ug/L) for fish and ~ 13 ppb for invertebrates TPAH50
- Early life stages most sensitive
- Oil mixing methods: for a given species and life stage, the toxicity of DWH oil to fish was generally similar across WAF preparation methods when toxicity is expressed in terms of the concentration of TPAH50
- Some toxic effects conserved across species

Physiological Oil Response Constellation



Toxicity Program: Surface Oiling Considerations

- Thin sheens (1 um or less) toxic to the sensitive early life stages (ELS) of fish and to invertebrates
- UV enhanced toxicity resulted in 10x to >100x increase in toxicity under ambient UV for semi-transparent inverts, and early life stage fish

Source: *Abt Associates*

Thin oil sheen generated in a beaker using DWH oil (~ 1um thick) as used in bioassays with fish and invertebrates.

Source: *NOAA*

DWH oil sheen photographed from an airplane

Surface Oil Observations Useful in Assessment

- Surface oil accumulates and persists in same areas as susceptible natural resources
- Many sensitive early life stages congregate at surface or in surface mixing layer or directly at or on surface
  - Planktonic
  - Neutrally or positively buoyant
- UV light penetrates in surface waters (15-30 m in GoM)
- Surface breathing animals (e.g., turtles and mammals and birds) inhale or aspirate oil

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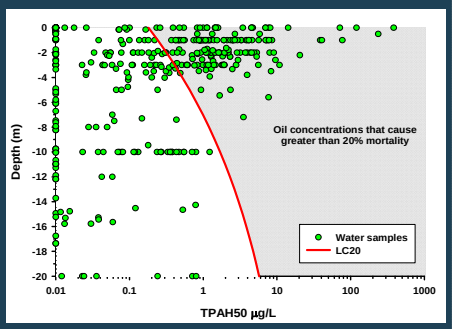
Many DWH Water Samples had TPAH Levels Exceeding Lethal Levels

- TPAH50 concentrations in water samples (green dots) plotted against LC20 values adjusted for photo-induced toxicity (red line).
- LC20 value (red line) increases (i.e., less toxicity) with depth because ambient UV light decreases.
- Samples in the gray-shaded area represent conditions in which mortality to ichthyoplankton would be expected to exceed 20%



Speckled Sea Trout ELS Data
(Water Column; Lay et al. 2015b)

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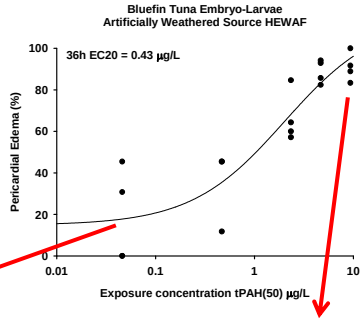
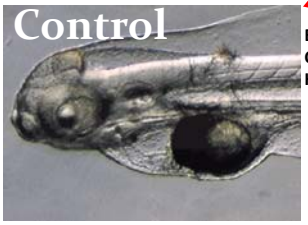
Exposure to Low Concentrations of DWH Oil Causes Cardiotoxicity: Bluefin Tuna

- Impaired cardiac development (deformities)
- Impaired cardiac function (e.g., arrhythmia)
- Similar to congestive heart failure in humans
- Have demonstrated in pelagic fish species and standard test species





Bluefin Tuna Larvae: Control Showing Healthy Heart

Bluefin Tuna larvae: Exposed to 9.4 PPB PAH showing extensive cardiac edema

20% cardiac edema to bluefin tuna at < 0.5 ppb

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Other Developmental Deformities Documented

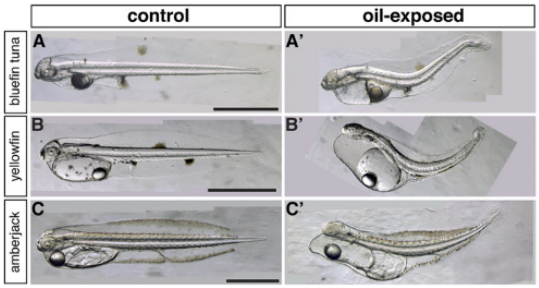

Fig. 2. Gross morphology of hatching stage larvae exposed to MC252 HEWAFs oil during embryonic development. Embryos were exposed from shortly after fertilization to 12–16 h after hatching. Unexposed controls incubated in clean water are shown in A–C, and oil-exposed (highest-dose tested) in A–C. Representative examples are shown for (A, A) bluefin tuna exposed to artificially weathered source oil (1 mg/L oil, 8.5 g/L PAH), (B, B) yellowfin tuna exposed to slick A (2 mg/L oil, 3.4 g/L PAH), (C, C) amberjack exposed to artificially weathered source oil (1 mg/L oil, 13.8 g/L PAH). (Scale bars, 1 mm.)

From: Incardona et al., (2014) Deepwater Horizon crude oil impacts the developing hearts of large predatory pelagic fish. PNAS

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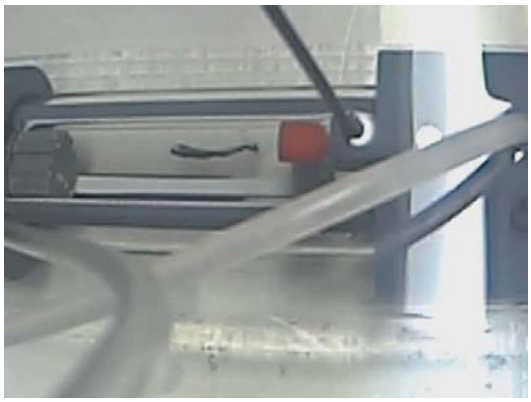
Swimming performance and aerobic scope in pelagic fish

Fully-weaned 34 dph Mahi-mahi *J. Stieglitz, 2012*



Acute Embryonic or Juvenile Exposure to *Deepwater Horizon* Crude Oil Impairs the Swimming Performance of Mahi-Mahi (*Coryphaena hippurus*)

Edward M. Mager, Andrew J. Esbaugh, John D. Stieglitz, Ronald Hoenig, Charlotte Bodinier, John P. Incardona, Nathaniel L. Scholz, Daniel D. Benetti, and Martin Grosell

Environ. Sci. Technol., **2014**, *48* (12), pp 7053–7061

Publication Date (Web): May 23, 2014 (Article)

DOI: 10.1021/es501628k

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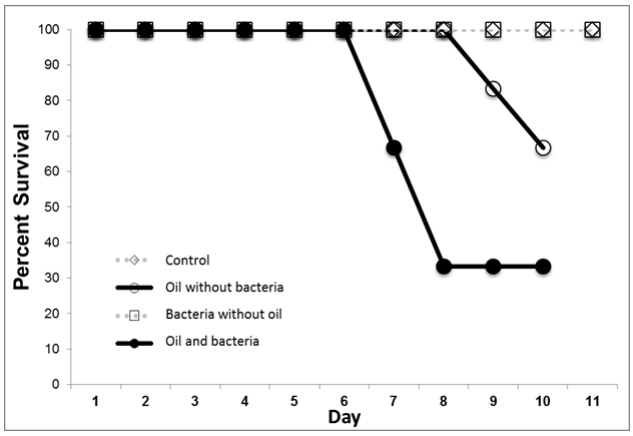
Effects of Multiple Stressors



Oil exposure 4d

Followed by 1h bacterial challenge

Figure 4.3-13. Percent survival of juvenile red drum exposed to one of four treatments: 1) neither oil nor bacteria (*Vibrio anguillarum*), 2) DWH oil without bacteria, 3) bacteria without oil, 4) DWH oil and bacteria. Exposure to oil and bacteria caused considerably more mortality than in the other treatments (Ortell et al. 2015).

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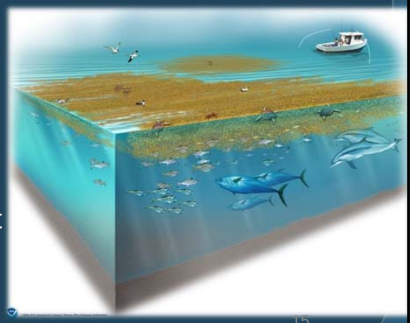
Surface Oil and Sargassum

Sargassum: designated as Essential Fish Habitat (EFH)

- Fish larvae and invertebrates, larger fish, sea turtles, sea birds rely on Sargassum as habitat, foraging area, protection from predators
- Sargassum concentrates in convergence zones -- as does surface oil
- Consider dispersant application sinks Sargassum (Powers et al. PLoS One)
- Loss of up to 23 percent of this habitat
- Total loss of *Sargassum*, including foregone area from lost growth is 4,300 square miles



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Benthos are not charismatic!

"I don't know why I don't care about the bottom of the ocean, but I don't."

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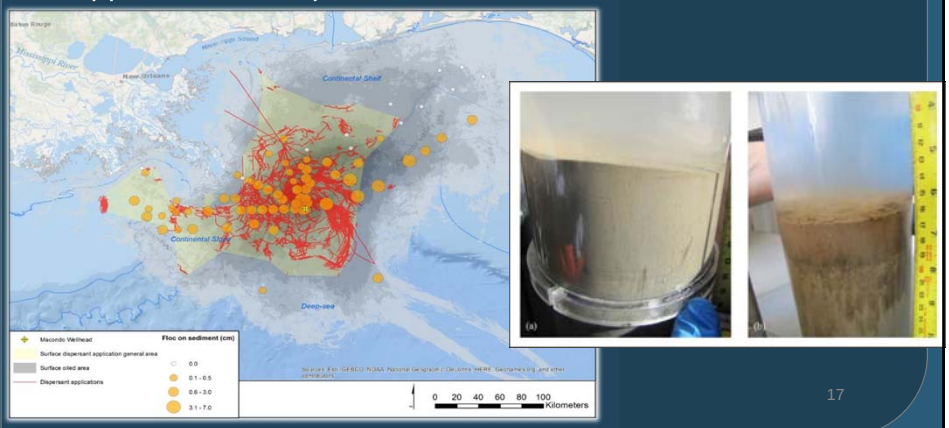
Surface Oil and Sea Floor Floc

- Larger quantities of floc were observed on the sea floor beneath areas experiencing persistent surface oil and application of dispersants



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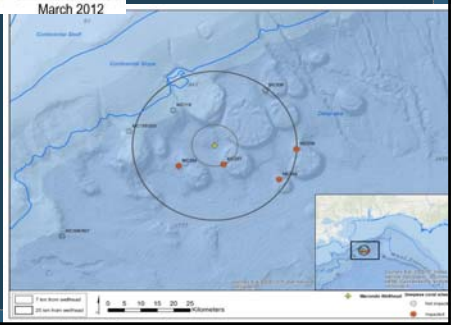
Deepsea Coral Colony Injury Progression

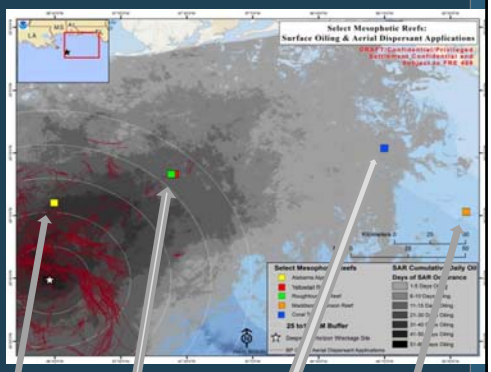
Progression of coral injury from coverage by flocculent material in 2010, through hydroid colonization in 2011 and onset of terminal branch loss in 2012

Map of locations of injured coral sites in relation to the DWH wellhead



Mesophotic Reefs

- Injured mesophotic reefs located under surface slicks (AA and RTR closer to release)
- Long term pre-spill monitoring (video transect) data on these reefs indicate acute coral mortality post spill
- Approximately 1/3-1/2 large sea fan colonies experienced injury
- Associated order of magnitude decreases in planktivorous fish abundances

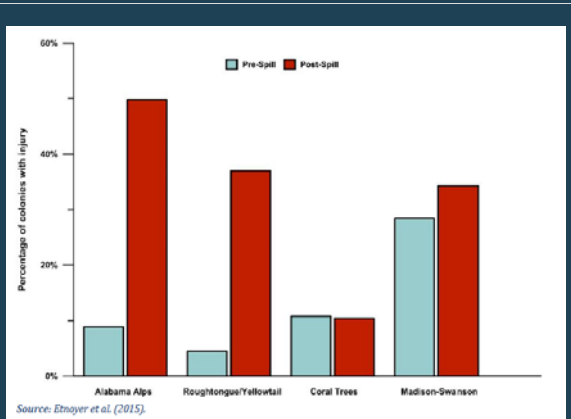


Alabama Alps

Roughtongue Reef

Coral Trees

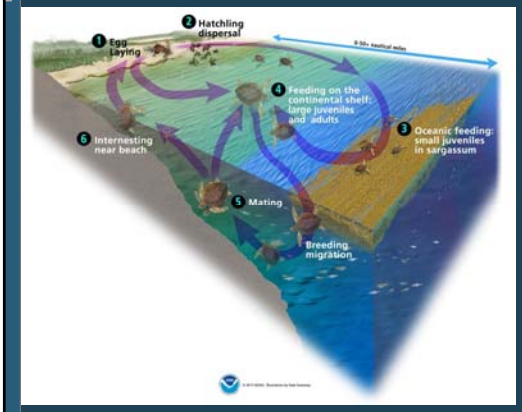
Madison Swanson



Source: Etnoyer et al. (2015).

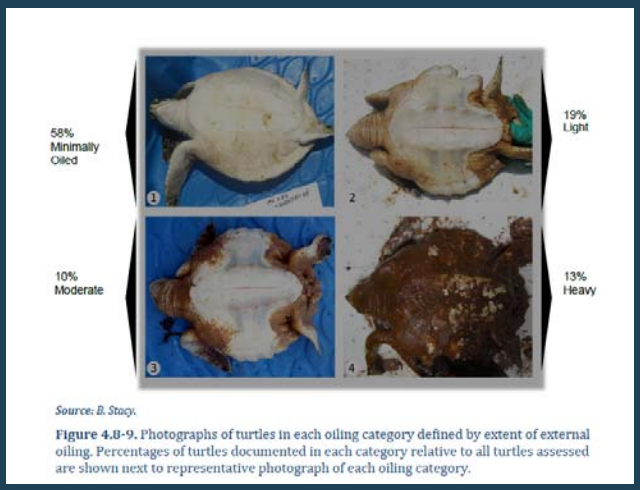
Figure 4.5-15. Prevalence of injured corals (large sea fans) at mesophotic reef sites in the northern Gulf of Mexico. Bars show the percentage of coral colonies observed in video transects with obvious injuries including bare, denuded, or broken branches; overgrowth; abnormal polyps; or severe discoloration. Pre-spill estimates were derived from video taken in 1989 and 1997 through 2003. Post-spill estimates were derived from video taken in 2010, 2011, and 2014.

Generalized Turtle Lifecycle



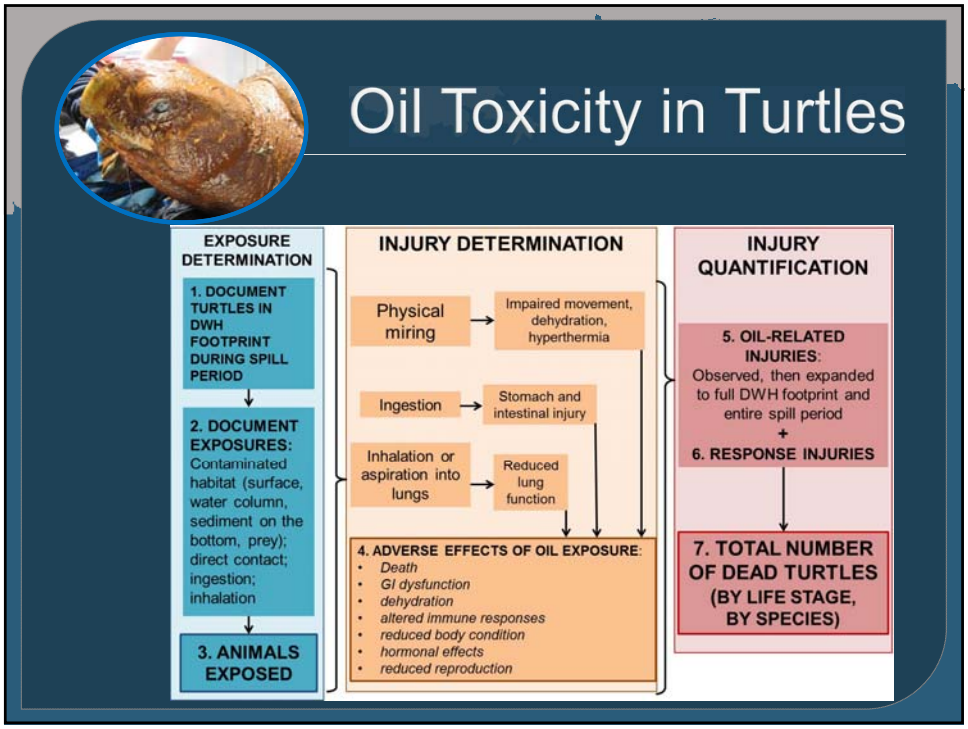
- Beach response activities
- Oil persisting in sand exposing eggs, hatchlings, adults
- Sargassum-oil interaction
- Water column exposure
- Contaminated prey
- Oil on water- inhalation, aspiration, miring in oil

Turtles Ingest Oil

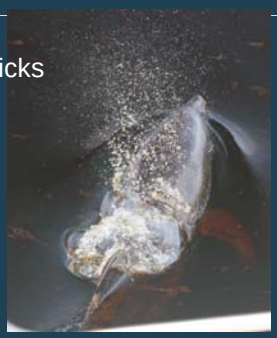


Source: B. Stacy.

Figure 4.8-9. Photographs of turtles in each oiling category defined by extent of external oiling. Percentages of turtles documented in each category relative to all turtles assessed are shown next to representative photograph of each oiling category.

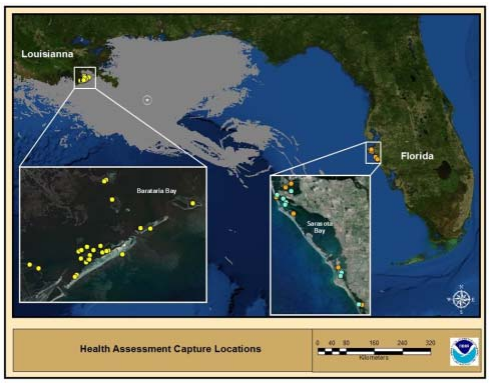


Marine Mammals



- Marine mammals can be exposed to surface slicks
  - Exposed via *inhaled, aspirated*, ingested, physically contacted, and absorbed oil
  - Non-NRDA work evaluating role of surface dispersants on aerosol formation
- Oil damaged tissues and organs; led to adverse health effects including lung disease, reproductive failure, adrenal disease, poor body condition
- Mammal exposure to DWH oil contributed to the largest and longest lasting marine mammal Unusual Mortality Event (UME) on record in the northern Gulf of Mexico (>1,000 stranded)
- Dolphin population recovery estimated to take decades

2011 Dolphin Health Assessments – Barataria Bay *(Schwacke et al., 2014)*

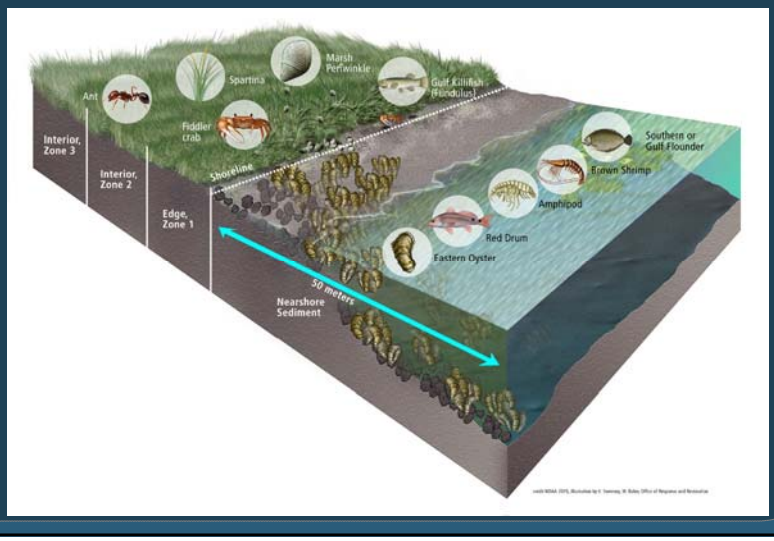


- 5 times more likely to have moderate- severe lung disease
- Hypoadrenocorticism
- Overall poor body condition
- High prevalence of abnormal liver enzymes, other blood abnormalities
- 48% guarded or worse prognosis; 17% poor/grave
- Tooth loss
- 11/15 mature females were pregnant; 46% increase in failed reproduction
- Consistent with strandings data
- Consistent with literature and EVOS mammal effects

Birds (DOI lead)

- Field studies documented number and distribution of carcasses and live birds impaired by oil
- Modeling accounted for birds not observed directly
- Toxicity studies demonstrated reproduction, anemia, immune function, heart abnormalities, other endpoints
- Plumage oiling impaired flight capability and led to behavioral changes in controlled studies

Nearshore Ecosystem



Nearshore: Vegetation

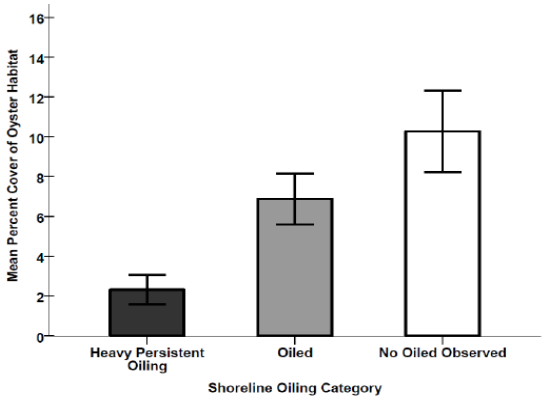
- Marsh *live plant cover* and *vegetation biomass*, reductions even in areas with as little as 10% documented oiling of plant stems
- Effects persisted for 4 years of study
- Live mangrove cover and growth rates reduced
- Response activities such as washing, cutting, and raking of oiled shoreline vegetation, stranding of oil booms impacted marsh animals and coastal wetland habitat
- Erosion
  - Areas of most heavy oiling and response actions had double yearly marsh edge erosion rates
  - Higher erosion rates also associated with areas that lost adjacent oyster habitat

Nearshore

- Multiple indicator species had reductions in injury metrics including survival, reproduction, growth, biomass, abundance
  - Shrimp
  - Amphipods
  - Fundulus
  - Juvenile southern flounder
  - Red drum
  - Fiddler crab
  - Insects

- 4-8.3 billion subtidal adult 'oyster equivalents' lost Gulf-wide from combination of oiling and river-water releases
- Seagrass losses documented oiling + response

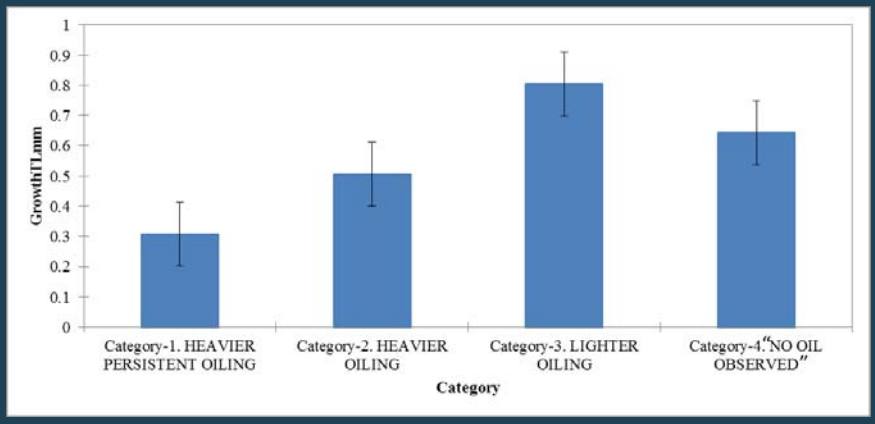
Oyster Cover and Degree of Oiling



Source: Powers et al. (2015b).

Figure 4.6-35. Percent cover of oyster by oiling category (mean ± 1 standard error) from Terrebonne Bay, Louisiana, to Mississippi Sound, Alabama. This figure demonstrates the effect of oiling on nearshore oysters. Oiled areas had lower oyster cover (percent of area) than non-oiled areas. Areas that experienced heavier persistent oiling had the lowest observed oyster cover.

Examples of Nearshore Faunal Effects



Source: *Powers and Scyphers (2015).*
Figure 4.6-25. Growth rates of juvenile brown shrimp associated with marshes of various degrees of oiling. Growth rates were reduced by 27 to 56 percent compared to sites that did not experience oiling.

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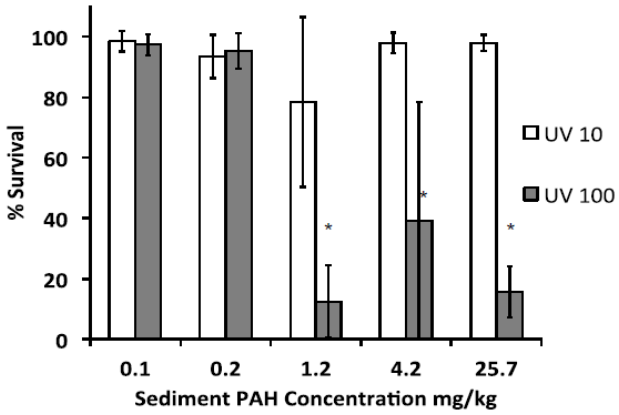
Fiddler Crab Larval Survival Following Maternal Exposure

Fiddler crab larval survival (24hrs) following adult exposure to PAH-contaminated sediments

Sum of 50 PAH reported here

Poster MP012



Roberts et al., UNT, SETAC 2013

DWH NRDA publications

- 30+ peer reviewed publications and counting……
  - Deepsea corals and benthos
  - Dolphins
  - Fish Toxicity
  - Sea Turtles
  - Oil in the environment
- Publications available to public: http://response.restoration.noaa.gov/deepwater-horizon-oil-spill/noaa-studies-documenting-impacts-deepwater-horizon-oil-spill.html

For More Information

http://www.gulfspillrestoration.noaa.gov

https://dwhdiver.orr.noaa.gov