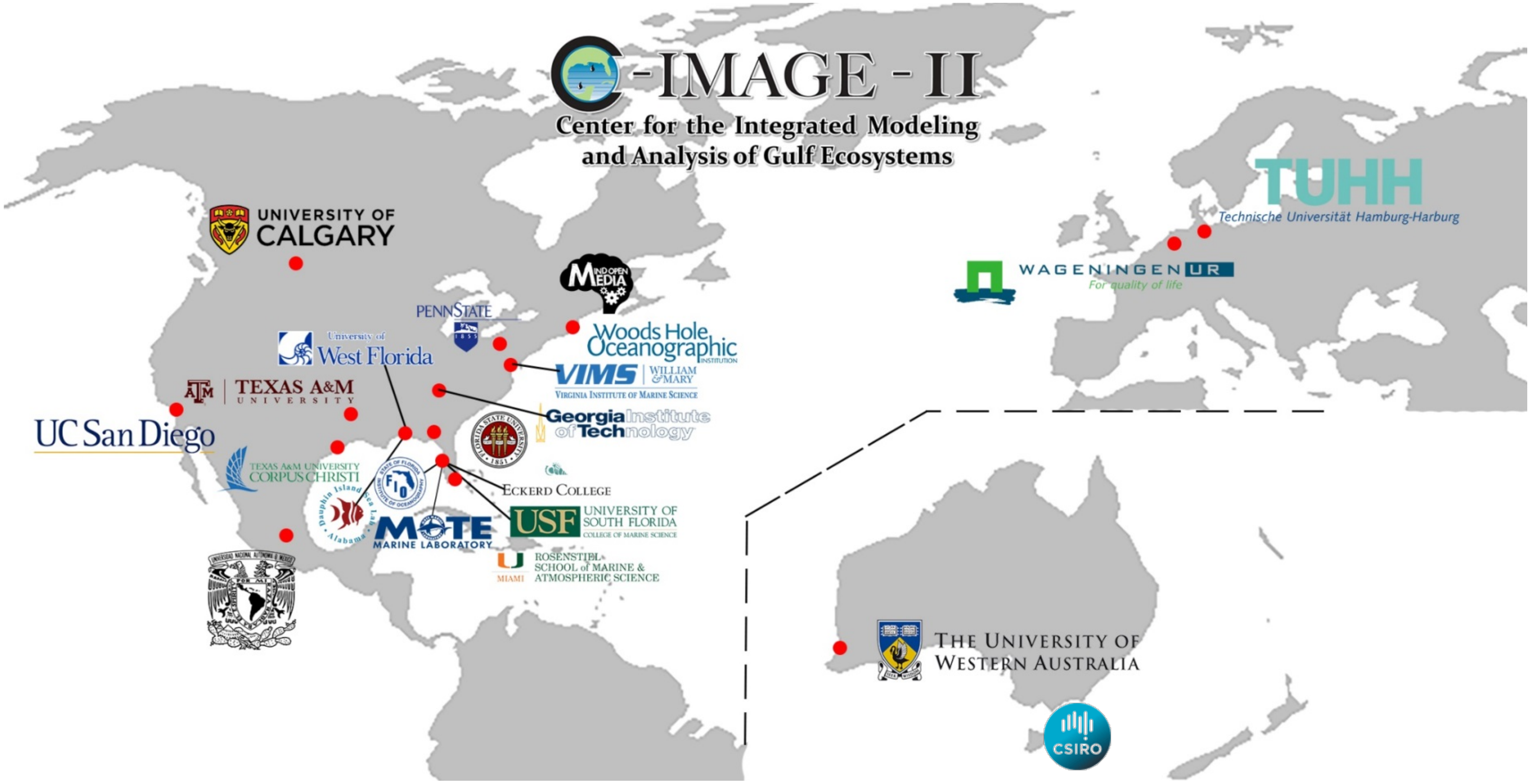
Ecosystem recovery following the DWH oil spill evaluated using an end-to-end model

Cameron Ainsworth, Michelle Masi, Lindsey Dornberger, Michael Drexler, Holly Perryman
University of South Florida
College of Marine Science

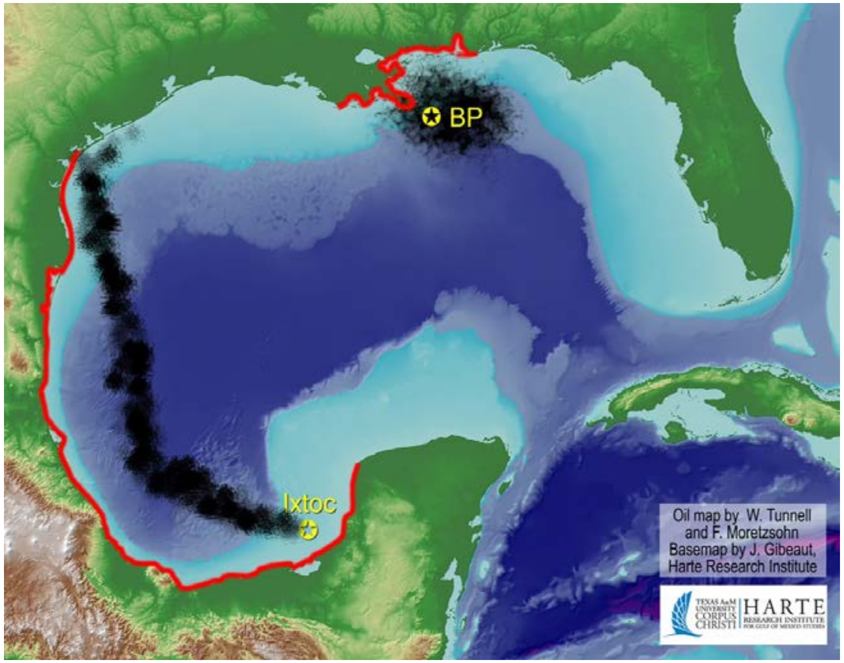
CIMAGE II

- Funded by the Gulf of Mexico Research Initiative since late 2011
- One of 15 funded centers nationwide, one of five in Florida
- 20 academic institutions in seven states and six countries



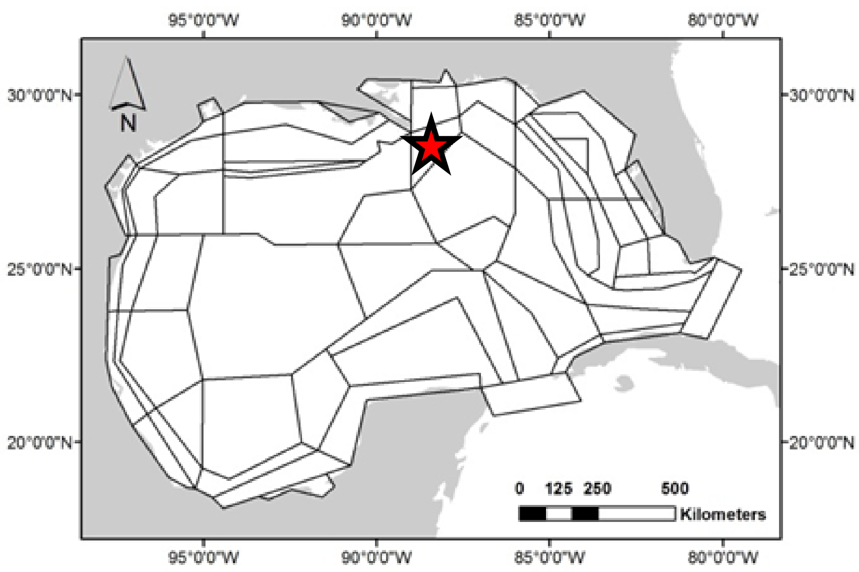
Modeling objectives

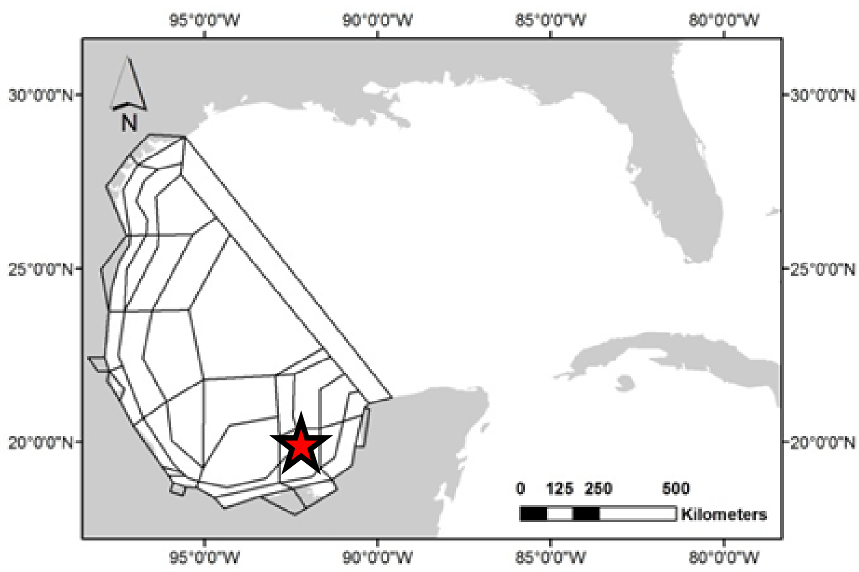
- Impacts:
    - Fisheries value
    - Fish community structure
    - Ecosystem biodiversity
    - Recovery time
- Evaluate impact of mitigation decisions (fisheries closures and dispersants)
- Socioeconomic analysis
- Evaluating in parallel DWH (2010) and IXTOC I (1979) oil spills



Atlantis summary

- Atlantis Gulf of Mexico model and a SWGOM model
- Major methodological papers so far on biomass distributions (2), diet matrix (2), larval connectivity, and oil dose-response
- 3D Irregular polygon geometry for computational efficiency



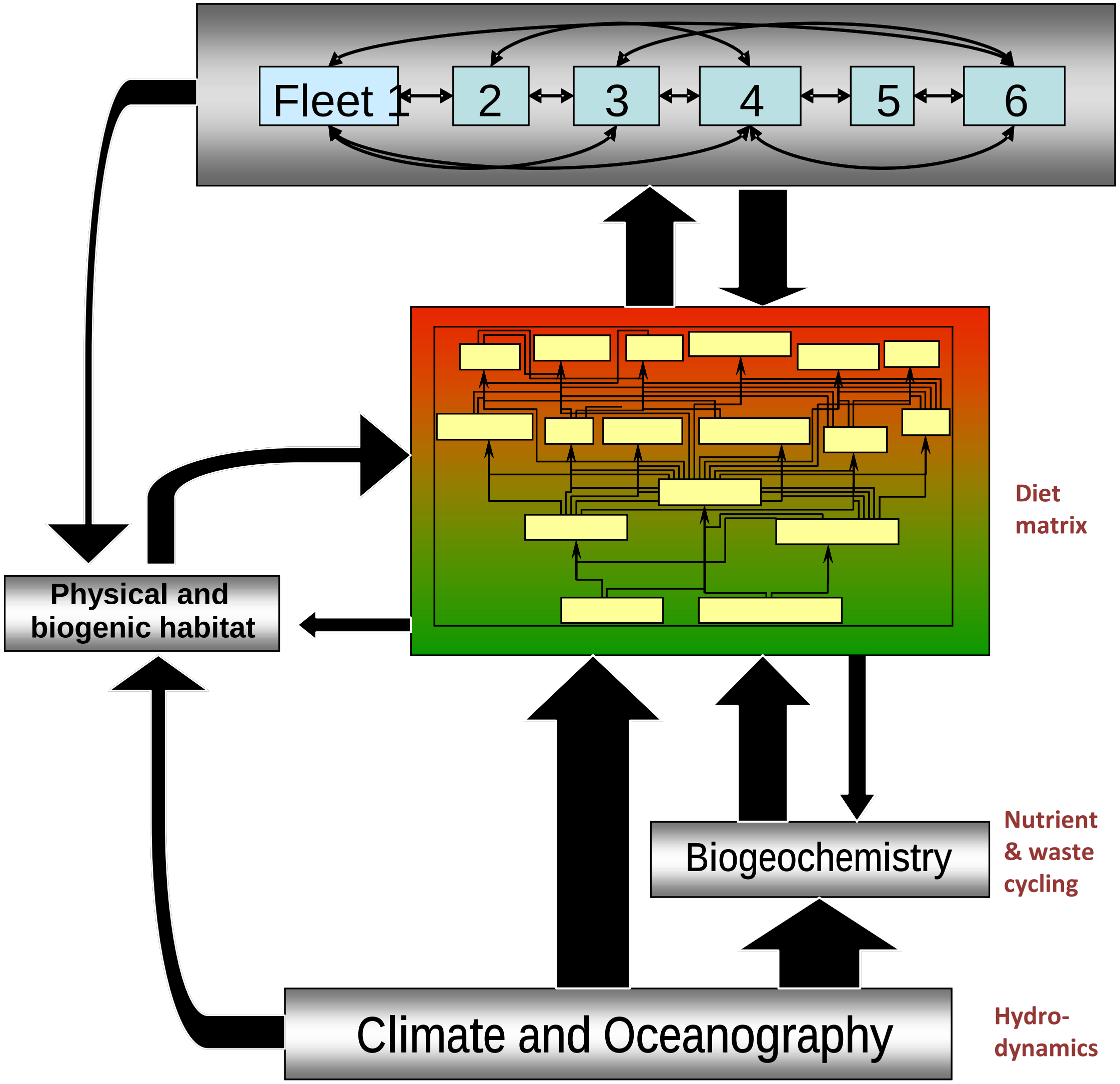


Model architecture

- Bacteria to apex predators (“end-to-end”)
- Ocean chemistry & physics (1° coupling to GOM HYCOM, NCDDC)
- 12 hour time step

Features

- Age structured
- Larval transport
- Biogenic & physical habitat associations
- Nutrient and waste cycling
- Fisheries accounting



Fulton, E. A., A. D. M. Smith, and C. R. Johnson. 2004. Biogeochemical marine ecosystem models i: Igbem - a model of marine bay ecosystems. Ecological Modelling 174:267-307.

Food web analysis

Michelle Masi, USF

1st diet study

Gut content analysis

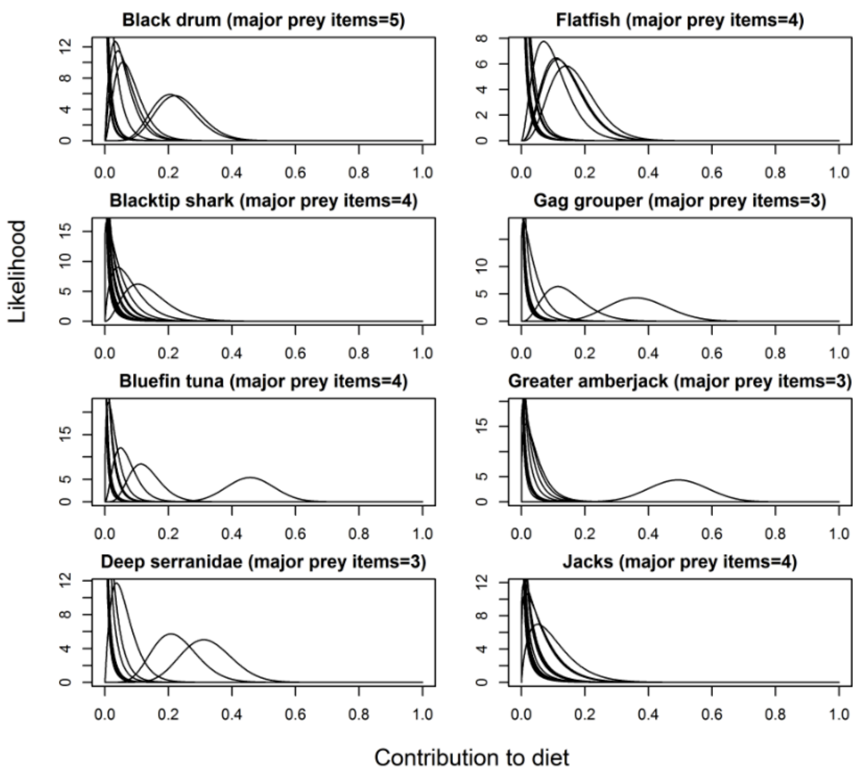
- ~1200 stomachs analyzed
- Some from C-IMAGE longline surveys
- Literature: Fishbase (235 spp.), SeaLifeBase (15 spp.), FWC FWRI (905 spp.)

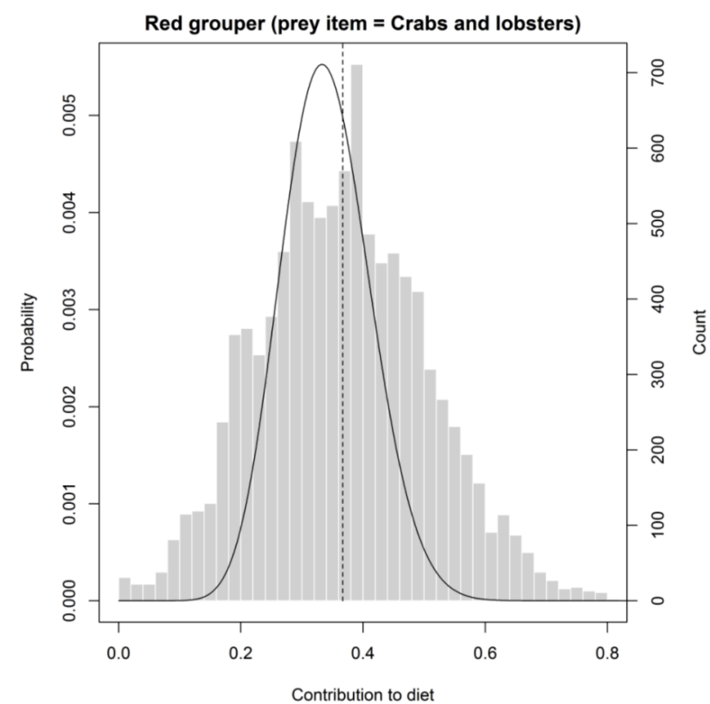
Masi, M., Ainsworth, C.H. and Chagaris, D. (2014). A probabilistic representation of fish diet compositions from multiple data sources: a Gulf of Mexico case study. Ecological Modelling, 284(2014): 60–74.

Food web analysis

Michelle Masi, USF

- Fit to a Dirichlet distribution (multivariate Beta) using MLE
- Provides diet estimates (modes of marginal Beta) and error range
- Diet error now being used in sensitivity analysis of Atlanits (Masi, in prep)





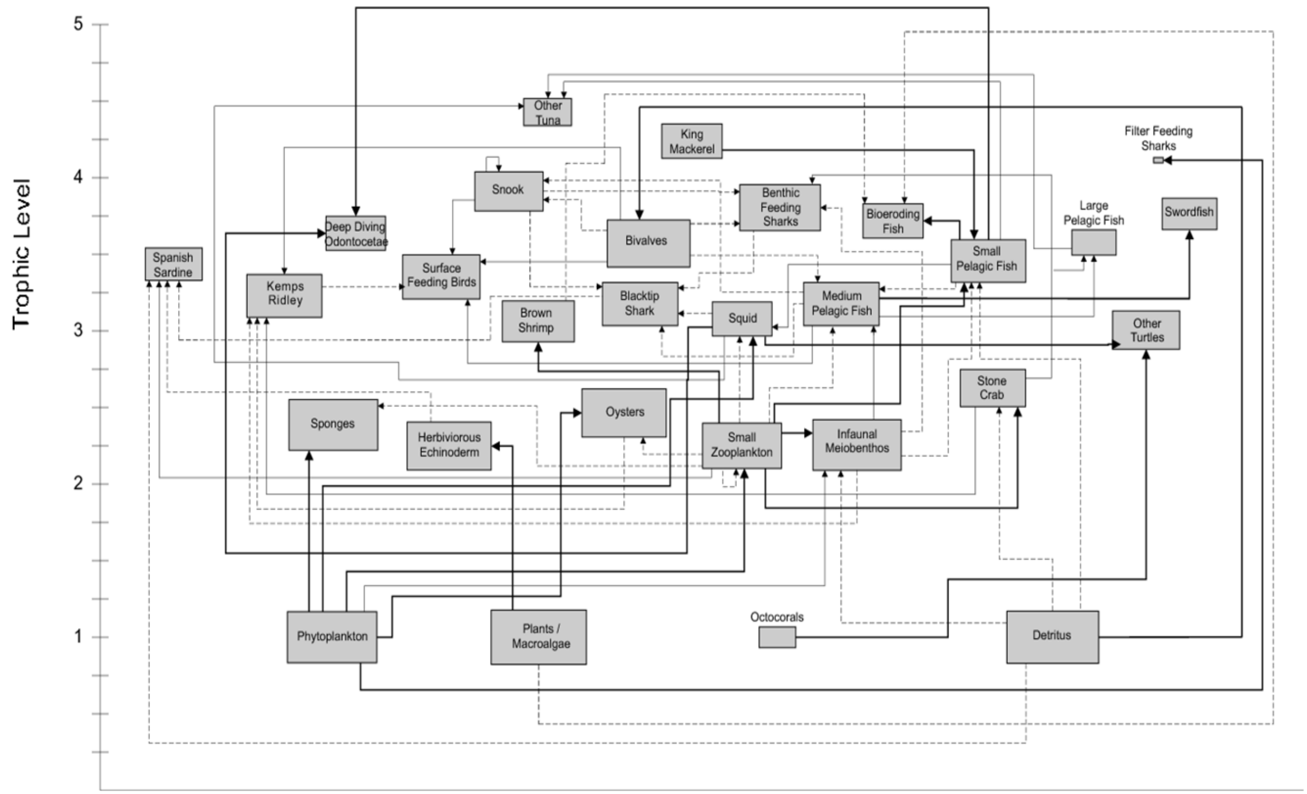
Masi, M., Ainsworth, C.H. and Chagaris, D. (2014). A probabilistic representation of fish diet compositions from multiple data sources: a Gulf of Mexico case study. Ecological Modelling, 284(2014): 60–74.

Food web analysis

Michelle Masi
Joe Tarnecki

2nd diet study

- +1000 additional stomachs (including CIMAGE)
- GOM Trophic Interactions Database (TAMUCC)



Improvement in Atlantis fit

- 2/3rd of groups improved
- 23% reduction in SS
- 28% reduction in bias
- Comparison with 10 published food webs

- Just published last week in Fish. Res.

MARFIN , CIMAGE, FL Sea Grant

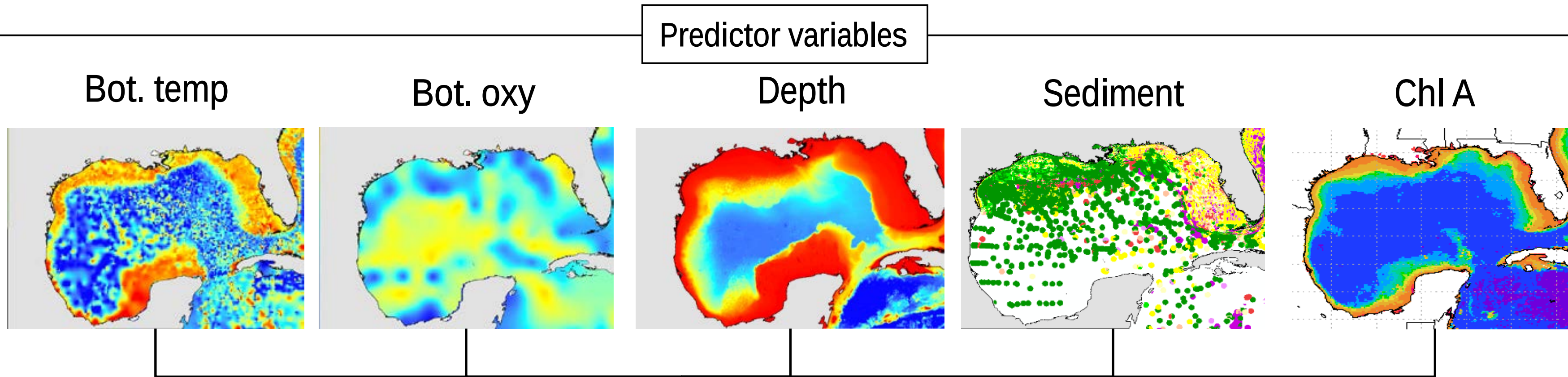
Tarnecki, J., Wallace, A., Simons, J.D. and Ainsworth, C.H. (in press). Progression of a Gulf of Mexico Food Web Supporting Atlantis Ecosystem Model Development. Fisheries Research.

GAM for biomass

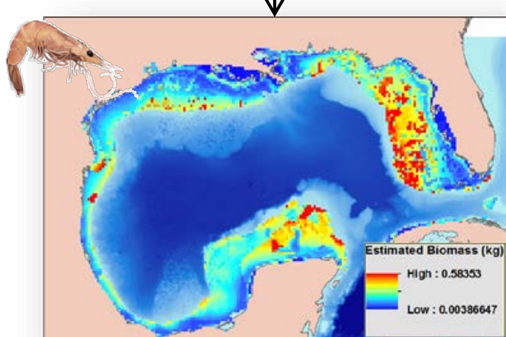
Mike Drexler, USF

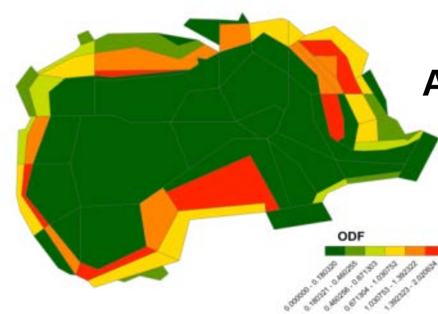
GAM

- Predicting biomass distributions for ~ 50 species groups using generalized additive modeling
- First paper (Drexler) used negative binomial GAM; revision (Gruss) used Delta method



GAM
abundance modeled
w/neg. binomial & log link





Atlantis

Drexler, M. and Ainsworth, C. 2013. PLoS ONE 8(5): e64458. doi:10.1371/journal.pone.0064458.

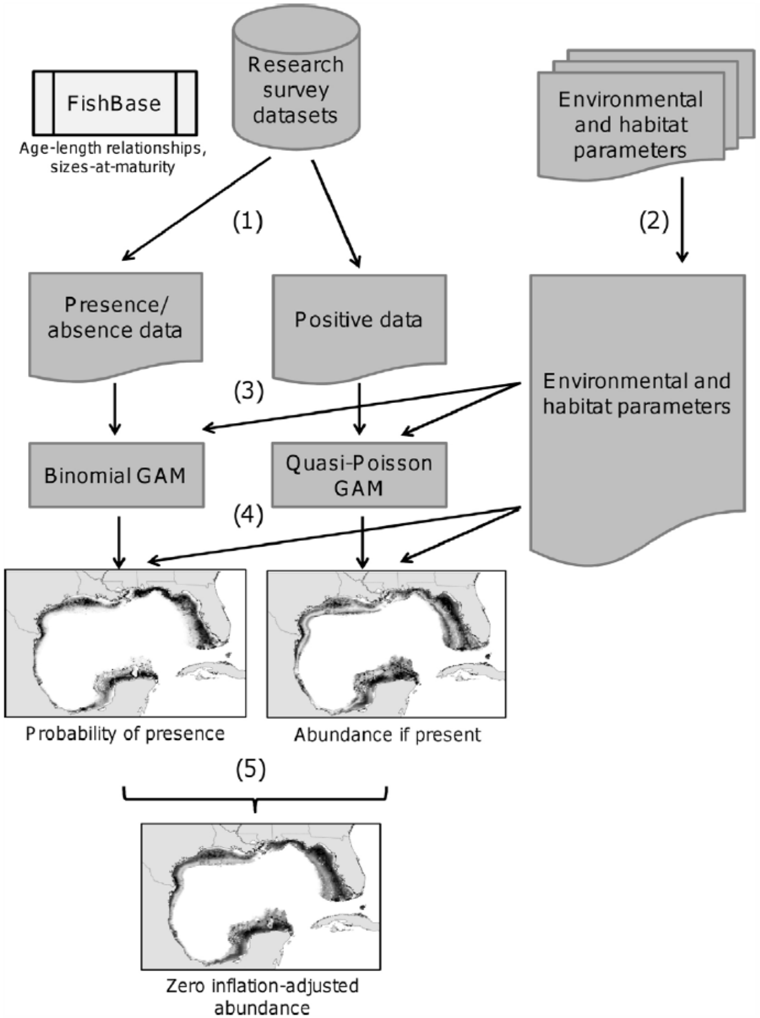
GAM for biomass

Mike Drexler, USF
Arnaud Gruss, UM

$$g\,(\eta) = s(\text{depth}) + s(\text{chl a}) + s(\text{temperature}) + s(\text{DO}) + \textit{factor}\ (\text{sediment type})$$

- η is probability of presence or abundance
- Logit-link/binomial and log-link/quasi-Poisson
- Uses SEAMAP groundfish trawl: includes validation to 1/3 of data set
- Automated model selection
- Methodology has spawned a Restore Act project (UM, Babcock)
- OSMOSE, Ecospace, Atlantis

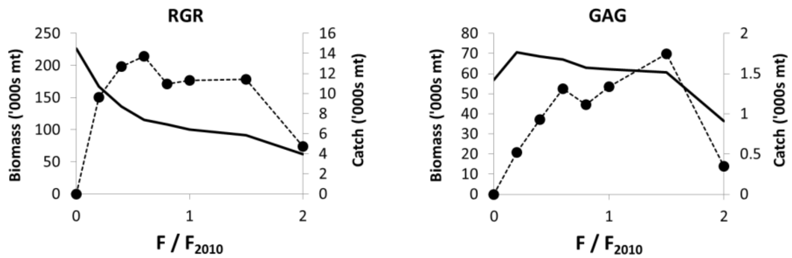
Delta method



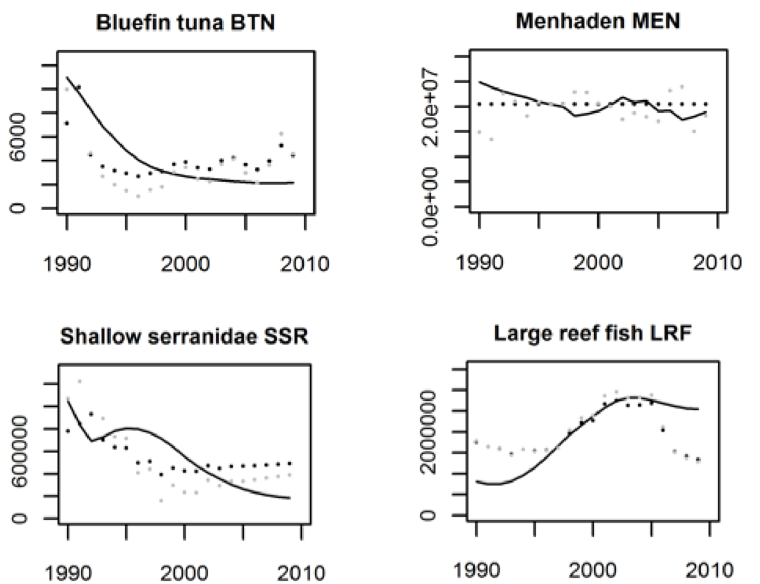
Grüss A, Drexler M., Ainsworth, C.H., 2014. Fisheries Research, 159: 11−24

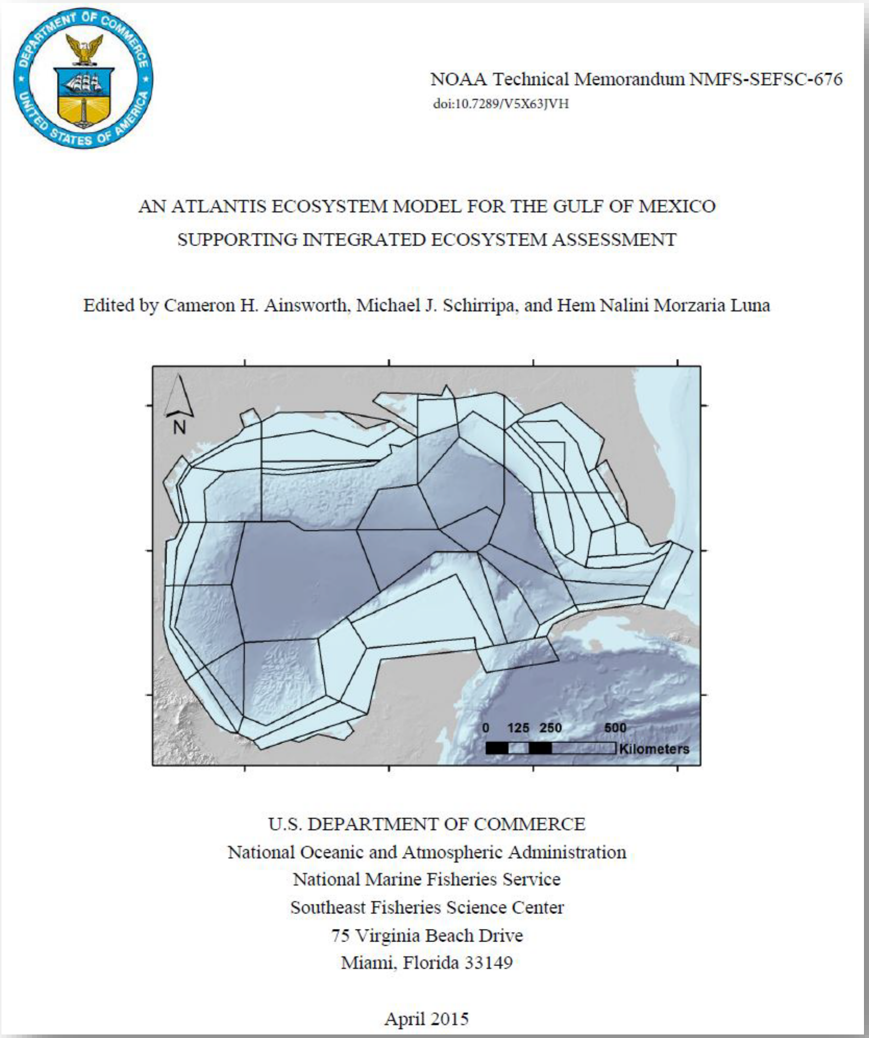
Diagnostics

Equilibrium catch & biomass



Historical reconstruction 1990-2010





NOAA Technical Memorandum NMFS-SEFSC-676

doi:10.7289/V5X63JVH

AN ATLANTIS ECOSYSTEM MODEL FOR THE GULF OF MEXICO SUPPORTING INTEGRATED ECOSYSTEM ASSESSMENT

Edited by Cameron H. Ainsworth, Michael J. Schirripa, and Hem Nalini Morzaria Luna

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southeast Fisheries Science Center
75 Virginia Beach Drive
Miami, Florida 33149

April 2015

Ainsworth, C.H., Schirripa, M.J. and Morzaria-Luna, H. (eds.), (2015). An Atlantis ecosystem model for the Gulf of Mexico supporting Integrated Ecosystem Assessment. US Dept. Comm. NOAA Technical Memorandum NMFS-SEFSC-676. 149 pp.

Modeling oil impacts

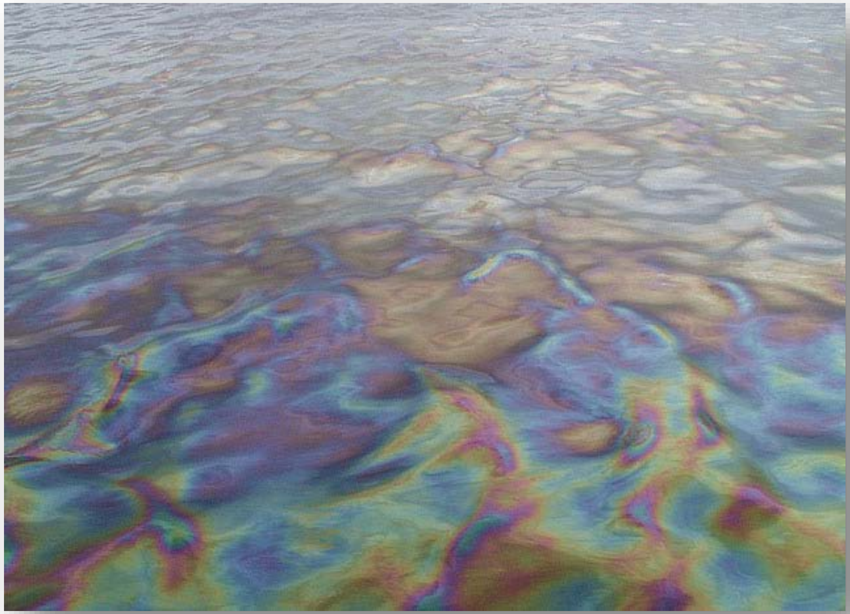
Effects included so far...

$\left.\begin{array}{l}\text{Vertebrate direct mortality}\\ \text{Vertebrate growth}\\ \text{Vertebrate recruitment}\end{array}\right\}$ Fish toxicology

Fisheries closures

Uptake-depuration dynamics

Mode of uptake (ingestion or absorption)



In progress...

Invertebrate toxicology

Benthic oxygen limitation

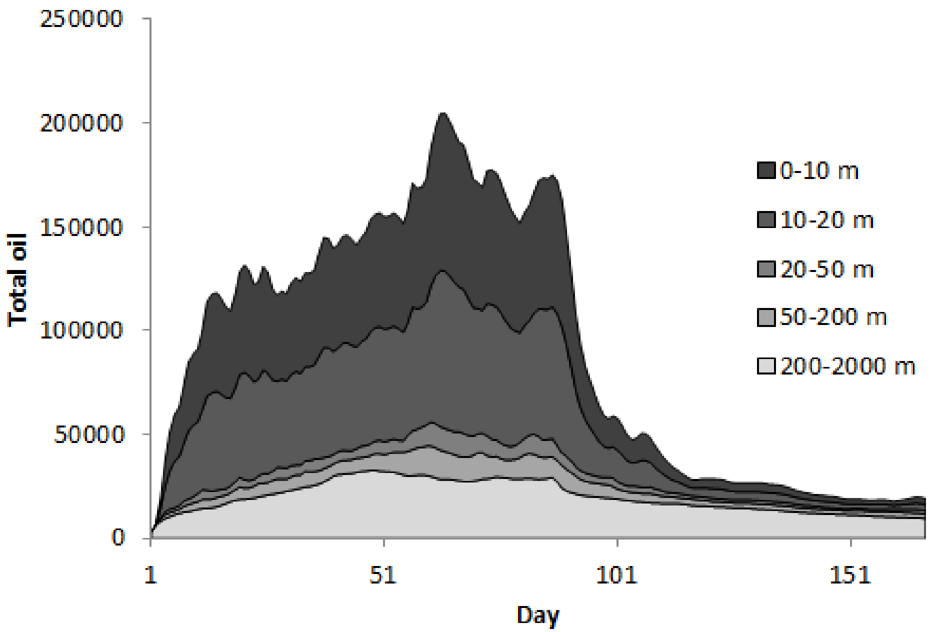
Zooplankton bloom

Oil distribution

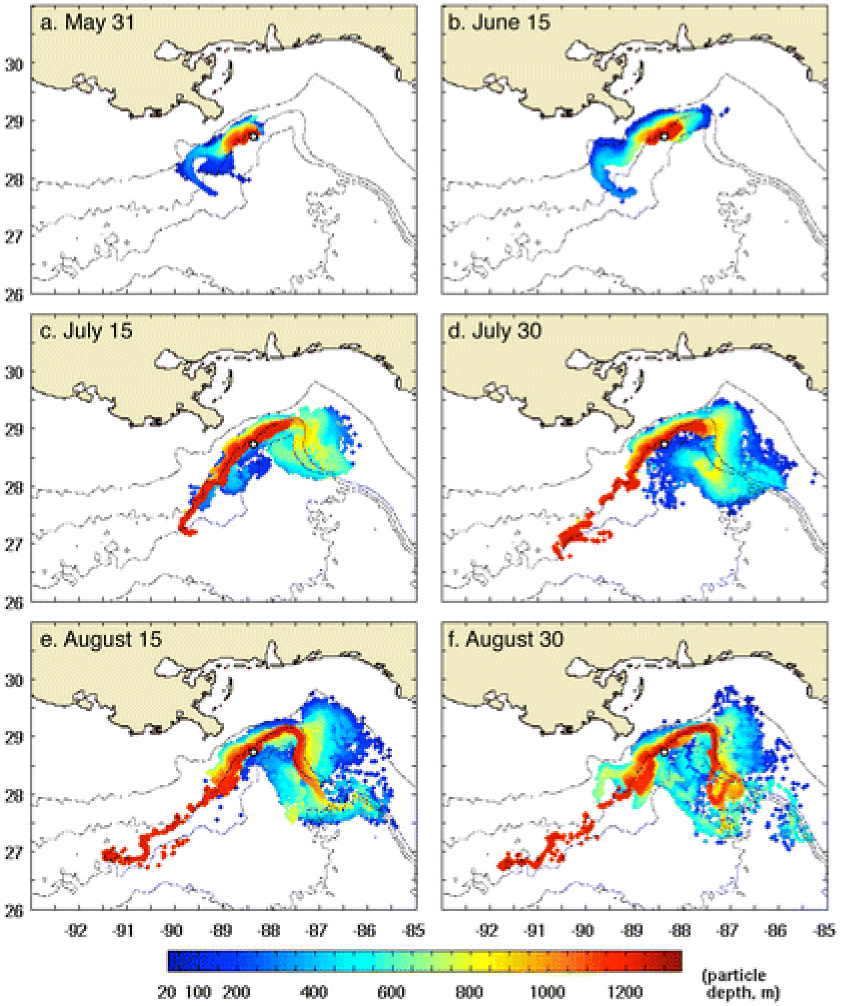
Claire Paris, UM

Dynamic oil concentrations

- Consults Lagrangian particle model for oil concentrations (Paris, UM)
- Includes microbial degradation (Müller, Valladares, Schedler, TUHH)



Paris et al. 2012



Paris, C.B, Le Hénaff, M., Aman, Z.M., Subramaniam, A., Helgers, J., Wang, D., Kourafalou, V.H., Srinivasan, A. 2012. Evolution of the Macondo Well Blowout: Simulating the Effects of the Circulation and Synthetic Dispersants on the Subsea Oil Transport. Environmental Science & Technology,; : 121203084426001 DOI: 10.1021/es303197h

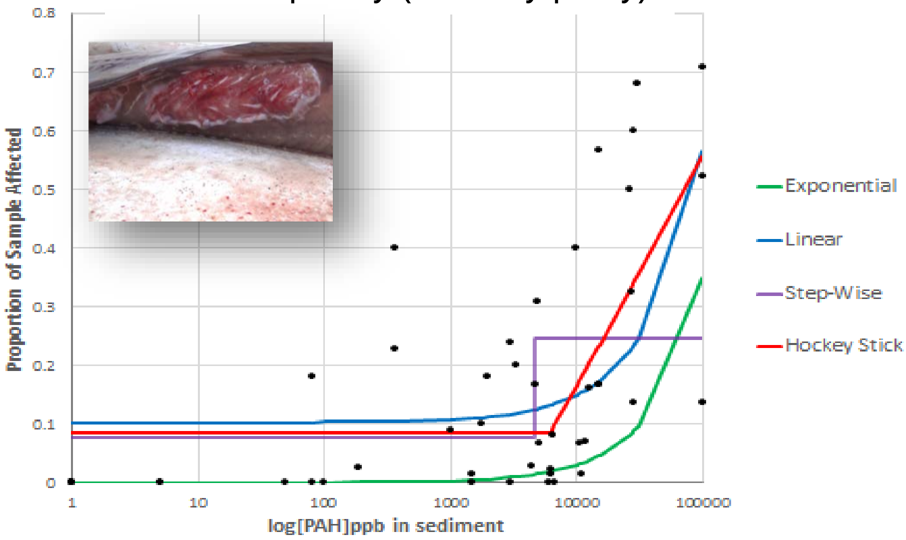
Dose response

Lindsey Dornberger, USF

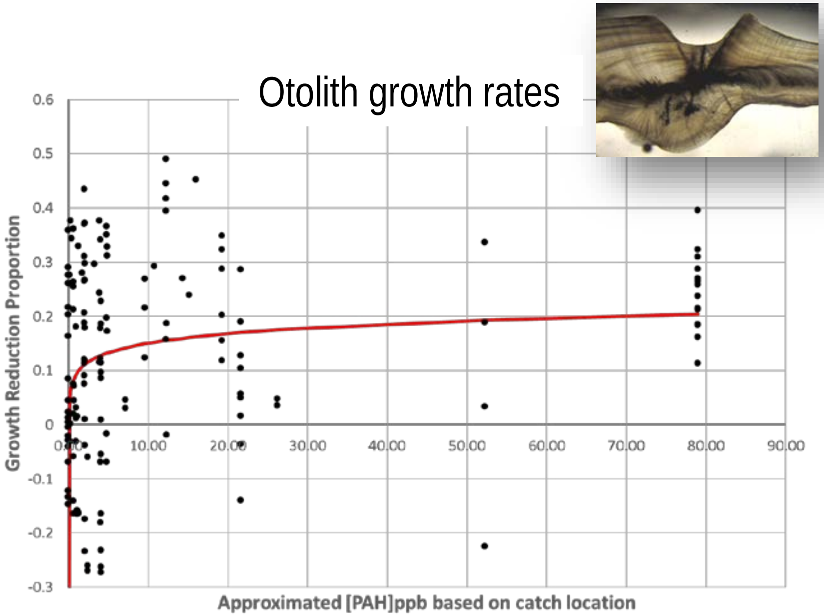
Growth and mortality functional responses

- AIC model selection
- Dornberger et al. *in revisions*
- CIMAGE responses (otolith/lesion) & literature

Lesion frequency (mortality proxy)



Otolith growth rates



Dornberger, L., Ainsworth, C., Gosnell, S., Coleman, F. *In revisions*. Developing a polycyclic aromatic hydrocarbon exposure dose-response model for fish health and growth. Marine Pollution Bulletin

Vertebrate growth & mortality effects

φ_t	Bioavailable oil concentration
E_t	# oiled grid points
$O_{i,t}$	Oil conc. at gridpoint *i*, time *t*
ρ	Depuration rate
μ	Uptake rate (*benthic or pelagic*)
α, β	Mortality model parameters
γ, δ	Growth model parameters
K	Sediment-to-water ratio
B	Benthic diet fraction

Uptake-depuration dynamics

$$\varphi_t = O_{i,t-1} \cdot \frac{E_t}{I} \cdot \sum_{i}^{I} (\mu \cdot O_{i,t}) \cdot e^{-\rho}$$

(ecotoxicology experiments forthcoming)

Mortality & growth dose-response

$$m_t = \alpha \cdot \log\left[K\varphi_t \cdot \frac{1}{\beta}\right] \cdot \omega^{-1}$$

$$g_t = 1 + (K\varphi_t)^{\gamma} - \delta$$

Ingestion / absorption uptake mode

$$M_t = m_{t_{pelagic}} \cdot (1 - B) + m_{t_{benthic}} \cdot B$$

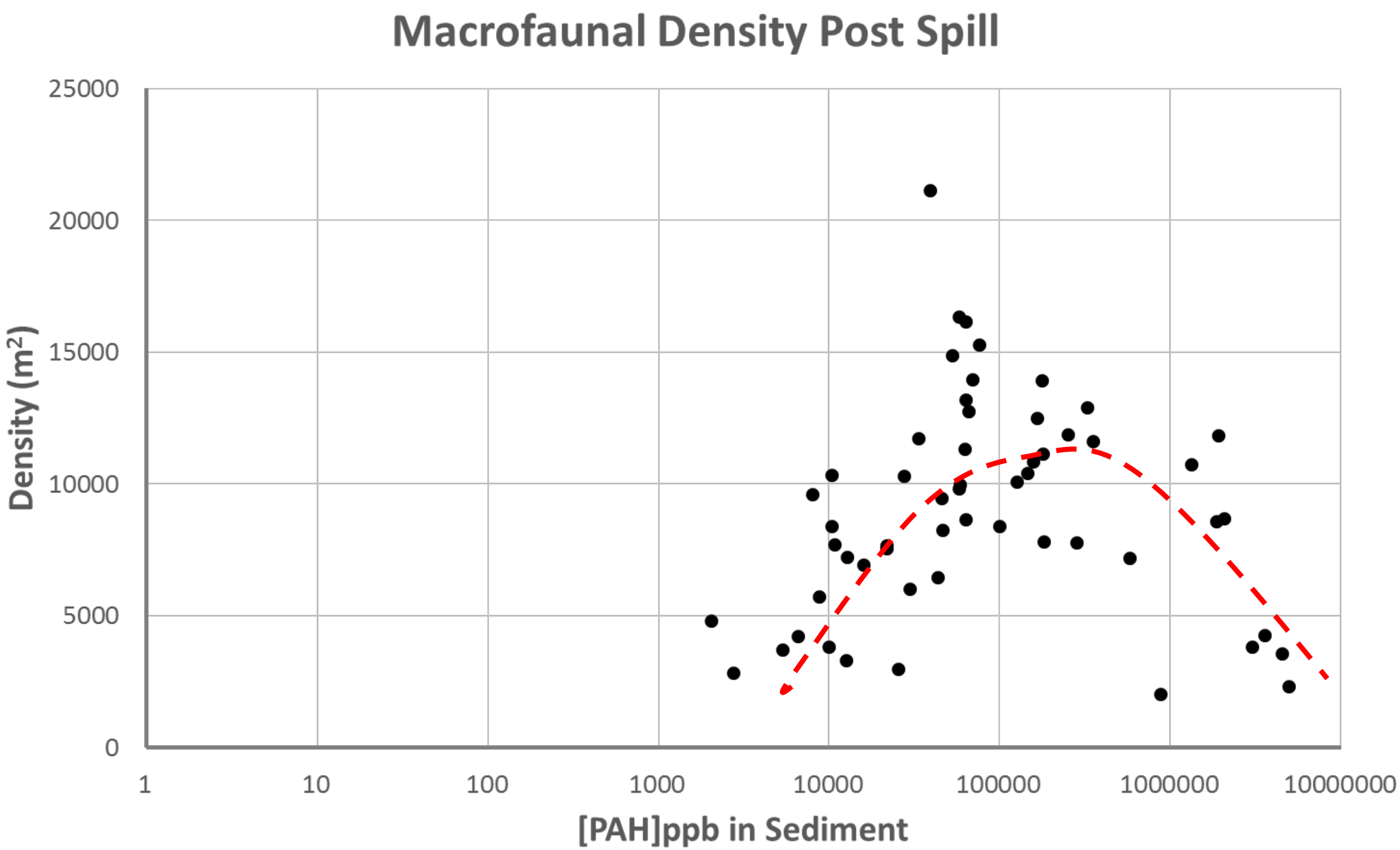
$$G_t = g_{t_{pelagic}} \cdot (1 - B) + g_{t_{benthic}} \cdot B$$

Dornberger, L., Ainsworth, C., Gosnell, S., Coleman, F. *In revisions*. Developing a polycyclic aromatic hydrocarbon exposure dose-response model for fish health and growth. Marine Pollution Bulletin

Invertebrate response

Lindsey Dornberger, USF

Work in progress

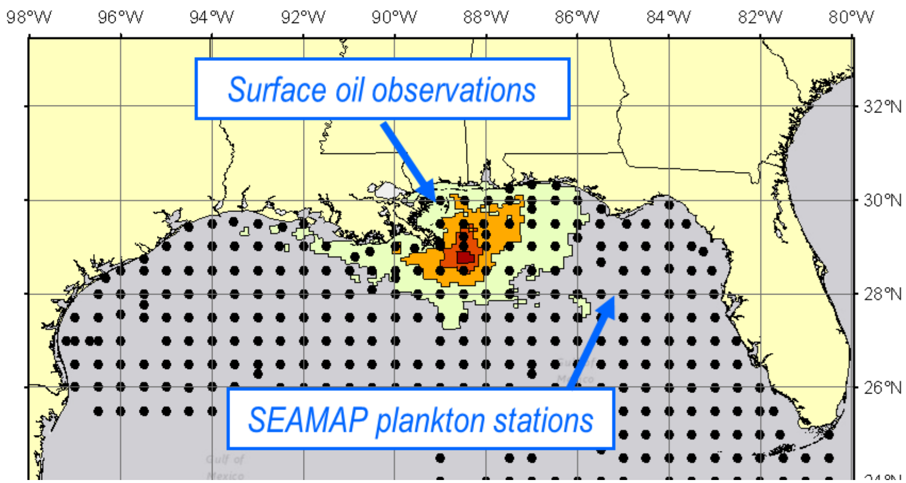


Montagna, P. A., Baguley, J. G., Cooksey, C., Hartwell, I., Hyde, L. J., Hyland, J. L., ... & Rhodes, A. C. (2013). Deep-sea benthic footprint of the Deepwater Horizon blowout. PloS one, 8(8), e70540.

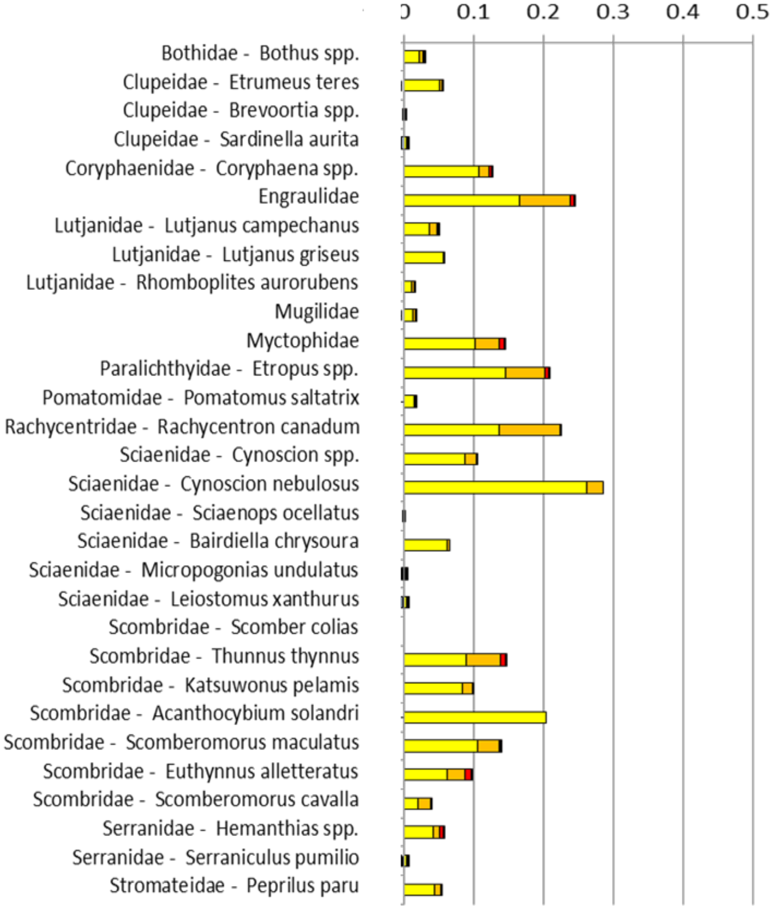
Recruitment effects

Emily Chancellor,
Steve Murawski,
USF

- Overlap between oil and ichthyoplankton provides recruitment impact



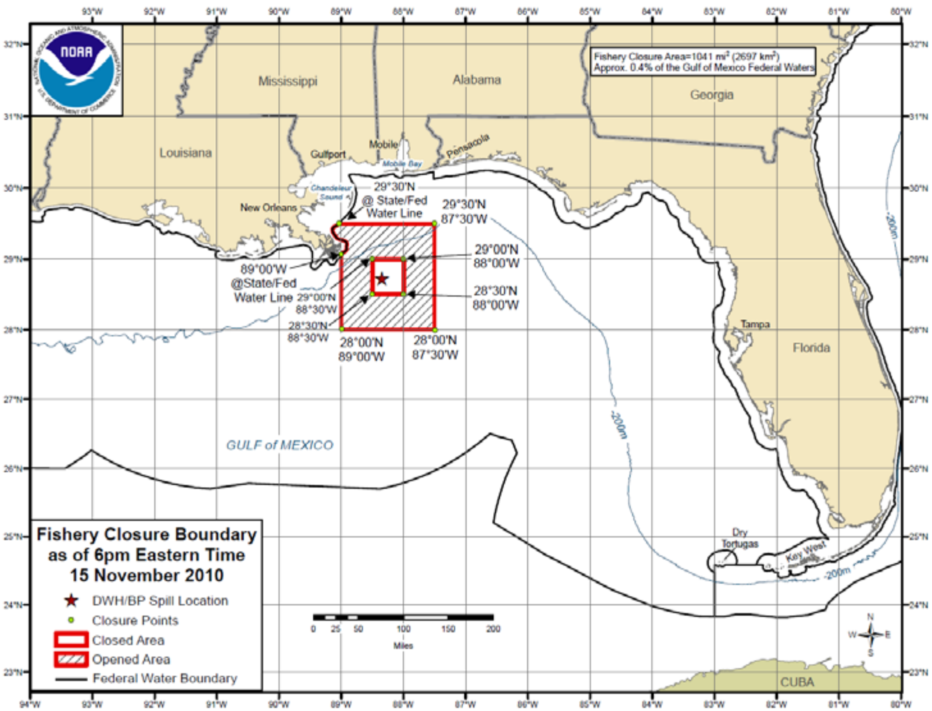
Relative losses



Chancellor, E. (2015) Vulnerability of Larval Fish Populations to Oil Well Blowouts in the Northern Gulf of Mexico. Master's Thesis. Marine Science. University of South Florida. Pp. 108

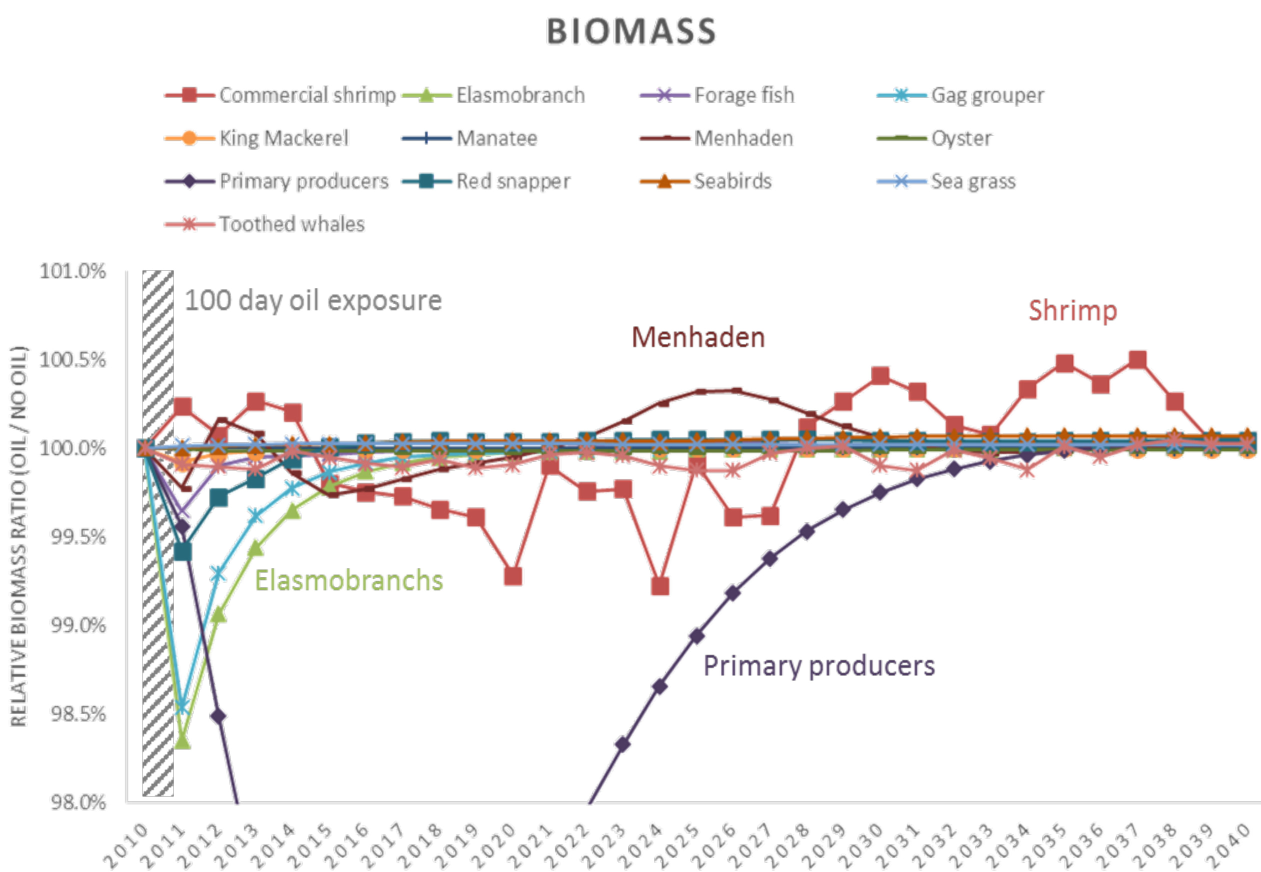
Fishery closures

- Complex history of closures updated daily in the model



DWHOS simulations

Averaged 'super' groups

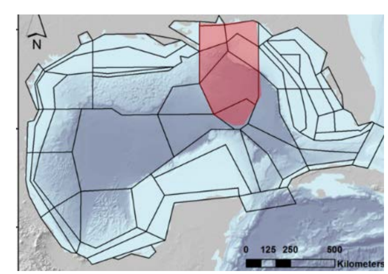


100 day exposure

Only a few percent change for most groups under conservative scenario

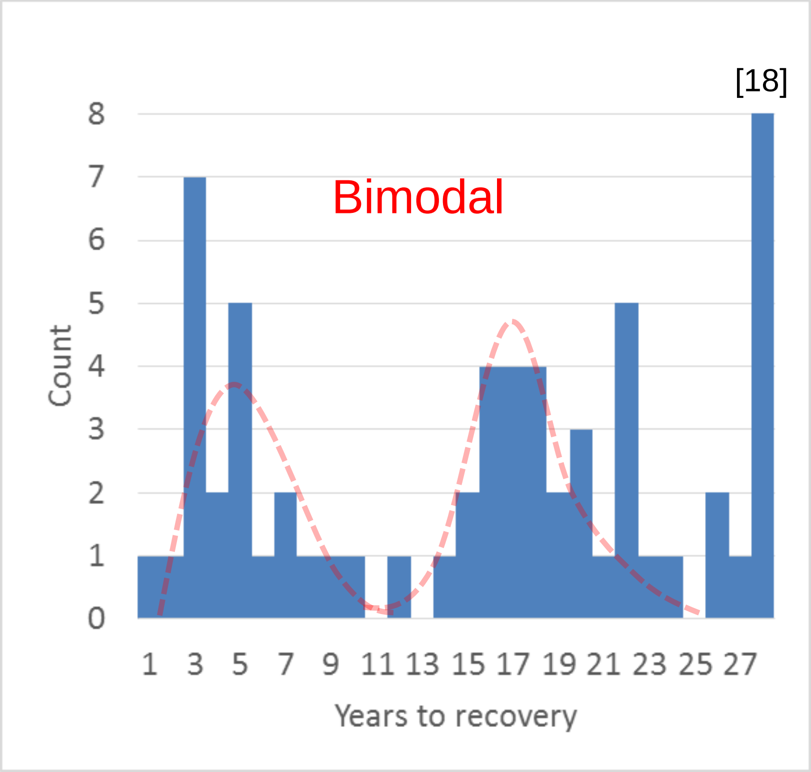
Most affected groups

- Elasmobranchs
- Gag, Red snapper
- Other Lutjanidae
- Other Demersals

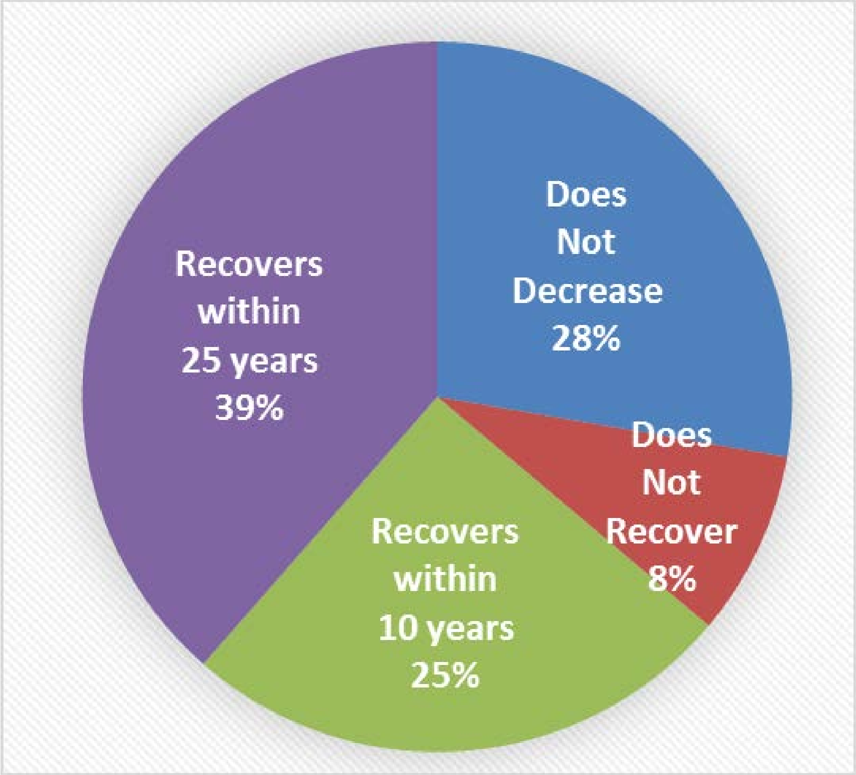


Recovery time

Recovery time

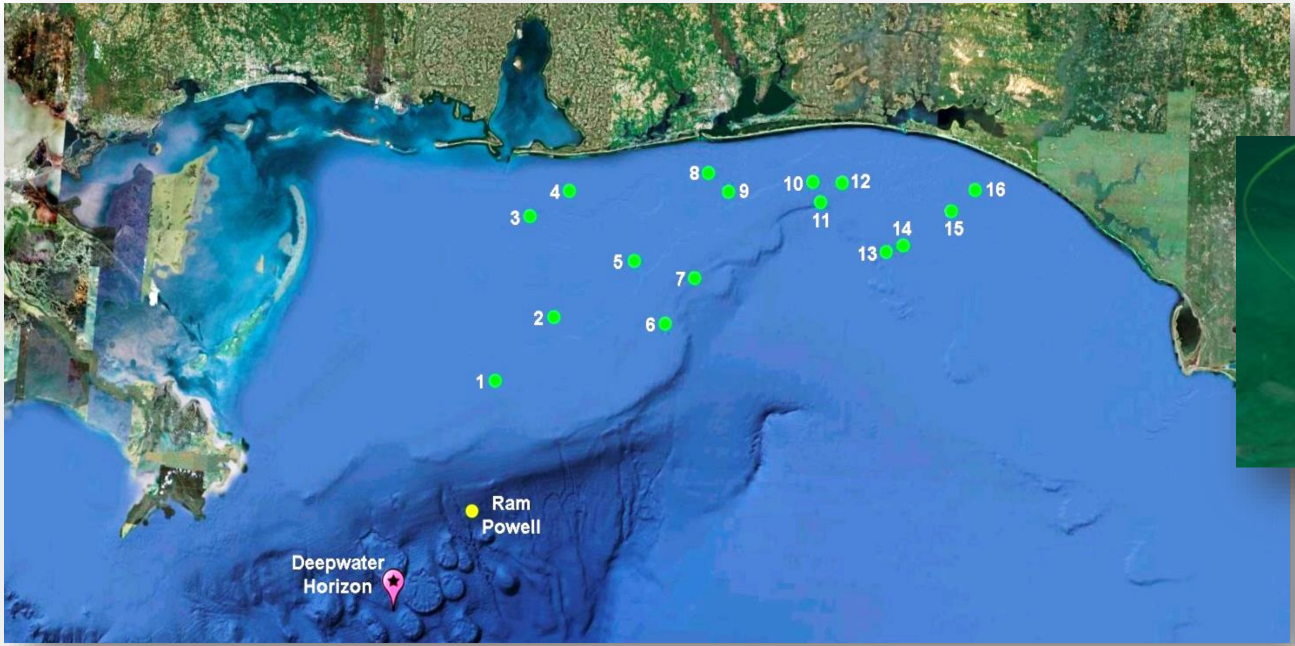


Functional group fate



Model validation

- Significant post-spill shifts in fish community structure (PERMANOVA $p<0.001$) (fewer planktivores, more invertivores)
- Poor recruitment apparent for some reef fishes (e.g., red snapper)
- PAHs persist in liver tissue samples into 2012; 2013 analyses ongoing
- Within species shifts observed in trophic position; smaller size-at-age
- Some recovery in community structure apparent by spring/summer 2013



W. Patterson, USA

Outputs

Improved socioeconomics

- David Yoskowitz (Harte)
- Shore-based industry impacts & indicators
    - Commercial harvesters
    - Primary dealers and processors
    - Seafood wholesalers and distributors
    - Grocers
    - Restaurants
    - Fuel service
    - Equipment retailers
    - Marinas
    - Hotels/motels/bed & breakfast
    - Boat building and repair

Virtual Ecosystem Simulator

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U South Florida (Murawski, Hollander, Romera)
Mote (Wetzel, Main)
U South Alabama (Patterson)
SEFSC-NOAA (Schirripa, Kelble, Zimmerman)
NWFSC-NOAA (Levin, Kaplan)
NEFSC-NOAA (Link)
University of Miami (RSMAS) (Die, Babcock, Paris)
Florida State University (Coleman, Gosnell)
FWRI (Mahmoudi, Chagaris)
CSIRO (Fulton, Gorton)
NCDDC (Beard, Parsons, Carleton)
UNAM (Gracia)
CICIMAR-IPN (Arreguin-Sanchez)
ICIMAP, UAM, & many others

GULF OF MEXICO RESEARCH INITIATIVE

Ainsworth lab, USF CMS

UNIVERSITY OF SOUTH FLORIDA COLLEGE OF MARINE SCIENCE
CSIRO
C-IMAGE-II
Deep-C CONSORTIUM
MOTE MARINE LABORATORY
RSMAS