Oil Spill Science:

I. Response, Forensics, & Damage Assessment

Asian Development Bank
Sri Lanka

Christopher Reddy
June 19, 2021 (EST)

WOODS HOLE OCEANOGRAPHIC INSTITUTION

Takeaways

1. Every oil spill is different.
2. Volume, type of oil, and location are the key drivers.
3. “Response”, “forensics”, and “damages” science are different.
4. Pre-existing relationships will lead to better outcome.
5. Early predictions on the negative impacts rarely occur.
6. Time and uncertainty paradigms.

The goal of an oil spill response:

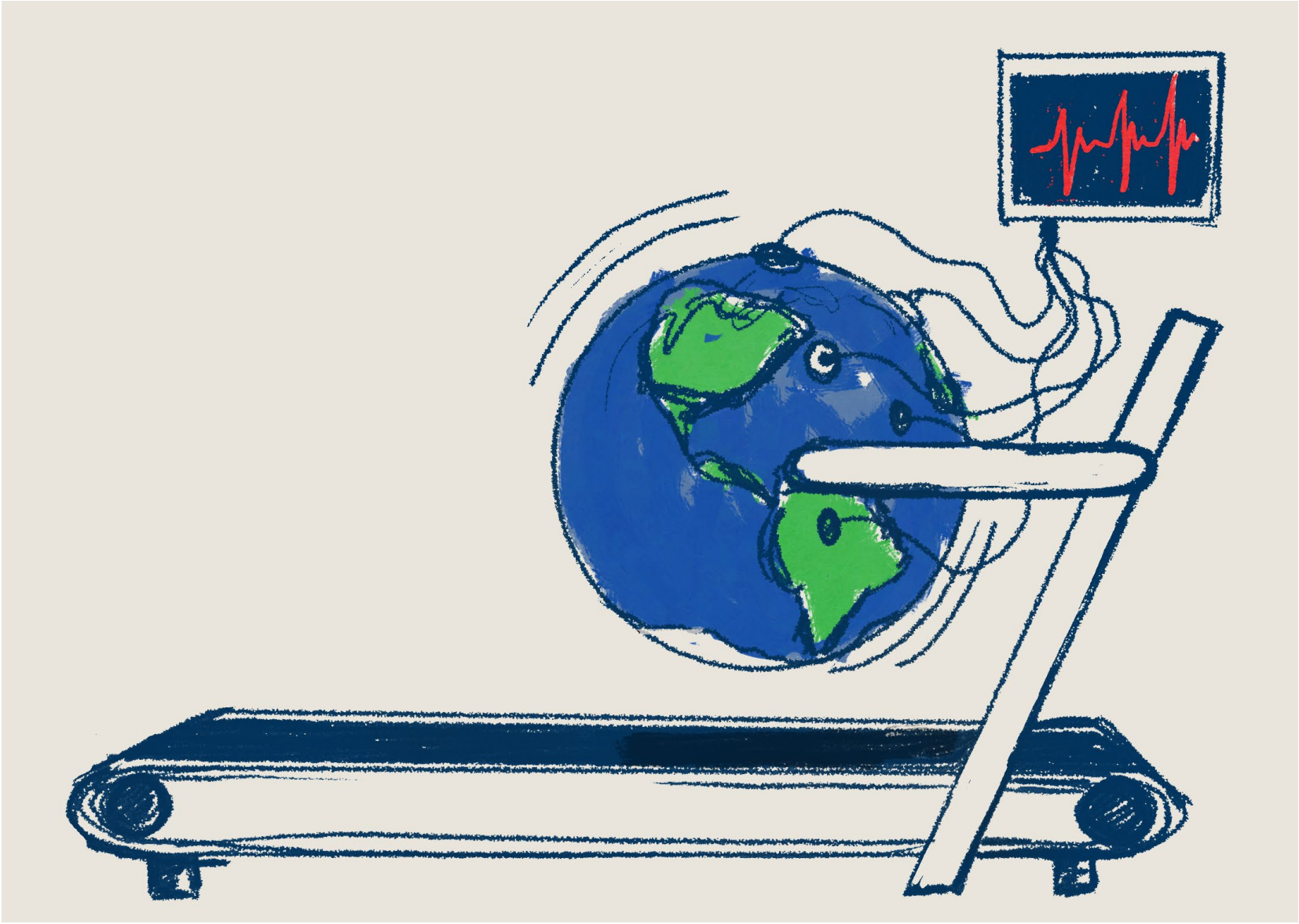
"Make a bad thing from getting worse"

Woods Hole Oceanographic Institution

Woods Hole, Massachusetts
United States of America

BACKGROUND

Pollution is a stress test on the ocean



North Cape oil spill

Home heating/diesel fuel

Rhode Island, January 1996

Bouchard 120 oil spill

Fuel oil

Buzzards Bay, MA, April 2003

Cosco Busan oil spill

Fuel oil

San Francisco Bay, CA, November 2007

Deepwater Horizon disaster

Crude oil

Gulf of Mexico, April 20, 2010

Texas City oil spill

Fuel oil

Texas, March 2014

Southern Star VII oil spill

Furnace oil

Sunderbans, Bangladesh, December 2014

Norilsk oil spill

Diesel tank

Russian Arctic, June 2020

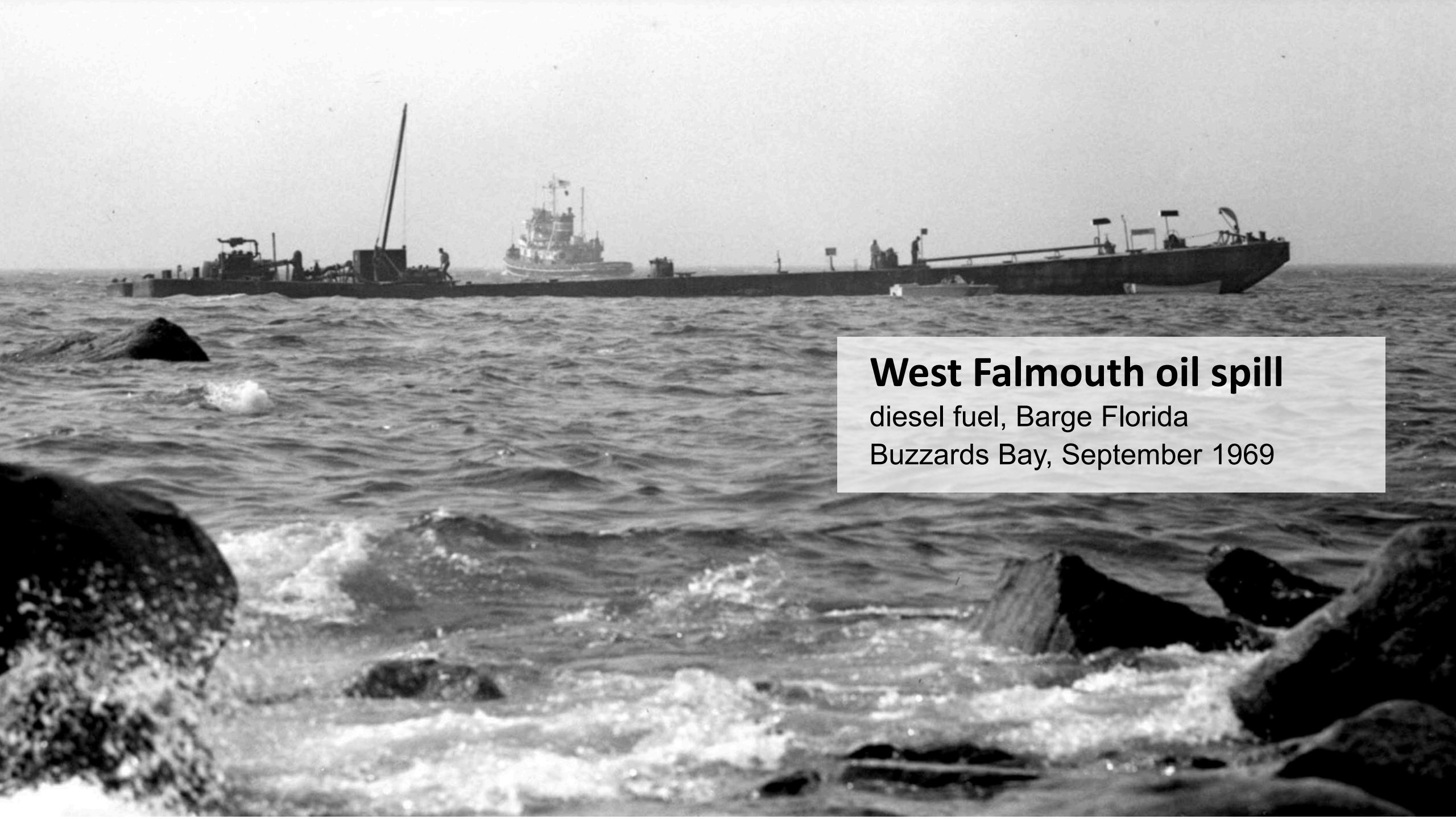
Mauritius oil spill

fuel oil, MV *Wakashio*
Indian Ocean, July 2020

Sri Lankan plastic spill

MV *X-Press Pearl*

Indian Ocean, May 2021



West Falmouth oil spill

diesel fuel, Barge Florida

Buzzards Bay, September 1969

USS Arizona

fuel oil

Oahu, Hawaii, ongoing

Yemen Tanker

Crude oil

Red Sea, 2019-2023

Outline

1. Volume, location, and oil type
2. Failing grade on the Bouchard 120 oil spill
3. Different roles and cultures in a crisis
4. Response vs. Damage assessment

Key Factors

a. Volume spilled
b. Location
c. Type of oil

Volume spilled

Challenges and impacts do not scale linearly with volume.

Cosco Busan oil spill

Bunker fuel

San Francisco Bay, CA, November 2007

Deepwater Horizon disaster

Crude oil

Gulf of Mexico, April 20, 2010

Location

Sensitivity of area
Timing
Resources
Infrastructure

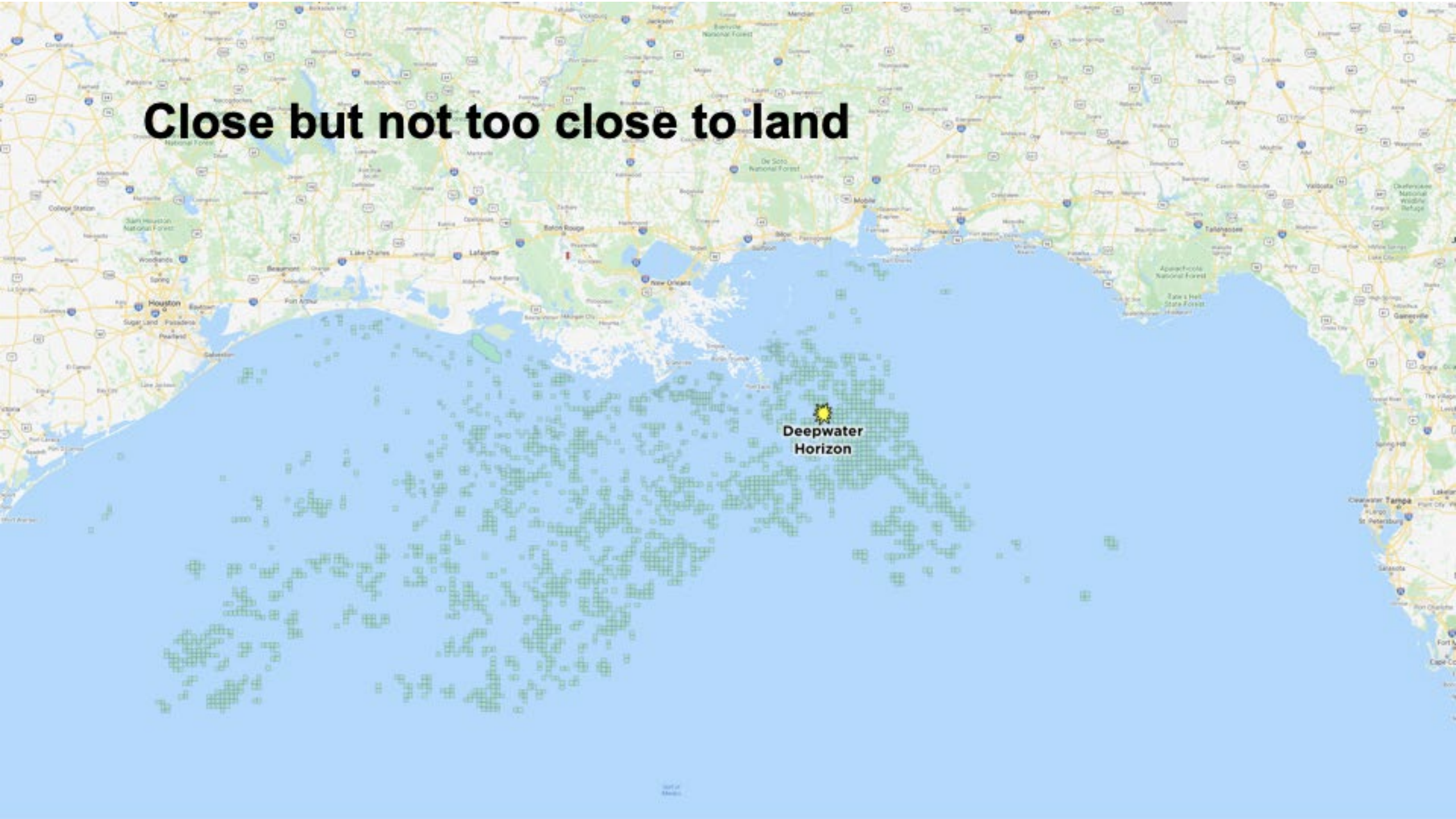
Deepwater Horizon disaster

Crude oil

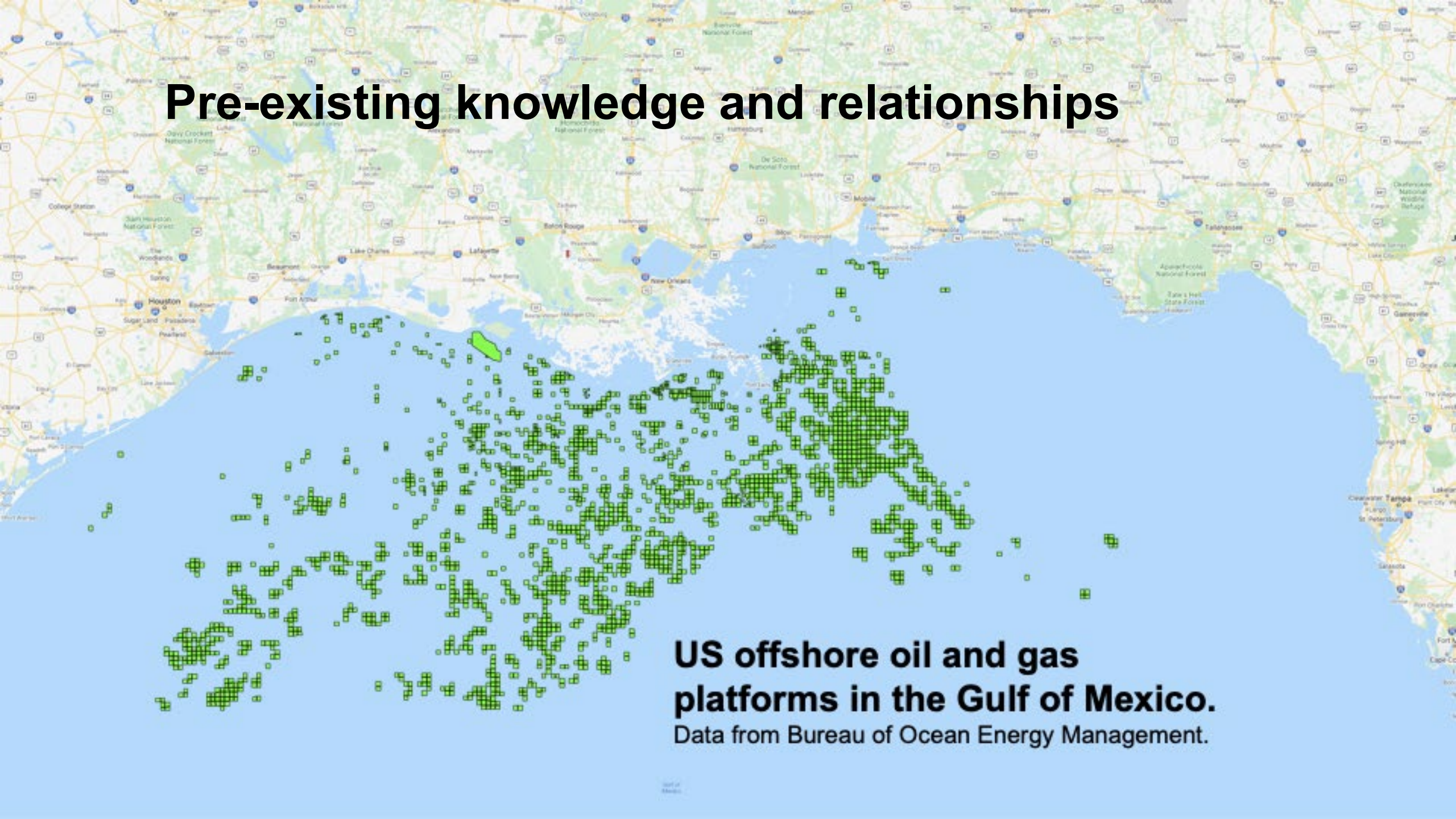
Gulf of Mexico, April 20, 2010

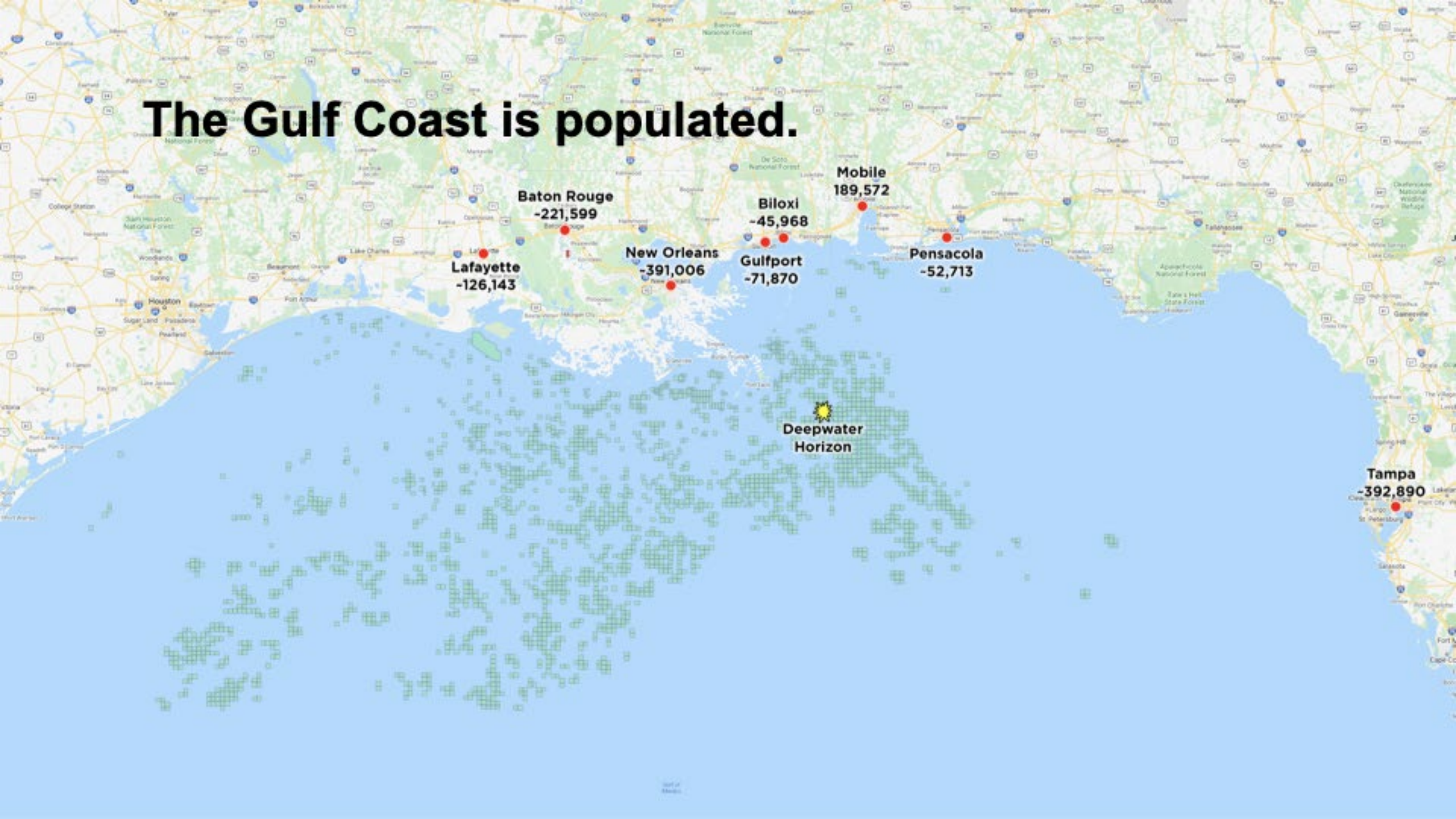
Location was a beneficial factor in the response to the Deepwater Horizon disaster

Close but not too close to land

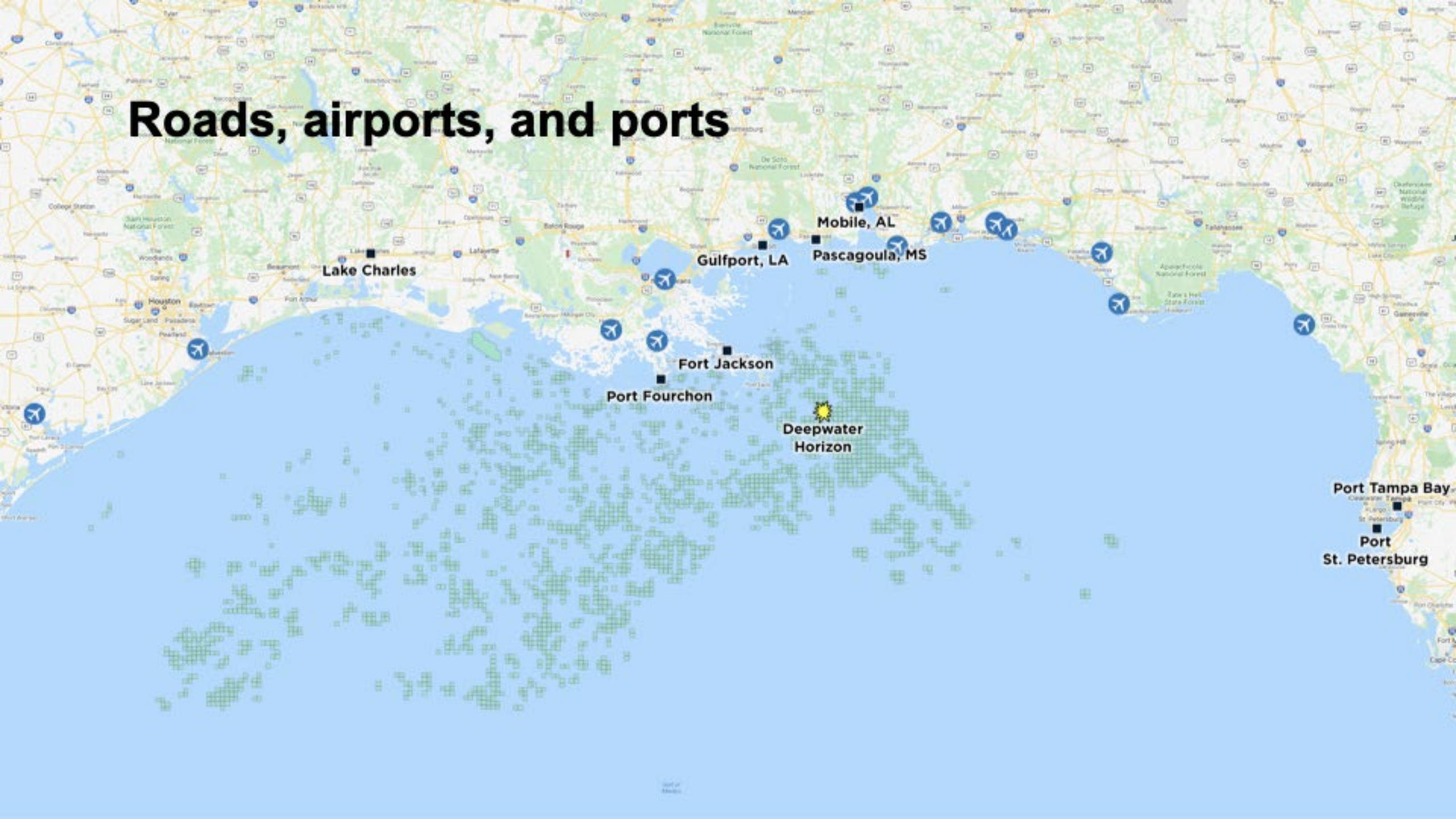


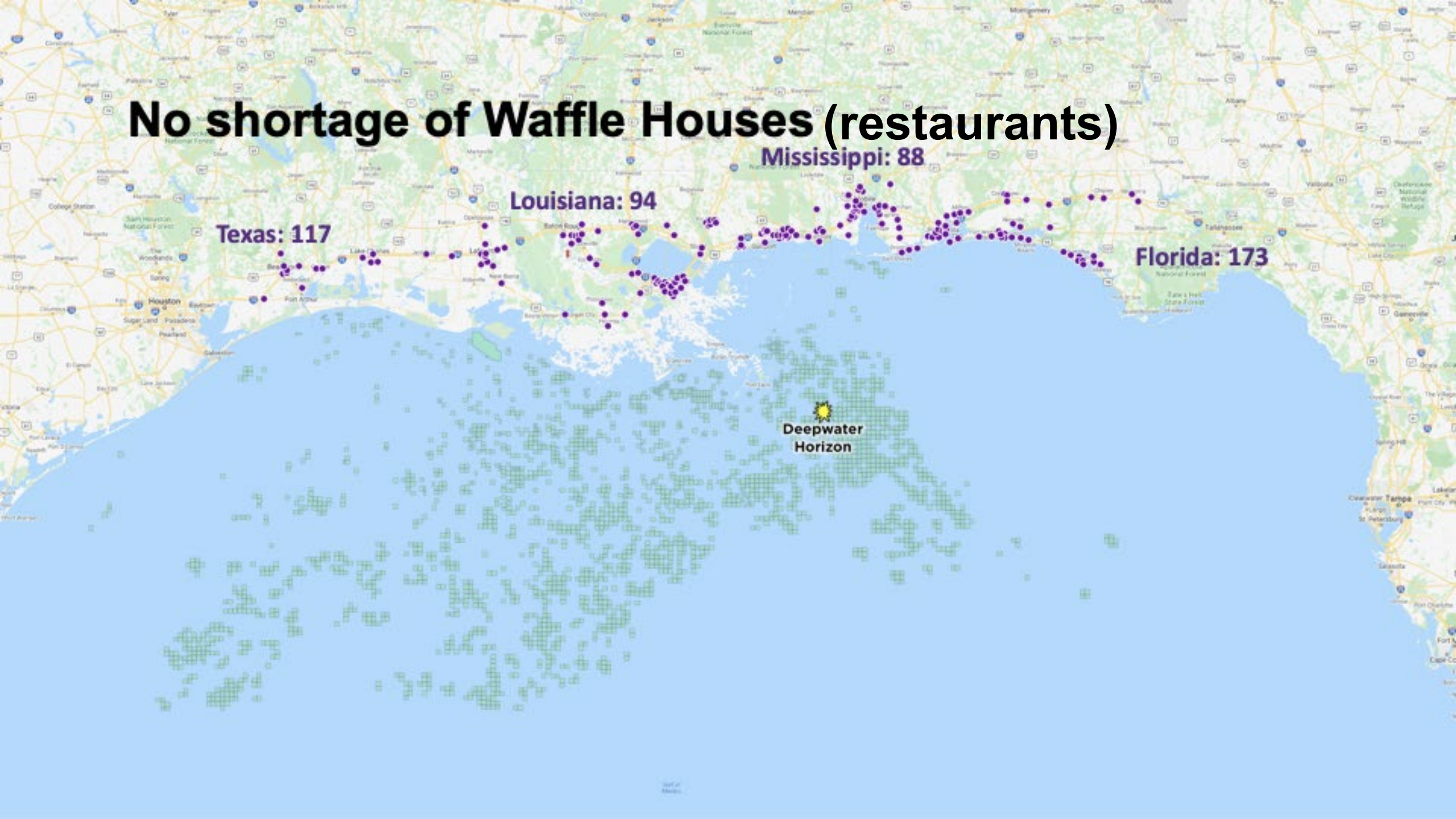
Pre-existing knowledge and relationships

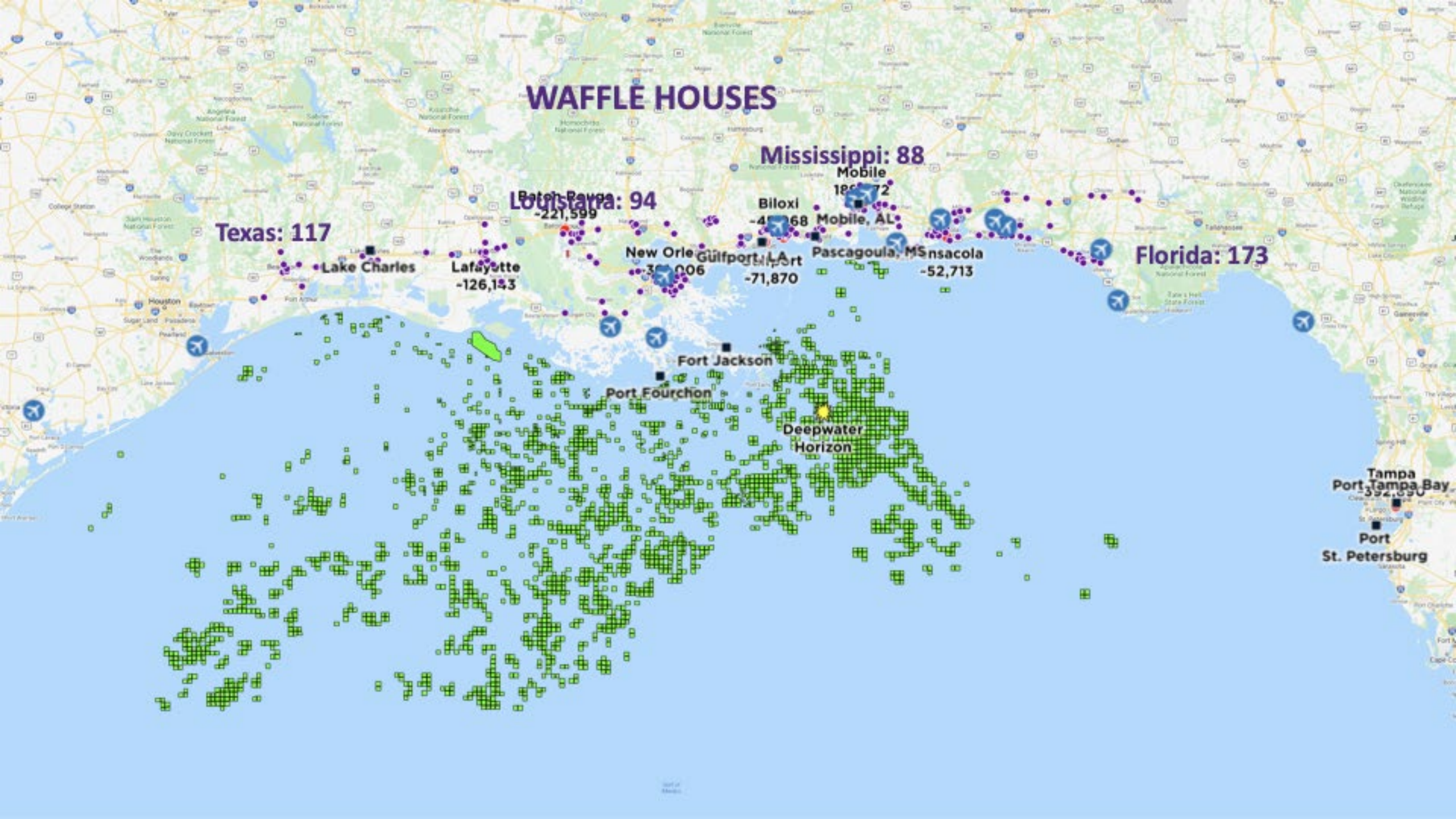



The Gulf Coast is populated.
Mobile
189,572
Baton Rouge
-221,599
Biloxi
-45,968
Lafayette
-126,143
New Orleans
-391,006
Gulfport
-71,870
Pensacola
-52,713
Deepwater
Horizon
Tampa
-392,890

Roads, airports, and ports




No shortage of Waffle Houses (restaurants)
Mississippi: 88
Louisiana: 94
Texas: 117
Florida: 173
Deepwater Horizon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Mississippi: 88
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Mobile
Biloxi
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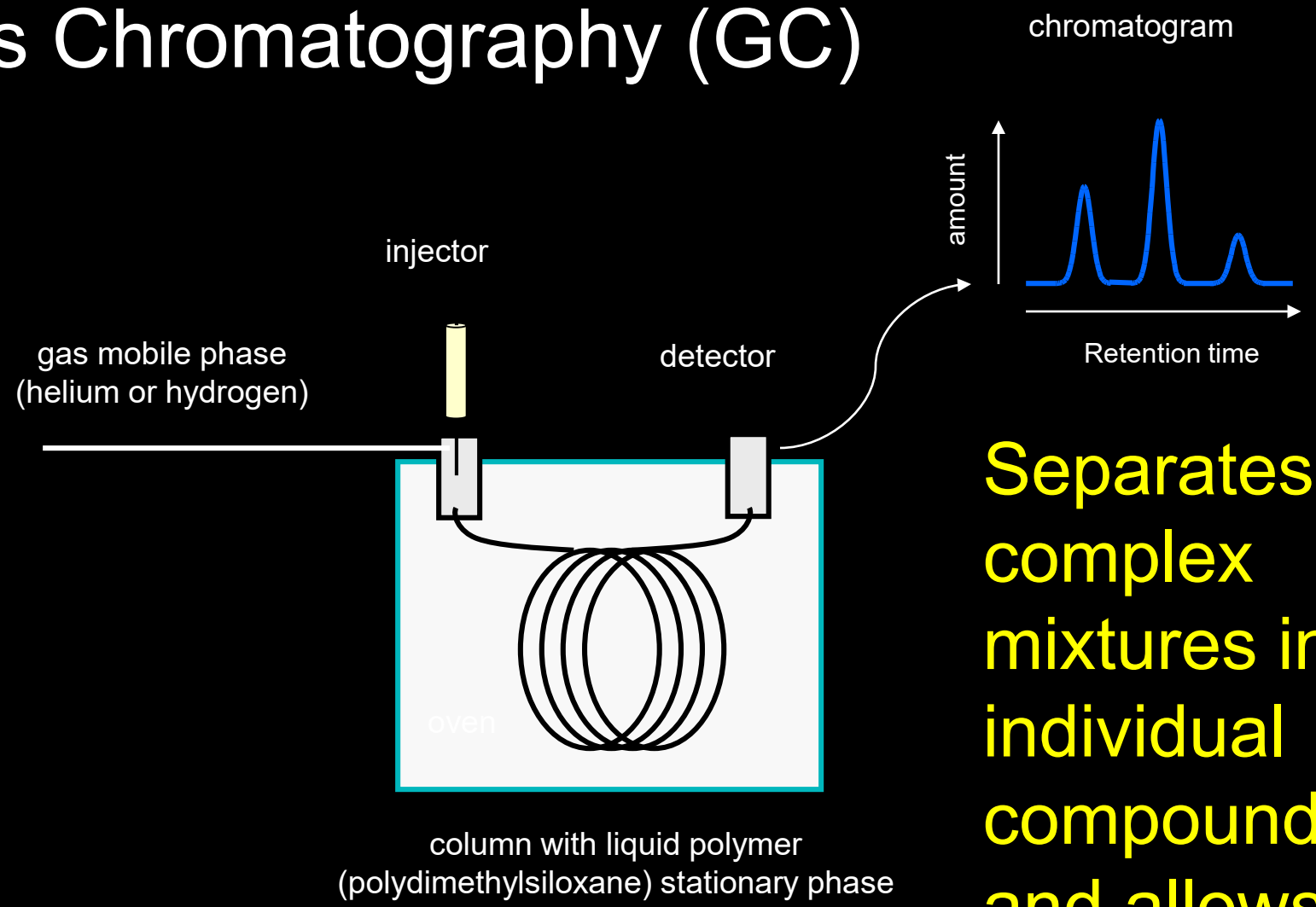
Gulfport, LA
Lake Charles
Lafayette
-126,143
-71,870
-52,713
Fort Jackson
Port Fourchon
Deepwater
Horizon
Tampa
Port Tampa Bay
Port
St. Petersburg

Type of oil

Different composition
Different response
Different fate
Different short- and long impacts

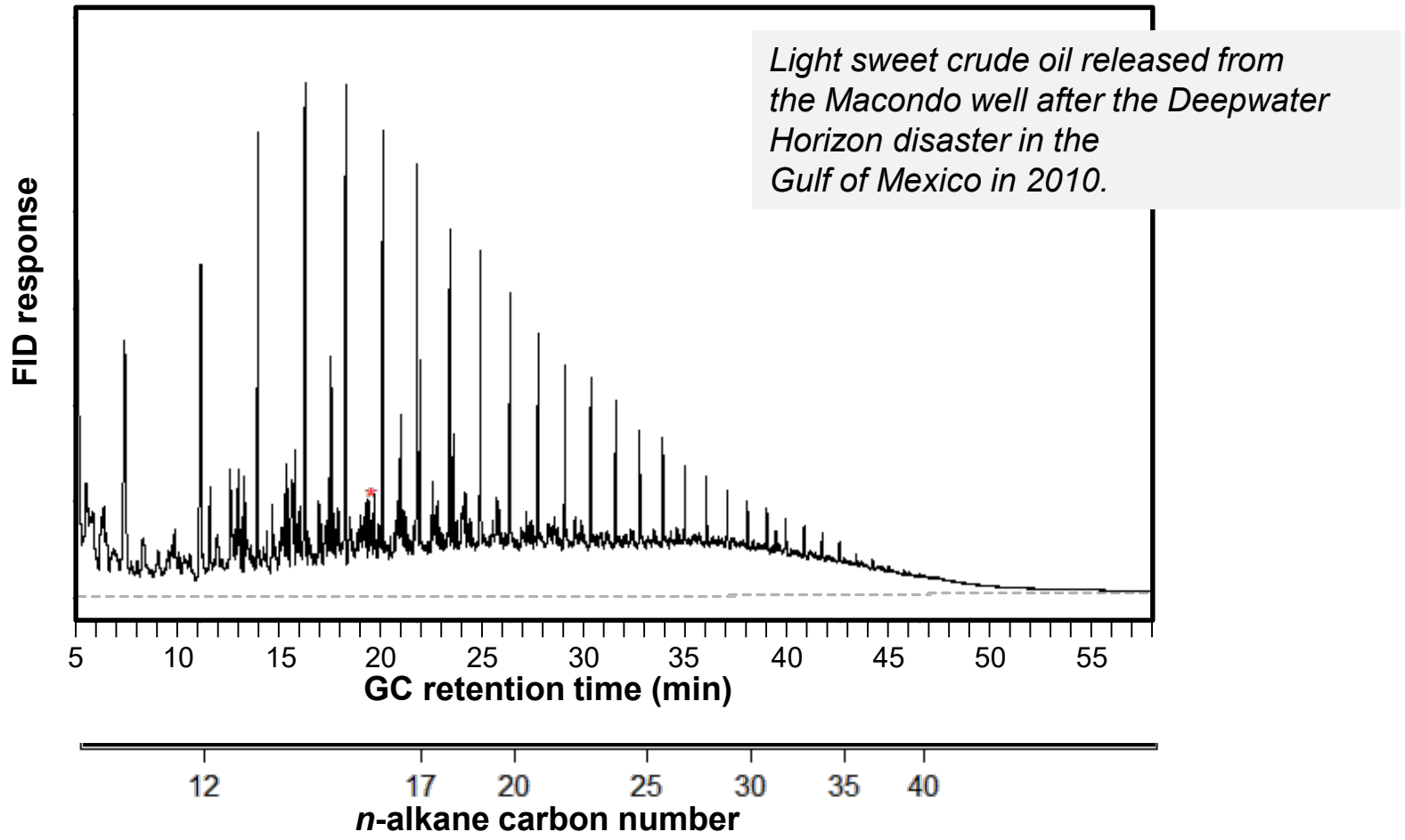
Gas Chromatography (GC)



Separates complex mixtures into individual compounds and allows them to be measured.

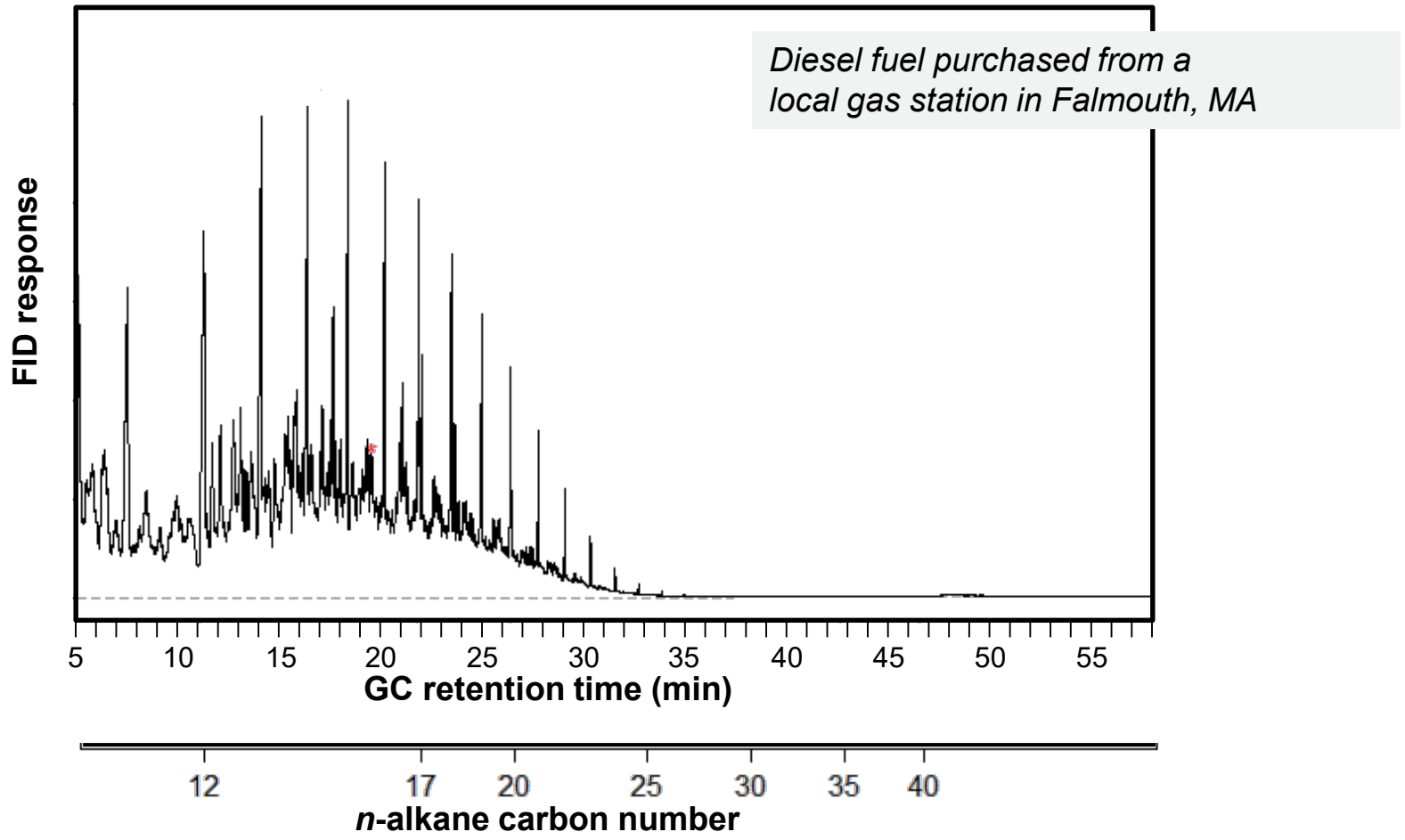
GC-FID chromatographs of crude oil and other refined products

Deepwater Horizon

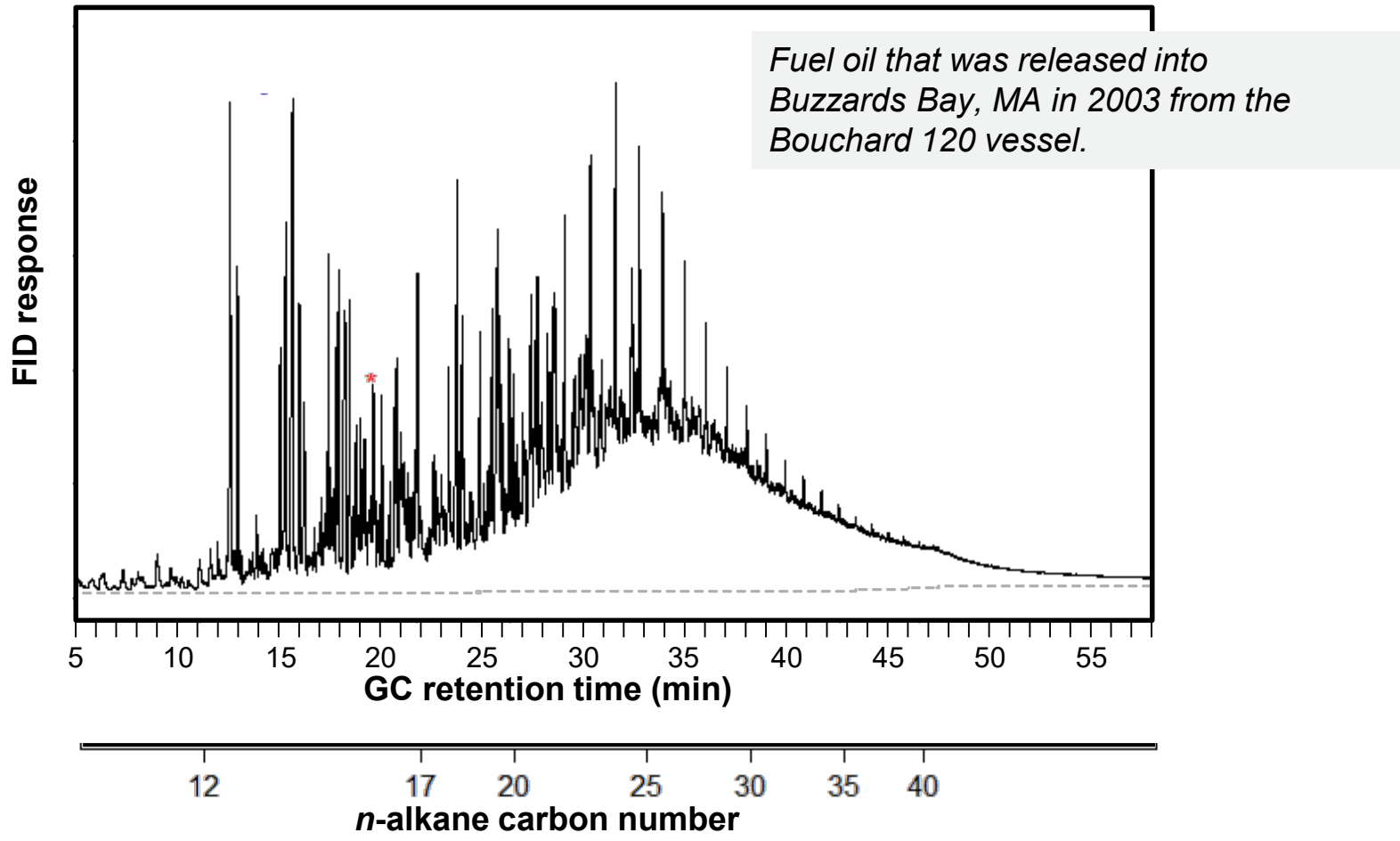


Light sweet crude oil released from the Macondo well after the Deepwater Horizon disaster in the Gulf of Mexico in 2010.

Diesel fuel

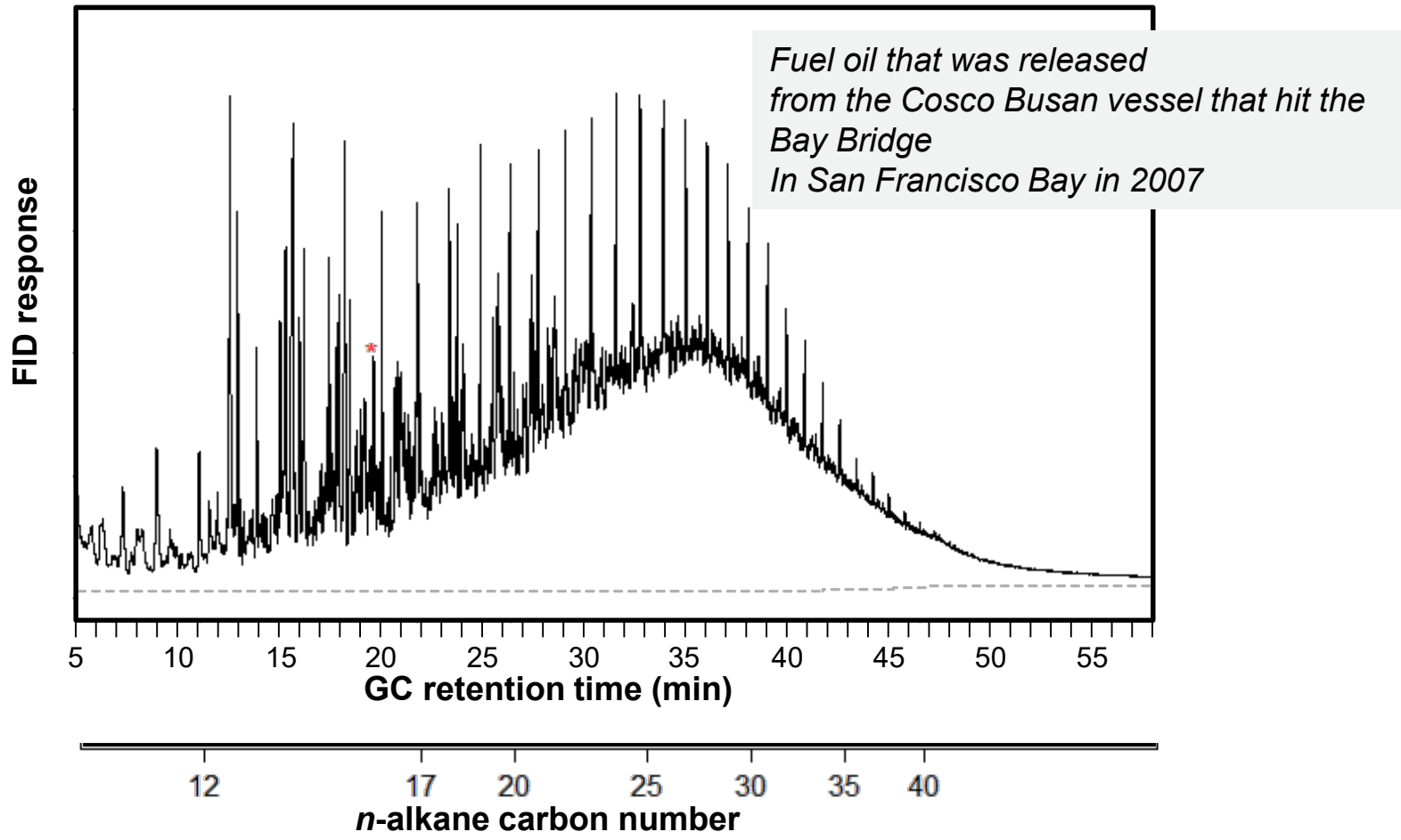

Diesel fuel purchased from a
local gas station in Falmouth, MA
FID response
5
10
15
20
25
30
35
40
45
50
55
GC retention time (min)
12
17
20
25
30
35
40
n-alkane carbon number

Bouchard 120 (fuel oil)



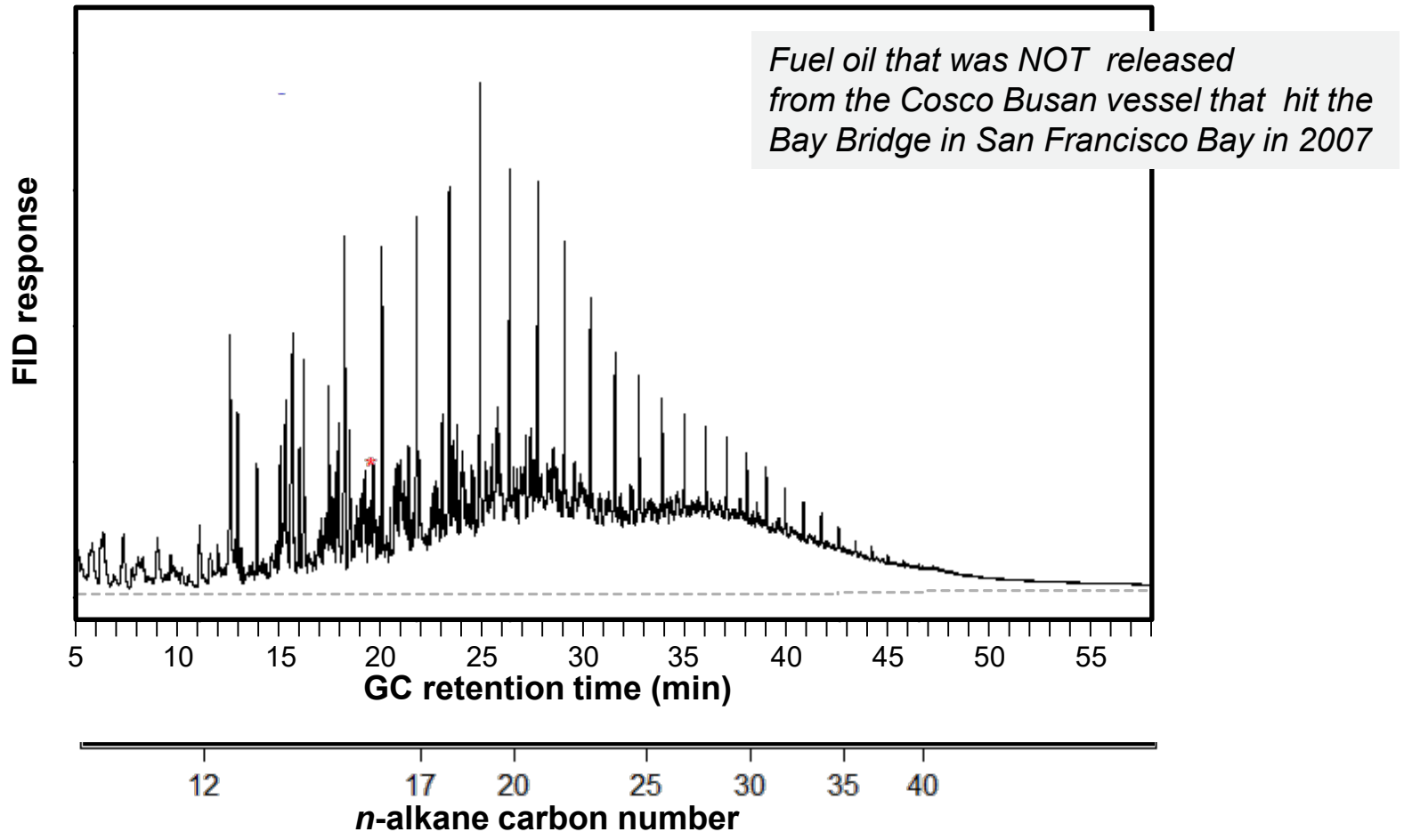
Fuel oil that was released into Buzzards Bay, MA in 2003 from the Bouchard 120 vessel.

Cosco Busan tank 4 *(fuel oil)*

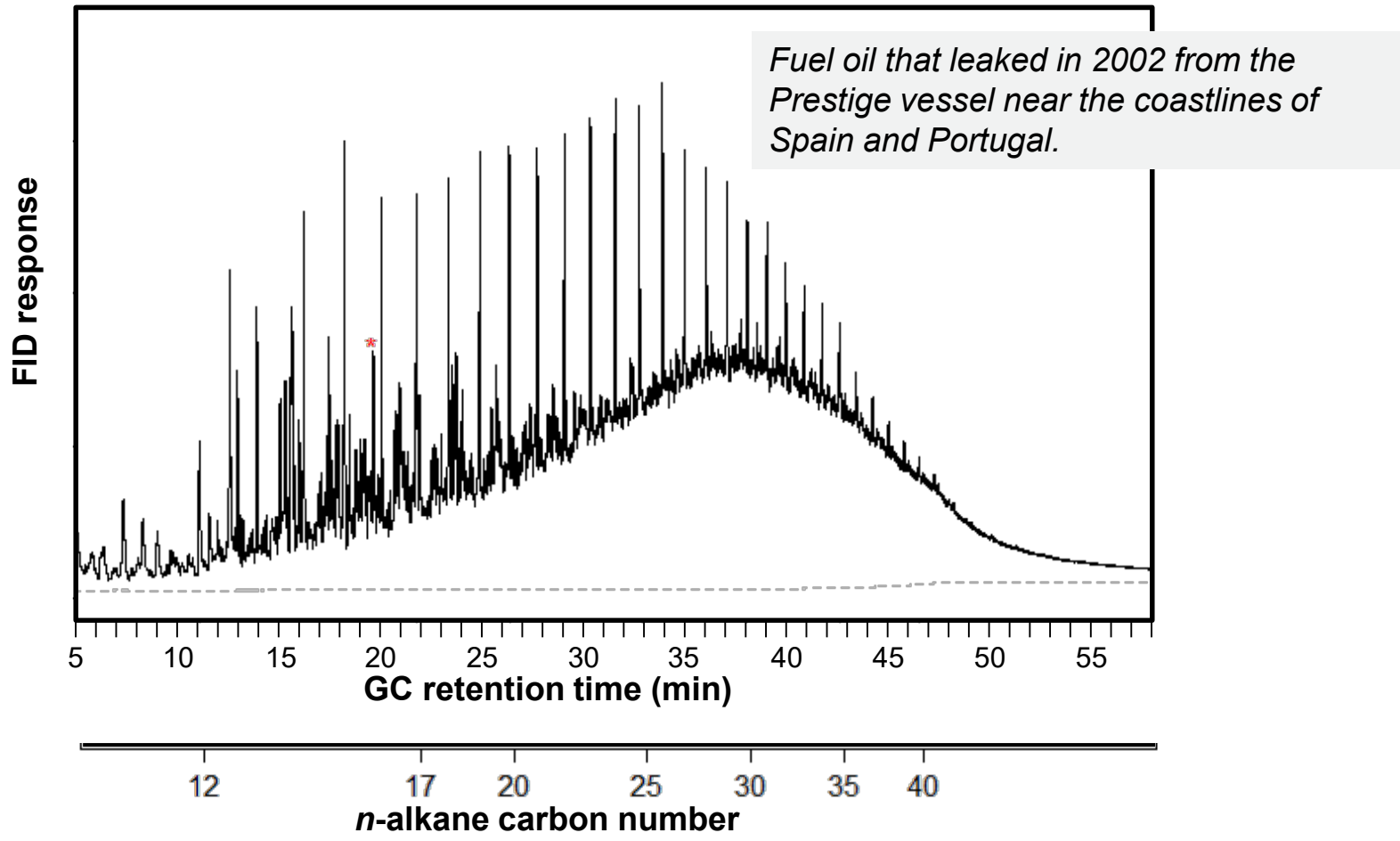


Fuel oil that was released
from the Cosco Busan vessel that hit the Bay Bridge
In San Francisco Bay in 2007

Cosco Busan tank 3 *(fuel oil)*

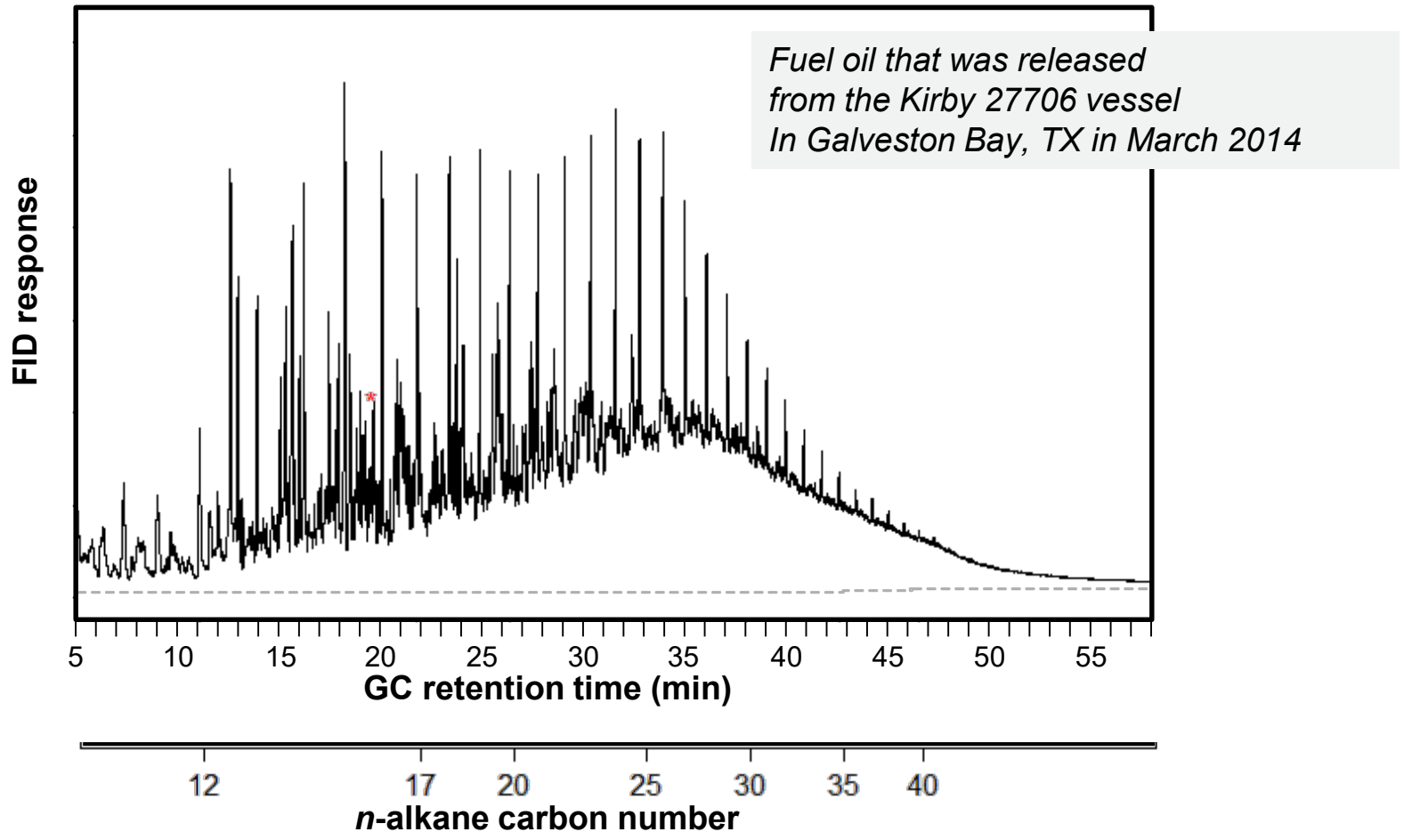


Prestige (fuel oil)

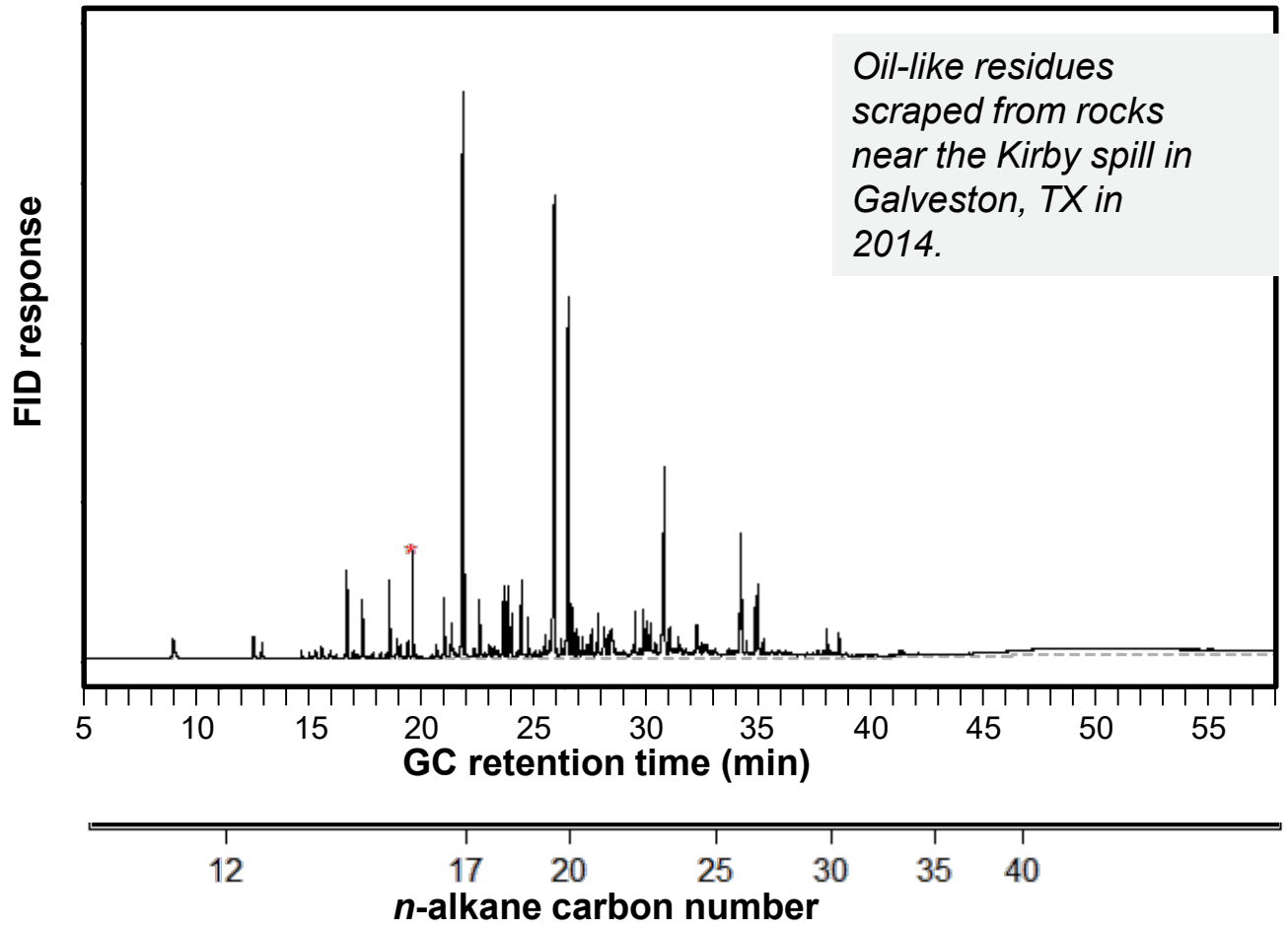


Fuel oil that leaked in 2002 from the Prestige vessel near the coastlines of Spain and Portugal.

Kirby barge (fuel oil)



Coal tar



Oil-like residues scraped from rocks near the Kirby spill in Galveston, TX in 2014.

2. Failing grade on the *Bouchard 120* oil spill


Bouchard 120
oil spill, Buzzards Bay, April 2003

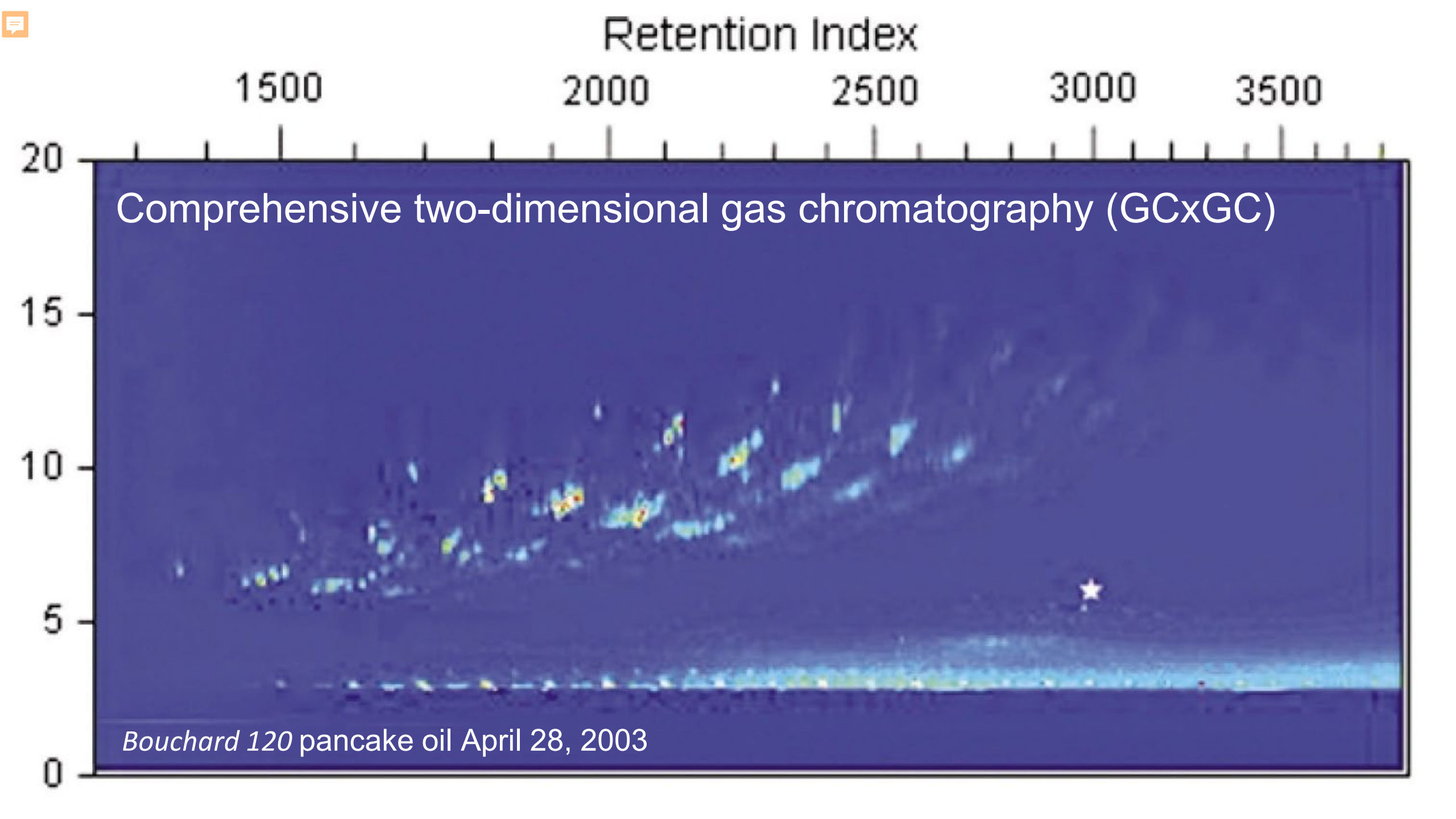

April 28, 2003


Buzzards Bay Oil Spill
Bouchard No. 6 Fuel Oil
Sta. #17 Pancake
41.31.85° North
70.46.70° West
Collected 28-April-03 rkn

New Bedford Whaling Museum; May 3, 2003

Attendees

1. Responders
2. The Public
3. Media
4. Business
5. Government
6. Academia
7. NGOs


Retention Index
1500
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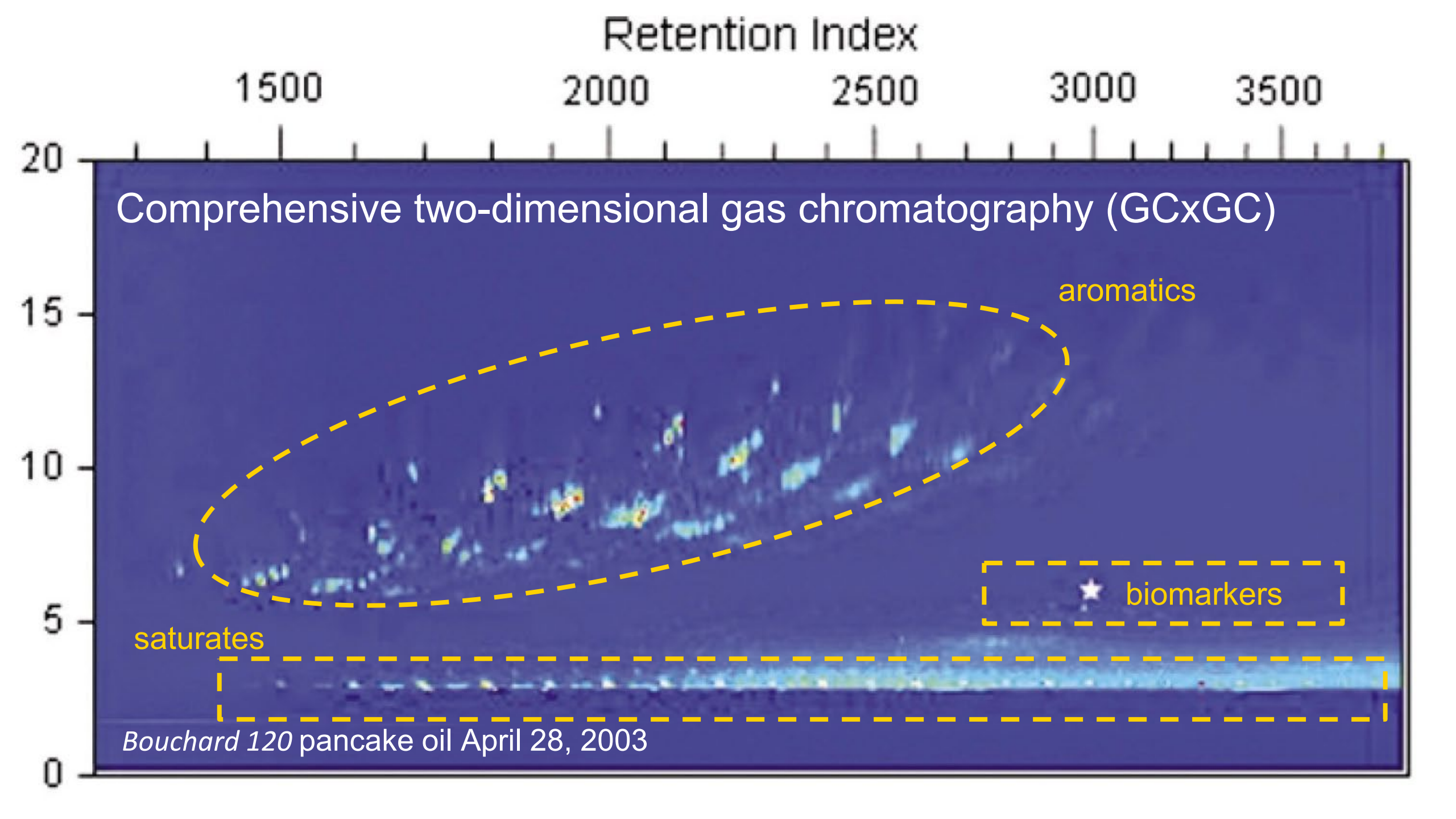
Comprehensive two-dimensional gas chromatography (GCxGC)
Bouchard 120 pancake oil April 28, 2003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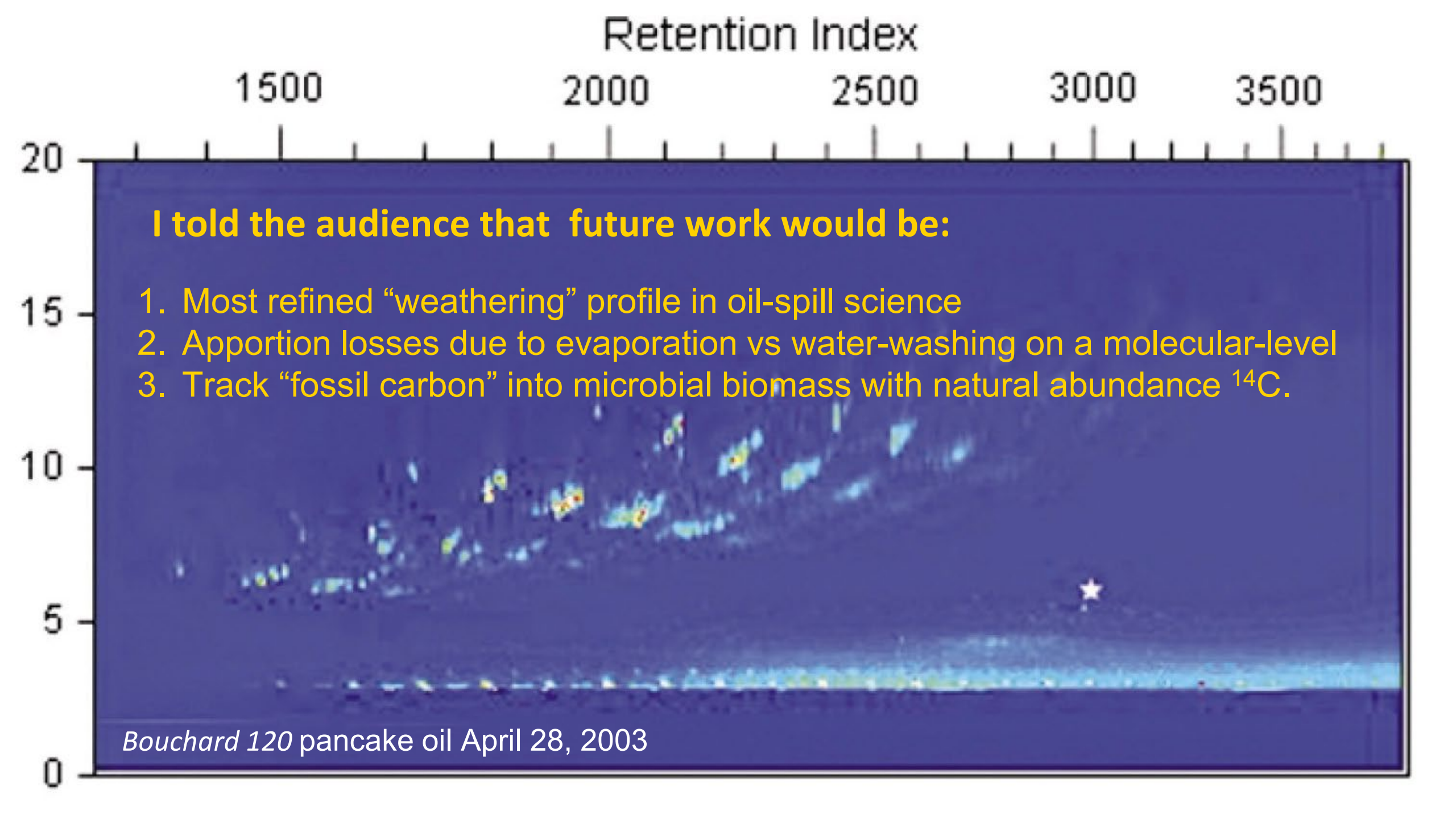
Comprehensive two-dimensional gas chromatography (GCxGC)
aromatics
biomarkers
saturates
Bouchard 120 pancake oil April 28, 2003


Retention Index
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0
I told the audience that future work would be:
1. Most refined “weathering” profile in oil-spill science
2. Apportion losses due to evaporation vs water-washing on a molecular-level
3. Track “fossil carbon” into microbial biomass with natural abundance ^{14}C.
Bouchard 120 pancake oil April 28, 2003

1. Most refined “weathering” profile in oil-spill science

Environmental Forensics, 7:33–44, 2006

ISSN: 1527–5922 print / 1527–5930 online
DOI: 10.1080/15275920500506758

Taylor & Francis
Taylor & Francis Group

Tracking the Weathering of an Oil Spill with Comprehensive Two-Dimensional Gas Chromatography

Robert K. Nelson,[1] Brian M. Kile,[1] Desiree L. Plata,[1] Sean P. Sylva,[1] Li Xu,[1] Christopher M. Reddy,[1] Richard B. Gaines,[2] Glenn S. Frysinger,[2] and Stephen E. Reichenbach[3]

[1]*Department of Marine Chemistry and Geochemistry, Woods Hole Oceanographic Institution, Woods Hole, MA, USA*
[2]*Department of Science, United States Coast Guard Academy, New London, CT, USA*
[3]*Computer Science & Engineering Department, University of Nebraska, Lincoln, NE, USA*

2006

2. Apportion losses due to evaporation vs water-washing on a molecular-level

John B. Phillips Award

The Phillips Award (first given in 2004 to honor the memory of Prof. John B. Phillips, the inventor of GCxGC) recognizes individuals who have typically worked in the GCxGC field for less than 10 years but have demonstrated good leadership through their scientific peer-reviewed work. Due to the COVID-19 pandemic, the Phillips award was not held in 2020, but both awardees (for 2020 and 2021) will be presenting lectures at this virtual symposium. For a full list of the John B. Phillips awards, please click on Prof. Phillips's picture.

2006

Environ. Sci. Technol. **2007**, *41*, 5738−5746

Disentangling Oil Weathering Using GC × GC. 1. Chromatogram Analysis

J. SAMUEL AREY,[†]
ROBERT K. NELSON,[‡] AND
CHRISTOPHER M. REDDY[‡]

Laboratory of Biochemistry and Computational Chemistry, Swiss Federal Institute of Technology, Lausanne, Switzerland, and Department of Marine Chemistry and Geochemistry, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts

this informs court se
decisions under the
2701−2761). Scienti
three decades, and n
still difficult to decou
compounds.

Commonly, inve
paring concentratio
sets between differe
data analysis techni
weathering processe
compound set (e.g.,
responsive to weat
(numerator). This en
can be compared a

2007

Environ. Sci. Technol. **2007**, *41*, 5747−5755

Disentangling Oil Weathering Using GC×GC. 2. Mass Transfer Calculations

J. SAMUEL AREY,† ROBERT K. NELSON,‡ DESIREE L. PLATA,‡ AND CHRISTOPHER M. REDDY‡

Laboratory of Biochemistry and Computational Chemistry, Swiss Federal Institute of Technology, Lausanne, Switzerland, and Department of Marine Chemistry and Geochemistry, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts

a viscous coating onto the g
and showed signs of slight
sample collected at 6 mont
sitional evolution (*3*). As exp
(*4*), conventional weather
differentiate the effects of e
degradation of these samp
expand on the Nelson et
weathered samples collecte
during the first 16 weeks
Moreover we combine a no
technique (*4*) together wi
rigorously differentiate eva
rienced by oil at Nyes Neck

Several existing models de
caused by weathering. Ma

2007

3. Track “fossil carbon” into microbial biomass with natural abundance ^{14}C.

Available online at www.sciencedirect.com
ScienceDirect
Organic Geochemistry 37 (2006) 981–989
Organic Geochemistry
www.elsevier.com/locate/orggeochem

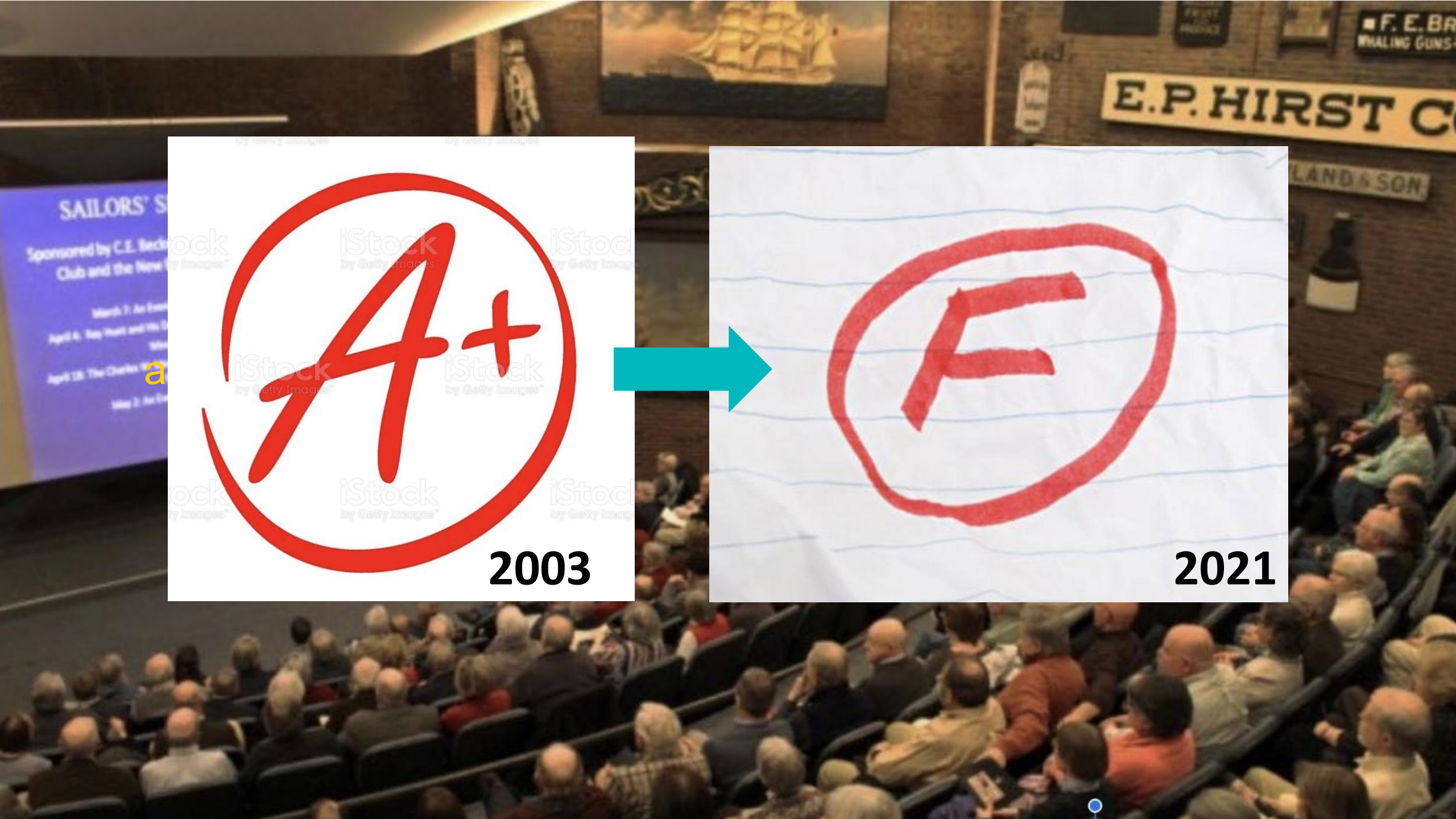
Intrinsic bacterial biodegradation of petroleum contamination demonstrated *in situ* using natural abundance, molecular-level ^{14}C analysis

Gregory F. Slater [a,*], Robert K. Nelson [b], Brian M. Kile [b], Christopher M. Reddy [b]

[a] *School of Geography and Geology, McMaster University, 1280 Main Street West, Hamilton, Ont., Canada L8S 4K1*
[b] *Department of Marine Chemistry and Geochemistry, Woods Hole Oceanographic Institution, Woods Hole, MA 02543, USA*

Received 24 October 2005; received in revised form 10 June 2006; accepted 19 June 2006
Available online 9 August 2006

2006


A+
2003
F
2021

I failed.

The audience **left hungry.**

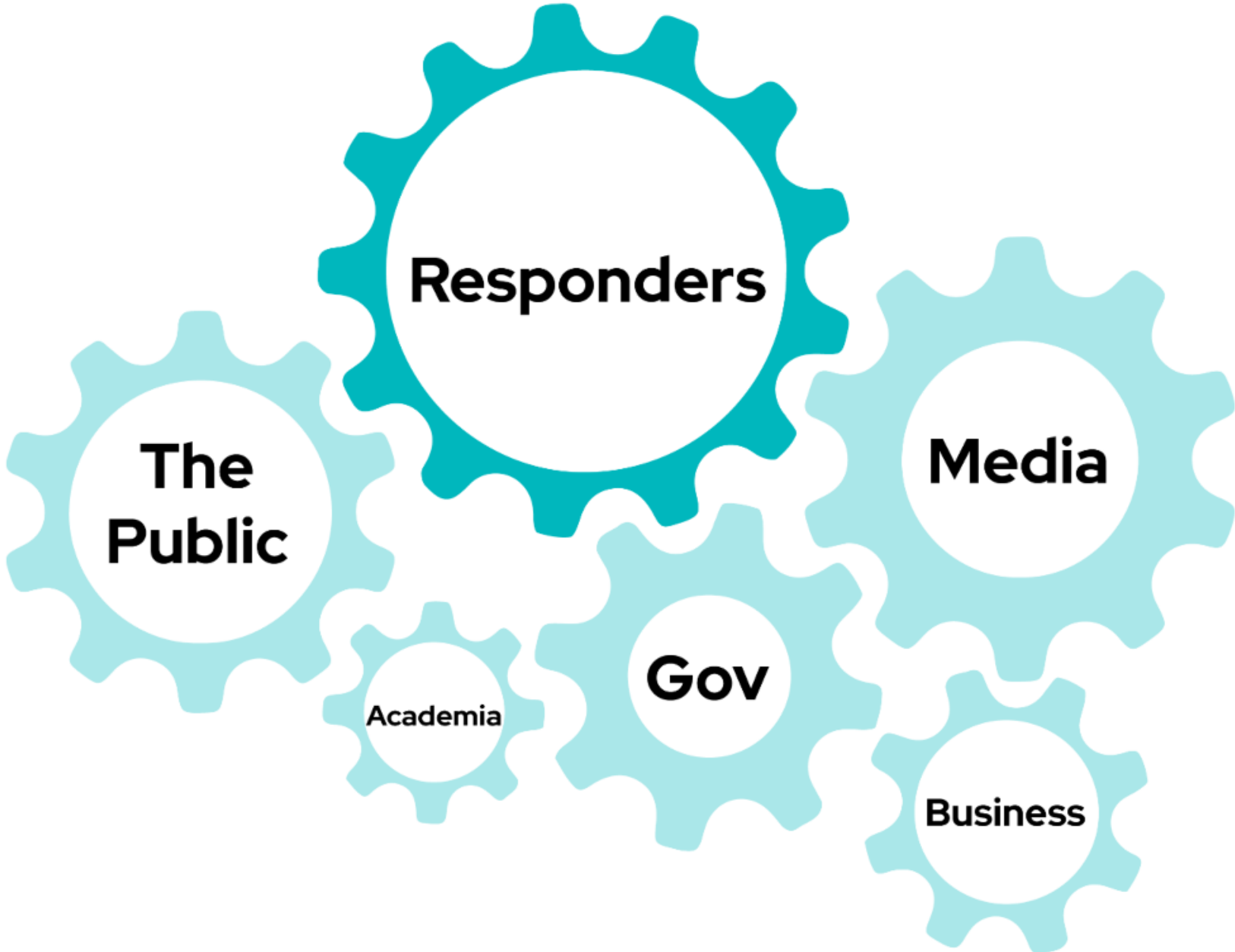
I served them **gourmet.**

They wanted **comfort food.**

I did not ask what they wanted.

They did not tell me.

3. Different roles and cultures in a crisis


Responders
The Public
Media
Academia
Gov
Business

PERCEPTION

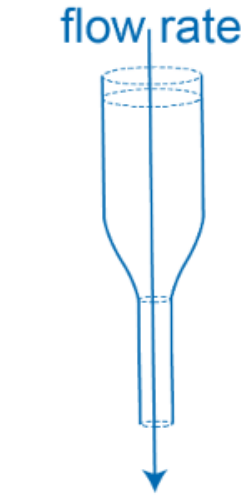
PERCEPTION

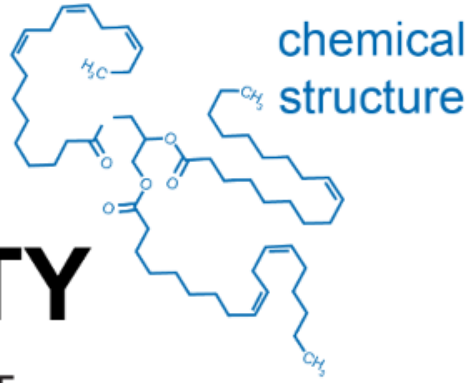
POLLUTANT

OCEAN

COVID-19

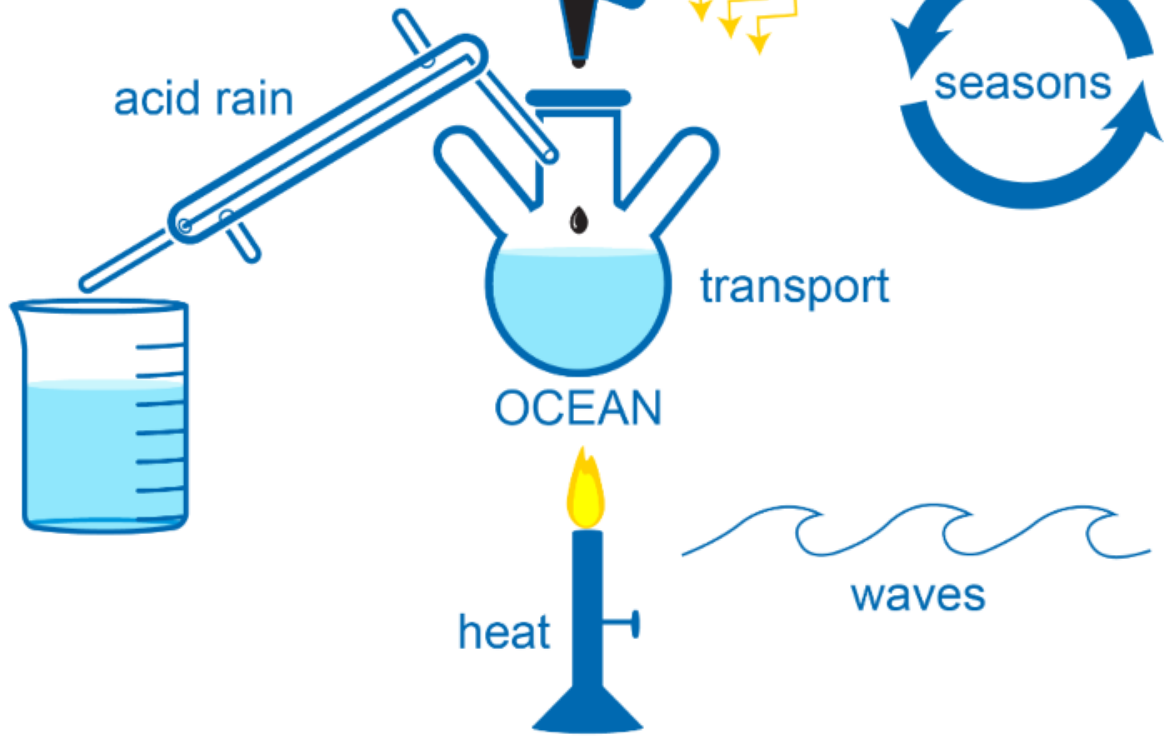
REALITY





POLLUTANT

concentration

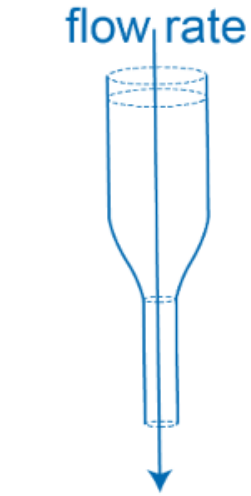


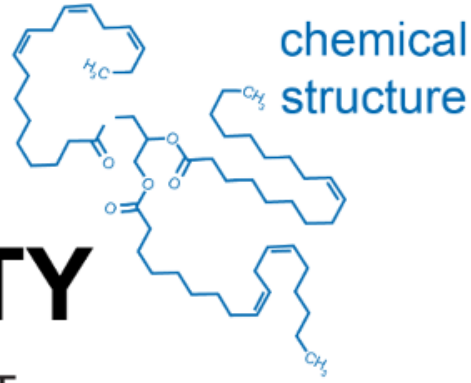
PERCEPTION

POLLUTANT

OCEAN

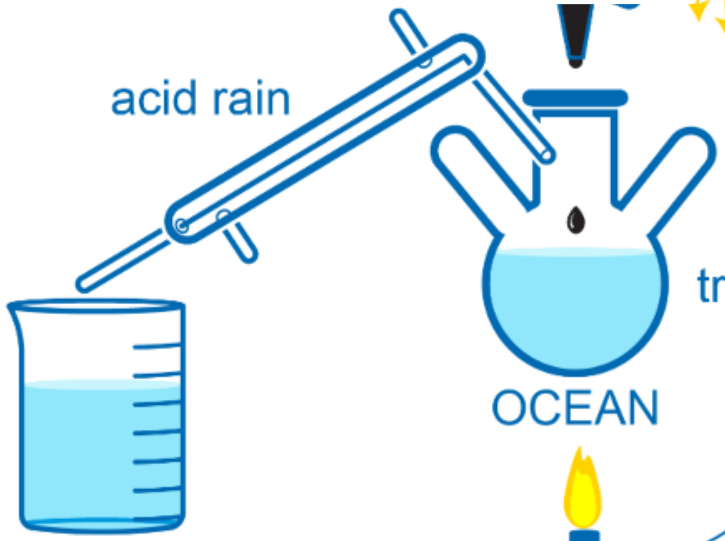
REALITY

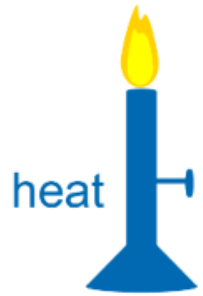


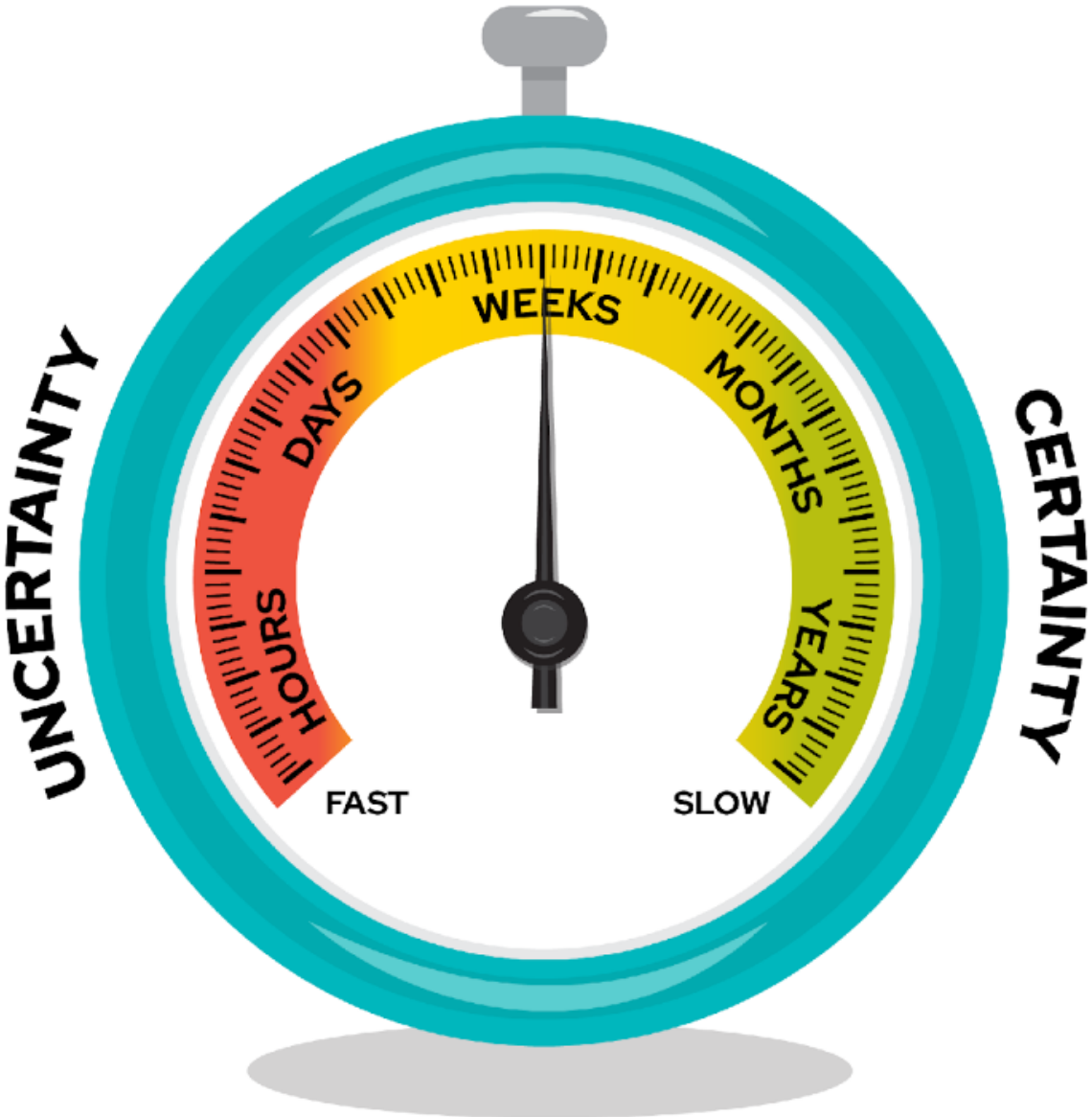


POLLUTANT

+ **pandemic**

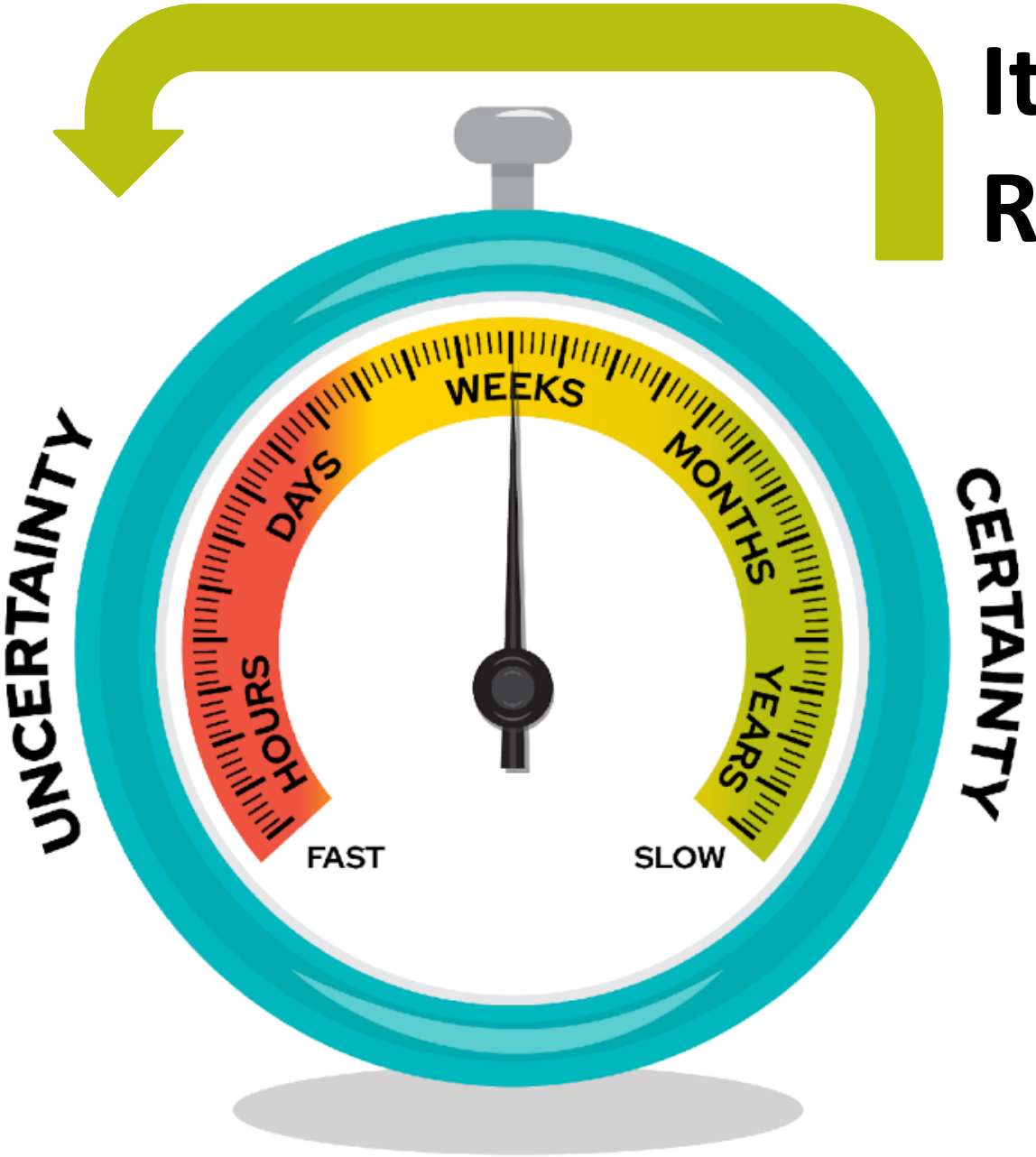






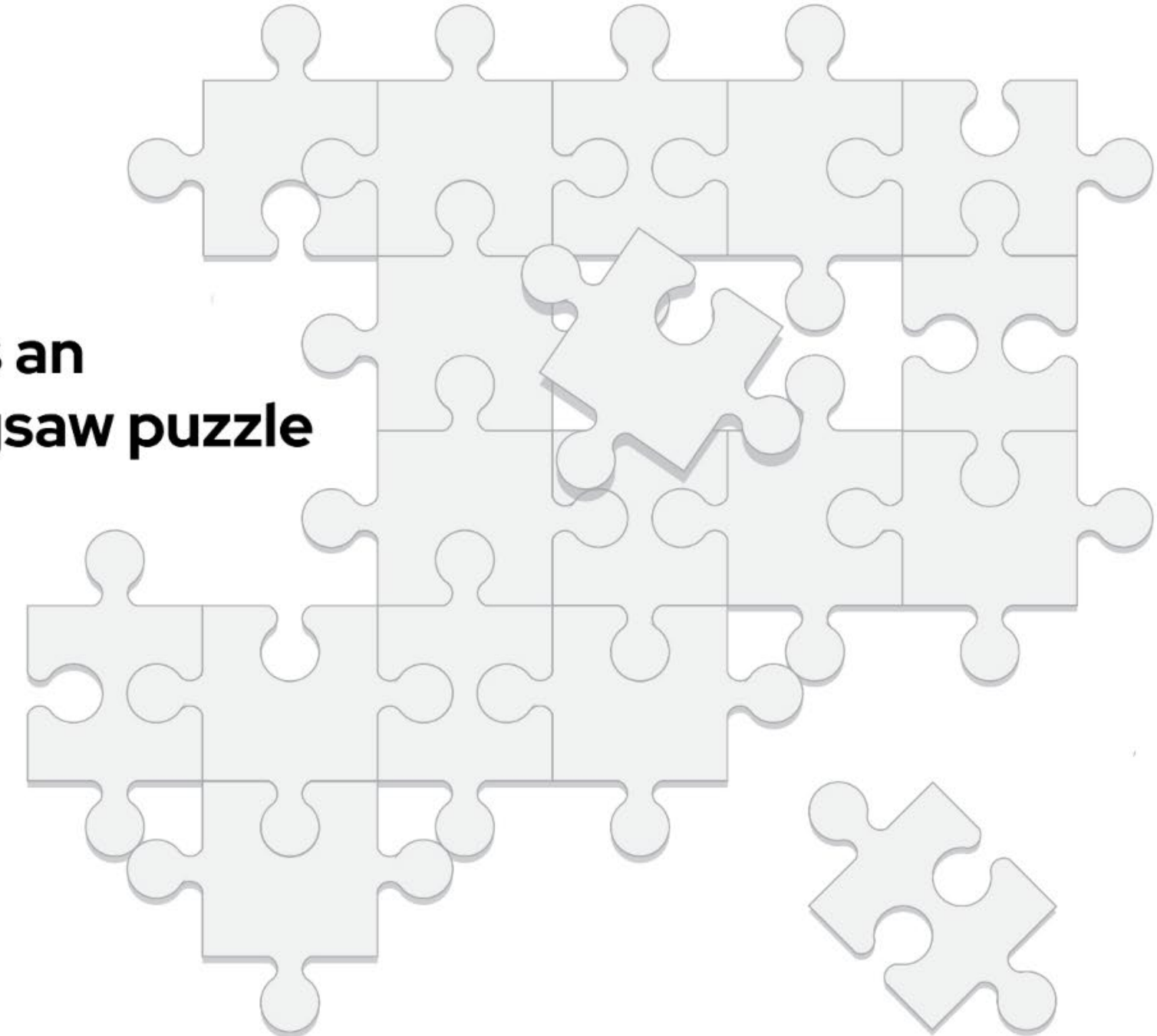
Time Ambiguity Meter

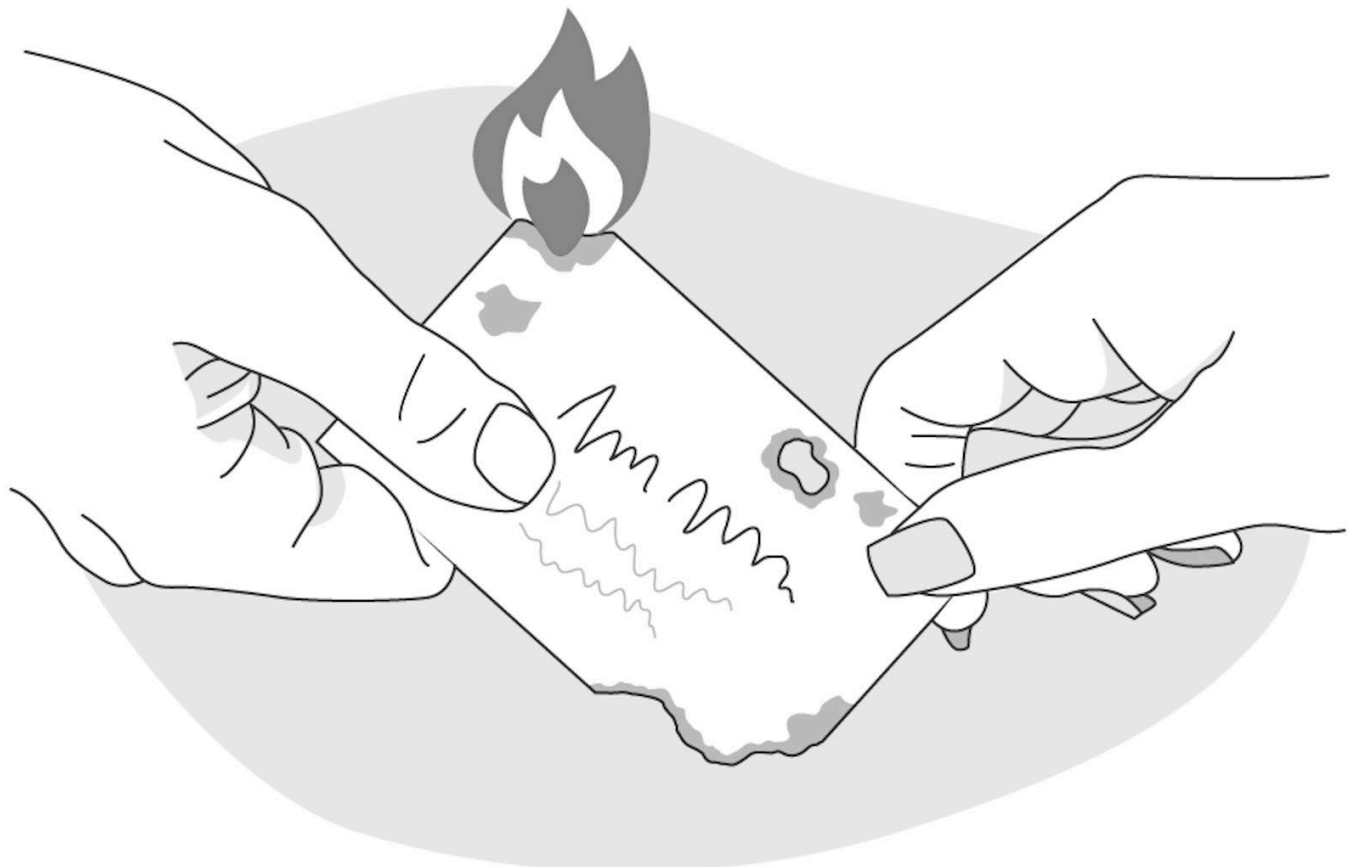
It can
RESET



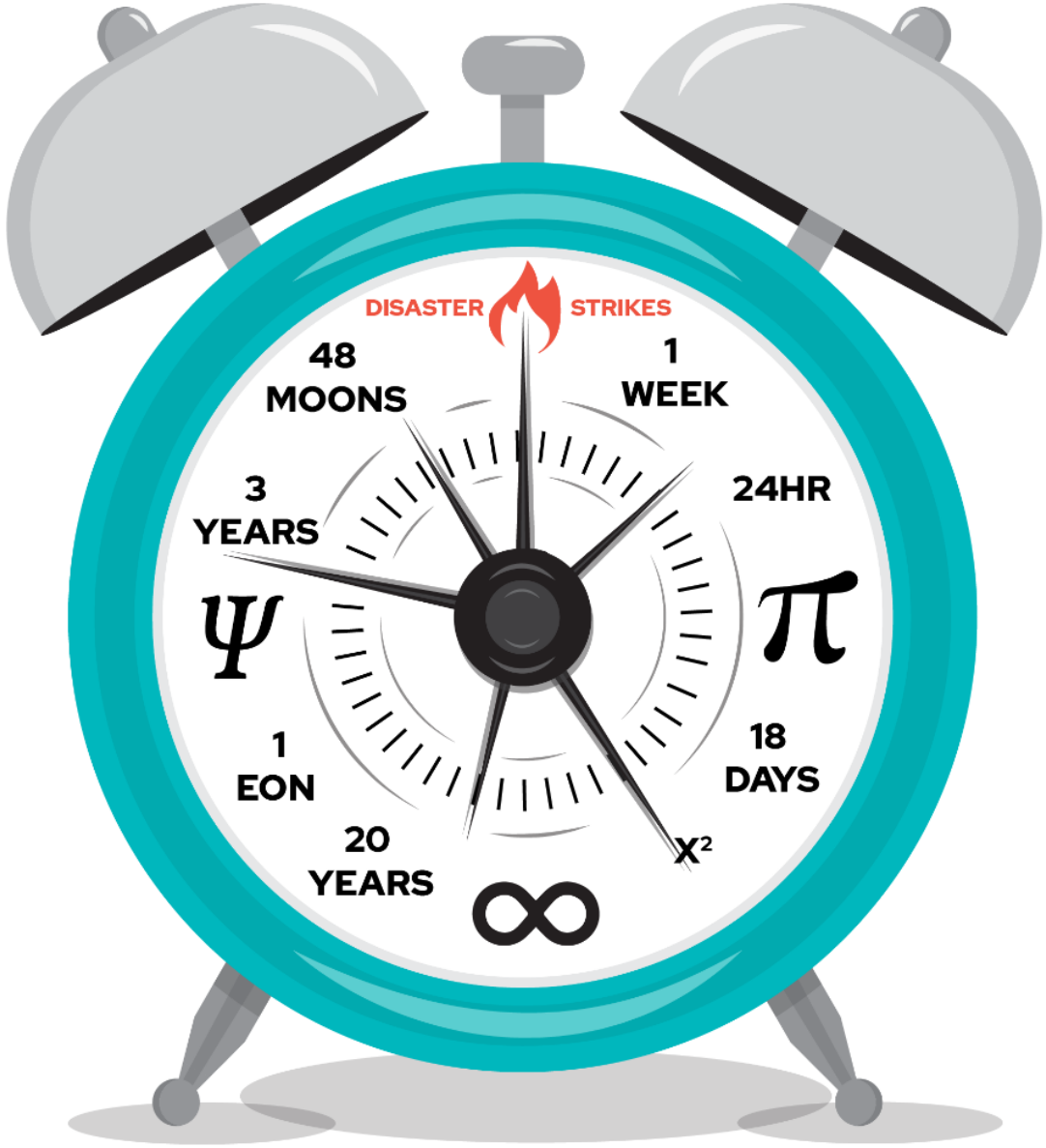
Time
Ambiguity
Meter

Science is an infinite jigsaw puzzle





A crisis is not the time to exchange business cards.



Chaos has its own recovery clock

Science Communication in a Crisis

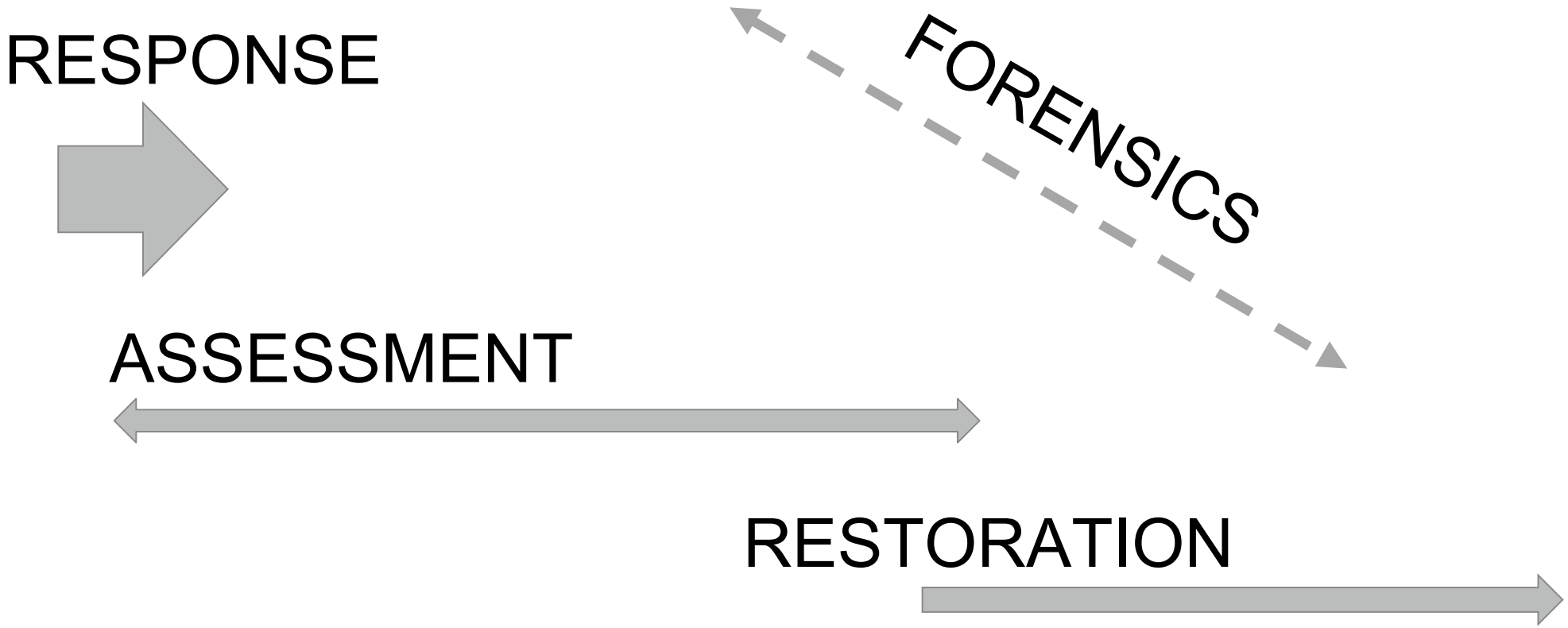
An Insider's Guide

CHRISTOPHER REDDY

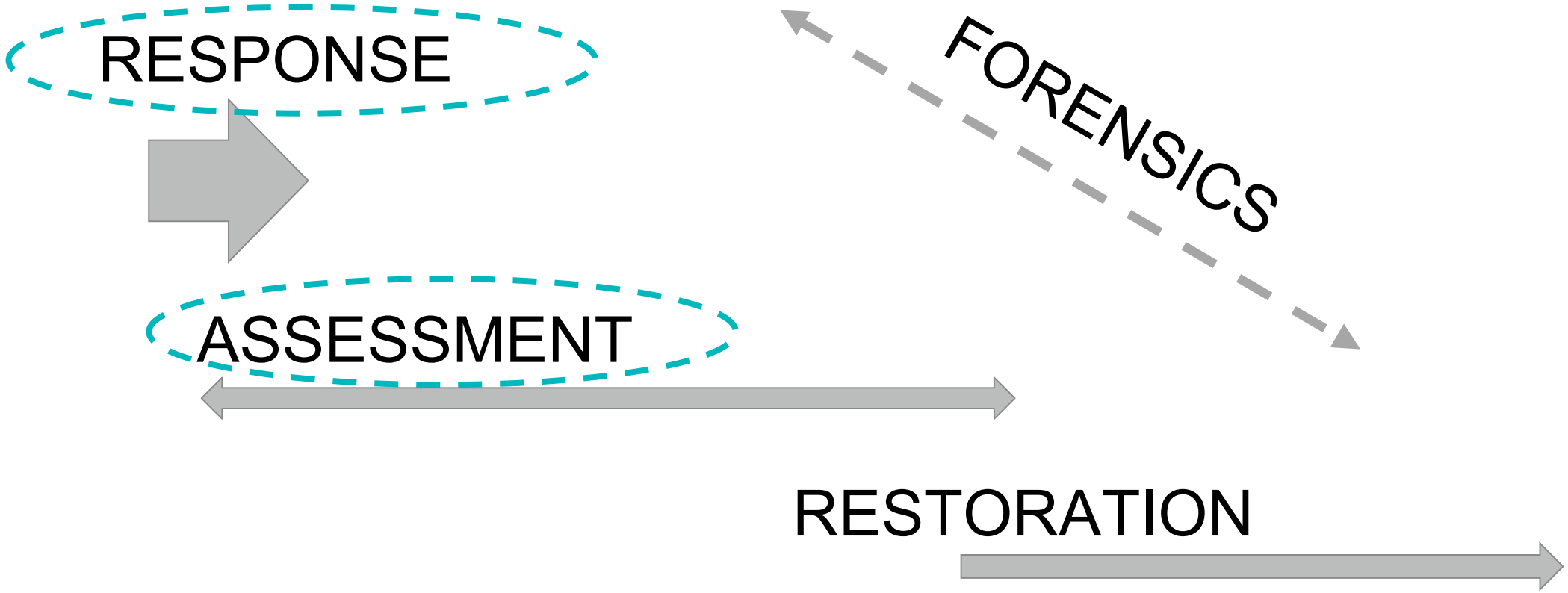
from Routledge

4. Response vs. Damage Assessment

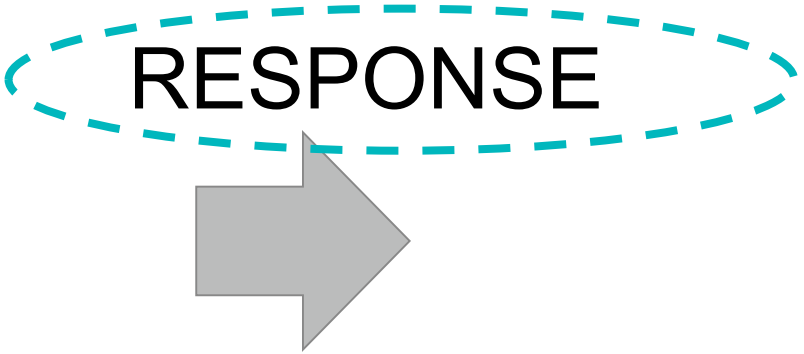
Gross anatomy of a marine incident



Gross anatomy of a marine incident

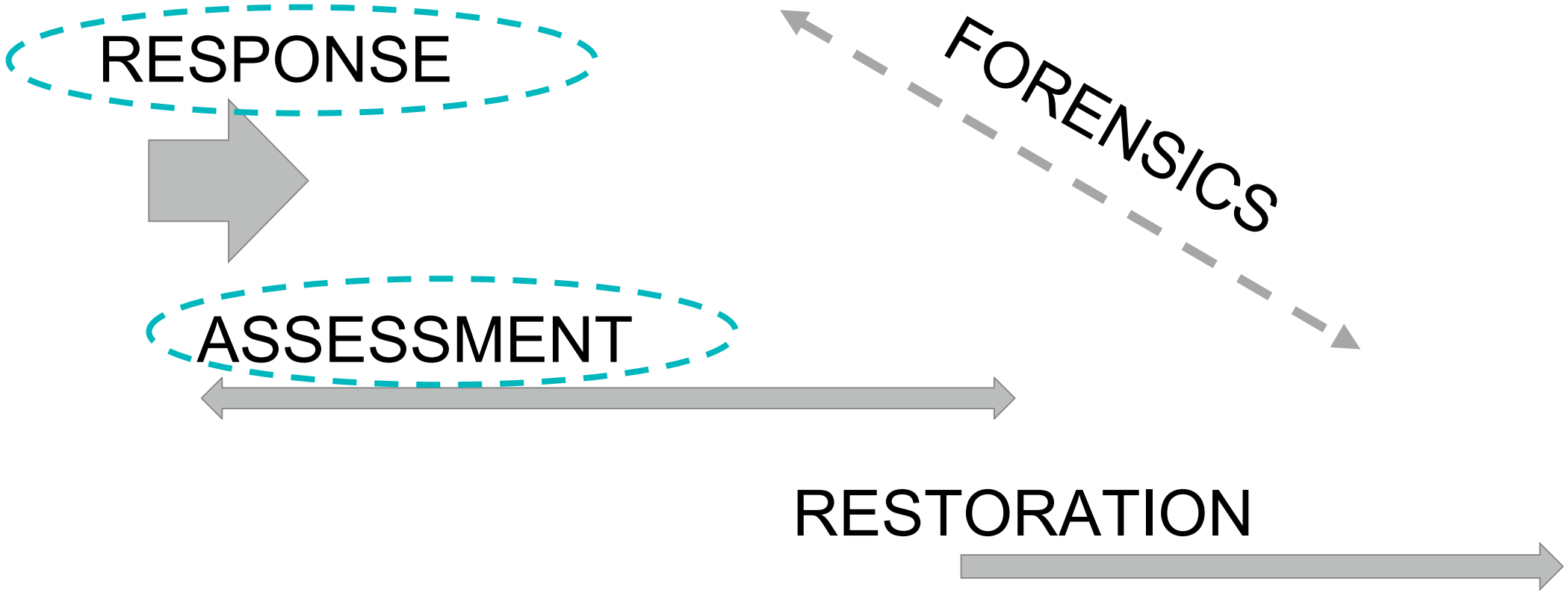


Gross anatomy of a marine incident



RESPONSE
ENDS WHEN
NO LONGER
ACTIONABLE
ACTIVITIES

Gross anatomy of a marine incident



Response science:

Proven

Fast

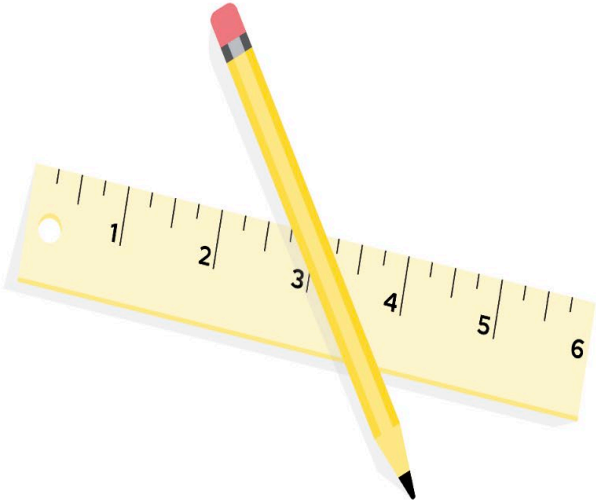
Useful to the response

Low- or high-tech

Less certainty is ok

Get to the right people

Don’t need a PhD



Damage assessment

Robust

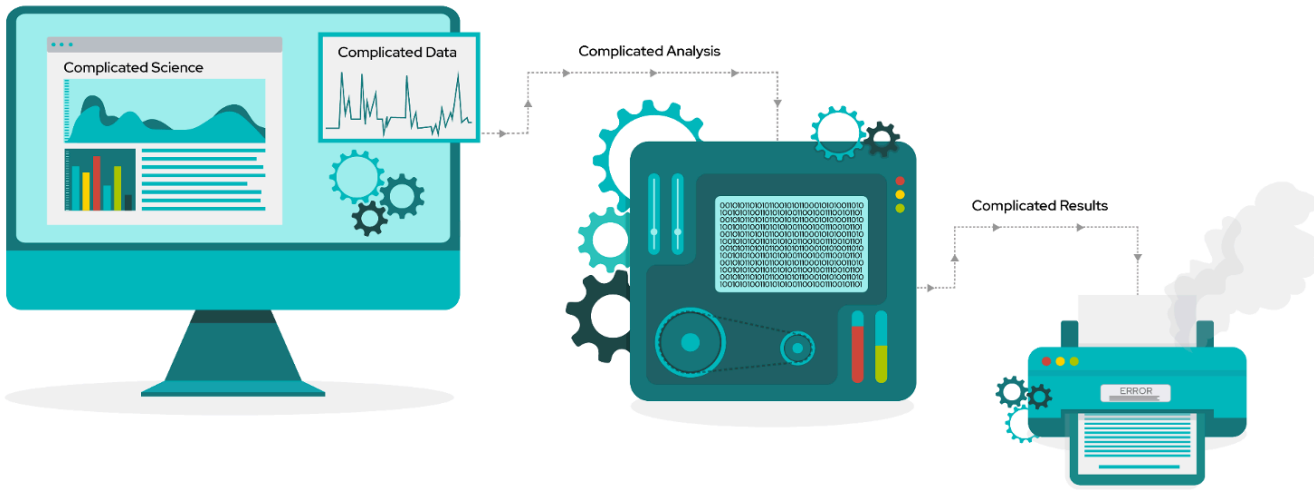
More time

Useful to the response

Low- or high-tech

High certainty

$$$ on the table



You need samples:

Provenance
Storage
Labelled
Hold time

Takeaways

1. Every oil spill is different.
2. Volume, type of oil, and location are the key drivers.
3. “Response”, “forensics”, and “damages” science are different.
4. Pre-existing relationships will lead to better outcome.
5. Early predictions on the negative impacts rarely occur.
6. Time and uncertainty paradigms.