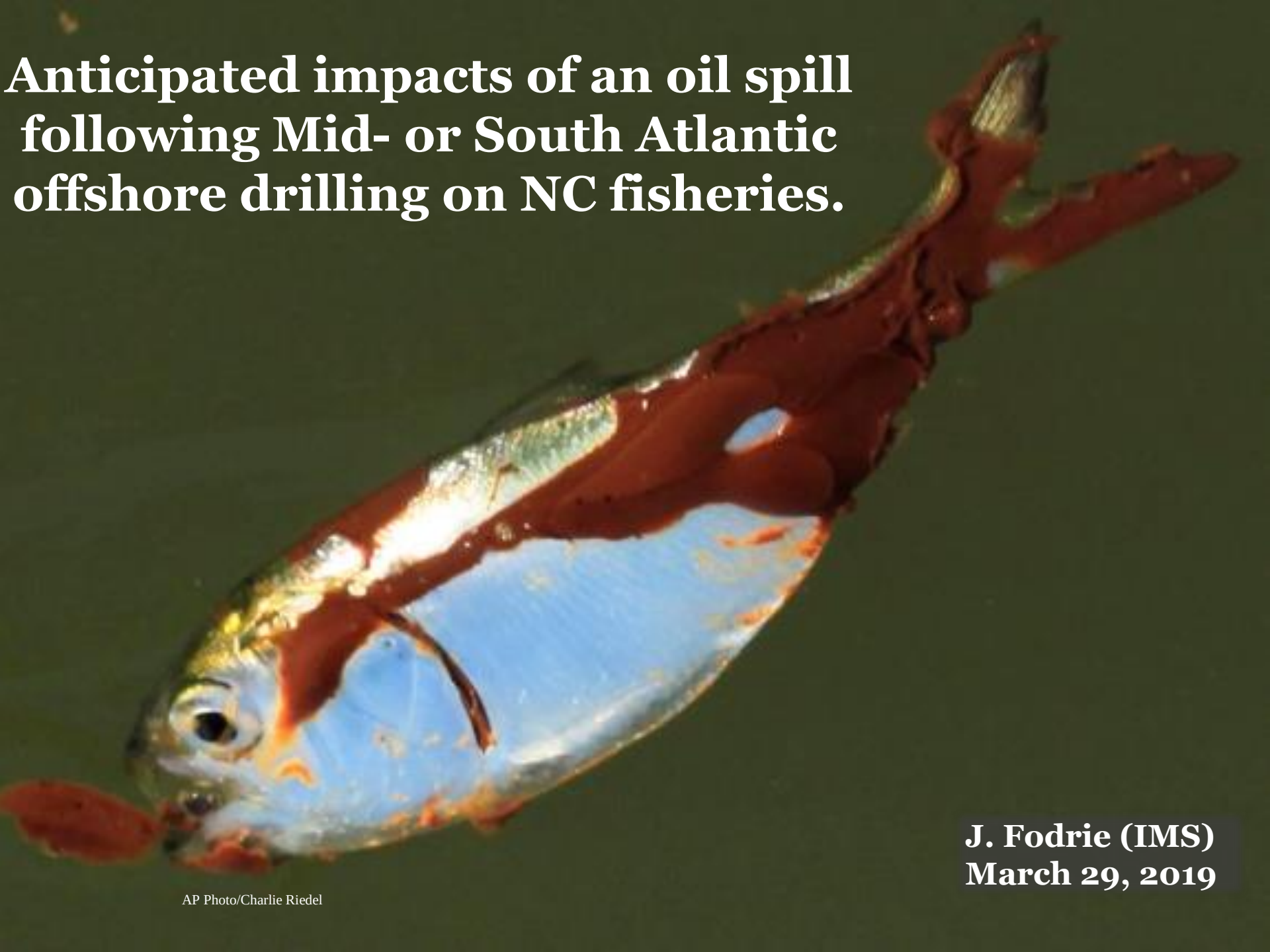
Anticipated impacts of an oil spill following Mid- or South Atlantic offshore drilling on NC fisheries.



AP Photo/Charlie Riedel

J. Fodrie (IMS)
March 29, 2019

"Commercial fishermen, [redacted], noted that commercial fishing has an economic impact of $700 million in North Carolina, [which] would be severely affected in the event of a spill." https://www.nccoast.org/2018/03/a-resounding-no-to-offshore-oil-drilling/

Impact of the *Deepwater Horizon* well blowout on the economics of US Gulf fisheries

U. Rashid Sumaila, Andrés M. Cisneros-Montemayor, Andrew Dyck, Ling Huang, William Cheung, Jennifer Jacquet, Kristin Kleisner, Vicky Lam, Ashley McCrea-Strub, Wilf Swartz, Reg Watson, Dirk Zeller, and Daniel Pauly

"The present value of total revenues that would be lost in the **commercial fishing sector** over the next 7 years, due to the DH well blowout, is estimated to be in the range of US$0.5-2.7 billion"

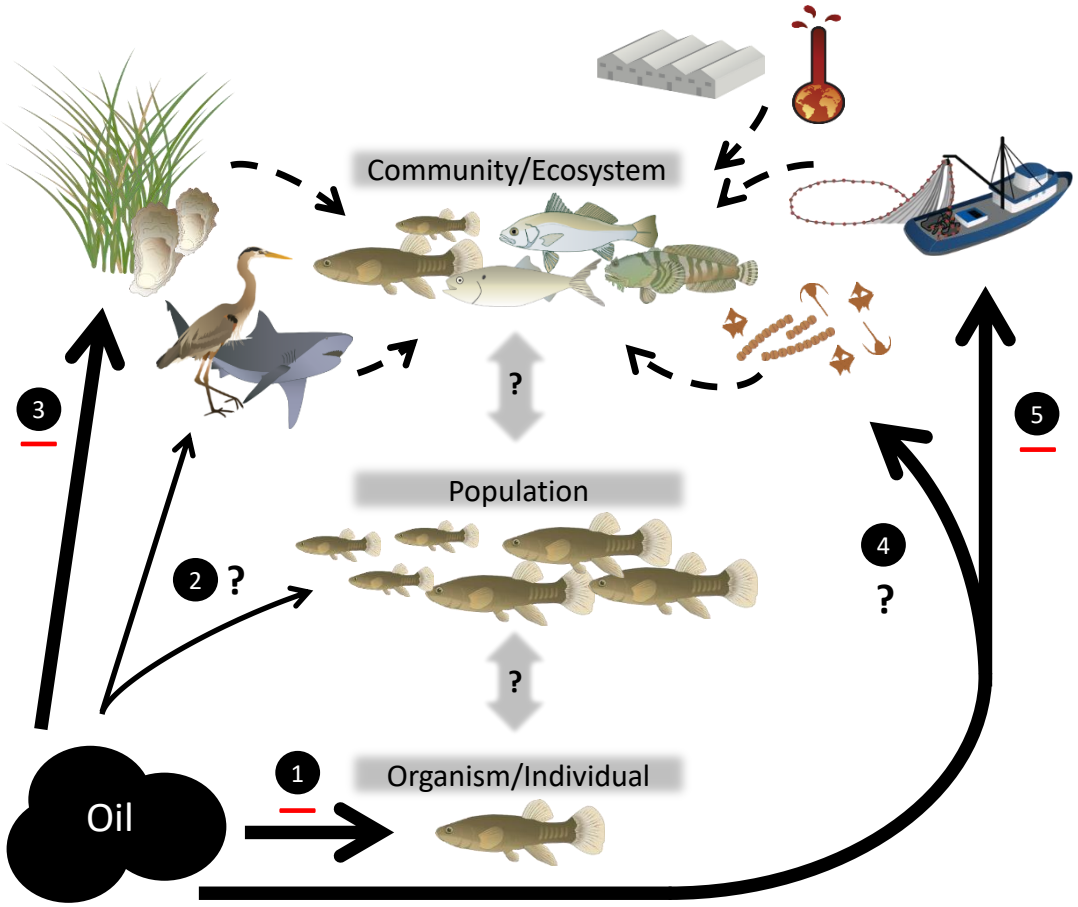
"The present value of losses in the **recreational fishing sector** [is] estimated to be in total revenues" US$1.4-2.4 billion

"For the three **mariculture** states, Florida, Alabama, and Louisiana, the total loss in revenue is estimated to be US$94–157 million"

Deepwater Horizon Spill (2010, 4.4 mb, 84d)

- Emulsified oil droplets could mechanically damage the feeding and breathing apparatus of relatively fragile taxa.
- Toxic PAHs can result in genetic damage, physical deformities and altered developmental timing for fishes.
- Impacts may be induced at very low (~1 ppb PAHs) levels of exposure when persistent over days to weeks.
- Chronic (sub-lethal) impacts.

Integrating studies across multiple hierarchies to understand basin-scale impacts



1. Genomic expression, physiological and developmental penalties
2. Potential mortality, especially during larval and juvenile stages
3. Habitat loss, degradation or alteration
4. Changes in primary production and basal resources
5. Fishery closures

— : Established negative effects of oil

? : Effects of oil are equivocal

: Indicates potential indirect effects of oil (+ other stressors) on fishes

Fodrie et al. 2014 (BioSci)

PNAS

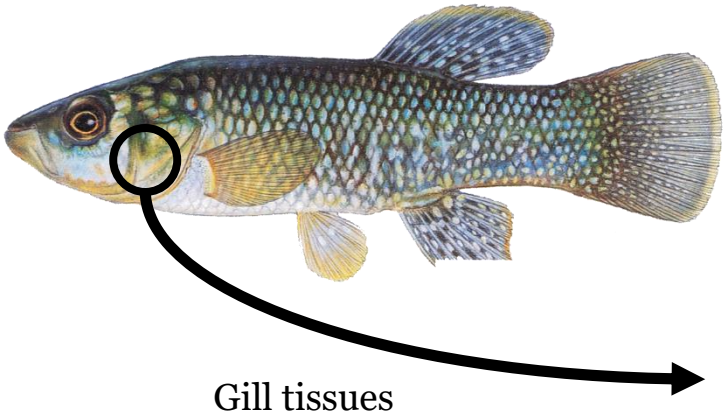
SPECIAL FEATURE

Genomic and physiological footprint of the *Deepwater Horizon* oil spill on resident marsh fishes

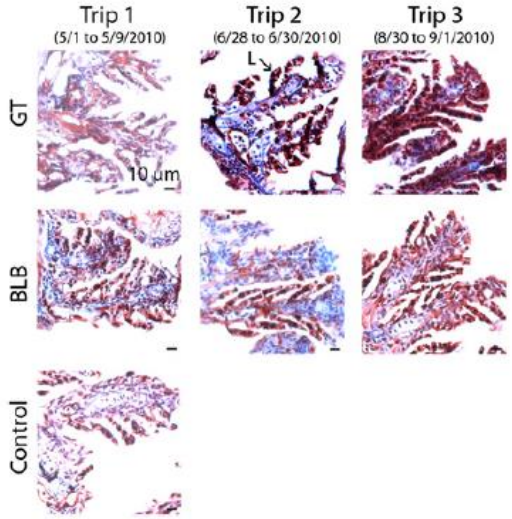
Andrew Whitehead[a,1], Benjamin Dubansky[a], Charlotte Bodinier[a], Tzintzuni I. Garcia[b], Scott Miles[c], Chet Pilley[d], Vandana Raghunathan[e], Jennifer L. Roach[a], Nan Walker[e], Ronald B. Walter[b], Charles D. Rice[f], and Fernando Galvez[a]

Departments of [a]Biological Sciences, [c]Environmental Sciences, and [e]Oceanography and Coastal Sciences, and [d]Coastal Studies Institute, Louisiana State University, Baton Rouge, LA 70803; [b]Department of Chemistry and Biochemistry, Texas State University, San Marcos, TX 78666; and [f]Department of Biological Sciences, Clemson University, Clemson, SC 29634

Edited by Paul G. Falkowski, Rutgers, The State University of New Jersey, New Brunswick, NJ, and approved September 1, 2011 (received for review June 13, 2011)



Gill tissues



Oiled, impaired

Not Oiled, healthy

PNAS

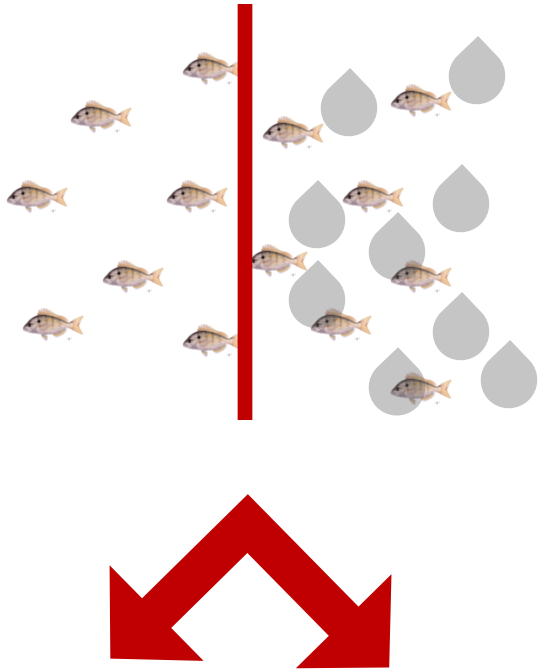
Deepwater Horizon crude oil impacts the developing hearts of large predatory pelagic fish

John P. Incardona[a,1], Luke D. Gardner[b], Tiffany L. Linbo[a], Tanya L. Brown[a], Andrew J. Esbaugh[c], Edward M. Mager[c], John D. Stieglitz[c], Barbara L. French[a], Jana S. Labenia[a], Cathy A. Laetz[a], Mark Tagal[a], Catherine A. Sloan[a], Abigail Elizur[d], Daniel D. Benetti[c], Martin Grosell[c], Barbara A. Block[b], and Nathaniel L. Scholz[a]

[a]Ecotoxicology Program, Environmental Conservation Division, Northwest Fisheries Science Center, National Oceanic and Atmospheric Administration, Seattle, WA 98112; [b]Hopkins Marine Station, Department of Biology, Stanford University, Pacific Grove, CA 93950; [c]Division of Marine Biology and Fisheries, Rosenstiel School of Marine and Atmospheric Sciences, University of Miami, Miami, FL 33149-1098; and [d]Genecology Research Centre, Faculty of Science, Health, Education and Engineering, University of the Sunshine Coast, Maroochydore DC, QLD 4558, Australia

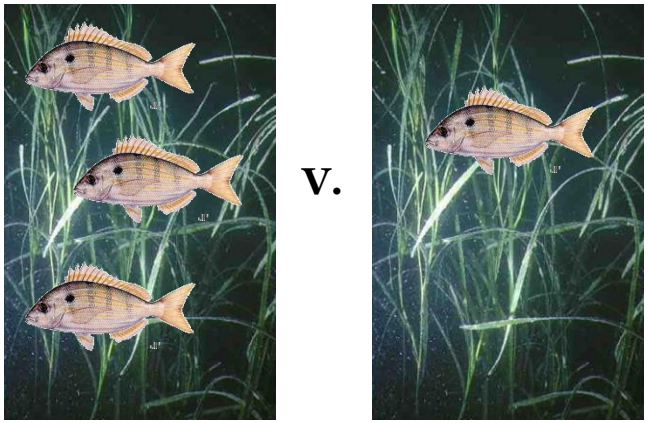
Are these effects apparent at population levels?

- Juvenile abundances are integrated products of early egg fertilization, larval survival, and settlement success.
- Juveniles aggregate in specialized nursery habitats, making sampling tractable.
- **Effects of oil pollution on early life stages should be detectable in time series data as shifts in the abundance of juvenile fishes.**
- CI, BACI, GLR approaches in literature



Pre-spill, or control site

Post-spill, or impact site



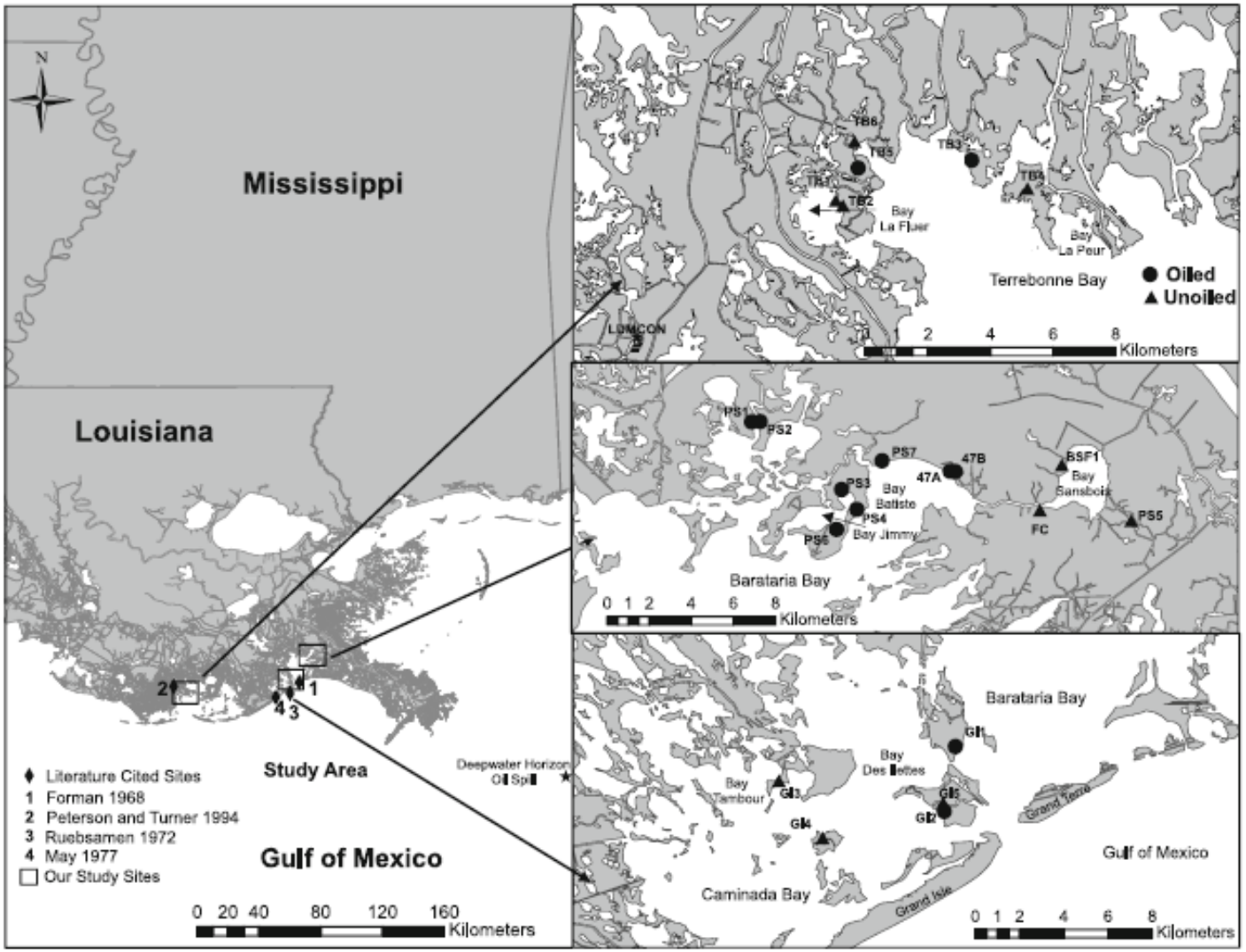
Species-by-species catch rates high in 2010 in seagrass nurseries

Scientific name	2006-09 CPUE	2010 CPUE	*P* (df = 851)	Trend
Lagodon rhomboides	644.9	1379.3	<0.001	↑
Eucinostomus spp.	119.9	60.2	0.086	NC
Bairdiella chrysoura	123.1	163.8	0.117	NC
Orthopristis chrysoptera	80.3	118.7	0.007	↑
Lutjanus griseus	23.6	43.0	0.003	↑
Stephanolepis hispidus	12.0	70.6	<0.001	↑
Lutjanus synagris	14.8	19.2	0.171	NC
Cynoscion nebulosus	13.4	36.5	<0.001	↑
Syngnathus spp.	11.6	20.1	0.057	NC
Chilomycterus schoepfi	7.4	18.6	<0.001	↑
Leiostomus xanthurus	4.6	2.6	0.533	NC
Opsanus beta	2.7	6.6	<0.001	↑
Arius felis	2.6	10.1	0.021	↑
Nicholsina usta	2.1	6.9	0.003	↑
Sphoeroides spp.	2.3	2.2	0.974	NC
Blenniidae	2.1	5.3	0.002	↑
Mycteroperca microlepis	2.0	1.7	0.773	NC
Paralichthys spp.	2.0	2.9	0.133	NC
Archosargus probatocephalus	1.6	5.9	<0.001	↑
Lactophrys quadricornis	1.5	3.2	0.036	↑

N = 167,740 fishes

Fodrie and Heck 2011 (PLoS)

Response of Louisiana marsh fish assemblages to the DHOS

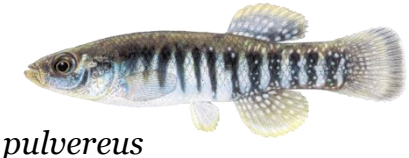


Able et al. 2015 (E&C)

Response of Louisiana marsh fish assemblages to the DHOS

Fundulus grandis

10 cm

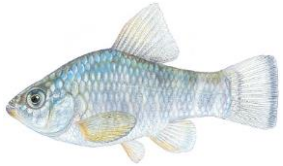


F. pulvereus

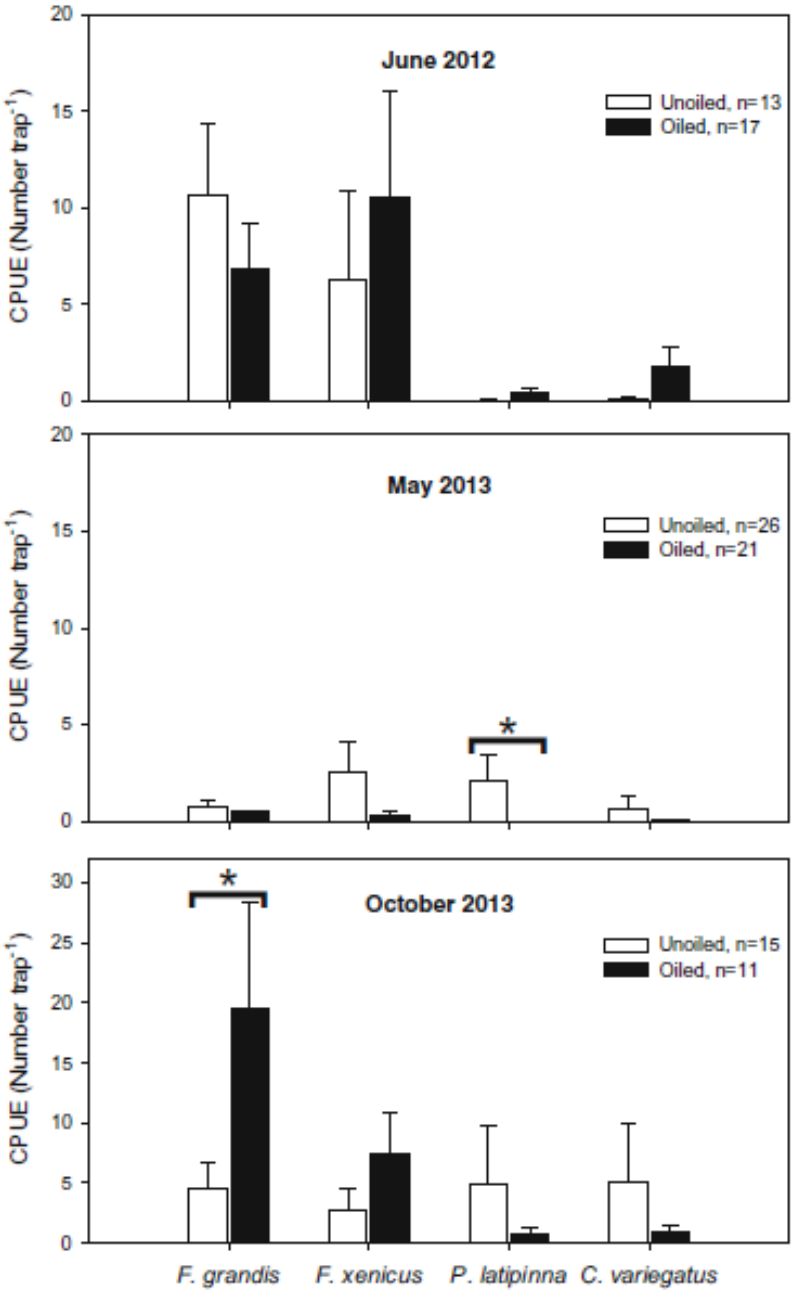
F. jenkensii

Adenia xenicus (*F. xenicus*)

Poecilia latipinna



Cyprinodon variegatus



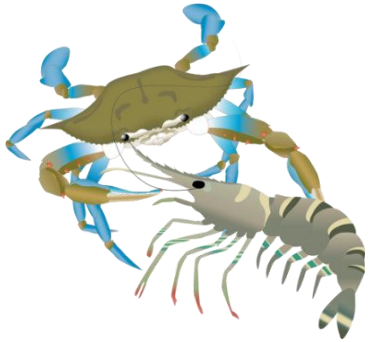
Illustrations by Joseph R. Tomelleri in "Fishes of Alabama"

Able et al. 2015 (E&C)

View of impact depends on approach

✗ ORGANISMS: 24 published studies (mostly lab); 13 species; genomic, physiological, developmental, reproductive, or survival costs in ~**97%** of cases

✓ POPULATIONS: 6 published studies (CI, BACI, etc.); >120 species; stable (or increasing) populations in >**99%** of cases

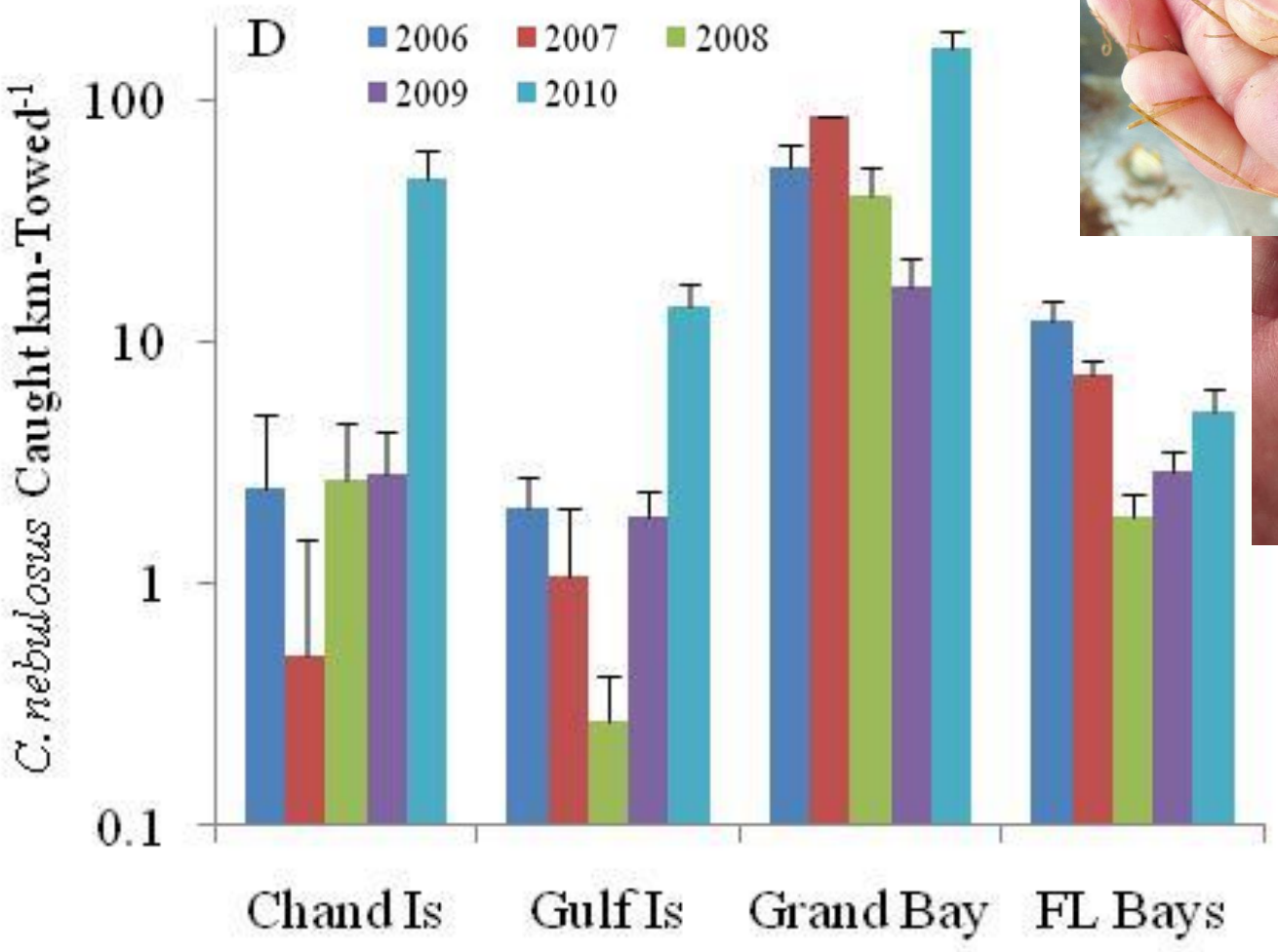


ian.umces.edu/symbols

5 ORGANISMAL studies (**80%** ↓), 3 POPULATION survey studies (**80%** =): **SAME DICHOTOMY**

Fodrie et al. 2014 (BioSci)

Reconciling organismal- and population-level results: 2010 fishery closures



Fodrie and Heck 2011 (PLoS)

Economic response to disasters

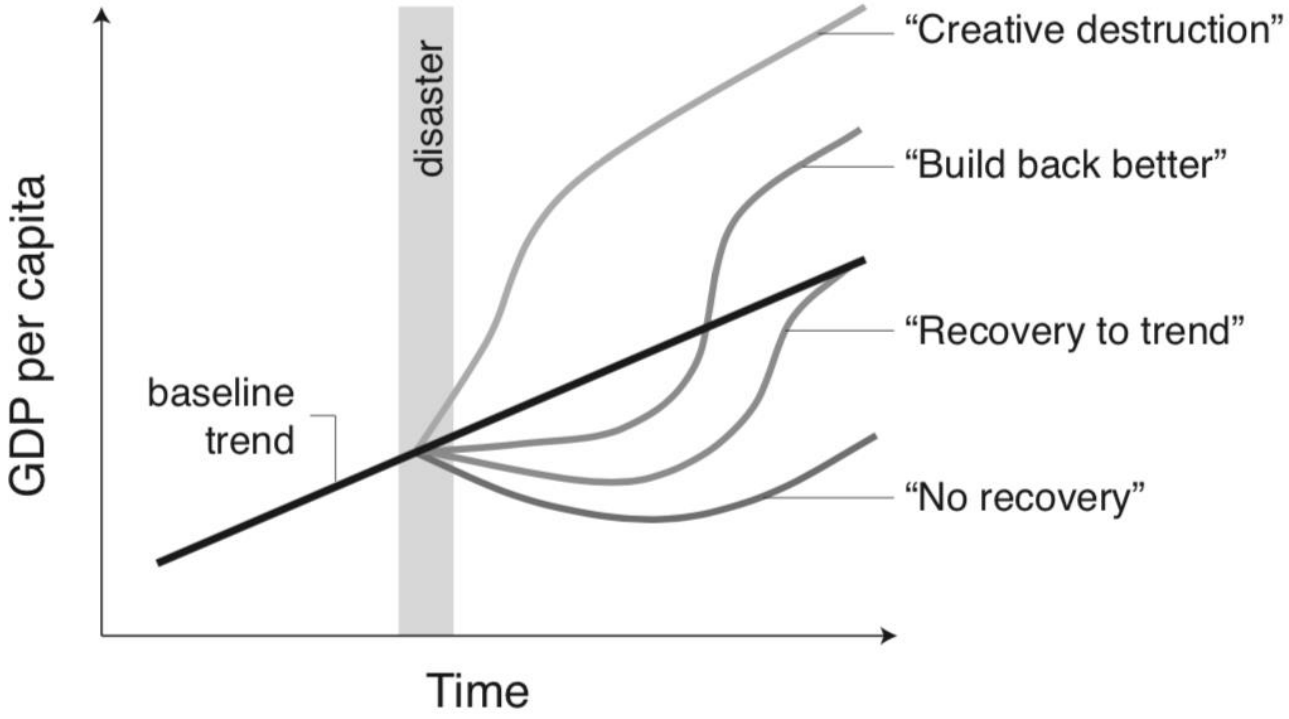
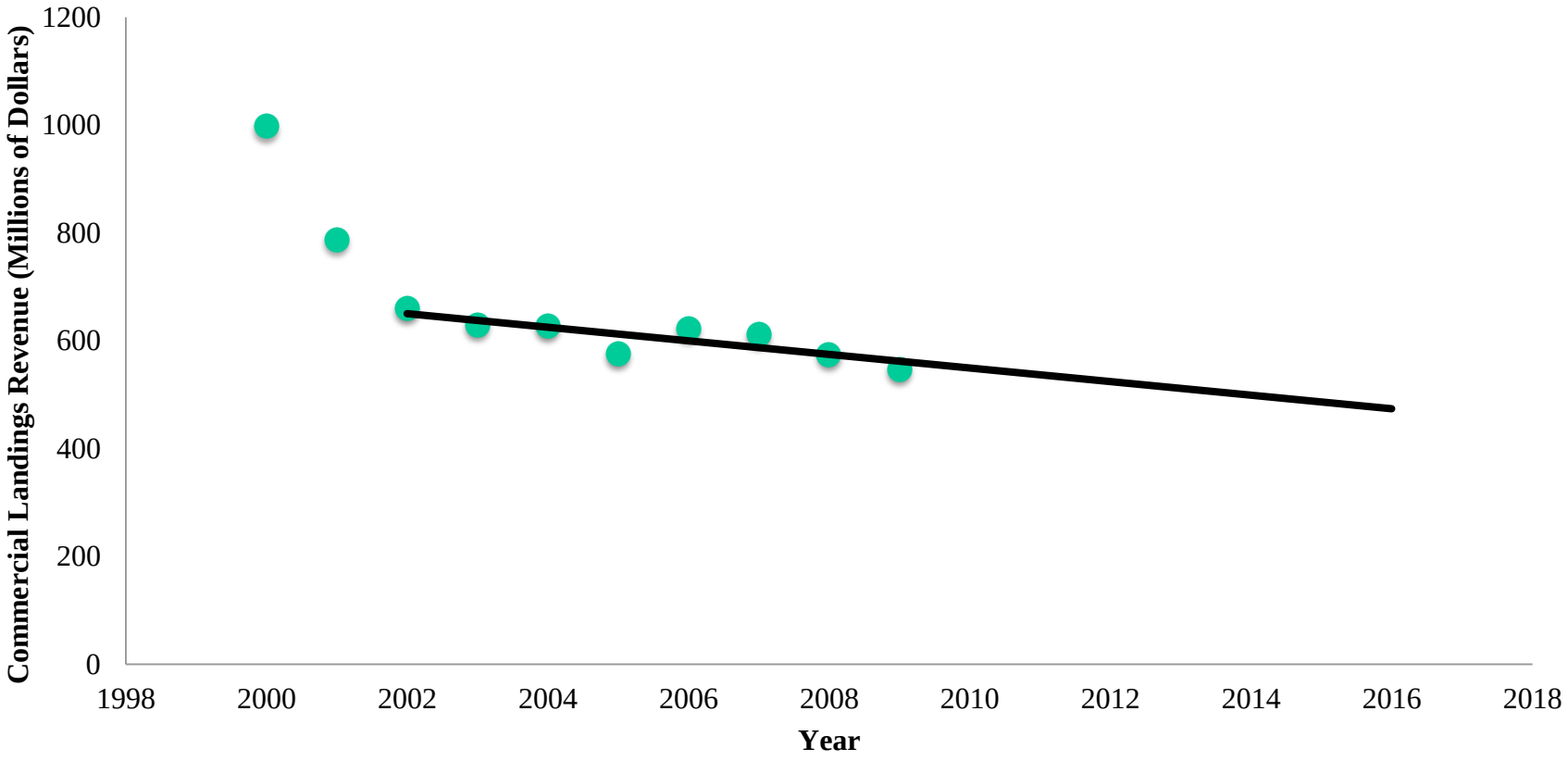


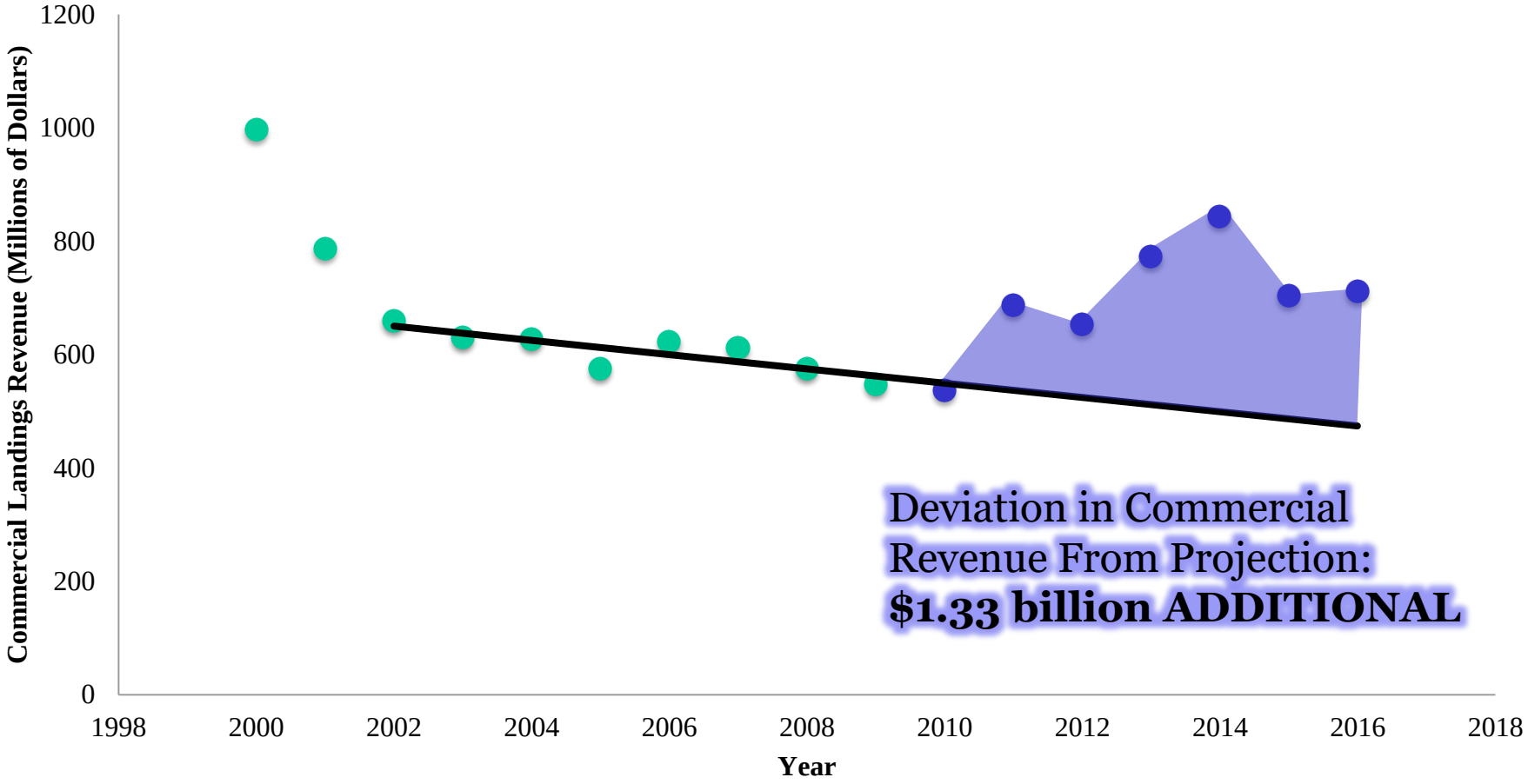
Figure 1: Four hypotheses, proposed in the literature, that describe the long-term evolution of GDPpc following a natural disaster.

Hsiang and Jina 2014

Total Commercial Revenue in the Gulf of Mexico



Total Commercial Revenue in the Gulf of Mexico



- essentially no effect on **recreational** fisheries
- potential negative effect on **shellfish mariculture** (Mississippi)

If the GOM is representative, data suggest fisheries systems may possess resilience to oil pollution

Acknowledgements

- K Able, F Galvez, K Heck, O Jensen, P Lopez-Duarte, C Martin, M McCann, S Swinea, E Turner, A Whitehead

- Thank you for listening!

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