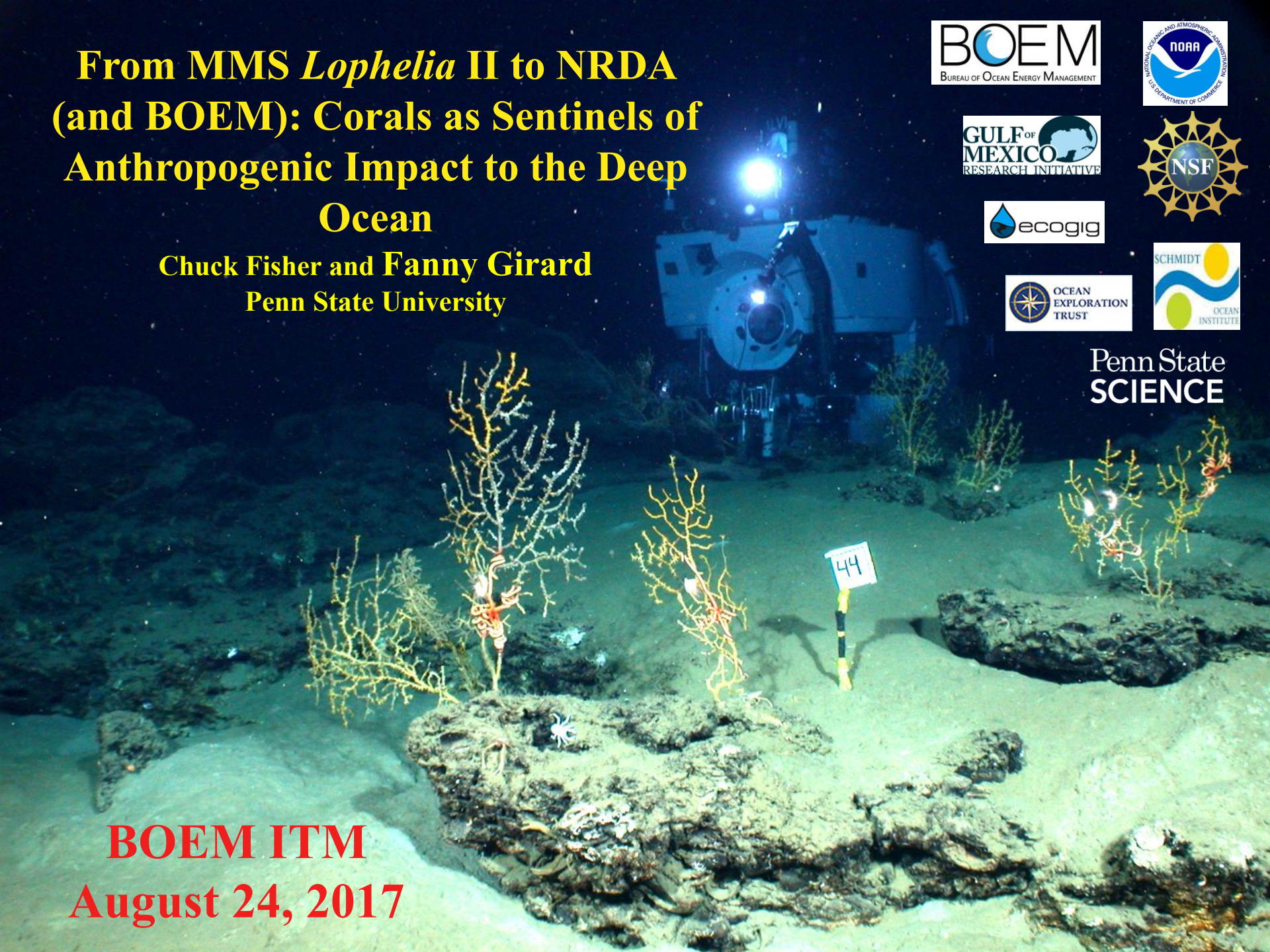
From MMS *Lophelia* II to NRDA (and BOEM): Corals as Sentinels of Anthropogenic Impact to the Deep Ocean

Chuck Fisher and Fanny Girard
Penn State University



BOEM ITM
August 24, 2017

The Lophelia II program had many specific goals. Broadly speaking, the goals were:

1) Discover and characterize deep water coral communities

   ("Rigs, Reefs, and Wrecks": who is where and what are the patterns)

2) Better understand the biology and ecology of the fauna: growth rates and ages, physiology (energy sources and resiliency), metapopulation structure (of species and communities)

3) Learn where they are likely to occur

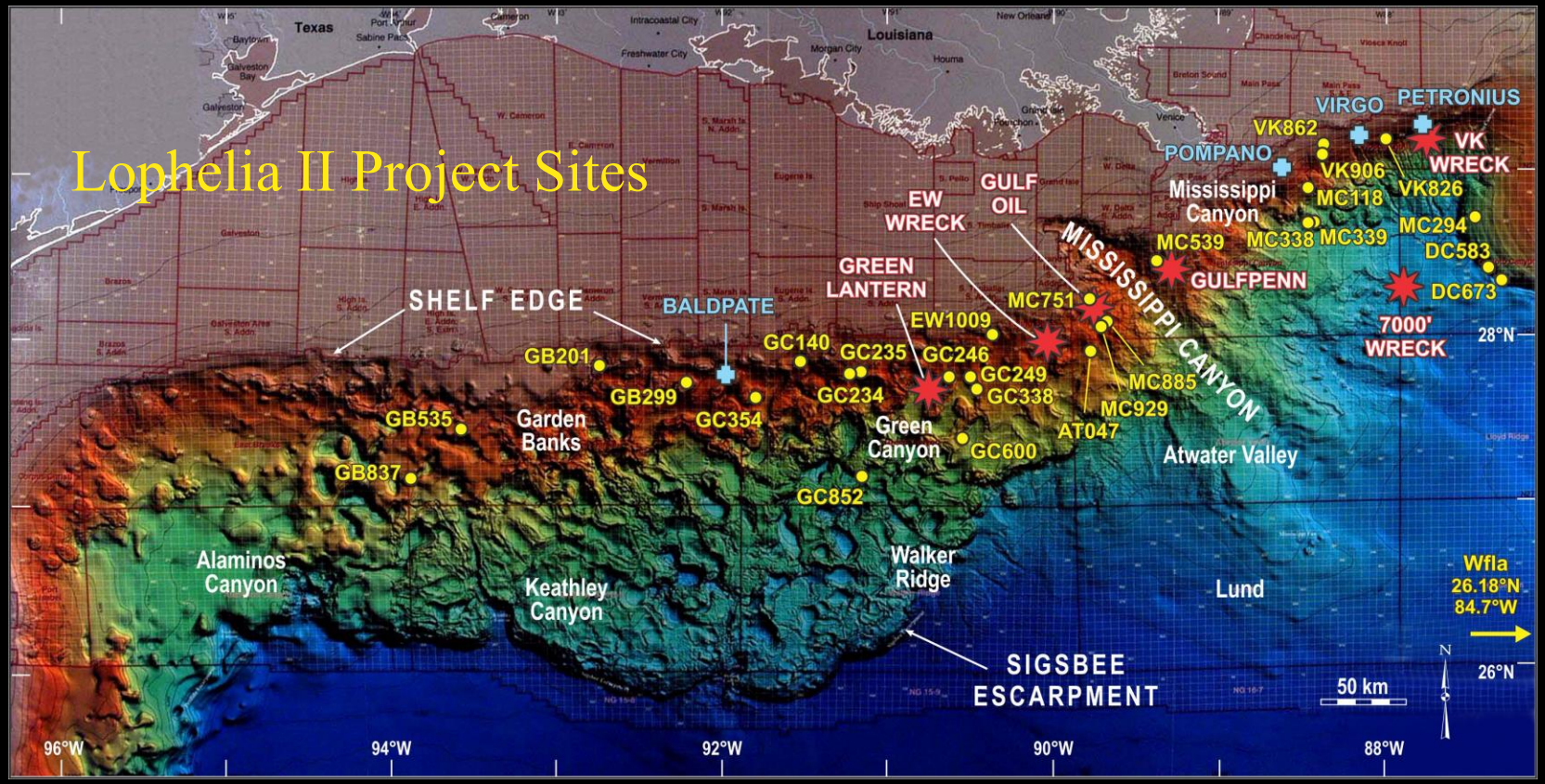
   (strengthen predictive power from surface ship data)

4) Characterize and study several deep water wrecks archeologically

Lophelia II

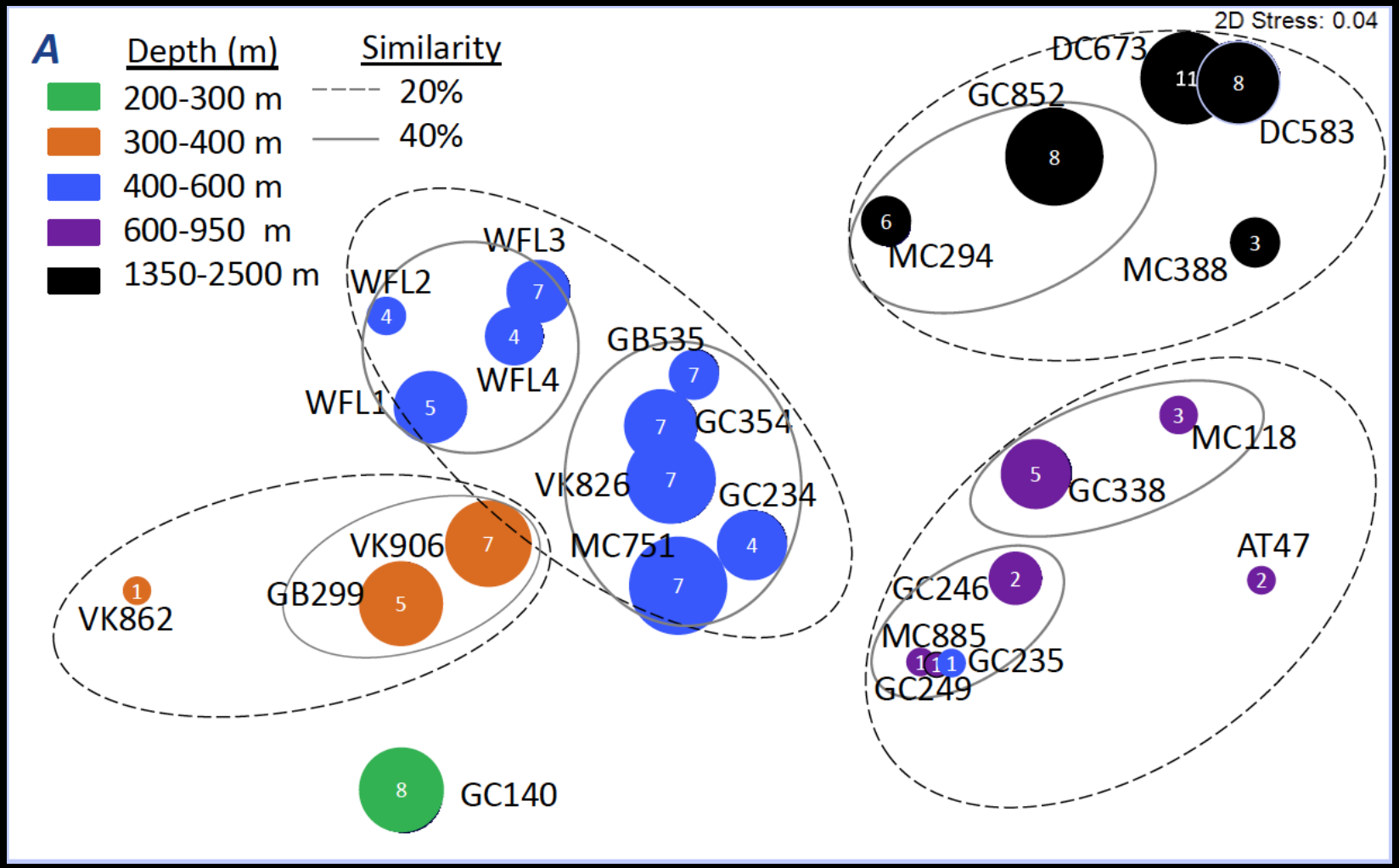
We learned a lot, including getting better at finding deep water coral sites

- Deep water coral communities proved to be very widespread



Lophelia II

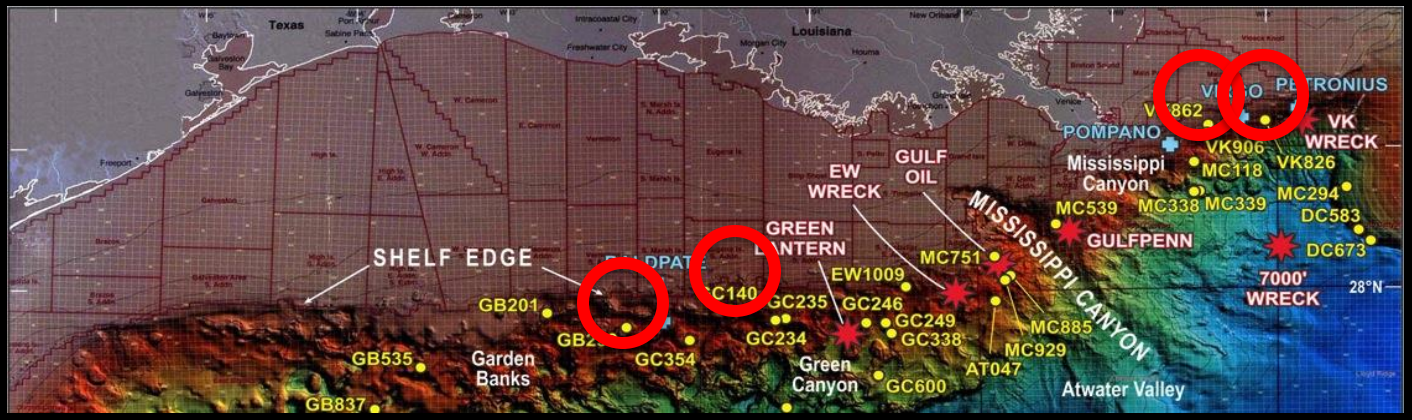
Different coral communities are found at different depths



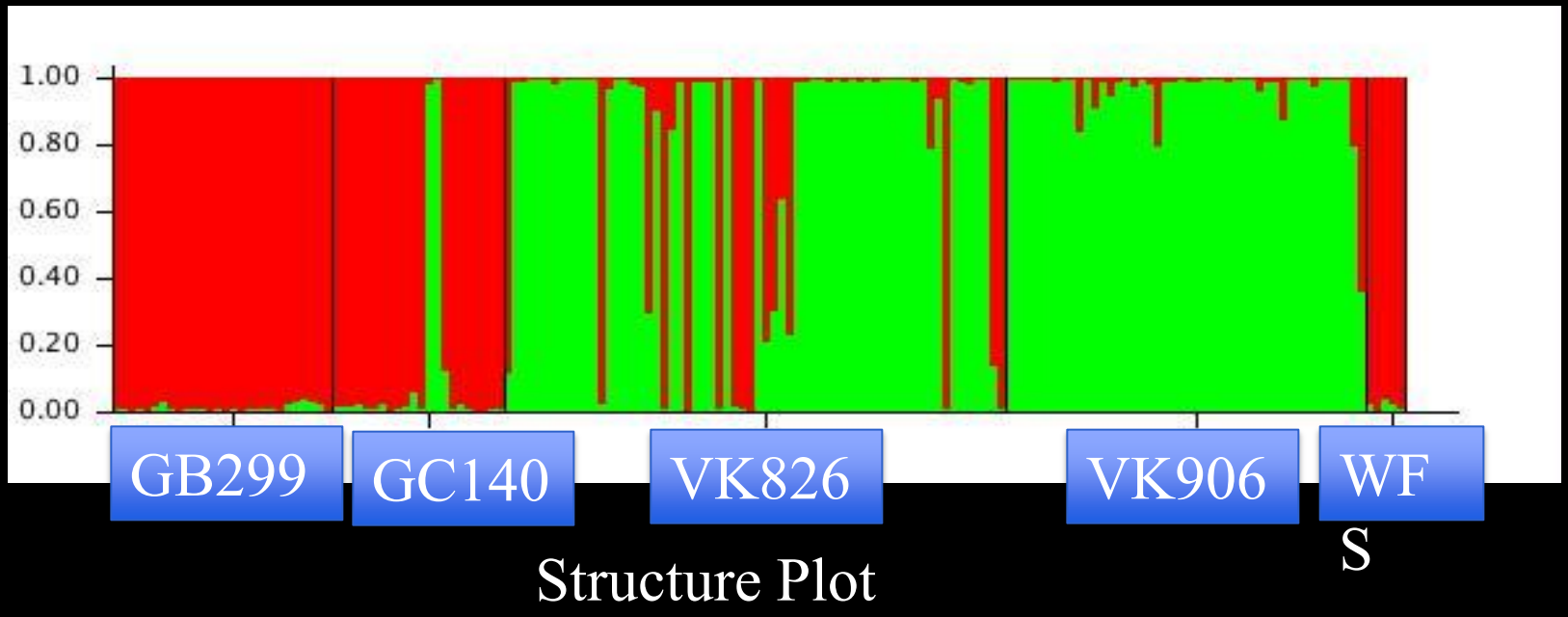
Multidimensional Scaling (MDS) plot

Lophelia II

Population genetic subdivision (a black coral example)

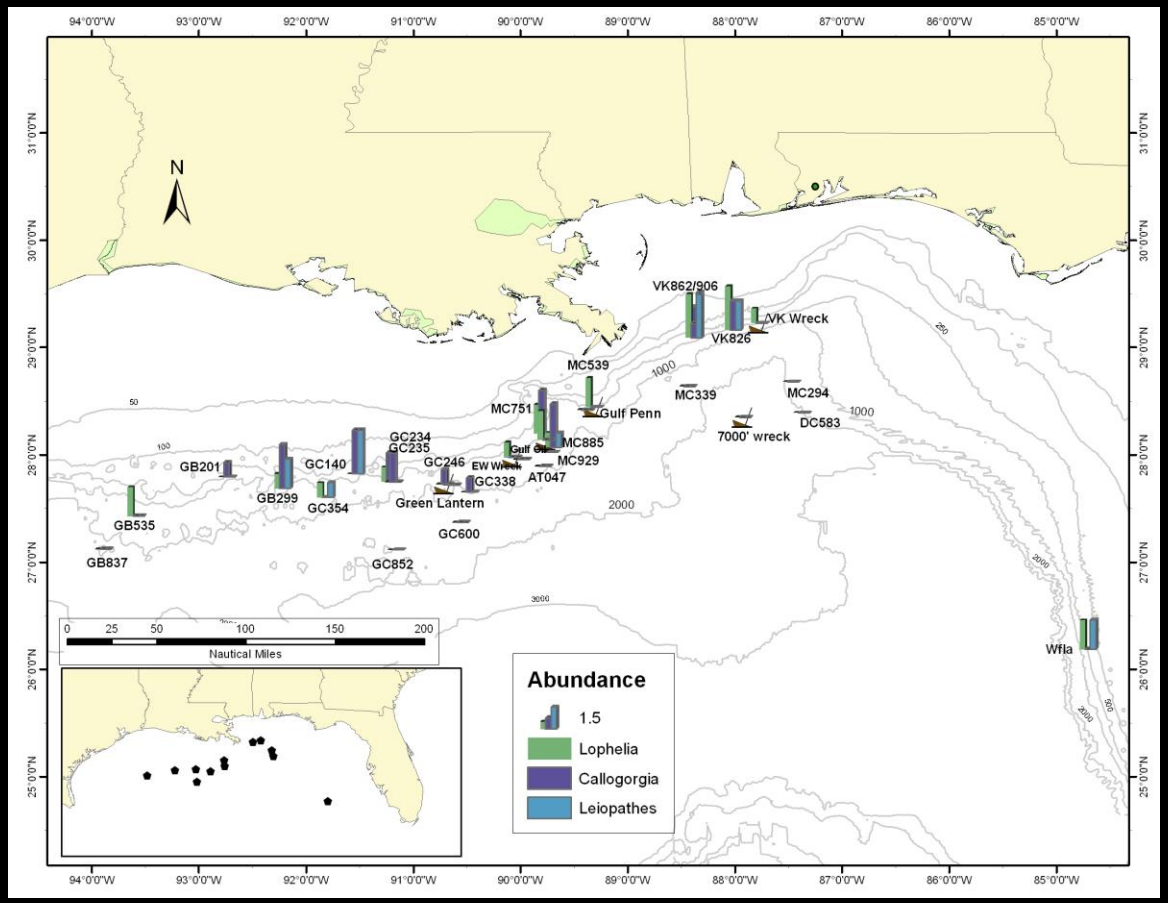


Leiopathes Population Genetics

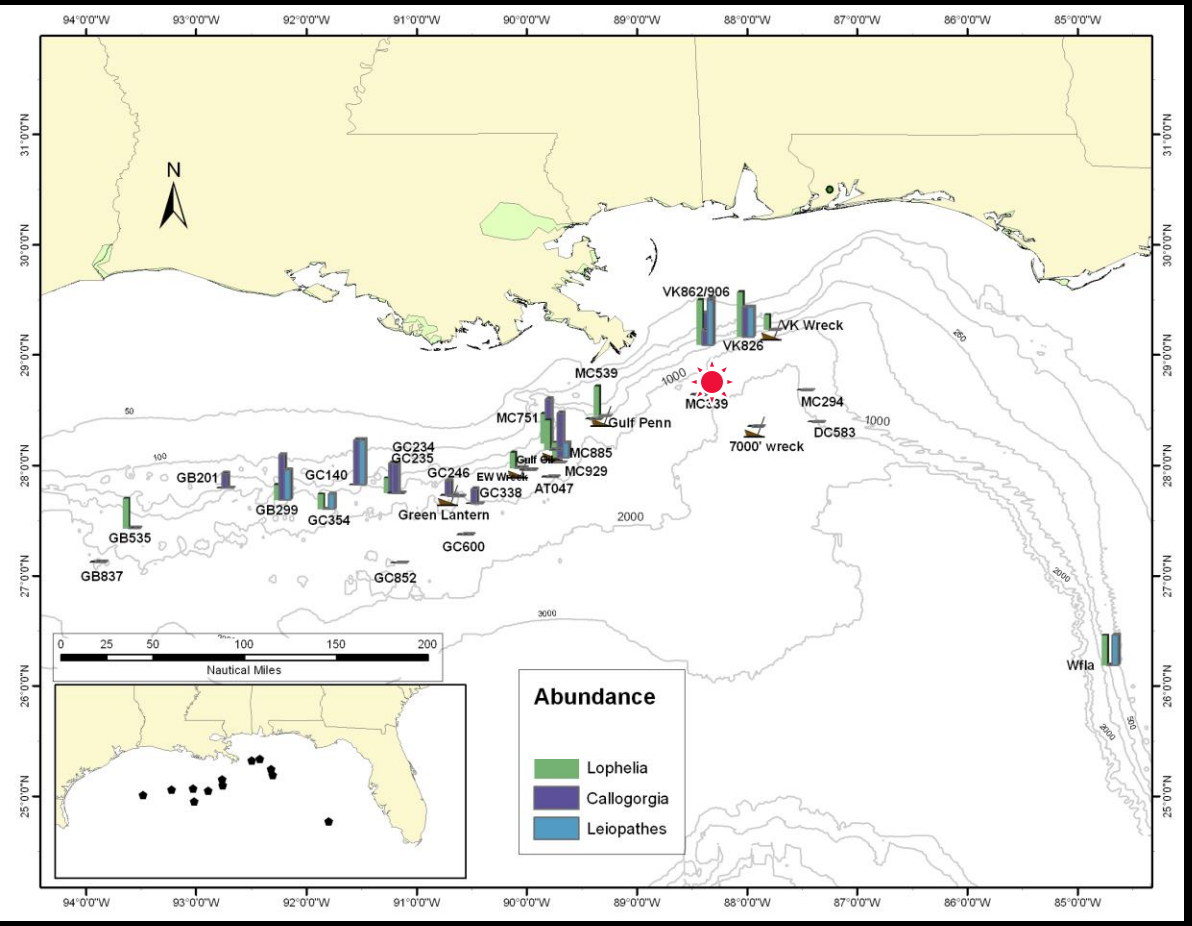


Structure Plot

Lophelia II project (from a pre-spill presentation)

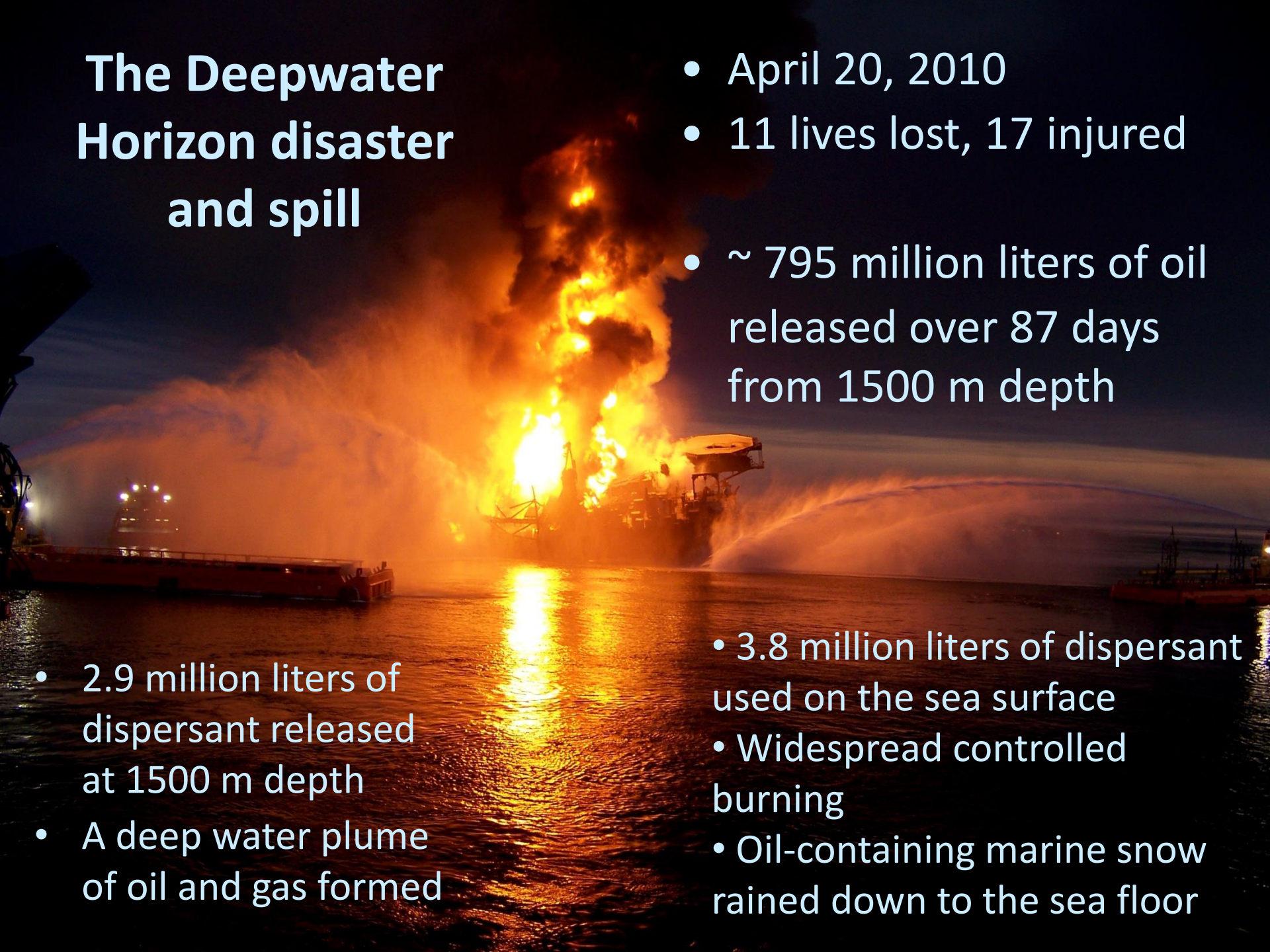


April 20, 2010:
Deepwater Horizon disaster and spill



The Deepwater Horizon disaster and spill

- April 20, 2010
- 11 lives lost, 17 injured
- ~ 795 million liters of oil released over 87 days from 1500 m depth



- 2.9 million liters of dispersant released at 1500 m depth
- A deep water plume of oil and gas formed

- 3.8 million liters of dispersant used on the sea surface
- Widespread controlled burning
- Oil-containing marine snow rained down to the sea floor

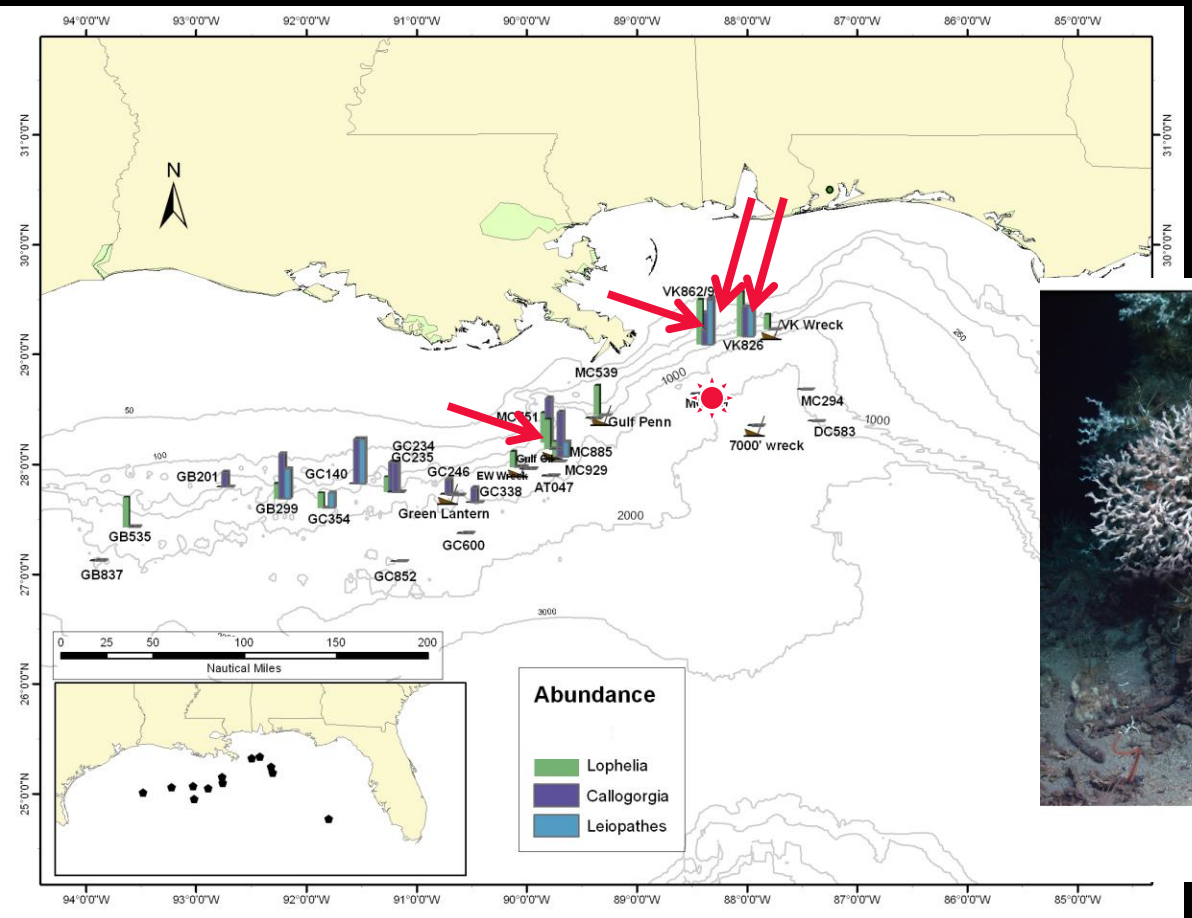
We were drafted to NRDA (by MMS, NSF, and NOAA) in April, and in July 2010:

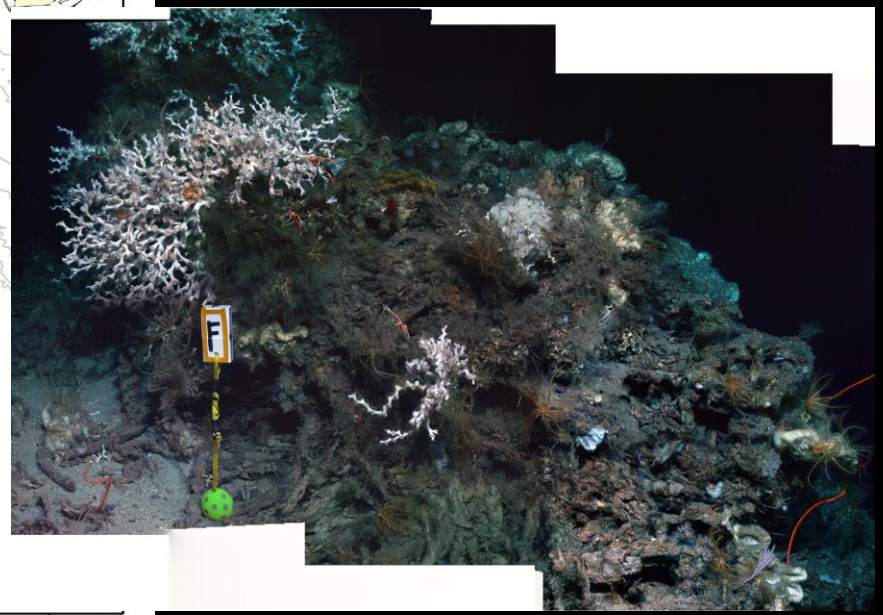
National Resource Damage Assessment response cruise to known rich coral sites with established, MMS, long term study stations

NRDA

Trustees

BP





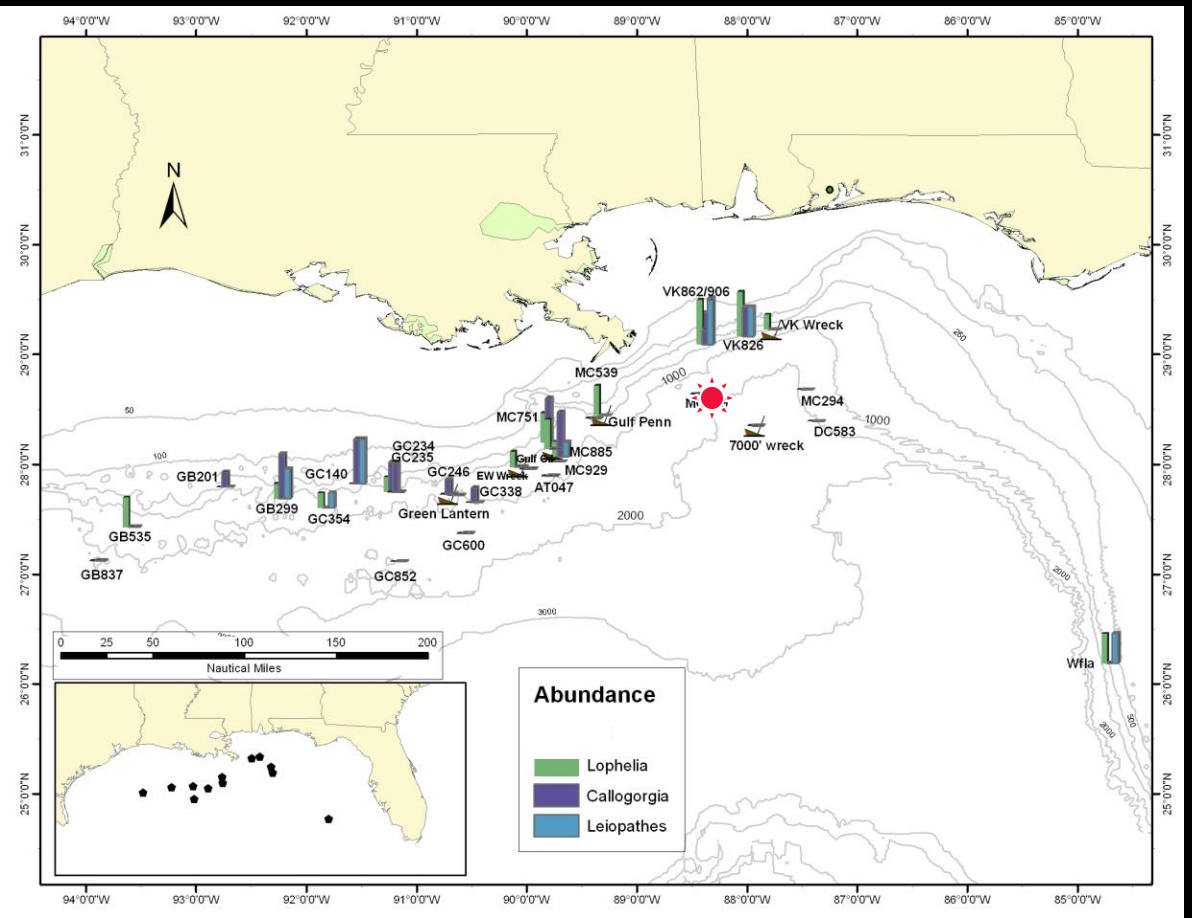
Oct.-Nov. 2010

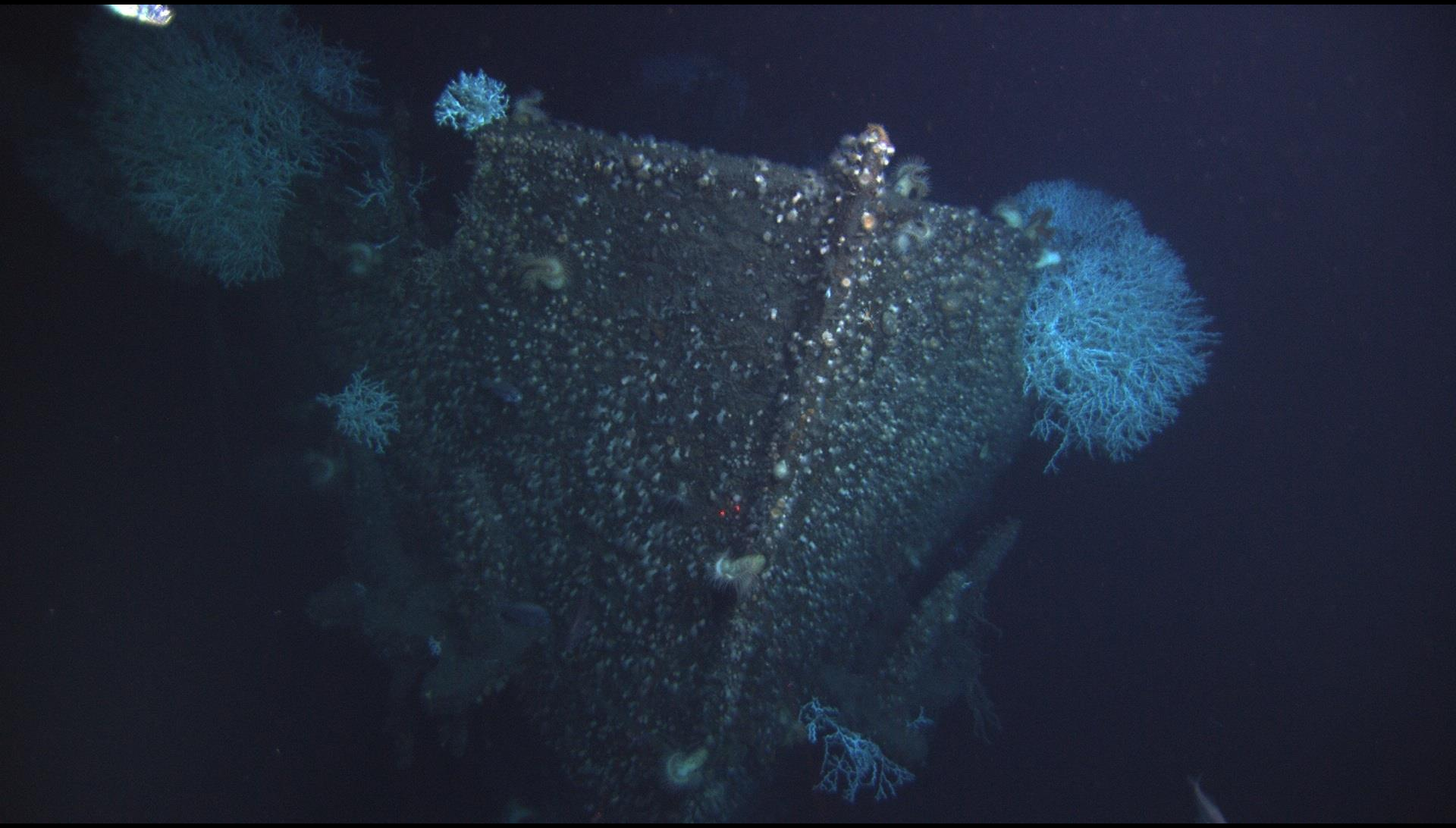
Revisited most of our deep coral study sites during a regularly scheduled BOEMRE/NOAA cruise

BOEMRE

NOAA

USGS science for a changing world



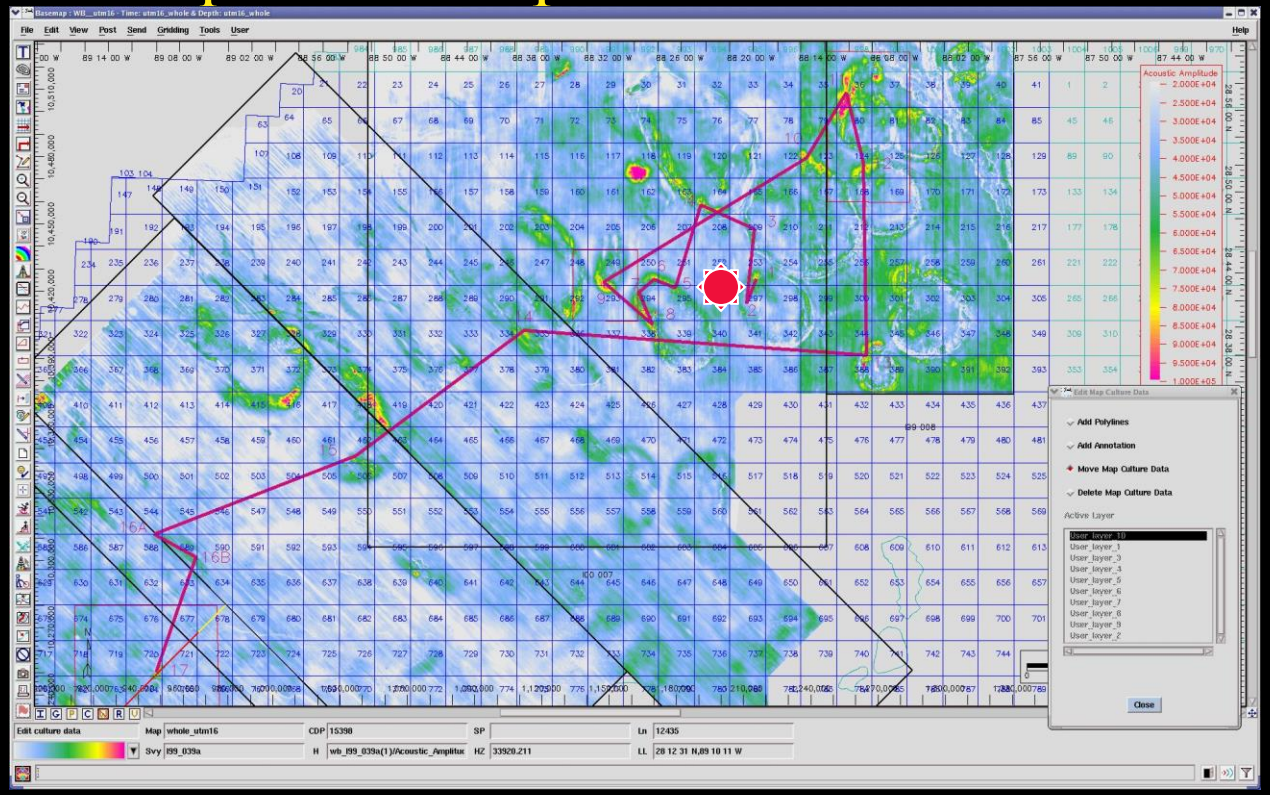


Explore for Hard Grounds near the spill site

NRDA

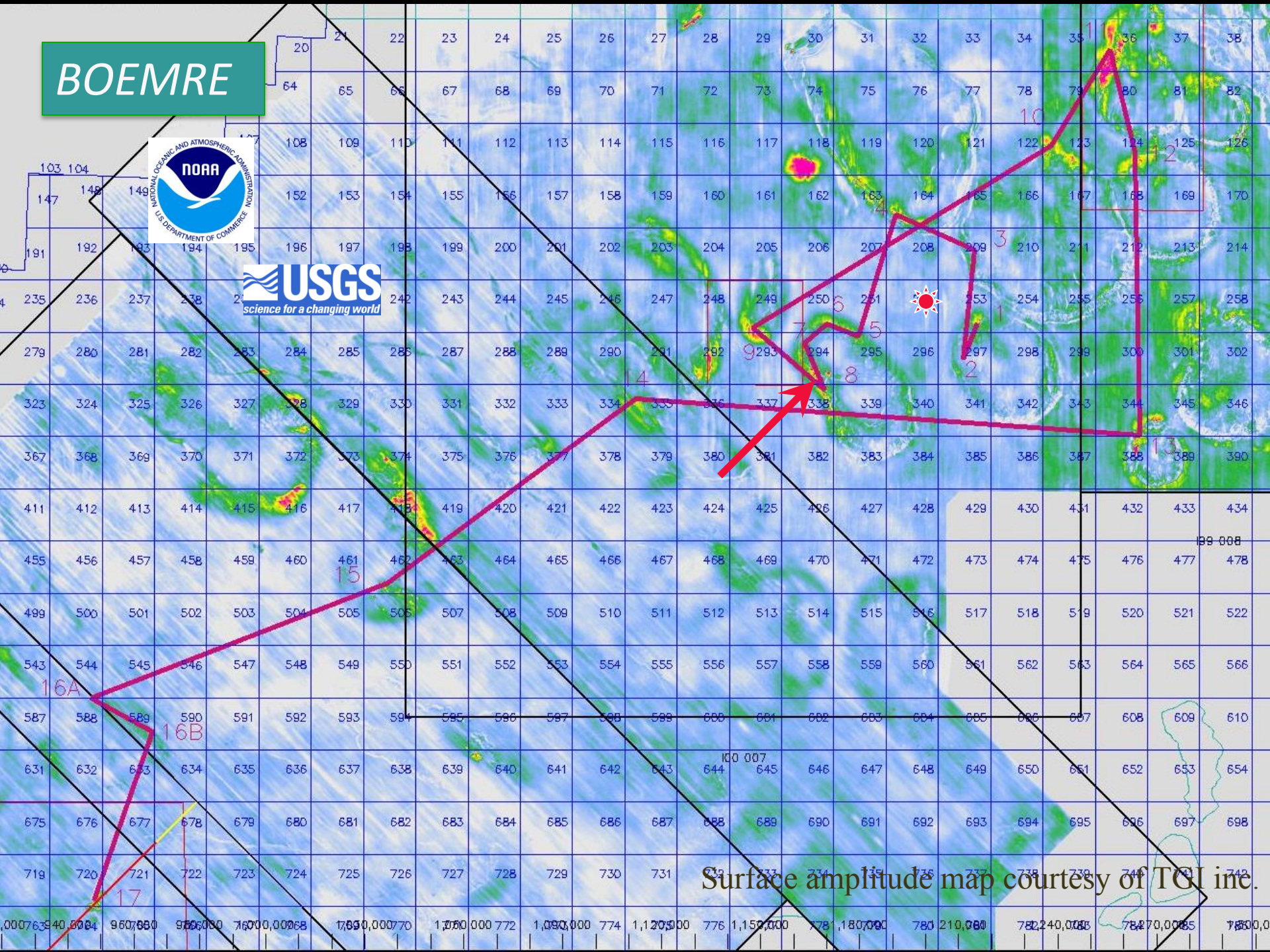
BOEMRE

(Using techniques developed for MMS/BOEMRE studies)



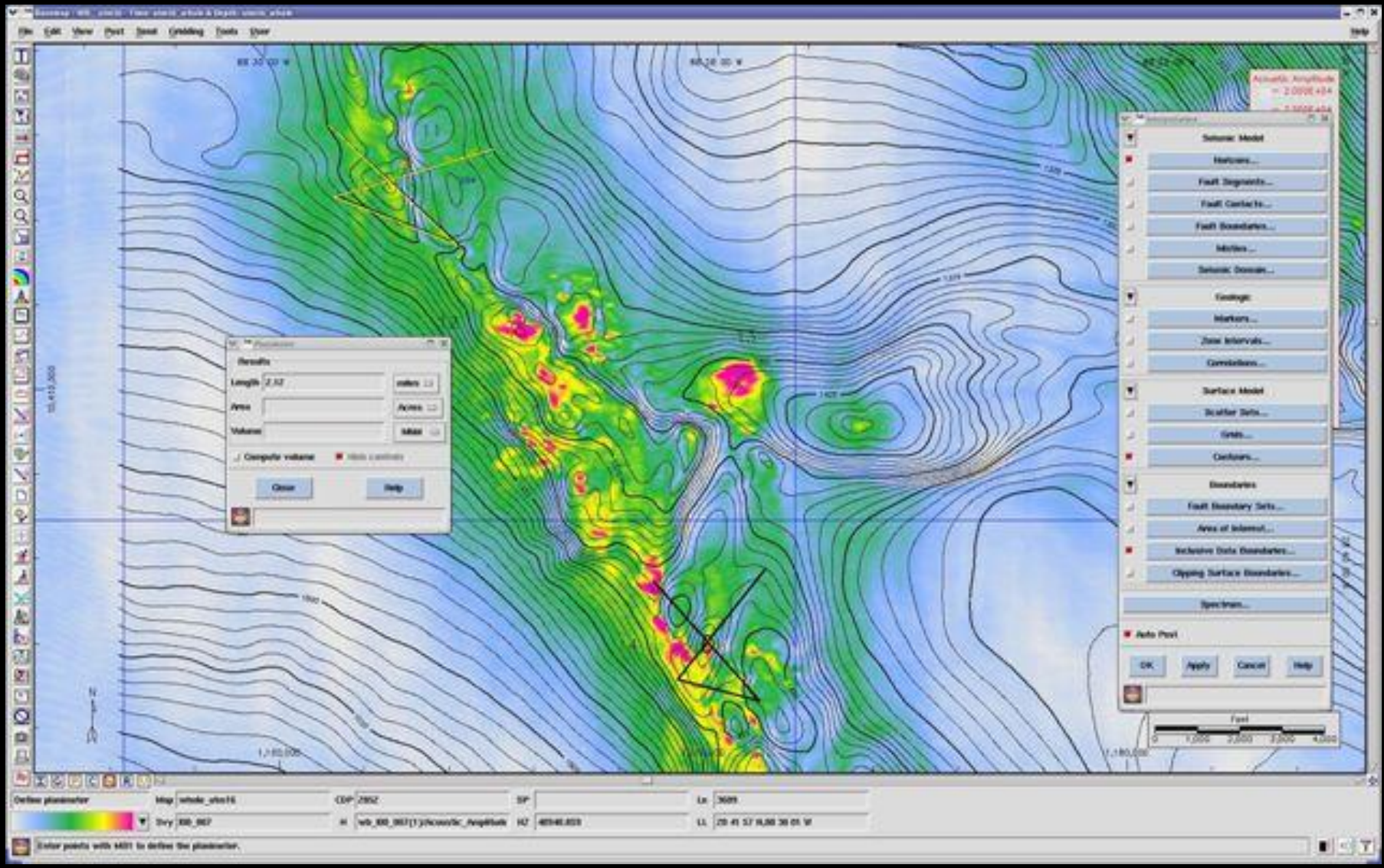
Surface amplitude map courtesy of TGI inc.

Cruise courtesy of Bill Shedd



Surface amplitude map courtesy of TGI inc.

Identified MC 338/294: 12 km to SW of Macondo For the last dive of the BOEMRE/NOAA cruise



During the last dive, Nov. 2010

We decided to "Publish" this finding as a press release.

The public was hungry for facts
Most other scientists had signed confidentiality agreements
This was not an official NRDA funded cruise (no confidentiality agreement)
Government releases were not being trusted.
And:
There were 50 people on the ship, with face book etc….
The release was "communicated" to the White House and then endorsed and released officially by NOAA, BOEM, Penn State, and Temple

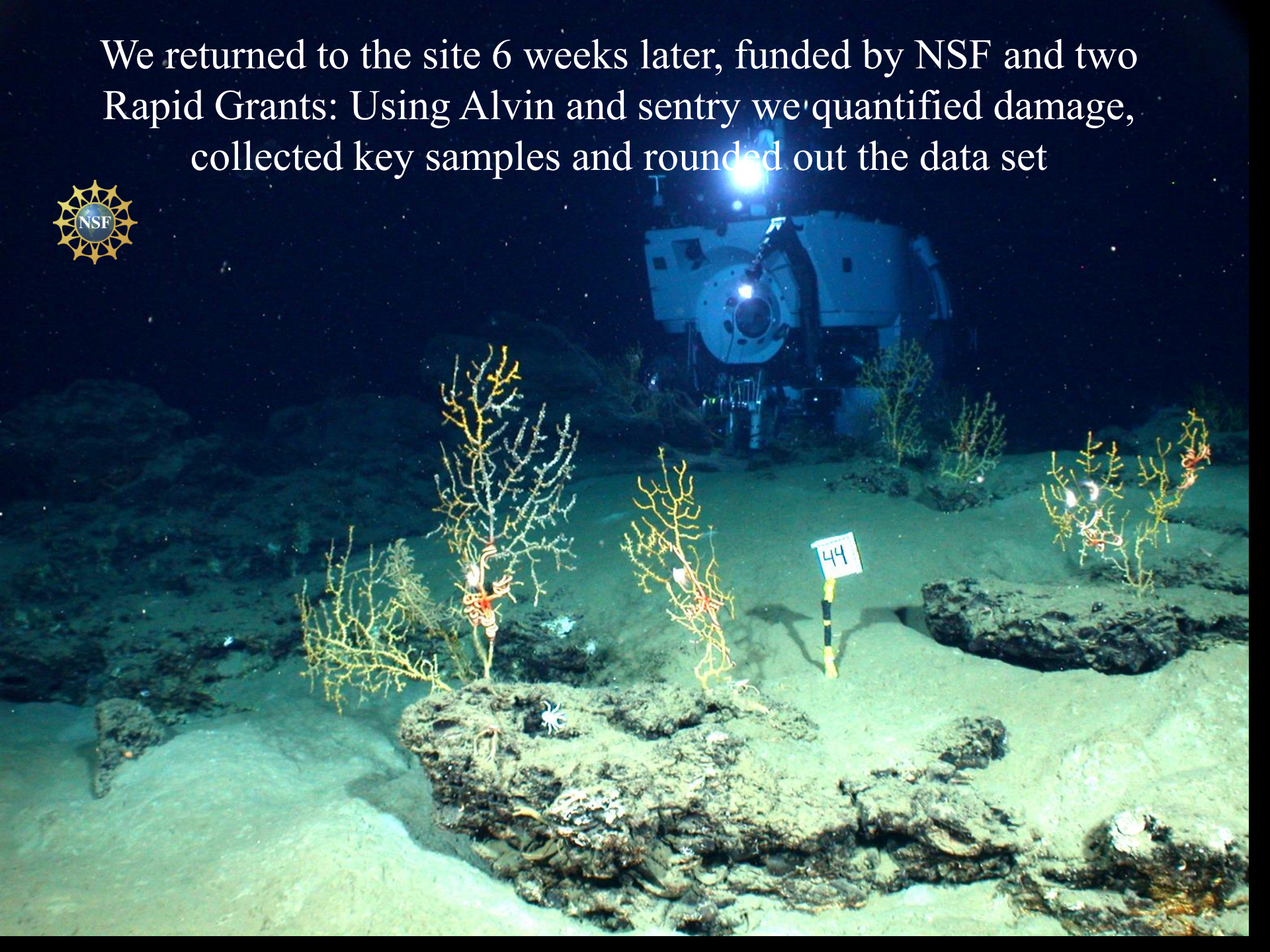
(not at the time by USGS or WHOI)

"Published" as press releases the day the cruise returned to port, after 2 days of intense negotiations.

Our Data

- The colonies were over 100yrs old, very recently covered with floc, and many were dying
- All over the rest of the Gulf, deep water corals were healthy
- The site was at the right depth and location for impact from a documented deep water plume from the spill
- The site was the closest one known to the DWH site

We returned to the site 6 weeks later, funded by NSF and two Rapid Grants: Using Alvin and sentry we quantified damage, collected key samples and rounded out the data set

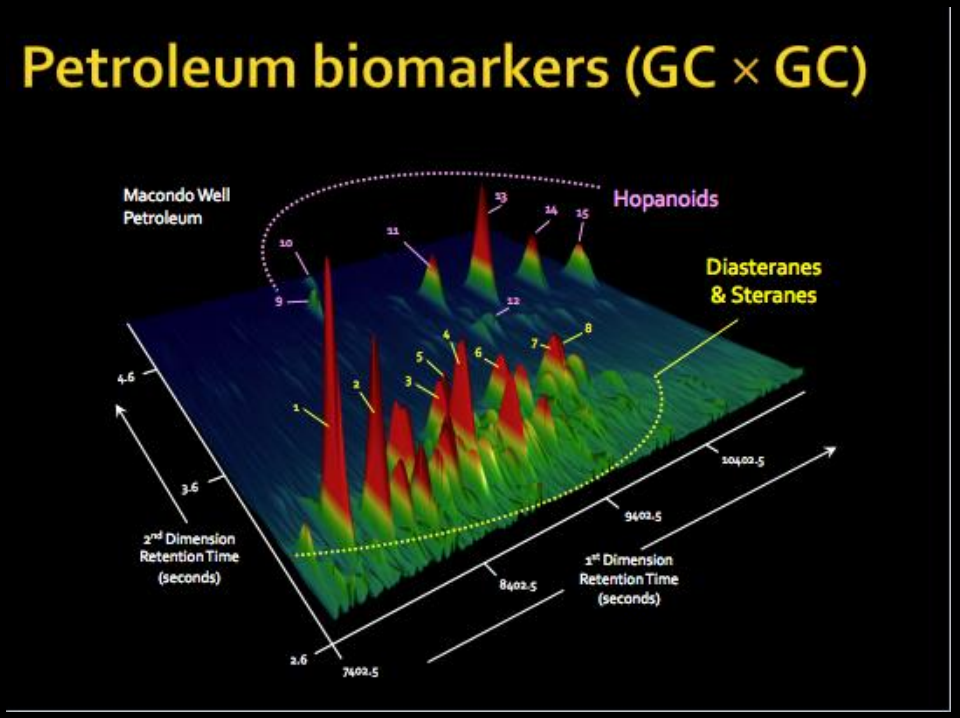


Impact of the *Deepwater Horizon* oil spill on a deep-water coral community in the Gulf of Mexico

Helen K. White[a,1], Pen-Yuan Hsing[b], Walter Cho[c], Timothy M. Shank[c], Erik E. Cordes[d], Andrea M. Quattrini[d], Robert K. Nelson[e], Richard Camilli[f], Amanda W. J. Demopoulos[g], Christopher R. German[h], James M. Brooks[i], Harry H. Roberts[j], William Shedd[k], Christopher M. Reddy[e], and Charles R. Fisher[b]

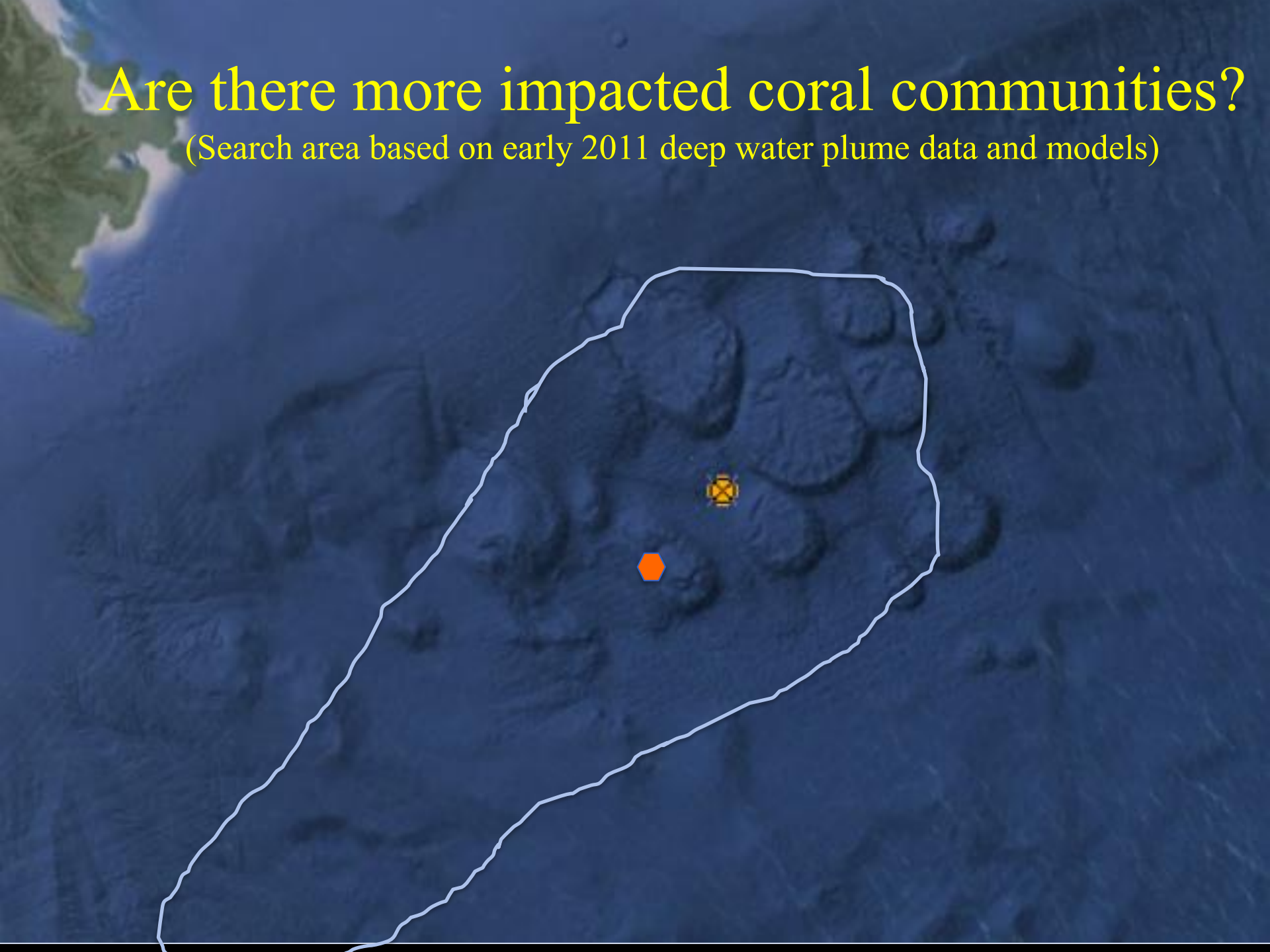
Proceedings of the National Academy of Sciences, 2012

The Connection: Oil fingerprints



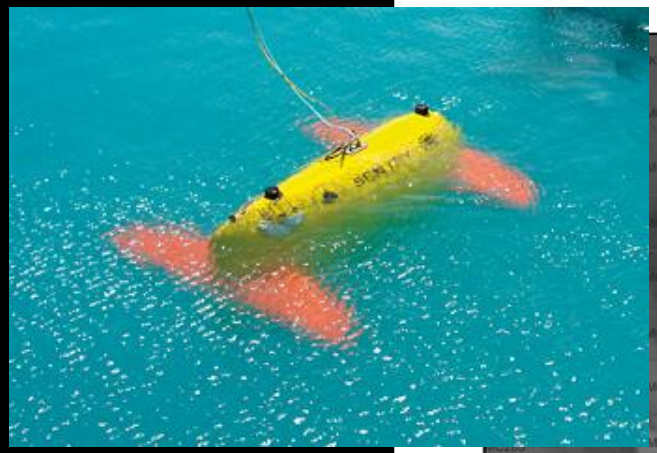
Are there more impacted coral communities?

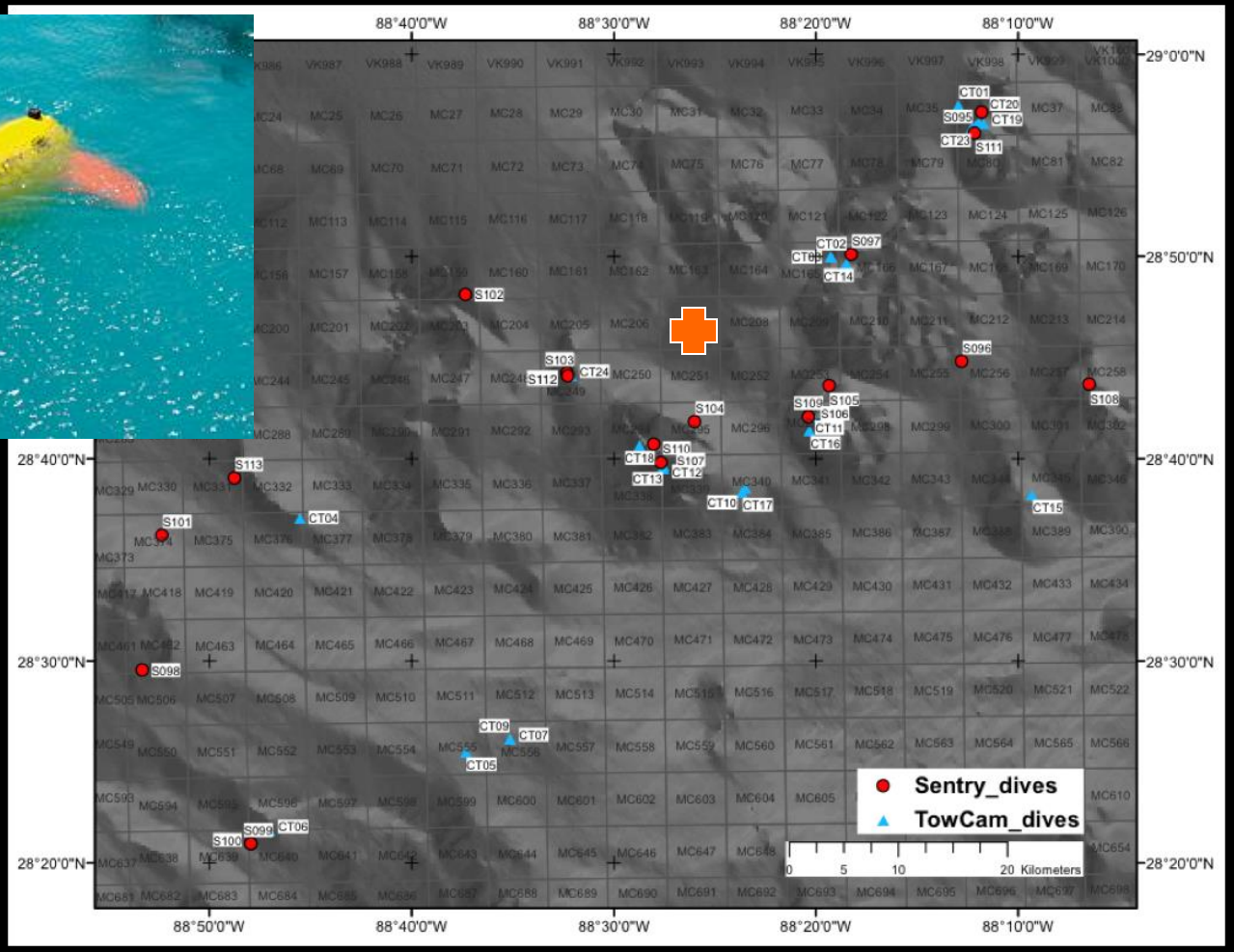
(Search area based on early 2011 deep water plume data and models)



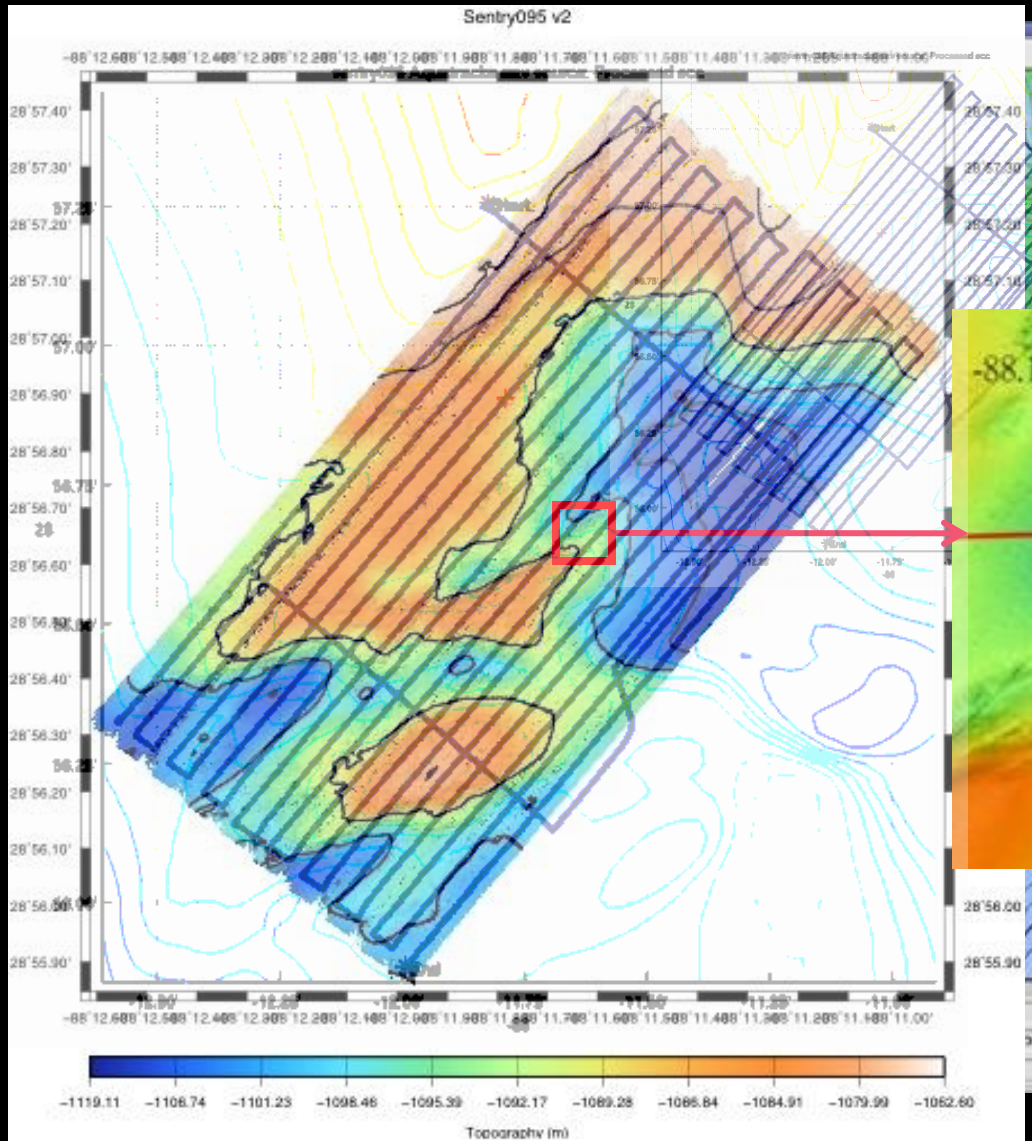
We spent one month at sea with an AUV and towed camera investigating sites identified from industry 3D seismic data at BOEM New Orleans*

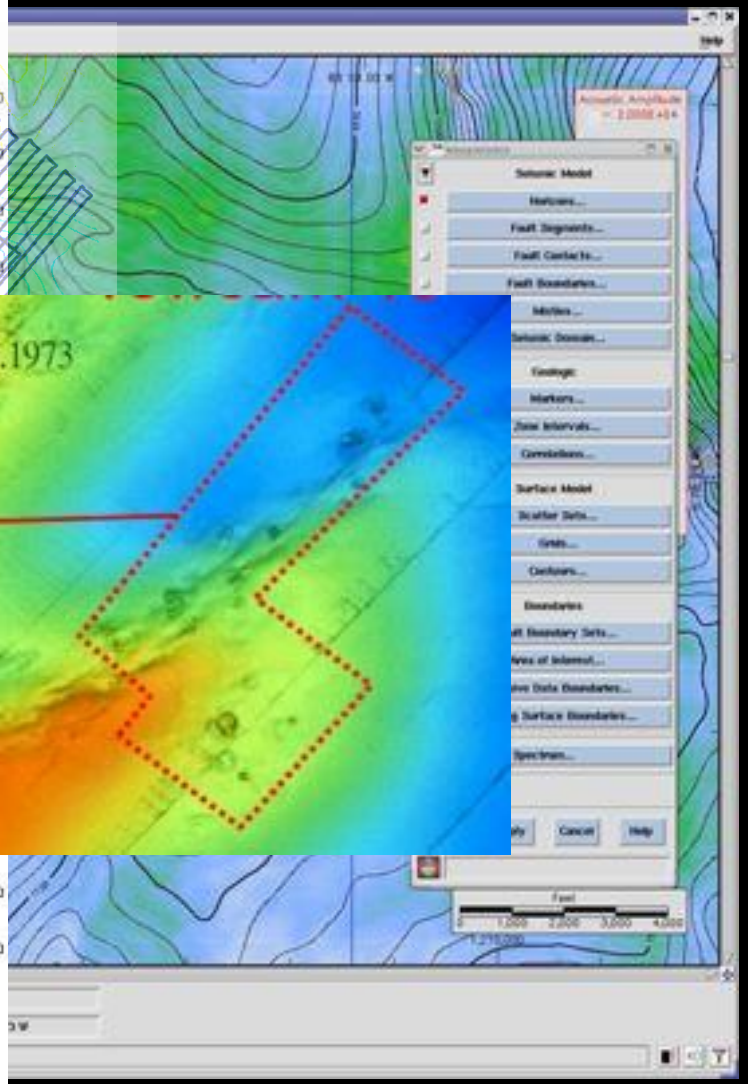
*During a 2 day meeting/negotiation with our team, Bill, and BP scientists



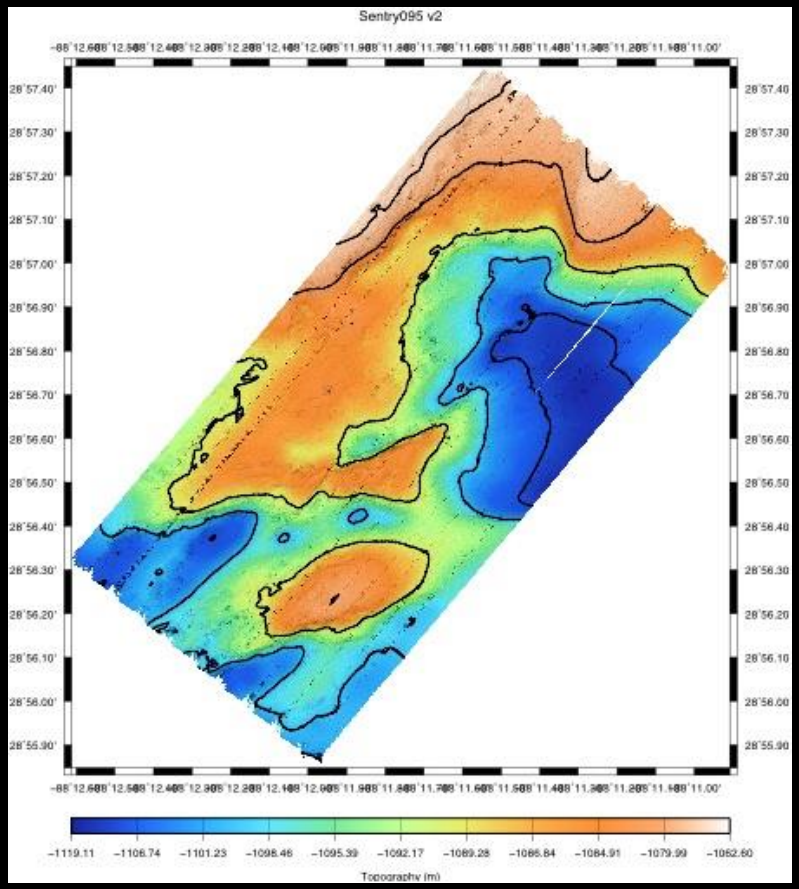


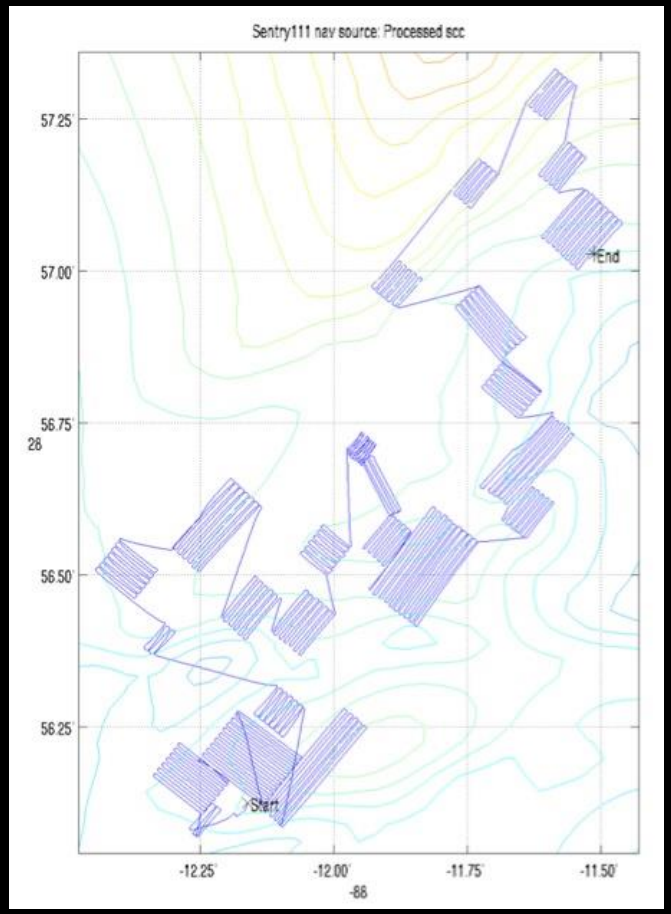
AUV Sentry Bathymetric Survey





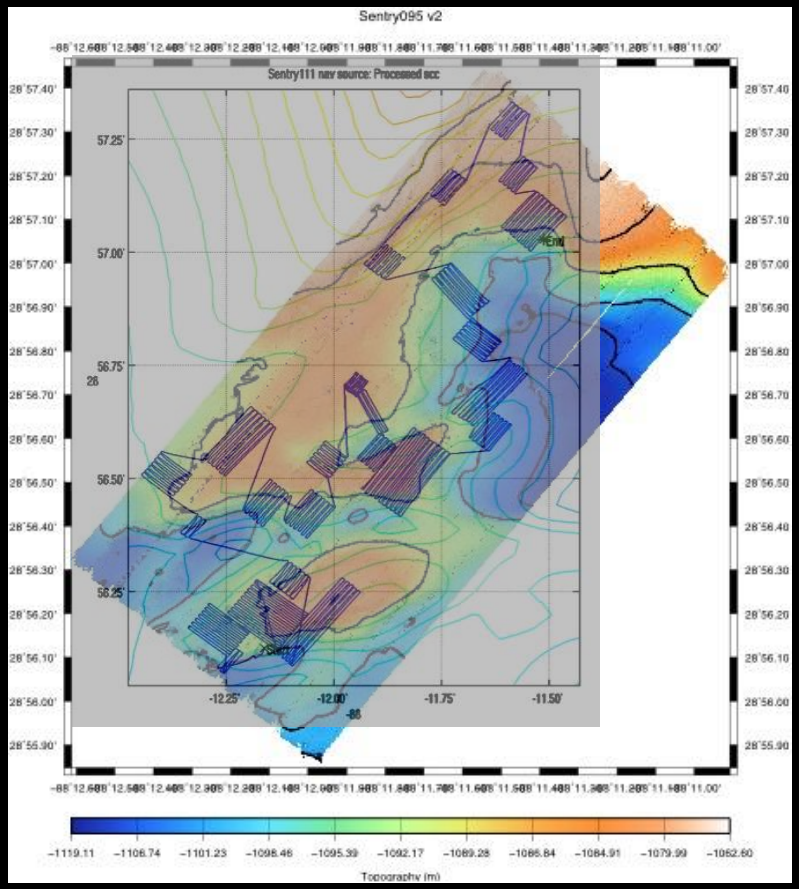
Send Sentry and/or TowCam back for photos



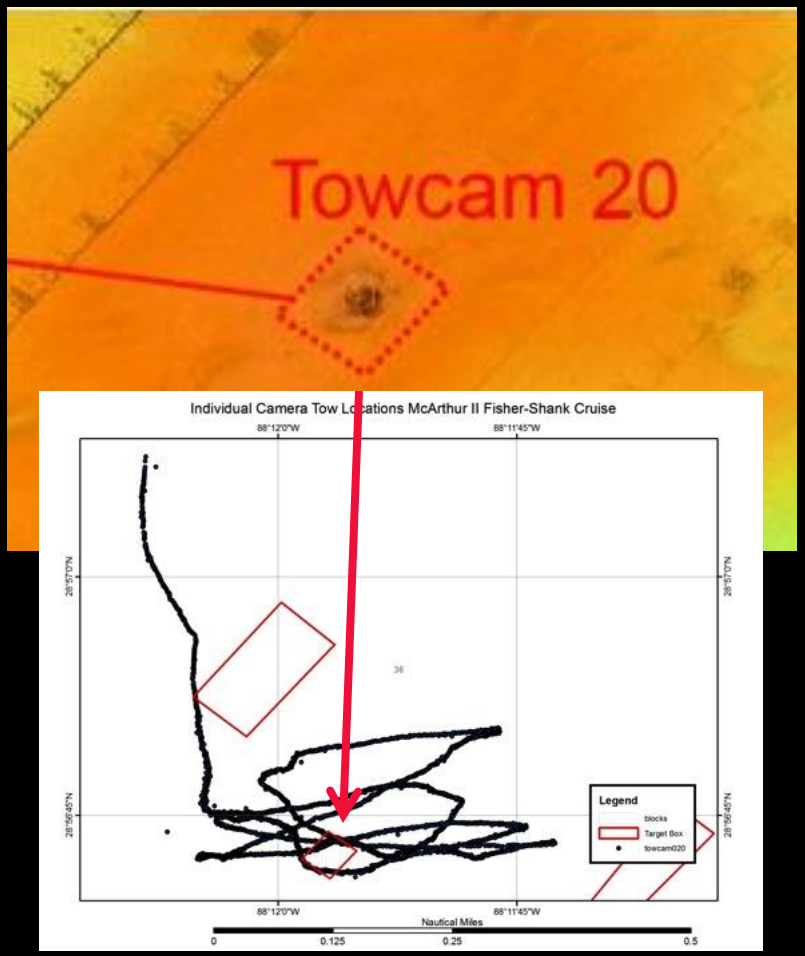


Sentry targets and tracklines

Send Sentry and/or TowCam back for photos



Sentry targets and tracklines



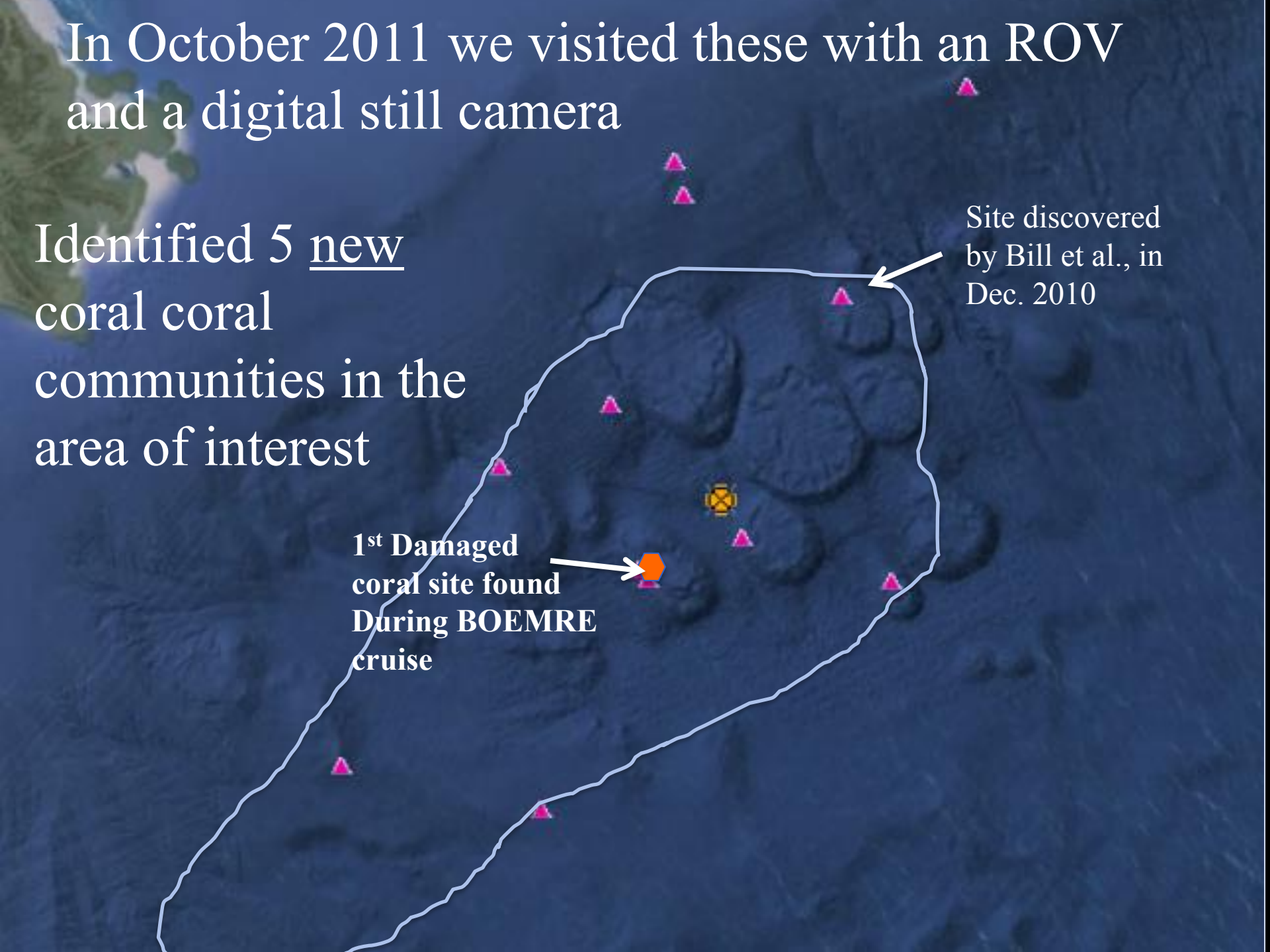
Tow cam target and tracklines

Results: 30 Day Cruise

- Sentry (Autonomous Underwater Vehicle)
  - 9 bathymetric mapping deployments
  - 16 imaging deployments
  - 68,416 photographs
  - ~20 with colonial corals
  - 5 new sites, 2 new areas
- Towed Camera
  - 26 deployments
  - 35,073 photographs
  - 0 with corals (1 false alarm)

In October 2011 we visited these with an ROV and a digital still camera

Identified 5 new coral coral communities in the area of interest

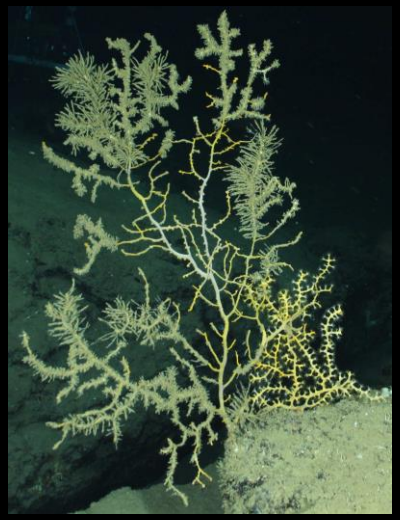


To identify communities impacted by the spill after the floc was gone we used our time course study from MC 294 and the telltale signature of patchy impact and hydroid colonization that is not found at control sites

Hsing, et al., 2013. Lasting impact of the Deepwater Horizon oil spill on a deep Gulf of Mexico coral community.
Elementa: Science of the Anthropocene. DOI 10.12952/journal.elementa.000012

Oct 2010 Dec 2010 Mar 2011 Oct 2011 Mar 2012

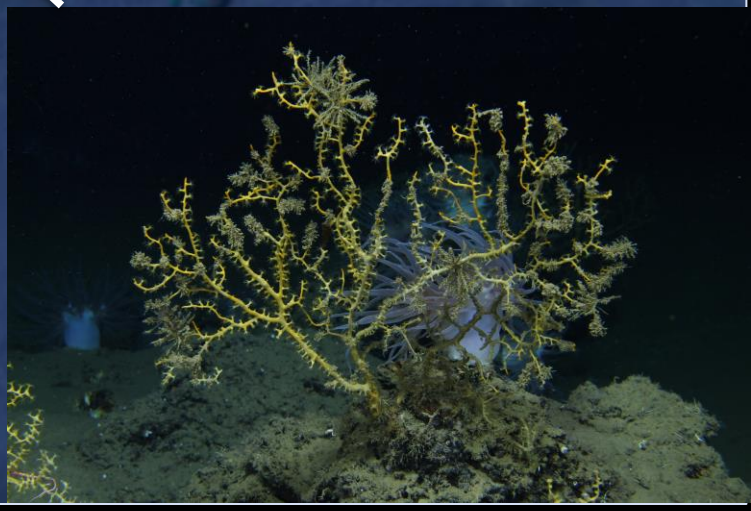



MC 297

13 km from MC294, 7 km from Macondo

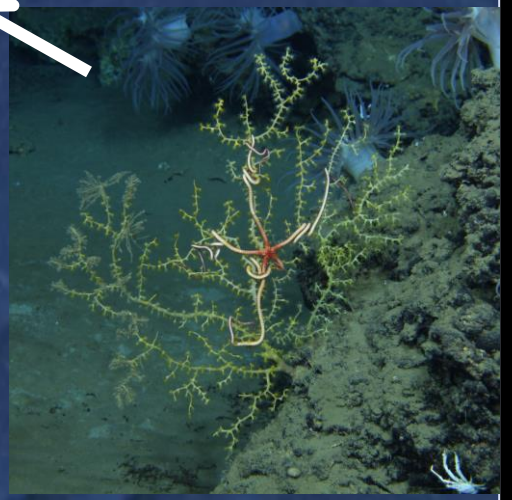
87 corals originally imaged
25 with no visible impact (29%)
14 impacted to over 50% of colony (16%)
35 colonized by hydroids (40%)
Telltale patchy impact signature



MC388/344

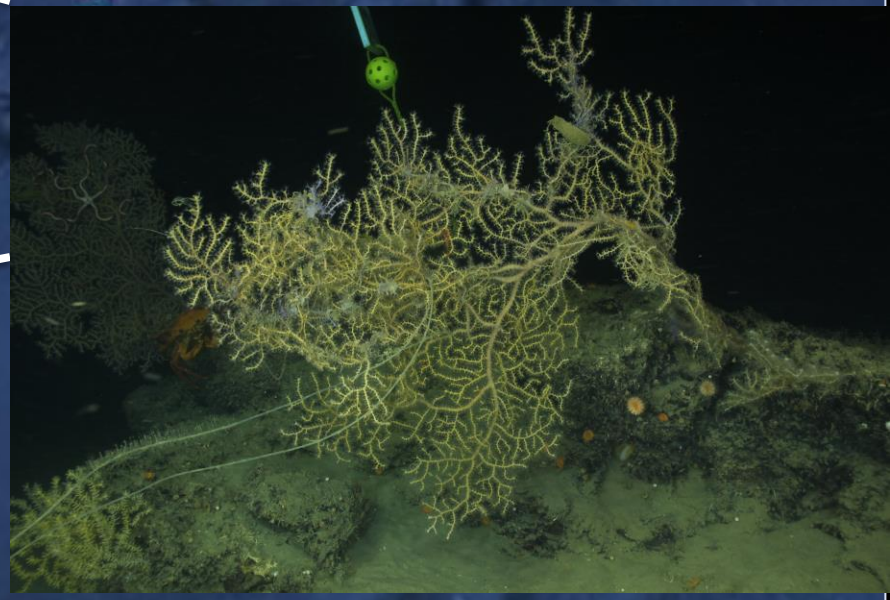
23 km from Macando at 1950m depth

- Lower level of impact
  - % corals and % of colonies
  - telltale patchy impact
  - 33 corals originally imaged
  - 29 more in 2012
    - With same pattern and level of impact

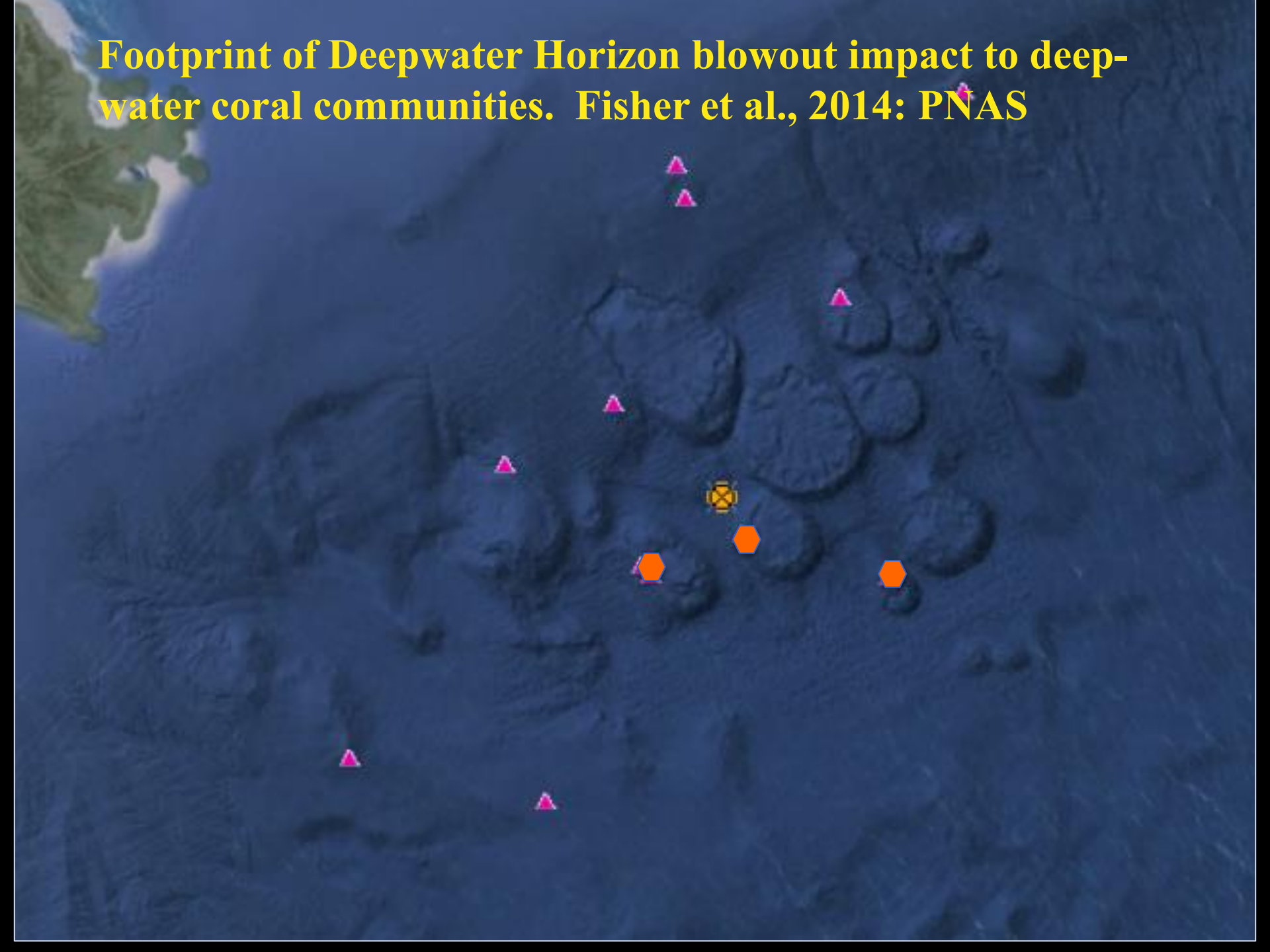


MC 159 and MC 506

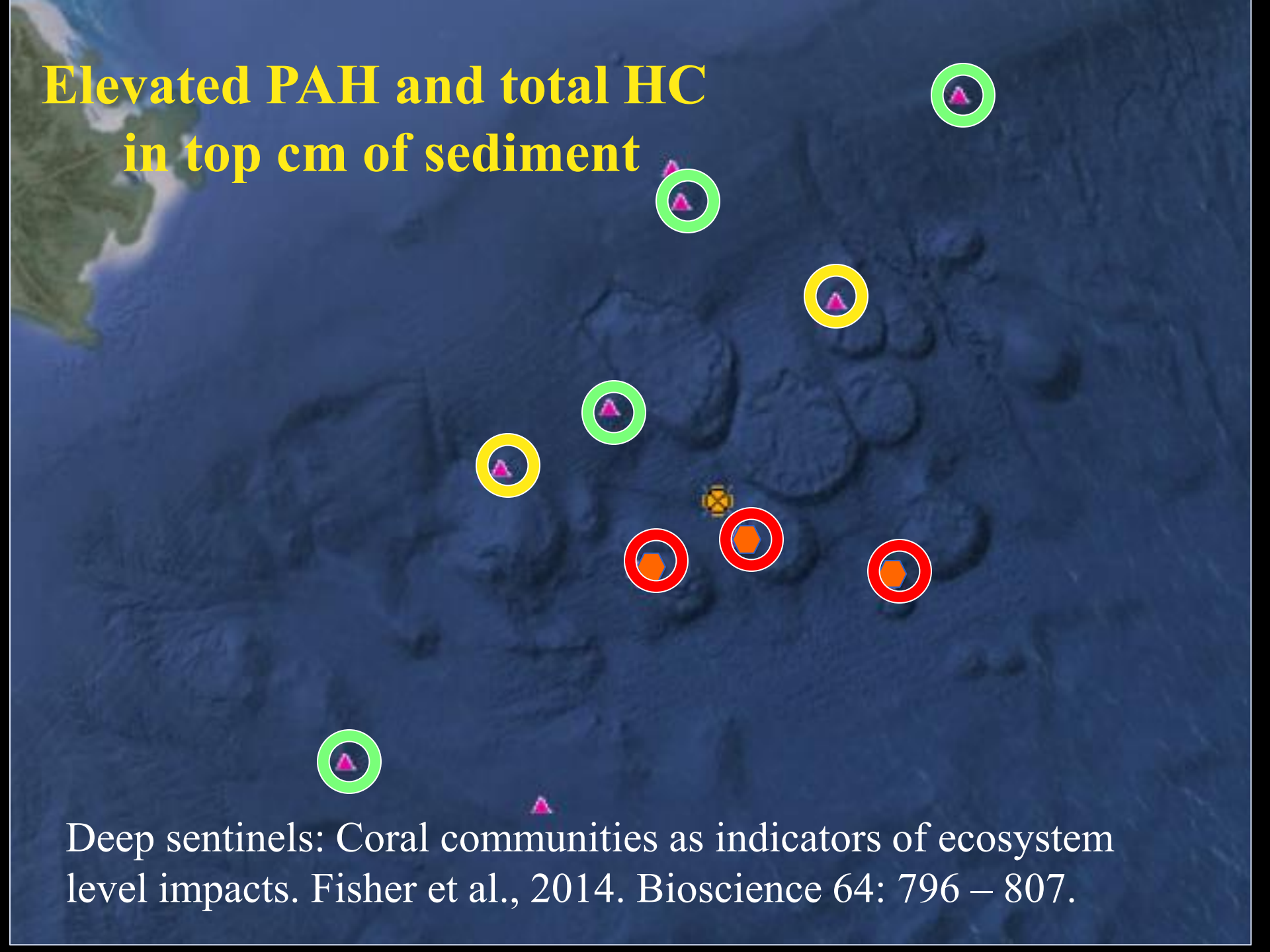
12 and 25 km from Macondo: Small sites with light impact and longline “complications”



Footprint of Deepwater Horizon blowout impact to deep-water coral communities. Fisher et al., 2014: PNAS

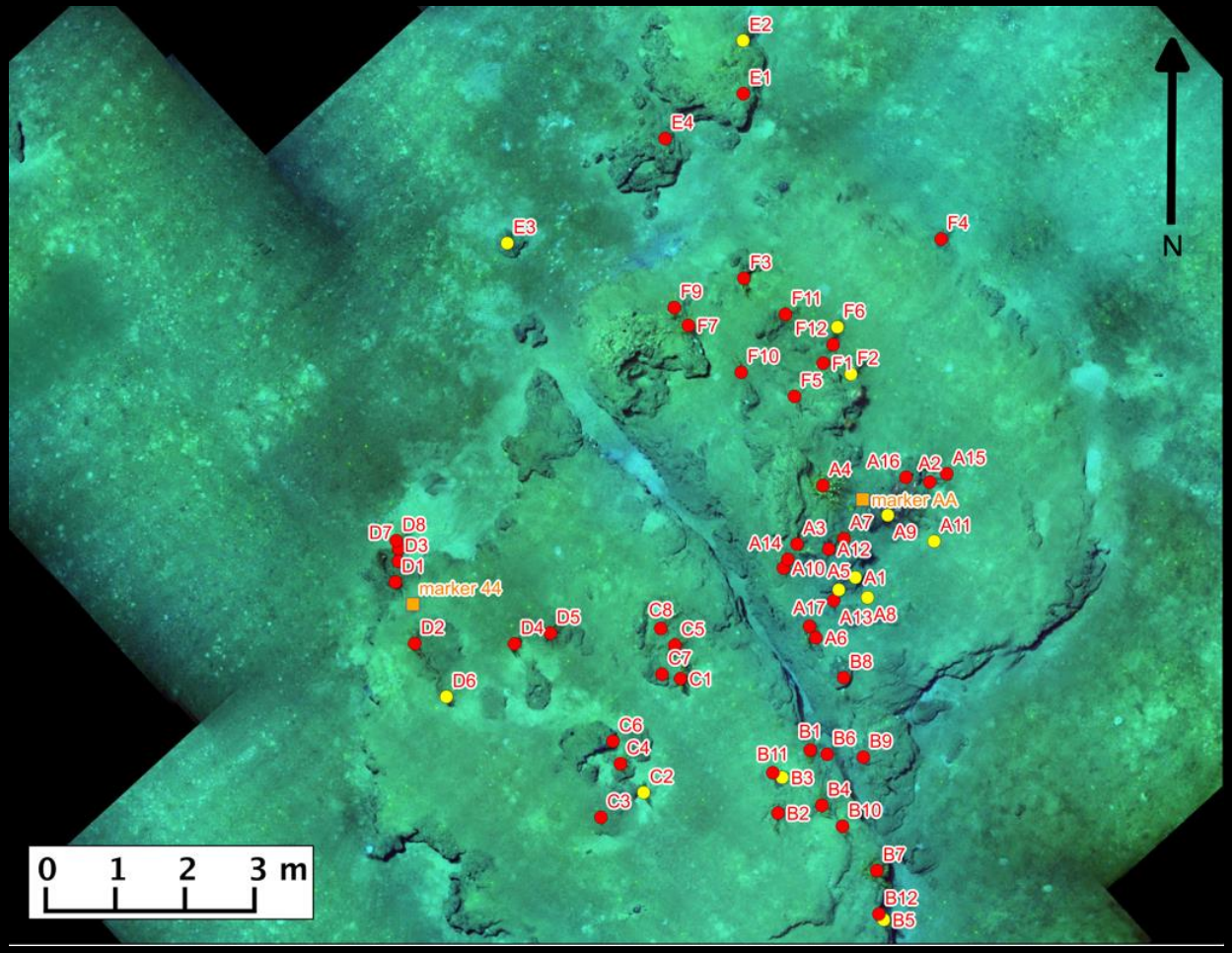


Elevated PAH and total HC in top cm of sediment



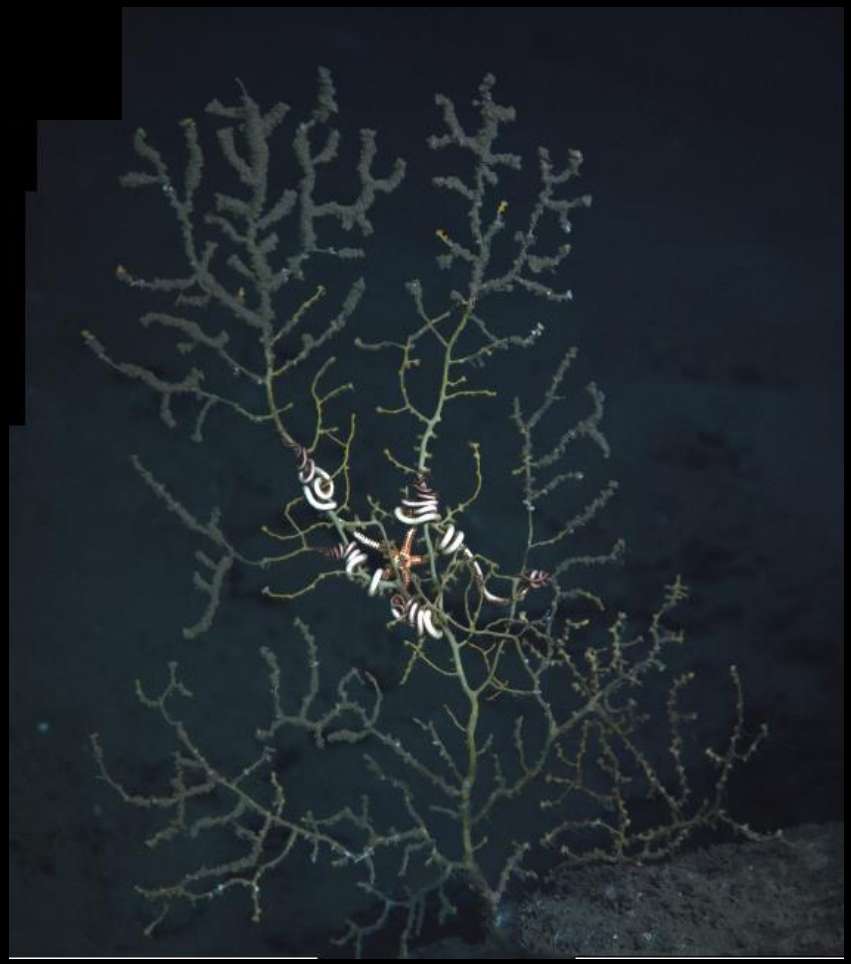
Deep sentinels: Coral communities as indicators of ecosystem level impacts. Fisher et al., 2014. Bioscience 64: 796 – 807.

Meanwhile, we are following the recovery of impacted corals to determine their ultimate fate

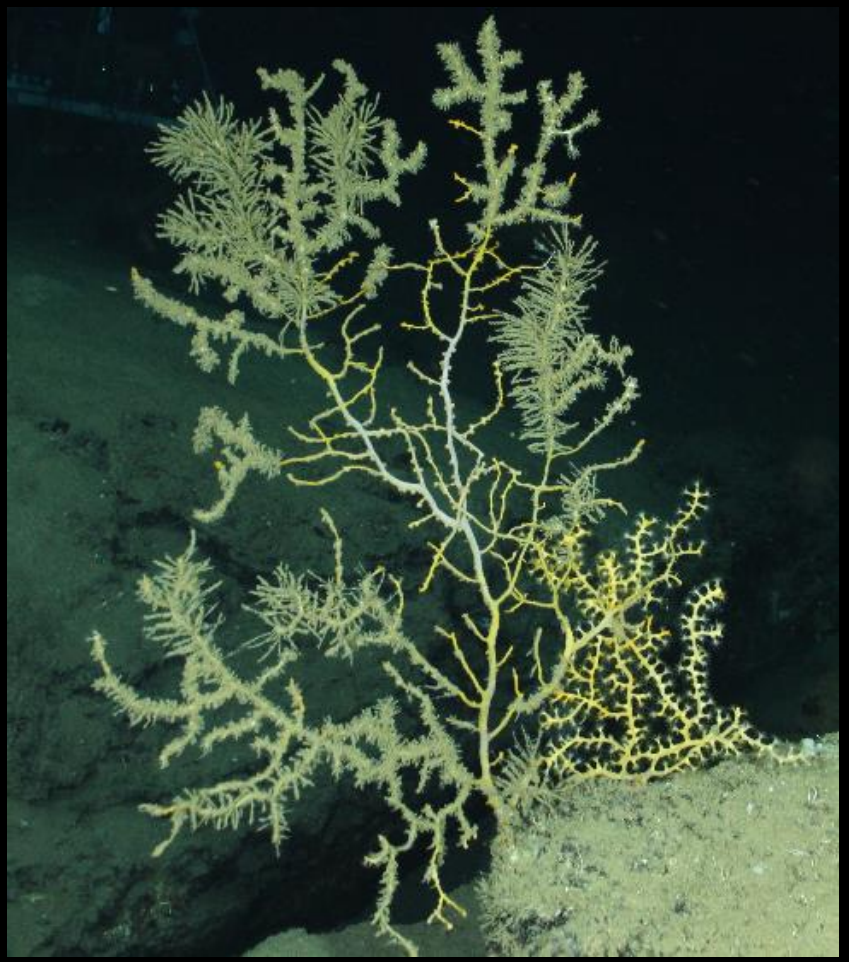


Central area of MC 294 community photo mosaic

Quantifying impact and tracking corals and individual branches over time

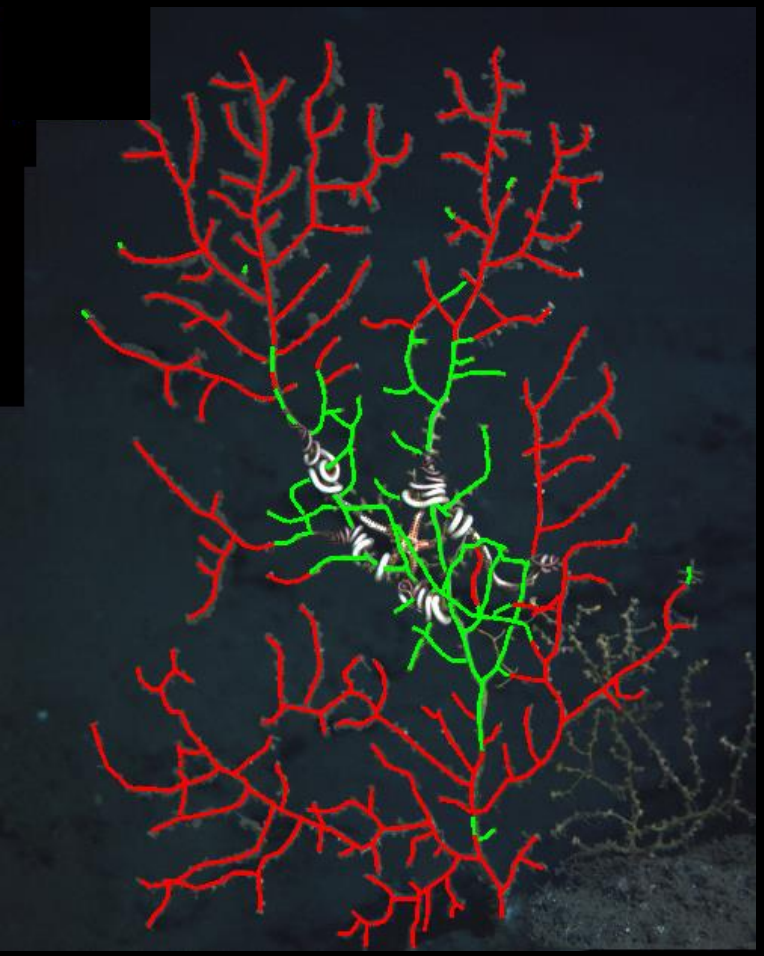


November 2010

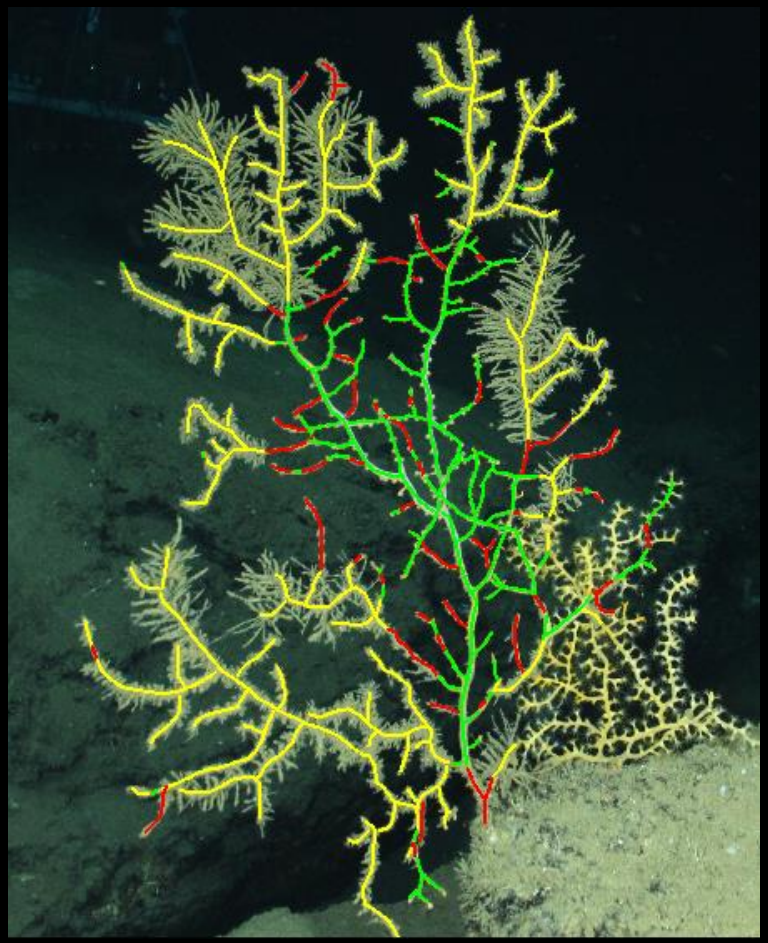


October 2011

Digitize each time



Nov. 2010



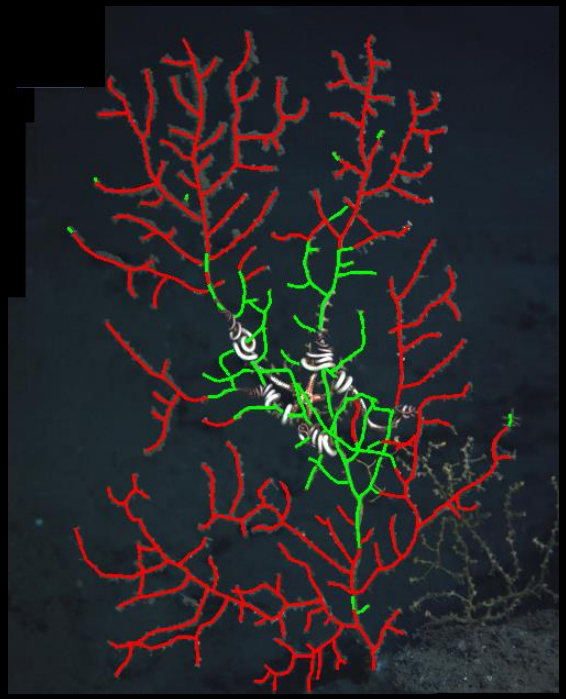
Oct 2011

Obviously impacted: dead, covered with floc, dripping tissue or mucous

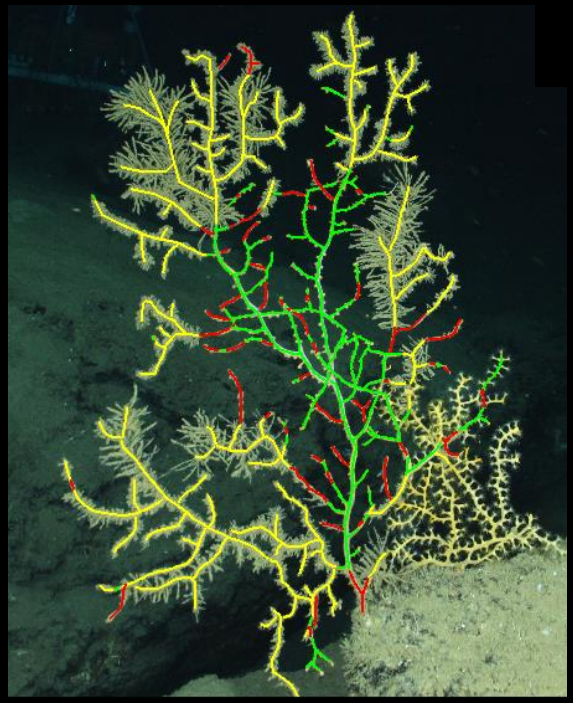
Live (or not sure)

Clearly covered by hydroids.

Digitize new condition on original image



November 2010

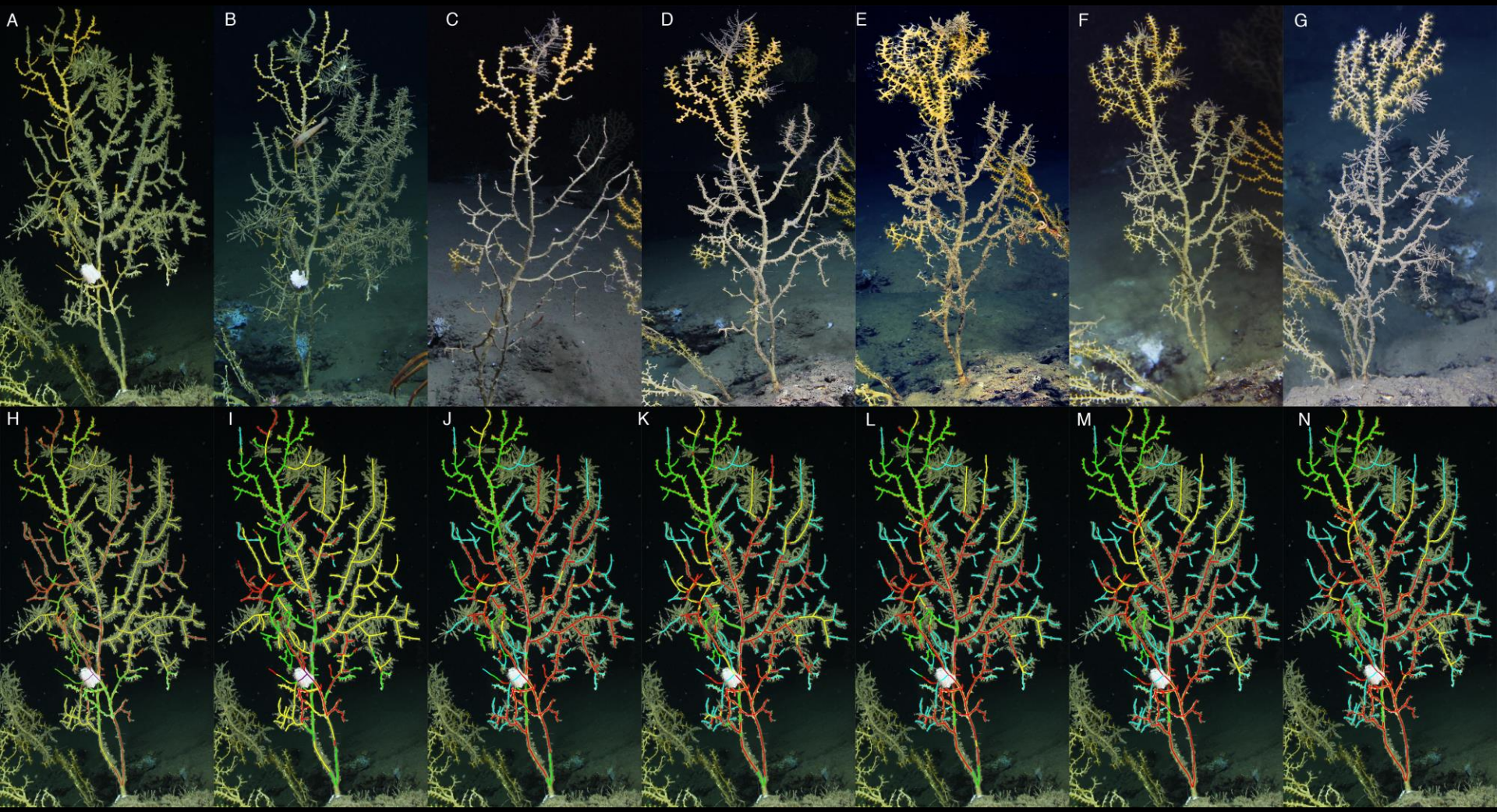


October 2011

Change
Nov. 2010-Oct. 2011

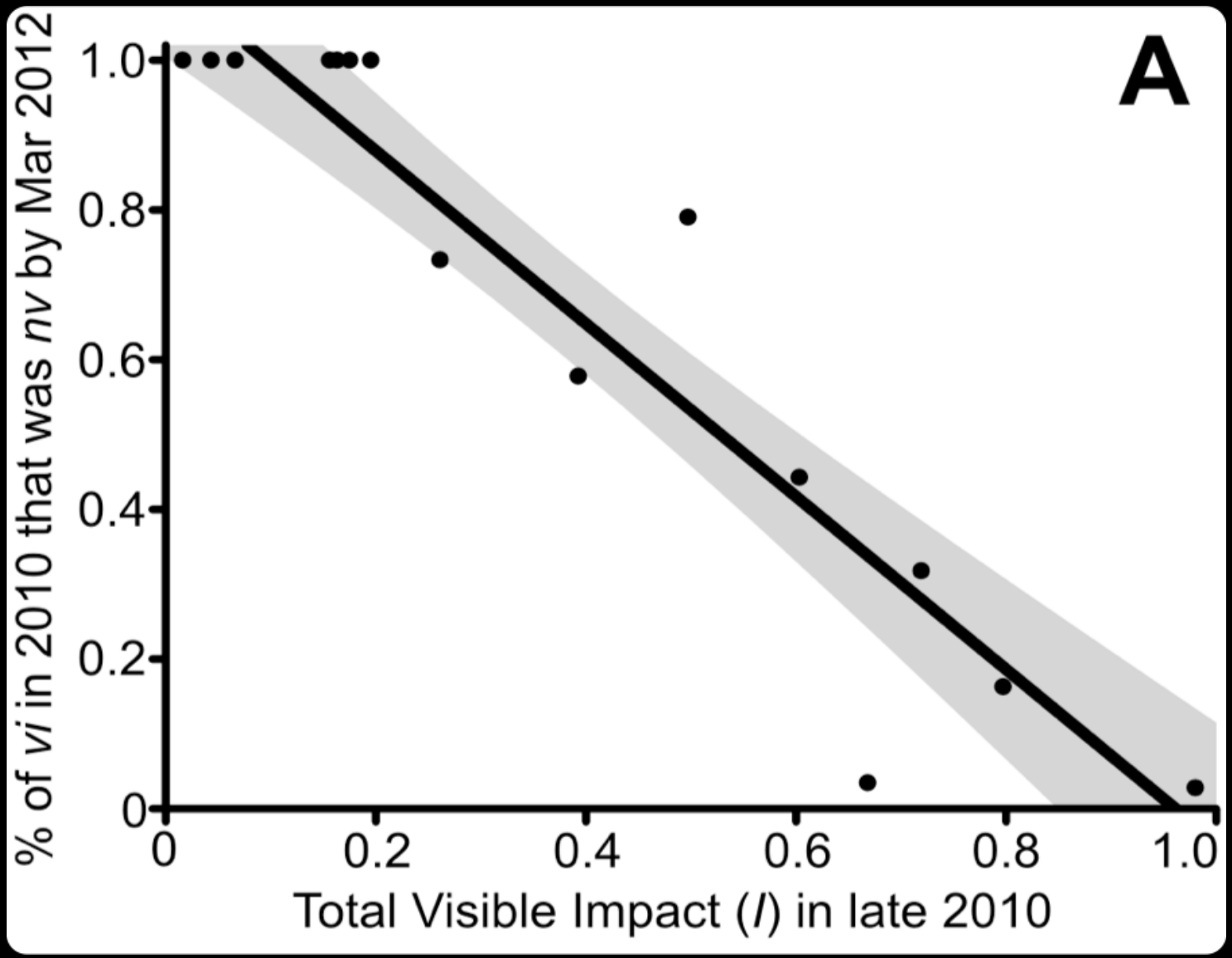
We are now monitoring over 400 corals every year

(with an army of excited and committed undergraduates)



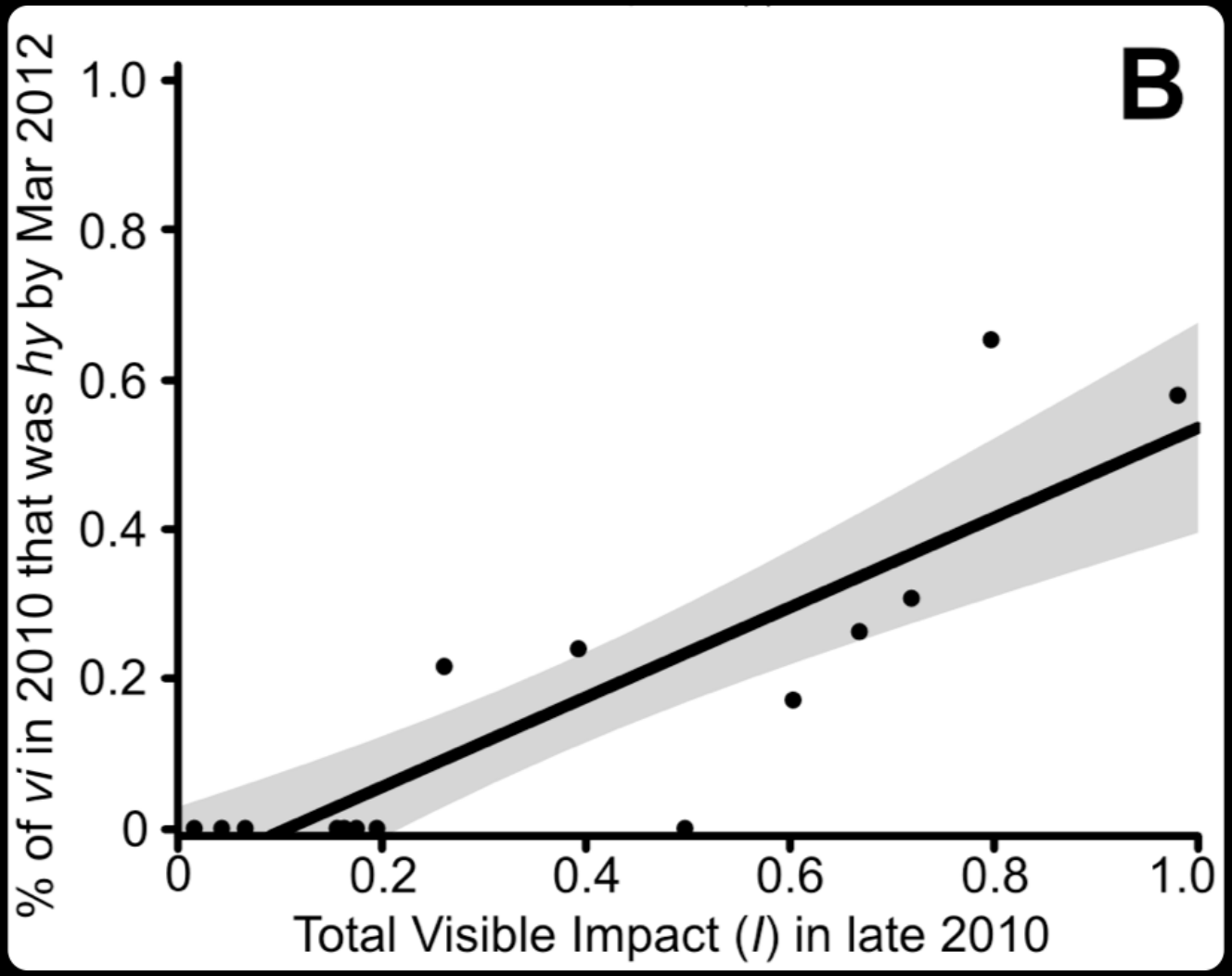
Apparent recovery as a function of degree of initial impact

% of branch recovery



Original level of Impact

Hydroid colonization as a function of degree of initial impact



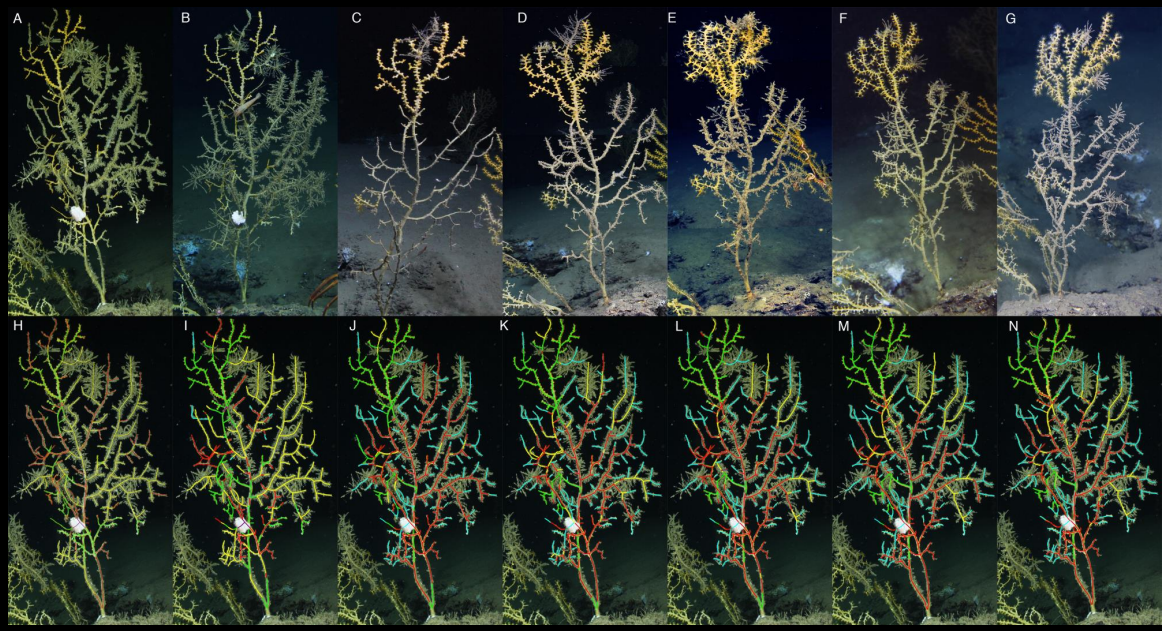
% of impacted branches colonized by hydroids

Original level of Impact

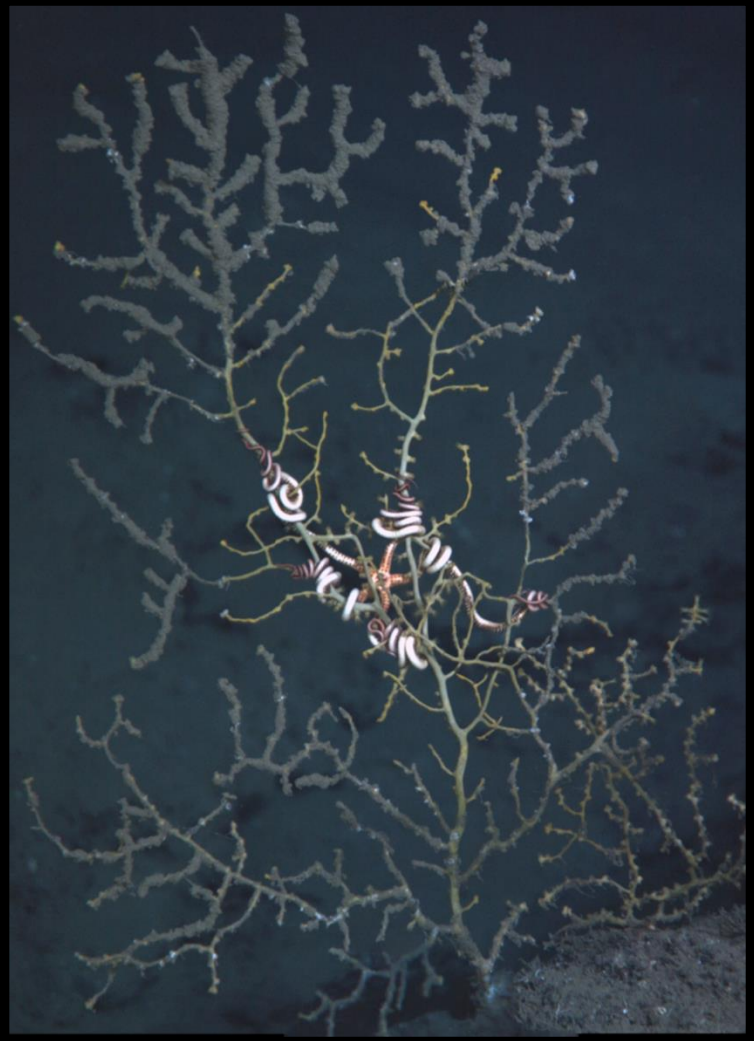
Monitoring corals:
(Life moves slowly in the deep sea)

- **Monitoring at control sites is providing new knowledge about growth patterns, associates, and the very low background rates of damage for several species (these corals live for centuries).**
- **Branch loss on impacted corals (shown in blue) is continuing and still a function of original impact (even to "healthy" parts of the corals).**
- **We can still detect an effect of original impact on growth rate.**

- We are modeling the data to determine the coral's ultimate fate
- We can use the data to back calculate when an impact occurred



Mutualistic symbiosis with ophiuroids limited the impact of the Deepwater Horizon oil spill on deep-sea octocorals (Girard et al., 2016. Marine Ecology Progress Series)



- The majority of corals at the impacted sites are associated with the ophiuroid species *Asteroschema clavigerum*
- Some corals lost ophiuroids the year after the spill, but none later
- A new technique was developed to measure the impact of ophiuroids in regions of the coral under their influence
- Ophiuroids benefit the host coral
  - The help protect from impact
  - They help corals recover

Conclusions: The spill

- The good news is that most of the deep Gulf of Mexico coral communities were not acutely impacted. But…
- The spill did significantly impact deep water megafauna communities to at least 23 km away and depths down to 1850 m.
- Many impacted corals will not recover
- The locations and depths of one deep site, suggests that a surface derived "toxic marine snow" was the likely cause for at least some of the deep sea damage.
- Therefore, the area where additional impact to corals may have occurred is much larger than originally thought.

Still too early to tell the ultimate fate of even acutely impacted corals, and we have no real idea of long-term subacute damages.

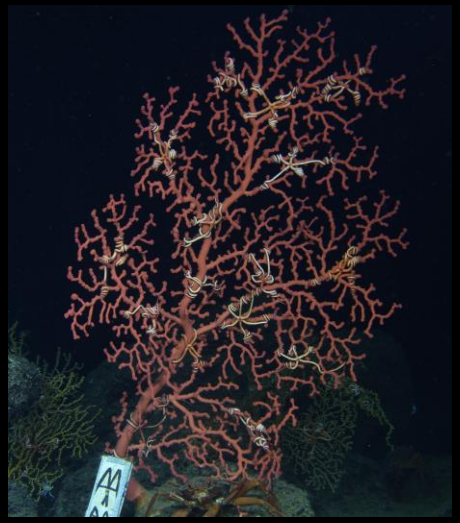
Take Home Message I

BP is paying over $270,000,000 for damage to the deep sea

- All of this will be used, through the trustees, for “restoration” of the open, Deep Gulf of Mexico
- Intelligent use of these funds is guided by what we learned with BOEM support

Take home message II: Octocorals are excellent deep-sea sentinels for anthropogenic impact

- Found all over the Gulf, at all depths
- Grow up above the sea floor (easy to see)
- Constantly "sample the water" (for gas exchange and food)
- Most octocorals are normally completely covered with living tissue
- Some species live for 100's to 1000's of years (death is a rare event)
- Adults don't move (attached to the sea floor)
- Their skeleton remains for years after they die (the "evidence" lasts in place for years)



Thank you for your attention