Oil Spill Response Options for the Flower Garden Banks National Marine Sanctuary

APPENDIX

May 25 – 26, 2016
Flower Garden Banks National Marine Sanctuary
Galveston, Texas

Coastal Response Research Center

Appendix A: Participant List

NOAA's Regional Preparedness Training (NRPT)
Environmental Tradeoff Analysis (ETA) for an Oil Spill Response
Impacting the Flower Garden Banks National Marine Sanctuary

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Appendix B: Training Agenda

State-of-Science of Dispersants and Dispersed Oil

NRPT Training

May 24, 2016
Flower Garden Banks, National Marine Sanctuary,
Galveston Texas

TRAINING AGENDA

9:00 am	Welcome and Logistics • Nancy E. Kinner, Coastal Response Research Center, University of New Hampshire • Charlie Henry, NOAA ORR, Gulf of Mexico Disaster Response Center • G.P. Schmahl, Flower Garden Banks, National Marine Sanctuary
9:15 am	Goals of Training
9:30 am	Efficacy and Effectiveness • Tim Nedwed, ExxonMobil Upstream Research Company
10:30 am	*Break*
10:45 am	Physical Transport and Chemical Behavior • Chris Barker, NOAA ORR ERD (remote)
11:45 – 12:45	*Lunch (1-hour break – on your own)*
12:45 pm	Degradation and Fate • Nancy Kinner
1:45pm	*Break*
2:00 pm	Eco-toxicity and Sublethal Effects • Lisa DiPinto, NOAA ORR ARD
3:00 pm	Public Health and Food Safety • Doug Helton, NOAA ORR ERD (remote)
4:00 pm	Adjourn

Appendix C: Training Presentations

Dispersant Efficacy & Effectiveness

Efficacy – do dispersants work in a controlled setting?
Effectiveness – do they have a benefit in the real world?

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Spill Response Options: *The Toolbox*

Mechanical Recovery: Booms & Skimmers

In-Situ Burning

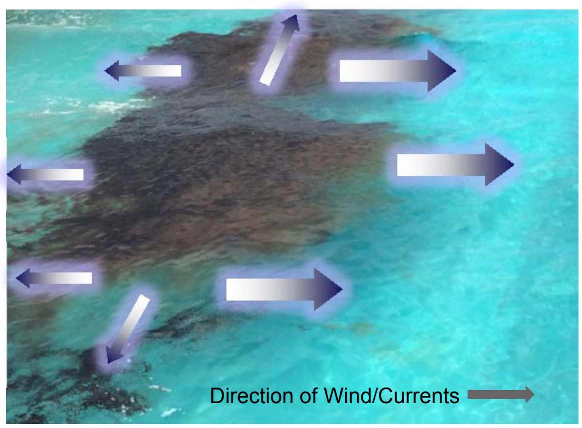
Aerial Dispersants

Boat-based Dispersants

Subsea Dispersants

Rapid Response is Key

- A slick continuously expands and oil thins
  - The size of the problem will increase with time
- Response options get less efficient with time
  - The goal is to respond as quickly and as close to the source as possible



Challenges to Oil Spill Response

- Weather
  - Recovery very challenged in rough seas (>2 M) or high winds (>25 kts)
  - Safety concerns In high seas and inclement weather
- Thousands of different oils with a wide range of properties
  - Weathering effects
- Remote locations may not have immediate logistical support
- Wide range of impacted habitats
  - Rocky beaches to sensitive marshes
- Very little to no daylight during winter at higher latitudes
- Limited access to impacted areas

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Dispersants

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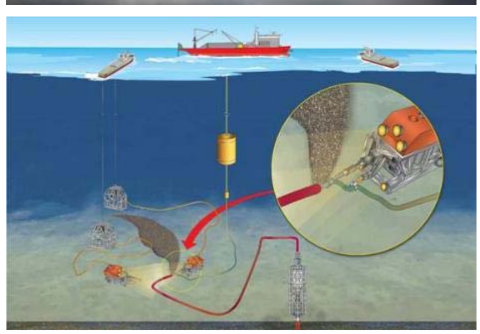
Introduction

Topics of Discussion

- Oil spill response options
- Background on dispersants
- Subsea dispersants
  - Observations on their use
- Summary



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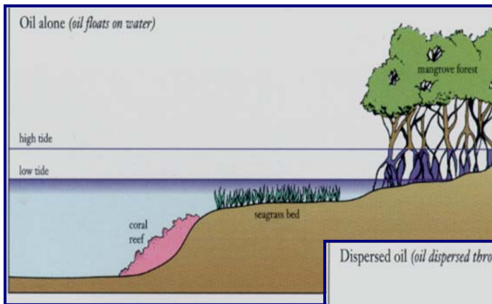
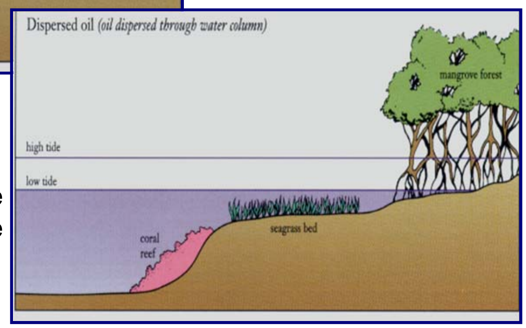
NEBA



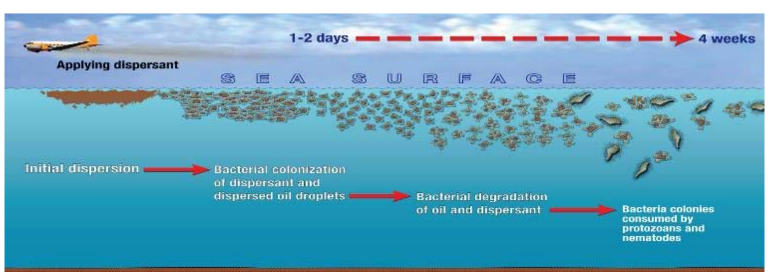
Limit Water Column Organism Exposure



Limit Surface Organism Exposure

Dispersants – What are they?

- Solutions of surfactants dissolved in a solvent
- Surfactants reduce oil-water interfacial tension – allows slick to disperse into very small droplets with minimal wave energy
- Dispersed oil rapidly dilutes to concentrations <10 ppm within minutes, <1 ppm within hours, ppb range within a day
- Each dispersed oil droplet is a concentrated food source that is rapidly colonized and degraded by marine bacteria
- Dilution allows biodegradation to occur within nutrient and oxygen limits



Graphic consistent with Venosa & Holder, EPA 2007

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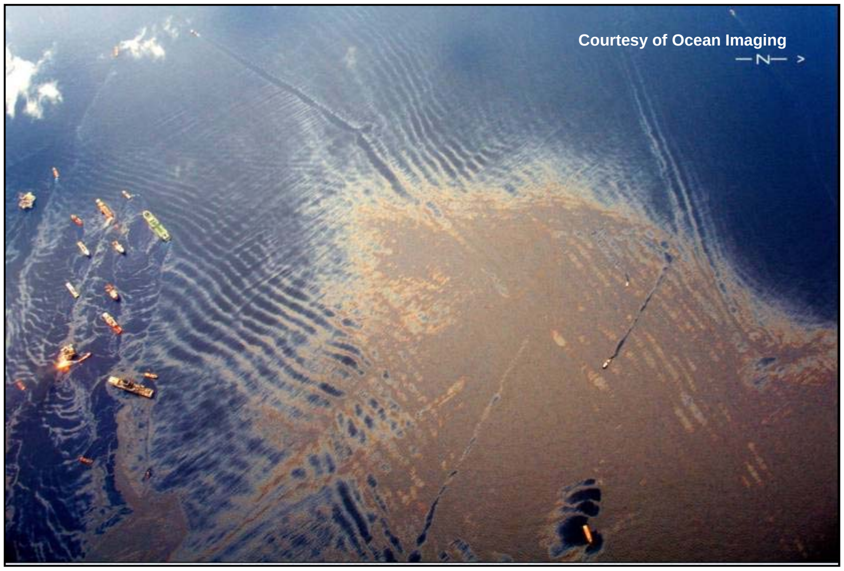
Encounter Rate



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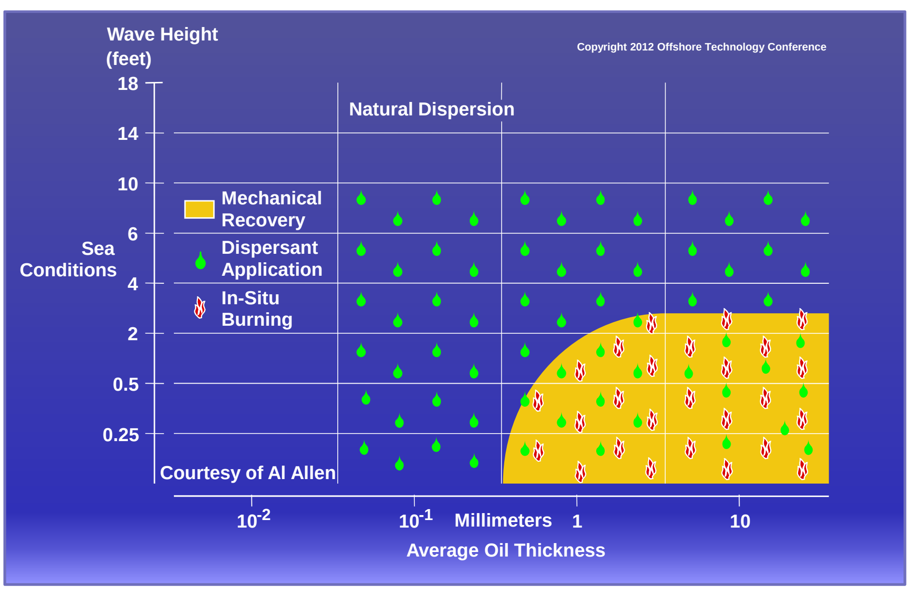
Spill Conditions Limit Response Options



Dispersant Ingredients & Toxicity

Modern dispersants use ingredients found in household products

Relative Toxicity: Environment Canada Study
(96 hr Rainbow Trout LC_{50})*

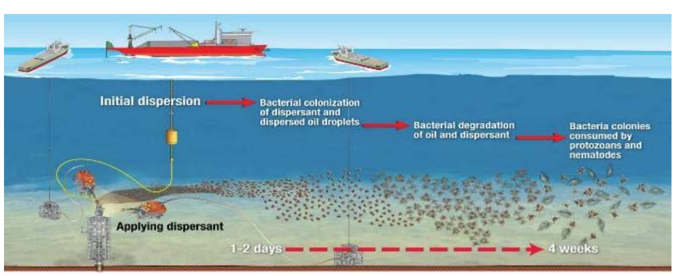
AGENT	**LC_{50} (ppm)**
Palmolive Dish Soap	**13**
Sunlight Dish Soap	**13**
Mr. Clean	**30**
Corexit® 9500 (27 times less toxic than dish soap)	**350**

Less toxic

*Lethal concentration to 50% of the test organisms

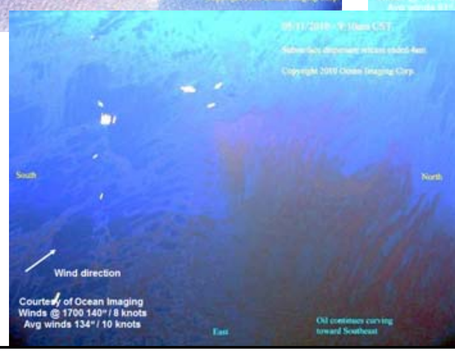
Subsea Injection of Dispersants

- Preliminary observations of Macondo experience
- Benefits of subsea injection
- Long-term fate and effects



Release Site May prior to injection

Release Site May 10: 11 hrs of Injection



Release Site May 11 5 hrs after Injection Ended

Dispersant Use Approval

- May require a low inherent toxicity and a minimum level of effectiveness
  - Verified by test protocols before placement on an approved list if required
- Regulations require that permission be obtained before dispersants are used in certain locations, especially when close to shore and/or in shallow water
  - A pre-approval process may be used, especially for offshore and/or in deep water
- Documentation to support their use is often based on an environmental risk-analysis of relevant scenarios and is part of an approved contingency plan
  - Scenario-based contingency plans should demonstrate that the use of oil spill dispersants will give the best overall response for the environment (NEBA-approach)
- Potential for significant differences from country to country

Dispersant Use Across the Globe

- Dispersants are a first or second response option in many countries today

- Angola
- Argentina
- Australia
- Belgium
- Brazil
- Brunei
- Cameroon
- Canada
- Chile
- China
- Columbia
- Côte d'Ivoire
- Croatia
- Cyprus
- Denmark
- Djibouti
- Ecuador
- Egypt
- El Salvador
- Eritrea
- France
- French Guiana
- Gabon
- Georgia
- Germany
- Ghana
- Greece
- Greenland
- Iceland
- India
- Indonesia
- Ireland
- Israel
- Italy
- Japan
- Kenya
- Kuwait
- Lebanon
- Libya
- Malaysia
- Malta
- Mexico
- Montenegro
- Morocco
- Namibia
- Nicaragua
- Netherlands
- New Zealand
- Nigeria
- Norway
- Oman
- Pakistan
- Papua New Guinea
- Philippines
- Poland
- Portugal
- Qatar
- Russia
- Saudi Arabia
- Senegal
- Sierra Leone
- Singapore
- South Africa
- South Korea
- Spain
- Sri Lanka
- Sudan
- Syria
- Tanzania
- Thailand
- UAE
- UK
- Uruguay
- US
- Vietnam

Countries where dispersants are first or second response option

Many countries consider dispersants an important tool in oil spill response. However, there is global inconsistency in the types of approved dispersants and how and when to use them.

Source: International Tanker Owners Pollution Fund (ITOPF)

energy API Used with permission of the API

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Summary

- Along with prevention, robust oil spill response is critical
- Highest priority in emergency response is human health and safety
- Basic strategy for addressing oil spilled from an offshore well
  - Respond as close to the source as possible
  - Utilize all appropriate tools to keep oil from reaching shorelines
- Dispersant use presents significant advantages over the limitations of mechanical recovery and should be considered as a primary response option
- Subsea injection can provide benefits over other oil spill response options

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Questions?

Backup Slides

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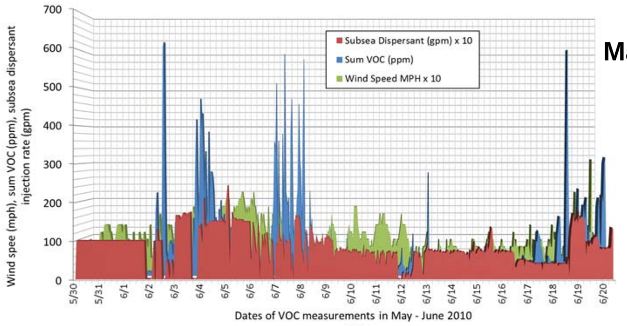
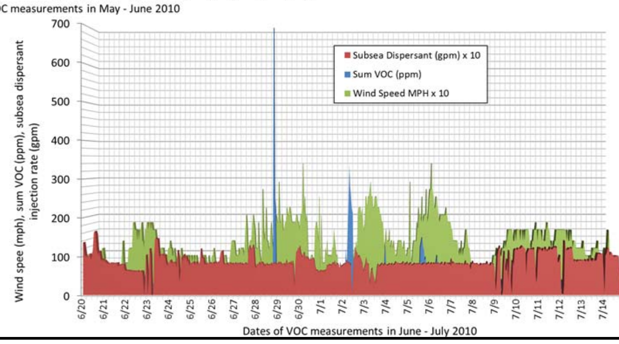
VOC Data from Vessels Near Well Site

May 30 – June 20, 2010



June 20 – July 15, 2010



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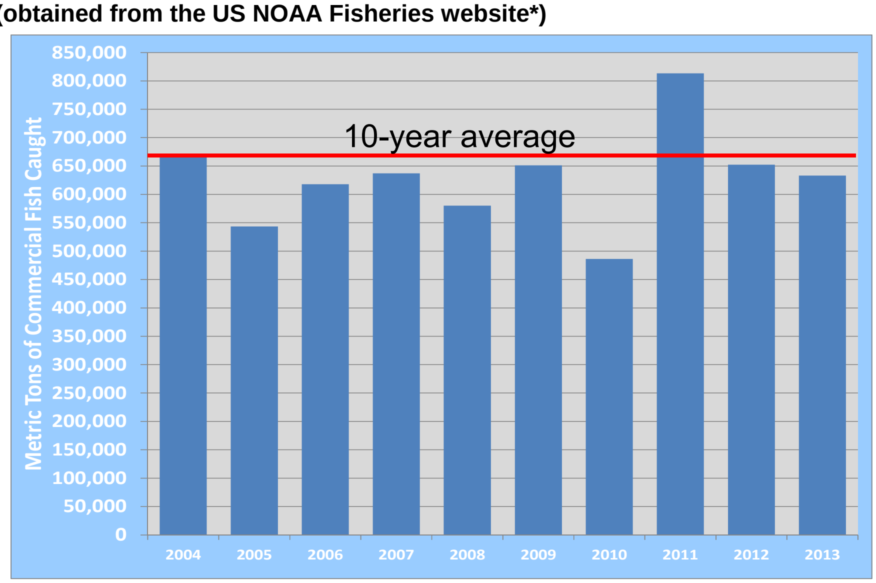
Commercial Fish Catch in the GOM

(obtained from the US NOAA Fisheries website*)



*Data available online as of November 2015 at http://www.st.nmfs.noaa.gov/st1/commercial/landings/annual_landings.html

Physical Transport

Flower Garden Banks NRPT Workshop

Christopher Barker, PhD

Emergency Response Division
NOAA Office of Response and Restoration

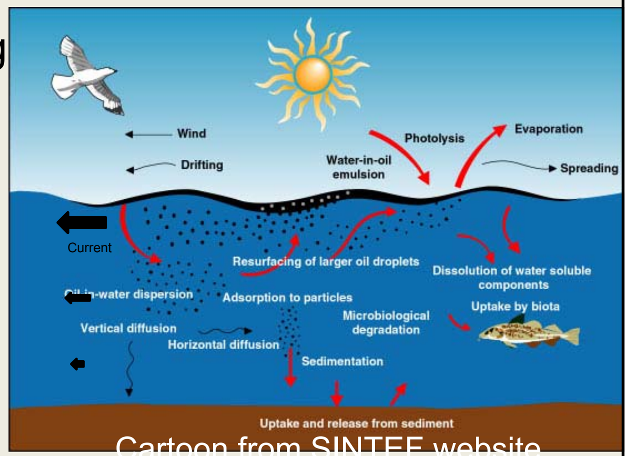
May 24, 2016

Oil Spill Transport: Takeaways:

- Oil properties play a major role in determining physical processes.
- Oceanographic and atmospheric conditions change with time and location.
- Need onshore winds to beach oil.
- As a spill progresses, oil concentration decreases.
- Because oil usually floats on the surface, it can collect in areas of surface convergence or along shoreline.
- Floating oil transport often dominated by winds
- Subsurface oil doesn't "feel" the wind.

What happens to oil when it is spilled in the marine environment?

- Oil Weathering
- Spreading
- Transport



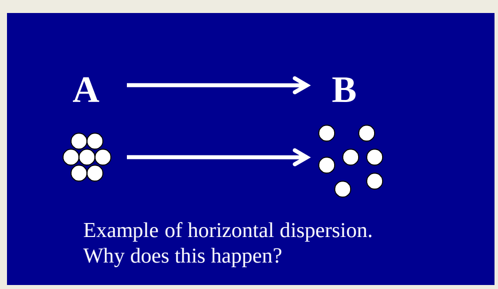
Cartoon from SINTEF website
http://www.sintef.no/static/ch/environment/oil_weathering_model.htm

Surface oil transport

Spreading due to gravity generally complete within first few hours then…

Subsequent oil movement results from:

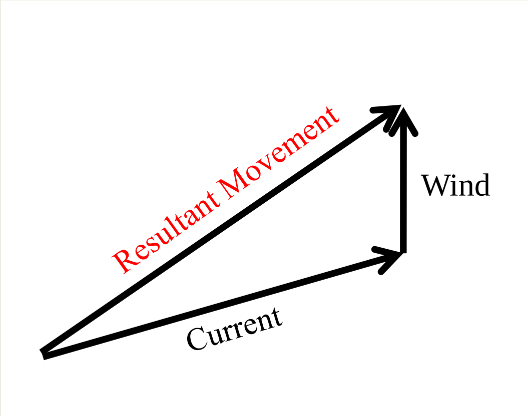
- Winds
- Currents
- Turbulence

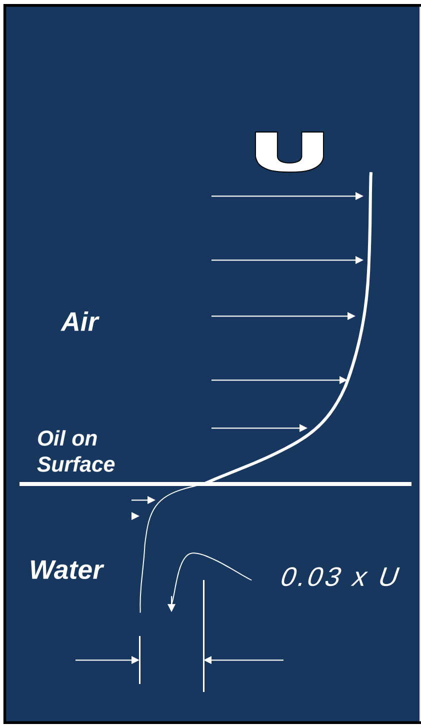


Example of horizontal dispersion.
Why does this happen?

Advection

Can be estimated as the vector sum of:
- Wind Drift
- Surface Currents





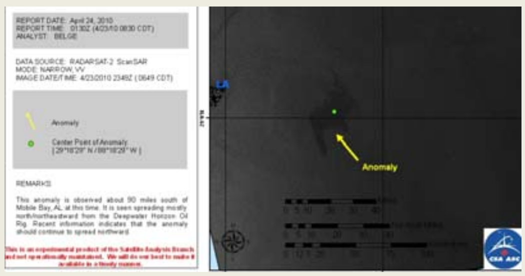
Wind

- Surface of the water (and oil) moves at about 3% of the wind speed.
- Example:
  - In a 20 knot wind, the oil moves at about 0.6 knots.
- How might this change as the oil weathers?

Windage

How fast the wind pushes a floating object

Rubber rafts	7%
Large Cabin Cruiser	5%
Raft with drogue	5%
Sailboats, Fishing Vessel	4%
Fresh Oil	3%
Surfboards	2%
Weathered tarballs	1%
Subsurface oil droplets	0%



DWH Satellite analysis of sea surface roughness used to detect oil.

Windage includes energy from small capillary waves which are damped by oil.

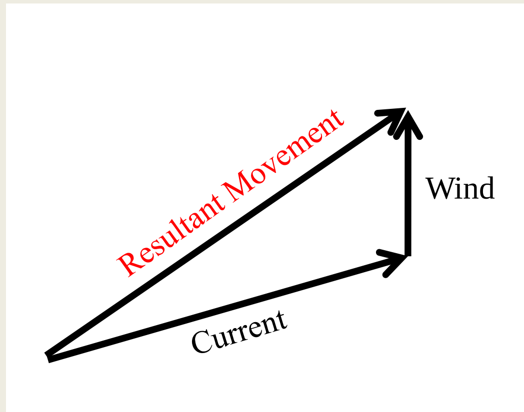
$$\frac{\partial}{\partial t}(\rho\vec{v}) + \nabla\cdot(\rho\vec{v}\vec{v}) = -\nabla p + \nabla\cdot(\overline{\overline{\tau}})$$

- 3% of wind speed is a handy "rule-of-thumb" for oil movement most applicable for fresh oil in light to moderate winds
- It parameterizes a number of very complex ocean-atmosphere-wave interactions
- Dependent on oil-type, wind strength, wave climate
- Changes over time due to weathering processes

$$\frac{\partial\rho}{\partial t} + \nabla\cdot(\rho\vec{v}) = 0$$

Advection

Can be estimated as the vector sum of:
- Wind Drift
- Surface Currents



Next look at currents

Length and Time Scale for Currents

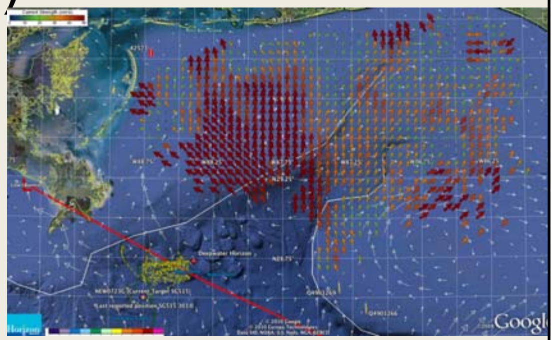
(or, how far the spill will move or spread over what time period)

Current Type	Length Scale	Time Scale	Uncertainty
River	10s of miles	Hours to days	Lowest
Tides	Miles	Hours	Low
Estuarine Circulation	10s of miles	Days	Medium
Coastal Flow	100s of miles	Days to weeks	High
Ocean Circulation	1000s of Miles	Months to years	Low-High

(but, don't forget weathering!)

Coastal (shelf) currents

- Complicated dynamics
  - wind-driven flow
  - freshwater influence
  - deep ocean influences
  - tides
  - topographic interactions…
- Strong variability on multiple time scales (seasonal, event-scale)

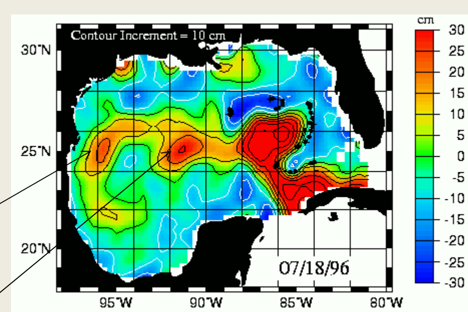


Snapshot of measured currents (colored vectors) and modeled currents (white vectors) in 2010

Are tides important here?

…in the GoM

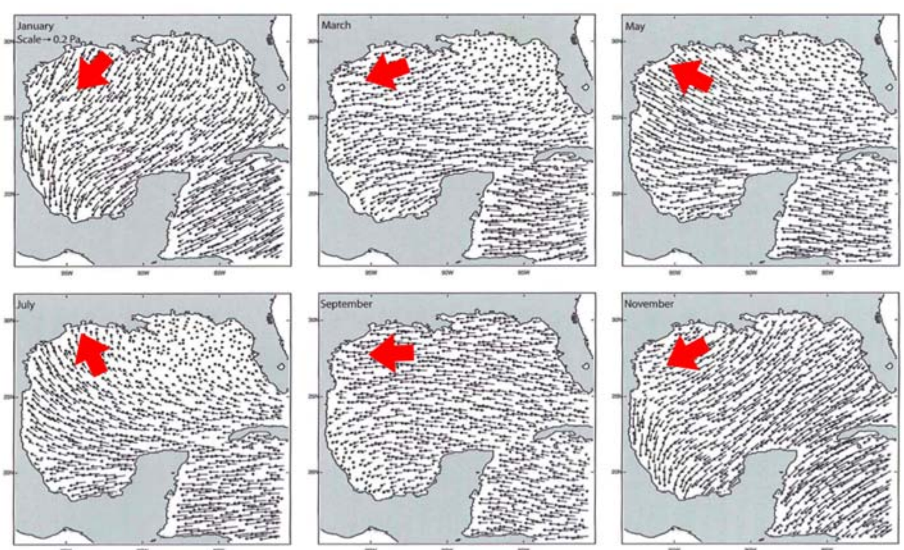
- The Loop Current is a warm ocean current that flows northward between Cuba and the Yucatán peninsula, moves north into the Gulf of Mexico, loops east and south before exiting to the east through the Florida Straits and joining the Gulf Stream



Where did these come from

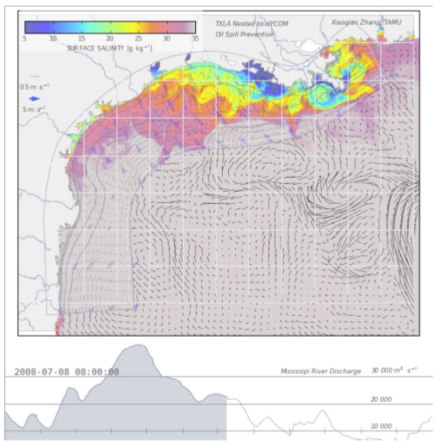
NW Gulf Bathymetry

Seasonal Winds

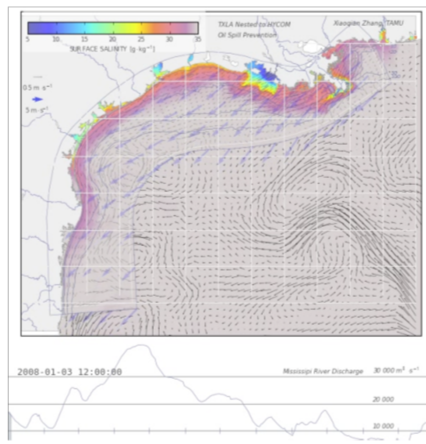


Morey et al, 2005, AGU Monograph: *Circulation in the Gulf of Mexico: Observations and Models*

River Plume



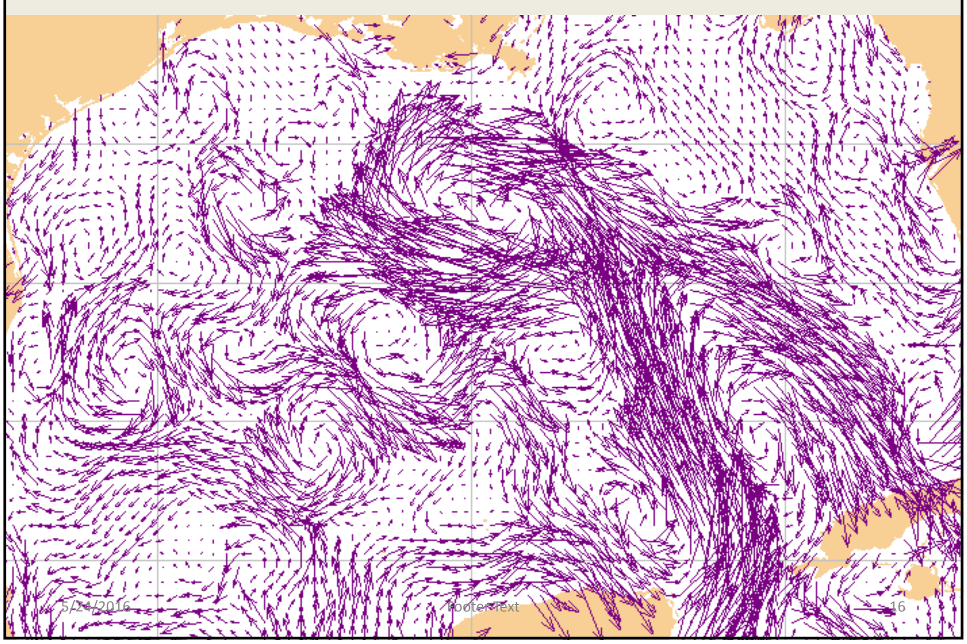
(a) Summer



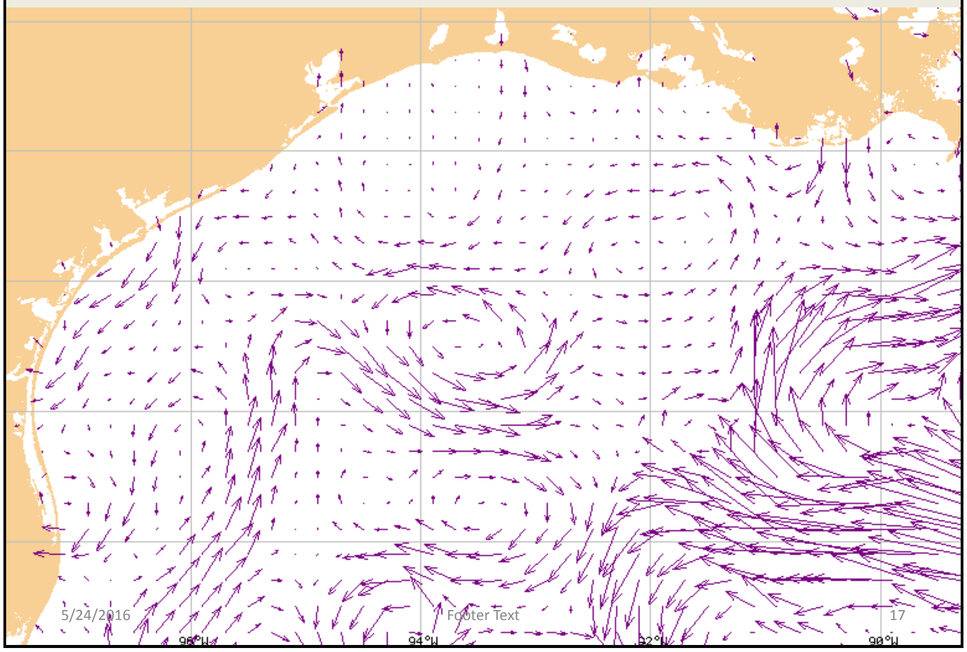
(b) Winter

Xiaoqian Zhang, http://pong.tamu.edu/∼zhangxq/

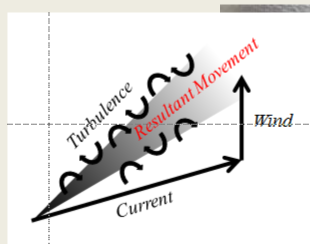
SSH-Derived Currents

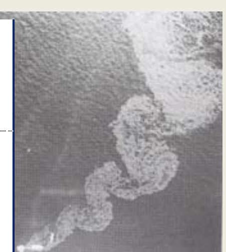


SSH-Derived Currents

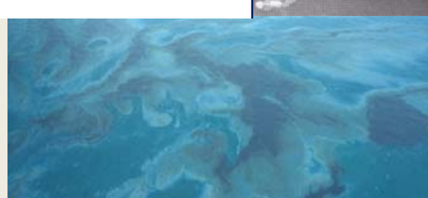


Turbulence





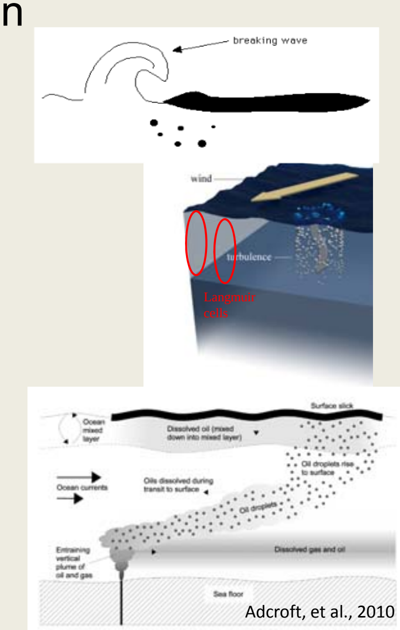
- These are small scale currents that ocean models may not resolve
- Turbulence will tear apart a slick and result in a patchy distribution spread over a larger area



- Response challenge: encounter rate
- Volume?

The missing 3rd dimension (dispersion)

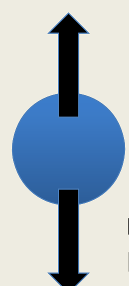
- Driven by wave energy – breaking waves
- Dependent upon oil type (viscosity, surface tension)
- Mixed to depth of ocean mixed layer
- Subsurface oil also subject to advective and diffusive transport, but:
  - No "wind-drift"
  - Diffusing in 3-dimensions
  - Vertical shear of currents
  - Less potential for convergence – i.e. concentrations reduce with time



Adcroft, et al., 2010

Rise Velocity

- Rise velocity is the balance between Buoyancy and Drag
- Radius is cubed in Buoyant force, squared in Drag force
- Larger Droplets: Faster rise velocity.



Buoyant Force:
$F_B = 4/3\pi r^3 (\rho_W - \rho_O)$

Drag Force:
$F_D = C_D \pi r^2 V^2$

- Small Droplets stay in the water column longer
- In a turbulent environment – they can stay under water forever

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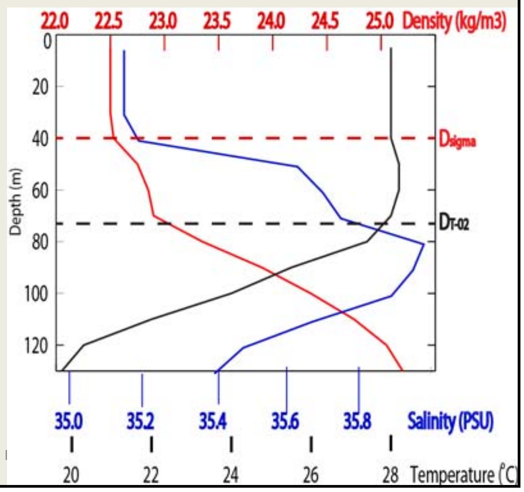
The Mixed Layer

- Region of relatively well mixed water:
  - Fairly constant temperature and salinity
- Dispersed Oil will mix relatively fast within this layer
- Very slow process for dispersed oil to get below the mixed layer.



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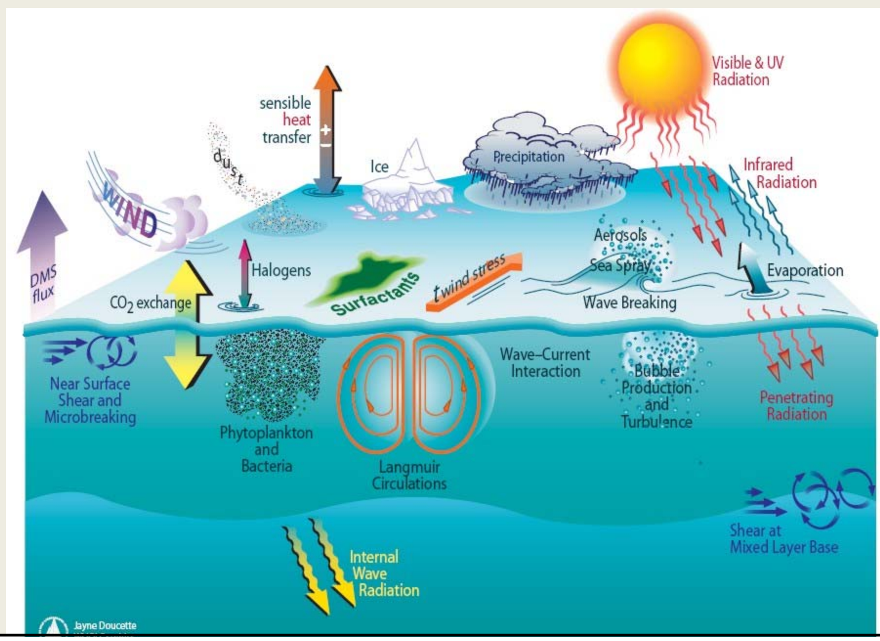
The Mixed Layer



The Mixed Layer

- So how thick is the mixed layer?
- Function of:
  Wind, Sun, Waves, Salinity, Currents – lots more.
- Regional, Seasonal, even Diurnal fluctuations
- Rule of thumb: ~ 10 m on the shelf.
- Offshore NW Gulf of Mexico:
  - Maxima of about 90–120m in February, and minima of about 20m from about May through October.
- Only way to know is to measure it.

Mass Conservation Always Holds

- The more water oil is mixed into, the lower the concentrations.
- You can have high concentrations in a small region, or effect a large region with low concentrations.
- You can not have high concentrations *and* a large region effected.
- In 3d there are no convergences – concentration always goes down.

0-D to 2-D to 3-D to 1-D

- Concentration of oil changes with how it spreads or converges
  - From a point
    - →Initial release
  - To 2-D
    - →Spreading
  - to 3-D
    - →Dispersion
  - To 1-D
    - →Convergence / Beaching

1 barrel = 42 gallons = 159 liters

2-D: Surface Slick

– 100 microns thick ("black oil"; ~2.5 barrels per acre)

Area = Vol/Th = 0.159 m^3/1e-4 m = 1590 m^2

~22 meter diameter sheen (~1/3 football field)

– 1 micron thick ("dull sheen", ~0.025 barrels per acre)

Area = Vol/Th = 0.159 m^3/1e-6 m = 159,000 m^2

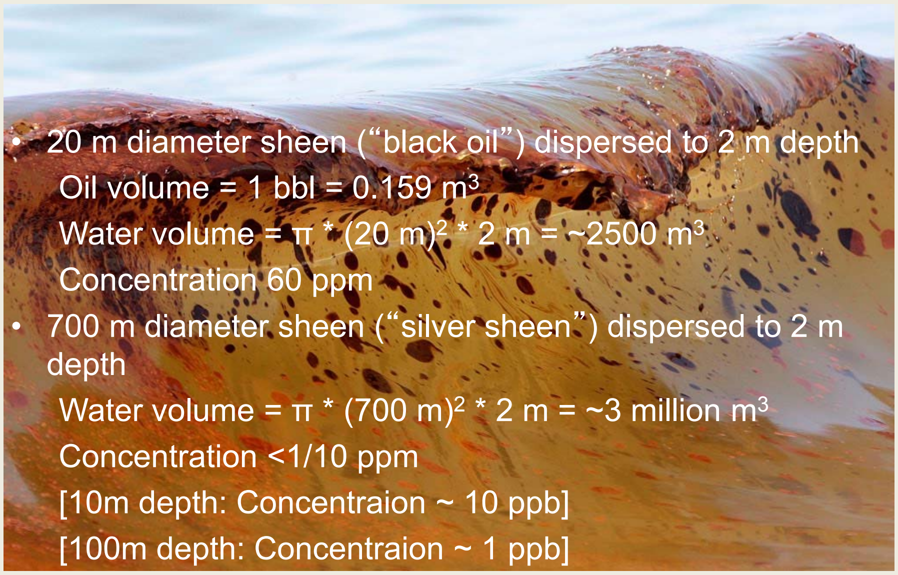
~225 meter diameter sheen (~30 football fields)

– 1/10 micron thick ("silver sheen", ~0.0025 bpa)

Area = Vol/Th = 0.159 m^3/1e-7 m = 1,590,000 m^2

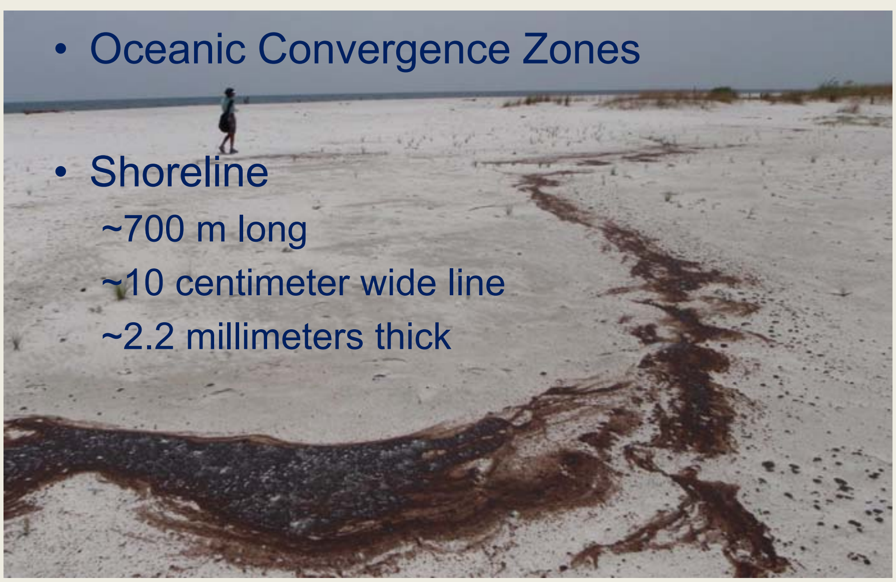
~700 meter diameter sheen (~300 football fields)

3-D: Dispersion



- 20 m diameter sheen (“black oil”) dispersed to 2 m depth
  - Oil volume = 1 bbl = 0.159 m^3
  - Water volume = π * $(20\ m)^2$ * 2 m = ~2500 m^3
  - Concentration 60 ppm
- 700 m diameter sheen (“silver sheen”) dispersed to 2 m depth
  - Water volume = π * $(700\ m)^2$ * 2 m = ~3 million m^3
  - Concentration <1/10 ppm
  - [10m depth: Concentraion ~ 10 ppb]
  - [100m depth: Concentraion ~ 1 ppb]

1-D: Convergence

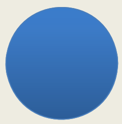


- Oceanic Convergence Zones
- Shoreline
  - ~700 m long
  - ~10 centimeter wide line
  - ~2.2 millimeters thick

Other Droplet Size Considerations

Spherical Droplets:

Volume: $4/3\pi r^3$ Surface Area $4\pi r^2$



Surface Area : Volume Ratio: $3/r$

The Smaller the droplet:

The more exposed surface area.

Faster Dissolution and Bio-degradation

Blowout Plume Dynamics

- A well blowout can be a very energetic plume
- Driven primarily by Buoyancy:
  - Oil is less dense than water
  - Usually has a lot of gas – much less dense.
- In this turbulent environment, droplets are formed
- Dispersants: smaller droplets
- The resulting Droplet Size Distribution (DSD) determines where the oil goes.

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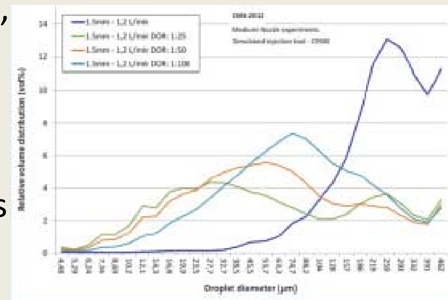

Blowout Plume Dynamics

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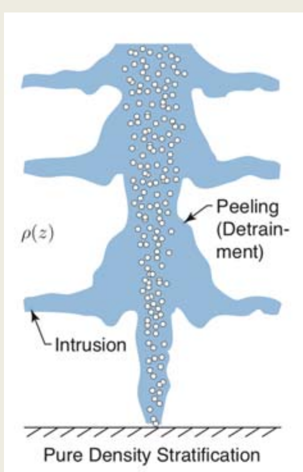
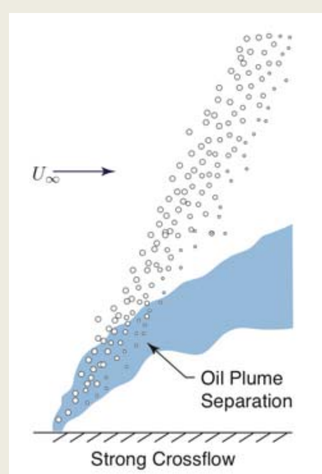




Blowout Plume Dynamics

- “layer” of dissolved constituents and tiny droplets

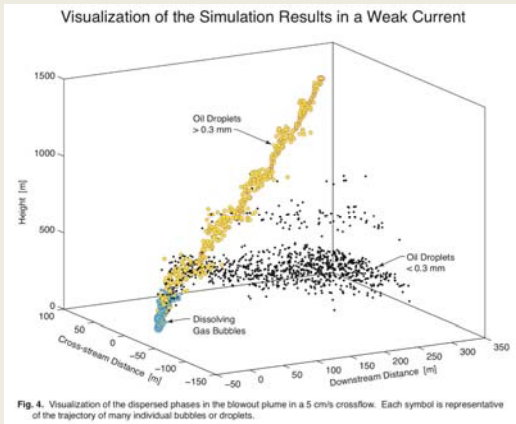
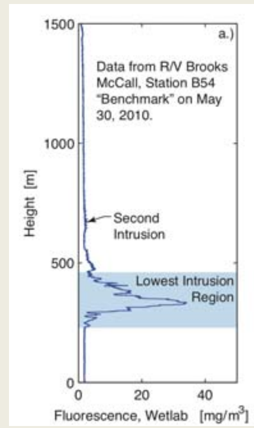


Fig. 4. Visualization of the dispersed phases in the blowout plume in a 5 cm/s crossflow. Each symbol is representative of the trajectory of many individual bubbles or droplets.



- Larger Droplets rise to the surface

Blowout Plume Dynamics

- Deep Gulf is much less energetic than the surface
- Less Mixing
- Slower Transport
- The “layer” will remain more or less at that depth.

- Concentration will decrease with:
  - Diffusion
  - Biodegradation

State-of-Science of Dispersants and Dispersed Oil: Degradation and Fate

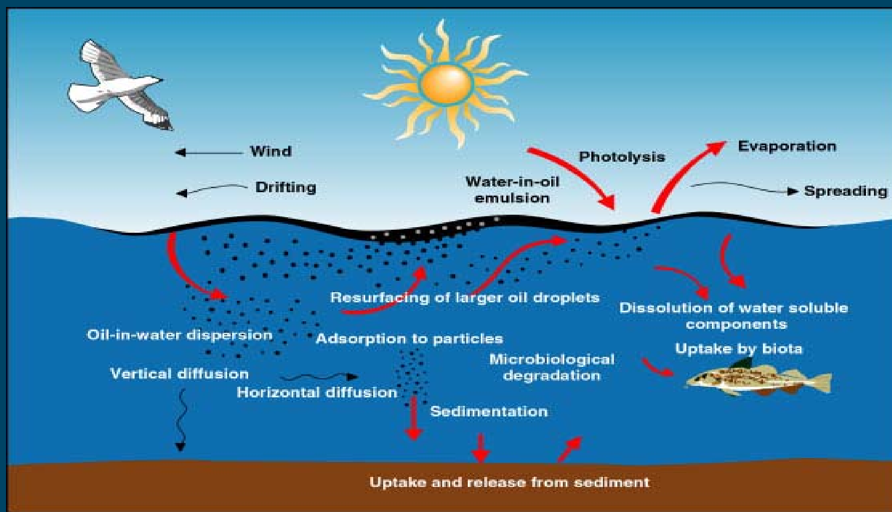
Nancy E. Kinner
Coastal Response Research Center
Center for Spills and Environmental Hazards

May 24, 2016
Flower Garden Banks Marine Sanctuary
Galveston, TX

Fate of Spilled Oil

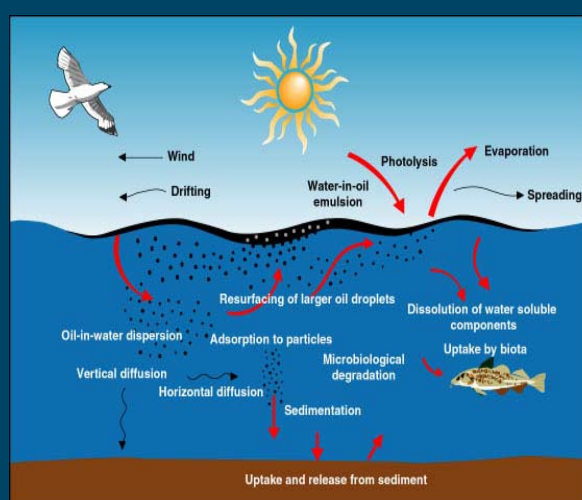
- "Big Picture" processes have not changed
- Oil weathers by:
  - Evaporation
  - Dissolution
  - Emulsification
  - Adsorption
  - Sedimentation
  - Degradation:
    - Photochemical
    - Microbial (biodegradation)

Weathering



Weathering

- **Function of Environmental Conditions**
  - **Temperature**
    - **(H_2O, Air)**
  - **Wind**
  - **Oil Type**
  - **Currents, Tides**



Today's Focus: Biodegradation

- **Tomorrow:**
  - **Some newer findings: adsorption/sedimentation and evaporation**

Basics

- **Oil biodegradation research has been conducted extensively since 1960s and 1970s**
- **Bursts of oil degradation and fate research associated with several key oil spills:**
  - *Exxon Valdez*, **AK**
  - **Deepwater Horizon, GOM**
  - **Methods for studying microbial processes have evolved greatly over time**
    - **Growing microbes on different food sources**
    - **Examine nuclear material (e.g., DNA, RNA)**

Basics

- Field of microbiology has grown
- Number of environmental microbiologists has also grown
- Number of microbiologists focusing on oil biodegradation has been cyclic
  - Exxon Valdez $
  - DWH $
  - National Science Foundation (NSF) funded almost no oil studies
    - Mostly hazardous waste, water and wastewater treatment microbiology

Caveats

- Result: Surge of microbiologists and new techniques into oil biodegradation research during and after DWH
- Scale of focus is often different
  - Oil spill response community scientists have worked with dispersed oil
    - e.g., water accommodated fraction (WAF)

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Caveats

- Oil spill is bad situation – goal is to protect resources at risk as best as possible
- Responders are choosing "least bad" option
- Dispersants chosen as response option to protect resources at risk and minimize shoreline clean-up
  - Not for biodegradation

Why am I giving this talk?

- Since 2004, CRRC co-director and CSE director
  - Oil spill focus
- Education in environmental engineering microbiology
  - Research in 1980s – 2000s on biodegradation of chlorinated solvents in groundwater
- Editorial board of Microbial Ecology 1998 to 2013
- Facilitated all State-of-Science of DDO panels
  - Including degradation & fate
- Degradation and Fate was a contentious topic (lots of passionately held opinions)

Biodegradation of Oil

- Many species/consortia of marine microbes (e.g., bacteria) degrade oil constituents
- Mineralization = Organic C to CO_2 (lots of organic C + O_2 CO_2 + H_2O + Energy (simple oil constituent))
- Electrons (e-) transfer from organic to O_2
  - Organic = e- donor (ED)
  - O_2 = electron accepter (EA)
- More complex oil compounds broken into simple compounds
  - Subsequent mineralization
- Oil constituents are naturally-occurring <u>not</u> exotic
  - E.g., natural oil seeps
- Oil constant biodegradation in oxygenated marine waters is relatively fast

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Environment without O_2 microbes use

- When O_2 is not present in environment, microbes use EA that is available
  - e.g., marine sediments with lots of organic C
  - e.g., Fe^{+3} NO^{-3}, SO_4^{-2}, other organics
  - Most marine sediments have abundance of SO_4^{-2}
  - Organic C + $SO_4^{-2} \rightarrow CO_2 + H_2^S$ + Less Energy (simple oil constituents)
- When SO_4^{-2} or other organics are EAs, biodegradation is much slower
  - Result - oil constituents in sediments are typically buried faster than they are biodegraded
    - Classic papers - return to marshes, etc. years later (30+) and where no to very low O_2, oil constituents still present

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Degradation of Oil

- Microbes can biodegrade
- Most hydrocarbon
  - O2 is key
  - Constituents are degraded at different rates
    - Function of mass available/time, composition of constituents, nutrients available

Microbes Performing Biodegradation

- Lots with "Latin" names
  - Molecular methods (DAN/RNA) expanded knowledge of these
  - Most are ubiquitous
  - In low numbers until spill
    - GOM natural seeps
  - Succession in microbial community

Access to Oil

- Slicks have low available surface to volume
- Microbes work on droplet surface area or dissolved compounds
- All about access of microbes to oil constituents
- Droplets are key
  - Small droplets are best (Brakstad et al., 2015 (10 vs 30 μm)
- Chemical dispersants + turbulence foster small droplet formation

Sequential Biodegradation

- Lots of research on this
- Relatively non-controversial
- Solubilities of constituents vary
- Complexity varies
- Weathered oil hard to biodegrade (e.g., asphaltenes)

Dispersant Degradation

- Surfactants in dispersants (e.g., DOSS) biodegrade
  - Most studies on Corexit
- Some may degrade more slowly
- Some decay in sunlight – less known about by-products

Factors of Importance

- Nutrients – localized impact, but in water column less so
- Temperature – deep water cold water microbe adapted
- Trace metals
- Type of oil (light vs. heavy)

Current Disagreements

- Rates of biodegradation with chemical dispersion
  - Lab study conditions
  - Controls
  - Measuring oil constituents vs. surrogates
  - “Null results” bias
  - Dispersant and oil concentrations

Current Disagreements

- DWH is a rare event
  - Most spills are short-term and surface slicks

Current Disagreements

- What is the baseline comparison?
  - Chemical dispersion vs. ?
  - ? = slick
  - ? = physical dispersion
- Problem is physical dispersion is minimal especially of surface slicks

Current Disagreements

- Addition of chemical dispersants suppresses biodegradation vs. physical dispersion
  - ??

Current Disagreements

- Focus on Corexit
  - Other dispersants too

Bottom Line

- DWH is a rare spill
  - Most are surface slicks
- Chemical dispersants used to disperse oil
  - Protect resources at risk
  - Minimize shoreline oiling
- Physical dispersion for surface slicks is not typical
- Biodegradation of oil is enhanced by chemical dispersion vs. remaining as surface slicks

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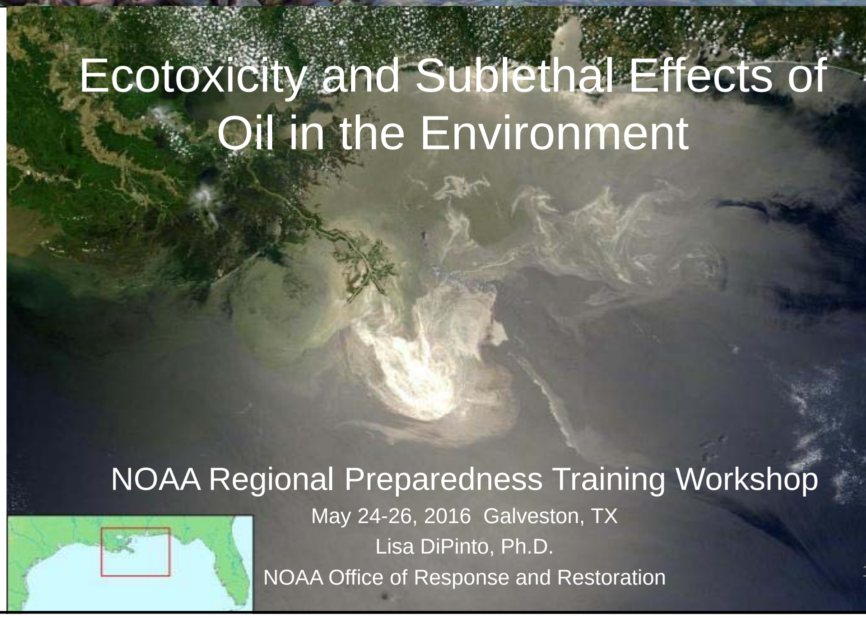

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Oil Toxicity Documented in Literature: Numerous Lab and Field Studies

- 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

2

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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

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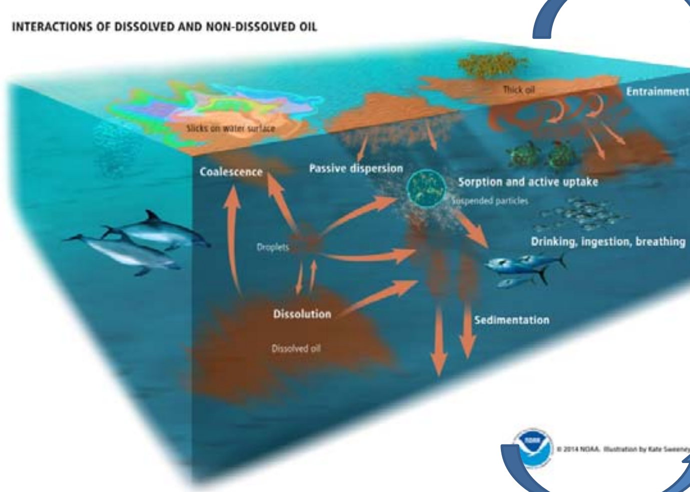
Oil Mixes, Disperses and Partitions in the Environment



Potential exposure- aquatic organisms:

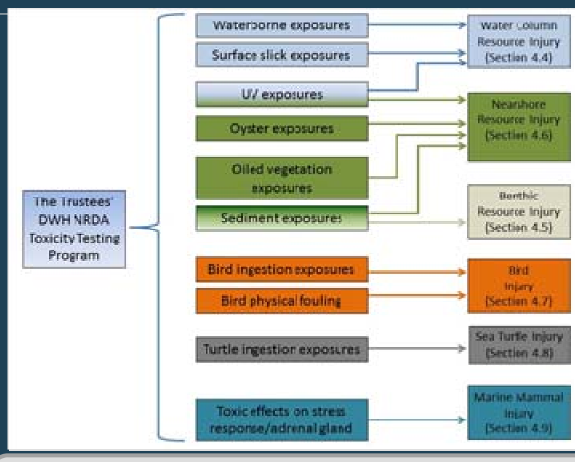
- Oil in water
- Oil on water
- Droplets and particles
- Dispersant
- Diet
- Physical effects

Potential exposure:

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

4

Deepwater Horizon Toxicity Program

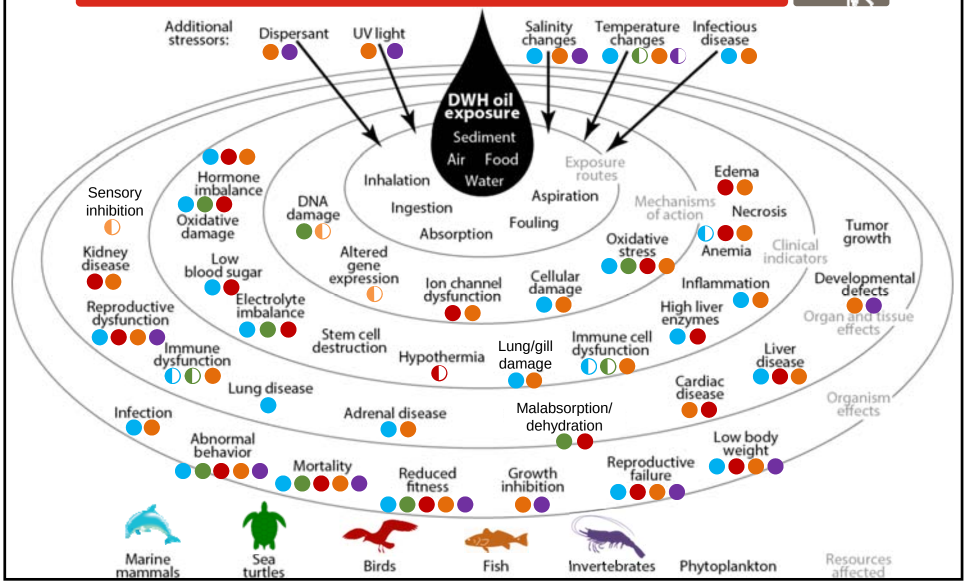


Tested 40 species including fish, invertebrates, plankton, 2 freshwater turtle species, birds, and a mammal adrenal cell line study

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.

DWH oil sheen photographed from an airplane

Source: *NOAA*

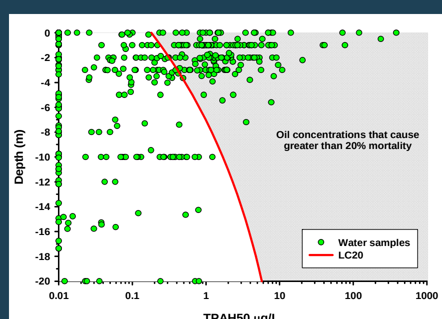
Surface Oil Observations Useful in Assessment

- 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

9

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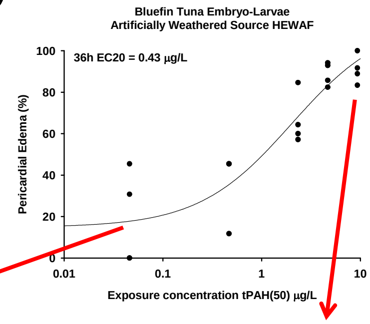
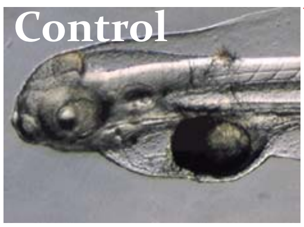
Exposure to Low Concentrations of DWH Oil Causes Cardiotoxicity: Bluefin Tuna

- 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

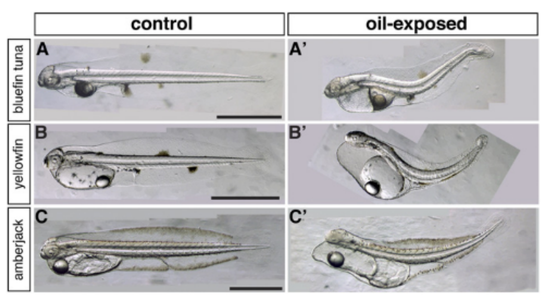

Fig. 2. Gross morphology of hatching stage larvae exposed to MC252 HEWAFs oil during embryonic development. Embryos were exposed from shortly after fertilization to 12–16 h after hatching. Unexposed controls in-cubated in clean water are shown in A–C, and oil-exposed (highest-dose tested) in A′–C′. Representative examples are shown for (A, A′) bluefin tuna exposed to artificially weathered source oil (1 mg/L oil, 8.5 µg/L ΣPAH), (B, B′) yellowfin tuna exposed to slick A (2 mg/L oil, 3.4 µg/L ΣPAH), (C, C′) amberjack exposed to artificially weathered source oil (1 mg/L oil, 13.8 µg/L ΣPAH). (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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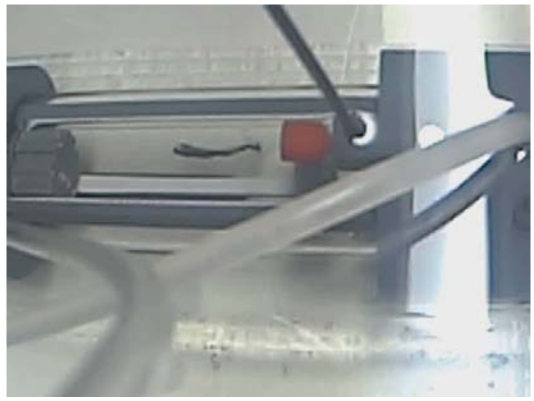
Swimming performance and aerobic scope in pelagic fish



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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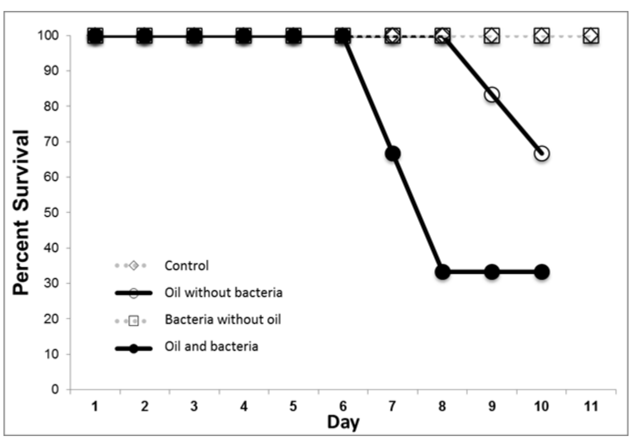
Effects of Multiple Stressors



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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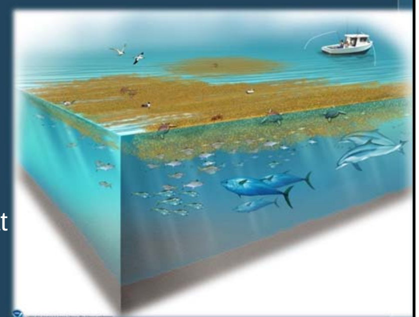
Surface Oil and Sargassum

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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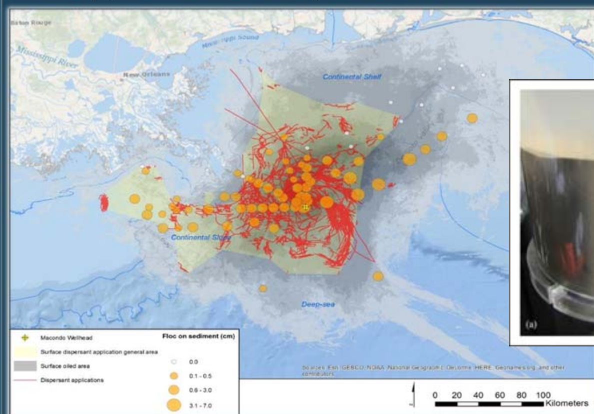
Surface Oil and Sea Floor Floc

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



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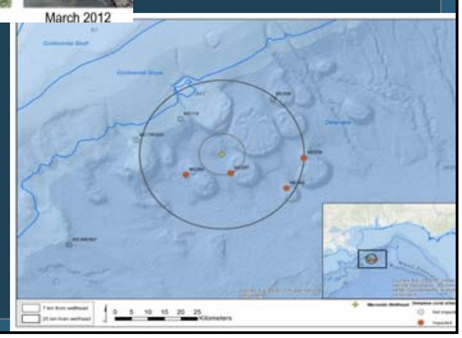
Deepsea Coral Colony Injury Progression

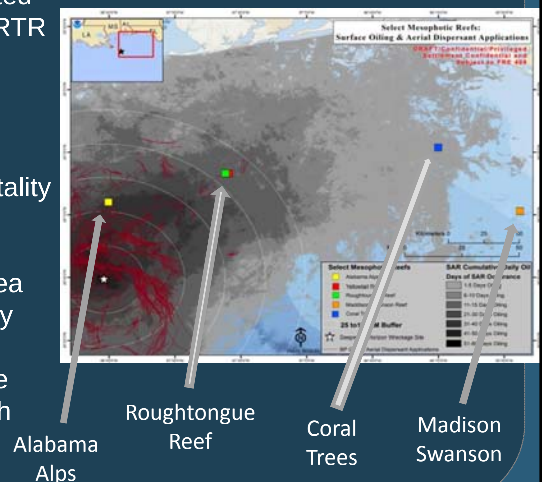
Progression of coral injury from coverage by flocculent material in 2010, through hydroid colonization in 2011 and onset of terminal branch loss in 2012

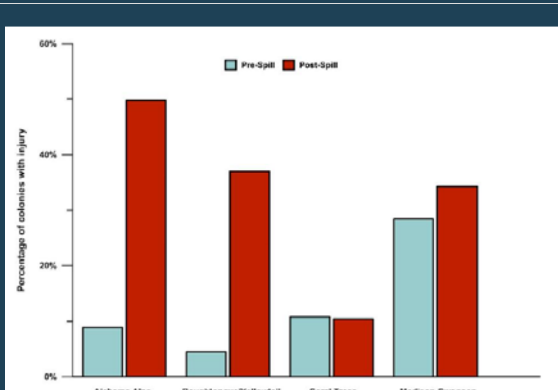
Map of locations of injured coral sites in relation to the DWH wellhead



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

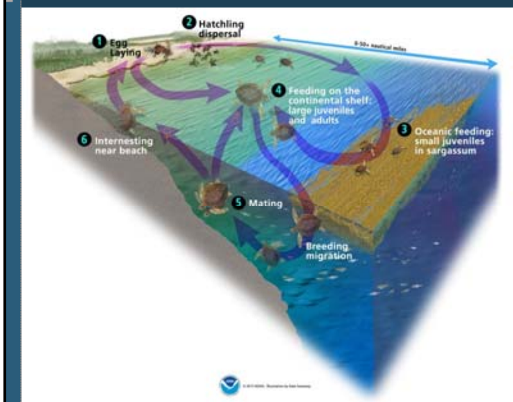




Source: Etnoyer et al. (2015).

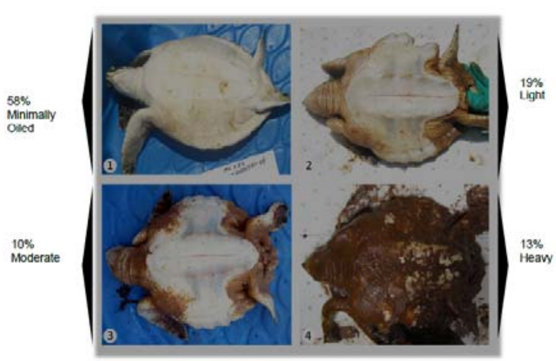
Figure 4.5-15. Prevalence of injured corals (large sea fans) at mesophotic reef sites in the northern Gulf of Mexico. Bars show the percentage of coral colonies observed in video transects with obvious injuries including bare, denuded, or broken branches; overgrowth; abnormal polyps; or severe discoloration. 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

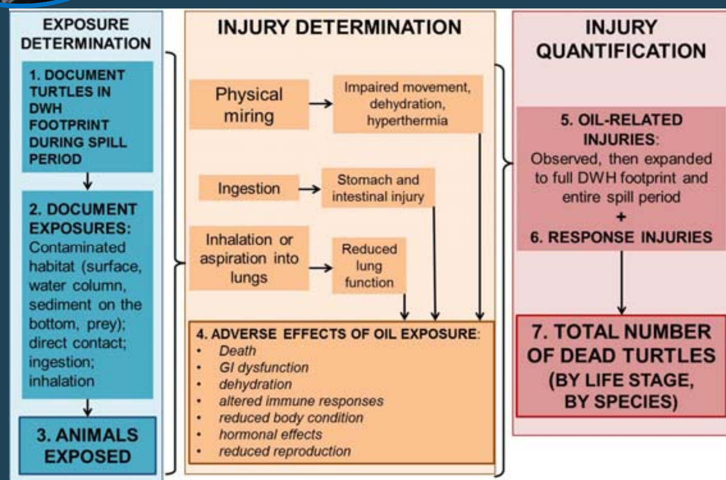
Turtles Ingest Oil



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.

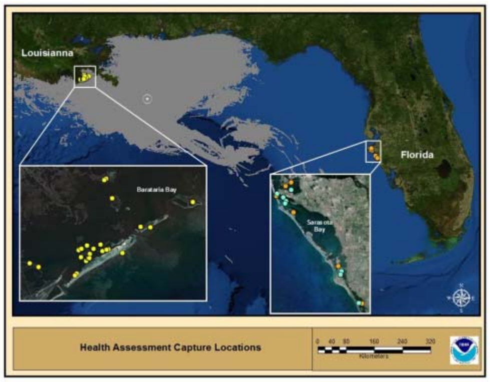
Oil Toxicity in Turtles



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)*

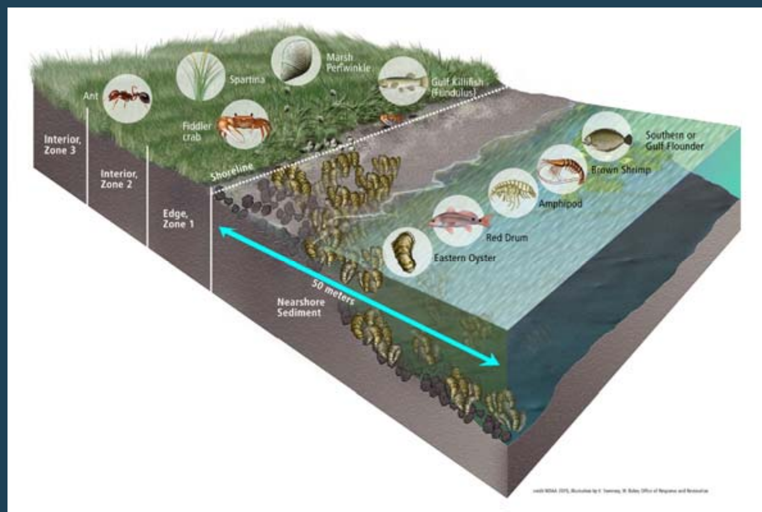


- 5 times more likely to have moderate- severe lung disease
- Hypoadrenocorticism
- Overall poor body condition
- High prevalence of abnormal liver enzymes, other blood abnormalities
- 48% guarded or worse prognosis; 17% poor/grave
- Tooth loss
- 11/15 mature females were pregnant; 46% increase in failed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

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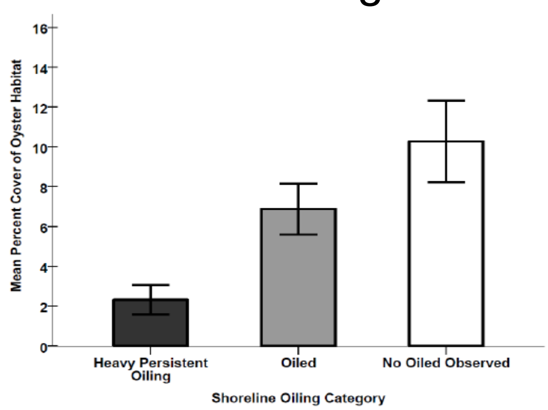
Oyster Cover and Degree of Oiling

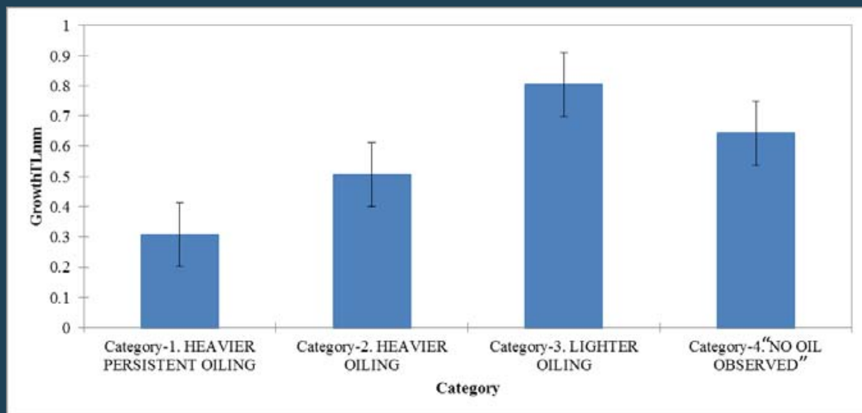


Source: Powers et al. (2015b).

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.

30

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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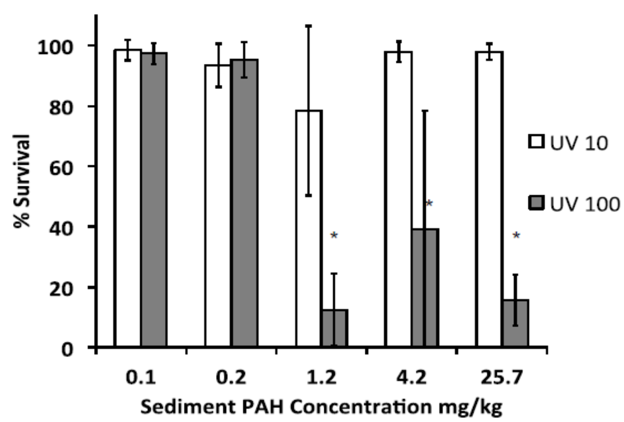
Fiddler Crab Larval Survival Following Maternal Exposure

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

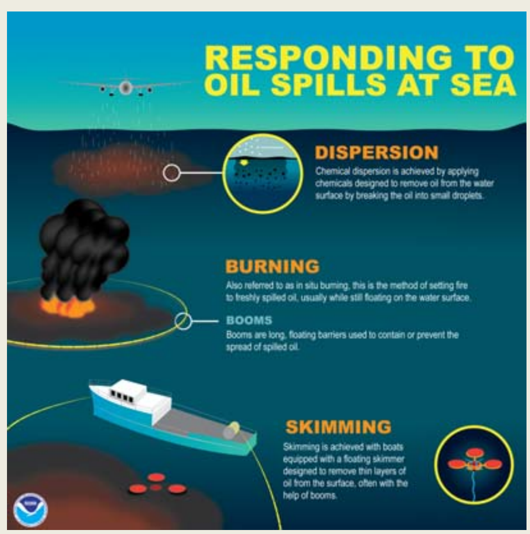
State-of-Science on Dispersants and Dispersed Oil: Public Health and Food Safety.

May 24, 2016
Flower Garden Banks
National Marine Sanctuary,
Galveston Texas

Doug Helton

Basic Options

- All response tools have limitations and trade-offs
- All have health and safety implications



2

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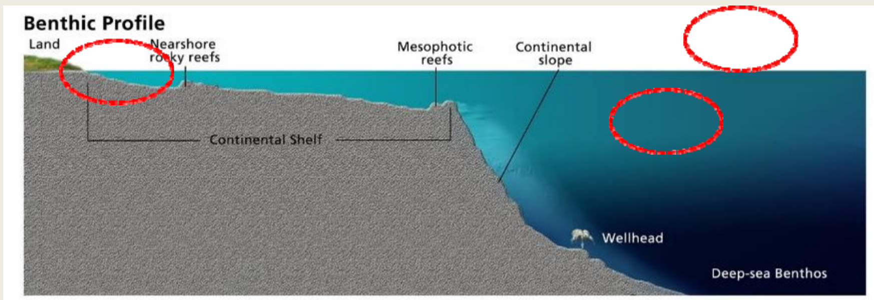
Changing the fate of the oil

- May be able to protect highly sensitive species and locations.
- Helps responders choose where the impacts are felt.
- Human impacts locations change too



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Safety of Responders

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The **NATION'S HEALTH**

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U.S. Gulf oil spill poses public health threat: Response targeting workers, residents, food and air quality

Kim Krisberg

Described as the worst environmental disaster in U.S. history, the massive oil spill in the Gulf of Mexico poses serious risks to human health too — risks that could persist far into the future and about which little is known.

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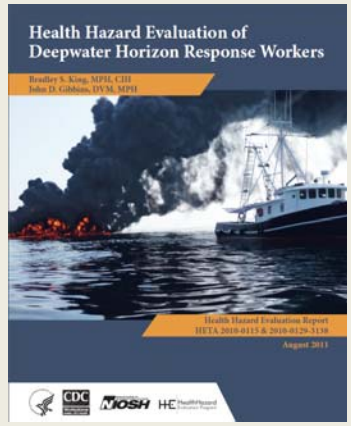
Human Health?

"Although all seven fishermen were hospitalized on the same day, we found that their symptoms could not be linked to the chemical dispersant… The seven fishermen worked on five different vessels, none of which were operating in the area of dispersant use."



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Journal List › CMAJ › v.182(12); 2010 Sep 7 › PMC2934792

CMAJ·JAMC

Medical knowledge that matters — Des connaissances médicales d'envergure

› Journal Home Page
› Information for Authors

CMAJ. 2010 Sep 7; 182(12): 1290–1292. PMCID: PMC2934792
doi: 10.1503/cmaj.109-3329

Gulf oil spill exposes gaps in public health knowledge

Cal Woodward

Author information ▶ Copyright and License information ▶

The Gulf of Mexico oil spill set in motion an army of health professionals deployed by Washington, states and centres of medical learning, all dedicated to helping Americans stay well in the throes of the catastrophe

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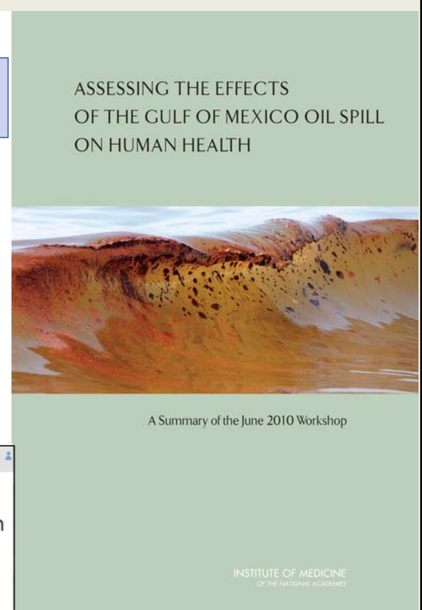
HEALTH

How Will The Gulf Oil Spill Affect Human Health?

June 23, 2010 · 12:00 AM ET
Heard on Morning Edition

RICHARD KNOX



8

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AGE OF HUMANS HUMAN BEHAVIOR MIND & BODY OUR PLANET

Breaking Down the Myths and Misconceptions About the Gulf Oil Spill

Does oil stick around in the ecosystem indefinitely? What was the deal with the deformed fish? Can anything bad that happens in the Gulf be blamed on oil?

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What are the risks for workers, public, and subsistence users?

Current evidence suggests minimal direct toxicity risks

Limited studies have been conducted to assess acute and chronic human health impacts

Environ Health Perspect. 2011 Aug; 119(8): 1062–1069.
Published online 2011 May 12. doi: 10.1289/ehp.1103507
PMCID: PMC3237364
Review

A Review of Seafood Safety after the *Deepwater Horizon* Blowout

Julia M Gohlke,[1] Dzigbodi Doke,[1] Meghan Tipre,[2] Mark Leader,[2] and Timothy Fitzgerald[3]

Possible Exposure Pathways

- Occupational and non-occupational
- Shorelines and Offshore
- Routes include inhalation, dermal absorption and ingestion.
- Offshore workers did come in contact with dispersants and oil
- Occupational exposures can be minimized by the appropriate use of personal protective equipment (PPE).

Uncertainties

- Hard to study in field conditions
- Limited epidemiological studies
- Baseline health status of workers unknown
- Conditions varied across region and job type and over time
- Hard to tease out oil versus dispersant versus other stressors:
  - physical stress, heat stress, psychosocial stress, ergonomic and other injury hazards; and pre-existing personal health risk factors.

Toxicity

- MSDS for dispersants warns against frequents and prolonged exposure to skin and inhalation risks
- Skin irritation and possible blood and kidneys
- Crude oil can cause similar conditions

Uncertainties

- Key chemicals are common in other products, so exposure hard to pinpoint
- Oils are complex mixtures with thousands of incompletely defined compounds
- Few long term studies
- But non-human studies raise concerns
  - endocrine disruption, reproductive failures, immune suppression and impaired cardiac development
  - But are they realistic doses?

Food security and seafood safety

- Biggest concern is for subsistence users, who by definition get a large part of their diet from a highly localized source
- Sensitive subgroups in Gulf
  - (e.g., Vietnamese-American community)
- PAHs persists longer in molluscan shellfish versus finfish (weeks to months rather than days to weeks)
- Dispersant constituents did not accumulate in fish and shellfish tissues
- There is a risk from not consuming seafood if the diet shifts to less wholesome items

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Uncertainties

- Bioaccumulation and depurations not well know for species and different species.
- Trade-off of more oil in coastal environments and possibly persisting for decades
- Humans are less willing to accept involuntary risk than voluntary risk (e.g., oiled fish vs. smoked fish)
- Risk communication is challenging

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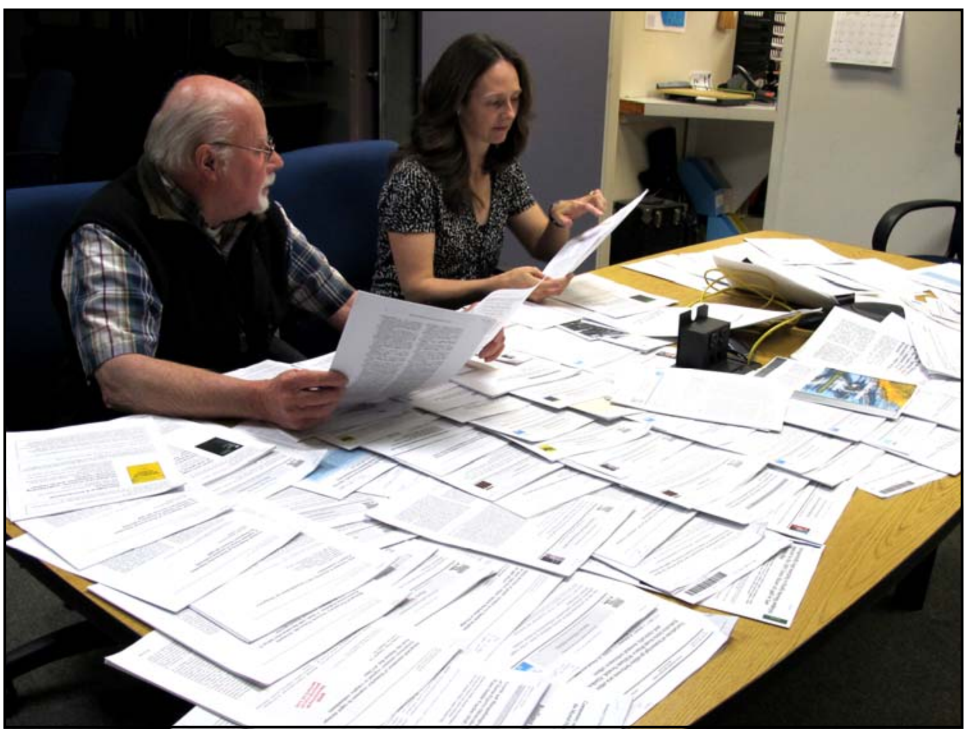
General conclusions

- None of the 6,000 water samples containing oil-dispersant exceeded EPA benchmarks for protection of human health
- None of the seafood testing found levels of human health concern
- “Although individuals directly handling dispersants or in the immediate area of dispersant applications during DWH may have been at greater risk of exposure and adverse effects than the general population, any adverse effects were expected to be mild”

17



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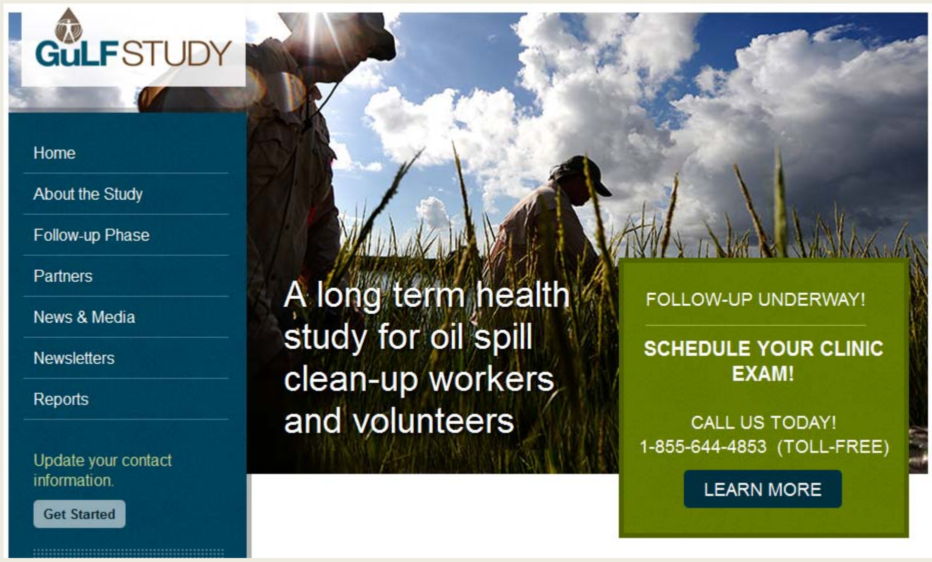
Gulf Long Term Follow-Up Study



Appendix D: Workshop Agenda

NOAA's Regional Preparedness Training (NRPT)
Environmental Tradeoff Analysis (ETA) for an Oil Spill Response
Impacting the Flower Garden Banks National Marine Sanctuary

May 25 – 26, 2016
Flower Garden Banks National Marine Sanctuary
Galveston, Texas

WORKSHOP AGENDA

Day 1: Wednesday, May 25

8:30 am Welcome and Introductions

- Nancy Kinner, Coastal Response Research Center, University of New Hampshire
- G.P. Schmahl, Flower Garden Banks National Marine Sanctuary
- Charlie Henry, NOAA Office of Response and Restoration (ORR), Gulf of Mexico Disaster Response Center

8:45 am Background and Workshop Goals

- Charlie Henry

9:00 am Participant Introductions

9:30 am Plenary Session: Flower Garden Banks National Marine Sanctuary

- G.P. Schmahl, Flower Garden Banks
  - Physical/Chemical Conditions
  - Biological Conditions
  - Regulatory Considerations

10:00 am Plenary Session: Oil Spill Response 101

- Paige Doelling, NOAA ORR and Steve Buschang, Texas General Land Office

10:15 am *Break*

10:30 am Plenary Session: Natural Resource Damage Assessment (NRDA)

- Lisa DiPinto, NOAA ORR, Assessment and Restoration Division

10:45 am Plenary Session: State-of-Science as Applied to Flower Garden Banks Marine Sanctuary

- Mechanical Recovery, *James Hanzalik, Clean Gulf Associates*
- *In Situ* Burning, *Charlie Henry*
- Dispersant Overview (Surface and Subsea Application), *Arden Ahnell, Exponent*
- Marine Snow/Oil Flocculation, *Jeff Chanton, Florida State University (remote)*
- Air Quality, *Ed Buskey, University of Texas at Austin (remote)*

12:00 pm *Lunch (on your own)*

1:15 pm Plenary Session: Current RRT Area Contingency Planning for Flower Garden Banks, Marine Sanctuary Area

- Mike Sams, U.S. Coast Guard

1:30 pm Plenary Session: Other Important Considerations, Process Subpart J Regulatory

- Greg Wilson, U.S. Environmental Protection Agency

1:45 pm Plenary Session: Environmental Tradeoff Analysis (ETA)

- Jim Staves, Environmental Consultant

2:00 pm Describe Scenario & Breakout Group Charge

2:15 pm Breakout Group Session I

- Identify resources at risk
- Establish initial response objectives and actions
- Current pre-authorization and exclusion zones as it applies to the Flower Garden Banks
- Identify NRDA activities during response

3:30 pm Group Reports

4:30 pm Adjourn

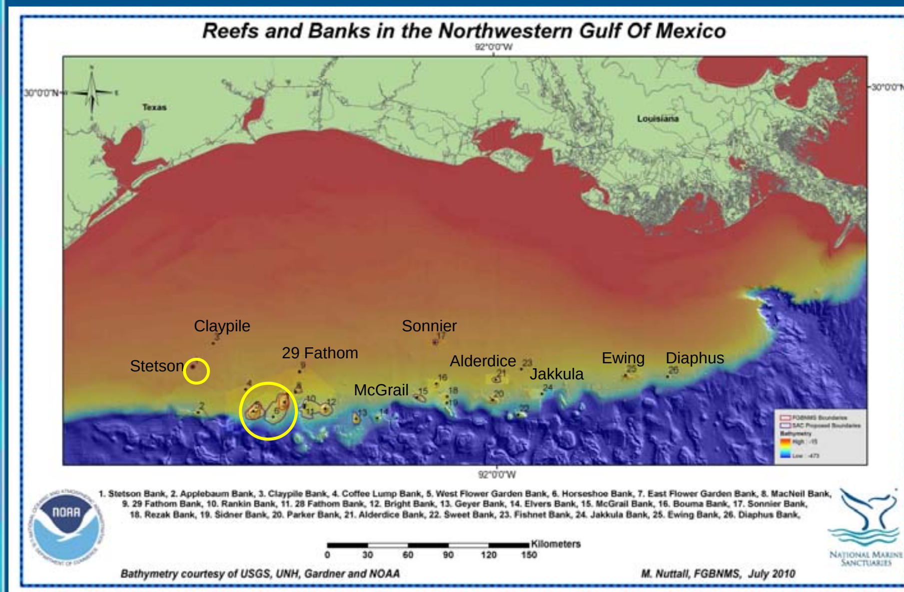
Day 2: Thursday, May 26

8:30 am	Recharge & Recalibrate
9:00 am	Breakout Group Session II • Identify initial response tradeoffs • Identify "external pressures" affecting decision-making • Discuss flow charts /decision trees for evaluating ETAs
11:00 am	Group Reports
11:30 pm	*Lunch (on your own)*
1:00 pm	Introduce Spill Scenario of ETA
1:15 pm	Breakout Group Session III • Decide on response options • Conduct ETA for spill scenario • Explore flow charts / decision trees
3:00 pm	Group Reports
4:00 pm	Wrap-Up and Path Forward
4:30 pm	Adjourn

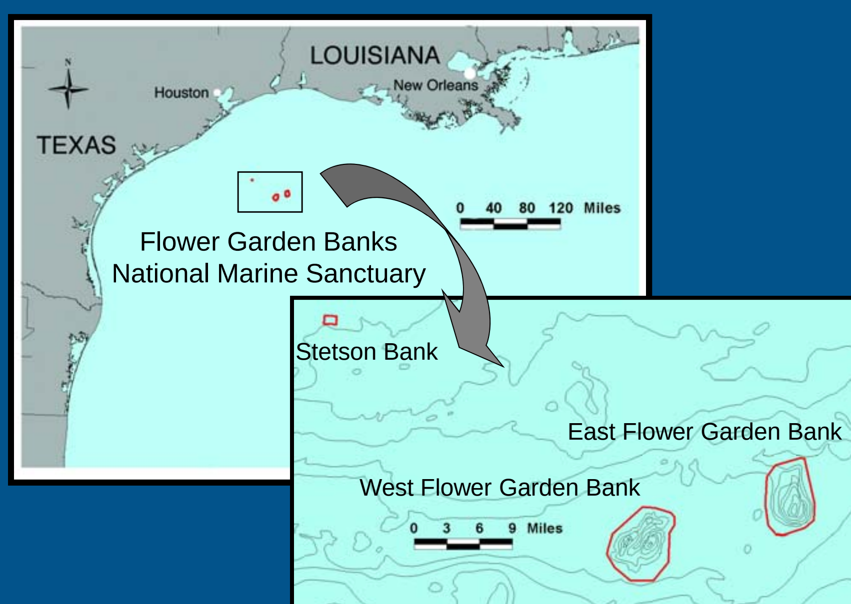
Appendix E: Workshop Presentations


AMERICA'S UNDERWATER TREASURES
Flower Garden Banks
National Marine Sanctuary
NOAA Regional Preparedness Training
G.P. Schmahl – Superintendent
May 25, 2016


National Marine Sanctuaries
National Oceanic and Atmospheric Administration
NATIONAL MARINE SANCTUARY SYSTEM
Olympic Coast
Greater Farallones
Cordell Bank
Monterey Bay
Channel Islands
Papahānaumokuākea
Hawaiian Islands Humpback Whale
American Samoa (U.S.)
Rose Atoll
Thunder Bay
Wisconsin
Stellwagen Bank
Mallows Bay
Monitor
Gray's Reef
Flower Garden Banks
Florida Keys
National Marine Sanctuary
Marine National Monument
Proposed National Marine Sanctuary
Image reproduced from the GEBCO world map, http://www.gebco.net



Reefs and Banks of the Northwestern Gulf of Mexico

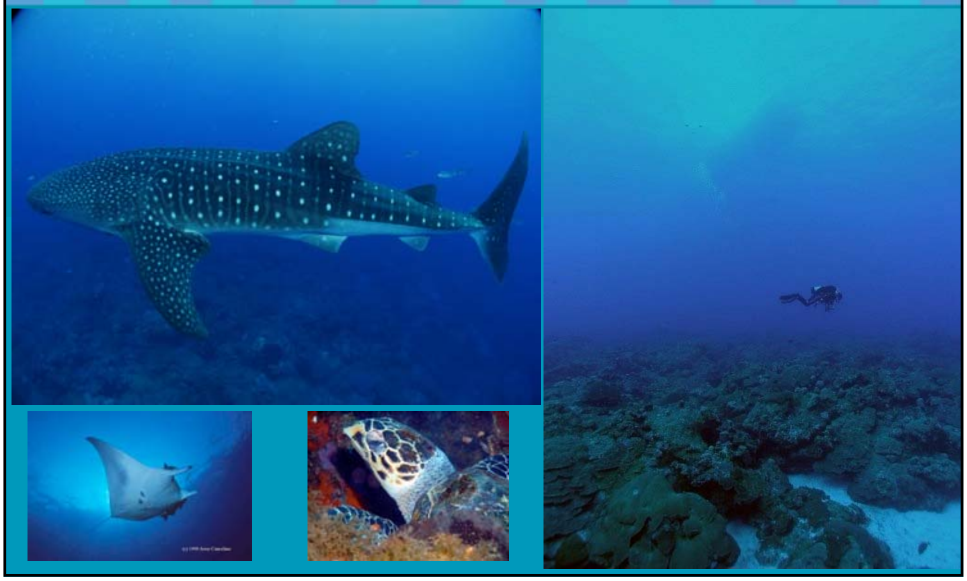


Flower Garden Banks National Marine Sanctuary

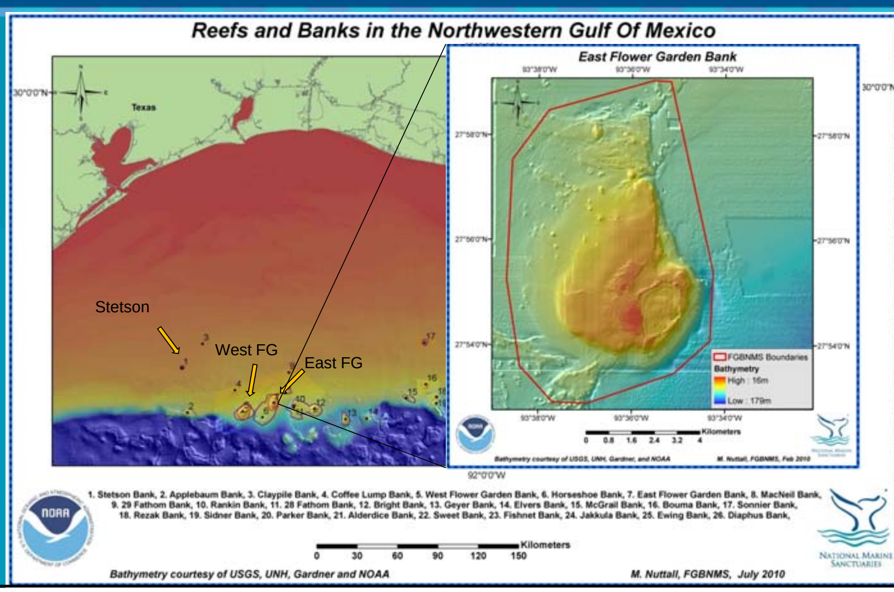
- Northernmost coral reef in the continental United States
- Includes: East and West Flower Garden and Stetson Banks
- Located 93 to 104 nautical miles offshore in the Gulf of Mexico
- Area: 145 square kilometers (56 square statute miles)
- Water Depth: 17 – 152 meters

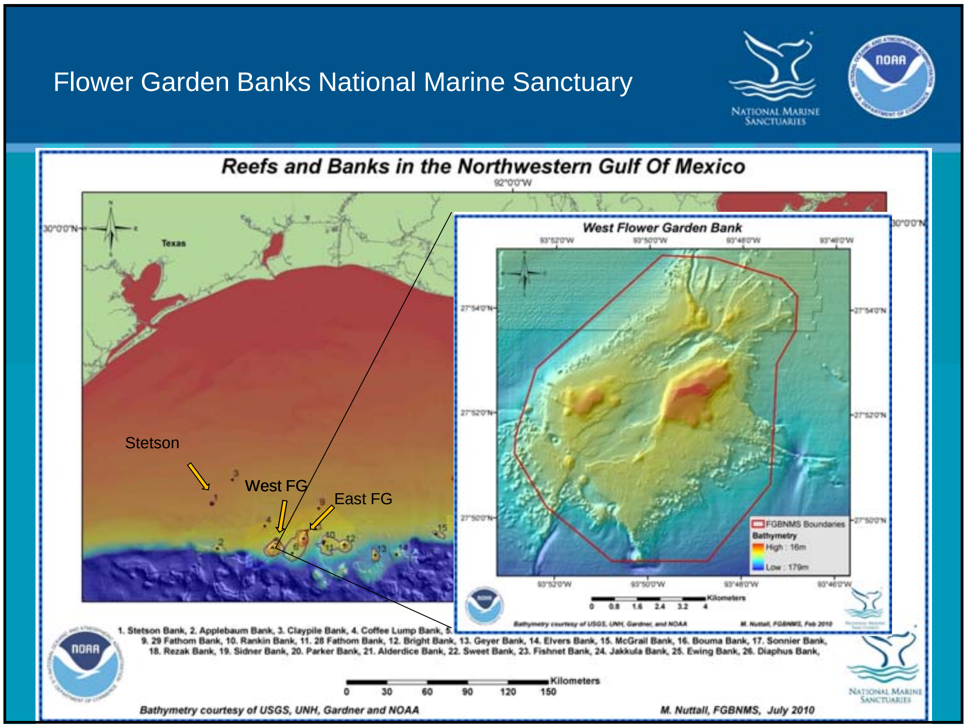
Remarkable Reefs of the Flower Garden Banks

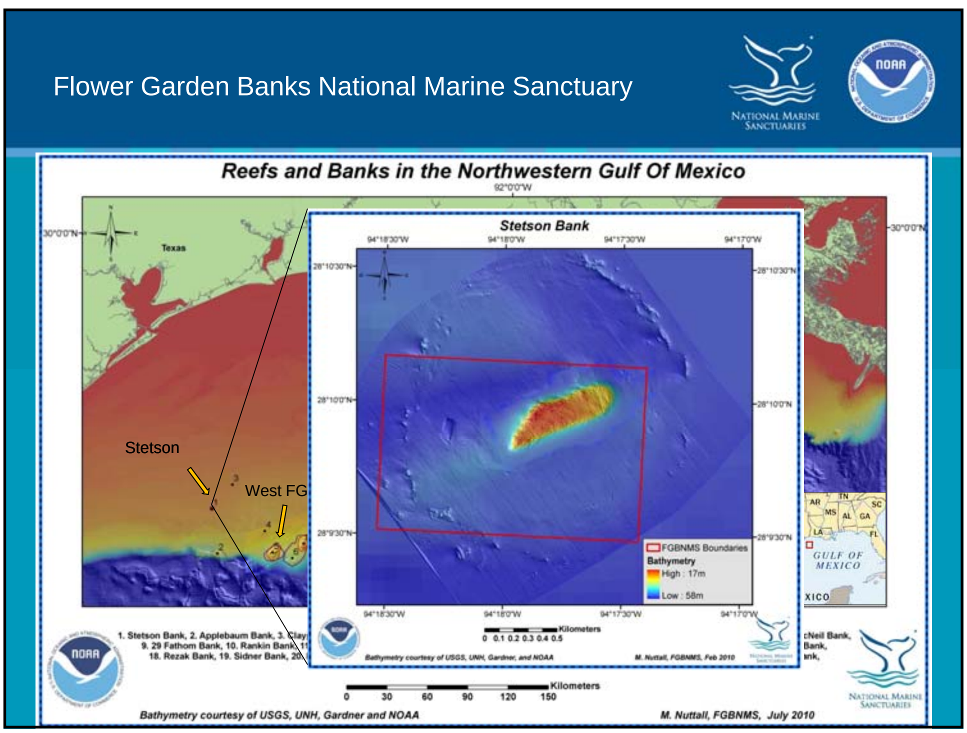
Flower Garden Banks National Marine Sanctuary

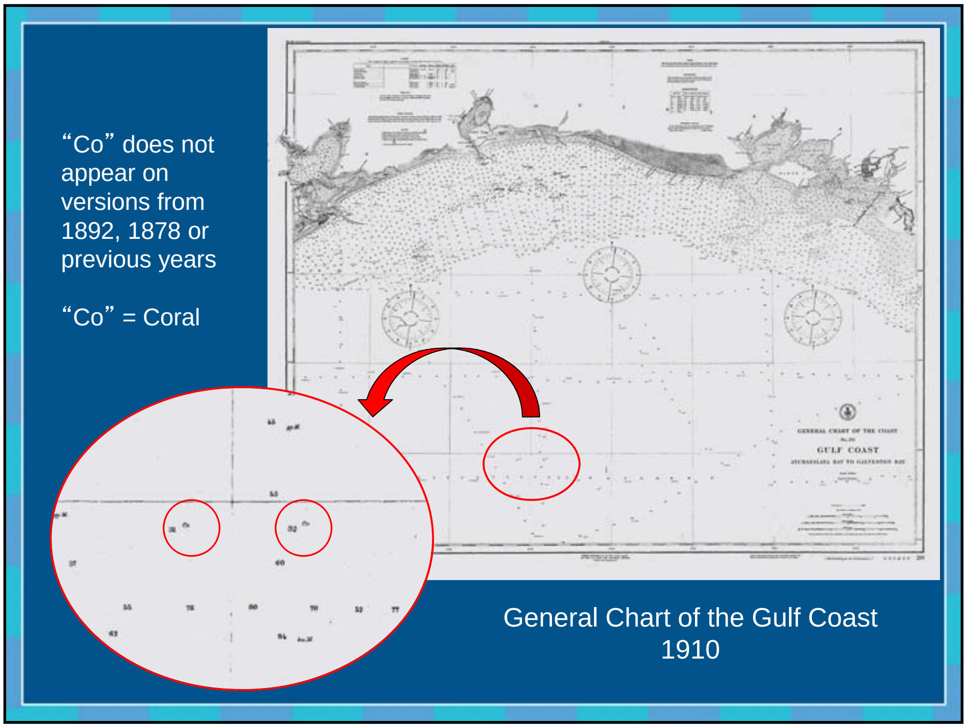


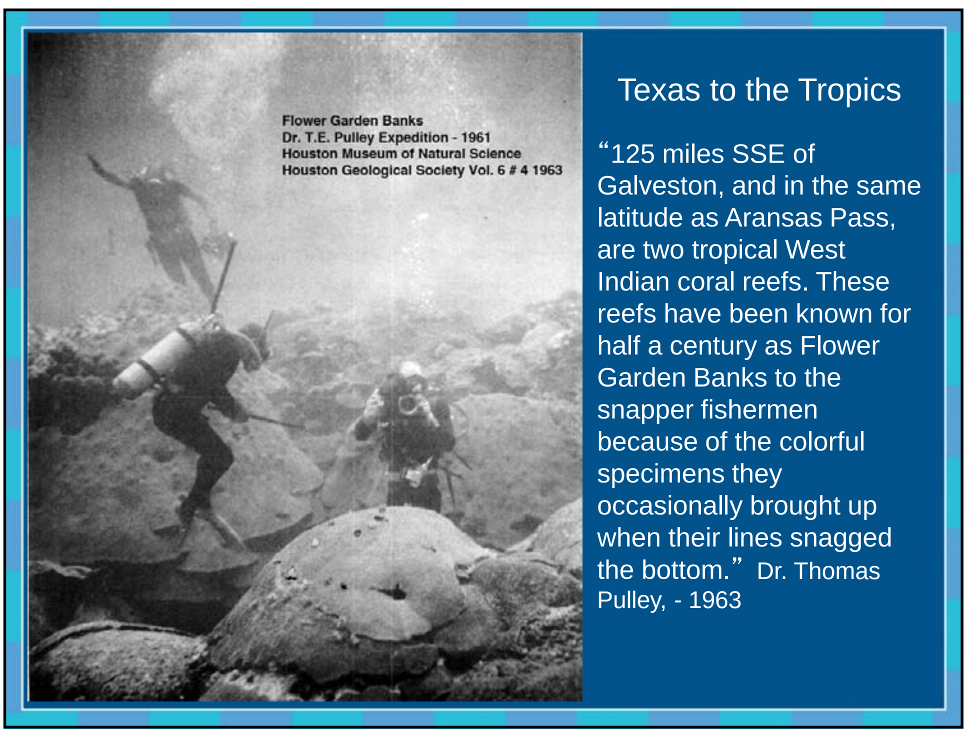
Flower Garden Banks National Marine Sanctuary



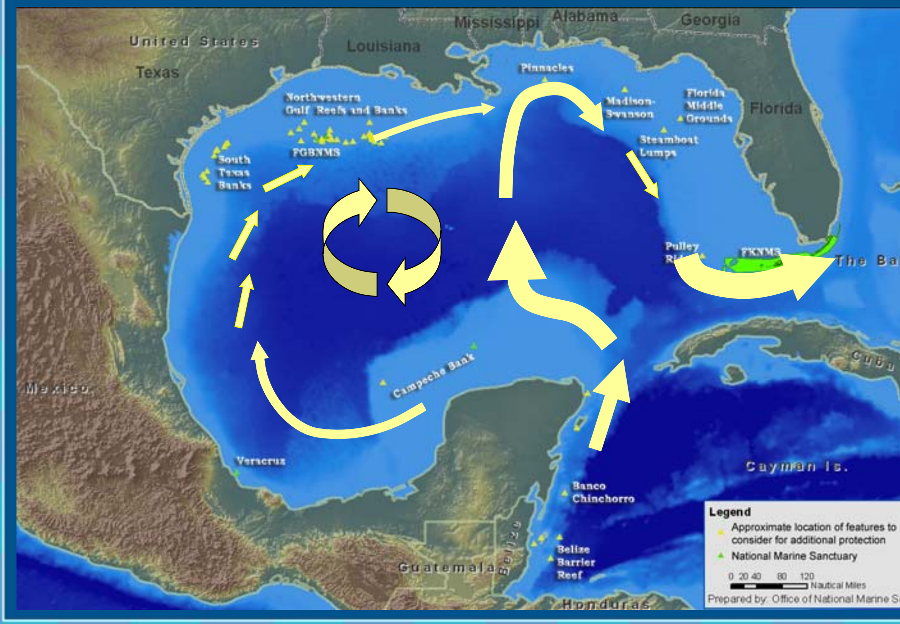

Flower Garden Banks National Marine Sanctuary
National Marine Sanctuaries
NOAA
Reefs and Banks in the Northwestern Gulf Of Mexico
Texas
Stetson
West FG
East FG
West Flower Garden Bank
FGBNMS Boundaries
Bathymetry
High : 16m
Low : 179m
Kilometers
1. Stetson Bank, 2. Applebaum Bank, 3. Claypile Bank, 4. Coffee Lump Bank,
9. 29 Fathom Bank, 10. Rankin Bank, 11. 28 Fathom Bank, 12. Bright Bank, 13. Geyer Bank, 14. Elvers Bank, 15. McGrail Bank, 16. Bouma Bank, 17. Sonnier Bank,
18. Rezak Bank, 19. Sidner Bank, 20. Parker Bank, 21. Alderdice Bank, 22. Sweet Bank, 23. Fishnet Bank, 24. Jakkula Bank, 25. Ewing Bank, 26. Diaphus Bank,
Kilometers
0 30 60 90 120 150
Bathymetry courtesy of USGS, UNH, Gardner and NOAA
M. Nuttall, FGBNMS, July 2010

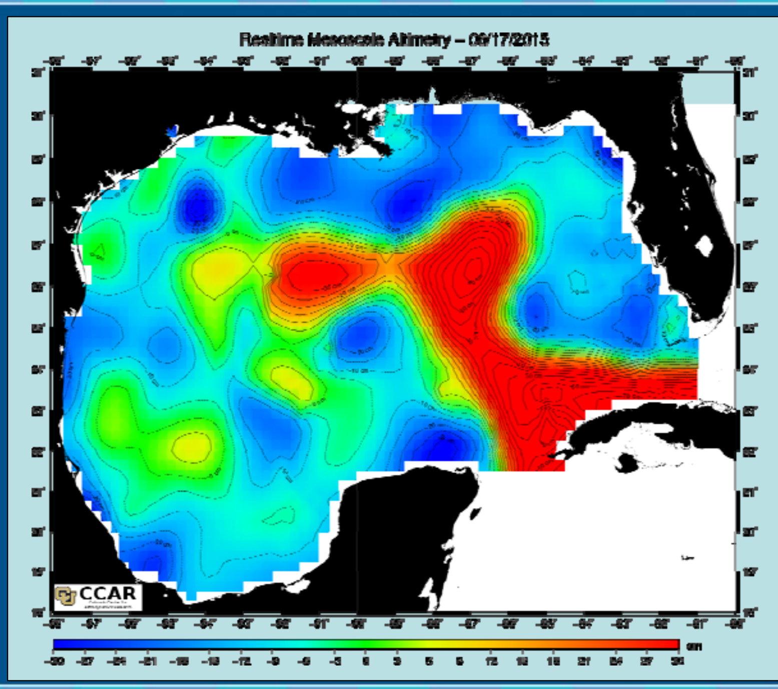

Flower Garden Banks National Marine Sanctuary
National Marine Sanctuaries
NOAA
Reefs and Banks in the Northwestern Gulf Of Mexico
Texas
Stetson
West FG
Stetson Bank
FGBNMS Boundaries
Bathymetry
High : 17m
Low : 58m
Kilometers
0 0.1 0.2 0.3 0.4 0.5
Bathymetry courtesy of USGS, UNH, Gardner, and NOAA
M. Nuttall, FGBNMS, Feb 2010
GULF OF MEXICO
Kilometers
0 30 60 90 120 150
Bathymetry courtesy of USGS, UNH, Gardner and NOAA
M. Nuttall, FGBNMS, July 2010


"Co" does not appear on versions from 1892, 1878 or previous years
"Co" = Coral
General Chart of the Gulf Coast
1910


Flower Garden Banks
Dr. T.E. Pulley Expedition - 1961
Houston Museum of Natural Science
Houston Geological Society Vol. 6 # 4 1963
Texas to the Tropics
"125 miles SSE of Galveston, and in the same latitude as Aransas Pass, are two tropical West Indian coral reefs. These reefs have been known for half a century as Flower Garden Banks to the snapper fishermen because of the colorful specimens they occasionally brought up when their lines snagged the bottom." Dr. Thomas Pulley, - 1963

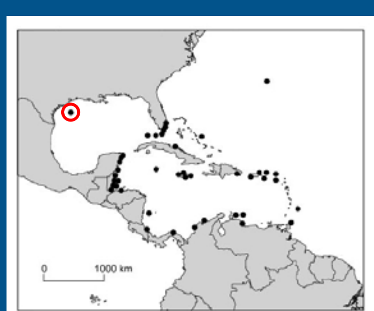
Gulf of Mexico “Loop Current” and Reef Features

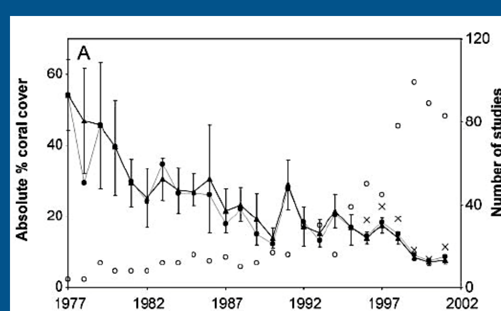




Long-term region-wide declines in Caribbean Corals

Gardner, T.A. et al., 2003. Science 301:958





Average hard coral cover reduced by 80%
(from 50% to 10%) in 30 years

Flower Garden Banks Long-term Coral Reef Monitoring

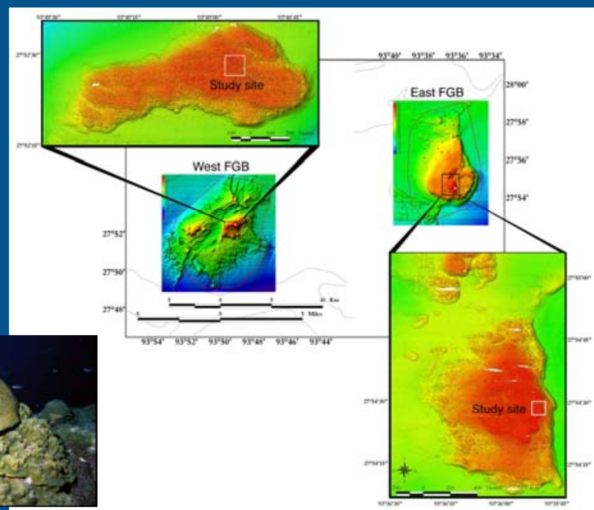
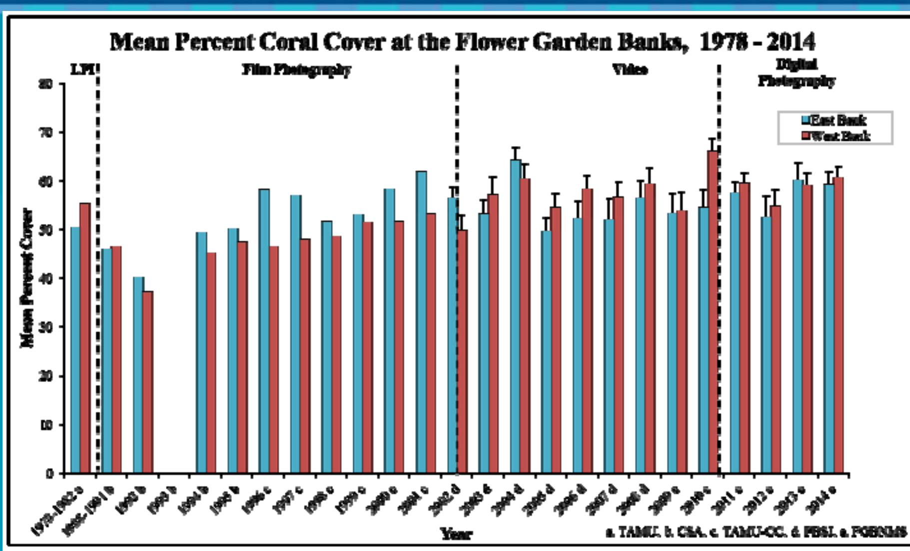


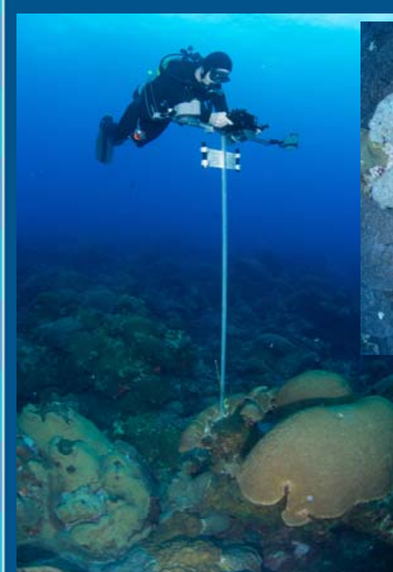
Photo: G.P. Schmahl

Historical Coral Cover Dataset



Major Reefs Living Coral Cover

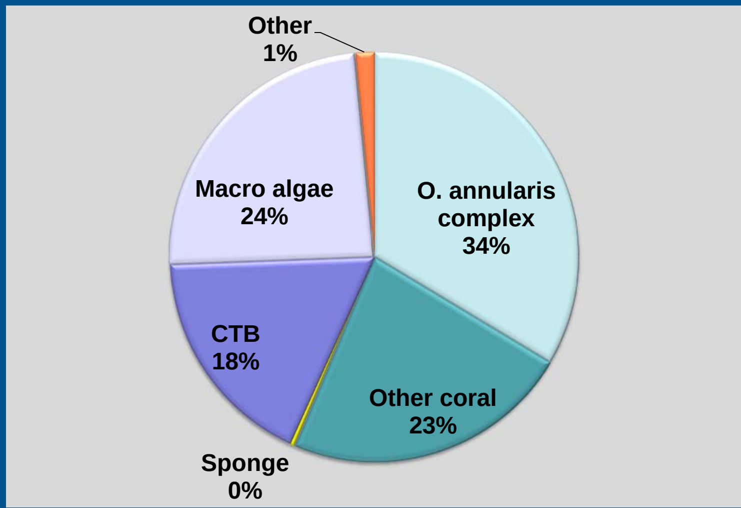
Location	Percent Coral Cover	Source
Flower Garden Banks	54	Johnston et al. 2015
Bonaire	10-38	Steneck et al. 2011
Bermuda	35	Jackson et al. 2014
Puerto Rico	7-36	Waddell and Clark 2008
Navassa Island	10-25	Waddell and Clark 2008
Florida Keys NMS	3–20	ONMS 2011
Jardin de la Reina, Cuba	7–19	Pina Amargós et al. 2008
Pedro Bank, Jamaica	5-19	Bruckner 2013
Cay Sal Bank, Bahamas	7-9	Bruckner 2011

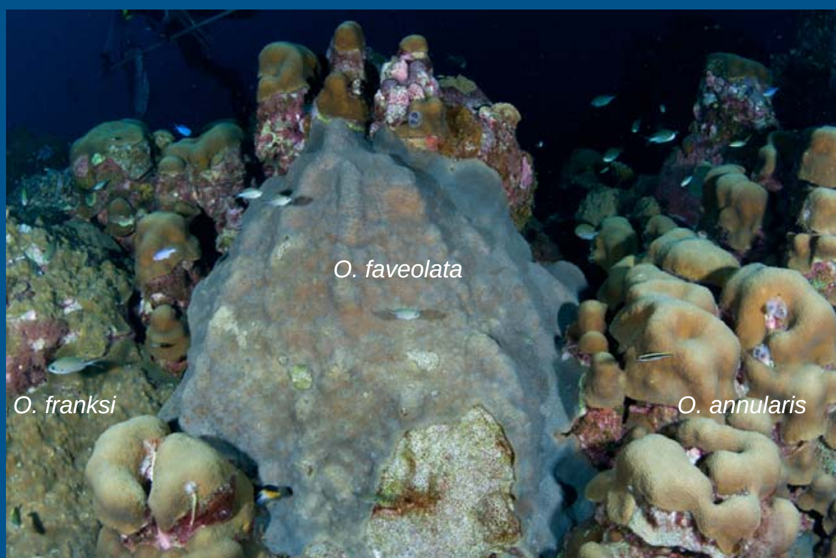


Long-term coral reef Monitoring

Permanent Photo Stations

Percent Benthic Cover – East FGB

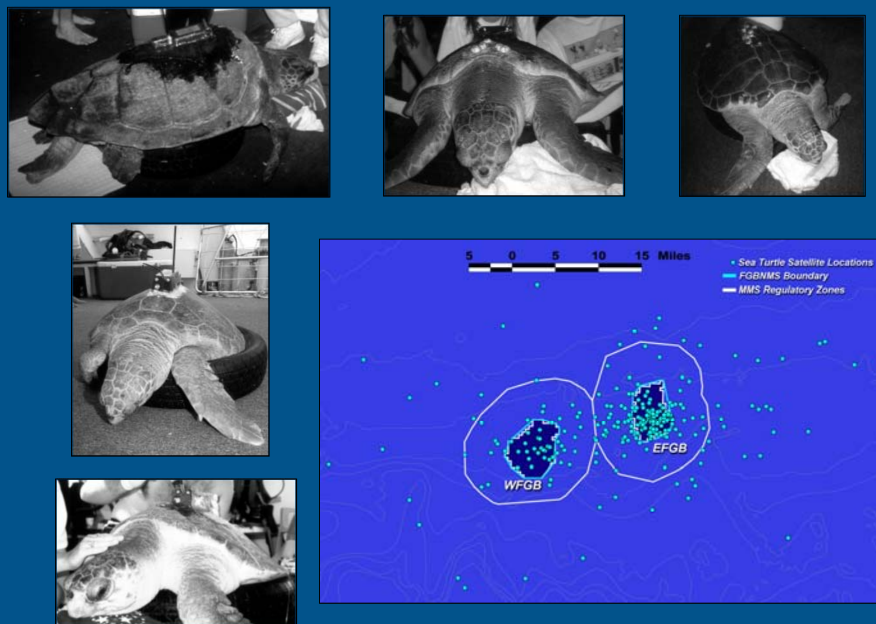




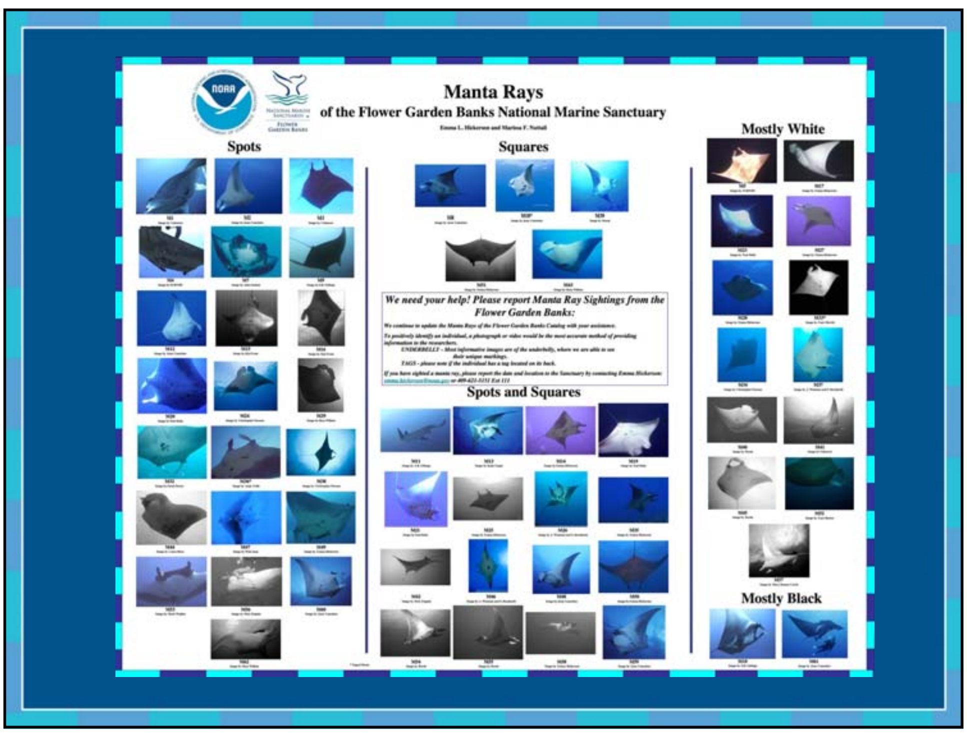
Flower Garden Banks – *Orbicella (Montastraea)* complex

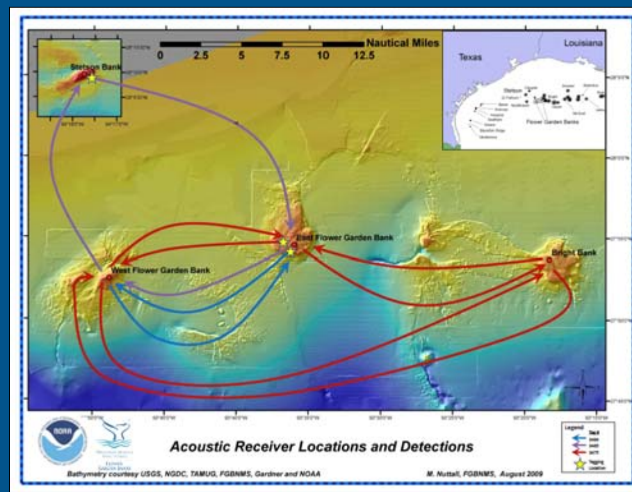
Acropora palmata - May 2005

Mass spawning events



“Mardi Gras Wrasse” – described from Flower Garden Banks


Manta Rays
of the Flower Garden Banks National Marine Sanctuary
Spots
Squares
Mostly White
We need your help! Please report Manta Ray Sightings from the Flower Garden Banks:
Spots and Squares
Mostly Black

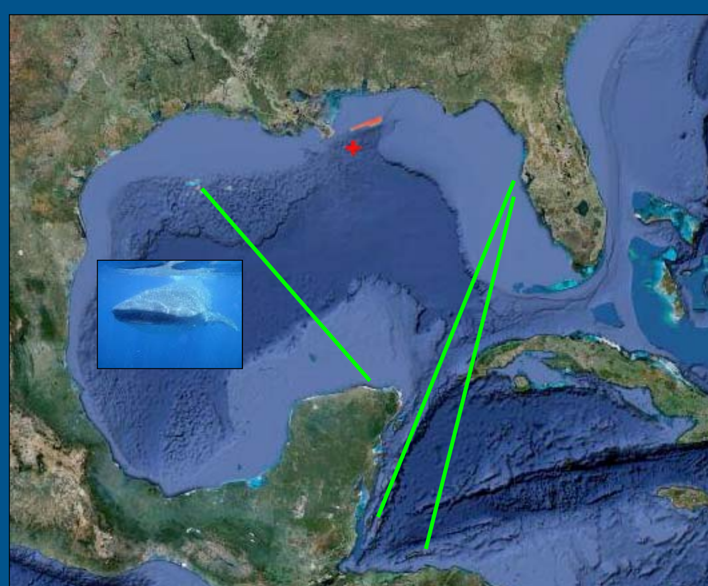


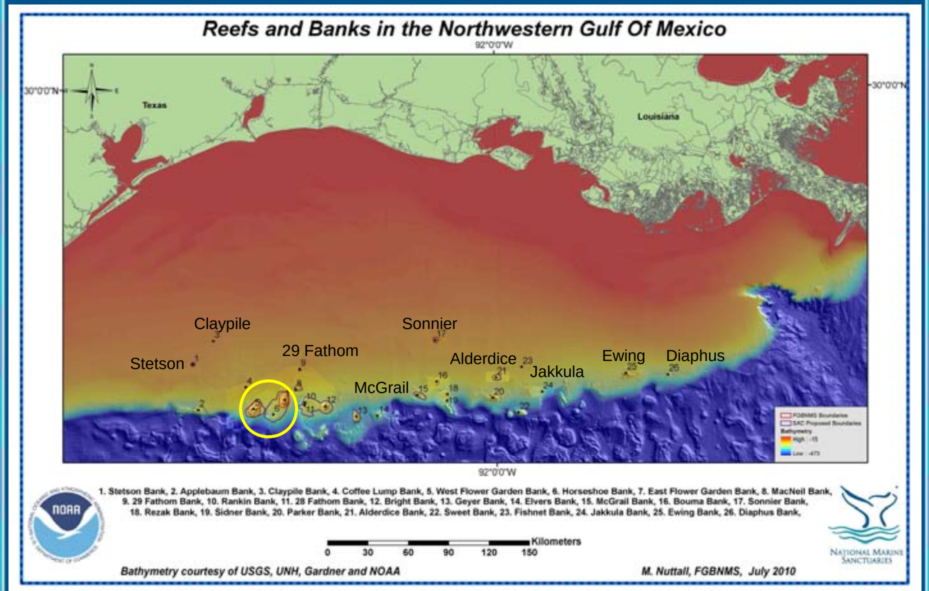
Manta Ray movement - FGBNMS

Whale shark migrations

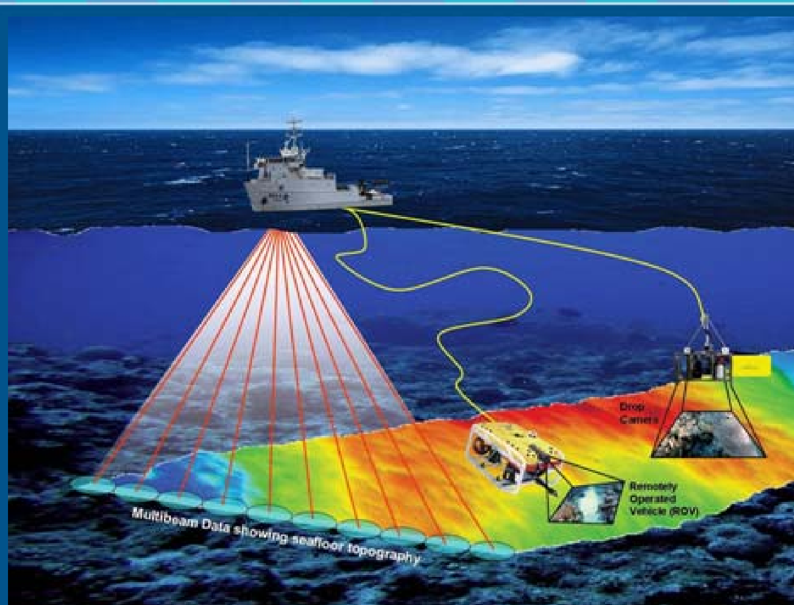
- **Holbox, Mexico (July 2008) to Bright Bank, NW GOM (October, 2008)**
- **Gladden Spit, Belize to Tampa, FL**
- **Honduras to Tampa, FL**

Source:
Dr. Rachel Graham, Wildlife Conservation Society

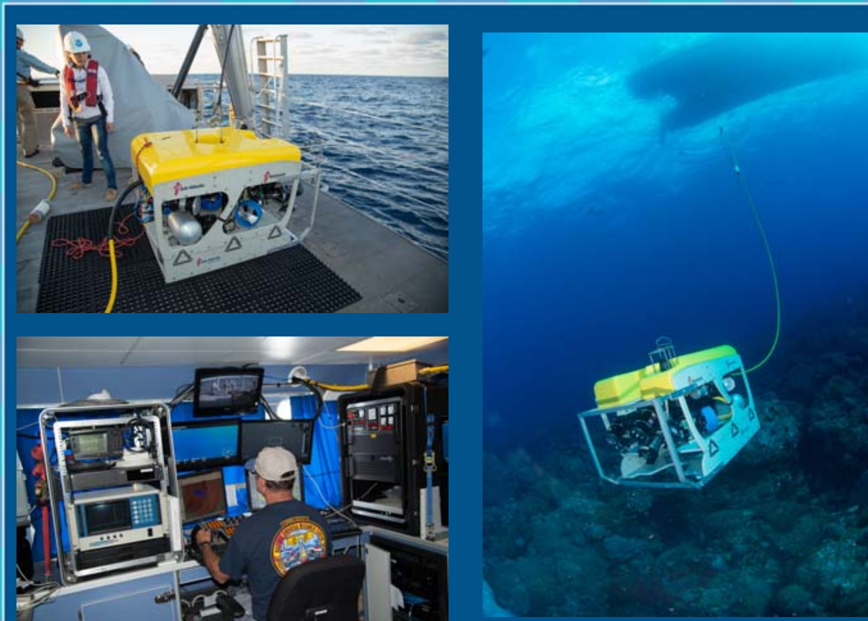




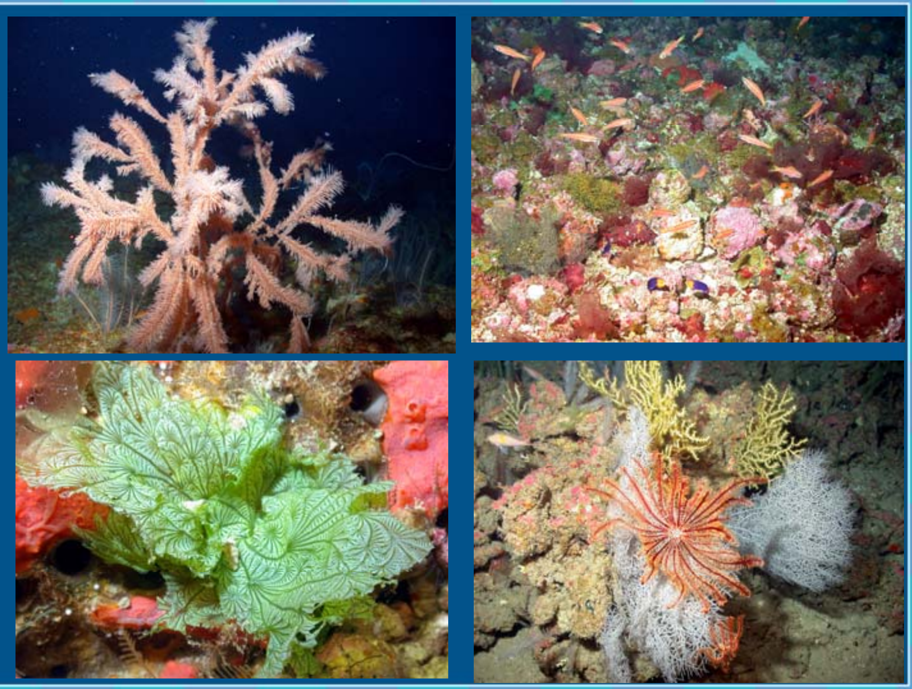
Reefs and Banks of the Northwestern Gulf of Mexico

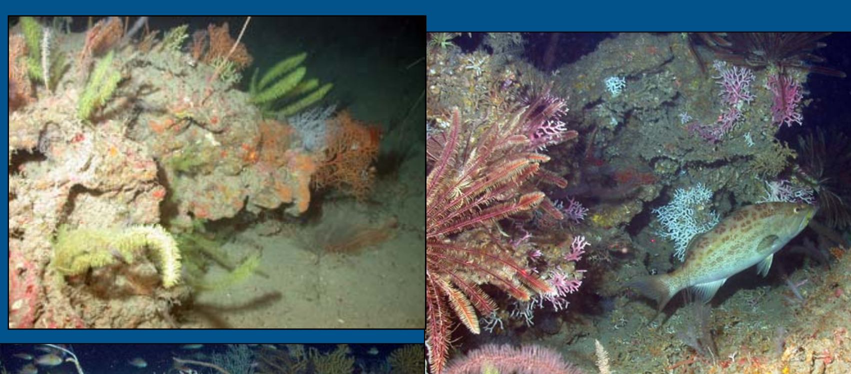


Seafloor Mapping and Characterization



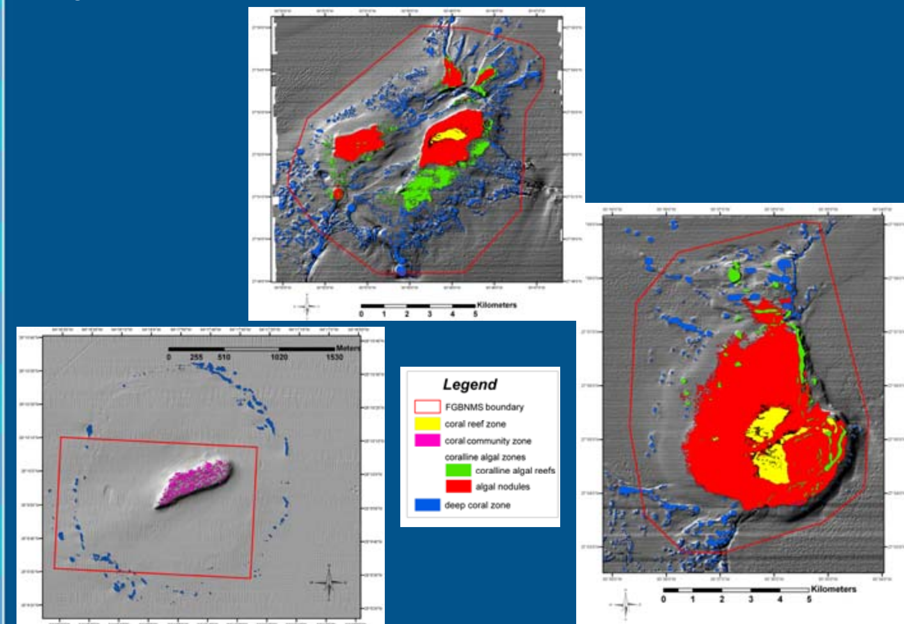
Mohawk ROV at East Flower Garden Bank, November 2013





Mesophotic Coral Communities of the northwestern Gulf of Mexico

Biological Habitat Classification Scheme - FGBNMS



Dominated by brain and star coral boulders:

Montastraea franksi

M. faveolata

M. annularis

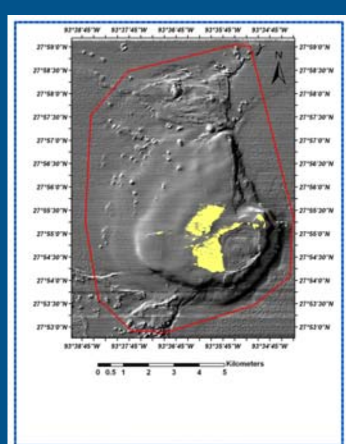
M. cavernosa

Diploria strigosa

Colpophyllia natans

Siderastrea siderea

Porites astreoides

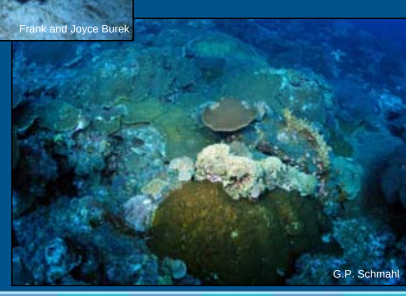


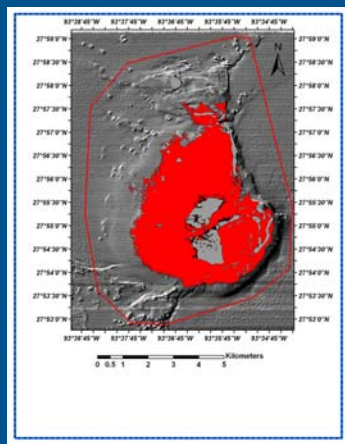
85’

Coral Reef/Coral Community Zone includes the following habitats:

Montastraea, *Stephanocoenia*, *Madracis*, sand community, mixed coral.

110’

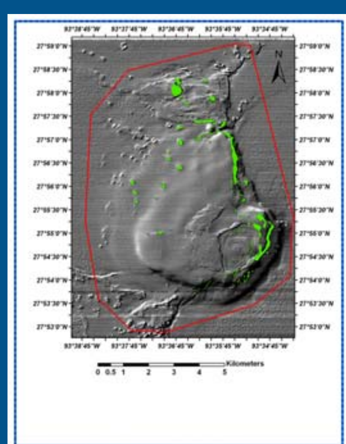


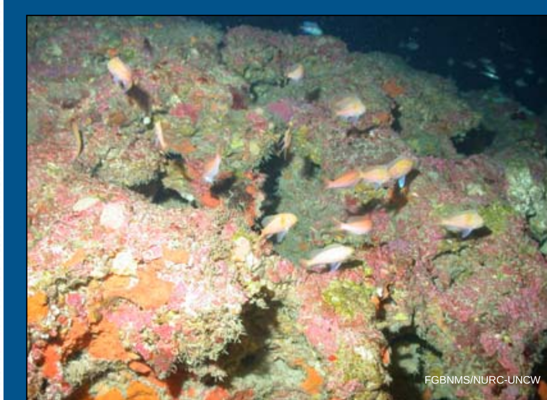


160’

Algal Nodule Habitat, within the **Coralline Algae Zone** includes these habitats:

Sand communities, leafy algae/sponge, octocoral, algal pavements, mixed coral

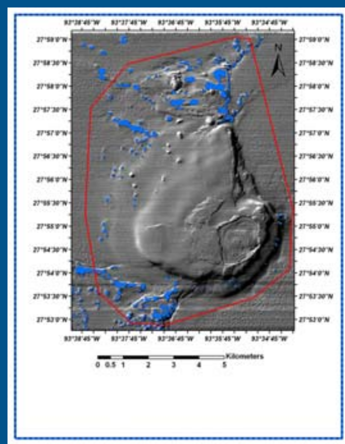




265’

Coralline Algae Reefs within the **Coralline Algae Zone**, includes these habitats:

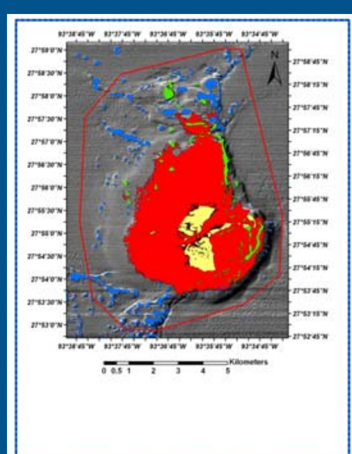
Sand communities, leafy algae/sponge, octocoral, algal pavements, mixed coral, antipatharians



332’

Deep Coral Zone, includes these habitats:

Octocoral, antipatharian, mixed coral, stony coral

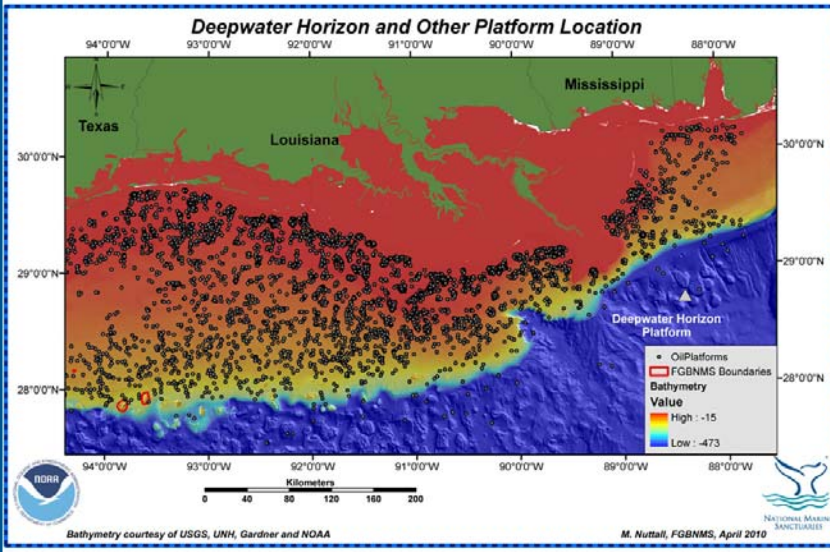


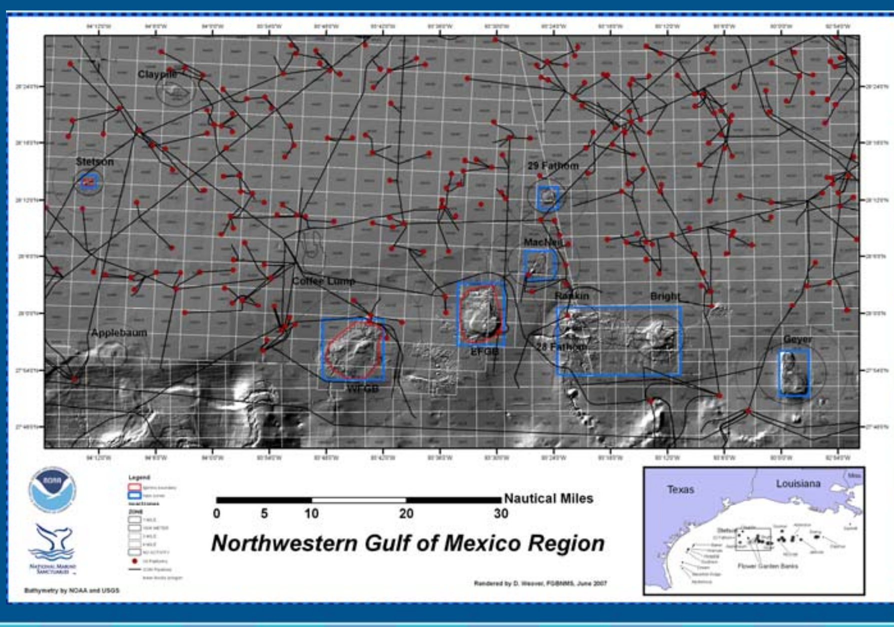
370’

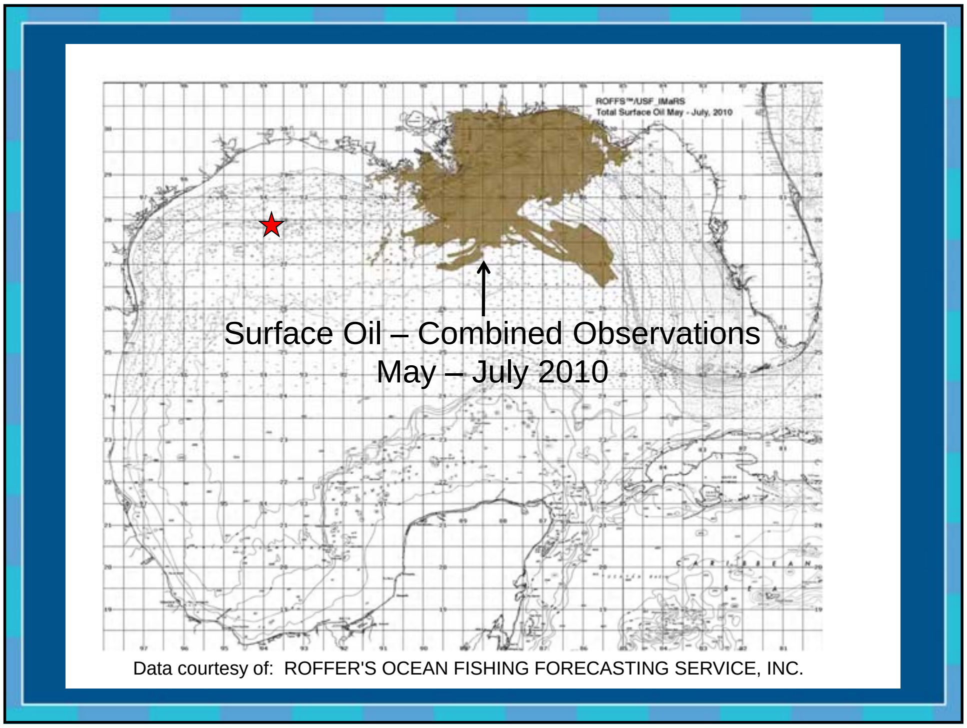
Soft Bottom Community Zone, includes these habitats:

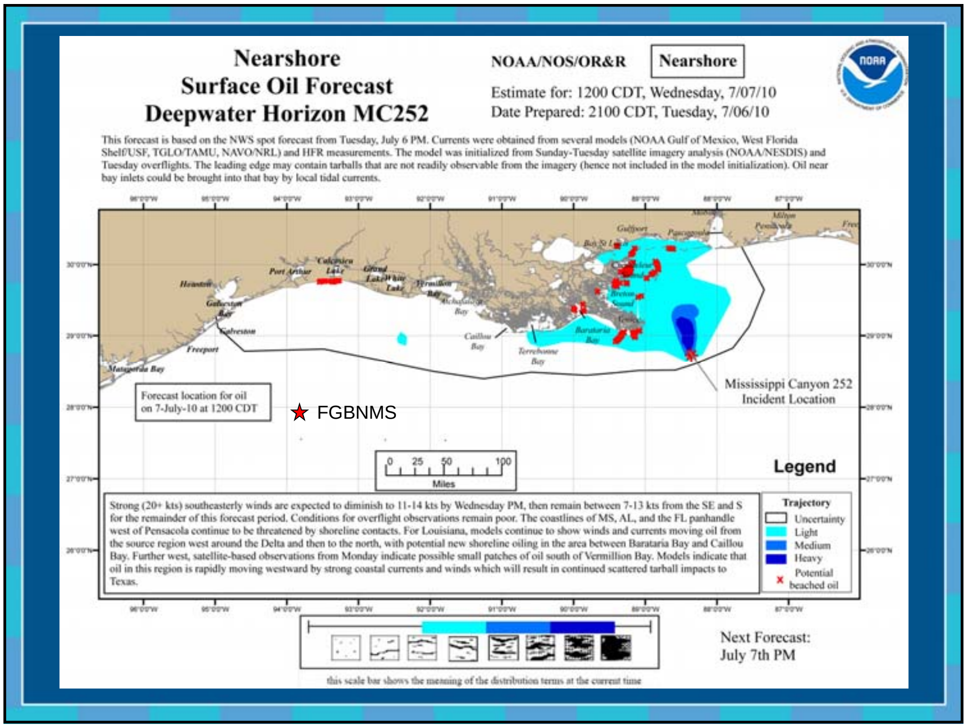
silt, fine, coarse, rubble

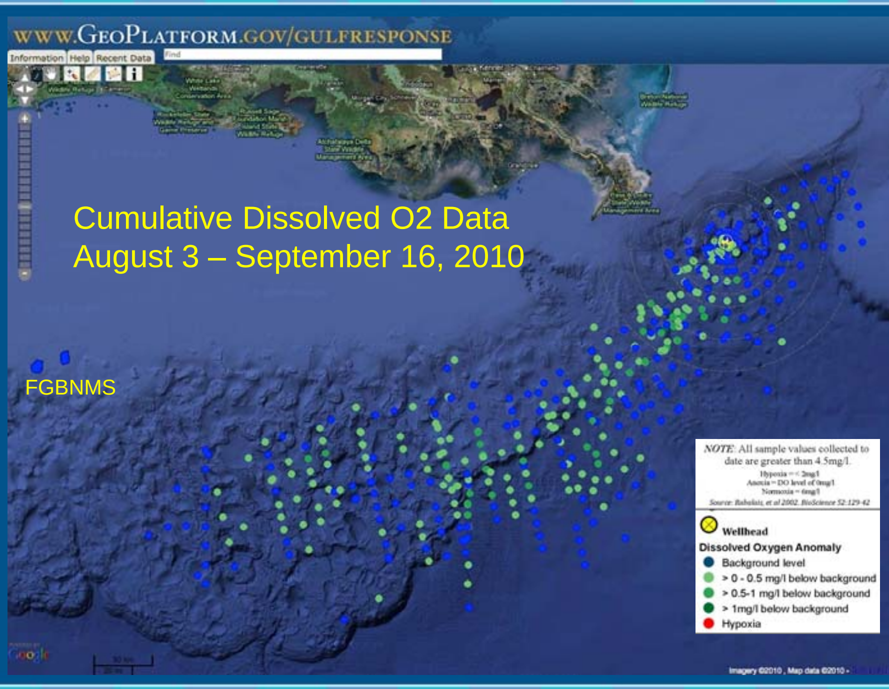
Oil and Gas Infrastructure



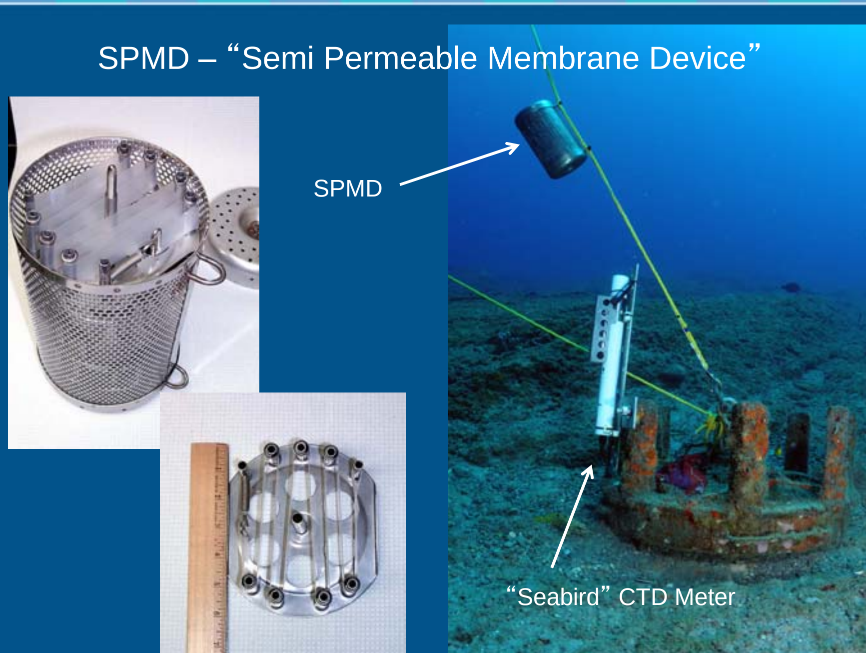



ROFFS™/USF_IMaRS
Total Surface Oil May - July, 2010
Surface Oil – Combined Observations
May – July 2010
Data courtesy of: ROFFER'S OCEAN FISHING FORECASTING SERVICE, INC.


Nearshore
Surface Oil Forecast
Deepwater Horizon MC252
NOAA/NOS/OR&R
Nearshore
Estimate for: 1200 CDT, Wednesday, 7/07/10
Date Prepared: 2100 CDT, Tuesday, 7/06/10
This forecast is based on the NWS spot forecast from Tuesday, July 6 PM. Currents were obtained from several models (NOAA Gulf of Mexico, West Florida Shelf/USF, TGLO/TAMU, NAVO/NRL) and HFR measurements. The model was initialized from Sunday-Tuesday satellite imagery analysis (NOAA/NESDIS) and Tuesday overflights. The leading edge may contain tarballs that are not readily observable from the imagery (hence not included in the model initialization). Oil near bay inlets could be brought into that bay by local tidal currents.
Mississippi Canyon 252
Incident Location
Forecast location for oil on 7-July-10 at 1200 CDT
FGBNMS
0 25 50 100
Miles
Legend
Strong (20+ kts) southeasterly winds are expected to diminish to 11-14 kts by Wednesday PM, then remain between 7-13 kts from the SE and S for the remainder of this forecast period. Conditions for overflight observations remain poor. The coastlines of MS, AL, and the FL panhandle west of Pensacola continue to be threatened by shoreline contacts. For Louisiana, models continue to show winds and currents moving oil from the source region west around the Delta and then to the north, with potential new shoreline oiling in the area between Barataria Bay and Caillou Bay. Further west, satellite-based observations from Monday indicate possible small patches of oil south of Vermillion Bay. Models indicate that oil in this region is rapidly moving westward by strong coastal currents and winds which will result in continued scattered tarball impacts to Texas.
Trajectory
Uncertainty
Light
Medium
Heavy
Potential beached oil
Next Forecast:
July 7th PM
this scale bar shows the meaning of the distribution terms at the current time

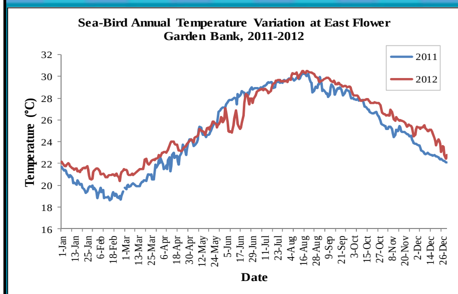


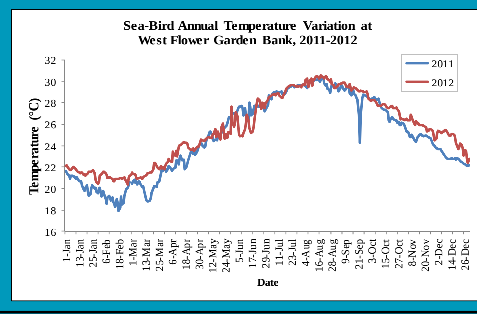
SPMD – “Semi Permeable Membrane Device”

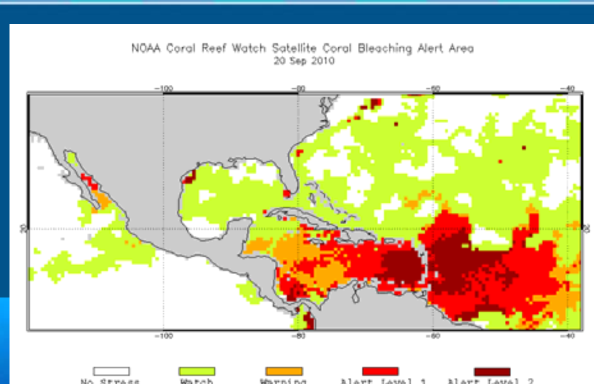


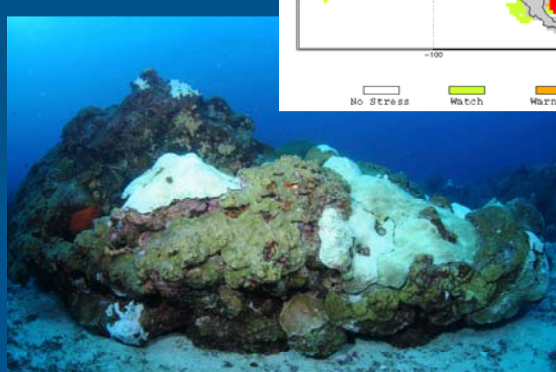
SPMD Maintenance – Flower Garden Banks - 2010

Water Quality Analysis



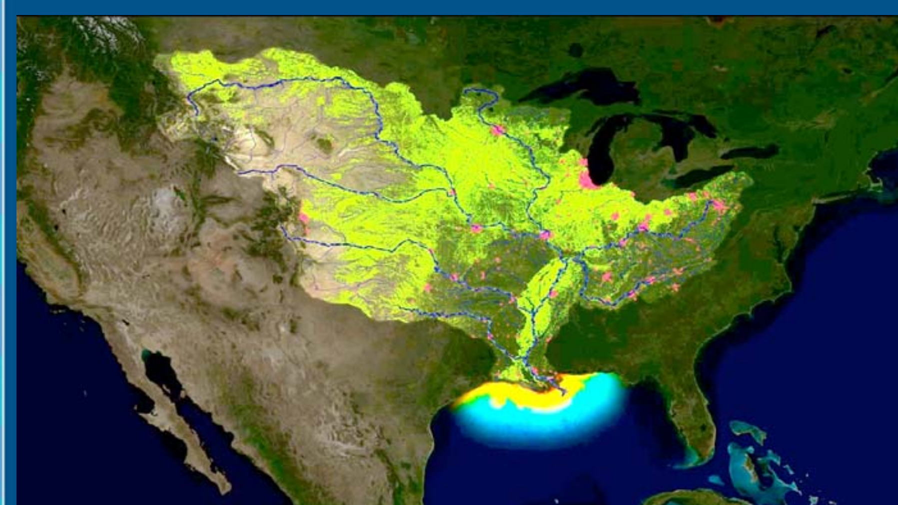






Coral Bleaching

West Flower Garden Bank – October 2010



Gulf of Mexico Watershed / “Dead Zone”

Texas / Louisiana Shelf – 3/14/2009

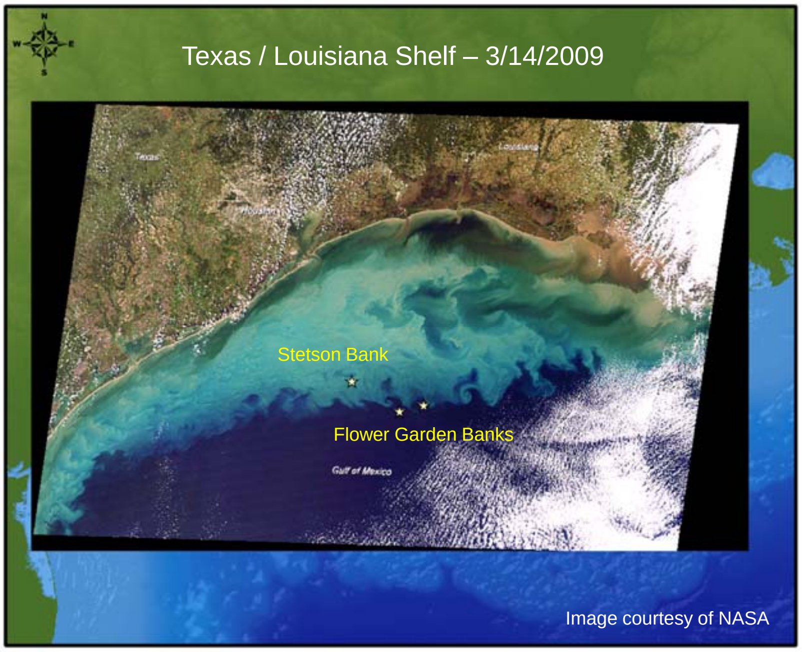
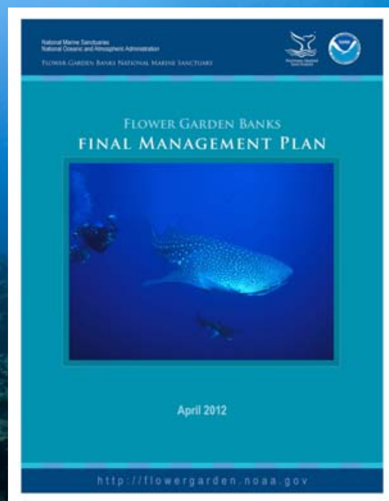


Image courtesy of NASA

Stetson Bank – September 2011

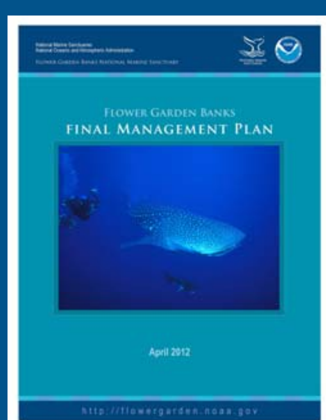
Algal Mats



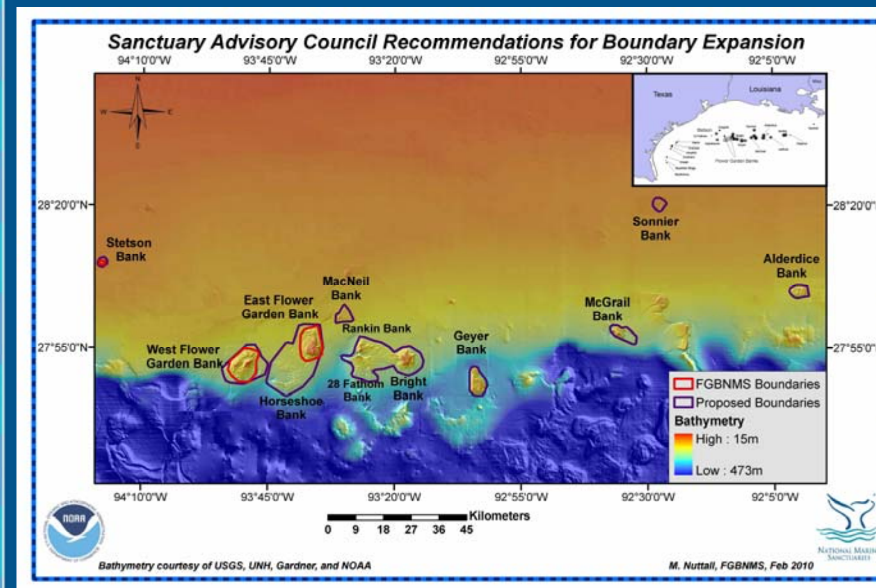
Flower Garden Banks
National Marine Sanctuary
Revised Management Plan

- Process began in 2007
- Draft released October 2010
- Final Plan released April 27, 2012
- Federal Register Vol. 77, No. 82
- Three Components:
  - Final Management Plan
  - Final Rule (New Regulations)
  - Environmental Assessment
- Regulations effective May 29, 2012

Management Action Plans:



- Sanctuary Expansion
- Education and Outreach
- Research and Monitoring
- Resource Protection
- Visitor Use
- Operations and Administration



FEDERAL REGISTER

The Daily Journal of the United States Government

Sign in Sign up

Proposed Rule

Revisions of Boundaries for Flower Garden Banks National Marine Sanctuary; Intent To Prepare Draft Environmental Impact Statement

A Proposed Rule by the National Oceanic and Atmospheric Administration on 02/03/2015

Federal Register Vol. 80, No. 22 / February 3, 2015

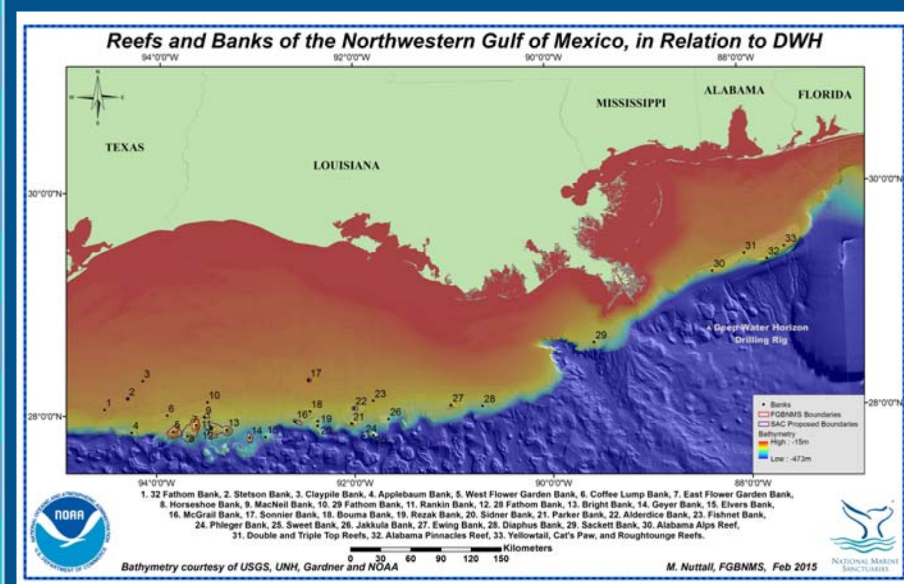
"Notice of Intent" – Public Scoping / Draft EIS

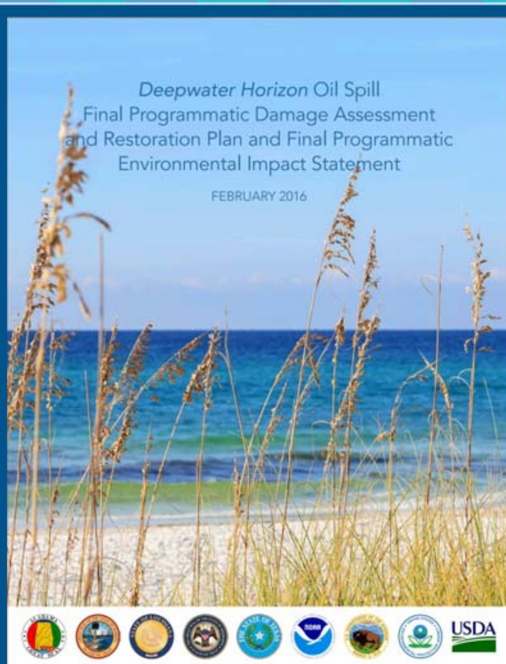
- New Orleans, LA – March 3rd / Airport Hilton
- Houston, TX – March 5th / Bayland Community Center
- Galveston, TX – March 11th / FGBNMS Office

Public Comment period closed: April 6, 2015

Public Comment Overview

Comment Category	Number of Comments
Individual	177
Organizational	23
General support	149
Resource-specific support	87
Use-specific support	54
Conditional support	15
Opposition	1



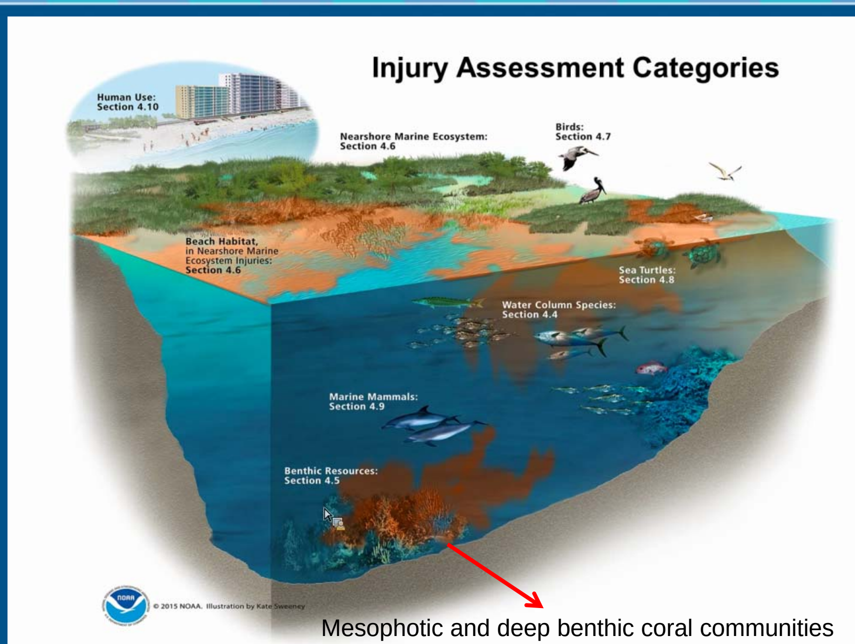


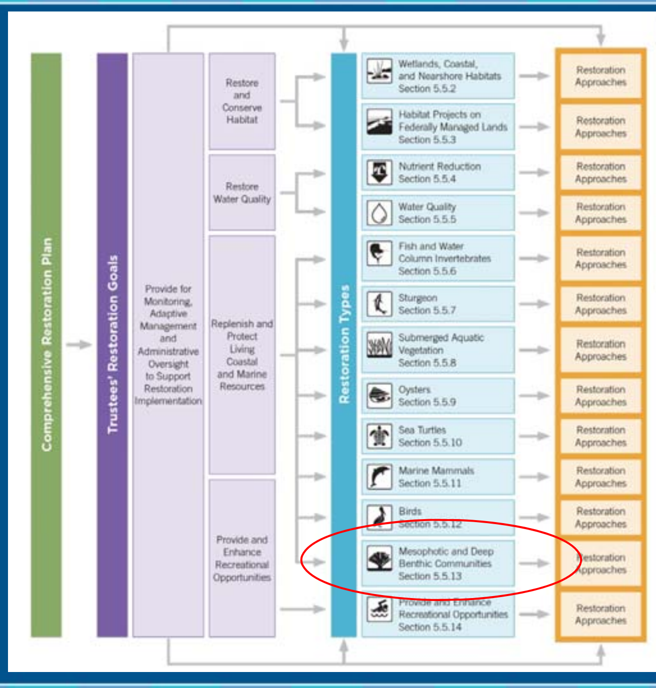
Deepwater Horizon Final Programmatic Restoration Plan

Published February 2016

Outlines Restoration Strategies for Injured Resources within various categories

15 year timeframe





design studies will ensure success of this technique by determining the optimal design for implementation and allowing responsive decision-making. Collateral injury to other natural resources is expected to be minimal due to the relatively small footprint of hard substrate placement on a vastly large expanse of soft sediment substrate. The Trustees do not anticipate that the approach will negatively affect public health or safety and consider it likely to benefit other natural resources. Although the Trustees find this overall restoration approach to be appropriate under OPA, they will ensure project appropriateness by conducting and selecting projects based on a project-specific evaluation of the OPA evaluation standards found at 15 CFR § 990.54(a).

D.7.2 Protect and Manage Mesophotic and Deep Benthic Coral Communities

This restoration approach focuses on establishing areas for spatially discrete management of and protection for mesophotic and deep benthic communities and associated resources. For some natural resources, projects that manage and prevent future injuries from known threats can often have more certain outcomes and be more cost-effective than projects designed to create these resources (Chapman & Julius 2005). The acquisition of equivalent natural resources or services for public management has long been considered as a viable restoration option (Wickham et al. 1993). The mesophotic and deep benthic coral communities would particularly benefit from a preventive restoration project because they are sessile and therefore susceptible to threats such as oil and gas activities, fishing activities, and marine debris. An MPA is defined as "any area of the marine environment that has been reserved by federal, state, territorial, tribal, or local laws or regulations to provide lasting protection for part or all of the natural and cultural resources therein" (MPA Executive Order 13158). Examples of federal MPAs include national marine sanctuaries (NMS), Essential Fish Habitat, habitat areas of particular concern, and oil and gas no-activity zones. Establishing protections

DWH Programmatic Restoration Plan, Chapter 5, Appendix D.7.2

National Marine Sanctuaries
National Oceanic and Atmospheric Administration

NATIONAL MARINE SANCTUARIES

FLOWER GARDEN BANKS

http://flowergarden.noaa.gov

Response Methods and Responsibilities

Steven Buschang, TGLO
State Scientific Support Coordinator, Paige Doelling,
NOAA Scientific Support Coordinator

Discussion Topics

- Regulatory - USCG, EPA, States, BSEE
  - Requirements- notifications, FRPs, OSROs, DCOs
  - Requirements- Jurisdictions, plans, liabilities, funds,
- Industry preparedness – e.g. Co-ops, MSRC, MWCC, HWCG etc.
- RRT
- Response methods

Natural Recovery

3 July 2010

27 July 2010

Berms and Barriers

Berms and Barriers

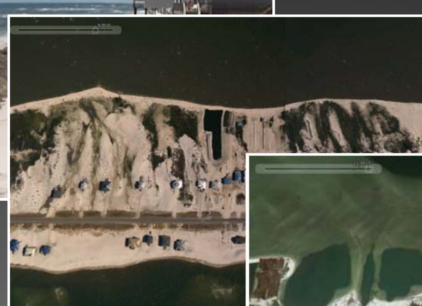


Photo: The Washington Post

Physical Herding

Manual Removal

Manual Removal

Skimming

Mechanical Removal

Sorbents

Vacuum

Debris Removal

Sediment Re-working/Tilling

Mechanical Beach Cleaners for Sediment Sifting

Beach Tech

Barber 600 HD
Surf Rake

Cherrington

Sand Shark

Vegetation Cutting

Flooding/Deluge

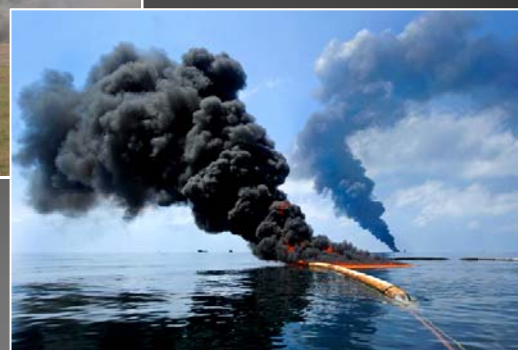
Low-pressure, Ambient-temperature Flushing

High-pressure Flushing

High-pressure, Hot Water Flushing

Surface Washing Agents

in-situ Burning



Dispersant Use

NOAA | National Ocean Service | Office of Response and Restoration

A Brief Overview of Natural Resource Damage Assessments

Lisa DiPinto, Ph.D.
Senior Scientist
NOAA's Assessment & Restoration Division
Office of Response and Restoration

NOAA Regional Preparedness Training Workshop
May 24-26, 2016
Galveston, TX

Tragically, events happen

Introduction to Natural Resource Damage Assessment (NRDA)

What is NRDA?

- A legal process to determine
  - Injuries to or lost use of the public's natural resources
  - Appropriate amount & type of restoration needed to offset losses

- Goal is to "make public whole" following release of hazardous substances & oil
- Federal, state and tribal "Trustees" representing the public are required to demonstrate causality between release and resource injury and lost use

Who are Trustees?

- Federal authorities
  - National Oceanic and Atmospheric Administration (NOAA)
  - United States Fish & Wildlife Service (USFWS)
- State agencies
- Indian Tribes

- NOAA is Trustee for:
  - Commercial/recreational fisheries
  - Migratory fish
  - Endangered/threatened marine species
  - Coastal habitats (e.g., wetlands)
  - National Marine Sanctuary/National Estuarine Research Reserve Resources

NRDA Laws and Regulations

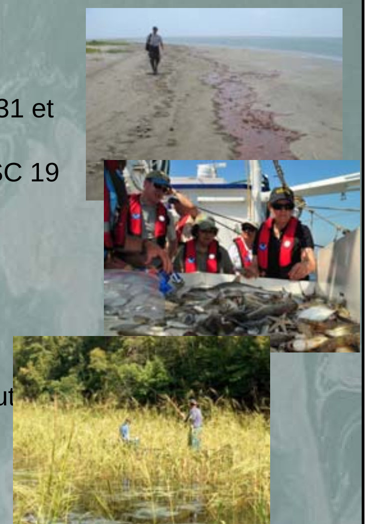
NRDA Statutory Authorities:

- CERCLA (Superfund)
- Oil Pollution Act
- Clean Water Act
- National Marine Sanctuaries Act (16 USC 1431 et seq.)
- Park System Resource Protection Act (16 USC 19 JJ)
- Applicable State laws

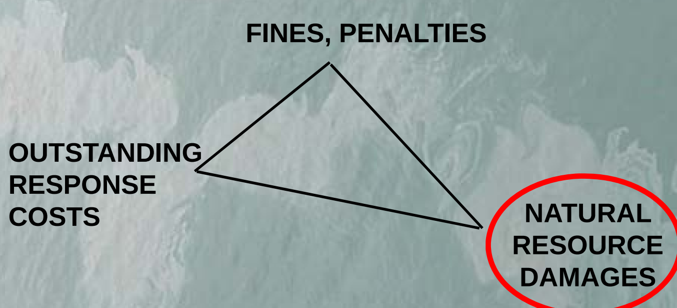
NRD Regulatory Authorities:

- CERCLA regulations, DOI (43 CFR Part 11)
- OPA regulations, NOAA (15 CFR Part 990)
- National Oil and Hazardous Substances Pollut Contingency Plan (NCP) (40 CFR Part 300)

States may also have NRDA Statutes



Potential Components of a Settlement



Process and Roles

Trustee Roles:

- Coordinate w/response agencies (e.g., USCG, EPA)
  - Integrate Trustee concerns & science into cleanup
- Assess injuries
- Evaluate & scale restoration alternatives to:
  - Return resources to baseline
  - Compensate for interim lost resources & services
  - "To make the public whole"
- Oversee and/or implement restoration plan
- Recover assessment costs

Process and Roles

<u>Causality:</u>

Release

↓

Pathway

↓

Exposure

↓

Injury

NOAA | National Ocean Service | Office of Response and Restoration

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

noaa

NRDA: The First 24 Hours

- Coordinate (NRTs, RPs, Contractors/Experts, SSC, OSC etc.)
- Integrate your efforts with ICS
  - Maximizes use of limited assets
  - Avoids duplication of efforts
  - Cost effective
- Develop and maintain situational awareness
- Share your data and findings
- Identify time critical data needs
- Cannot document every injury

National Oceanic and Atmospheric Administration • National Ocean Service • Office of Response and Restoration noaa

Ephemeral Data Considerations

- Document wildlife animals (e.g., fish, turtles, birds)
- Document extent of oiling
- Beach closures, advisories, boat access restrictions
- Environmental samples
- Baseline (areas where oil predicted to impact, reference areas)
- Water column data
  - Fingerprinting
  - Support water column modeling (e.g., fate, transport, toxicity)

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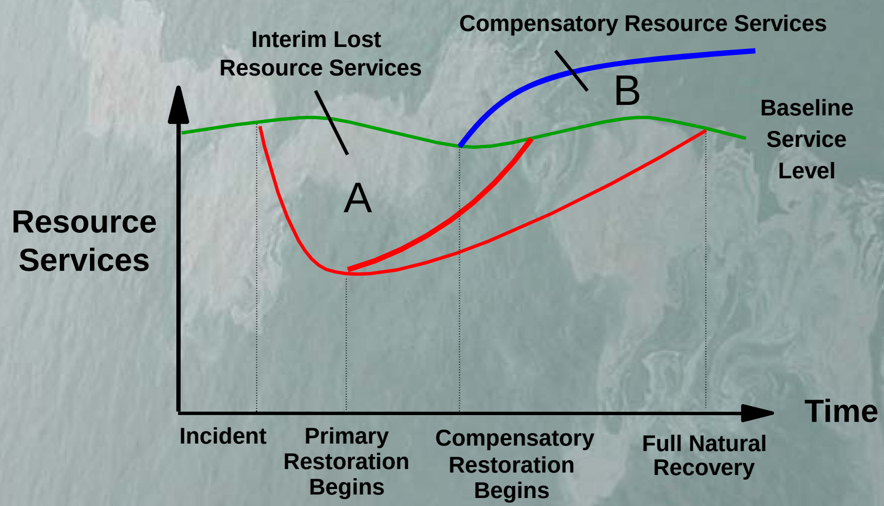
Transitioning beyond first 24h

- Focus sampling/design to conduct studies for longer term impacts and recovery trajectory
- Can consider response data to help determine areas for further study
- Determine timeline for data collection
  - Window of opportunity
  - One-time event vs collection over time?
- Coordinated effort

National Oceanic and Atmospheric Administration • National Ocean Service • Office of Response and Restoration

Scaling Injuries and Restoration



DARRP

Some Takeaways

NRDA is Restoration-Focused

- Purpose is to determine type and amount of restoration needed to compensate the public for injuries to their resources
- Restoration is considered early and throughout the process
- Injuries are balanced against, and directly scaled to restoration

NRDA as a Cooperative Process

- Getting to restoration requires a common vision & coordination with Co-Trustees and the public
- Moves faster if Responsible Party shares the same vision and works cooperatively with the Trustees

NRDA is a Legal Process

- Trustees are required to demonstrate causality between release and resource injury and lost use; sound science is key to success!
- Strategy must be encompassing and flexible

U.S. Department of Commerce | National Oceanic and Atmospheric Administration | Damage Assessment, Remediation, and Restoration Program

For More Information

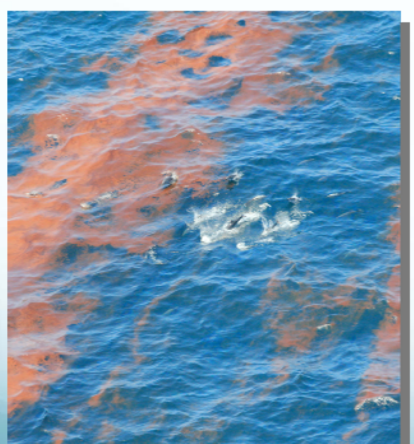
www.darp.noaa.gov

www.doi.gov/restoration

Lisa DiPinto, Ph.D.
NOAA Office of Response and Restoration
lisa.dipinto@noaa.gov
410-353-3050

NOAA | National Ocean Service | Office of Response and Restoration

A Good Assessment is the Key to A Good Restoration



Offshore Mechanical Oil Recovery Systems NOAA NRPT

Galveston, TX
May 25, 2016

James Hanzalik
Clean Gulf Associates

OFFSHORE RESPONSE

MSRC Responder Class OSRV

- 15 Dedicated Oil Spill Response Vessels nationwide
  - Dedicated special purpose
- High capacity skimming systems
  - Boom-oil containment
  - Storage
- Floating inventory of ocean boom for enhanced "U" skimming
  - ~2,240m on Gulf of Mexico OSRVs post DWH

- 210 ft (64m) length
- 12 knot speed of advance
- 4,000 bbl (636m^3) temporary storage
- 2 Oil water separators

- Berthing for 38
- Medical facility
- Helicopter deck
- Command and control capability

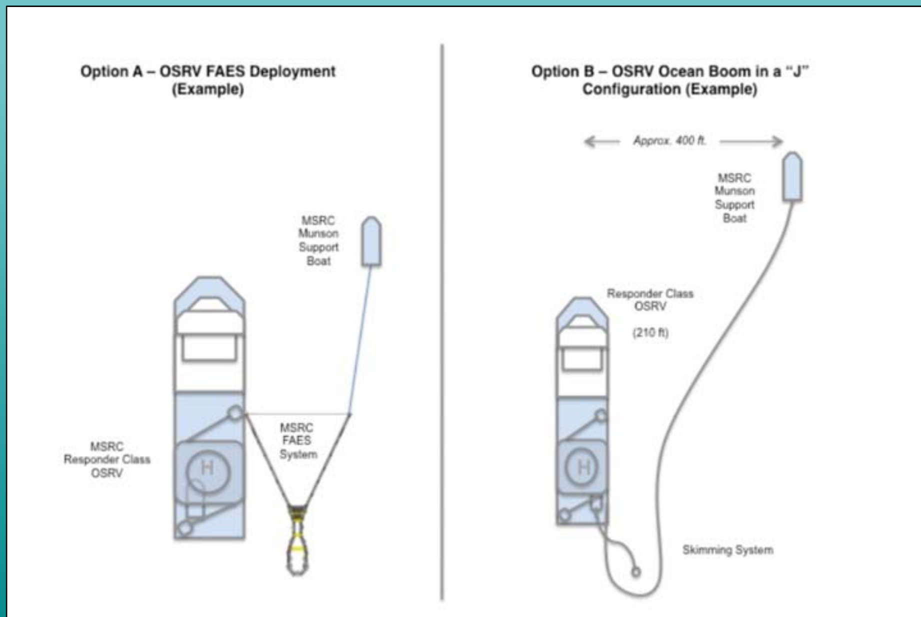
MSRC

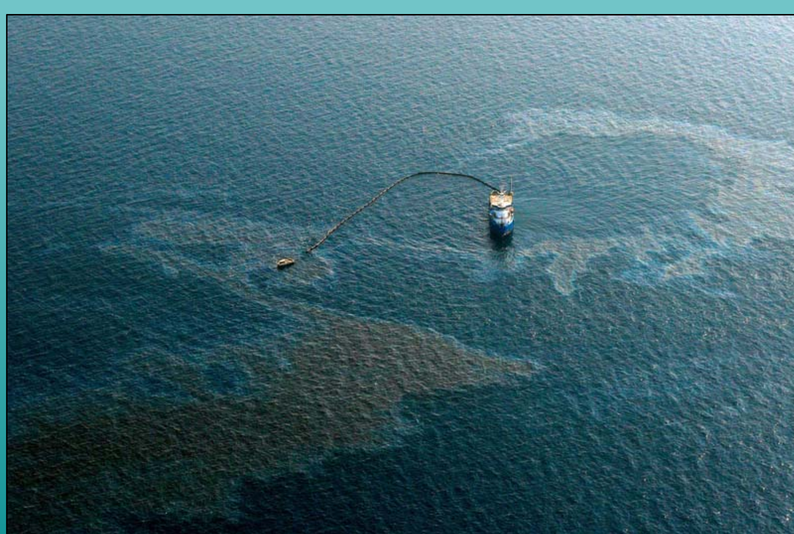
MSRC Spill Response Capabilities – OSRVs

- 15 Responder Class OSRVs (7 in Gulf of Mexico)
  - ➢ Dual option recovery systems
  - ➢ Significant on-board storage (4,000 bbl.) to ensure continuous operations
  - ➢ Accommodates 38 personnel for sustained offshore operations
  - ➢ 13 ft. draft design provides nearer to shore capability

Enhanced Encounter Rate with Norwegian Buster

J Configuration/Transrec for debris-laden conditions


Option A – OSRV FAES Deployment
(Example)
MSRC
Munson
Support
Boat
MSRC
FAES
System
MSRC
Responder Class
OSRV
Option B – OSRV Ocean Boom in a "J"
Configuration (Example)
Approx. 400 ft.
MSRC
Munson
Support
Boat
Responder Class
OSRV
(210 ft)
Skimming System



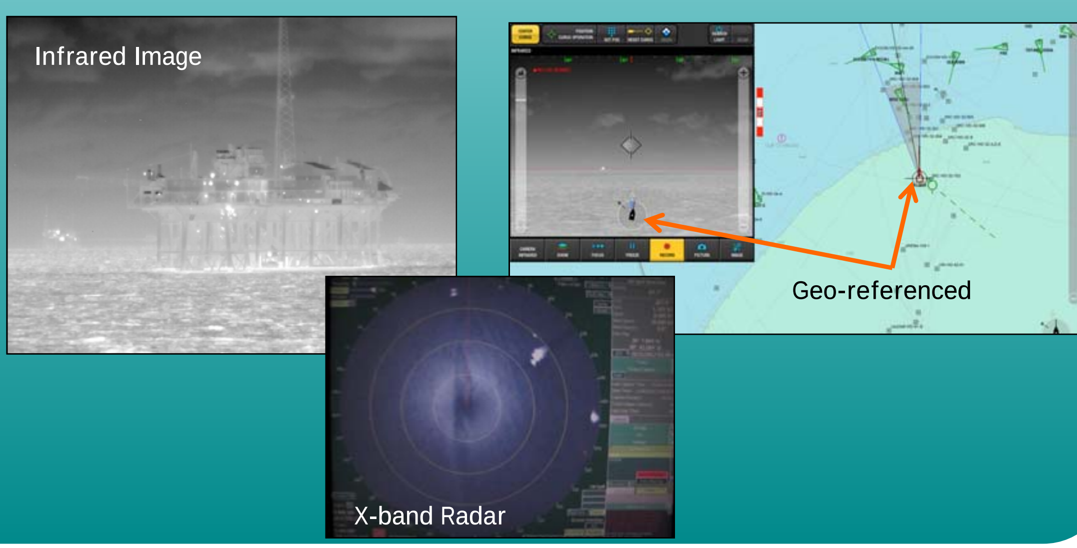
95' Fast Response Vessel

- All Aluminum Construction with 200 mile range and speed in excess of 24 knots
- Equipped with Aptomar SECurus Integrated Oil Detection System
- Has (2) Sided Mounted 3-Brush Skimmers
- (4) GOM Based Vessels

APTOMAR–RUTTER INFRARED CAMERA/X-BAND RADAR

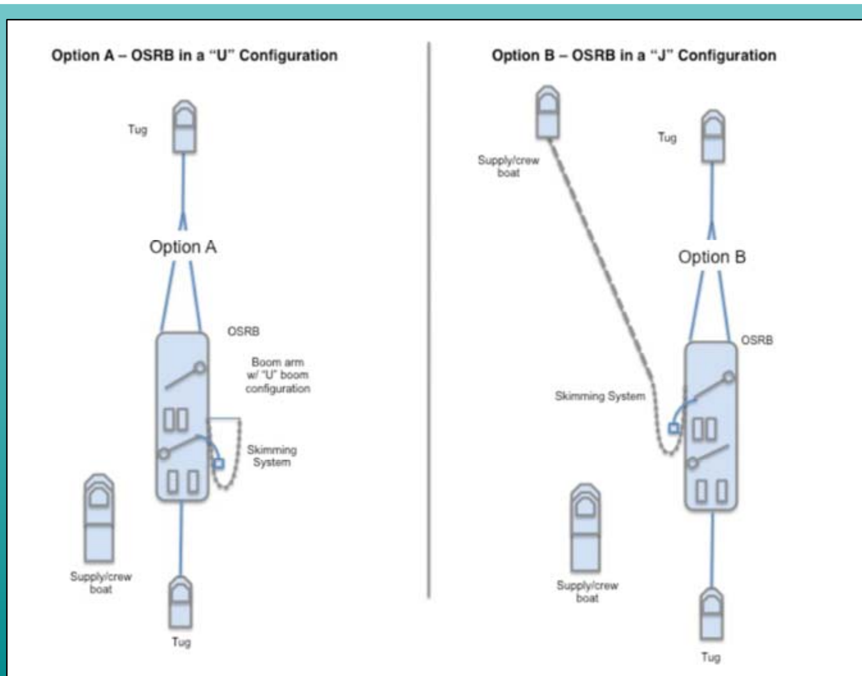
- Nitrogen-Cooled Infrared Camera
- X-band Radar
- Data Transfer capability for still and video images
- Gyro-Stabilized camera
- Accurate Geo-Referenced to chart information

24-Hour Skimming Operations



Oil Spill Response Barges (OSRBs)

- Converted from oil storage to skimming barges
- 19 Barges Nationwide
  - Dedicated
- High capacity skimming systems
  - New technology dual skimmers
  - Boom-oil containment
  - Storage
- Floating inventory of ocean boom for enhanced "U" skimming
  - Approximately 2,600 ft each post-DWH



High Volume Open Sea Skimming System (HOSS)

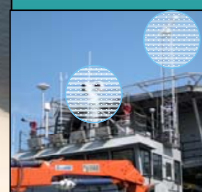
- Constructed for Well Blowouts
- 72K Barrel/day recovery rate
- New (4) 5-Brush Lamor skimmers
- Massive Swath - 2,640' 67" Sea Sentry Boom
- 4,000 Barrel Storage Capacity
- Helipad
- Based in Harvey, LA

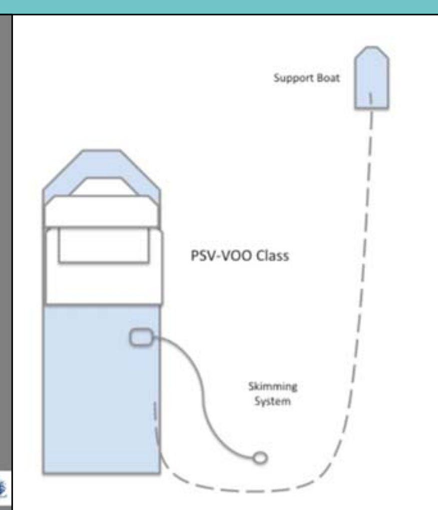
High Volume Open Sea Skimming System (HOSS)

Capable of Skimming 24/7

Offshore during MC-252 spill

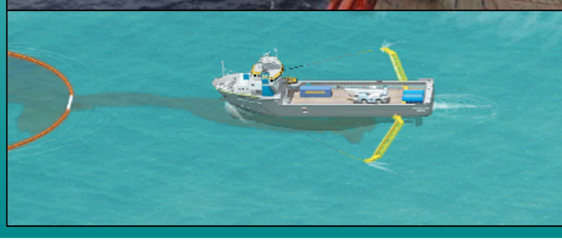
- 12 personnel to operate
- Equipped with Aptomar-Infrared Camera/X-Band for low/no light tracking of spills





KOSEQ Skimming Arms

Dutch High Seas Skimming System



- Developed, Constructed and Refined for over 46 Years
- Used during Sea Empress, Erika, Prestige & MC-252 Oil Spills
- Effective in 10 ft seas

KOSEQ Skimming Arms

Perfectly suited for large Platform or Offshore Supply Vessels

- Deployable on large Petroleum Industry Dedicated Vessels
- Rapidly transported by truck and easily assembled
- Simple to deploy and retrieve
- Requires no assist vessels

KOSEQ Skimming Arms

Efficient Brush or Weir Skimmer

- Provides 48-hour surge capability
- Can be fitted with a weir or brush skimmer

Enhanced Skimming

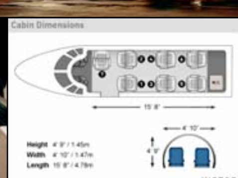
- Boom Barge -25K feet Offshore boom
- Boom “gated” for enhanced swath

Fast Response Unit

- Deployable on smaller (140’ or larger) Petroleum Industry Dedicated Vessels
- 100 barrels of storage
- Rapidly transported by truck and easily assembled
- Additional 440’ of offshore 67” Sea Sentry boom & Reel for enhanced swath width

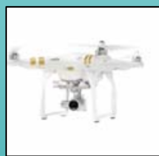
Offshore Surveillance Capabilities

Tactical Skimming Direction



- Cessna CJ3 Citation
- 2,000 mile range
- Unique Rapid Assessment Capability
- Can Provide Direction to Deployed Skimming Assets
- Increases Oil Skimming Effectiveness

Offshore Surveillance Capabilities

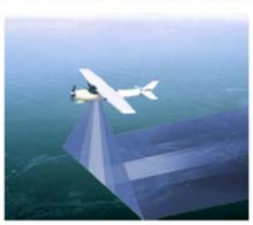


UAS

- Conducted offshore test
- 15-20 minute duration
- Line of Sight
- 200' Altitude
- UAS to be deployed major CGA skimming assets within the year

MSRC Level ABC Remote Sensing For Tactical Oil Spill Surveillance

Level A -- Aircraft
Ocean Imaging Corporation



Provides wide-area spill detection, thickness interpretation, and oil distribution mapping

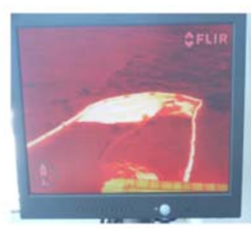
Multispectral/TIR Cameras

Level B -- Balloon
Maritime Robotics

Tethered up to 500 ft. Medium range coverage with long "hang' time

TIR and HD Cameras

Level C -- Close-In



Optimizes close-in recovery techniques

X Band Radar and TIR Camera

Tactics


TACTICS MANUAL
EQUIPMENT GUIDEBOOK
EQUIPMENT GUIDEBOOK
SAFETY (SAF)
OffShore
TASK FORCE
MODEL (TFM)
ON WATER RECOVERY GROUP

In-situ Burning

25 May 2016

Charlie Henry
Director, NOAA's GOM Disaster Response Center

Five Emergency Response Questions?

- What was spilled? (Oil Chemistry)
- Where is it going? (Oil Forecasts)
- What's at risk? (RAR/ESI)
- How will it hurt? (Potential Impacts)
- What can be done to mitigate the hurt?

(Alternative Response Technologies)

DO NO MORE HARM THAN GOOD

Was there any in-situ burns during the Exxon Valdez Response?

Burning Oil at Sea Research

Basics of Burning Oil at Sea

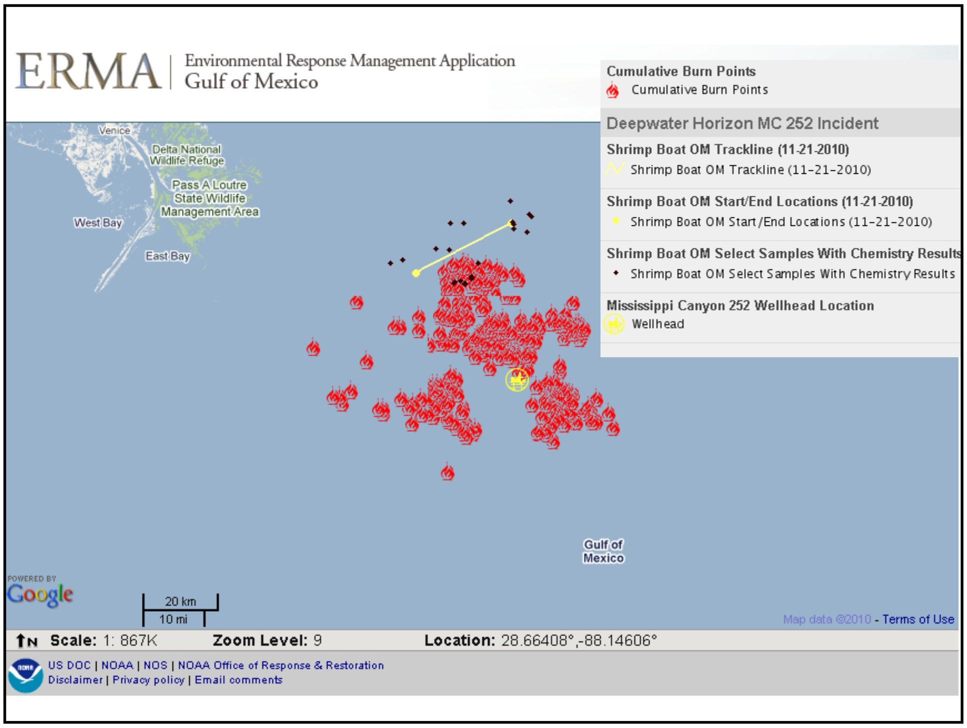
- **Oil must be several mm thick to support sustained combustion on water – thicker better.**
- **<u>Requires mechanical recovery prior to burning</u>.**
- **Oil must not be emulsified (water-in-oil) more than 50% (maybe a bit higher water content if you can get a hot enough fire initiated).**
- **Ignition systems maybe hand deployed or helio-torch (jellied gasoline).**
- **Not 100% Efficient (is anything 100% efficient?)**

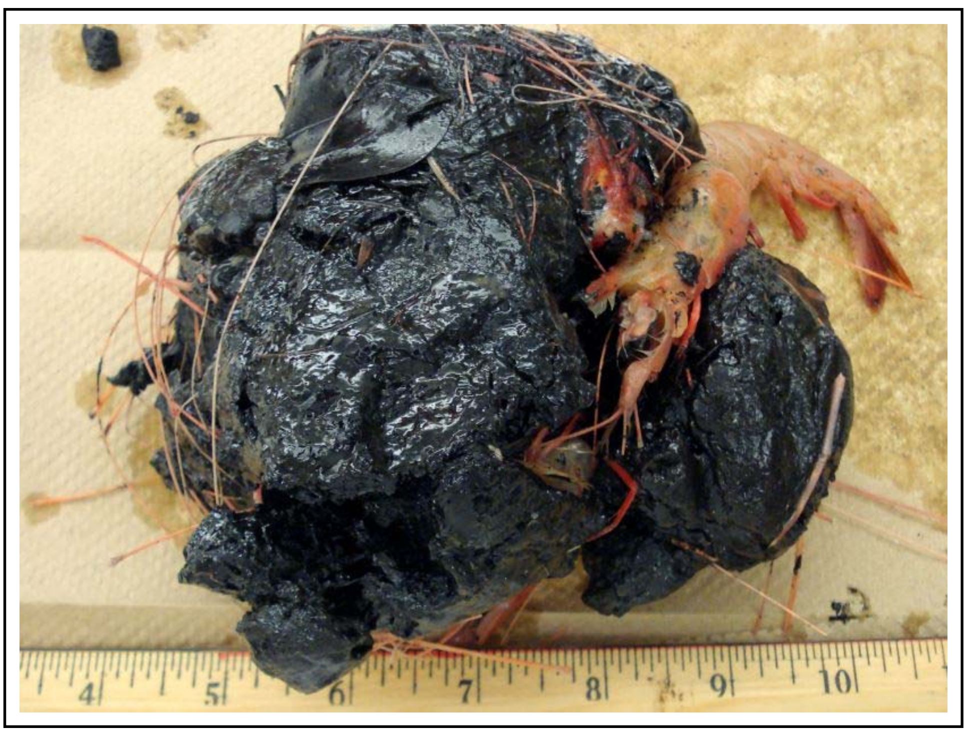
12

Burn Effectiveness In General

- **90-98% Effective at removing surface oil.**
- **Primary products are CO_2 and H_2O.**
- **Some 5% of the oil removed from the surface are incomplete combustion by-products:**
  - **particulates such as smoke and soot**
  - **Polynuclear Aromatic Hydrocarbons (pyrogenic)**
- **Plume monitoring may be required (SMART).**
- **Surface residues are highly distilled oil residues and may sink especially after the begin to cool.**

13


ERMA
Environmental Response Management Application
Gulf of Mexico
Cumulative Burn Points
Cumulative Burn Points
Deepwater Horizon MC 252 Incident
Shrimp Boat OM Trackline (11-21-2010)
Shrimp Boat OM Trackline (11-21-2010)
Shrimp Boat OM Start/End Locations (11-21-2010)
Shrimp Boat OM Start/End Locations (11-21-2010)
Shrimp Boat OM Select Samples With Chemistry Results
Shrimp Boat OM Select Samples With Chemistry Results
Mississippi Canyon 252 Wellhead Location
Wellhead
Venice
Delta National Wildlife Refuge
Pass A Loutre State Wildlife Management Area
West Bay
East Bay
Gulf of Mexico
POWERED BY Google
20 km
10 mi
Map data ©2010 - Terms of Use
N Scale: 1: 867K Zoom Level: 9 Location: 28.66408°,-88.14606°
US DOC | NOAA | NOS | NOAA Office of Response & Restoration
Disclaimer | Privacy policy | Email comments


4
5
6
7
8
9
10

PROS:

- **Removes a large amounts of oil very fast (>2000 bbl/hr) – much faster than a skimming system.**
- **No storage capacity issues.**
- **Removes the bulk of the oil from the water surface with no significant increase in dissolved hydrocarbons into the water column.**
- **Often has a relatively broad window of opportunity (often days).**

CONS:

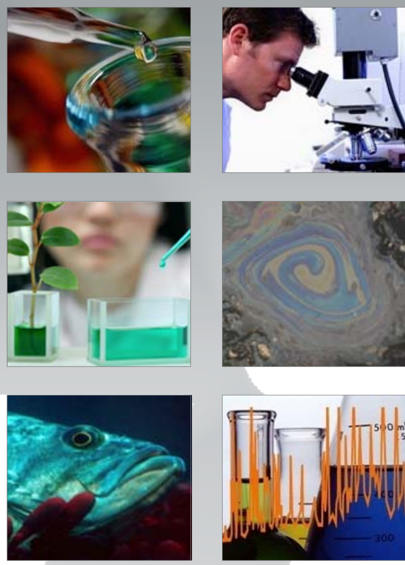
- **Limited to same mechanical encounter rate challenges as skimming operations.**
- **Moves pollution from water to air.**
- **Highly visible plume (public is often alarmed).**
- **Combustible liquids only (not emulsified oil).**
- **Requires specialized fire boom systems.**
- **May require air monitoring (SMART and maybe other requirements).**
- **Will likely require wildlife monitoring.**

CONS:

- **May require RRT approval (Preauthorization)**
- **Residues may sink (often sink) – exclusion zones pre-identified in RRT6 Authorization (maybe these should be revisited -expanded).**

19

health & environmental sciences • failure analysis & prevention



Exponent®

Dispersants Overview

Presentation to:

NOAA Regional Preparedness Training Session

Galveston TX May 25 2016

A leading engineering & scientific consulting firm dedicated to helping our clients solve their technical problems.

Exponent®

NEBA Tradeoffs:

2

1. Oil on Water Surface
2. Oil on Shoreline
3. Oil in Water Column

Source: NOAA

Waterfowl and seabirds are vulnerable to surface oil

Source: HDR

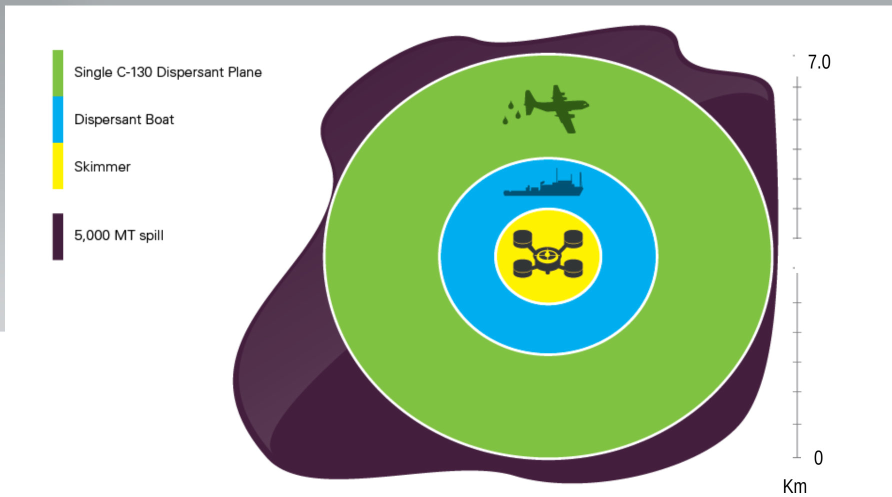
Oil reaching shorelines threaten ecologically valuable nearshore habitats and coastal marshes.

Source: USGS

Oil dispersed into the water column may increase exposures of fisheries resources.

Exponent 3

And Response Method Strengths Vary

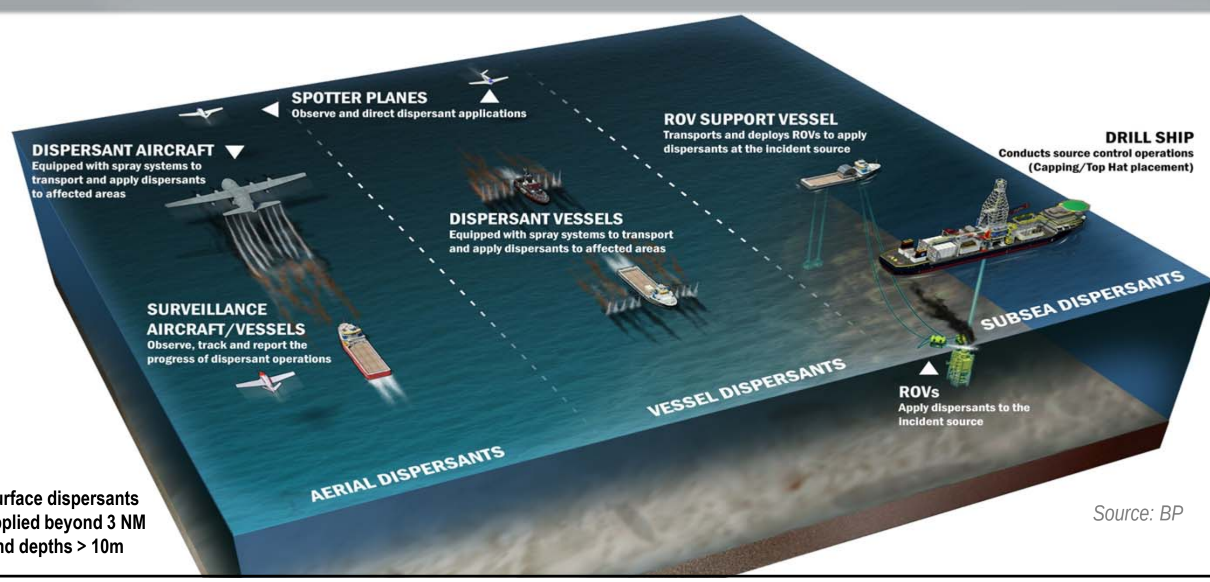


Source: BP

Relative Area Coverage in 2 Days of Operation

Exponent 4

Oil Spill Dispersants Response Methods



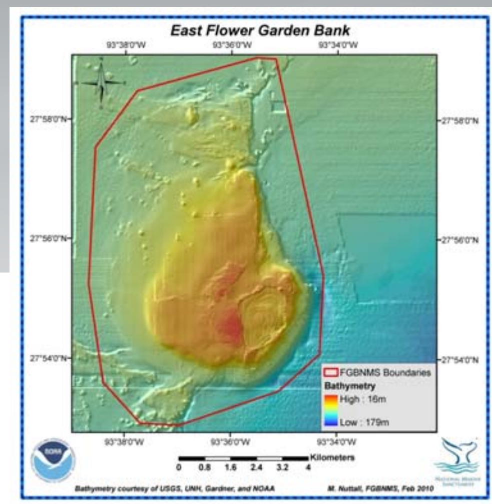
Surface dispersants
applied beyond 3 NM
And depths > 10m

Source: BP

Exponent 5

FGBNMS and Oil Spill Dispersants

Busy Location
Reef Depth 16M+



Exponent 6

Surface Dispersant Application

Advantages
- Rapid response time
- Large encounter rate
- Bigger window of opportunity
- Enhanced biodegradation

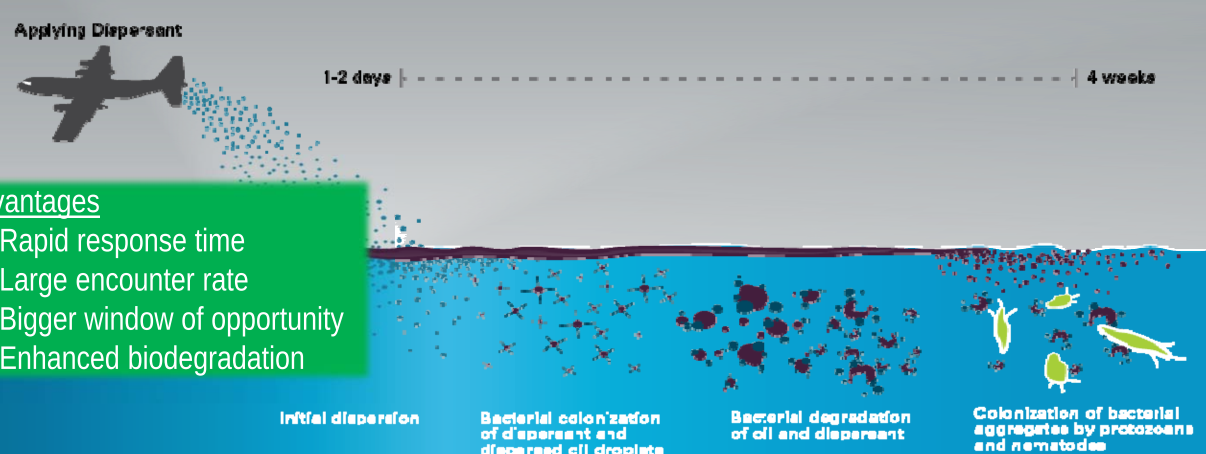
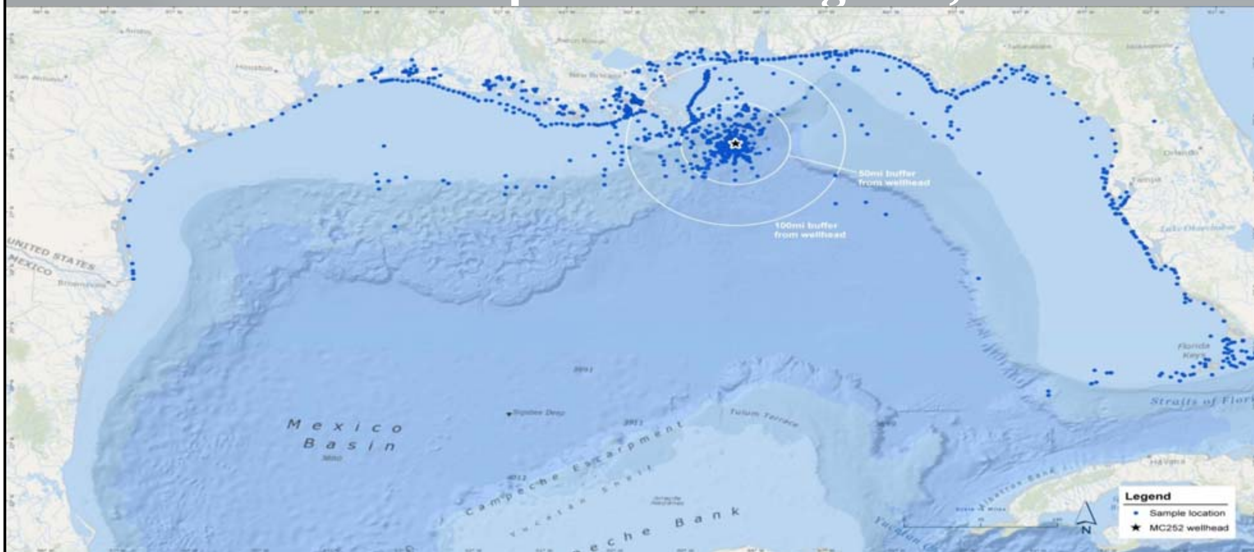


Chart from NOAA Response And Restoration Web Page

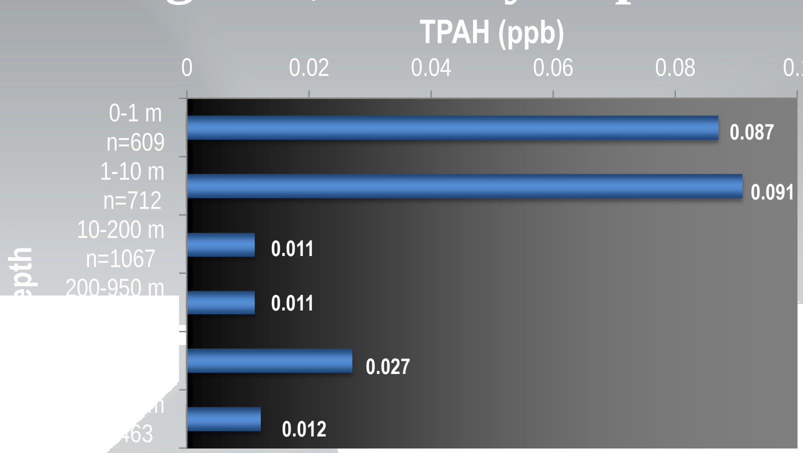
Exponent 7

More than 11,500 Whole Water Samples were Collected for DWH between April 20 and August 3, 2010



8

Total PAH Concentrations Between April 20 and August 3, 2010 by Depth



O-1 max 105000ug/l 1-10 max 44.9 ug/L

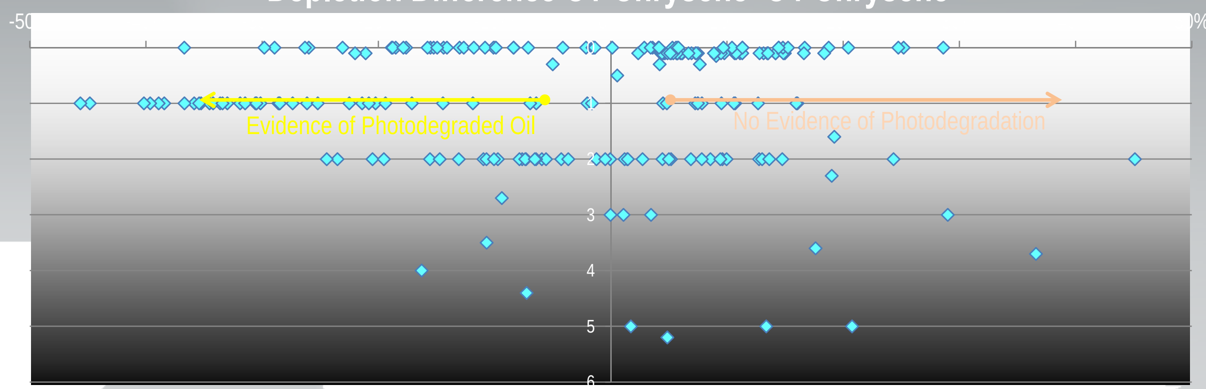
- Geometric means were calculated to represent the central tendency of the data

From Morrison, Murray, Cook & Boehm, GoMRI Conference 2016

Exponent 9

Depth of Entrainment Can Be Determined By Evaluating Photodegradation of PAHs

Depletion Difference C1-Chrysene–C4-Chrysene



- No evidence of photodegraded Macondo oil was found at depths below 4.5 meters in the water column

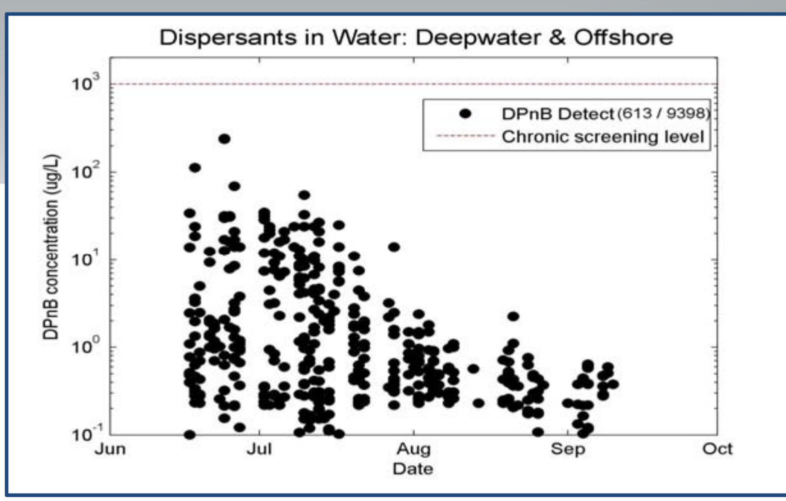
From Morrison, Murray, Cook & Boehm

Exponent 10

Offshore and Deep-water Sampling Zones

Dispersant Related Chemicals

- No exceedances of benchmarks for dispersant related chemicals (1mg/L)
- Detects for DPnB (one of the more persistent dispersant related chemicals) indicates a decreasing trend in concentrations over time

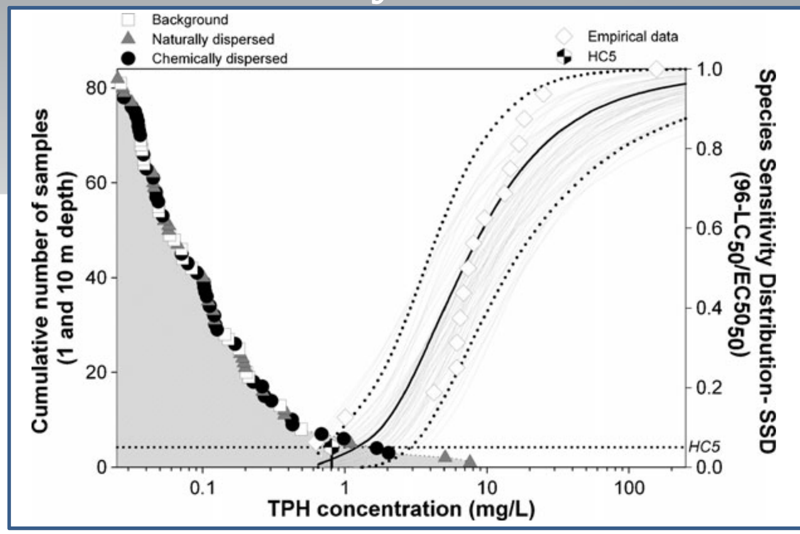


From *Deepwater Horizon MC 252 Operational Science Advisory Team Report* Dec. 2010

Exponent 11

DWH SMART Tier III Dispersant Application M/V International Peace Study

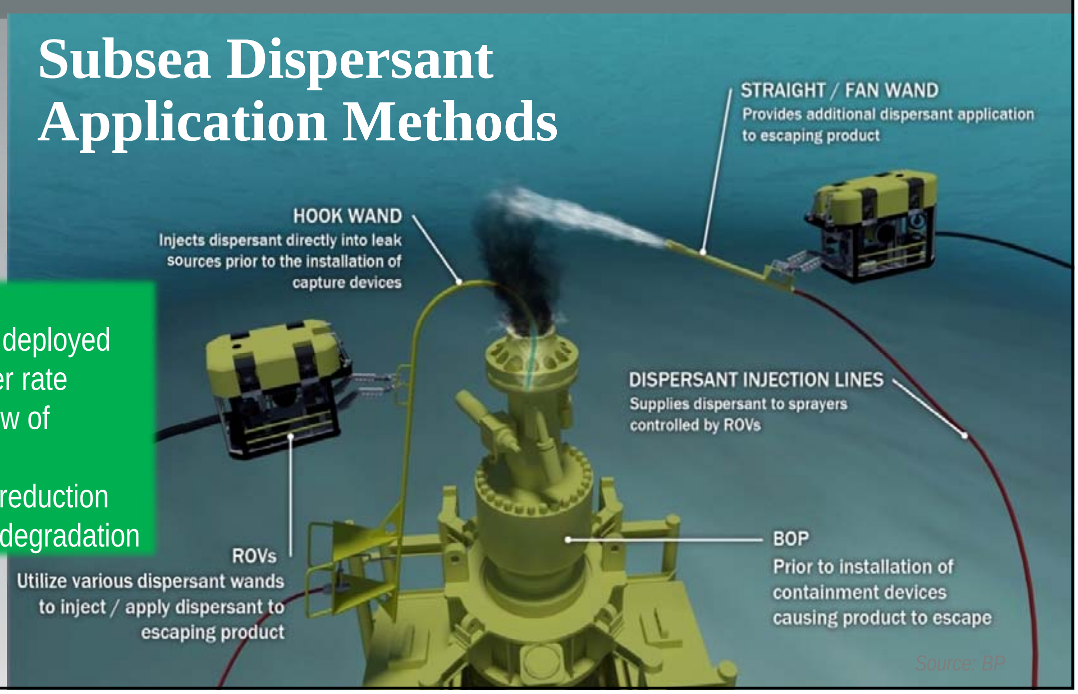
- Sampling before and after surface dispersant at 1 ad 10 M depth
- TPAH and TPH concentrations variable
  TPAH <0.01–77.33 µg/L
  TPH <0.01–5.1 mg/L)
- DPnB concentration <003ug/L to 100 ug/L
- 94% of data below TPH 5% hazard concentration



Data from Bejarano, Levine & Mearns 2013

Exponent 12

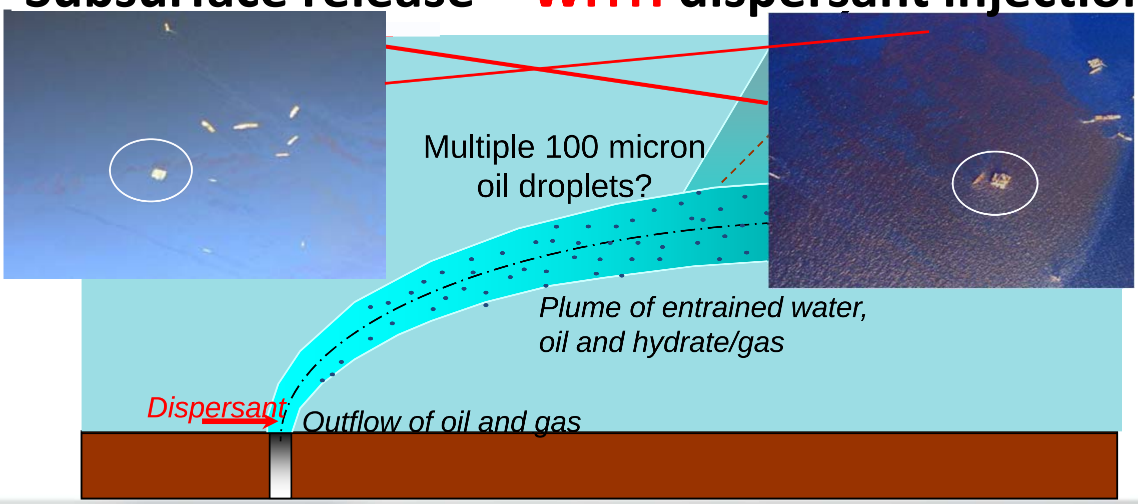
Subsea Dispersant Application Methods



Advantages
- On 24/7 once deployed
- Best encounter rate
- Biggest window of opportunity
- Surface VOC reduction
- Enhances Biodegradation

Exponent 13

Subsurface release – WITH dispersant injection

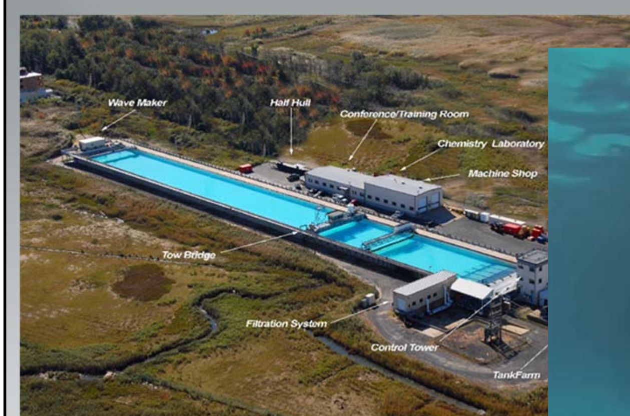


Large oil droplets will give a more vertical stream of oil resulting in a thick surface oil slick directly above the release point

From SPE 2016 HSSE Conference Paper 179401 • Subsea Dispersant Injection • Brandvik

Exponent

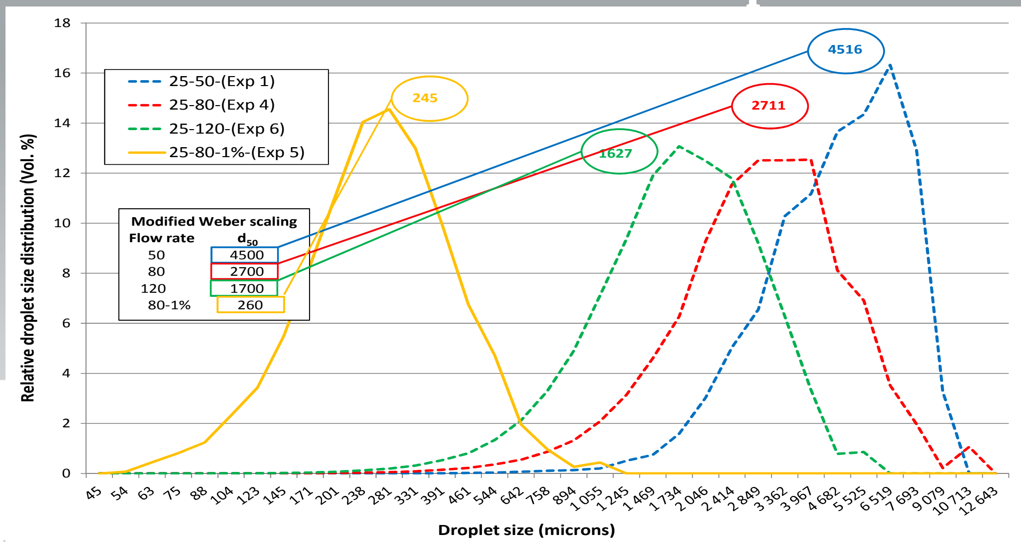
Large-scale Subsea Dispersant Injection Tests 14



Large-scale testing at Ohmsett, NJ
US Bureau of Safety and Environmental Enforcement (BSEE) Facility

From SPE 2016 HSSE Conference Paper 179401 • Subsea Dispersant Injection • Brandvik

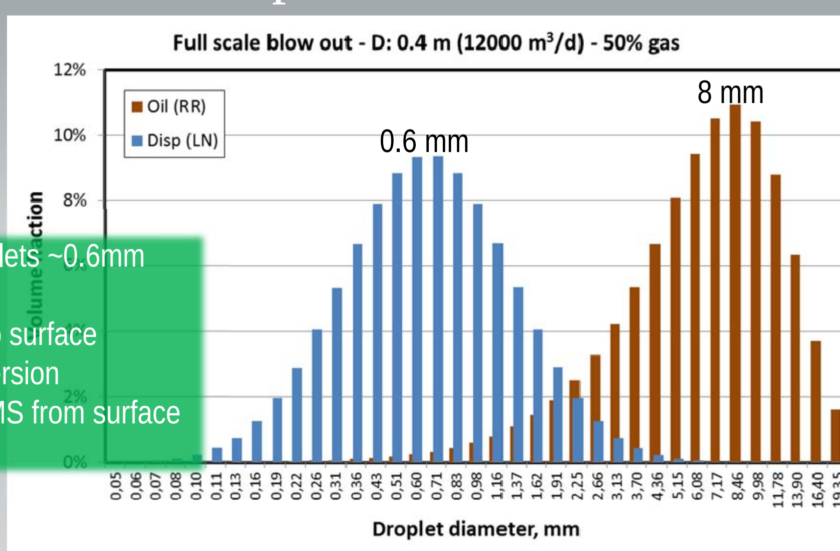
Predicted vs. measured oil droplet sizes



Oil droplet sizes (mm) as a function of nozzle size, flow rate and dispersant injection

From SPE 2016 HSSE Conference Paper 179401 • Subsea Dispersant Injection • Brandvik

Predicted SSDI Droplet size distributions: full scale



Dispersant treated droplets ~0.6mm

Suggests

- Droplets still head to surface
- Easier surface dispersion
- Exposure to FGBNMS from surface oil dispersion

From Johansen, Brandvik, Farooq 2013

Summary

- **FGBNMS Scenarios could involve surface or subsea dispersants**
- **Subsurface dispersants not likely to create direct exposures**
- **Surface oil entrainment with or without dispersants possible concern**
  - DWH data suggests concentrations
    - Total PAH geomean of large data set ~ 0.1 ug/L in 0 to10 M
    - Dispersant range - 0.1 to 300 ug/L
    - TPH can be in ppm range 1 M short term below dispersant application
    - Surface entrainment of oil observed during DWH was less than 5M
- **Much new research on subsurface dispersant**

Closing Comment: review new dispersant research for realistic conditions

- Rapid Sedimentation caused by
  - Oil interactions with marine snow
  - Oil interaction with microbes
  - Oil interaction with clay minerals

Daly, K.L., U. Passow, J. Chanton, and D. Hollander. 2016 Assessing the Impacts of Oil-Associated Marine Snow Formation and Sedimentation during and after the Deepwater Horizon Oil Spill. **Anthropocene**, http://dx.doi.org/10.1016/j.ancene.2016.01.006

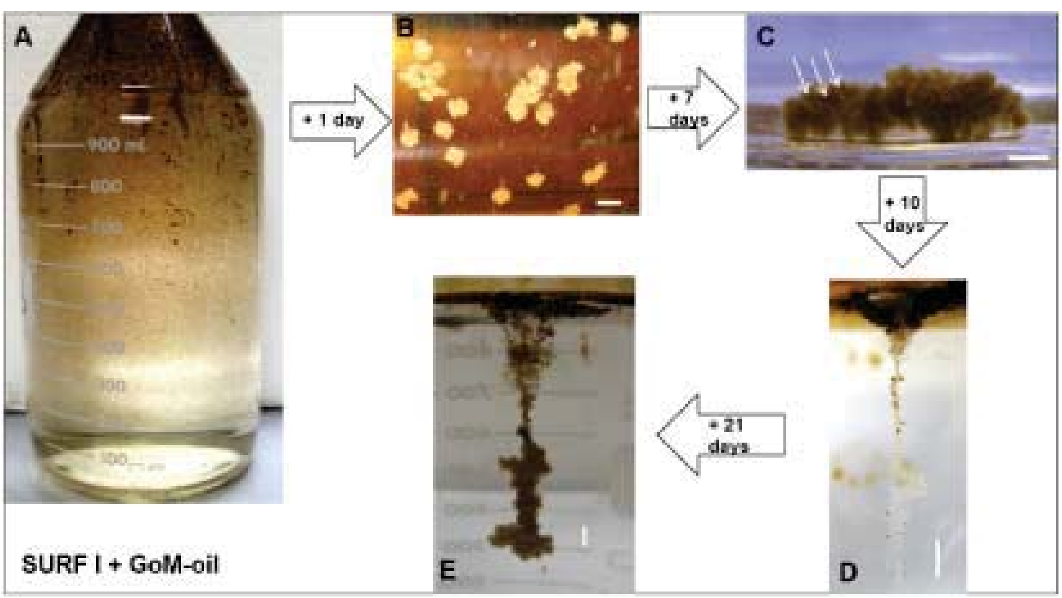
Participants in this work were funded by GOMRI consortiums, Ecogig, and C-Image, Deep-C,

Mechanism of oil sedimentation

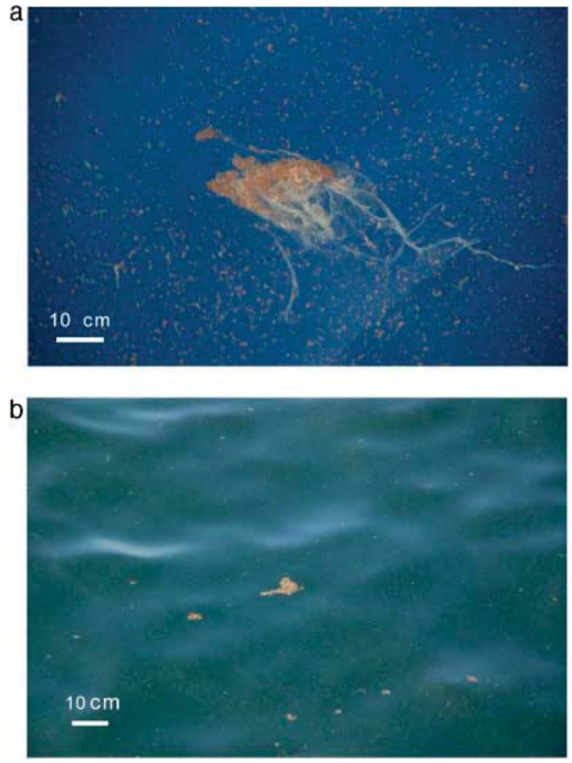
- 1. Interaction of petroleum-derived compounds with the high concentrations of marine snow and suspended particulates at the surface *(Passow et al, 2012; Ziervogel et al, 2012; Joye et al, 2014; Kenner et al, 2014).*

Uta Passow UCSB

GULF OF MEXICO RESEARCH INITIATIVE



GULF OF MEXICO RESEARCH INITIATIVE



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Oil Sedimentation.

- 2. Surface burning likely consumed 5-6% of the oil *(Lehr et al 2010),* and allowed black carbon and ash to fall to the seafloor *(see Koelmans et al 2006; Mari et al 2014).*
- 3. Zooplankton can transport oil to the sediment in their fecal pellets following ingestion (Muschenheim & Lee 2002).

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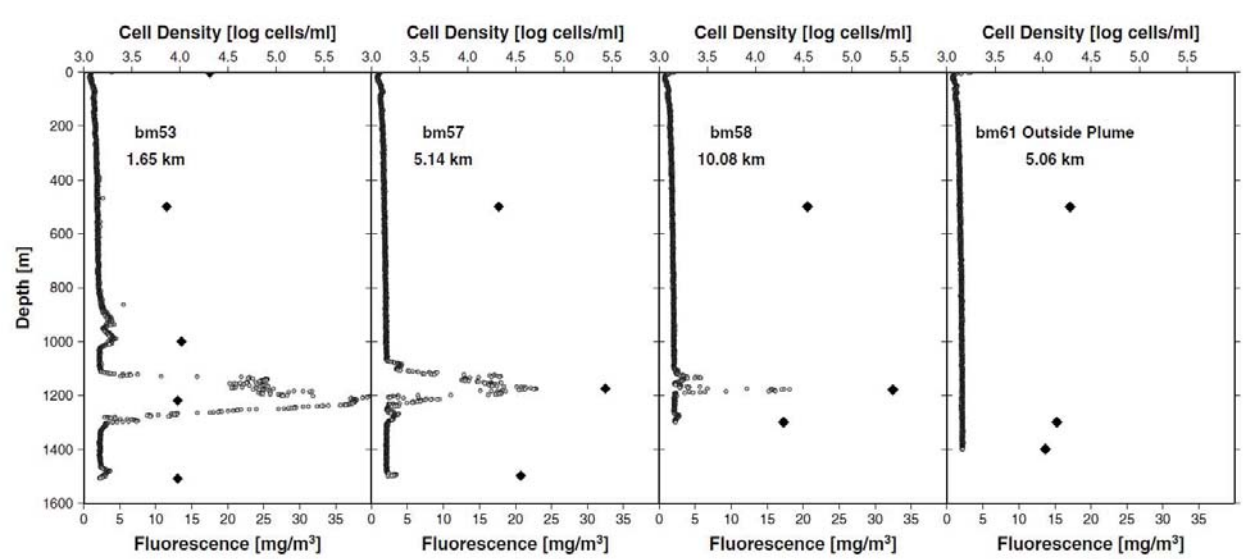
Oil Sedimentation.

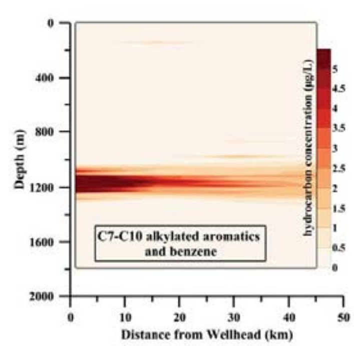
4. MOSSFA- like event in the deep water plume at 1000-1300 m.

Valentine et al., 2014

- Microbial density was high in this plume *(Hazen et al 2010),*
- *Colwellia* produce floc consisting of oil, carbohydrates and biomass when incubated with MC-252 oil *(Baelum et al., 2012).*
- Microbial produced floc captures the suspended hydrocarbon-rich particles, formed OMAs, and led to the deposition on the seafloor.
- *Colwellia* was also abundant in the surface sediments in the area *(Mason et al, 2014).*



Hazen et al., 2010



Spier et al., 2013

DSH-08 December 2010
26 nm NE – 1115 m Sediments

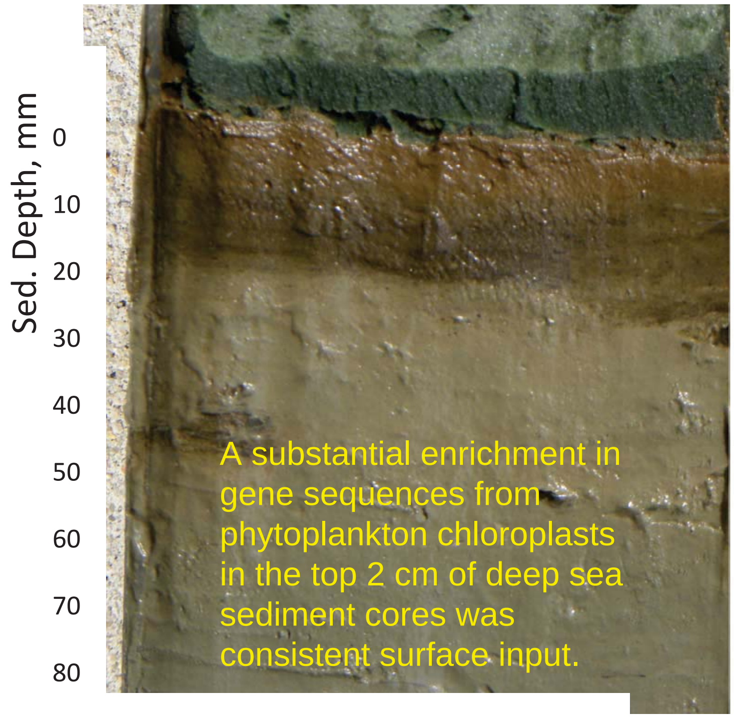
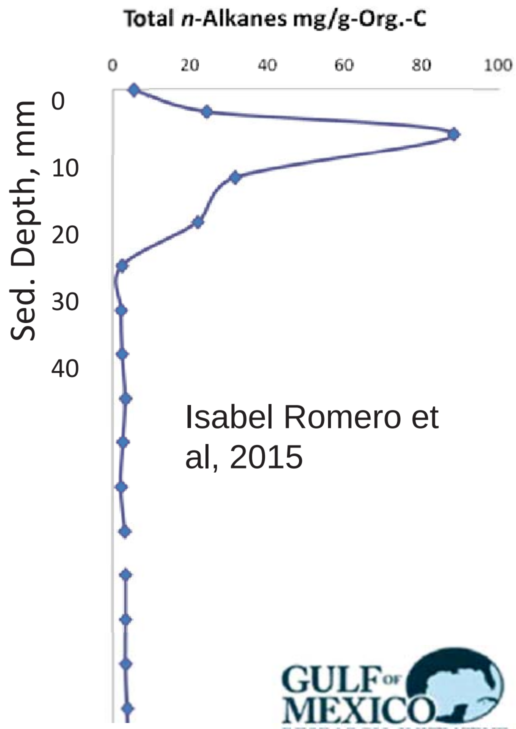
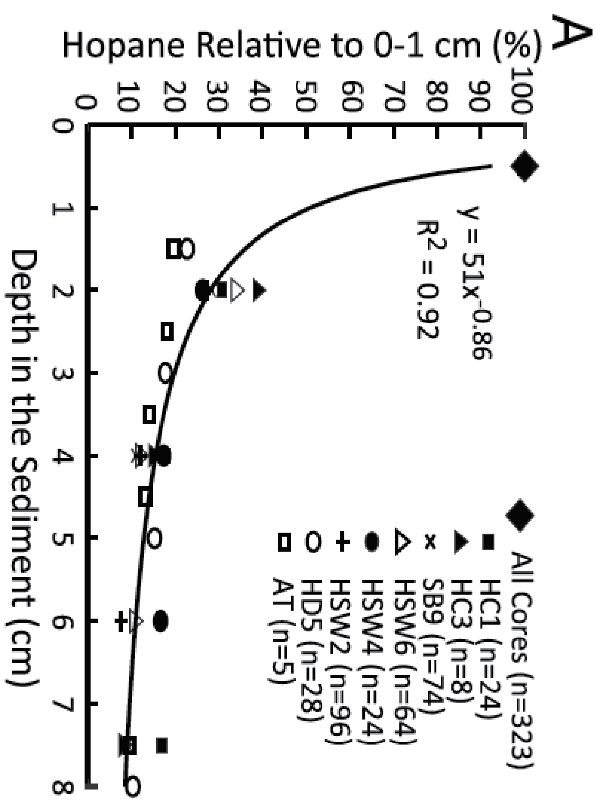


Photo from David Hollander.



Isabel Romero et al, 2015

GULF OF MEXICO RESEARCH INITIATIVE



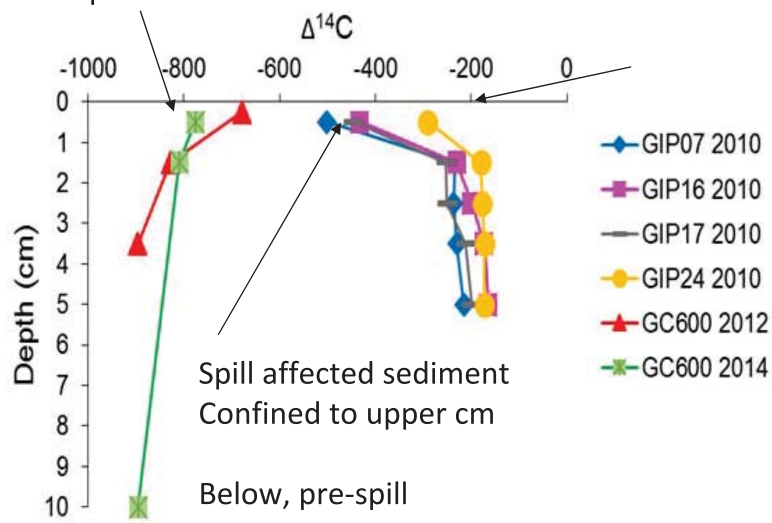
D. Valentine et al., 2014

Again consistent with deposition from above

GULF OF MEXICO RESEARCH INITIATIVE

Fossil Carbon Penetration DwH

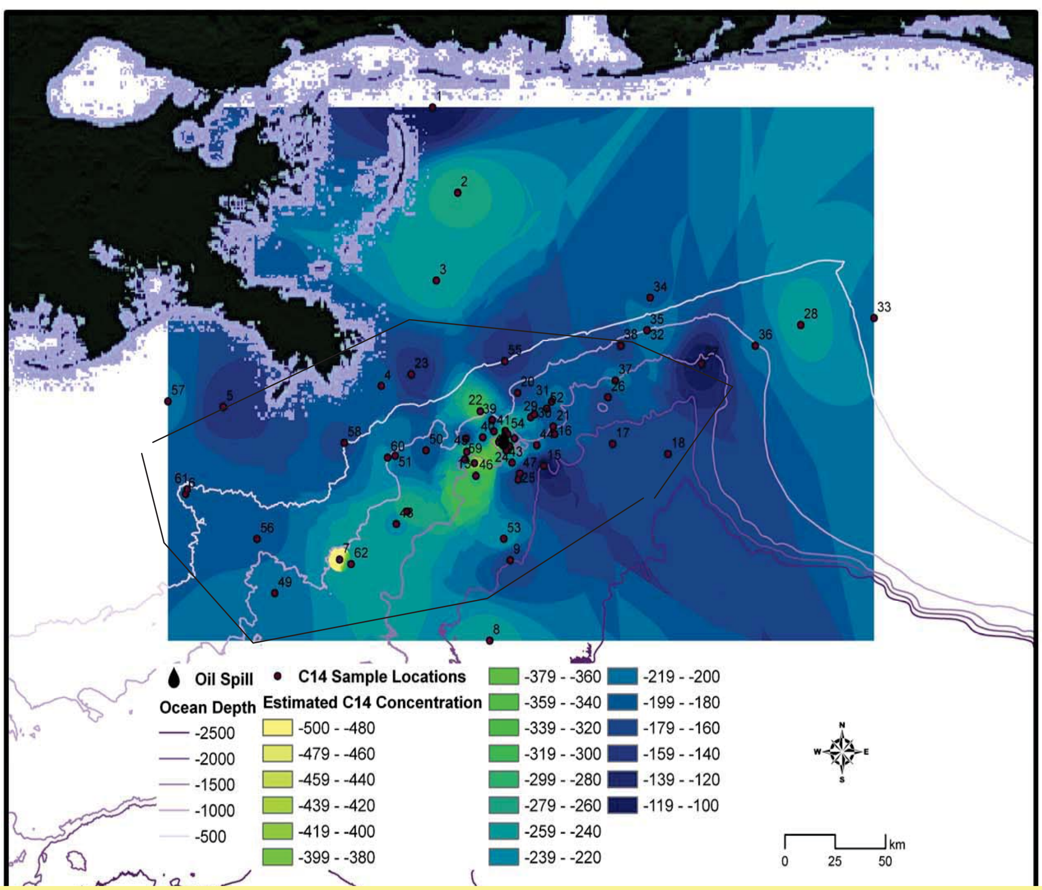
Seep sediment



Spill affected sediment
Confined to upper cm

Below, pre-spill

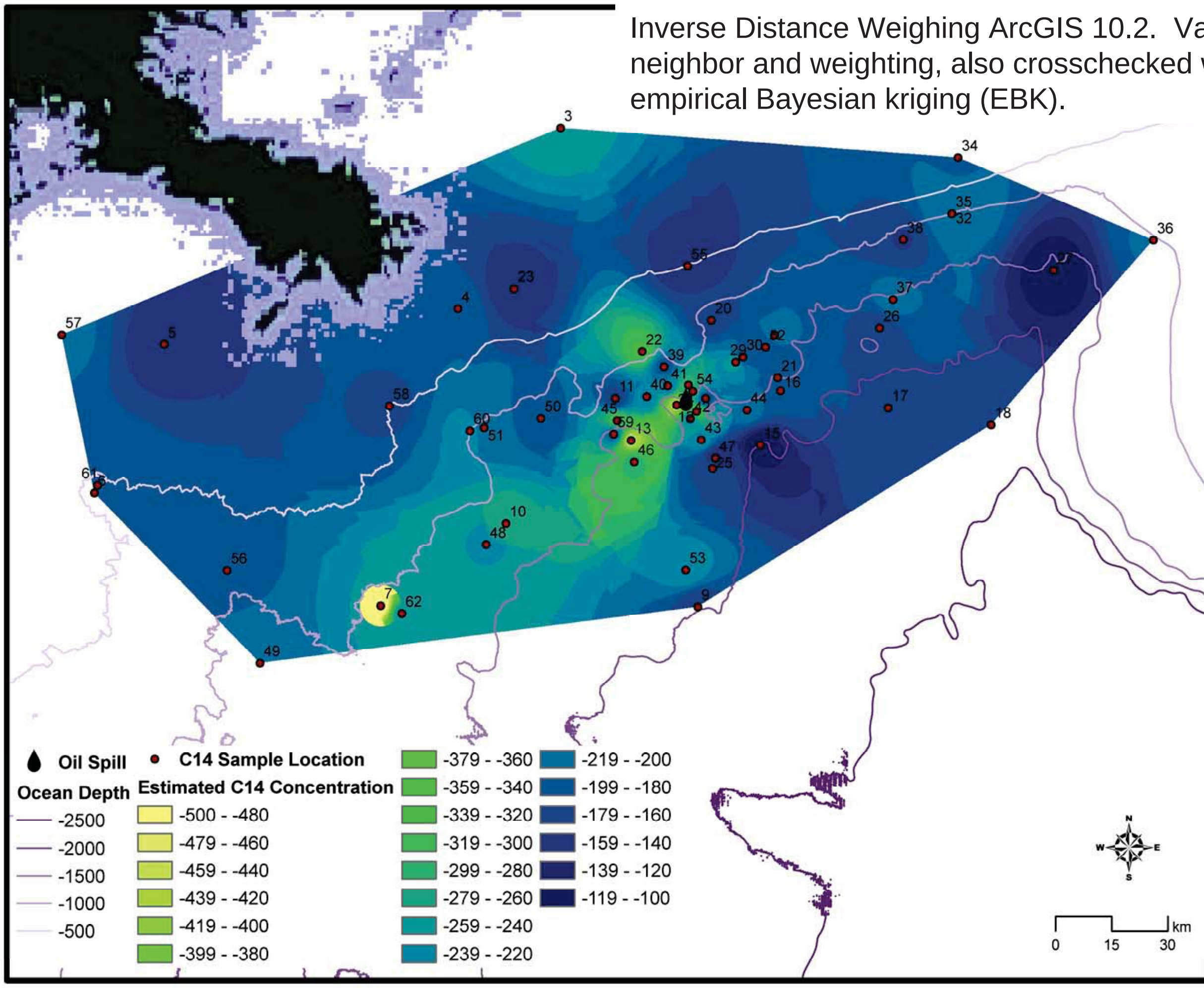
Oil deposition from above



Brighter colors depict more ^{14}C depleted petro-residues, Chanton et al., 2015

Environmental Science and Technology, 49, 847−854 es-2014-046524. doi. 10.1021/es5046524

Inverse Distance Weighing ArcGIS 10.2. Varied neighbor and weighting, also crosschecked with empirical Bayesian kriging (EBK).



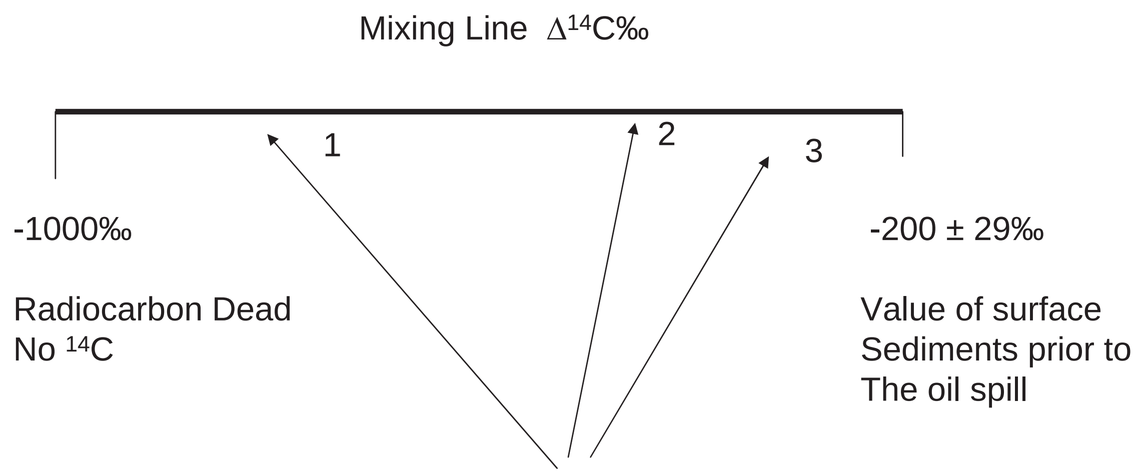
Two endmember model for sediment studies

Mixing Line

-1000‰

-200 ± 29‰

Two endmember model for sediment studies



Position on mixing lines gives % dilution with petrocarbon
1 more than 2, 3.

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Two endmember mixing model

- $\Delta^{14}C$ of -1000‰ for petro-carbon
- Average underlying oiled surface layer, -200‰ (± 29‰)
- Measured value *1 = x (-1000‰) + (1-x) (-200 ± 29‰)
- Give fraction of organic matter that is fossil,
- *% OC, * (1-ϕ) times area of each section, integrate to 1 cm depth….. Gives fossil carbon flux1.6-2.6 x 10^{10} grams oil-derived C
- Divide by amount of oil from spill
- Gives 0.5 to 9.1% of spill oil went to the seafloor.
- Best estimate, 3-5%.
- Valentine et al., 2014→ hopane approach 1.8 to 14.4% of total.

GULF OF MEXICO RESEARCH INITIATIVE

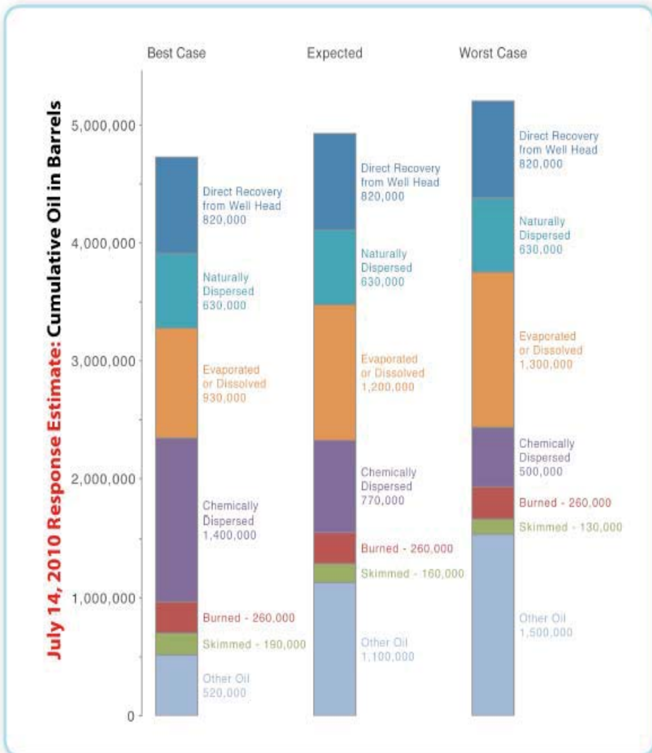


Figure 12: Response estimates produced by the Oil Budget Calculator showing best case, expected, and worst case volumes of the seven different portions that the calculator tracks individually, of the cumulative volume of oil discharged through July 14, 2010. These estimates served solely as a guide for the national response to the Deepwater Horizon MC252 Gulf Incident. The best and worst cases are defined in Appendix 1: they are the combinations of values of the seven variables depicted in each stack that correspond to the lower and upper endpoints of a 95% confidence interval for the volume of "Other Oil".

So what?

MOSSFA not included in 2010 Oil Calculator Oil Reckoning

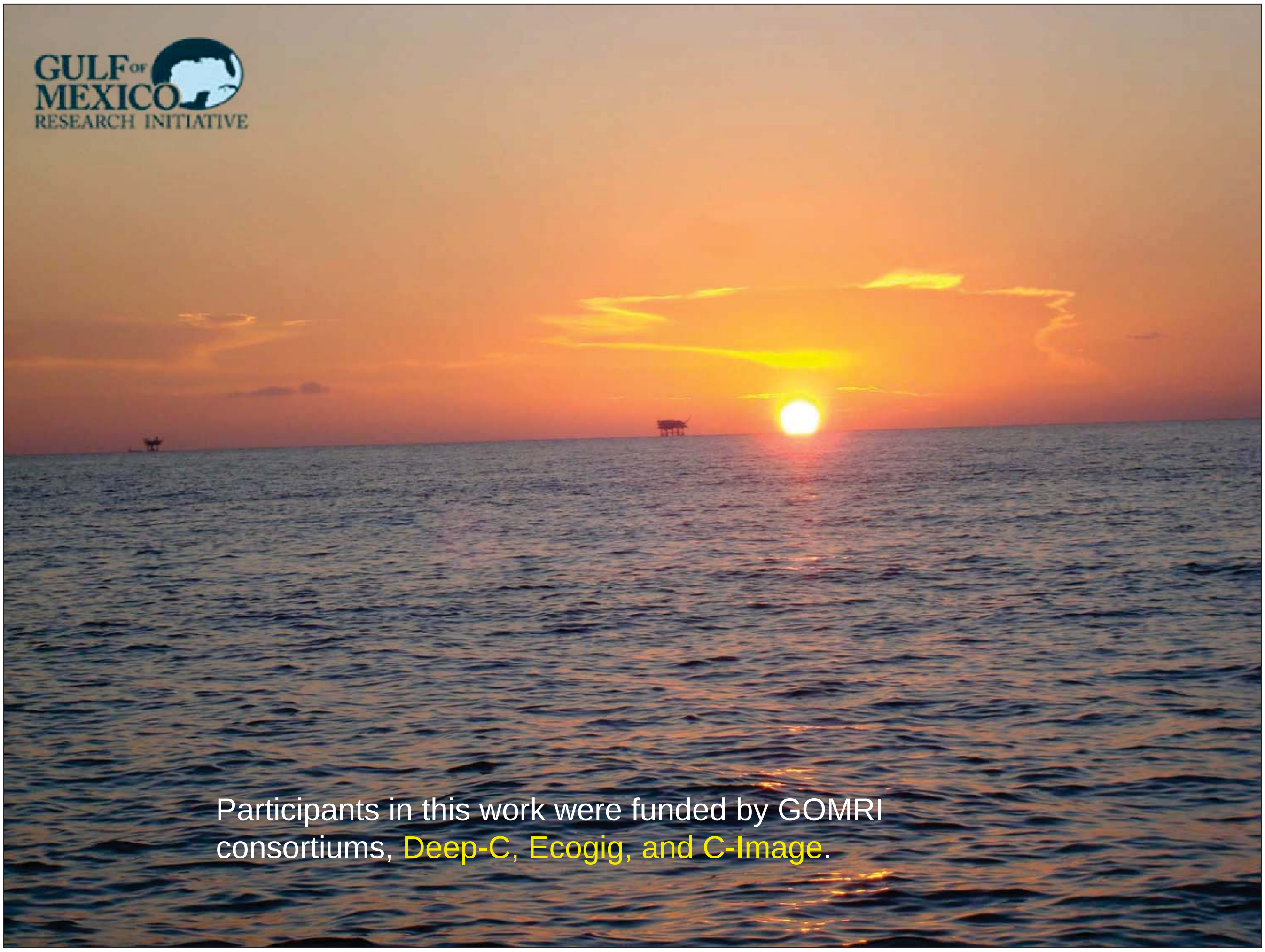
No good model to predict it.

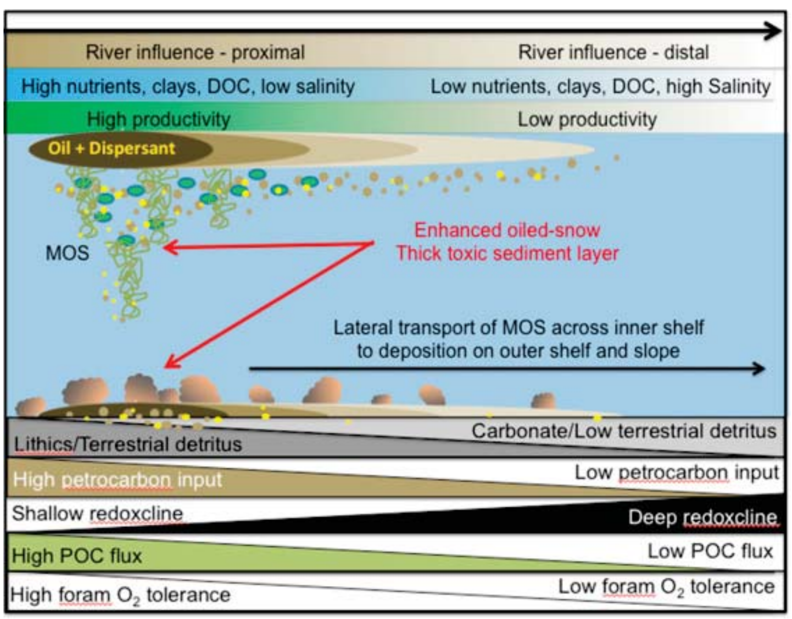
GULF OF MEXICO RESEARCH INITIATIVE

So What cont.

- Petrocarbon breaks down more slowly in sediments due to oxygen limitation
- Sediments may serve as long term storage for hydrocarbons for as yet unknown periods.
- With that storage, there is potential for re-exchange with the water column due to either chemical or physical processes that occur in surface sediments including benthic predation, chemical degradation and infaunal mixing.

GULF OF MEXICO RESEARCH INITIATIVE





GULF OF MEXICO RESEARCH INITIATIVE

Diagram illustrates the environmental gradients of material properties and fluxes associated with a point source of oil released in regions influenced by river outflow compared to offshore regions not influenced by riverine processes. Gradient shifts include the concentration and composition of suspended particles (clays to carbonate), the magnitude of particulate organic carbon (POC) and petrochemical fluxes to the seafloor, the depth of the sediment redoxcline, and the tolerance of benthic organisms, such as foraminifera, to different oxygen levels in sediments. Oil-mineral aggregations (OMAs) may sediment separately or in association with marine oil-snow (MOS). These environmental gradients overlap and interact with gradients generated by oil spills, e.g., oil and dispersant distributions, causing a complex temporal-spatial distribution of interactive effects.

Air quality, oily aerosols

Dr. Ed Buskey, Professor
University of Texas at Austin
Director of the DROPPS Consortium

DROPPS* Consortium: Overarching Research Goals

- Distribution, dispersion and dilution of petroleum under the action of physical and chemical processes
- Chemical evolution and biological degradation of petroleum caused by interaction with marine bacteria and plankton; effects of oil and dispersant on planktonic ood web
- Production of oily aerosols and effects on human health
- Focus on small scale processes; link these to mesoscale with mesocosms and modeling efforts

*DROPPS: Dispersion Research on Oil: Physics and Plankton Studies

Presenting results from Johns Hopkins University

- Not my research or area of expertise!
- Early results of ongoing research
- Focus on physical processes that cause oil to splash into air
- Addition of dispersants create smaller aerosol droplets (sub-micron)
- Future studies on how far these aerosols travel
- Human health effects

On Phenomena Affecting Oil Droplets Generation and Aerosolization:

People who did all the work

David W. Murphy, Cheng Li, Xinzhi Xue, Nima N. A-Mohajer, Kaushik Sampath, Vincent d'Albignac, David Morra ……...

Presentation by

Joseph Katz

Department of Mechanical Engineering

Johns Hopkins University

Supported by

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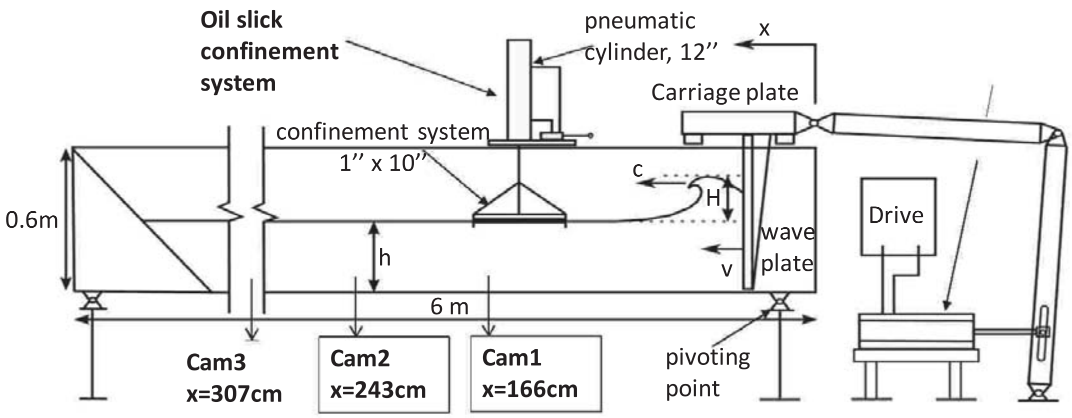
Droplet Generation by Wave Breaking
Tilting (Small) Wave Flume Facility



Wave Tank
- Dimensions: 6 x 0.6 x 0.3 m
- Removable top (safety)

Wave maker
- maximum stroke: 1.3 m
- rms error: <0.9 cm
- wave height: 18.2 cm- 34.5cm
- water depth: 20 - 30 cm
- wave celerity: 1.78-2.41 m/s

Stroke (cm)	Height (m)	V_{max} (m/s)	Wave Speed (m/s)	Frequency (Hz)	Intrusion Depth (m)	Energy dissipation (m^2s^{-3})
53.34	0.29	1.26	2.88	0.75	0.17	~ 0.01
45.72	0.25	1.08	2.27	0.75	0.13	~ 0.007
45.72	0.22	0.90	1.94	0.625	0.07	~ 0.004

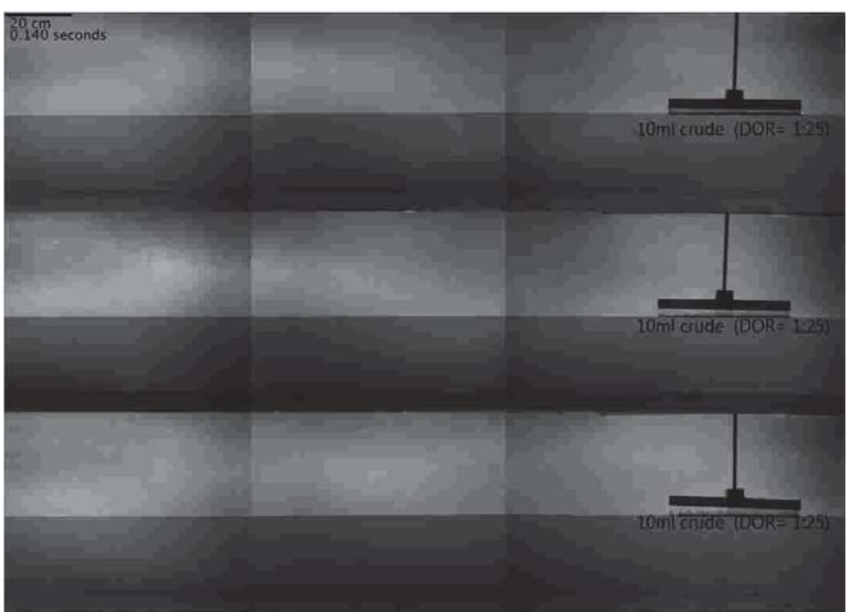
High Speed Video Showing 3 Breaking Waves

- 10ml crude oil confined in 2.54x25.4 cm^2 area introduced at x=150cm
- Oil premixed with Corexit 9500, DOR: 1:25 for 3 case

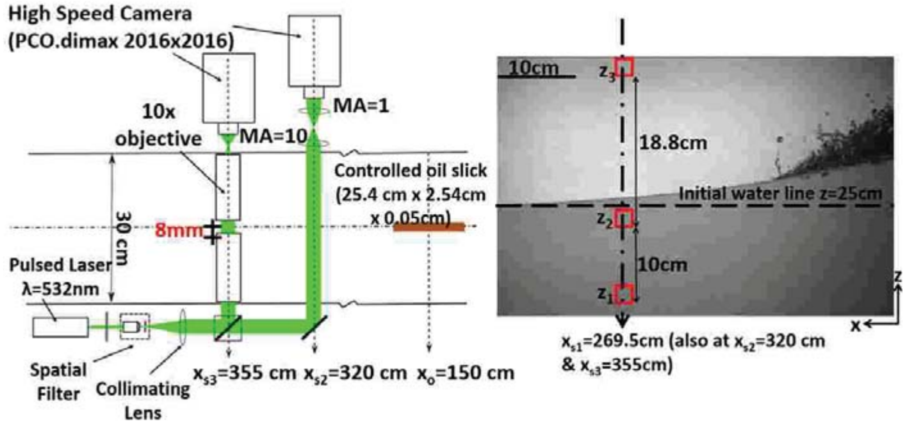
Stroke: 53.34 cm;
Frequency = 0.75 Hz;
h=28.8 cm

Stroke = 45.72 cm;
Frequency = 0.75 Hz:
H=24.9 cm

Stroke = 45.72 cm
Frequency = 0.625 Hz;
H=22.1 cm



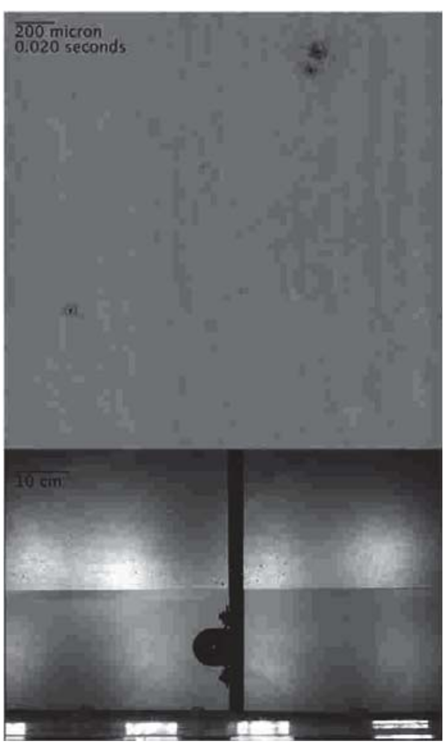
Measuring Droplet Size Distributions



Fluid	Oil Property				Dimensionless Number			# of runs	Multiresolution Sizing		
	Density (kg/m^3)	Viscosity (cSt)	Interfacial Tension (mN/m)	Surface Tension (mN/m)	Oh(50μm-500μm)	We (500μm)	Re		MA=1	MA=10	Fluorence Microscopy
Crude Oil	877	9.4	19	28	0.3-0.1	106.7	114.4	5	√	√	√
Crude Oil DOR 1:500	877	10.1	2.35	22.5	0.9-0.3	862.5	106.4	4	√	√	√
Crude Oil DOR 1:100	877	10.6	1.2	24.7	1.3-0.4	1689.1	101.4	6	√	√	√
Crude Oil DOR 1:25	877	12	0.28	28	3.0-0.9	7239.2	89.6	4	√	√	√
Fish Oil	924.4	63.1	14.9	22.5	2.2-0.7	143.4	17.0	3	√	×	×
Motor Oil	877.6	306.5	19	24.7	9.3-2.9	106.8	3.5	3	√	×	×

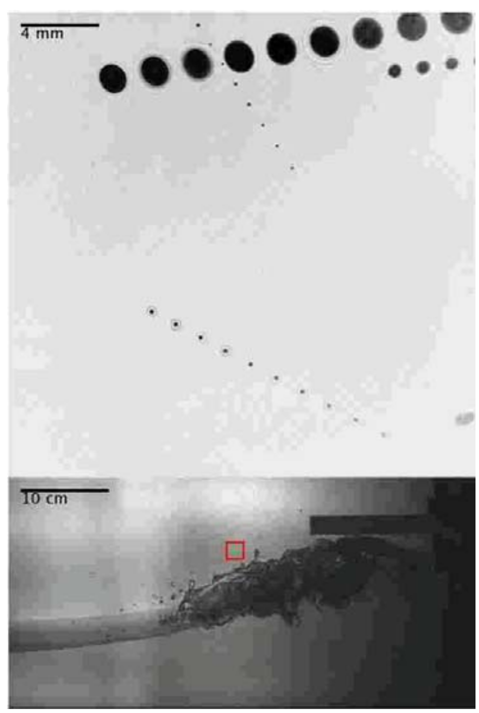
Subsurface Droplets (DOR1:25)

FOV=2.23 mm x 2.23 mm



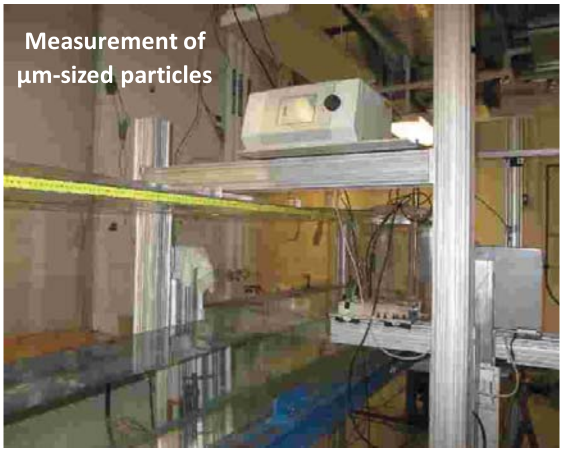
Aerosol droplets (DOR1:25)

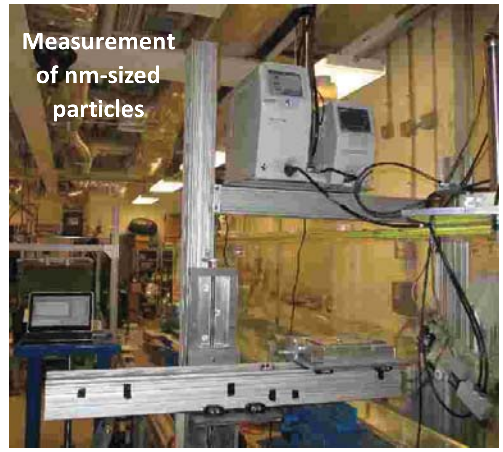
FOV=2.2 cm x 2.2 cm



Wave Tank System

Experimental set-up:



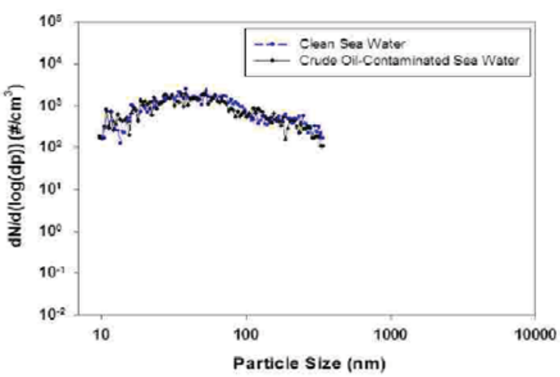


- **Micron-sized and nano-sized aerosolized particles**
  Detection of nano-sized particles in 2 modes: dry and at RH = 80%
- **Total polycyclic aromatic hydrocarbons (PAH)**
- **Total volatile organic compounds (VOC)**

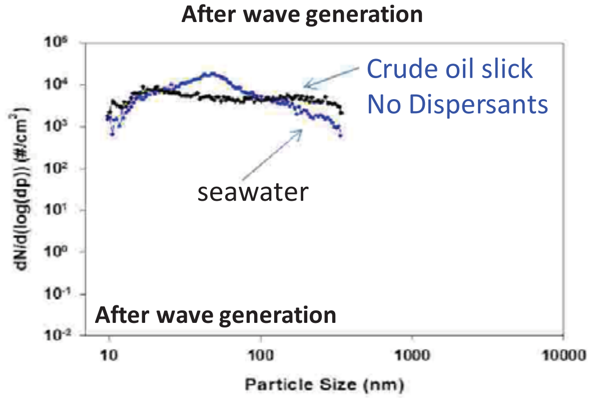
Effect of Dispersants on Nano-scale Aerosol Concentration

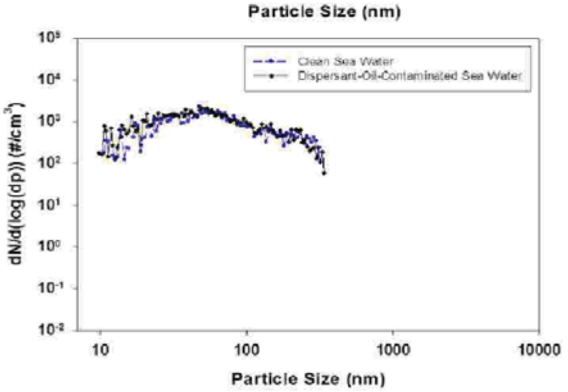
H=45.7 cm (intermediate) Wave

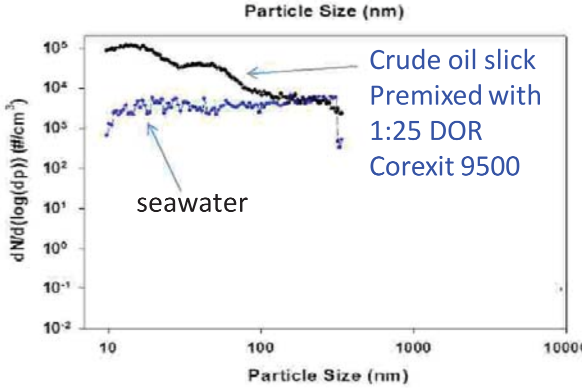
Before wave generation



After wave generation

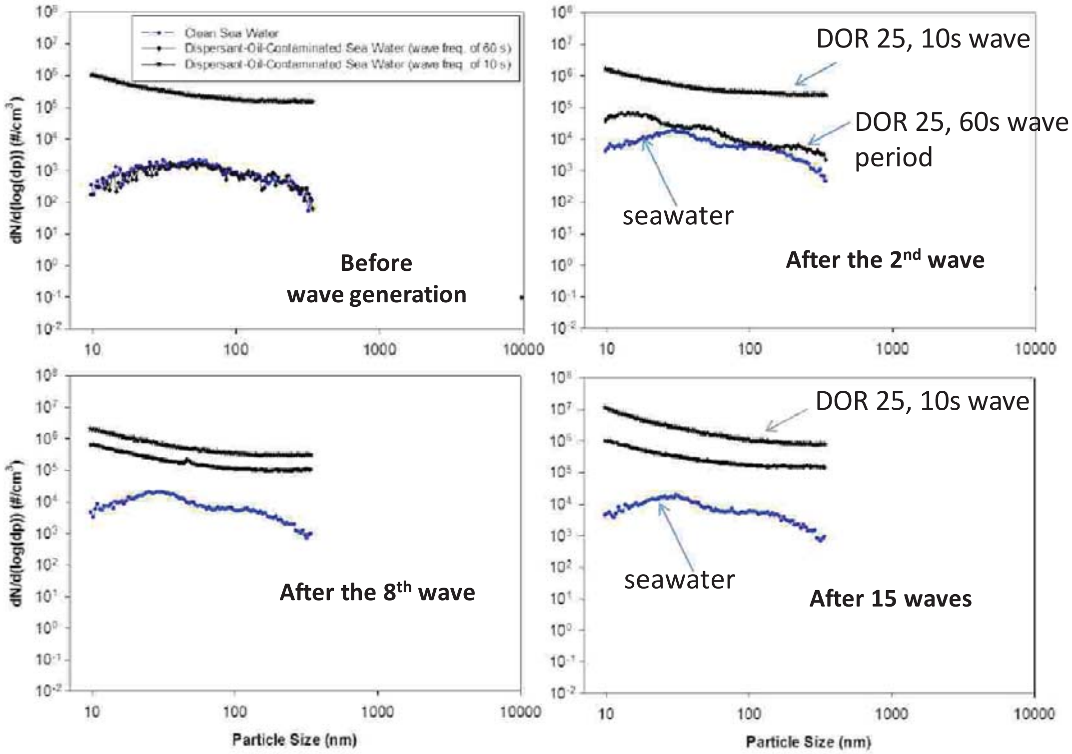




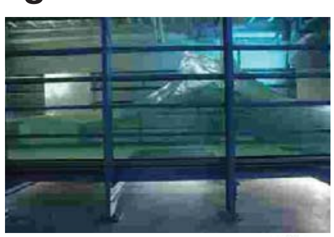


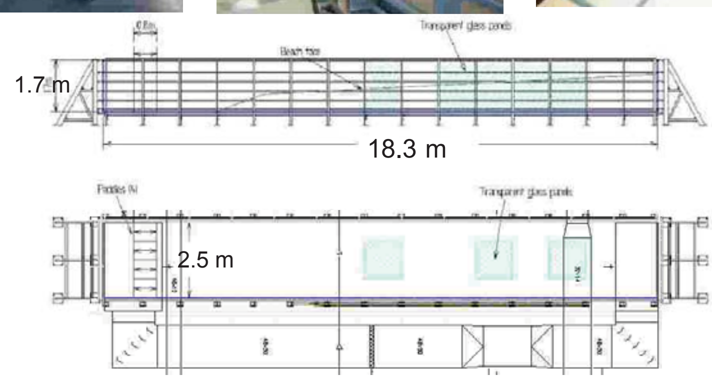
Effect of Dispersants on Nano-scale Aerosol Concentration

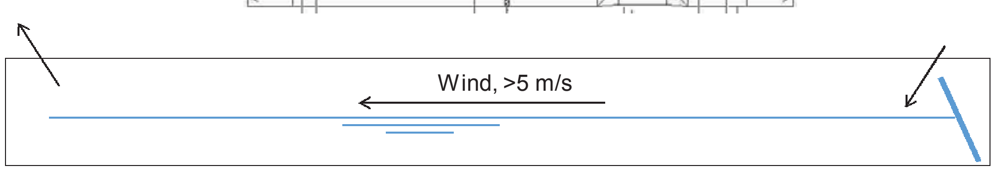
H=53.3 cm (large) Wave



Large Wave Tank – Conversion to a Wind-Wave Facility







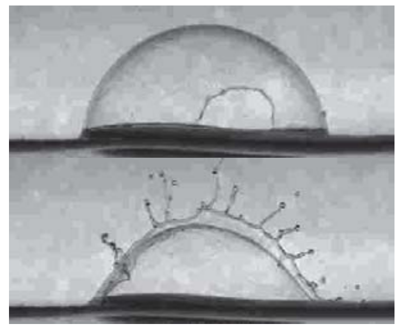
(Rain)drop Impact on a Floating Immiscible Oil Layer: Splash Behavior and Droplet SizeS

Summary of Results presented in Murphy et al., 2015. *J. Fluid Mech.* **780**, 536-577

- Marine Aerosol
  - Raindrop impact causes generation of marine aerosols
  - Marine aerosol production by rainfall has not not previously investigated
  - Might contribute to aerosolization of crude oil slicks

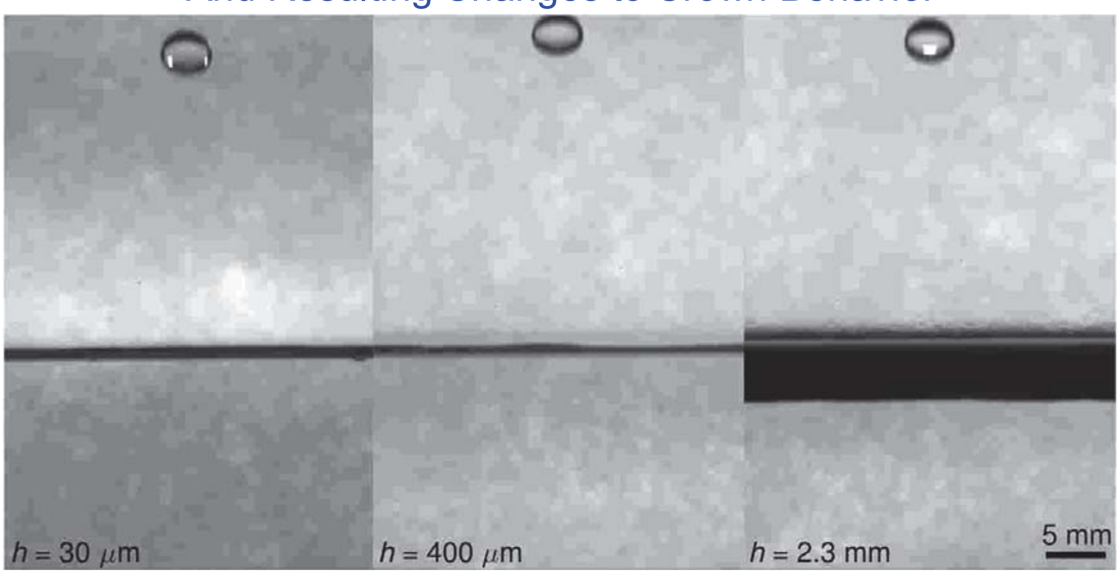
Raindrop Splash (no oil)

- Objective:
  - Investigate the effect of raindrop impact on an oil slick on generation of oily aerosols
  - Determine the effect of oil layer properties (thickness, oil properties) and raindrop scales (size and speed) on the splash behavior and size distributions of aerosolized droplets



Bubble Bursting (no oil)

Classification of Oil Layer Rupture And Resulting Changes to Crown Behavior



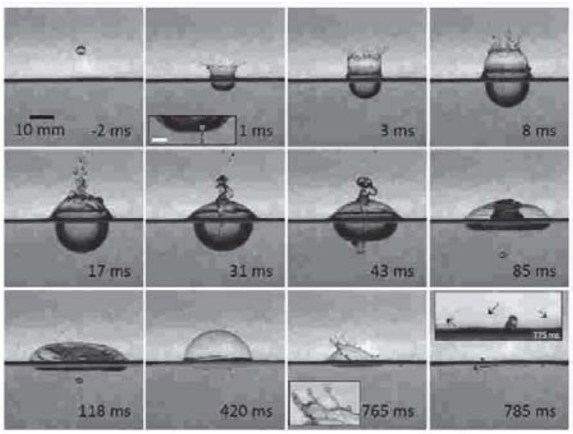
Crude oil layers

u = 7.2 m/s We_d = 2964

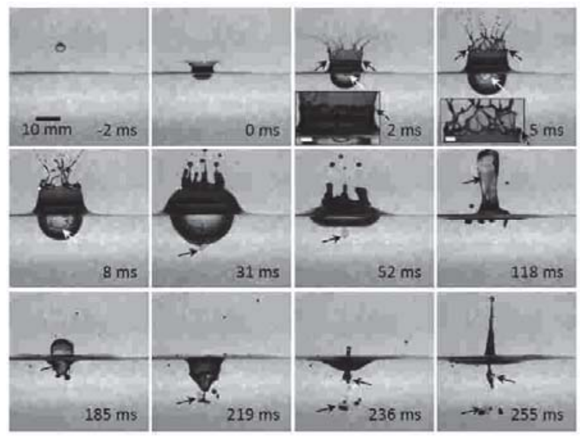
d = 4.1 mm Fr_d = 1288

Classification of Oil Layer Rupture And Resulting Changes to Crown Behavior

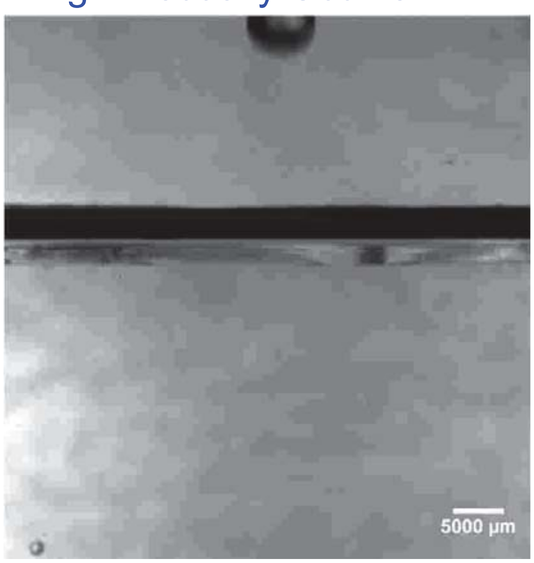
No Oil



500 µm Oil Layer



No Crown Formation for High Viscosity Gear Oil

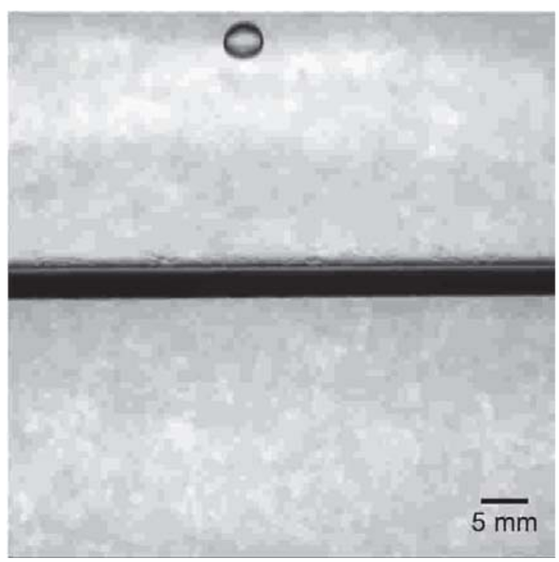


Gear oil layer

h = 600 µm
u = 5.2 m/s
d = 3.8 mm

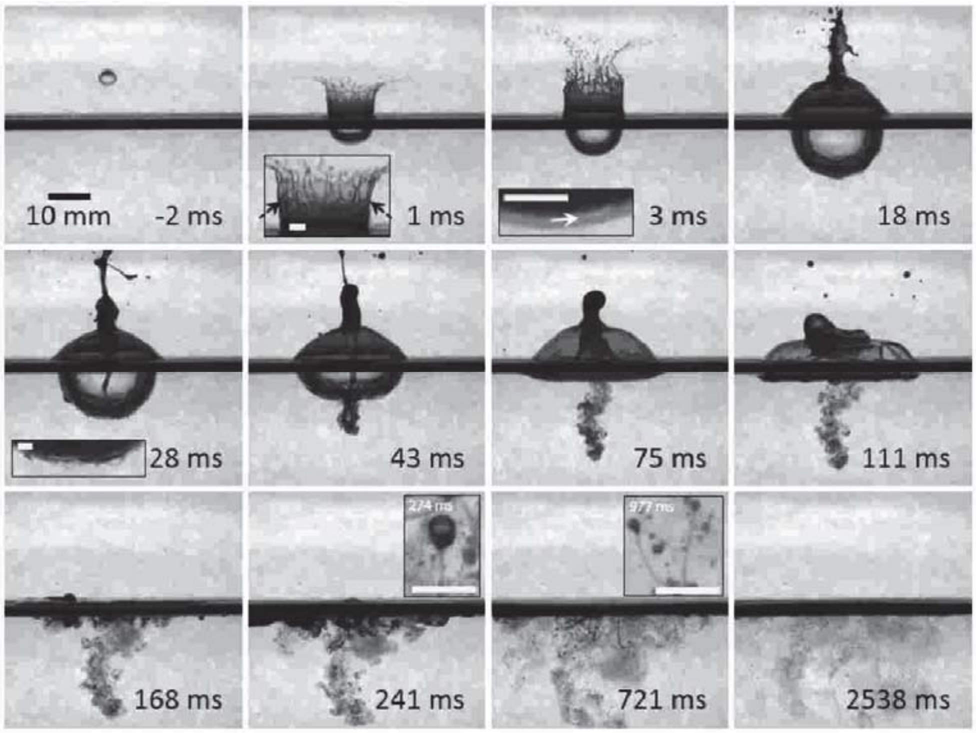
We_d = 1450
Fr_d = 1689

Effect of Dispersants



500 µm crude oil slick premixed with Corexit 9500A dispersant (DOR 1:25)

Effect of Dispersants



Lung epithelial toxicity assessment

Ramana Sidhaye, MD
Assistant Professor
Johns Hopkins University
Division of Pulmonary and Critical Care

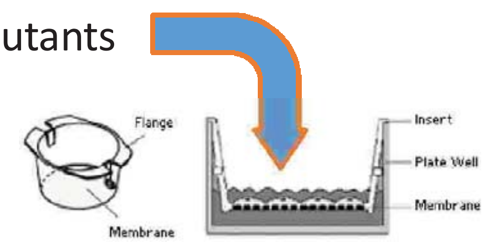
Airway Epithelium

- In addition to the air, we breath in all the various other components in the air
- The airway epithelium is the first line of defense against the respirable environment

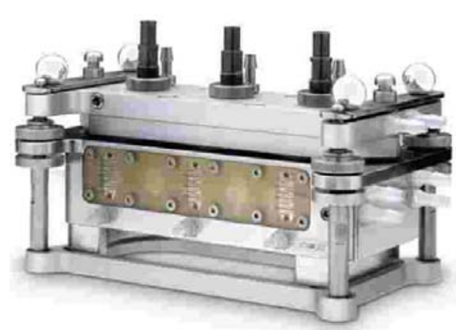
Cellular Toxicity

Simple Method:

Pollutants



Exposure Chamber:



Need to make measurements during an actual oil spill

- Members of DROPPS have been meeting with and attending South Texas Coastal Zone Area Committee meetings
- We are trying to be prepared to either go out with oil spill responders, or have them make measurements for us
- Most interested in measuring aerosol droplets of oil downwind of oil slick
- Also interested in measurements of subsurface oil droplet size with submersible holographic system

Any questions? (remember this isn't my research!)

National Oil and Hazardous Substances Pollution Contingency Plan

Subpart J - Use of Dispersants and Other Chemicals

US EPA - Office of Emergency Management

May 2016

1

Disclaimer

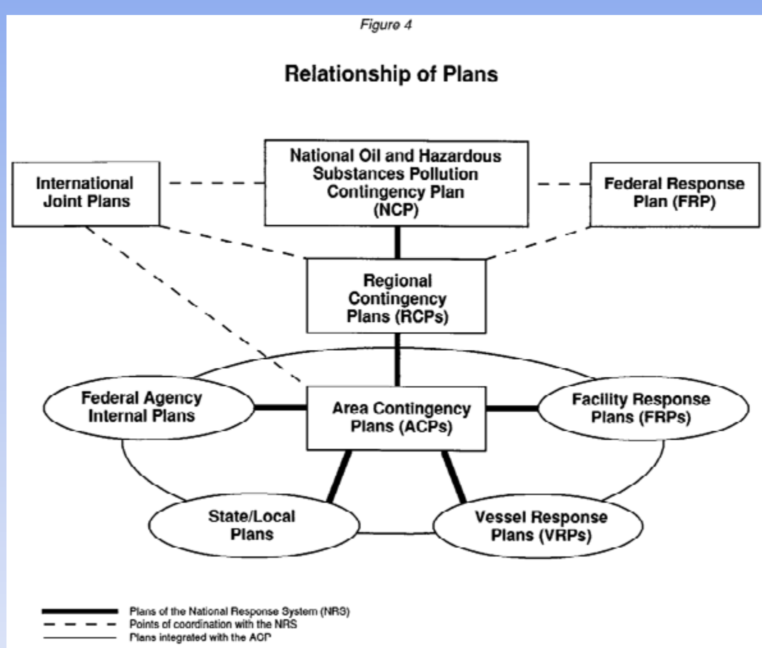
- EPA participation in this workshop should not be interpreted to mean endorsement or agreement with its outcomes or recommendations, nor with specific planning, preparedness and response determinations
- Decisions for the use of dispersants or any other chemical agent are governed by provisions in the Clean Water Act and implemented through the NCP, including Subpart J
- In the event any material presented conflicts with the statute or regulations, the statute or regulations control

2

National Oil and Hazardous Substances Pollution Contingency Plan (NCP)

- Code of Federal Regulations (CFR), Title 40, part 300
- Divided into 11 subparts (Subpart K reserved for federal facilities)
  - Subpart A - Introduction
  - Subpart B – Responsibility and Organization for Response
    - Worker Health and Safety – 40 CFR 300.150
  - Subpart C – Planning and Preparedness
    - Area Contingency Planning (ACP) – 40 CFR 300.210
  - Subpart D – Operational Response Phases for Oil Removal
  - Subpart E – Hazardous Substance Response
  - Subpart F – State Involvement in Hazardous Substance Response
  - Subpart G – Trustees for Natural Resources
  - Subpart H – Participation by Other Persons
  - Subpart I – Administrative Record for Selection of Response Action
  - Subpart J – Use of Dispersants and Other Chemicals
- Covers both oil and hazardous substance removal
  - Certain subparts are tailored to respond to oil removal or to hazardous substance response

3



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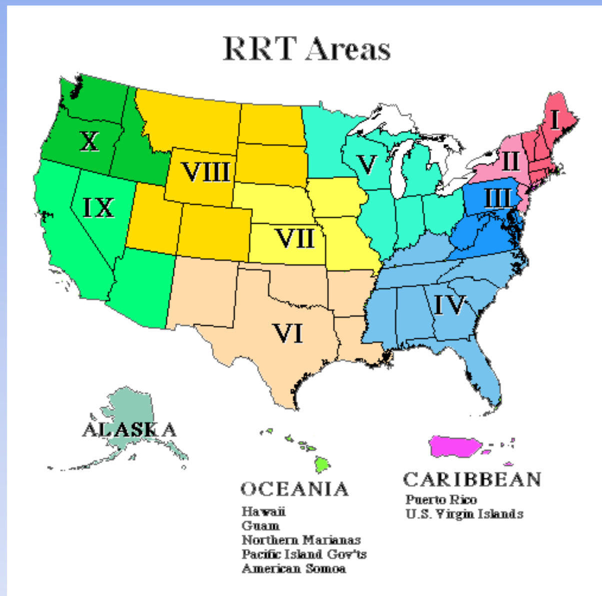


5

Fish and Wildlife and Sensitive Environments Plan (FWSEP)

- All ACPs incorporate detailed annex containing FWSEP
  - Consistent with the RCP and NCP
  - Prepared in consultation with the USFWS and NOAA and other interested natural resource management agencies/parties.
- Among other requirements, the annex is to:
  - identify and establish priorities for fish and wildlife resources and their habitats and other important sensitive areas requiring protection from any direct or indirect effects from discharges,
  - provide a mechanism to be used during a spill response for timely identification of protection priorities of those fish and wildlife resources and habitats and sensitive environmental areas that may be threatened or injured by a discharge, and
  - identify potential environmental effects on fish and wildlife, their habitat, and other sensitive environments resulting from removal actions or countermeasures, including the option of no removal
    - Based on the evaluation of potential environmental effects, the annex should establish priorities for application of countermeasure and removal actions to habitats within the geographic region of the ACP

6

Authority for Subpart J under the Clean Water Act

- 33 USC 1321 (d)(2)(G) – Prepare a schedule, in cooperation with the States, identifying—
  - (i) dispersants, other chemicals, and other spill mitigating devices and substances, if any, that may be used in carrying out the Plan,
  - (ii) the waters in which such dispersants, other chemicals, and other spill mitigating devices and substances may be used, and
  - (iii) the quantities of such dispersant, other chemicals, or other spill mitigating device or substance which can be used safely in such waters,

  which schedule shall provide in the case of any dispersant, chemical, spill mitigating device or substance, or waters not specifically identified in such schedule that the President, or his delegate, may, on a case-by-case basis, identify the dispersants, other chemicals, and other spill mitigating devices and substances which may be used, the waters in which they may be used, and the quantities which can be used safely in such waters

- EO 12777 delegates 33 USC 1321(d)(2)(G) to the EPA Administrator
- Implemented under Subpart J of the NCP

7

NCP Subpart J – Use of Dispersants and Other Chemicals

- Authorization of Use (40 CFR 300.910)
  - RRTs and ACs address the desirability of using appropriate dispersants, other products listed on the NCP Product Schedule, and burning agents
  - RCPs and ACPs shall, as appropriate, include applicable preauthorization plans and address the specific contexts in which such products should and should not be used
  - Pre-authorization plans require approval of:
    - EPA RRT representative
    - States with jurisdiction over the waters of the area to which a preauthorization plan applies and;
    - DOC and DOI natural resource trustees
  - Authorization of use for spill situations that are not addressed by the preauthorization plans requires:
    - Concurrence of the EPA representative to the RRT
    - As appropriate, concurrence of the RRT representatives from the states with jurisdiction over the navigable waters threatened by the release or discharge
    - Consultation with the DOC and DOI natural resource trustees

8

NCP Subpart J – Use of Dispersants and Other Chemicals

- Authorization of Use
  - Exception only to prevent or substantially reduce threat to human life
    - Insufficient time to obtain the needed concurrences/consultations
    - OSC must inform the EPA RRT representative and, as appropriate, the RRT representatives from the affected states and, when practicable, the DOC/DOI natural resources trustees as soon as possible
    - Not intended to circumvent preauthorization or case-by-case use authorizations
      - NCP addresses worker health and safety under 40 CFR 300.150
  - The use of burning agents on a case-by-case basis
    - Concurrence of the EPA RRT representative
    - As appropriate, concurrence of the RRT representatives from the states with jurisdiction over the navigable waters threatened by the release or discharge
    - In consultation with the DOC and DOI natural resource trustees, when practicable
  - Sinking agents not authorized for application to oil discharges

9

NCP Product Schedule Listing

- Includes data and information requirements for dispersants, surface washing agents, surface collecting agents, bioremediation agents, and miscellaneous oil spill control agents (MOSCAs)
- Specific to dispersants
  - Components and percentages (may be claimed CBI)
  - Effectiveness and acute toxicity testing
  - Recommended application procedures, concentrations, and conditions for use depending upon water salinity, water temperature and other application restrictions
- Listing does **NOT** mean that EPA approves, recommends, licenses, certifies, or authorizes the use of the product on an oil discharge
  - Only that product has met **minimum** requirements for listing
- 117 products (April 2016)
- https://www.epa.gov/emergency-response/national-contingency-plan-subpart-j

Subpart J Proposed Rulemaking

- Last major revision in 1994
- Proposed Rule - 80 FR 3380, January 22, 2015
- Public comment period closed on April 22, 2015
- Docket ID No. EPA-HQ-OPA-2006-0090
- Comments posted to the docket are publically available
  - https://www.regulations.gov
- 81,973 total comments including
  - 596 individual entries
  - 6 separate mass mailer campaigns
- Statues updates: http://www.reginfo.gov/public/

11

NET ENVIRONMENTAL BENEFIT ANALYSIS (NEBA)

THE EVOLVING STATE OF THE ART

WHAT IS NEBA?

- A STRUCTURED APPROACH USED BY THE RESPONSE COMMUNITY AND STAKEHOLDERS DURING OIL SPILL PREPAREDNESS PLANNING AND RESPONSE, TO COMPARE THE ENVIRONMENTAL BENEFITS OF POTENTIAL RESPONSE TOOLS AND DEVELOP A RESPONSE STRATEGY THAT WILL REDUCE THE IMPACT OF AN OIL SPILL ON THE ENVIRONMENT. (IPIECA, 2015).

4 STAGES OF THE NEBA PROCESS

- **COMPILE AND EVALUATE DATA** TO IDENTIFY AN EXPOSURE SCENARIO AND POTENTIAL RESPONSE OPTIONS, AND TO UNDERSTAND THE POTENTIAL IMPACTS OF THAT SPILL SCENARIO.
- **PREDICT THE OUTCOMES** FOR THE GIVEN SCENARIO, TO DETERMINE WHICH TECHNIQUES ARE EFFECTIVE AND FEASIBLE.
- **BALANCE TRADE-OFFS** BY WEIGHING A RANGE OF ECOLOGICAL BENEFITS AND DRAWBACKS RESULTING FROM EACH FEASIBLE RESPONSE OPTION.
- **SELECT THE BEST RESPONSE OPTIONS** FOR THE GIVEN SCENARIO, BASED ON WHICH COMBINATION OF TOOLS AND TECHNIQUES WILL MINIMIZE IMPACTS.

NEBA PROCESS CAN BE APPLIED BEFORE OR DURING A SPILL

- PLANNING PHASE – HYPOTHETICAL SCENARIOS.
- RESPONSE PHASE – KNOWN SCENARIO. EXISTING NEBAS MAY BE MODIFIED OR NEBA PROCESS CAN BE USED BY ENVIRONMENTAL UNIT.
- DRILLS – REGION VI HAS UTILIZED “EXPEDITED NEBAS” AS A WAY OF SIMULATING NEBA ACTIVITIES OF AN ENVIRONMENTAL UNIT.

USE OF THE NEBA PROCESS IN THE US

- CONSENSUS ECOLOGICAL RISK ASSESSMENT (CERA) – SIMILAR TO NEBA. TYPICALLY DOES NOT ADDRESS SOCIO-ECONOMIC OR CULTURAL CONSIDERATIONS (AURAND, ET AL., 2000).
- CERA GUIDANCE DEVELOPED BY US COAST GUARD IN 2000.
- SEVERAL CONDUCTED SINCE 1990S. NONE CONTEMPLATED AN UNCONTROLLED SUBSEA OIL RELEASE.

CHALLENGES TO THE USE OF NEBA

- LARGE COMMITMENT OF TIME AND FUNDING FOR VARIED STAKEHOLDERS.
- PERCEIVED BIAS TOWARDS NEAR SHORE ENVIRONMENTAL RESOURCES
- INCREASED RELIANCE ON USE OF WEB-BASED MEETING TOOLS IN PLACE OF PHYSICAL MEETINGS

EVOLVING GUIDELINES

- 2000 - DEVELOPING CONSENSUS ECOLOGICAL RISK ASSESSMENTS: ENVIRONMENTAL PROTECTION IN OIL SPILL RESPONSE PLANNING A GUIDEBOOK. U.S. COAST GUARD. WASHINGTON, D.C.
- 2013 - ASTM STANDARD NUMBER F2532 - 13: *STANDARD GUIDE FOR DETERMINING NET ENVIRONMENTAL BENEFIT OF DISPERSANT USE*. ASTM INTERNATIONAL, WEST CONSHOHOCKEN, PA. WWW.ASTM.ORG
- 2015 - *RESPONSE STRATEGY DEVELOPMENT USING NET ENVIRONMENTAL BENEFIT ANALYSIS (NEBA)*. IPIECA-IOGP GOOD PRACTICE GUIDE SERIES, OIL SPILL RESPONSE JOINT INDUSTRY PROJECT (OSR-JIP).
- TBD – API. RESPONSE STRATEGY DEVELOPMENT USING SPILL IMPACT MITIGATION ASSESSMENT (SIMA) IN THE UNITED STATES
- TBD – API. GUIDANCE ON IMPLEMENTING NEBA (NEBA ENGINE)

EVOLVING PRACTICES

- USE OF NEBA PROCESS DURING RESPONSE ACTIONS BY ENVIRONMENTAL UNIT OF THE NIMS INCIDENT COMMAND SYSTEM (ICS)
- SOCIO-ECONOMIC IMPACTS ADDRESSED BY UNIFIED COMMAND, OUTSIDE OF THE NEBA PROCESS
- INCREASED RELIANCE ON “EXPEDITED NEBAS” OR “ENVIRONMENTAL TRADE OFF ANALYSIS” WITH FEWER STAKEHOLDERS DURING RESPONSE PLAN DEVELOPMENT AND DRILLS.
- COORDINATION WITH RESOURCE TRUSTEE EMERGENCY CONSULTATION PROCESSES

POTENTIAL ACTIVITIES FOR GULF OF MEXICO

- GULF–WIDE NEBA THAT CAN BE ADAPTED FOR INDIVIDUAL USE CASES
- COMPREHENSIVE "RESOURCES AT RISK" (RAR) DOCUMENT(S) THAT CAN BE USED FOR NEBAS, PLAN DEVELOPMENT, AND DRILLS
- DRILL OR INCIDENT SPECIFIC RAR'S TO BE POSTED ON NOAA WEBSITE
- "METHOD NEBA" SPECIFIC TO SUBSEA DISPERSANT INJECTION TO BE CONDUCTED BY API FOLLOWING D3 RESEARCH

POTENTIAL NAME CHANGE

- SPILL IMPACT MITIGATION ASSESSMENT (SIMA)

Appendix F: Breakout Group Members

NOAA's Regional Preparedness Training (NRPT)
Environmental Tradeoff Analysis (ETA) for an Oil Spill Response
Impacting the Flower Garden Banks National Marine Sanctuary

May 25 – 26, 2016
Flower Garden Banks National Marine Sanctuary
Galveston, Texas

BREAKOUT GROUPS

Group A	Group B	Group C	Group D
Downstairs: Conference	**2nd Floor: Library**	**Downstairs: Shelly's Office**	**2nd Floor: Ballroom**
Group Lead: Charlie Henry	**Group Lead: Mike Sams**	**Group Lead: Paige Doelling**	**Group Lead: Mark Miler**
Arden Ahnell	Darice Breeding	Jorge Brenner	Kris Benson
Steve Buschang	Marty Cramer	Victoria Broje	Patrick Cuty
Lisa DiPinto	Steve Gittings	Michael Condon	Andrea Grupe/Zoe Reed*
Mike Drieu	James Hanzalik	Ronnie Crossland	Dan Hahn
Chris Hale*	Whitney Hauer*	Matthew Johnson	Joseph Kuehl
Emma Hickerson	Tony Knap	Aaron Rice	George Pontikos
Joanie Steinhaus	Tim Nedwed	G.P. Schmahl	Roger Prince
John Temperilli	Ellis Pickett	Jim Staves	Melissa Simpson
Brandi Todd	Steve Spencer	Andy Tirpak	Rusty Swafford
		Raven Walker*	Thomas Tregle
			Ann Hayward Walker

*note taker

Appendix G: Breakout Group Template

NOAA's Regional Preparedness Training (NRPT)

Environmental Tradeoff Analysis (ETA) for an Oil Spill Response
Impacting the Flower Garden Banks National Marine Sanctuary

Breakout Group

Wednesday, May 25
2:15 PM Breakout Group Session I

Identify resources at risk

Establish initial response objectives and actions

Current pre-authorization and exclusion zones as they apply to the Flower Garden Banks

Identify NRDA activities occurring during response

Thursday, May 26

9:00 AM Breakout Group Session II

Identify response options				
Identify response tradeoffs for the options				
Identify "external pressures" affecting response decision-making				
Identify the key elements that would drive the decision-making process				

Knowledge gaps

Additional notes

Thursday, May 26

1:15 PM Breakout Group Session III

Determine the response options that are applicable to the spill scenario			
Discuss the tradeoffs that are applicable to the spill scenario			
Capture the key elements that drove the decision-making process			
List key elements not considered in the Session II discussion			

Based on these tradeoffs, recommend to the Federal On Scene Coordinator (FOSC) which response option(s) should be used in the spill scenario

Capture the common key elements that drove the decision-making process

Knowledge gaps

Additional notes

Appendix H: Group A Breakout Session Notes

NOAA's Regional Preparedness Training (NRPT)
Environmental Tradeoff Analysis (ETA) for an Oil Spill Response
Impacting the Flower Garden Banks National Marine Sanctuary

Breakout Group A

Wednesday, May 25
2:15 PM Breakout Group Session I

Identify resources at risk

Habitat types:

- benthic communities- shallow coral reef, mesophotic coral, deep sea corals, soft-bottom; brine seep
- surface layers- Sargassum
- water column-
- Rigs – birds, turtles & butterflies use rigs to feed/rest

Species:

- Mammals – orcas sighted many years ago, sperm whales deeper, atlantic spotted dolphin, bottlenose dolphin, Marine Mammal Protection Act
- Sea turtles – loggerheads, hawksbills (both t/e), potentially leatherbacks in the area
- Fish – reef associated vs. more pelagic species. Wahoo is a seasonal fish highly targeted by rec fishers (aggregate along West & East Banks), lionfish, marbled grouper (rare in the Gulf but utilize FGB)
- Rays & sharks- (hammerhead congregations, rays congregate as well), whale sharks, tiger sharks
- Corals – black coral, elkhorn & staghorn, star coral (4 listed; all are managed/protected)
- Birds – migratory (FGB is a major corridor/flyway for birds)
- Plankton of various spp. – early life stages are to be considered; (coral gametes float though over time they do sink/spread in water column); fish spawn (whale sharks feed off of fish spawn)

15 total species endangered & threatened (on ESL)
23 species of interest

Human use:

- Fishing (commercial and rec)
- Scuba diving
- Oil and gas
- Shipping
- Sailing
- Historical value (really old coral!)

*flyovers for coral spawn events – get baseline measurements

Group A

Establish initial response objectives and actions

- Protection of (1) public/ responders (2)control the source (3) containment & cleanup of oil spill (4) minimize & mitigate environmental impact (5) keep public and stakeholders informed

Actions:

- Coordination with FGB staff, Trustees
- Modelling trajectories – weather & oceanographic models
- Getting spill info – characteristics of oil, where is the spill, where it's coming from, etc. & specifics of event (assessing the incident)
- Identifying the RP
- Notifications – required by law; based on RP or source of spill; phone tree is initiated
- Set up Incident Command – event based decision on location of Command Post (RP vs. Mystery source)
- Establish an envi. Data management plan for collection & storage

Current pre-authorization and exclusion zones as they apply to the Flower Garden Banks

- RRT: surface dispersant use or in situ burning in the GOM (NOT for subsurface use); exclusion zone around FGB (FGB has say on use of in situ burning since they are "owners")
- DOI resources? USFWS covers Birds, sea turtles only when nesting

Identify NRDA activities occurring during response

- NRDA & NOAA DRC are alerted at the same time – coordinated response
- NRDA wants to document ephemeral info – time is of importance
- Scale is an issue; smaller scales are more manageable when it comes to coordination
- Samples sometimes have to be split between response agencies
- NRDA starts looking for experts on resources (species, habitats etc.) – what data exists and/or what data do we need; what methods are used to survey resources
- Operational data – NRDA relies on their contractors (because response personnel are busy!) to get operational details
- RP goes out on site with NRDA
- NRDA coordinates with Trustees, needs a cooperative agreement with RP, and has to go to NPFC

Group A

Thursday, May 26
9:00 AM Breakout Group Session II

Identify response options	Mechanical removal – skimming, booming, suction	In situ burn	Surface dispersant	Subsurface dispersant	No response
Identify response tradeoffs for the options	• +No additional chemicals being added • +a fraction of the oil is removed from the env. • -time (it's a slow process); time to mobilize also takes more time • low encounter rate (you don't treat as much as the oil vs. other methods) • skimming is limited by sea state conditions • response fleet size (# available skimmers) is a limitation if the spill is very large	• +removes large fraction of oil from surface • +removes oil faster than skimming • -must be done early in the process (emulsification) • -Requires mechanical collection (herding) to burn the oil • -Requires specialized boom • -availability of equipment • -Burn residue sinks (impacts natural resources) • -adverse effect on air quality	• +speed of deployment • +high encounter rate • +effective • Weather dependent • Limited by sea state (it won't be as effective if there are very calm seas) • Limited by assets • Toxicity • Moving the oil deeper which could/will impact natural resources in Mixed Layer…but salvaging surface organisms/resources • Potentially increases	• At this time it is a secondary response option based on source location	• +Might be appropriate for very light oils • +Less physical encounters with natural resources • Increases risk of oil coming to shore • Increases risk of encounter to surface natural resources • Persistence in the environment

	• surface-dependent resources such as turtles, mammals, sargassum habitats etc. are at risk from vessel encounters & related response activities	• containment is limited by sea state • -natural resources (mammals, birds, turtles etc.) adversely impacted	aerosol & droplet formation • Limitation – required to adhere to monitoring plans (TIER 1, TIER 2 or other)		
Identify "external pressures" affecting response decision-making	• Public perception that mechanical removal is the preference • public & political: time/getting the oil removed as fast as possible • other response options coming from public can interfere with response decision making	• Public concern if it's nearshore • Exemptions/exclusion zones • Cannot have a sensitive population down-wind (humans, corals [residue], anything…)	• RRT or pre-approval needed • Public perception that dispersants are extremely toxic to health (humans and marine resources) • Political: time getting the oil removed as fast as possible	•	• Public pressure to DO SOMETHING! • Political
Identify the key elements	• Weather • Availability of assets	• Weather • Availability of assets	• Weather • Availability of assets	•	• Weather • Availability of assets

that would drive the decision-making process	• Size & nature of spill • Type of oil/nature of oil • Time of year/ seasonality • Location • Oceanographic conditions • Biological priorities (e.g. spawning events) • Trajectory	• Size & nature of spill • Type of oil/nature of oil • Time of year/ seasonality • Location • Oceanographic conditions • Biological priorities (e.g. spawning events) • Trajectory	• Size & nature of spill • Type of oil/nature of oil • Time of year/ seasonality • Location • Oceanographic conditions • Biological priorities (e.g. spawning events) • Trajectory		• Size & nature of spill • Type of oil/nature of oil • Time of year/ seasonality • Location • Oceanographic conditions • Biological priorities (e.g. spawning events) • Trajectory

Knowledge gaps

- Hydrate zones – what is the effect of response options on hydrate zones? No empirical data.
- There is an evolving science related to use of subsurface disp. in the deep, deep sea.
- What is the safest vs. least safe response option for responders?
- How much residue from in situ burning actually sinks?
- Aerosols from surface dispersants – what is the real impact?
- Effect of dispersant on marine snow formation?
- Baseline information/data needed for FGBNMS resources.
- At what depth does sub-surface dispersant become successful vs. not?

Additional notes

- Emergency responders hope for in subsurface dispersant use: 80% effectiveness (reduction in oil reaching the surface)
- Mechanical removal is the least efficient method of removing oil from the open water env. (experience supports that)
- For all response options: offers for assistance and solutions from public actually impedes response
- ADCPs & knowledge of the various currents related to the Banks is crucial for decision making
- Dispersant + oil = sinking Sargassum

Group A

Thursday, May 26

1:15 PM Breakout Group Session III

Determine the response options that are applicable to the spill scenario	**No Response is not an option based on the trajectory and landfall**	**Mechanical recovery**	**Surface dispersant off the shelf**	**Surface dispersant after slick passes the Banks (morning application)**
Discuss the tradeoffs that are applicable to the spill scenario	•	• 5-6 hour minimal transit time (using CGA boats) • Get on scene 10 or 11 pm • Much more risk to responders – night operations	• 2-3 hour transit time • Natural dispersal vs. dispersed oil • Turtle vs. coral • Concern for air-breathers (turtles and mammals) vs. value of centuries old coral • Colonial bird nesting (rookery islands and on beach) • Kemp's Ridley turtle nesting season	•
Capture the key elements that drove the decision-making process	•	• Very low success rate of mass spawners (fish & coral) so prioritize older/mature wildlife (turtles,	• Plane access (2 planes) for aerial dispersal • Very low success rate of mass spawners (fish & coral) so	•

		mammals, air-breathers) • Surface-feeding animals need to be considered (manta rays, whale sharks) • Evaporation by the time it hits the Banks	prioritize older/mature wildlife (turtles, mammals, air-breathers) • Surface-feeding animals need to be considered (manta rays, whale sharks) • Evaporation by the time it hits the Banks • Surface currents • Concentration of dispersants used • Mixing zone – temperature layer marks the mixing layer (do we have proper instrumentation in place to confirm mixing layer?) • Uncertainty re: coral impact	
List key elements not considered in the Session II discussion	•	• Pre-determined response rescue team specifically for spotting and capturing turtles (& perhaps mammals) need to be On-Call	• In real life scenario, we would not advocate the use of dispersant until it had passed over the	•

		• Lights	Banks, but it this case the currents are in our favor	

Based on these tradeoffs, recommend to the Federal On Scene Coordinator (FOSC) which response option(s) should be used in the spill scenario

Minimal Regret

1. Mechanical recovery of oil at night; mobilize megafauna rescue operations
2. Once the slick has passed the FGB, aerial and boat dispersant surface application (this happens next morning);
3. Continue mechanical recovery and on-water assets to treat remaining fraction of oil

Capture the common key elements that drove the decision-making process

- Value of coral vs. value of turtles – what is the ultimate cost of impact to either? Can a reef be replaced or restored? Can a turtle population be restored?
- Value of charismatic megafauna?
- Safety restriction zones are activated – fishing area closures

Knowledge gaps

- What is the dispersant concentration that causes negative impact to coral species? Duration vs. concentration
- We need better identification of mixing layer data (temp etc.) in and around the Banks (only 2 buoys currently within the Banks)
- Micro-movements of water around the Banks – water movement responds to the bathymetry. More data needed.

Additional notes

- We need teams of trained, pre-approved scientists that can deploy monitoring equipment on a moment's notice – they need to get on scene to capture measurements that response personnel are too busy to capture
- Key take home from this drill - emergency responders tend to take aggressive action early on, BUT after consultation with the experts (in this case FGBNMS staff & scientists) the response decisions were altered based on local knowledge.
- We recognize that early dispersant deployment could result in a west-ward drift that could impact the West FGB

Appendix I: Group B Breakout Session Notes

NOAA's Regional Preparedness Training (NRPT)
Environmental Tradeoff Analysis (ETA) for an Oil Spill Response
Impacting the Flower Garden Banks National Marine Sanctuary

Breakout Group B

Wednesday, May 25
2:15 PM Breakout Group Session I

Identify resources at risk

- Seabirds and whales are not in the area
- Air: Seabirds (migration pattern is not in the Banks, but they could be attracted if they think it's land with spill)
- Sea surface:
  - Sargassum communities– 120+ species
  - Fish eggs (not a research priority for FGB) and larvae (coral is important)
  - Dolphins, sea turtles, whale sharks
- Water column
  - Jelly fish
  - Rays – Eagle and mobula
  - Fish eggs and larvae
  - Dolphins, sea turtles, whale sharks
  - Hammerhead sharks
  - Manta rays
  - Fish
- Benthic:

  Coral reefs 20-50 m
  - 20+ species corals hard corals
  - Sponges
  - Associated invertebrates
  - Algae communities
  - (no shipwrecks)

  Deep corals: 50-70+ meters
  - Coraline algae
  - Sponges
  - (as you go to further depths, lesser concentrations of communities, there are deep fish, anthiids are important group of fish)
- Ecosystem services: tourism, diving, commercial and recreational fishing
- Cultural resources: are none

Group B

Establish initial response objectives and actions

Response objective: minimize impact to RARs
Prioritize RARs:
- Protect the habitat (coral): loss to coral is a very long term impact
- Avoid surface contact to those organisms that need air contact

ID Response Actions:
- Trajectory/model -
    - in-water measurement, buoys (2, 30 miles apart, currents are not correlated), gliders (not as effective)
- Mobilize response resources to mitigate effects of oil spill
    - Start as far away from FGB as possible
- Surveillance (aerials)
- Monitor
- Analyze oil type and properties, oil weather, take oil sample

Initiate notification

Current pre-authorization and exclusion zones as they apply to the Flower Garden Banks

- FGB is a pre-auth for disp, but consultation should take place with the superintendent
    - Effort should be made for applying disp as far away as possible
    - FGBNMS requests notification, can be used for consultation for RARs
- In-situ burn is excluded

Identify NRDA activities occurring during response

- Water sampling
- Air sampling
- Passive sampling
- Document of the FGB, have a good baseline already but still document the corals
- Sediment samples
- Biota sampling
- Survey recreational activities
- Wildlife observations
- Source oil samples

Other thoughts:
- Environmental sensitivity index for FGB, include vulnerability
    - Include in ERMA, make available shape file for other GIS platforms
- Want a geographic response plan for the Houston/Galveston and other ACP

Group B

Thursday, May 26
9:00 AM Breakout Group Session II

Identify response options	**No Action**	**Mechanical Recovery: containment and recovery**	**In-situ Burn**	**Surface Dispersant**	**Subsea Dispersant**
Identify response tradeoffs for the options	- more certainty that benthic organisms would not be exposed -allowing oil to weather, emulsify, breakup and more difficult to treat later - may hit shoreline - risk to human health, wildlife on surface, risking to shipping, boating, recreational/commercial impacts -disturb the shipping fairway - responder risk reduced	- takes longer to get out, 5-6 h (24 knots) - removing oil from the environment - deal with the waste - not as efficient offshore (<10% roughly) - weather dependent - logistics and responder safety and exposure risk - a lot more equipment – risk of ship strike, increased air pollution, etc.	- the residue that sinks will smother the benthos, the subsurface trajectory would be important but difficult to predict, further off shore, the residue would breakup as it sinks - in-situ burn offshore is unlikely - transfer to the atmosphere, air quality, smoke - remove up to 90% captured oil - herding agents (not stock piled), no boat, would take 12 h, may work at higher seas - fire boom w/ boat, 10-12 h from dock to location (12 knots)	- 1.5 h to get out by flight - dispersed oil in water column is better that oil slick on surface -organisms that come to the surface, density of organisms greater than elsewhere (turtles not dolphins) v organisms in the water column above 10 m (mantas, eagle rays, whale sharks, plankton, fish species) - fish eggs/larvae at surface v adult species in water column -oil slick will stay on the surface and continue to have soluble components (1 ppb) will continue to be in the water column without the dispersant - Acute exposure would be greater with dispersant for a shorter period of time with dispersant but sub lethal concentration might be greater with an oil slick for a longer period of time - reduce risk to responder and the public	- dispersed oil in water column is better that oil slick on surface - applicable for subsea, well control (not vessel, pipeline) - Higher exposure to water column and benthos than surface - safer for responders - efficient dispersant because applied to fresh oil - 3 days to get out - Requirements for monitoring is more complex, harder to monitor the subsurface - Can use less dispersant (100:1) rather than surface (20:1) - likely to sacrifice deep habitat organisms, near field - 24 h operation
Identify "external pressures" affecting response decision-making	(for spill of significance) -public would not be happy -organizationally, fed and state would have political pressure	- preferred option - pressures to maintain on scene presence despite limited vessel capability	- concern that residue mass will sink and smother benthos - perception that the smoke will impact wildlife	(if used over the bank) -perceived damage of dispersant (getting overspray to charismatic megafauna)	- public perception is negative - politicians making the most of disaster to further their agenda

	- media would also be unhappy		and/or humans	-would need to search for damage and deal with claims -turtles: if there are turtles are present, automatic no application of dispersant, however the oil slick may be more damaging	- perception that there is less known about fate and impact
Identify the key elements that would drive the decision-making process	- size of spill - type of oil - spill trajectory - weather, sea-state, cloud cover - time of spill	- time on scene - size of spill - type of oil - spill trajectory - weather, sea-state, cloud cover - time of spill - location - likelihood of using alternative response options	- Need to have confidence that any residue that may sink would be far away from FGBNMS	-the timing on spawning, timing of species presence (probability of losing a year class of coral does not have long term implications)	- safety of responded, reduce VOCs at the surface - depth of well head (400 ft is too shallow bc of gas coming out of well) - proximity to shore - size of spill - type of oil - spill trajectory - weather is less of a driver - time of spill

Knowledge gaps

- The effect of disp and disp oil (DDO) on adult species at low levels (e.g., whale sharks), likely will never know this, this is not a driver for decision-making.
- The trajectory of a sinking residue after in-situ burn

Additional notes

- Bioremediation was discussed but not considered for the table
- Water column will have sub lethal concentration (1 ppb) even without the use of dispersant
- Explore feasibility of herding agents. Limited stock pile in GOM. Herding is only used for in-situ, doesn't last long enough for mechanical recovery
- Significant increase in capability since Macando and the ability to skim at night
- there is a near field impact to benthos around the area where subsea dispersant were applied (may be from additional factors than just the dispersant, sediment loaded flocculent material, the mud coming out from the well)

Thursday, May 26

1:15 PM Breakout Group Session III

Sunset: 20h11

FOSC would consult with NMS superintendent

Determine the response options that are applicable to the spill scenario	Aerial surface dispersants until 1830 h leaving the airport today, trial test to see if dispersible, if dispersible, keep dispersing - mobilize right now from Houma - person on craft to do Tier 1 monitoring from NOAA, USCG - comms on plane can communicable on shore	Mechanical recovery leaving bw 14-1500 h. Thurs night and Fri day is the time window to skim. Breaking waves on Sat - OSRP vessel to skim, w/ X-Band and IR - Get other 2 95s would be there Fri AM to skim - Vessel of opportunity skimming - Reduced skimming at night - 10-15% recovery possible
Discuss the tradeoffs that are applicable to the spill scenario	- Dispersant and disp oil would be in the upper mixing layer. The reef is 20 m deep but you have 10-12 mi away from reef when disp was applied. - Oil is not on surface: marine mammals, turtles, birds - Responder safety - Socio-economic, bird sanctuary, of gulf coast is at less risk - weather more suitable for disp over mechanical recovery Or, wait 1 day - No plume through FGBNMS but slick passes over may hit turtles	- Skim less as weather gets worse. -
Capture the key elements that drove the decision-making process	- mitigate exposure to RAR -Need a competent Tier 1 observer - NMS manager is OK with dispersant before slick hits FBG v wait until after the slick passes and then apply dispersant -4 h more time delay before getting mechanical to arrive on scene -Encounter rate is much better -weather is optimal for dispersant use	- weather is driver
List key elements not considered in the Session II discussion	- Respect policy to use dispersant as far away from NMS as possible - Ability to get competent Tier 1 observer	

Group B

Based on these tradeoffs, recommend to the Federal On Scene Coordinator (FOSC) which response option(s) should be used in the spill scenario

Send out mechanical recovery and dispersant out ASAP
If NMS manager is OK

- Trial disp run
- If dispersible, dispersant as much as possible on Day 1
- Skim overnight
- If needed, apply dispersant on Day 2
- Anything passes by, mechanically recover
- If not dispersible, mechanically recover

If NMS is not OK

- Trial disp run
- If dispersible, deploy mechanical recovery on Day 1
- Skim overnight
- Wait until slick passes NMS before adding dispersant on Day 2 and Day 3
- Continue mechanical recovery to catch oil moving towards shore
- Bring in more shoreline protection and recovery resources e.g., booming sensitive areas, near-shore skimming assets by Day 4

Capture the common key elements that drove the decision-making process

- Reduce risk to FGB sanctuary resources surface dwelling organisms (turtles, marine mammals)
- Threat to shoreline and tourist

Knowledge gaps

Additional notes

-The current scenario is real life is much more complicated but for this drill it is simplified
- Assumed started weathering at 7 AM
- Bc no RP, don't have to go through options
- in-situ burn is excluded bc the remaining residue may sink
- Beach can be cleaned pretty easily
- Longer you wait, emulsify more, heavier to pick up
- Bc no RP, there isn't oil company skepticism on response option, or liability if dispersed and plume goes through FGBNMS and 1 ppb would cause impact. NRDA is a concern for deep pockets
- Shake test on boat for dispersant efficiency
- USCG needs to understand the hiring process for non-BOA contract
- If there is a trial run, what is the lag time from the Tier 1 observer communicating with the FOSC that the dispersant application is OK
-Assuming 100 dispersion in upper 20 m of the FGB NMS, it would be 130 ppb

Appendix J: Group C Breakout Session Notes

NOAA's Regional Preparedness Training (NRPT)
Environmental Tradeoff Analysis (ETA) for an Oil Spill Response
Impacting the Flower Garden Banks National Marine Sanctuary

Breakout Group C

Wednesday, May 25
2:15 PM Breakout Group Session I

Identify resources at risk

- Coral reef (benthic, pelagic, surface); T&E species
- Benthic community (60m-120m) – deepest parts of sanctuary are comprised of soft-bottom
- Deep reef black coral and gorgonians (120m)
- Habitat v organisms
- Soft v hard corals- speed of recovery (depth dep)
- Potential sensitive biological features
- Deep reef (>300m) not a habitat of concern here
- Deep reef v mesophotic – mesophotic corals here
- Organisms – brittle stars, fish species (imp commercially and recreationally – yellow edge grouper & tilefish, grouper species), small populations are a concern or slow to recover species, and populations/species only found in FGB
- Identify depth, species, location, seasonality (spawning events) and level of concern (T v E)
- Life-stage cycles – stages more sensitive than others
- Months and species of aggregations
- Hammerheads aggregate in FGB (Winter to Spring), grouper spawning aggregations (spring – summer)
- Document seasonal, spatial, depth of spawning aggregations by species and species of concern -> temporal doc for concerns
- Focus on certain depths for areas of concern – what is most sensitive or important habitat
- 50m-20m is coral reef cap is most sensitive area
- Corals, concentration on econ important species assoc with corals (snapper/grouper complex), polychaetes, crabs, small fish (system drivers) – key organisms for diversity & success of reef
- Isolated – don't understand recruitment very well -> many are prolific spawners so may have potential to re-colonize
- Seasonality components of habitat and organisms
- Turtles – loggerhead, hawksbill, and leatherback – typically in 50m or greater
- Pelagic community – additional fish, whale sharks, shark species, rays – especially manta rays, turtles, some transient mammal species (whale), spotted dolphins (important – not commonly seen in Gulf)
- Larval species – where located? Surface water v pelagic environment
- Whale sharks don't aggregate in this area of GoM
- Not spawning area of other fish (outside of groupers and corals)
- Whale Sharks tend to be sub-adults, not juveniles but not full adults – same for Hammerheads
- Surface community:
- Not concerned for birds – few offshore species
- Sensitive coral larvae – short window of time
- Sponges, brittle stars, polychaetes – broadcast spawning will allow for eggs in water column –

question of timing
- Larvae will concentrate in top 10-30ft approx
- Socio-economic impacts

Establish initial response objectives and actions

- Objectives:
- Human health & safety primary concern
- Protection of most sensitive environ resources (see above)
- Integrate overall response plan with FGBNMS response plan – advisory council for MS
- Obtain situational awareness
- Economic impact – maritime transits, commercial/recreational fishing, recreational diving
- Source control
- Actions:
- Wildlife observer/recovery team
- Trajectory and fate
- Determine response management
- Potential removal of coral and relocation – likely not feasible
- Initiate surveys – operational support, aircraft, satellites
- Prevent oil from reaching FGB
- Assess feasibility and impact of dispersants
- Buoys for surface currents – ADCP's for deep currents – oil companies can deploy on-call
- Understand current movements
- OSRP Plan – is it applicable?
- Looking at possible solutions – mechanical removal, dispersants, ISB, nothing
- Communication/Engagement with stakeholders
- Evaluate response techniques

Current pre-authorization and exclusion zones as they apply to the Flower Garden Banks

- Pre-authorized:
- Surface dispersants only
- *Nothing for subsea at this point
- Exclusion zones:
- Not specified
- Is exclusion zones for ISB, not for dispersants

Identify NRDA activities occurring during response

- Situational Awareness – resources at risk, response actions, sampling, remote sensing of dispersal, wildlife damage assessment, baseline values/samplings, establish injury (monitoring program), long-term recovery, naturally occurring biological issues – doc injury as occurs if assoc with oil,
- Deploy SPMDs
- Communicate/identify with trustees; get input – general coordination with response
- Apply/develop best management practices to minimize damage – related to response
- Initiate federal consultations

Thursday, May 26
9:00 AM Breakout Group Session II

Identify response options	No action, Natural attenuation, Monitoring	Mechanical Recovery	Surface Dispersant	In-situ burn	Subsurface Dispersant
Identify response tradeoffs for the options	- Accepting risk natural dispersion of oil - Impact above 10m - Microbial degradation (weeks) - Possibility of returning - More extended surface impacts - Decrease toxicity, increase stranding/smothering - Size of oil droplets impacts biodegradation & persistence	- Encounter rate - Response time for assets - Will not remove all oil - Safety issues - Risk to wildlife - Ability to recover impacted wildlife - Health issues for responders - Disposal issues - Air pollution - Benign to environment for recovered oil - Can be effective in appropriate conditions	- Shift oil into water column - Remove oil from surface - More bio-available to small organisms - Easier biodegradation - Reduced dispersion size - Higher concentration in top 10m - Much higher encounter rates - Response time – faster - Short-term and local net loss of organisms - Increased potential for exposure to coral	- Shift oil into atmosphere - Encounter rate - Response time for assets - Will not remove all oil - Safety issues - Risk to wildlife - Potential wildlife recovery - Health issues for responders - Immediately reduces risk to surface organisms - Potential impact to coral - Quick removal from boom - Long-term persistence of sunken residue	- Ability to keep significant percent of oil from surface - Keep from surface but shift to water column/sediments/deep water - High oil concentrations in water column at spill location - Safety and well control - Oil dispersed elsewhere may travel to FGB at depth? - Marine snow - Potential to control dispersion below surface
Identify "external pressures" affecting response decision-making	- Potential shoreline impact - Political external pressures - Negative public	- Visibility of response action - Historically/publicly preferred option - Snake oil salesmen	- Certain vulnerable environmental windows - Public perception - Political/agency	- Regulatory requirements (monitoring) - Public perception - Visibility of	- Certain vulnerable environmental windows - Public perception - Political/agency

	perception - Competing interests - Maritime traffic - Regulatory requirements	- Compliance with contingency plan - Urgency for action from response groups - Utilization of existing resources - Regulatory requirements	perception - Stakeholder concerns - Chemical concerns - Loss of consumer confidence - Economic impacts - Regulatory requirements	response action - Maritime traffic	perception - Stakeholder concerns - Chemical concerns - Loss of consumer confidence - Economic impacts - Regulatory requirements - Fear of unknown
Identify the key elements that would drive the decision-making process	- Weather - **Safety** - Type of spill (size, location, scenario, trajectory, expected impact) - Time of year - Expected persistence - Natural Resources present - Response resources available	- Weather - **Safety of response personnel** - Type of spill (size, location, scenario, trajectory, expected impact) - Time of year - Expected persistence - Natural Resources present - Response resources available - Expected efficiency - Removes oil from local environment - Waste disposal options - Response time vs spill size	- Weather and extent of water column mixing & oil penetration - Weather forecast - Transport forecast - Public perception - Political response - Natural resources present - Seasonality - Expected efficiency - Type of spill/oil - Persistence in environment - Speed of response - Window of opportunity	- Safety - Availability of response resources - Weather and extent of water column mixing & oil penetration - Weather forecast - Transport forecast - Public perception - Political response - Natural resources present - Seasonality - Expected efficiency - Type of spill/oil - Persistence in environment - Speed of response - Window of opportunity	- Volume of oil dispersed - Scenario specific - Weather and extent of water column mixing & oil penetration - Weather forecast - Transport forecast - Public perception - Political response - Natural resources present - Seasonality - Expected efficiency - Type of spill/oil - Persistence in environment - Speed of response - Window of opportunity

Knowledge gaps

- Fate of subsea dispersion

Group C

- Local oceanographic conditions - Lack of fate & transport knowledge - Lack of information of vulnerability in water column – assumptions mid-column less vulnerable - Aspects of FGB resiliency – coral recruitment, speed of recovery - Ability to assess long-term effect vs short-term effects - Effect of dispersants – do they reduce, increase, or cause no change? - Lack of deep water habitat knowledge – how is it effected?

Additional notes

- Highly scenario dependent - Marine snow and volume of spill

Group C

Thursday, May 26
1:15 PM Breakout Group Session III

Determine the response options that are applicable to the spill scenario	Aerial dispersal (0-10hr)	Aerial dispersal (Day 2)	Mechanical (Day 1-3)	Boat dispersal (Day 2)	No Action
Discuss the tradeoffs that are applicable to the spill scenario	- Reduce some surface of oil before reaching FGB - Uncertainty of impacts to coral at FGB – may be minimal?	- All surface oil could be dispersed - Localized & temporary increase of oil concentration in water column - Can expect biodegradation	- May have oil reach shoreline - Reduction in surface oil - Reduce efficiency on day 3 due to wide spreading & thinning of oil & sea state	- Localized & temporary increase of oil concentration in water column - Some oil removed from surface	
Capture the key elements that drove the decision-making process	- Trajectory/Proximity to FGB - Nightfall - Window of opportunity - % of oil can be dispersed?	- Past the FGB - A lot of surface oil can be dispersed quickly & prevent from moving to shoreline - Oil is still dispersible	- Response visibility - No approvals needed - Resources are available - Immediate deployment	- Option in toolbox in case other options are precluded by weather - Limited encounter rate	
List key elements not considered in the Session II discussion	- Time-lag for dispersal discussions/consultations	- Discussions completed	-	-	

Based on these tradeoffs, recommend to the Federal On Scene Coordinator (FOSC) which response option(s) should be used in the spill scenario

Deploy mechanical recovery immediately (with approval for night operations); aerial dispersion application on day 2 if mechanical is predicted not to be able to recover all recoverable oil by day 2; use mechanical recovery to continue demonstrating response actions in vicinity of landfall

Group C

trajectory

Capture the common key elements that drove the decision-making process

Onshore: - Sea turtles potentially nesting - Heavy recreational beach use - Environmental issues – effects to critical habitats (estuaries, mangroves, etc); retention of oil in SEDs of sandy beaches, - Political & public concerns/pressure - Potential oil sinking in near shore SEDs Offshore: - Wildlife risk at surface – sea turtles, mammals, sargassum patches - Reduce damage to habitat (oil droplets on coral) – more important long-term - Lack of stratification in water column - Political concerns/pressure - Essential fish habitat (entire GoM)

Knowledge gaps

- Biological impact of the concentration of physically or chemically dispersed oil (hydrocarbon effects on corals) - How much will be dispersed prior to reaching FGB – will any go over FGB?

Additional notes

- ISB – not practical because of time constraints in scenario - West Bank may be more effected than East Bank with dispersion concentrations?????? - Work through the night with mechanical removal (skimmers) if safe - Methods most effective in first 48hrs

Appendix K: Group D Breakout Session Notes

NOAA's Regional Preparedness Training (NRPT)
Environmental Tradeoff Analysis (ETA) for an Oil Spill Response
Impacting the Flower Garden Banks National Marine Sanctuary

Breakout Group D

Wednesday, May 25
2:15 PM Breakout Group Session I

Identify resources at risk

- Sargassum mats, turtles, 15 threatened or endangered species of whales, coral species, and marine mammals. Birds, recreational diving spaces, fishing (recreational and commercial), shipwrecks, oil platforms, human health and safety/personnel (public and employees), ship channel traffic, essential fish habitat, water quality, plankton, habitat area of particular concern (subset of EFH). Fish, crustaceans. Nursery and spawning areas/habitats.
- Benthic: soft corals, hard corals, algae, other encrusting organisms, soft-bottomed habitat concerns.
- Pelagic fish species, zooplankton. Manta rays and whale sharks are specifically protected by marine sanctuary regulations. Sharks.
- Cephalopods

Establish initial response objectives and actions

- Establish Unified Command and issue notifications.
- Assess if this is an ongoing or one-time release and scale the incident in time and space.
- Secure the source (and identify and characterize the spilled oil and obtain a sample)
- Protect human health and safety.
- Establish safety zone.
- Identify specific environmental resources present/at risk. Identify environmental priorities and protection strategies. Identify and monitor current conditions and wind/weather conditions.
- Assess leak trajectory. Identify the resources available for reference for existing planning documents associated with previous responses.
- Assess booming/skimming/in-situ burning/containment measures and if it's practical/necessary
- Define operational period and response planning.
- Identify stakeholders and information sources.
- Establish a joint information center.

Current pre-authorization and exclusion zones as they apply to the Flower Garden Banks

- Pre-approved, no exclusion for FGB. Coordinate with superintendent of the sanctuary.
- Identify existing current pre-authorization and exclusion zones as they apply to the FGB.

Identify NRDA activities occurring during response

- Collect baseline information, and, if appropriate, emergency rescue potentials.
- Start the NRDA pre-assessment which would allow for the decision of a full NRDA to be made.

Group D

- Water sampling in and around the slick.
- Identify stakeholders.
- Establish NRDA command.

Group D

Thursday, May 26
9:00 AM Breakout Group Session II

Identify response options	No Response (Natural Attenuation with Monitoring) **– assuming crude oil**	Mechanical Recovery **– assuming crude oil**	In situ burn -assuming surface oil **– assuming crude oil**	Dispersant application (surface) **– assuming crude oil**	Dispersant application (sub-surface) **– assuming crude oil** -assume well blow out
Identify response tradeoffs for the options	-Any other response option would cause more injury than no action -Monitoring requirement: complex (water quality, aerial…) -resource prioritization -seasonality and species sensitivity and vulnerability -community scale impacts	-Logistical requirements (ships, resources, spatial scale, transit times, storage capacity…) -encounter rate -not a 'green' solution – must still dispose of waste (changing where it ends up in the environment – reused in industrial purpose) -personnel safety -community scale impacts	-Logistical requirements (ships, resources, spatial scale, transit times…) -no storage requirements that mechanical clean up requires -encounter rate -personnel safety more complex -in situ burn not allowed at FGBNMS (burn residue, wind direction) therefore additional actions needed -smothering effect of burn residue -specialized boom -not a primary response option (supplemental) -typically involves RRT (regional response team) conversation	-typically involves RRT (regional response team) conversation -not a primary response option (supplemental) -Logistical requirements (ships, resources, spatial scale, transit times…) -no storage requirements that mechanical clean up requires -high encounter rate -SMART monitoring required -moving pollution to different media -resource prioritization -seasonality and species sensitivity and vulnerability -marine snow	-requires RRT (regional response team) concurrence -not an initial response option (supplemental) -resource prioritization -seasonality and species sensitivity and vulnerability -marine snow -Logistical requirements (ships, resources, spatial scale, transit times…) -no storage requirements that mechanical clean up requires --high encounter rate (at point source, with mixing) -NRT monitoring protocol required

Group D

Identify "external pressures" affecting response decision-making	-shoreline impacts bias: FGBNMS offshore location -public and political perception: perceptions of risk equating into fear, wide range of process understanding	-public and political perception: positive	-public and political perception (dirty smoke plumes) -political pressure (inexpensive in comparison to mechanical removal) -potential marine life impacts (turtles) -community scale impacts	-public and political perception: perceptions of risk equating into fear, wide range of process understanding -serious negative perception of chemical dispersants (adding chemicals to the environment…) -communication and changing public perception of negative perception (fear and mistrust) of chemical dispersants and offshore environment -environmental trade-off analysis -community scale impacts	-public and political perception: perceptions of risk equating into fear, wide range of process understanding -serious negative perception of chemical dispersants (adding chemicals to the environment…) -communication and changing public perception of negative perception (fear and mistrust) of chemical dispersants and offshore environment -environmental trade-off analysis -lack of independent/academic research support -community scale impacts
Identify the key elements that would drive the decision-making process	-resource prioritization -seasonality and species sensitivity and vulnerability -no response possible due to conditions (weather, environment…) -fate and trajectory	-weather -limited response possible due to conditions (weather, environment…) -fate and trajectory modeling -longer window of opportunity	-weather -fate and trajectory modeling -moving pollution to atmosphere -effects of smothering effect of burn residue -narrow window of	-weather -fate and trajectory modeling (oil coming down)	-weather less of an issue -fate and trajectory modeling (oil coming up)

	modeling		opportunity -exposure to smoke plume (public and economic [shipping lanes, rigs]) -high removal rate -additional removal option when mechanical resources are exceeded (i.e. skimmers, vessels, boom)		

Knowledge gaps

-Species toxicology (exposure, duration, and dosage)
-Fate and transport modeling (3D modeling [i.e. current modeling])
-No research (DwH funded) correlation to response decisions, yet

Additional notes

-reminder not to calibrate to DwH (i.e. amount of burn residue from single release would be much smaller)
-social media has made public opinion stronger
-speed of information flow has changed response
-public attention span short
-traditional limitations on nighttime operations are changing

Group D

Thursday, May 26
1:15 PM Breakout Group Session III

Determine the response options that are applicable to the spill scenario	Mechanical Cleanup	Dispersants	Shoreline Cleanup
Discuss the tradeoffs that are applicable to the spill scenario	• Weather conditions, locations of response vessels (Options: Galveston 3, Corpus Christi, Lake Charles) Leave LC on standby	• Potential for resource damage (specifically FGBNMS resources) • Recreational use of shore / beach	• Economic Impacts for recreational use
Capture the key elements that drove the decision-making process	• Mobilization (eta on scene 12-24 hours minimum) • Are there enough assets to respond on time? • Weather window based on forecast is 48 hours. • Decanting of oily water is an option in federal waters (behind the boom) • The potential for the slick breaking up is high • Mobilization of remote sensing equipment to guide ships to thickest portion of slick. • Make an estimate of what fraction of the oil you could collect in the best case scenario. • 24 hours on scene before weather becomes prohibitive.	• DC3 in Houma can be on scene in 4 hours • C130 in Stennis or Arizona can be on scene in 12 hours (pilots in Arizona) • "As far from the sanctuary as possible" • Spotter aircraft would precede and be launched from Houma • Dispersants must have SMART monitoring? (Tier 1 by plane) • Response window of 2 hours on day 1 to accomplish: • Window 4 to 6 hours of time = maximum of three runs • RRT approval must be made immediately. • Sanctuary consultation. • Initial • Sunset is 2015.	• We want to act to minimize the amount of oil that will reach the beach. Since it is possible that some oil will strand on the beach, we should prepare for shoreline cleanup.

	• Storage capacity is adequate.	• **Try as early as possible and/or wait until slick passes sensitive / protected areas.** • Waiting to apply dispersants ill minimize the potential risk to FGBMNS.	
List key elements not considered in the Session II discussion	•	•	•

Based on these tradeoffs, recommend to the Federal On Scene Coordinator (FOSC) which response option(s) should be used in the spill scenario

1) Mechanical cleanup launching from Galveston and Corpus Christi and putting Lake Charles responders on standby.
2) There was not enough time to apply dispersants prior to reaching FGBNMS. There is still time to apply dispersants after the slick has passed FGBNMS.
3) Simultaneous application of dispersants while mechanical removal is underway will require careful management. (SIMOPS)

Capture the common key elements that drove the decision-making process

- Window for hitting it early was too tight

Knowledge gaps

- Estimate of amount of oil collection that is possible
- Ocean Current Information

Additional notes

- No response not an option; it would have impact on near/onshore
- Time zero is noon today
- In situ burning is probably not an option due to approval time (within the response time frame window)
- Minimal regret
- Should we consider standardized dispersant testing on vessels? (Like Sintef)
- This is in an area of Bluefin tuna spawning

Appendix L: Workshop Spill Scenario

Five Emergency Response Questions?

- What was spilled? (Oil Chemistry)
- Where is it going? (Oil Forecasts)
- What's at risk? (RAR/ESI)
- How will it hurt? (Potential Impacts)
- What can be done to mitigate the hurt?

  (Alternative Response Technologies)

DO NO MORE HARM THAN GOOD

THIS IS ONLY A DRILL
NRPT Oil Spill Scenario – Garden Banks Mystery Spill

- Just before noon on 26 May, two BSEE employees in route to an offshore platform observe a slick 6 miles long by 0.5 miles wide that is greater than 60% dark oil coverage.

- The mystery spill was observed in the Garden Banks Lease Area. The source of the spill could not be determined by the observers. The leading edge was located at 27 degrees 45 minutes N Lat. 93 degrees 20 minutes W Long.

- Once the helicopter landed at the Shell Auger Platform, a National Response Center (NRC) notification was made. The BSEE employees also notified their HQ office in New Orleans and the USCG (note, the Shell Auger platform is not suspected – it was simply their destination).

2

THIS IS ONLY A DRILL
NRPT Oil Spill Scenario – Garden Banks Mystery Spill

- The observers estimated that the volume of oil was 1000 bbls (42,000 gal), but the true volume could be as much as 2000 bbls or even 500 bbls as on-water estimations are difficult to make and prone to error because of the difficulty in estimating true oil thickness.
- The NOAA Scientific Support Coordinator was notified and coordinated an initial trajectory analysis and spot weather forecast.
- Given the threat to the Flower Gardens, the waters of the Gulf of Mexico, and Texas Coastal Zone, the USCG FOSC has initiated a response.

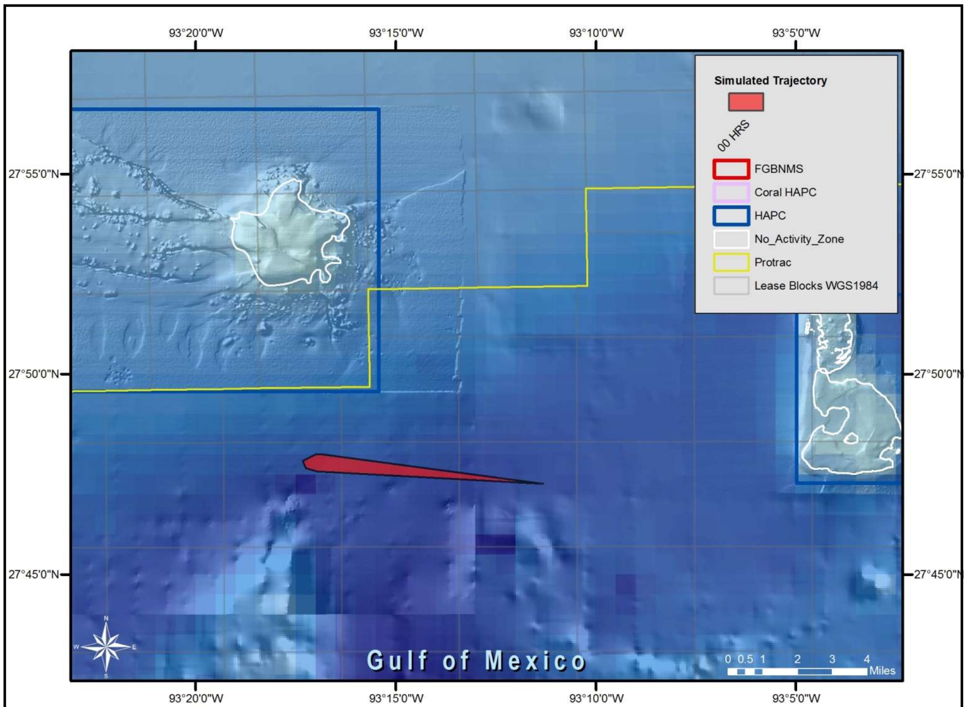
3

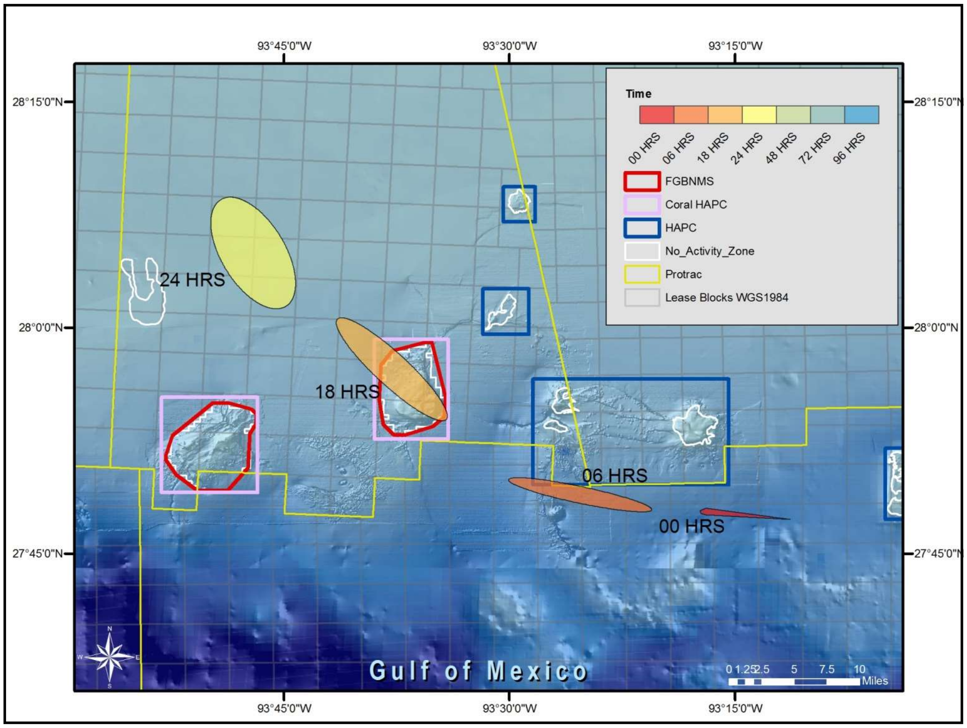
26 May 2016 - Noon

THIS IS ONLY A DRILL

- At Noon on 26 May 2016, the leading edge of the reported slick was located roughly 20 miles ESE of the East Flower Garden Bank of the Flower Garden Banks National Marine Sanctuary (FGBNMS).
- Winds are currently 10-15 knots out of the ESE and ocean currents along the shelf are running W at just under 0.5 knots. The slick is expected to pass over the East Bank of the FGBNMS overnight.
- The trajectory forecast predicts that the slick will develop a more NE track once it moves over the shelf and toward the Texas coast.
- Landfall of any remnants of the slick is possible on Memorial Day on beaches in the Bolivar - Galveston area and potentially even further to the south depending on the longshore current speed. Beach oiling will likely be sporadic tarballs and streamers of emulsified weathered oil.

5





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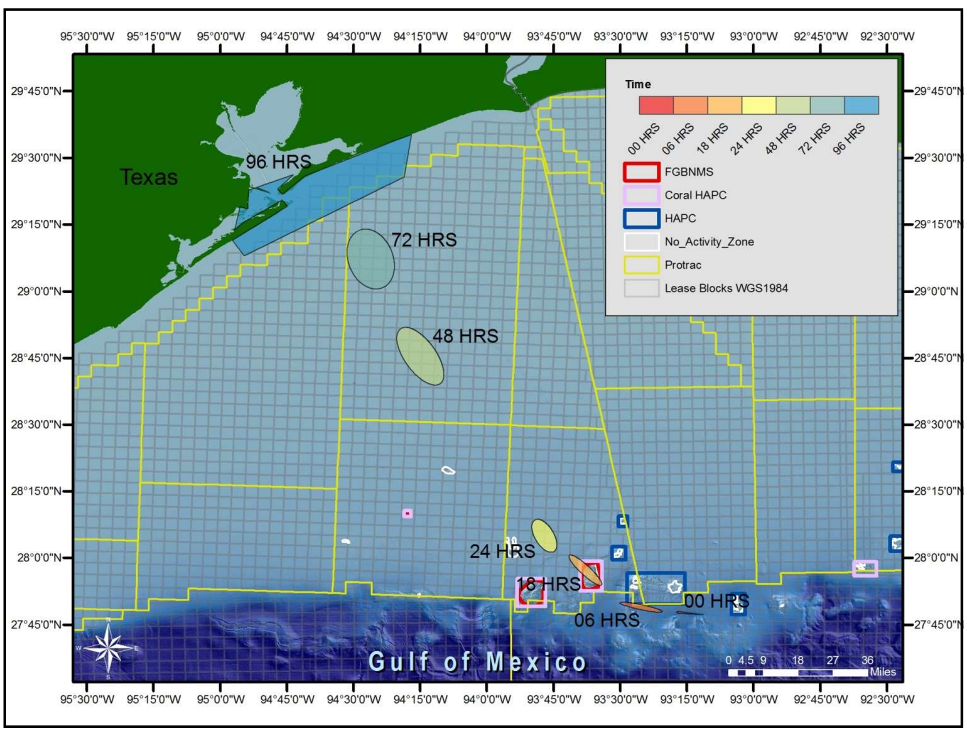

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THIS IS ONLY A DRILL
NRPT Oil Spill Scenario – WX

- Thursday, 26 May 2016
  ESE at 10-15 knots, Seas 2-4 feet
- Friday, 27 May 2016
  SE at 15-20 knots, Seas 3-5 feet
- Saturday, 28 May 2016
  SE at 15-20 knots, Seas 4-6 feet
  (frequent breaking waves and white caps)
- Sunday, 29 May 2016
  SE at 20-25 knots, Seas 5-7 feet
- Monday, Memorial Day (Sunny)
  SSE at 10-15 knots, Seas 3-5 feet

9

- What was spilled? (Oil Chemistry)

- Unknown Crude Oil
- Estimated API Gravity – 32 to 34
- Estimated Evaporation – 30 to 35 % in the first 48 hrs.
- Estimated Natural Dispersion – 10 to 15%