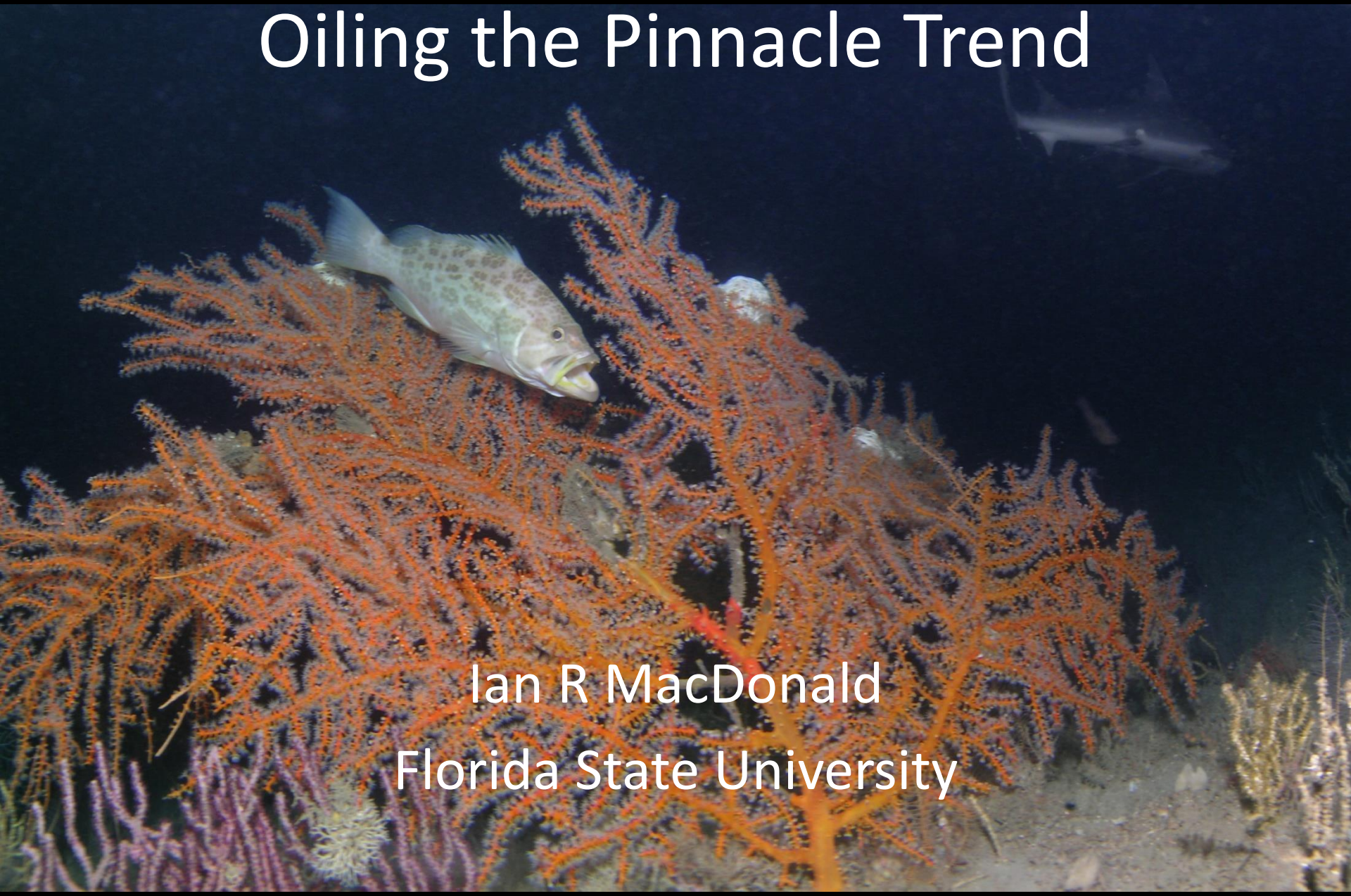
Oiling the Pinnacle Trend



Ian R MacDonald
Florida State University

Outline

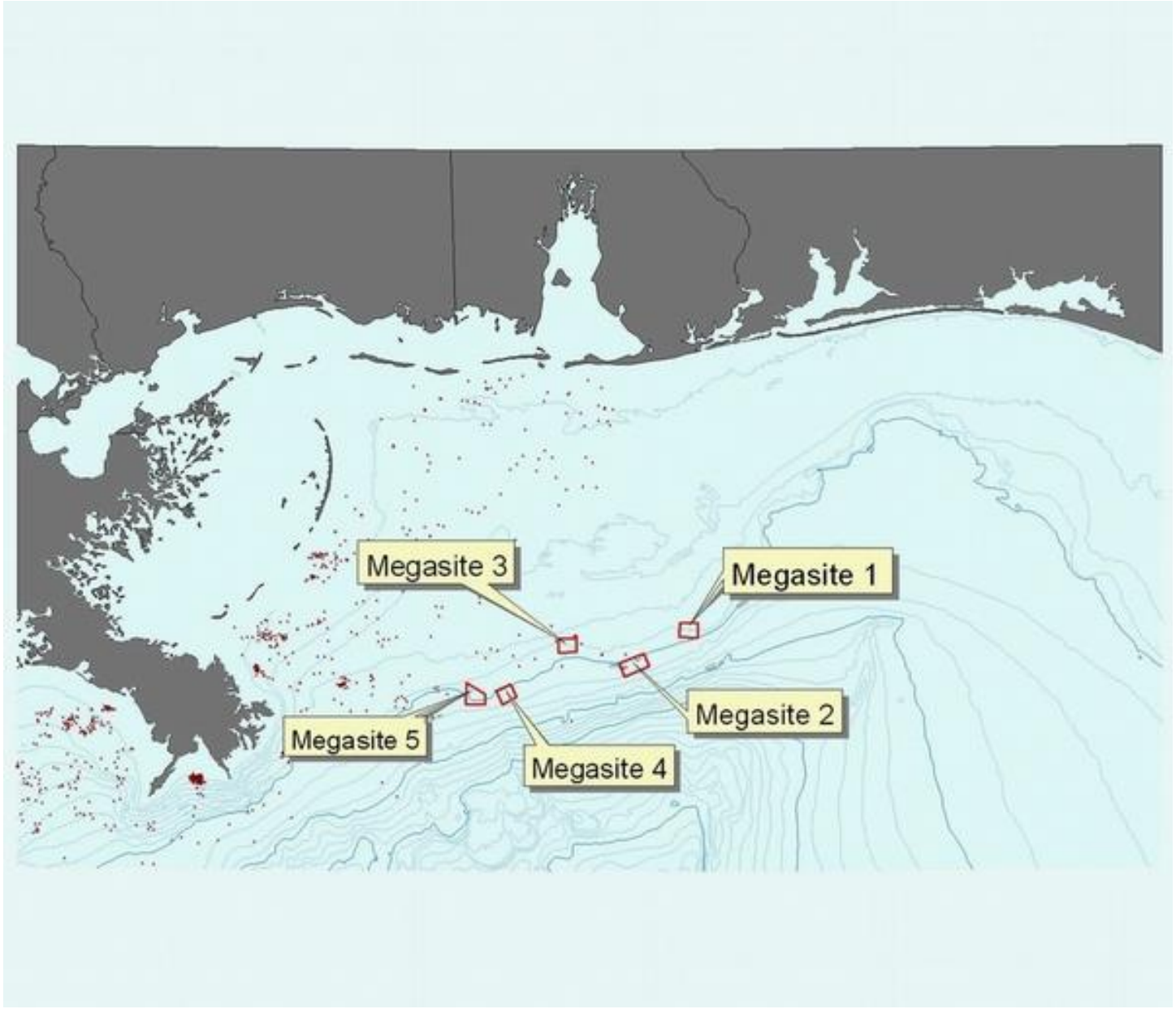
- Pinnacle Trend Coral Ecosystem
- Spread of surface oil during DWH
- Effects of dispersant application and burning
- Mesophotic coral injury
- Recovery and prospects for protection

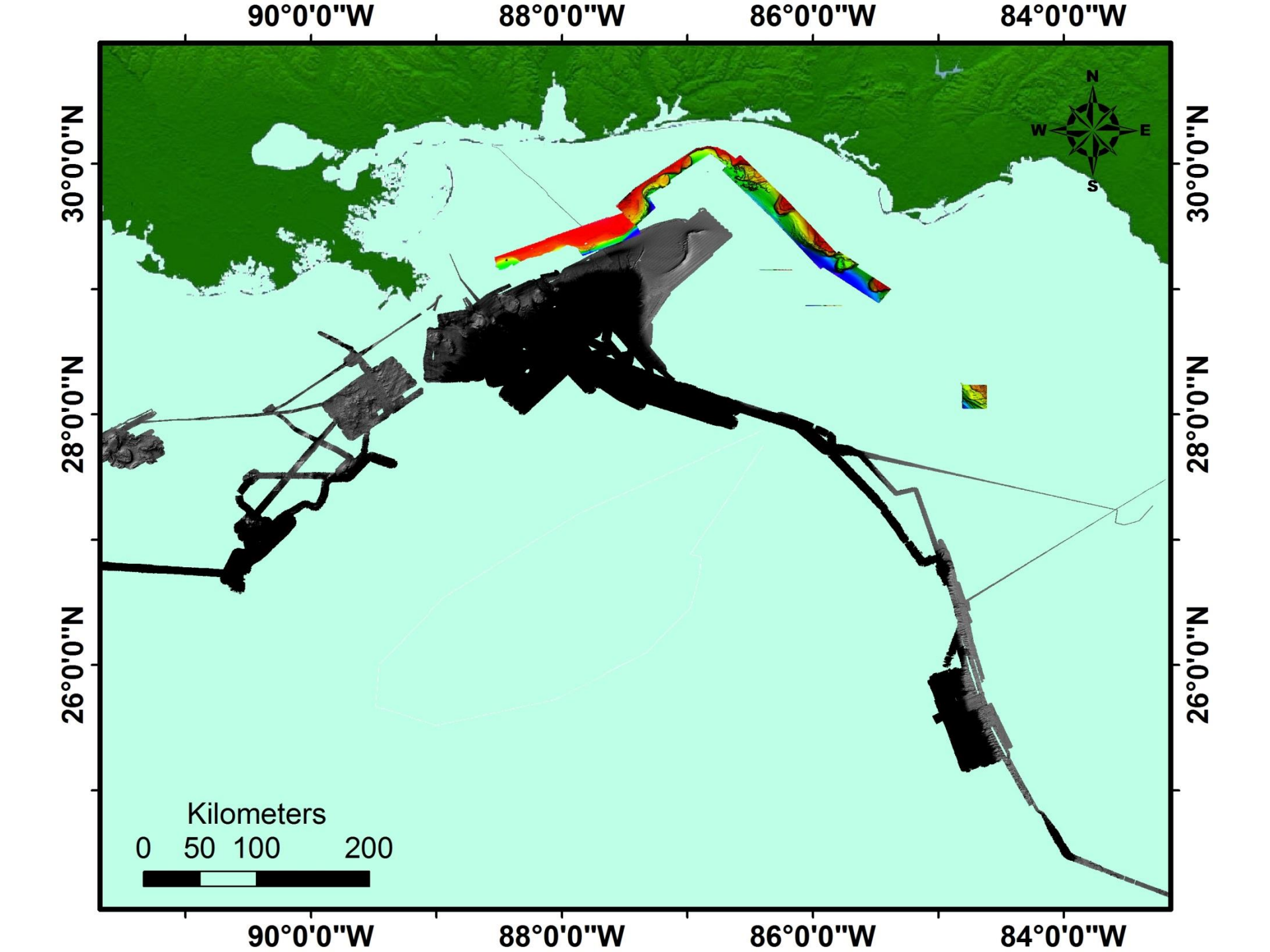
Acknowledgements and Collaborators

- Funding and guidance
  - NOAA/NRDA
  - GOMRI ECOGIG and Deep-C Research Consortia
  - BOEM
- Collaborators
  - O. Garcia-Pineda, A. Beet, S. Daneshgar Asl, P. Etnoyers, L. Feng, G. Graettinger, D. French-McCay, J. Holmes, C. Hu, F. Huffer, I. Leifer, F. Mueller-Karger, A. Solow, M. Silva, G. Swayze

- Publications
  - Silva, M. et al. (2015) Coral injuries observed at Mesophotic Reef Communities following the Deepwater Horizon oil discharge, Deep-Sea Research II
  - Etnoyer, P et al. (2015) Decline in condition of gorgonian octocorals on mesophotic reefs in the northern Gulf of Mexico: before and after the Deepwater Horizon oil spill, Coral Reefs
  - MacDonald I. et al. (2015) Natural and unnatural oil slicks in the Gulf of Mexico, J. Geophys. Res. Oceans

MAMES Overview

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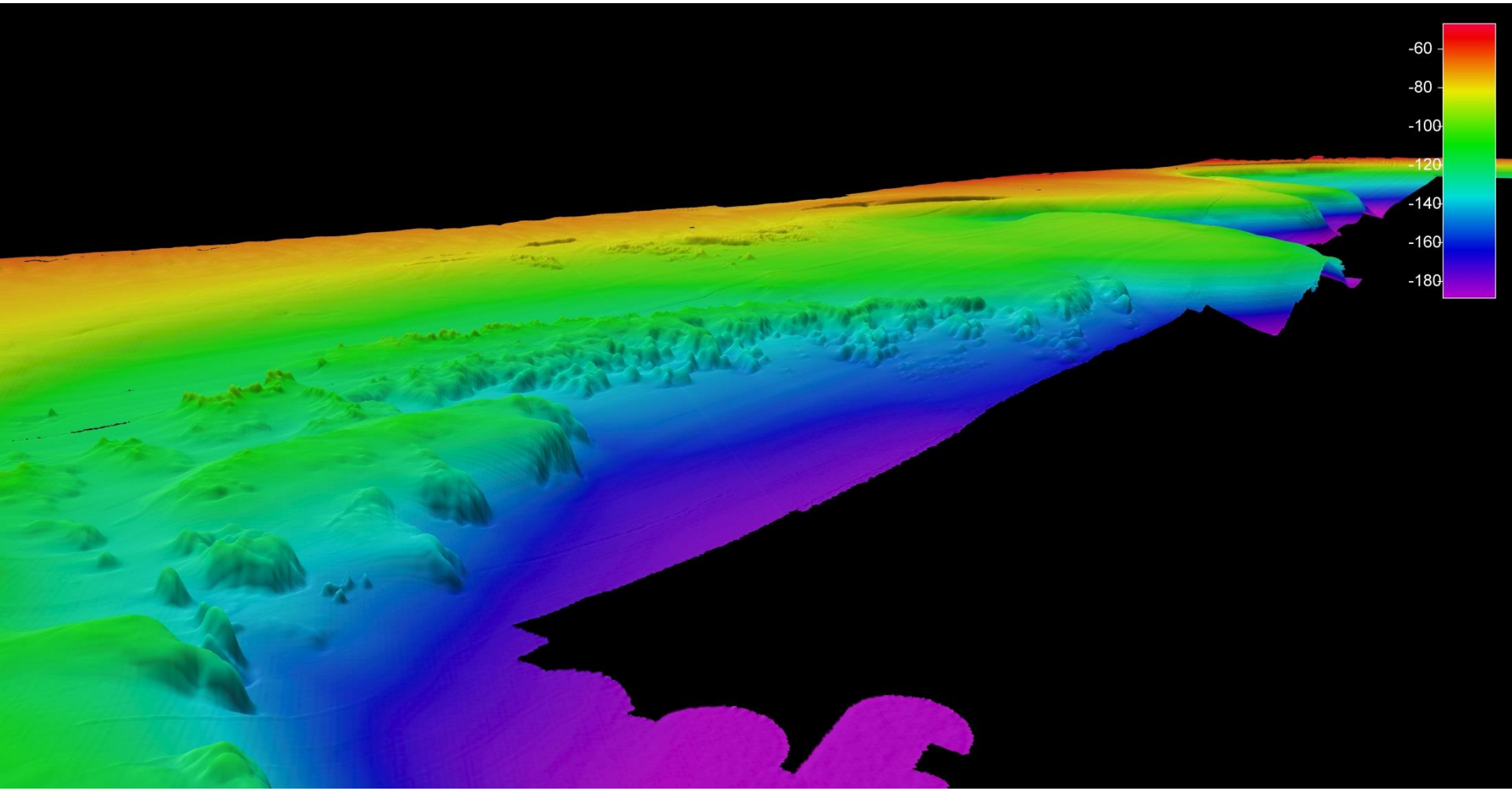
30°0'0"N
28°0'0"N
26°0'0"N
N
W
E
S
Kilometers
0 50 100 200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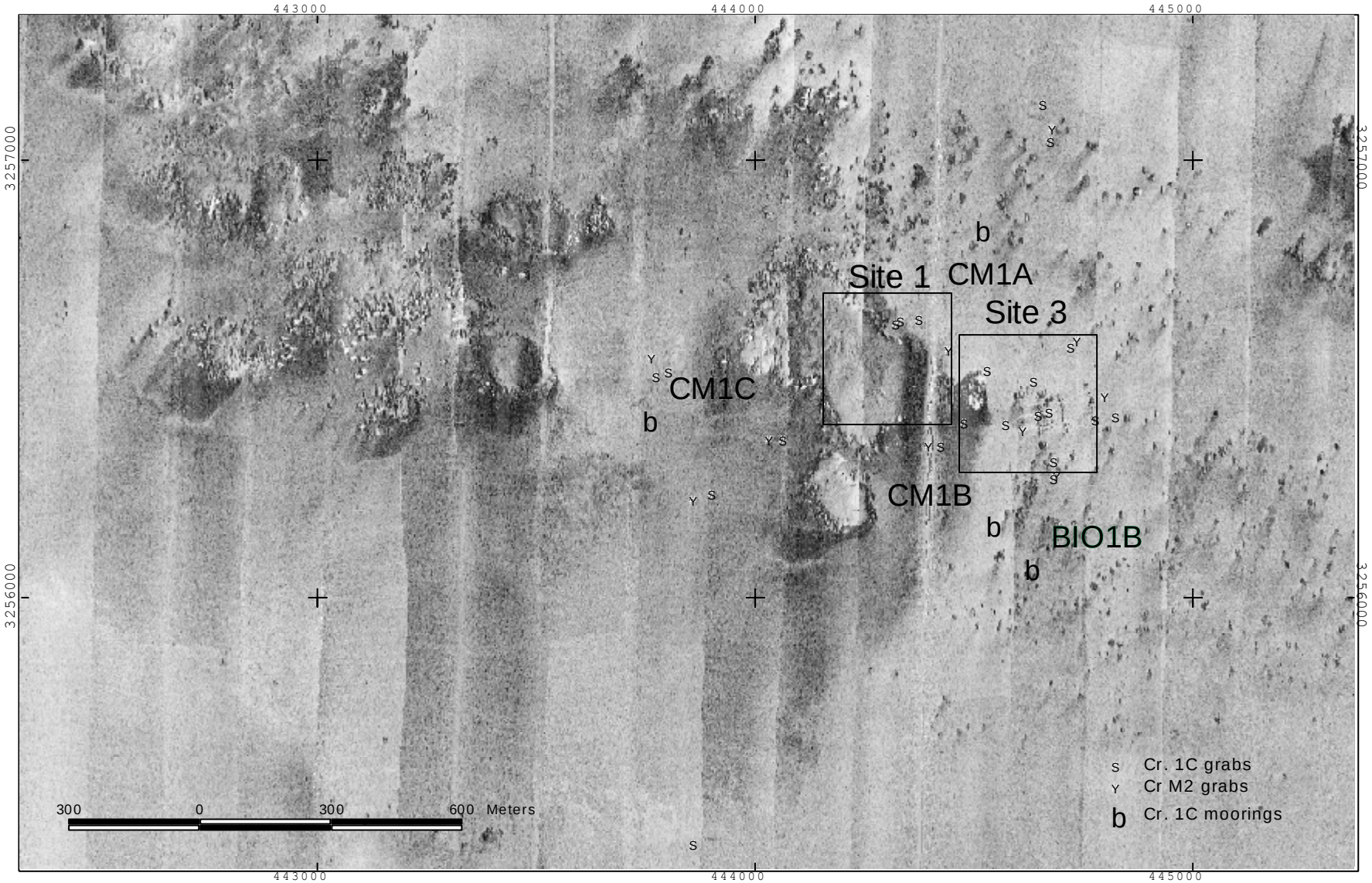
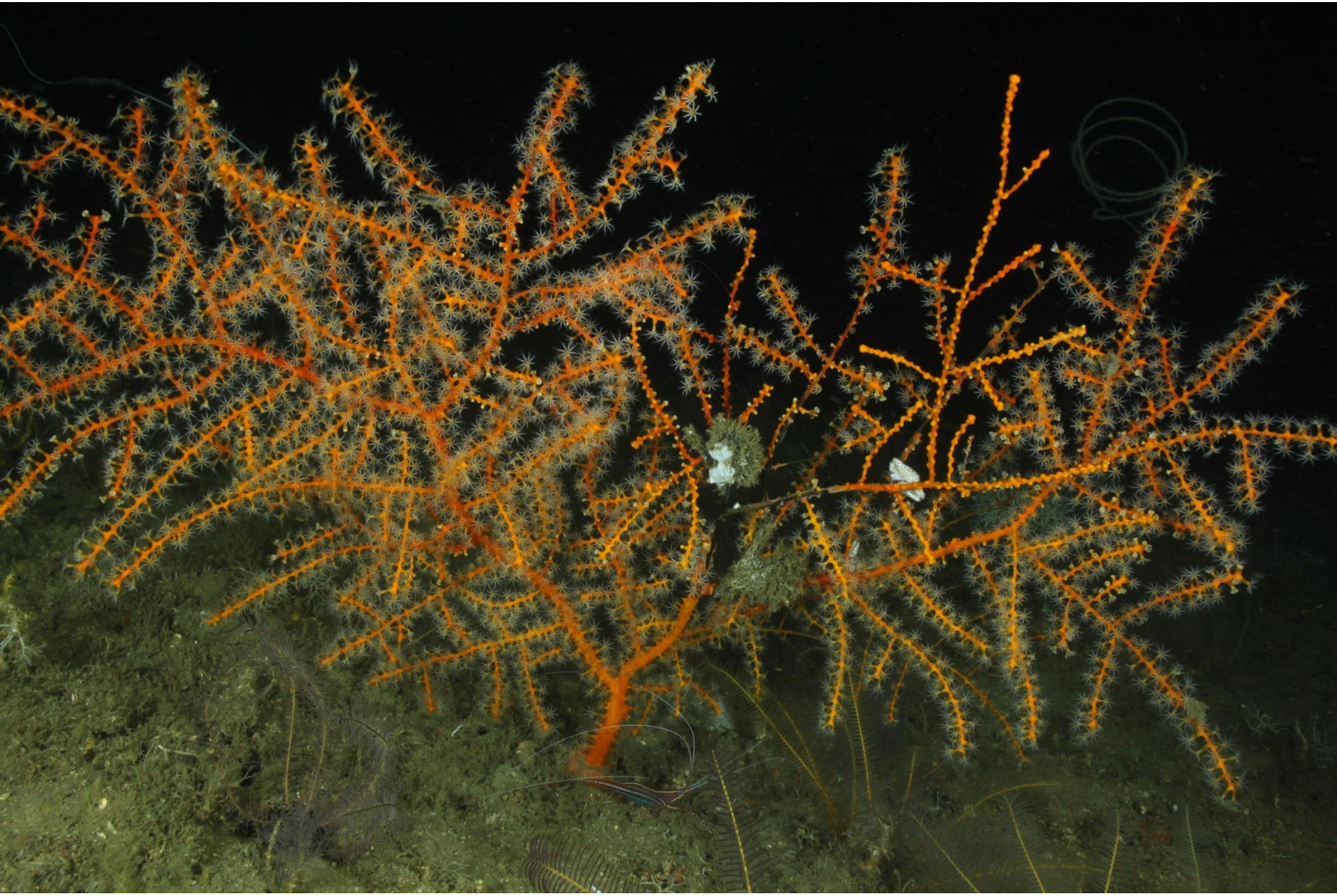
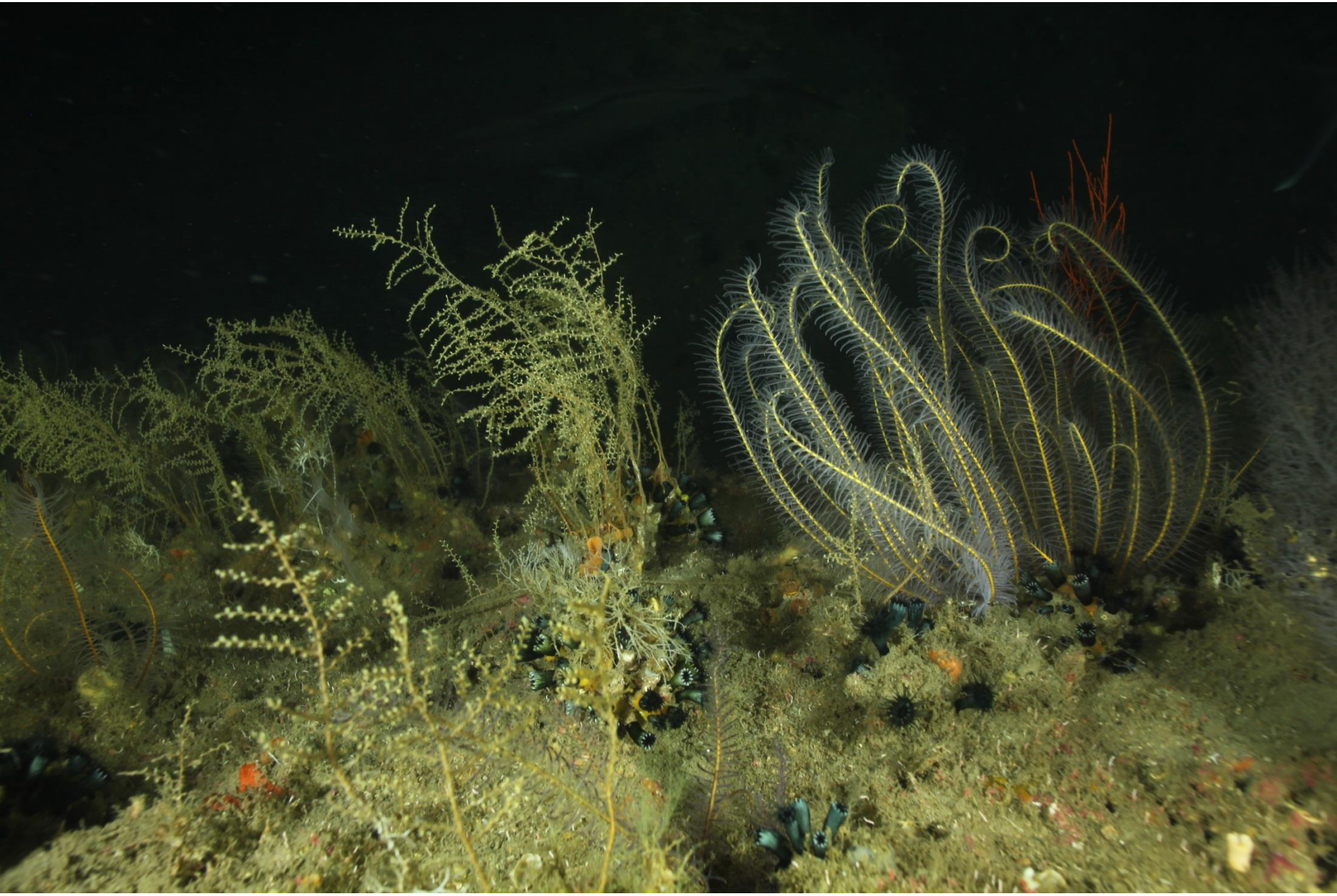
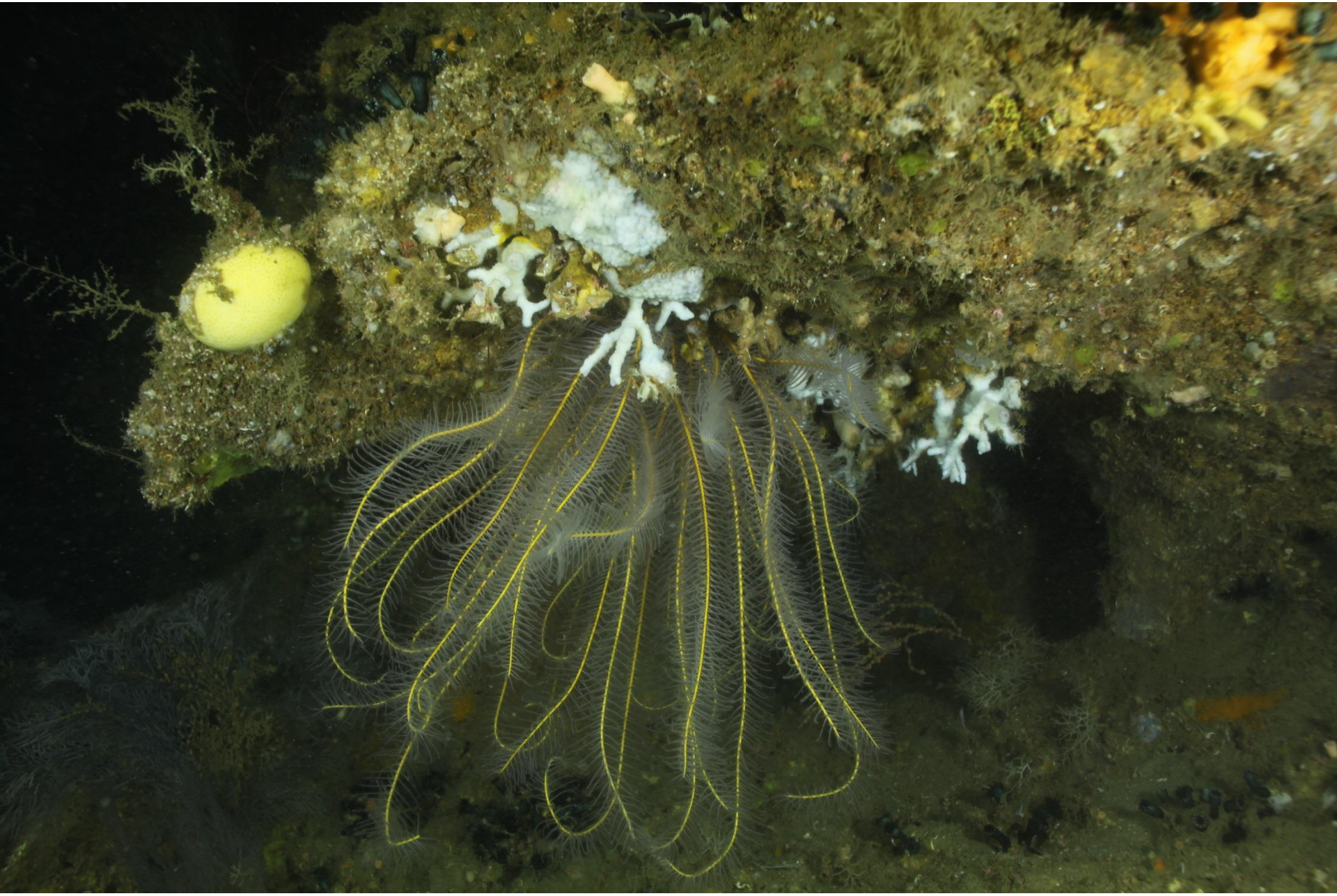
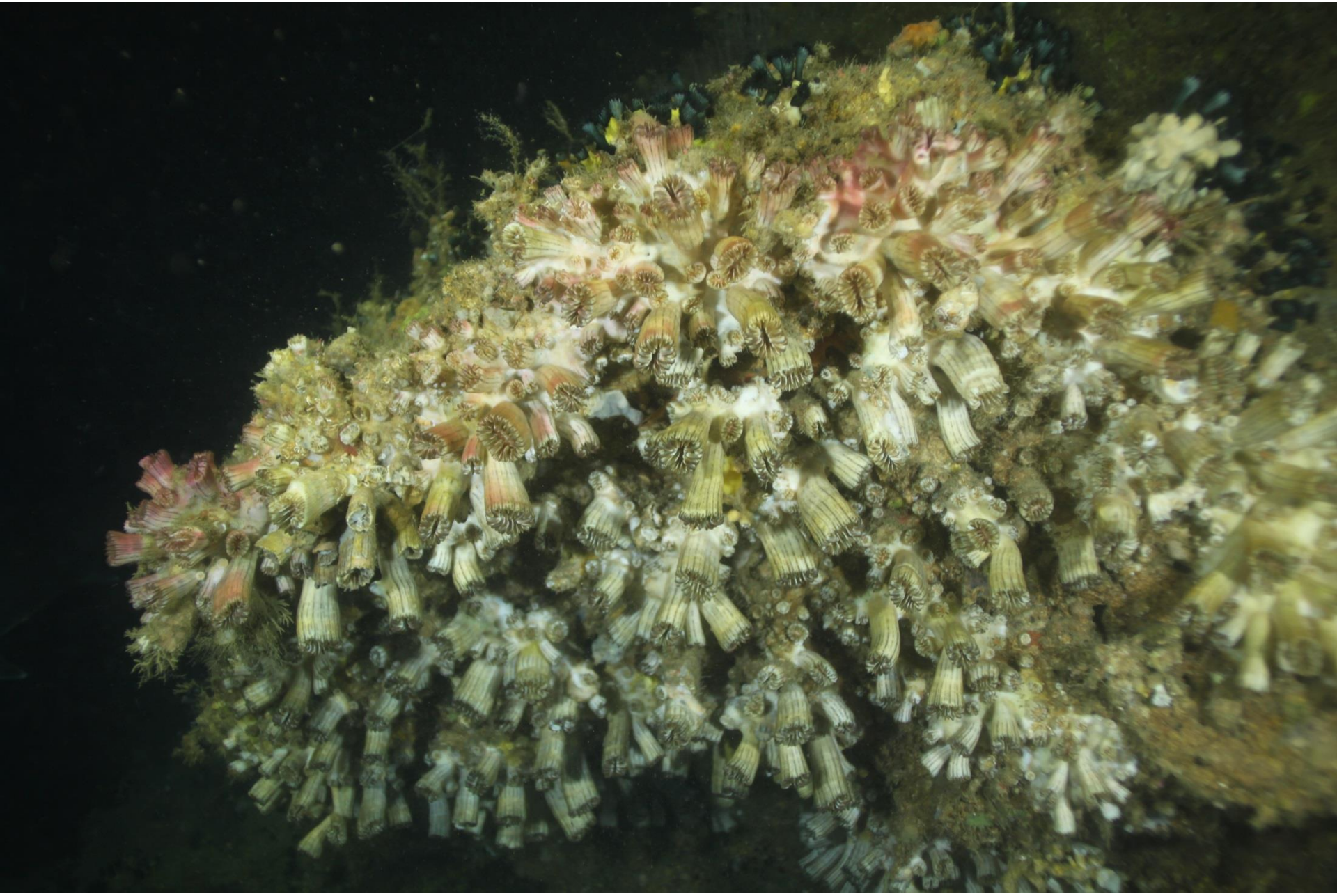


Megasite 1 detail 1 and 3

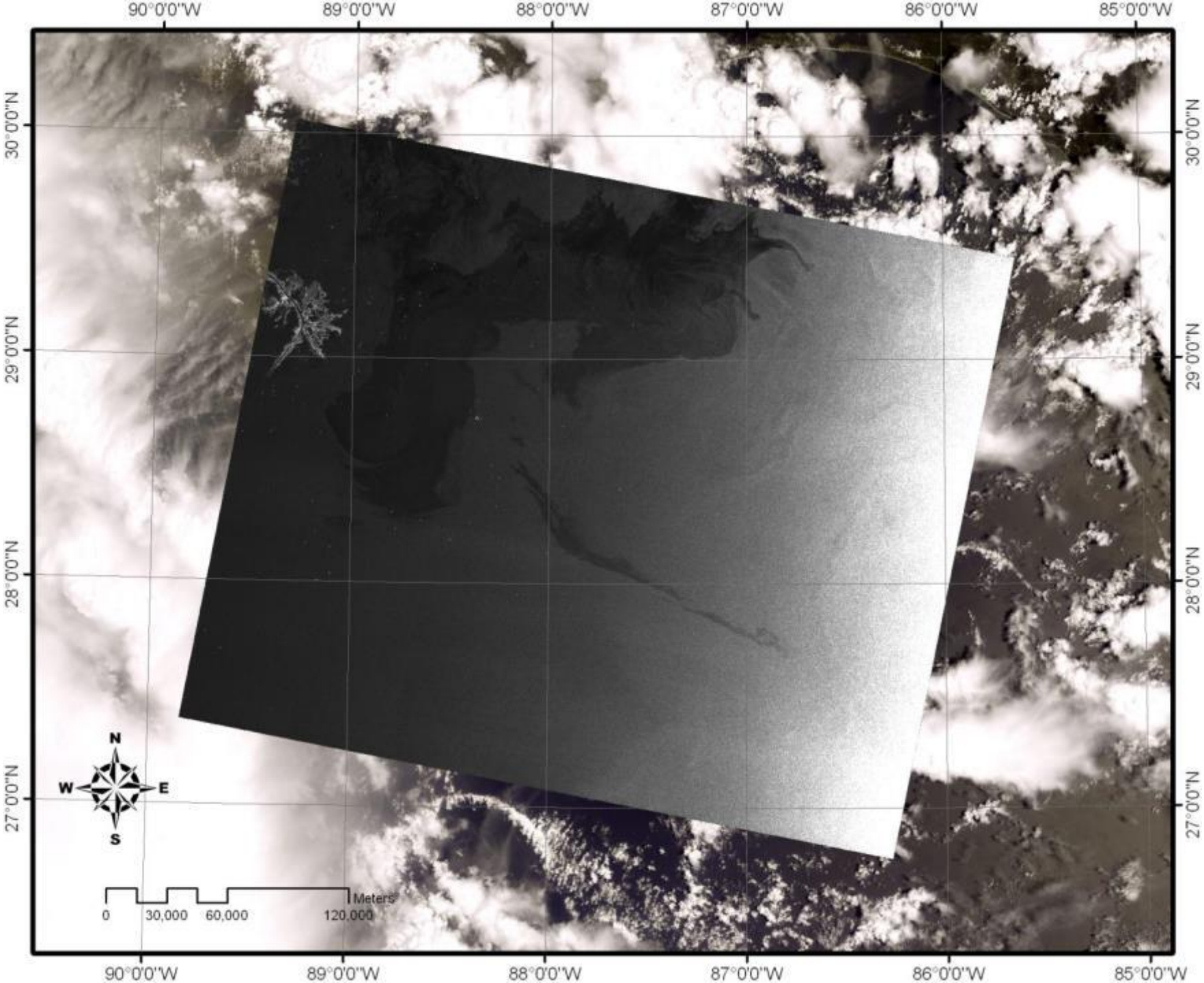








Surface oil: 22 May of DWH discharge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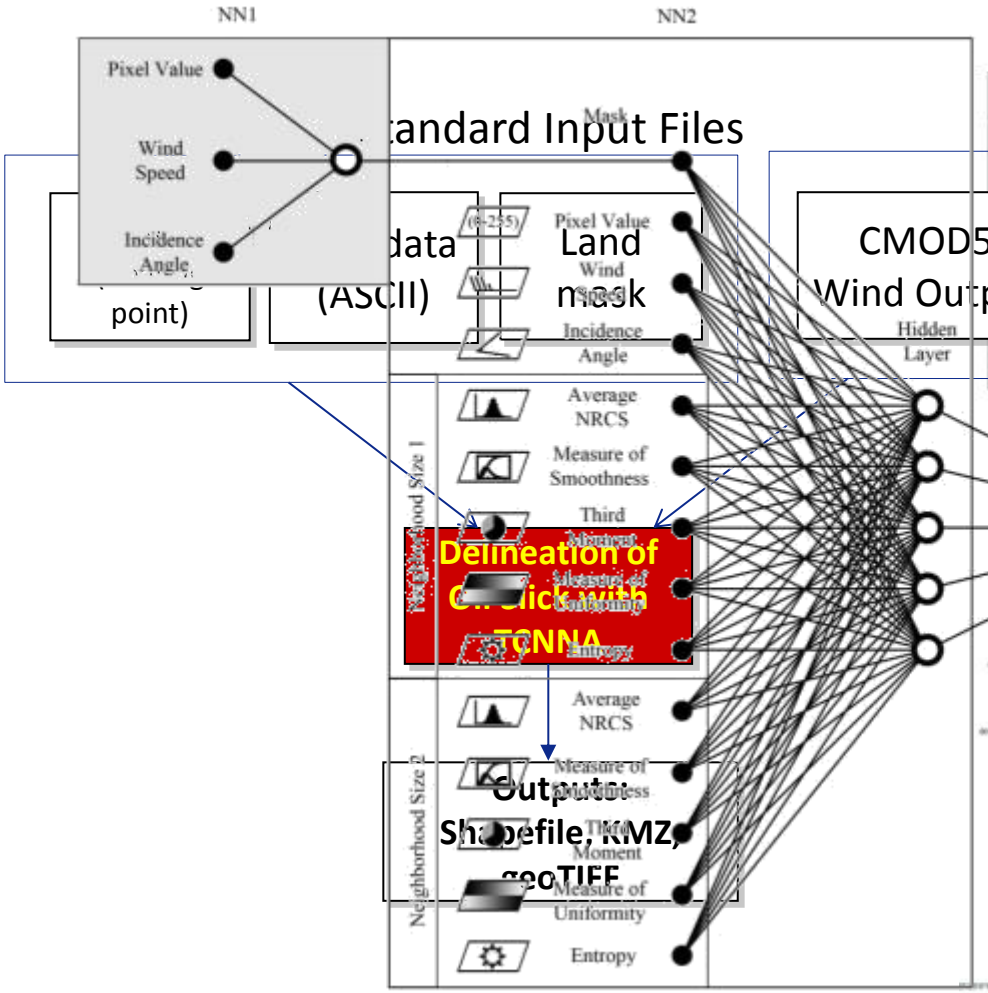
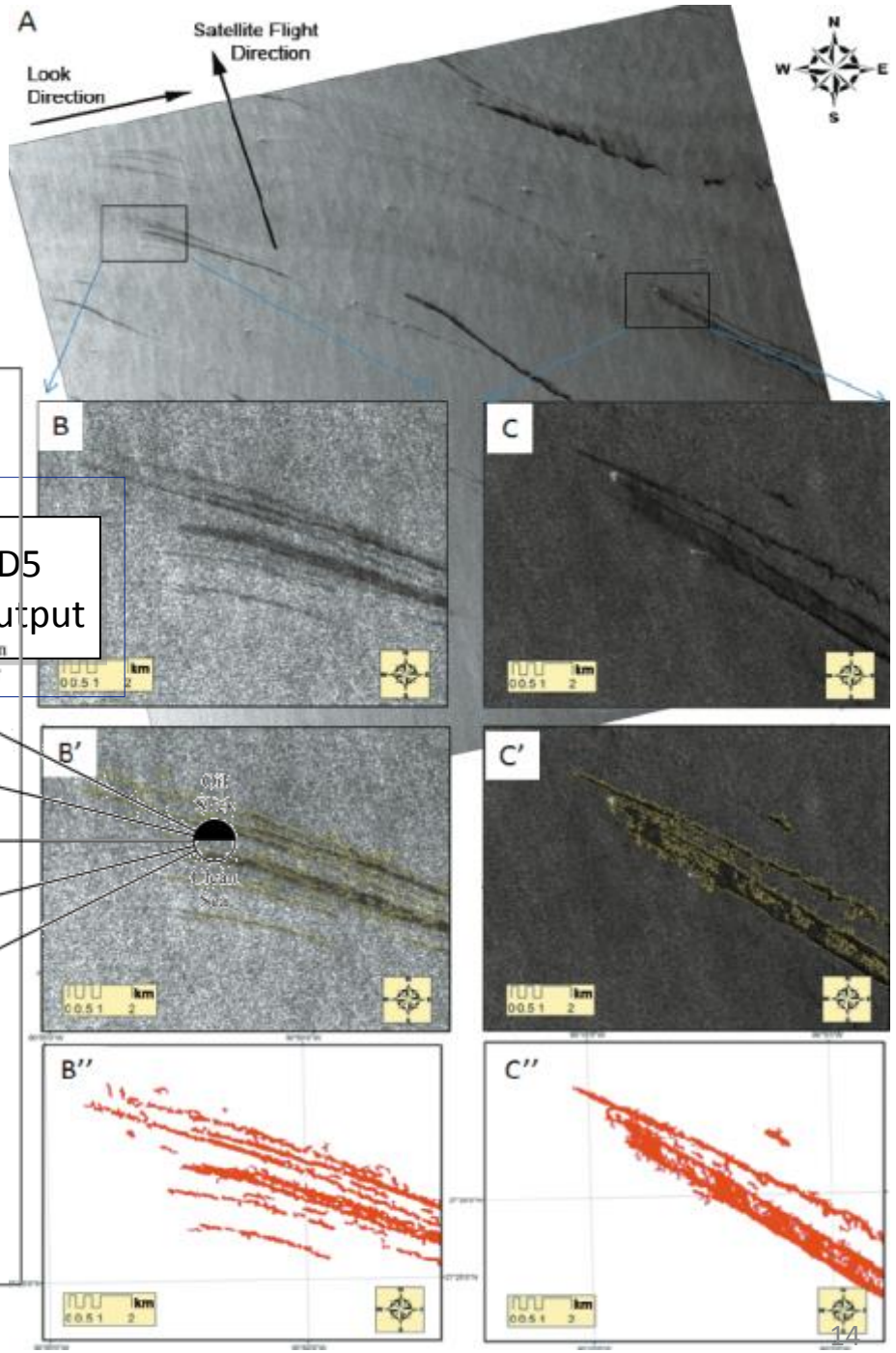
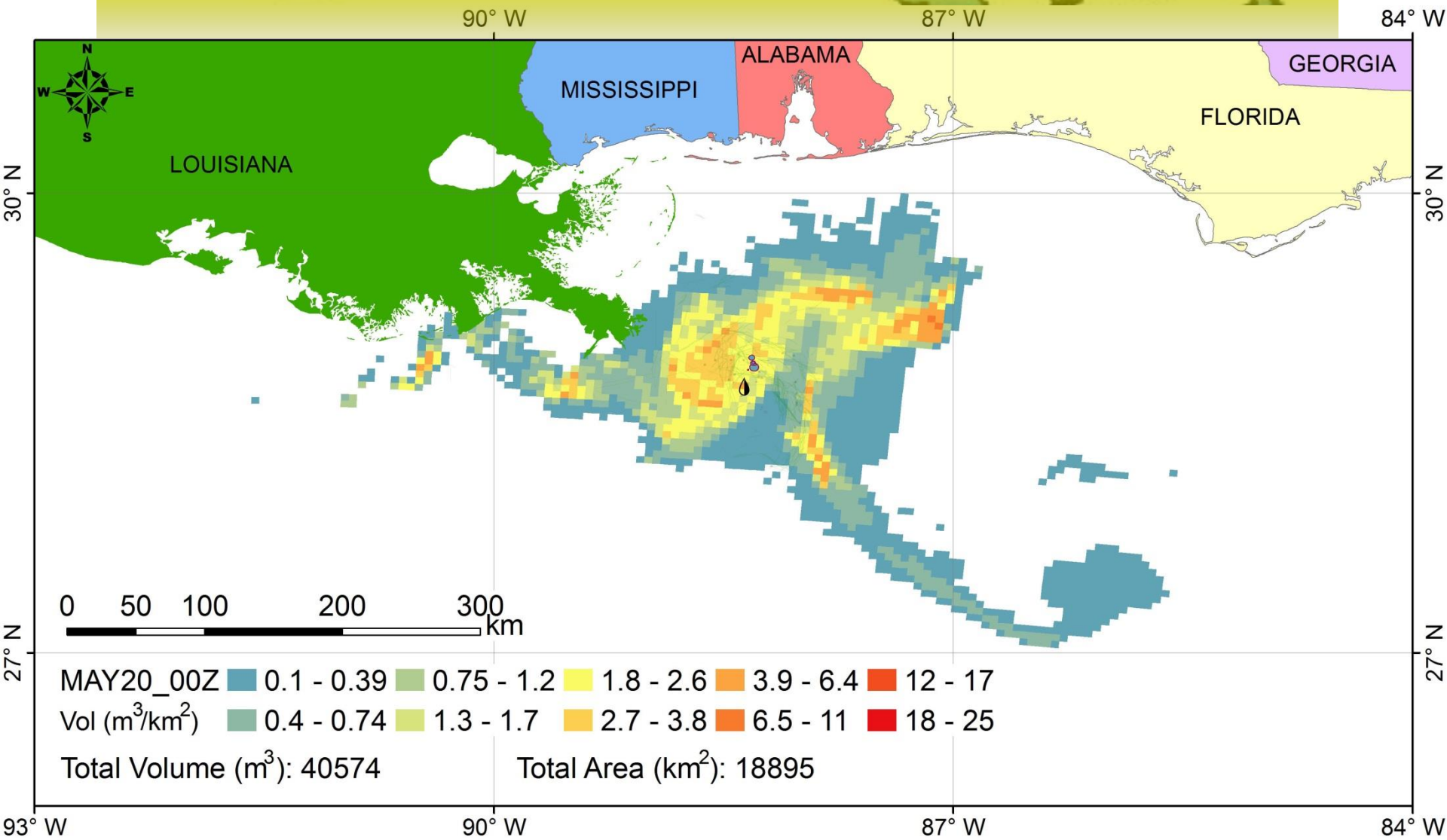
85°0'0"W
30°0'0"N
29°0'0"N
28°0'0"N
27°0'0"N
N
W
E
S
0
30,000
60,000
120,000
Meters

Automated SAR Oil Spill Mapping Product
Oil Spill Module (TCNNA)

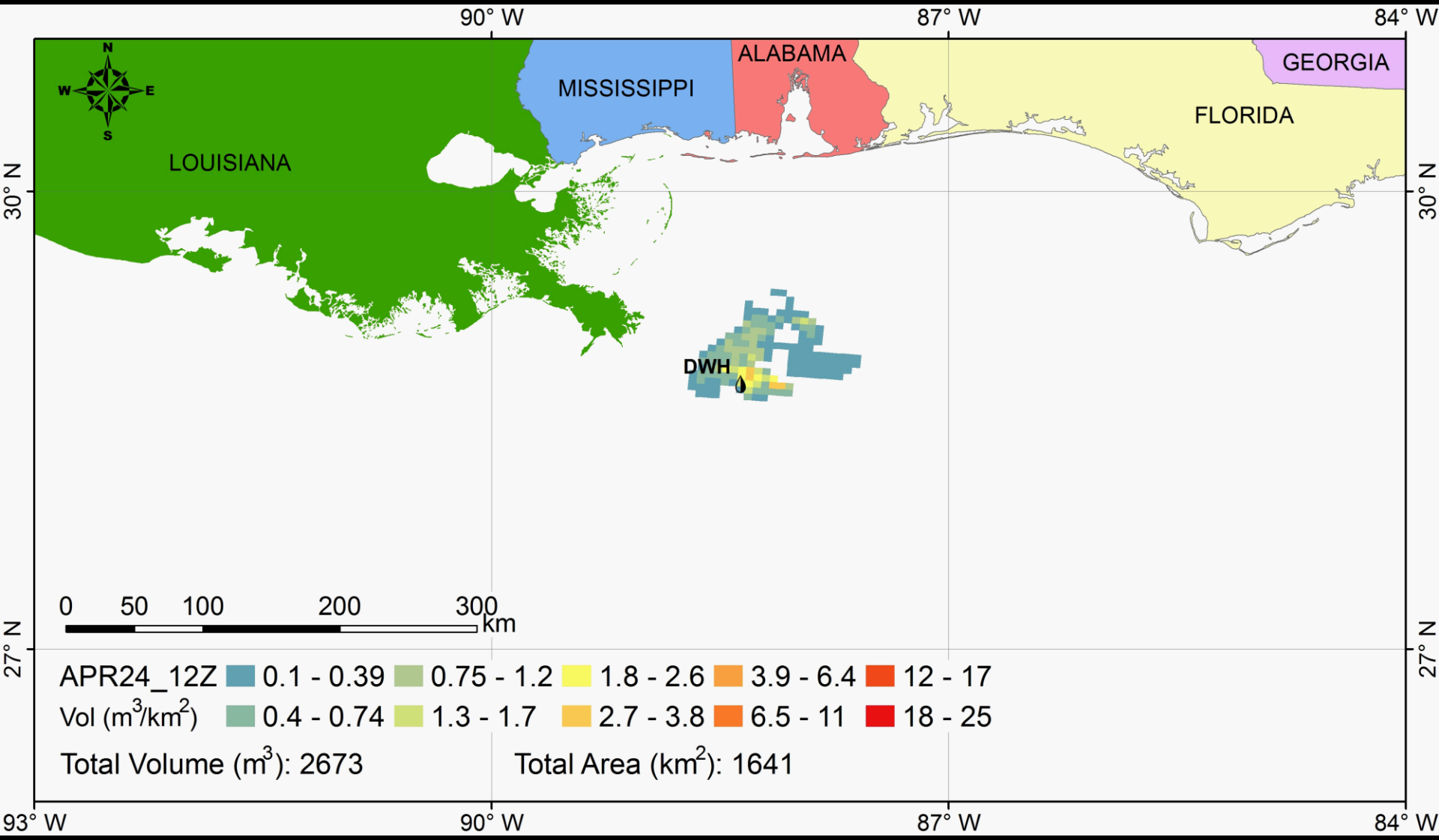




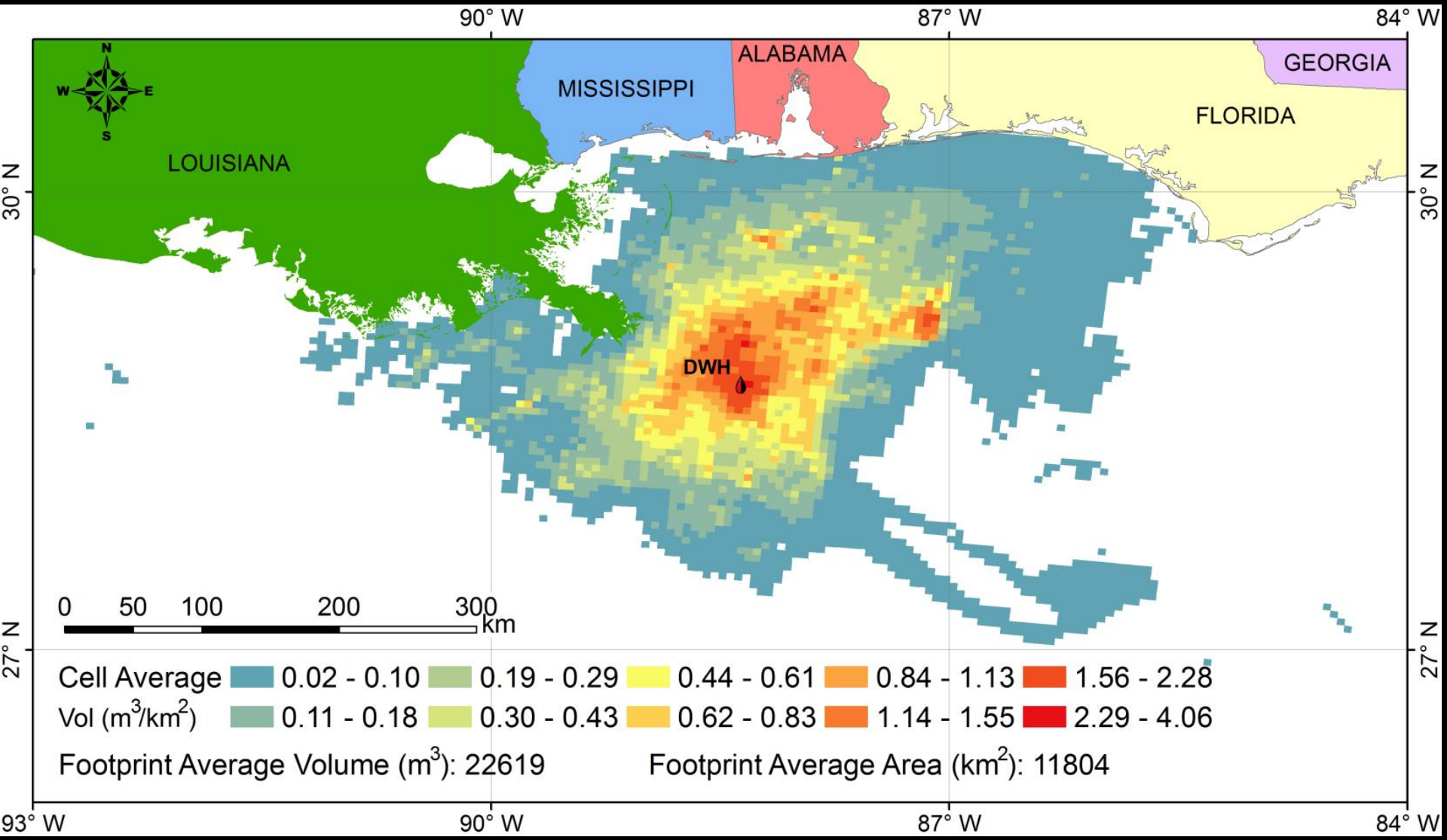
Garcia-Pineda, O. *et al.* Detection of floating oil anomalies from the deepwater horizon oil spill with synthetic aperture radar. *Oceanography* **26**, 124-137 (2013).



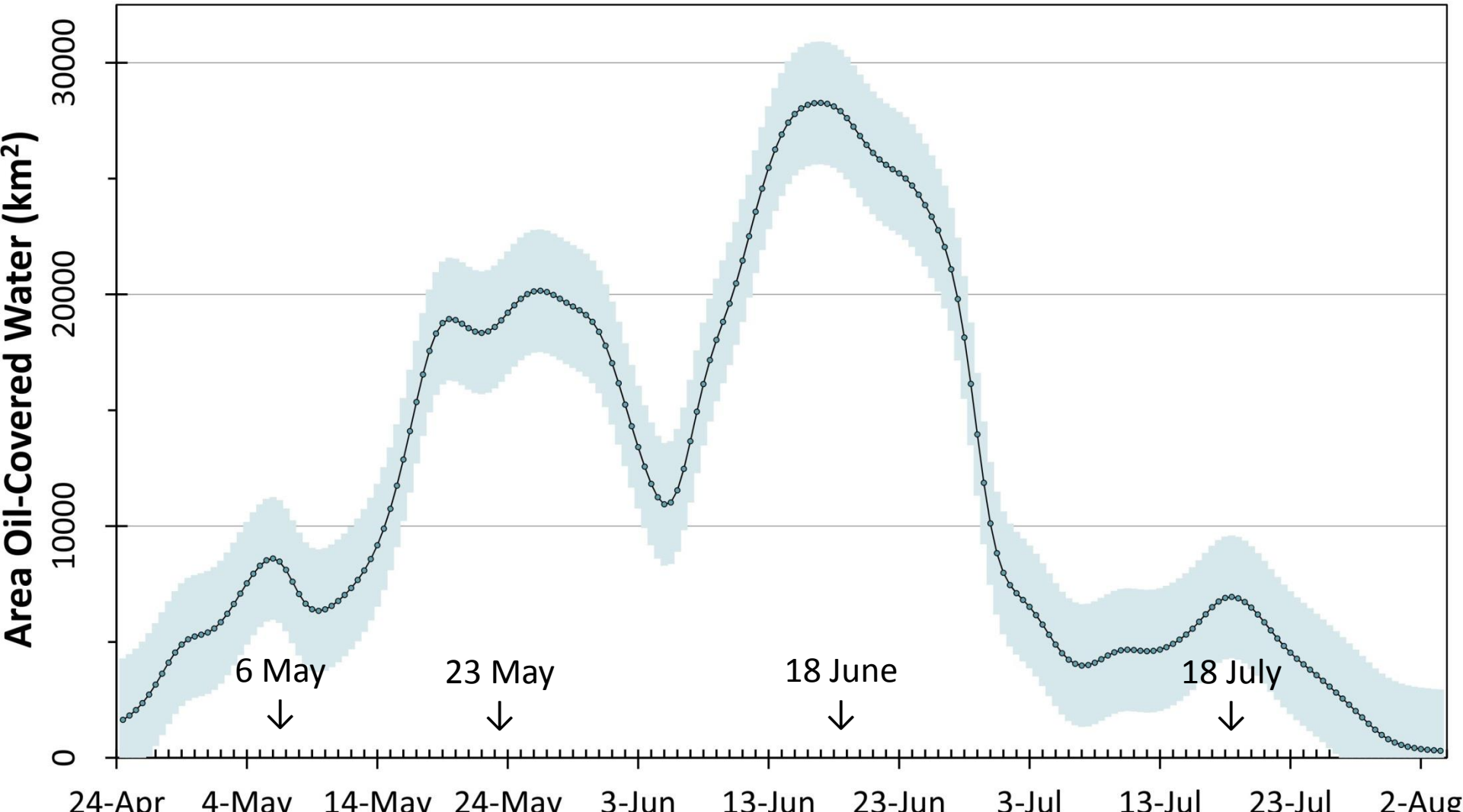
Surface volume: 12-h best estimate from SAR



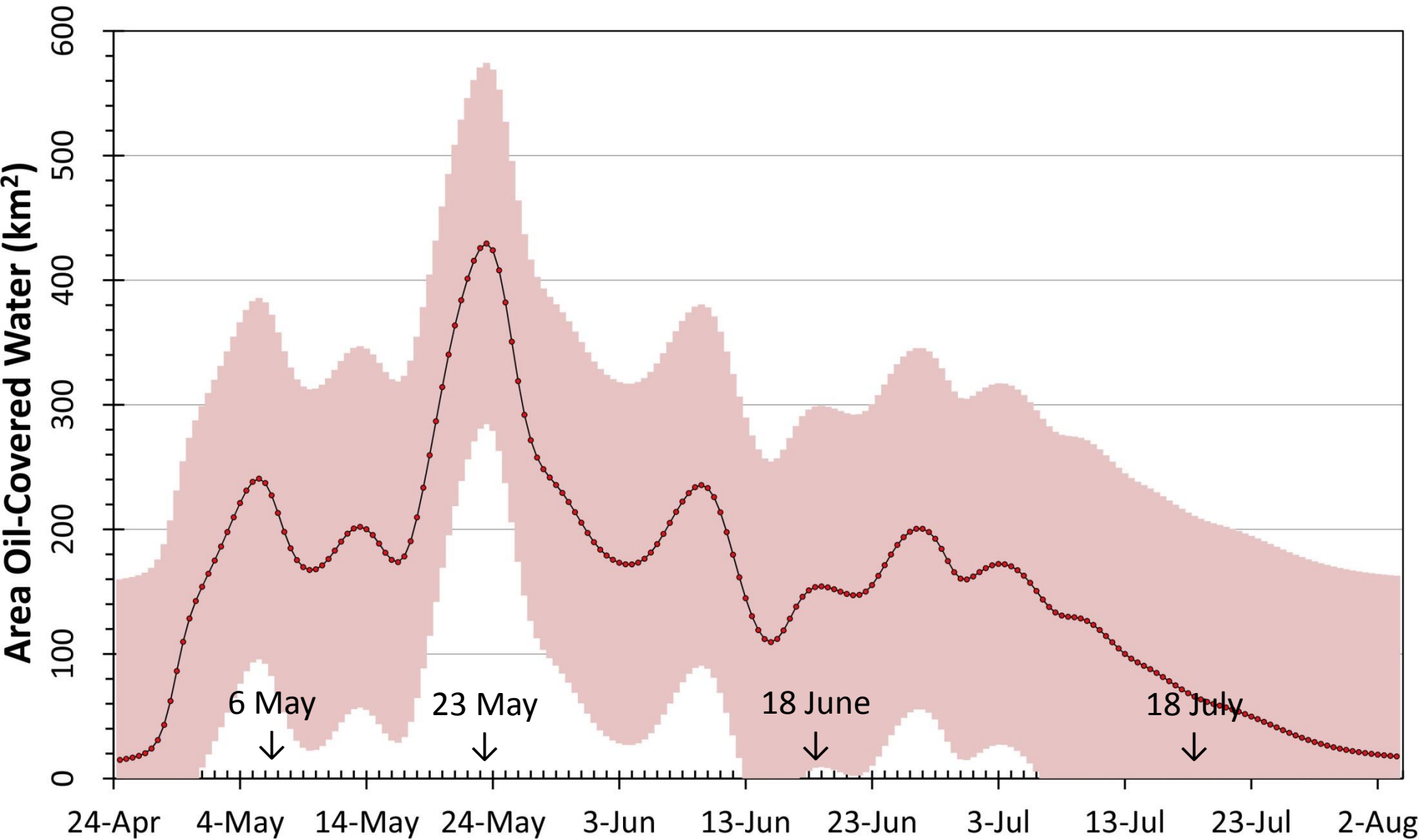
Average Volume (m^3/km^2)



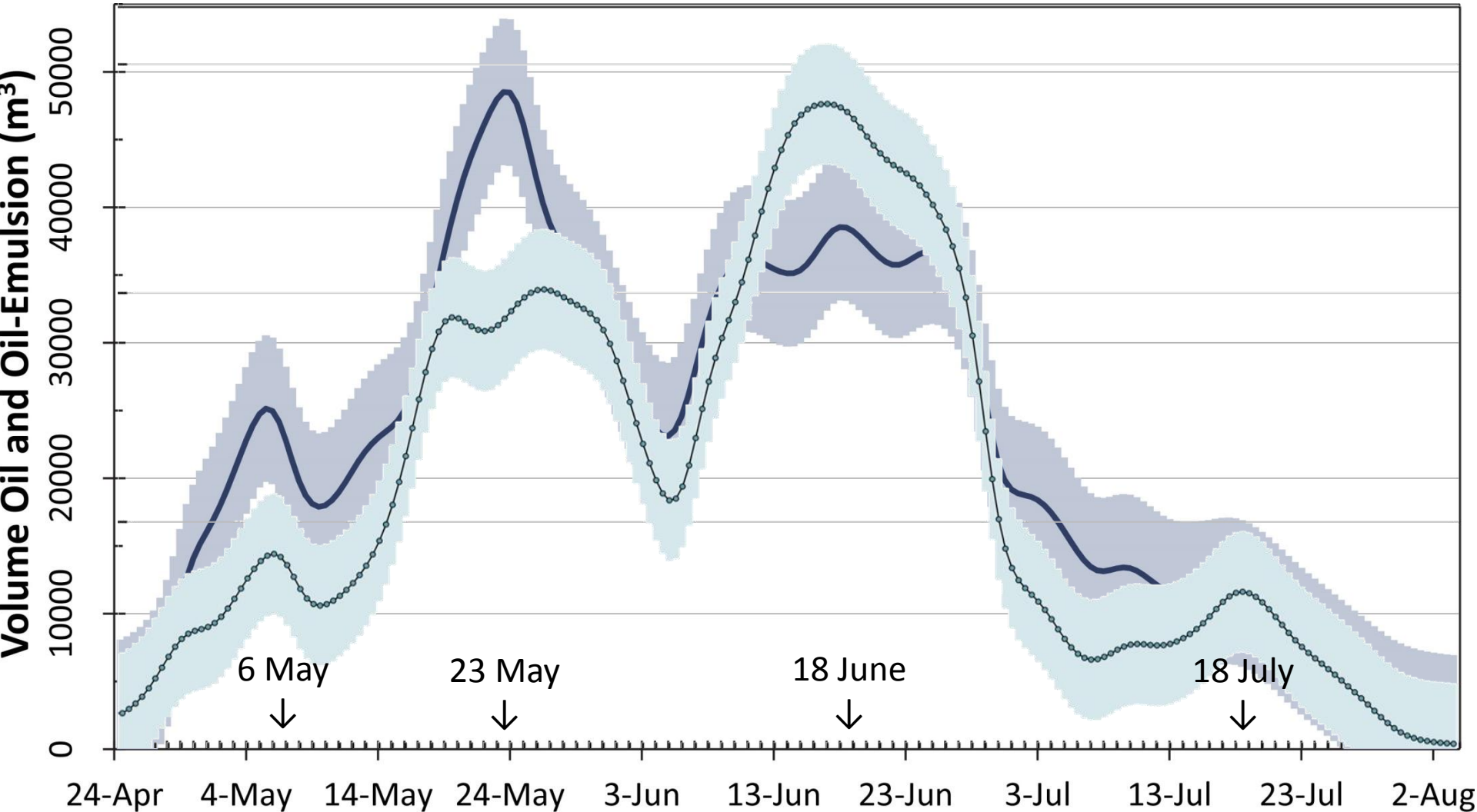
Time Series of DWH Oil
Oil-Covered Water—all thicknesses



Time Series of DWH Oil
Oil-Covered Water—Thick Oil (~70 µm)

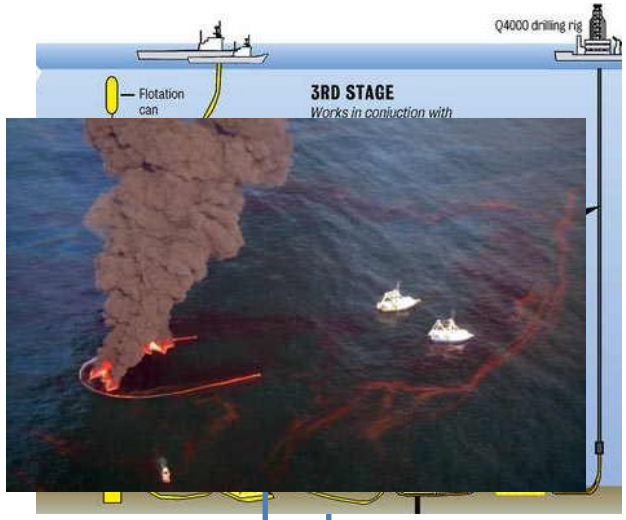


Time Series of DWH Oil
Daily SAR Volume of Surface Oil



Oil Budget Calculator

Deepwater Horizon



TECHNICAL DOCUMENTATION

November 2010

A Report by:

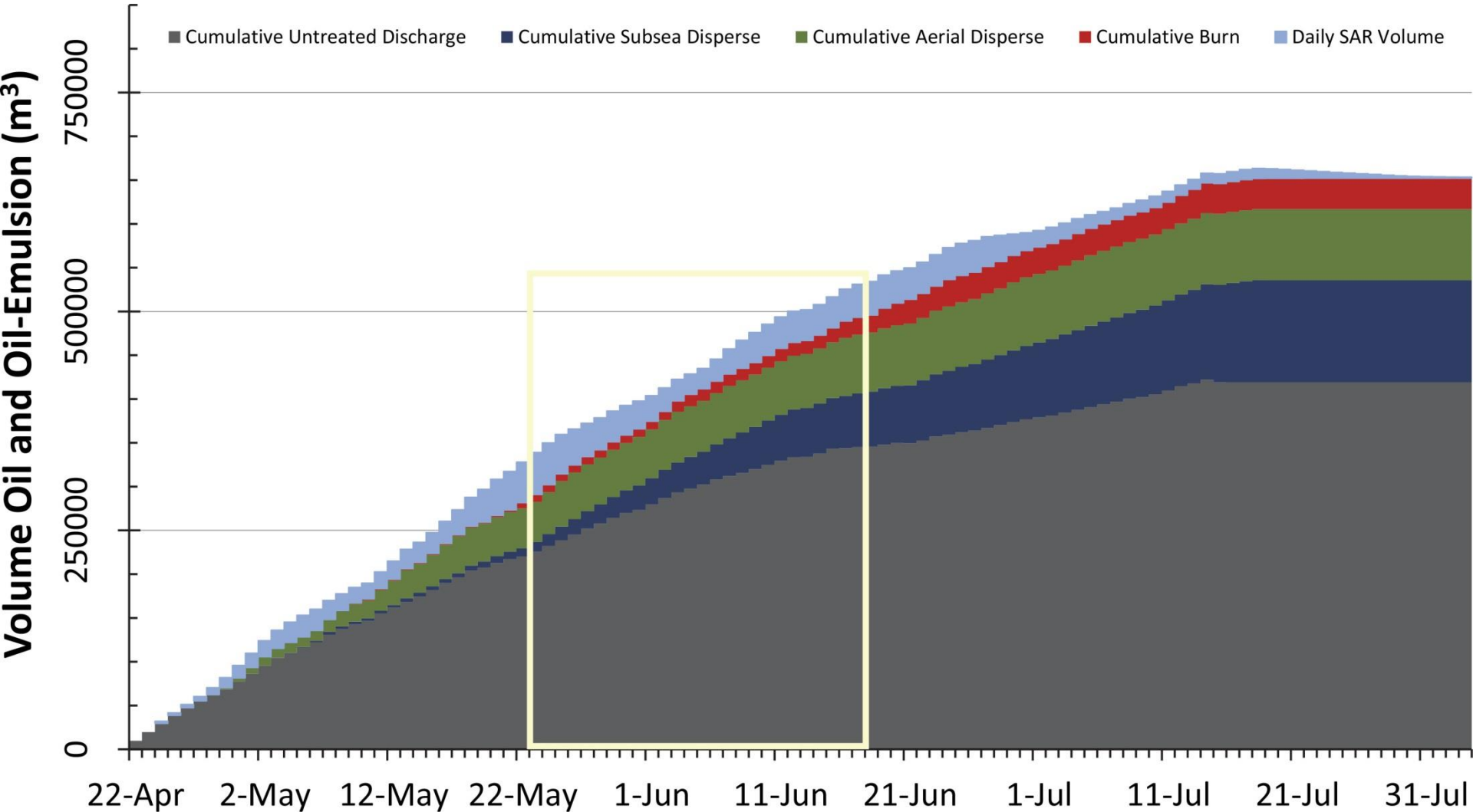
The Federal Interagency Solutions Group,
Oil Budget Calculator Science and Engineering Team

Appendix 3

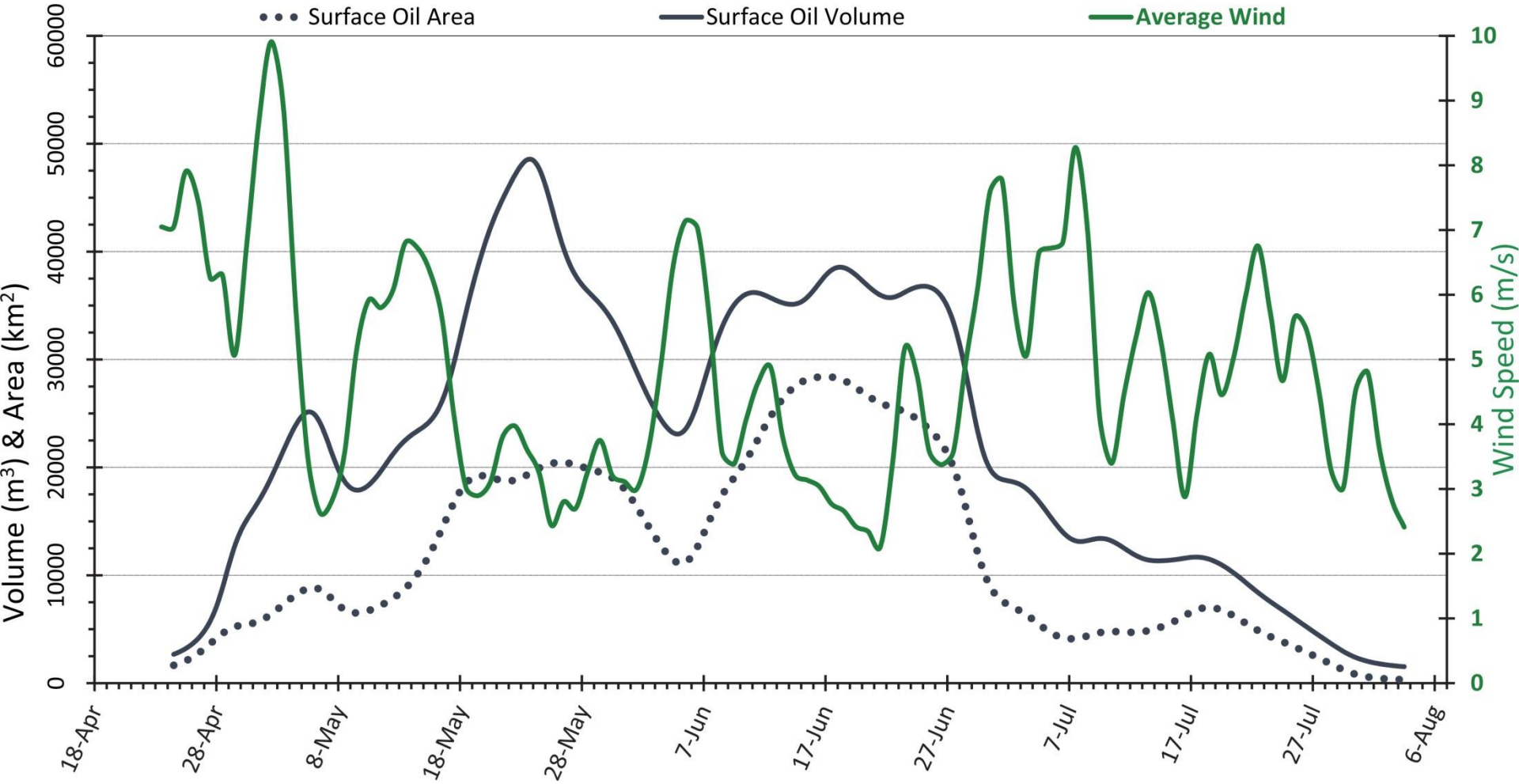
Data Input Used by Calculator

Date	Government Estimate of Discharge VRG bbls	Inland Recovery IR tons	Oil Burned VBU bbls	Oil Collected via RITT/TopHat VDT bbls	Oily Water Collected VOW bbls	Subsurface Dispersants VCBg gallons	Surface Dispersants VCSg gallons
04/20/2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00
04/21/2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00
04/22/2010	62200.00	0.00	0.00	0.00	0.00	0.00	1701.00
04/23/2010	62100.00	0.00	0.00	0.00	1630.00	0.00	0.00
04/24/2010	61900.00	0.00	0.00	0.00	155.00	0.00	0.00
04/25/2010	61800.00	0.00	0.00	0.00	0.00	0.00	9818.00
04/26/2010	61700.00	0.00	0.00	0.00	7832.00	0.00	14486.00
04/27/2010	61600.00	0.00	0.00	0.00	18557.00	0.00	27078.00
04/28/2010	61500.00	0.00	95.00	0.00	3306.00	0.00	42143.00
04/29/2010	61400.00	0.00	0.00	0.00	3245.00	0.00	40913.00
04/30/2010	61300.00	0.00	0.00	0.00	1427.00	2196.00	4900.00
05/01/2010	61200.00	0.00	0.00	0.00	992.00	0.00	11653.00
05/02/2010	61000.00	0.00	0.00	0.00	0.00	3399.00	0.00
05/03/2010	60900.00	0.00	0.00	0.00	0.00	5812.00	0.00

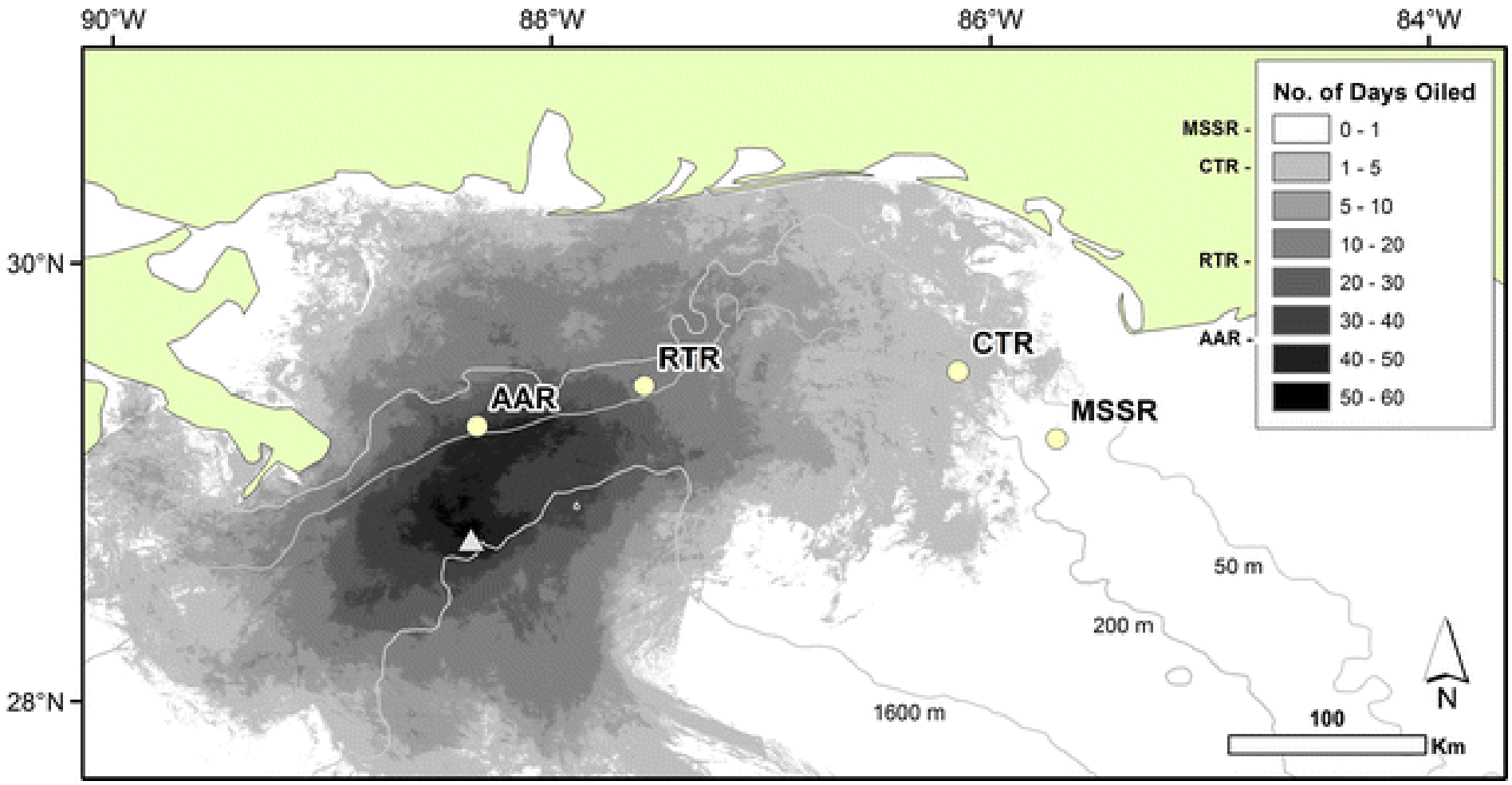
Time Series of DWH Oil
Cumulative Discharge & Daily SAR Volume

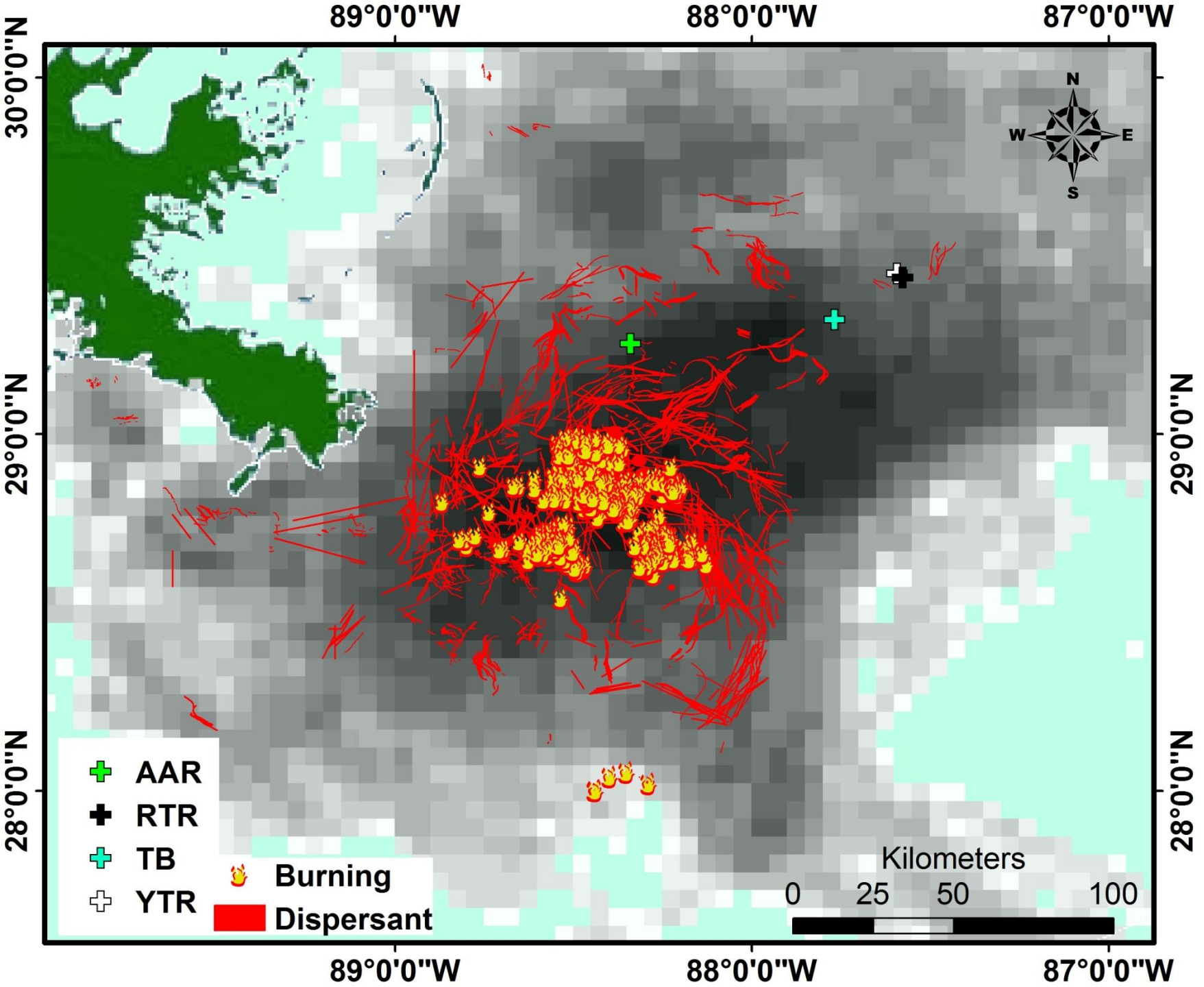


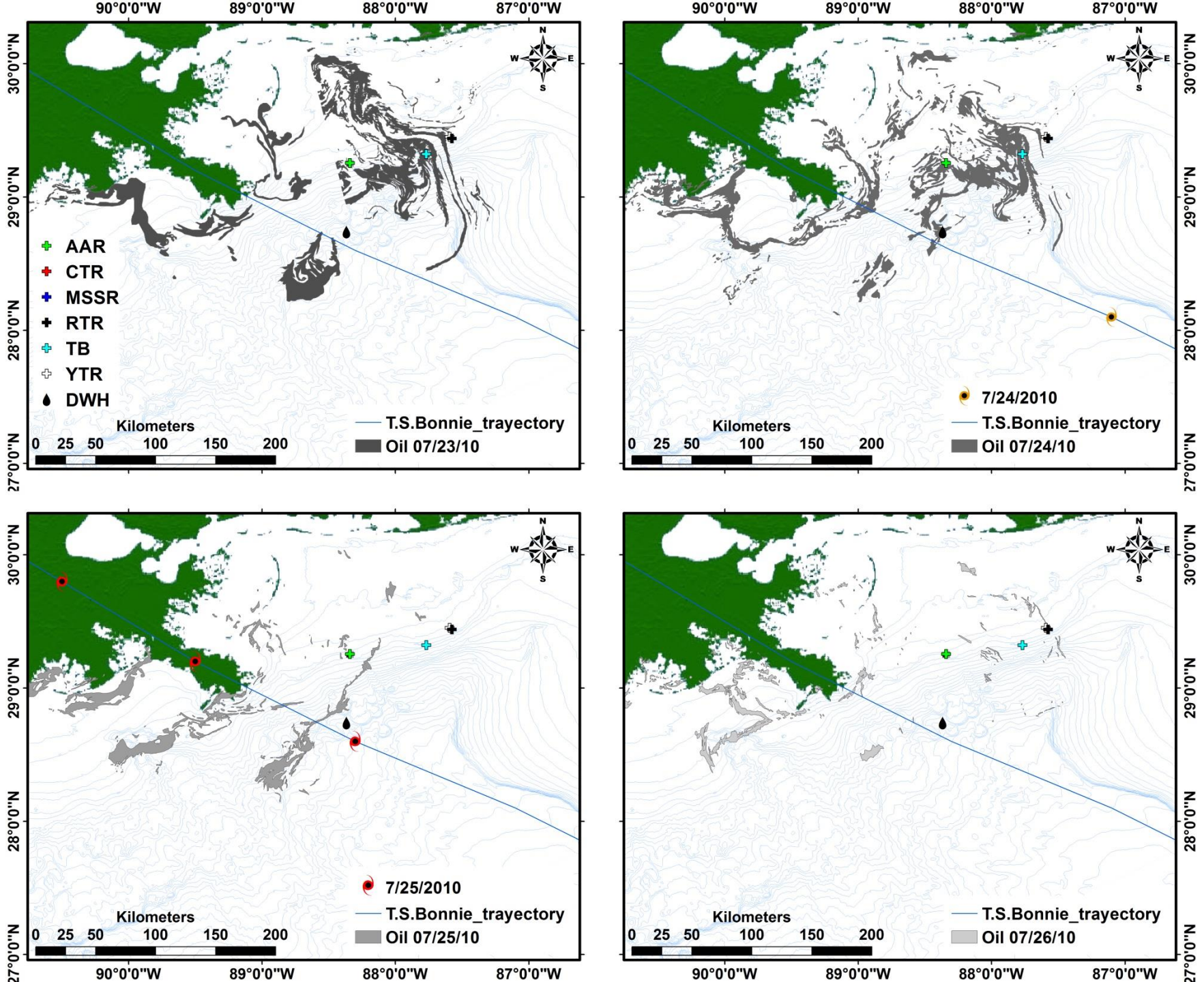
Surface Oil & Average Wind



Mesophotic Study Sites




89°0'0"W
88°0'0"W
87°0'0"W
30°0'0"N
29°0'0"N
28°0'0"N
N
W
E
S
AAR
RTR
TB
YTR
Burning
Dispersant
Kilometers
0
25
50
100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89°0'0"W
88°0'0"W
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30°0'0"N
29°0'0"N
28°0'0"N
27°0'0"N
N
W
E
S
AAR
CTR
MSSR
RTR
TB
YTR
DWH
Kilometers
0 25 50 100 150 200
T.S.Bonnie_trayectory
Oil 07/23/10
7/24/2010
T.S.Bonnie_trayectory
Oil 07/24/10
7/25/2010
T.S.Bonnie_trayectory
Oil 07/25/10
T.S.Bonnie_trayectory
Oil 07/26/10

Study sites

Reef Site	Distance (km)	Longitude	Latitude	Depth (m)	Area (km^2)
Alabama Alps (AAR)	57	-88.33924	29.253668	74	0.276
Talus Block (TBR)	87	-87.76679	29.320955	130	0.023
Yellowtail (YTR)	109	-87.59169	29.450339	64	0.119
Roughtongue (RTR)	109	-87.57581	29.439161	66	0.140
Coral Tree (CTR)	231	-86.13945	29.486935	88	0.143
Madison Swanson (MSSR)	266	-85.67931	29.186576	73	0.402

Injury scale

Level	Description	Injury Area (%)
0	Uninjured	Less than 1%
1	Mild	1% to 10%
2	Intermediate	10% to 50%
3	Severe	50% to 90%
4	Extreme	Over 90%

Documenting Coral Damage

- We used the macro SLR mounted on the ROV arm to image gorgonians on the Alabama Alps Reef (AAR). of the variety of damages that were documented.
- No collections were made, but similarly damaged specimens have been collected.

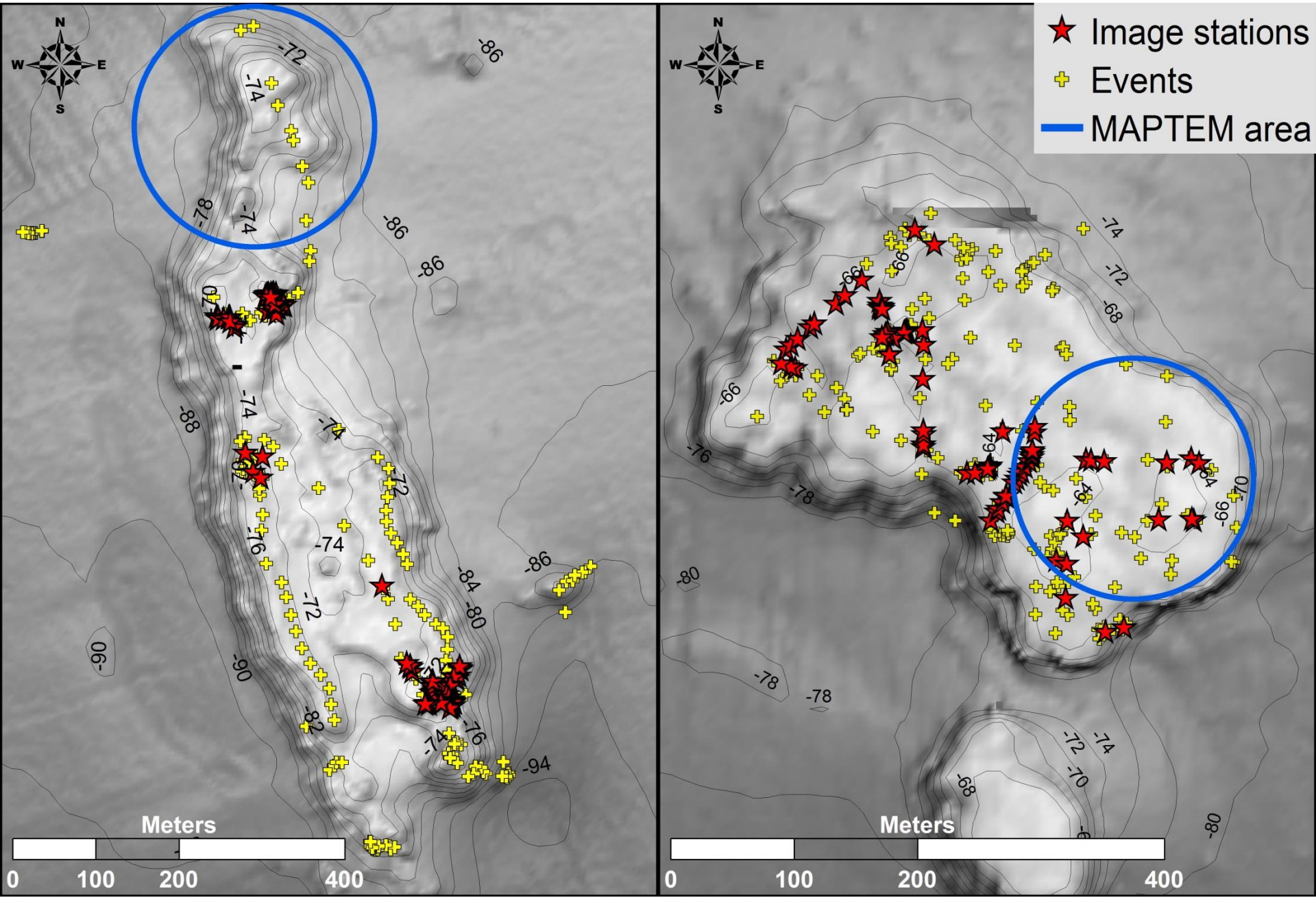
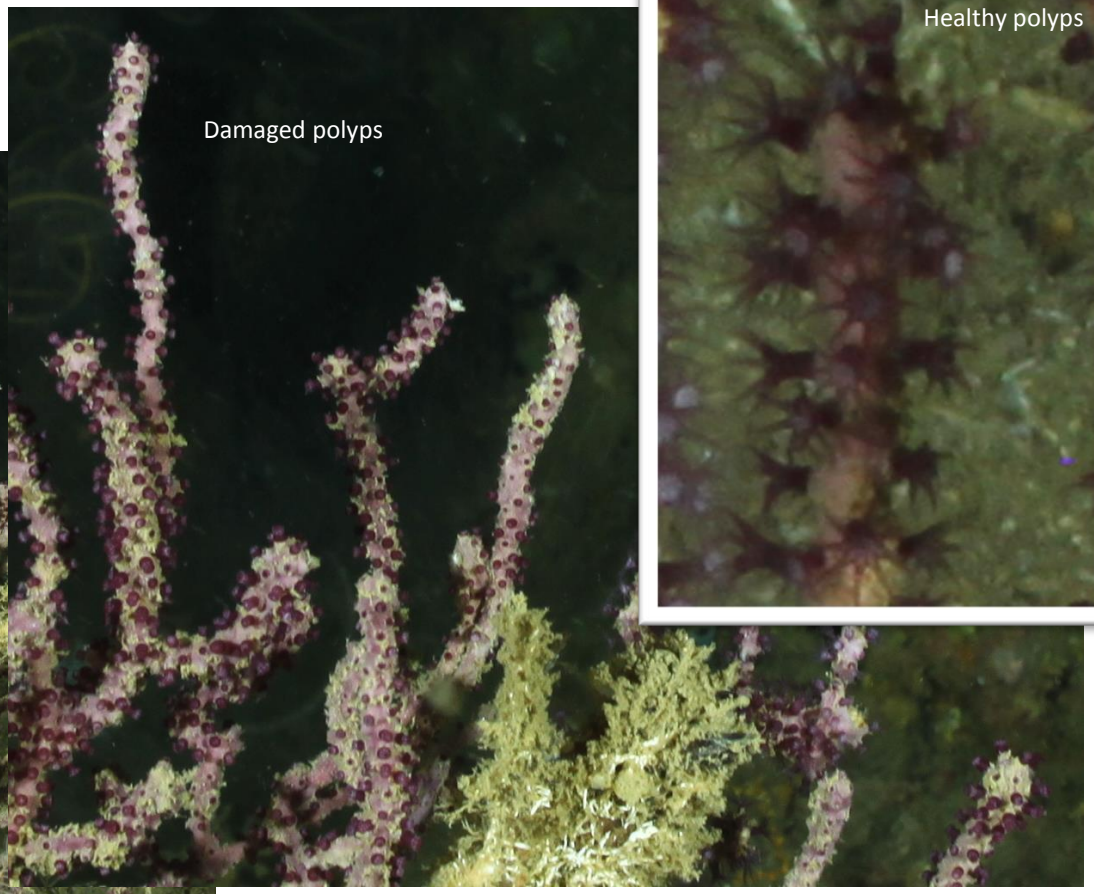


Image stations
Events
MAPTEM area
N
W
E
S
Meters
0
100
200
400
Meters
0
100
200
400

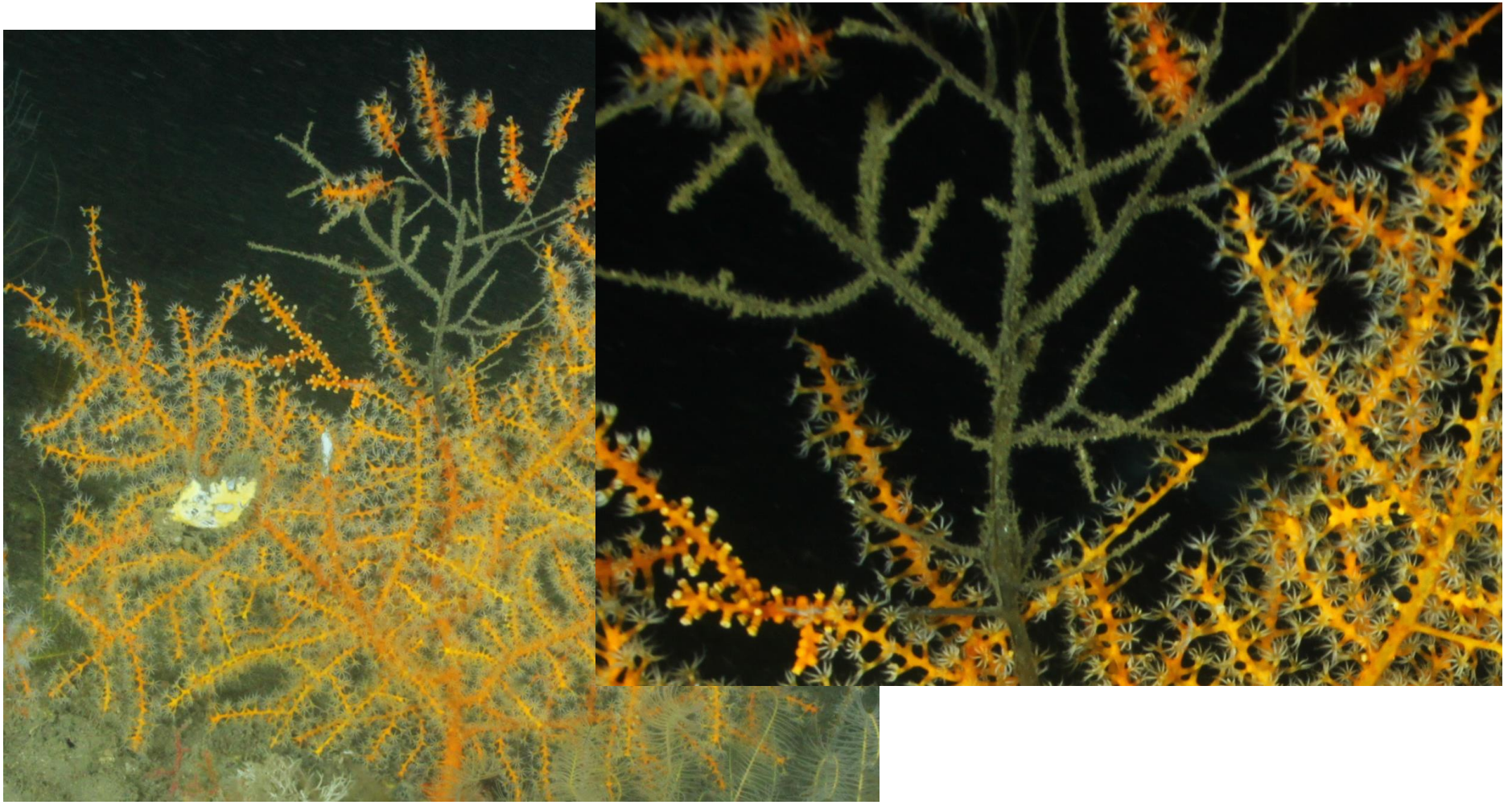
Photographs analyzed

Site	Date	Study ID	Taken	Analyzed
AAR	1997	CSA-TAMU	187	77
	1998	CSA-TAMU	164	71
	1999	CSA-TAMU	188	70
	2011	This study	633	104
RTR	1997	CSA-TAMU	181	139
	1998	CSA-TAMU	171	124
	1999	CSA-TAMU	144	99
	2011	This study	741	81
Total AAR-RTR			2409	765



Purple Thesia sp?
Polyps stunted withdrawn or dead

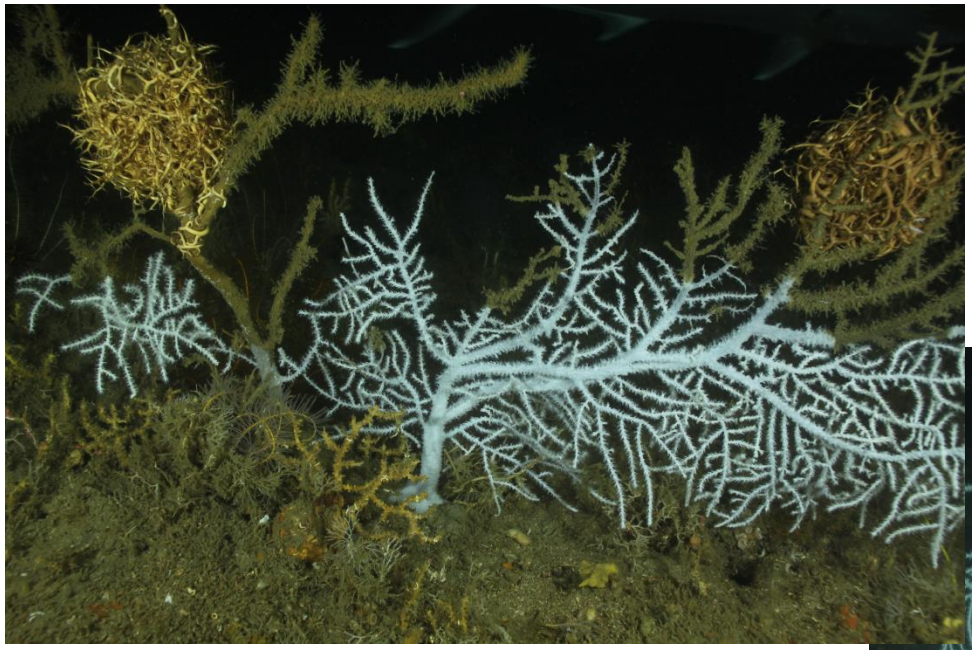
In this damage mode, the individual polyps have lost tissue or disappeared. The contrast with healthy polyps extended so that the 8 tentacles are clearly visible is quite stark (healthy polyps shown upper right). Where polyps are eroded, there is an overgrowth of algal film—distinctly greenish in color.

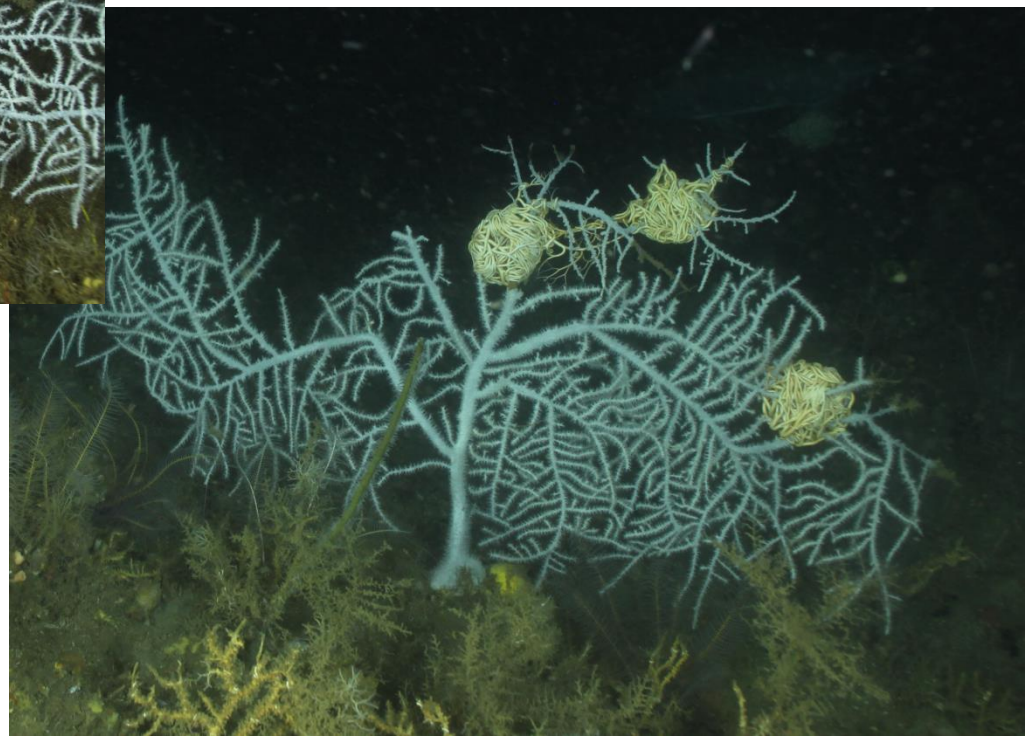


Swiftia sp

Round-shot damage

In this mode, a large area of dead tissue is surrounded by relatively healthy tissue. Although in this close-up, it appears that the polyps in the lower left have been damaged.

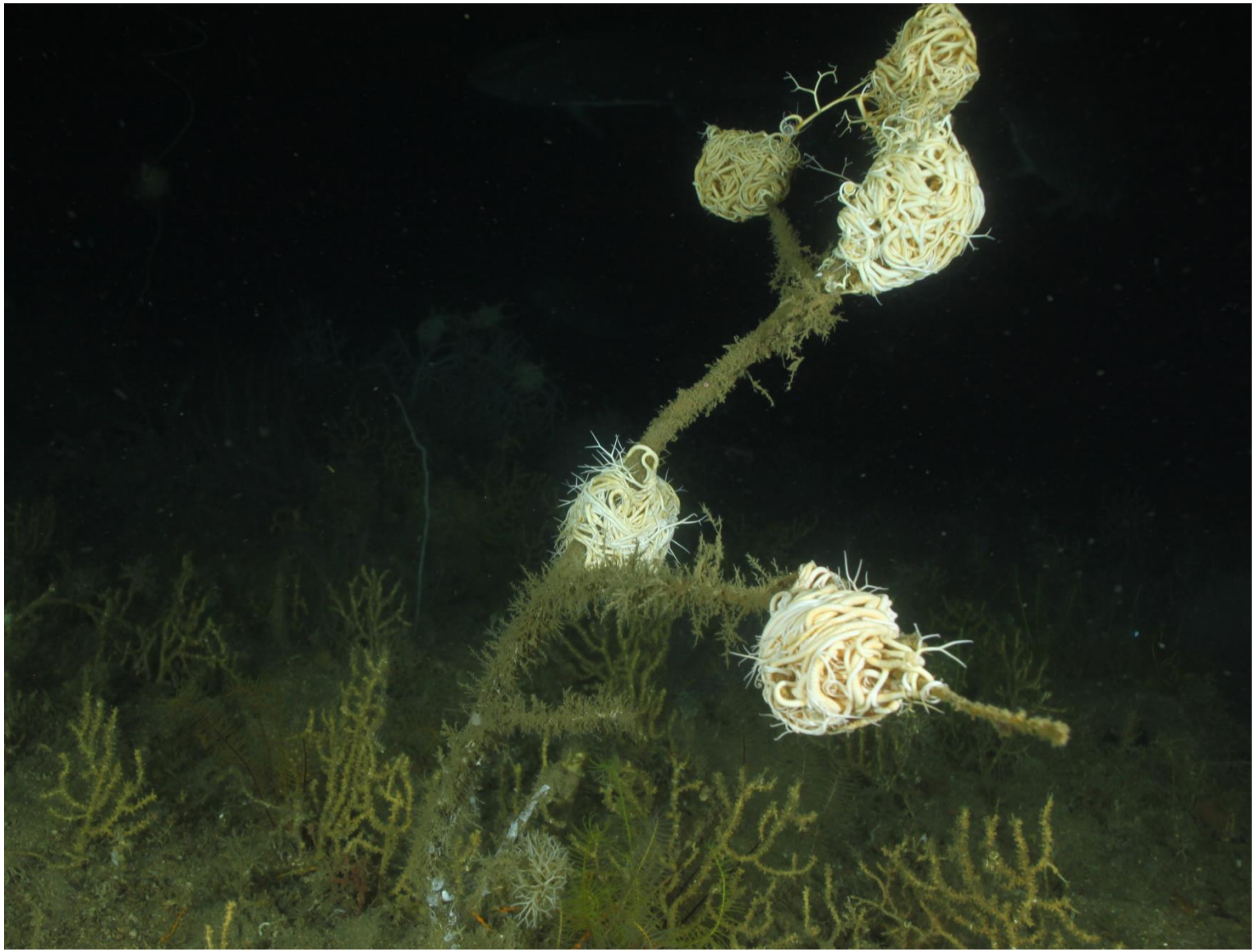




Hypnogorgia sp

Progressive truncation

Healthy *Hypnogorgia* are symmetrical and rounded. These two specimens show how damage lead to tissue death, over-growth with algal material (left) followed by loss of arms (right). Truncated specimens provide evidence of damage even when the algal overgrowth is not readily apparent. The fallen arms can be seen in specimen at right.

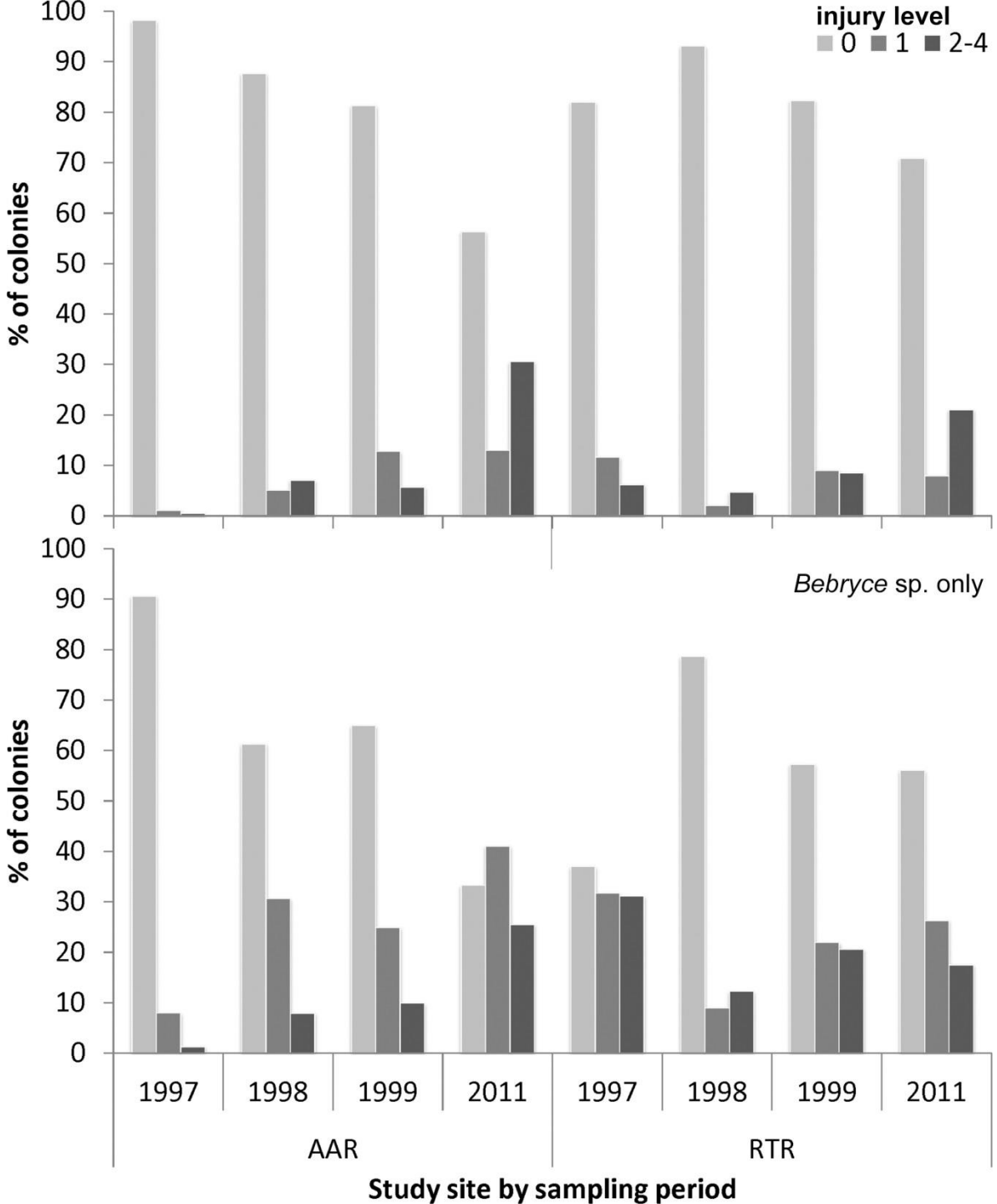


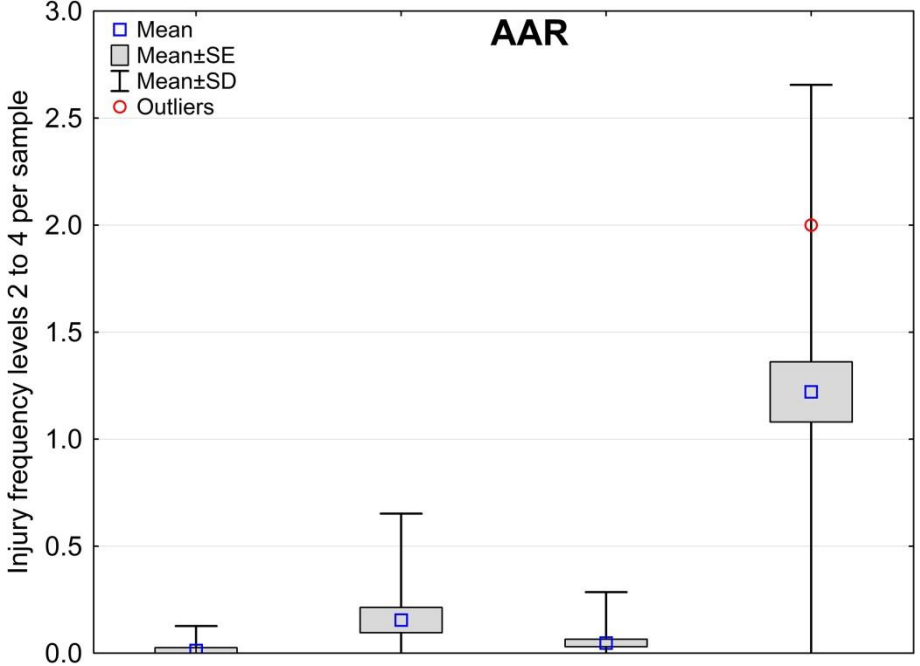
Standing dead stolan

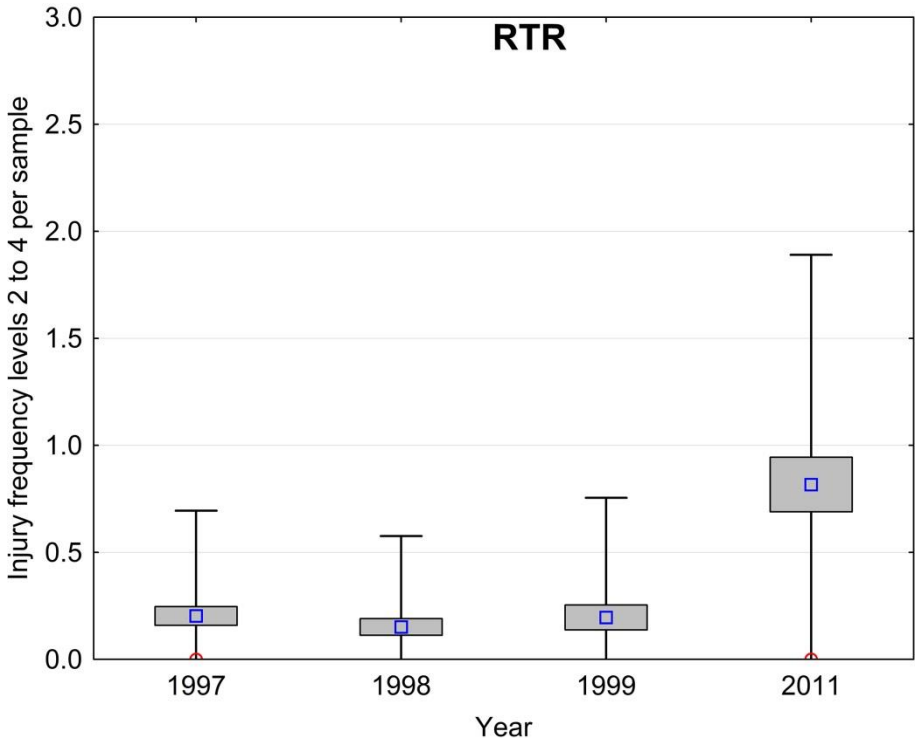
Basket stars and other commencials persist on dead corals

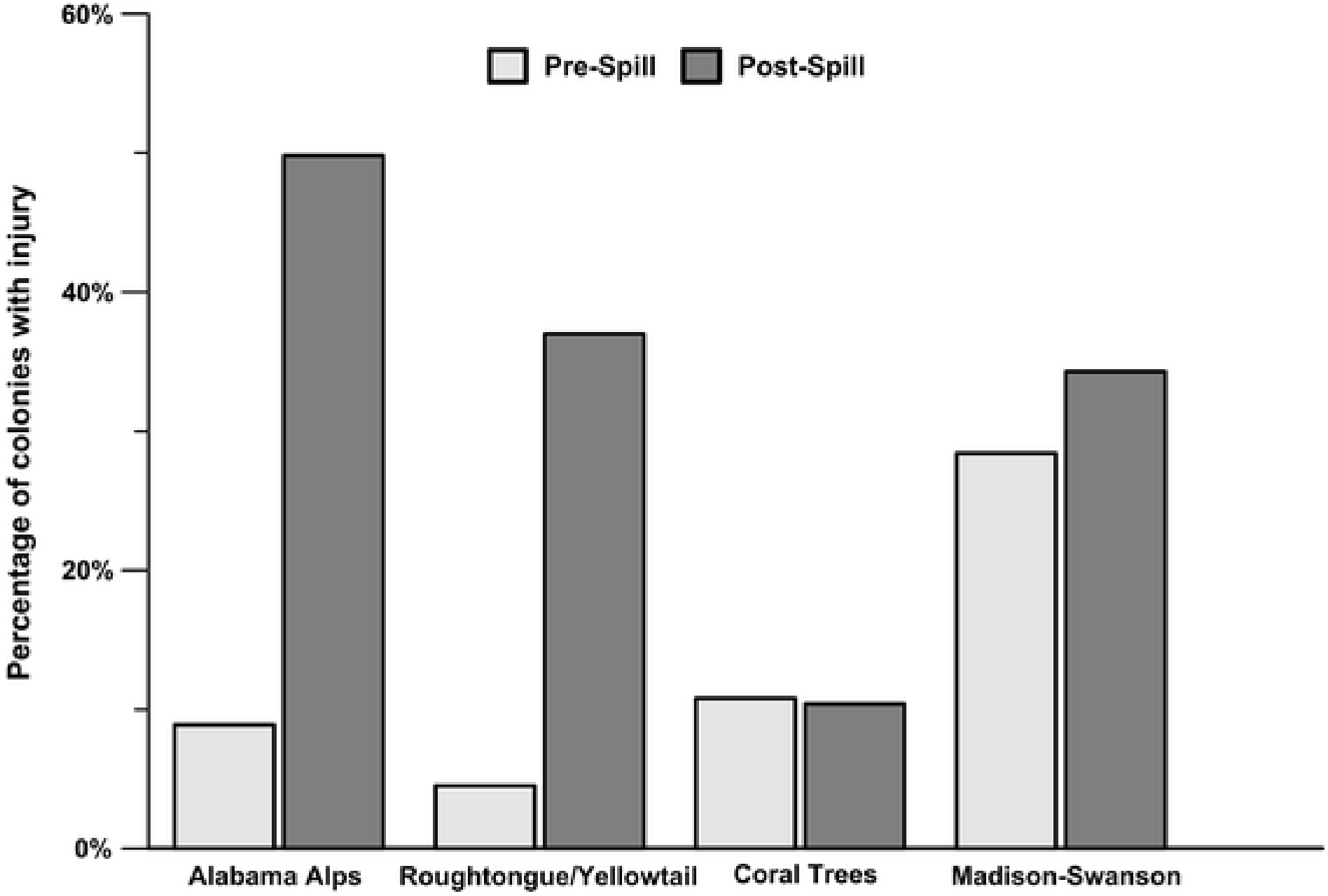
Percent injured overall

		Injured corals (%)				
Injury Level		0	1	2	3	4
AAR	1997	96.0	3.2	0.4	0.0	0.4
	1998	78.2	14.4	7.0	0.4	0.0
	1999	81.4	12.8	4.5	1.3	0.0
	2011	52.3	18.0	14.1	8.3	7.3
RTR	1997	68.9	17.7	10.2	2.4	0.9
	1998	89.6	3.8	5.6	1.0	0.0
	1999	71.9	14.4	6.7	4.4	2.5
	2011	64.2	17.6	10.8	1.6	5.9
Total AAR-RTR		72.5	13.5	8.5	2.8	2.7

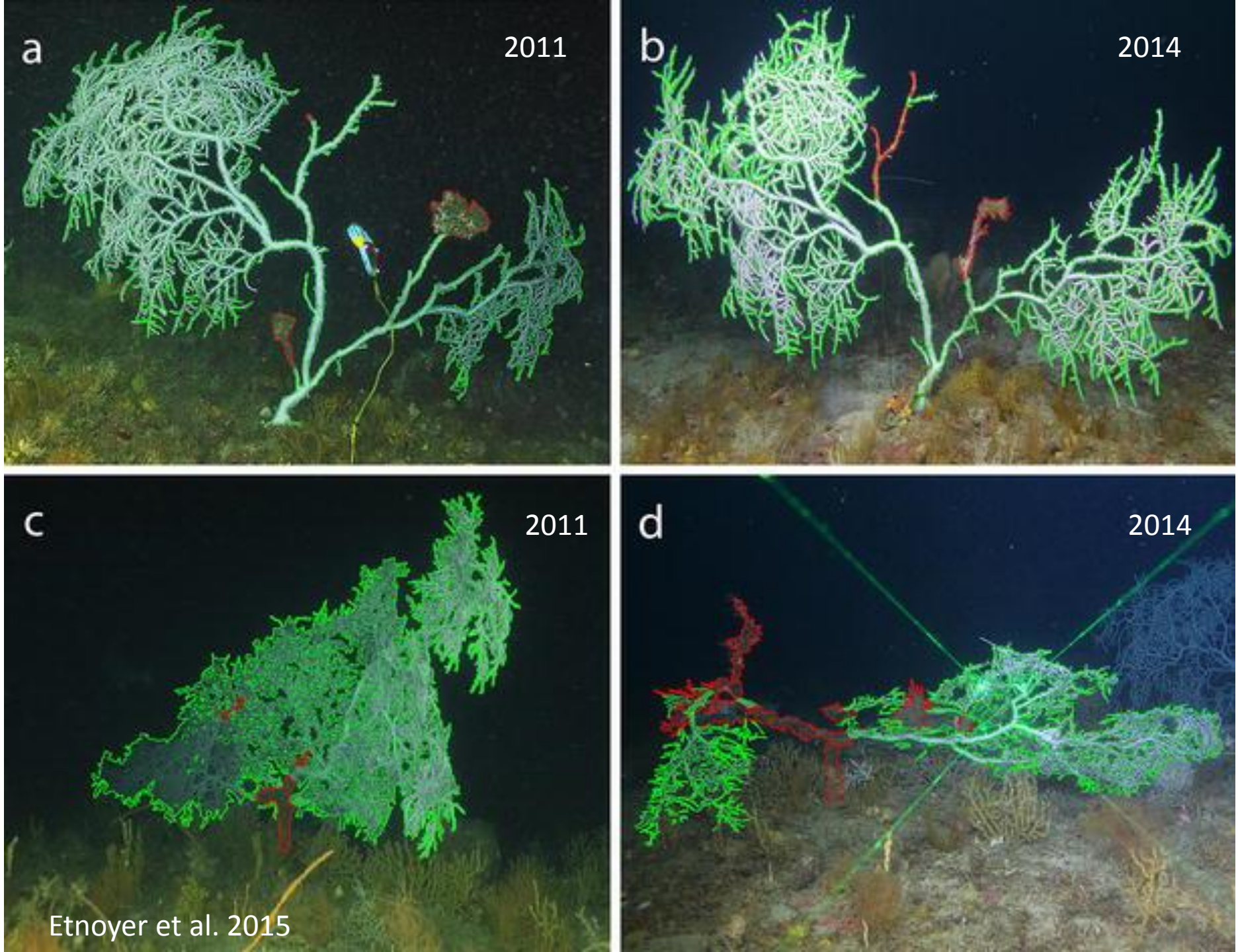

injury level
0
1
2-4
% of colonies
100
90
80
70
60
50
40
30
20
10
0
Bebryce sp. only
% of colonies
100
90
80
70
60
50
40
30
20
10
0
1997
1998
1999
2011
1997
1998
1999
2011
AAR
RTR
Study site by sampling period

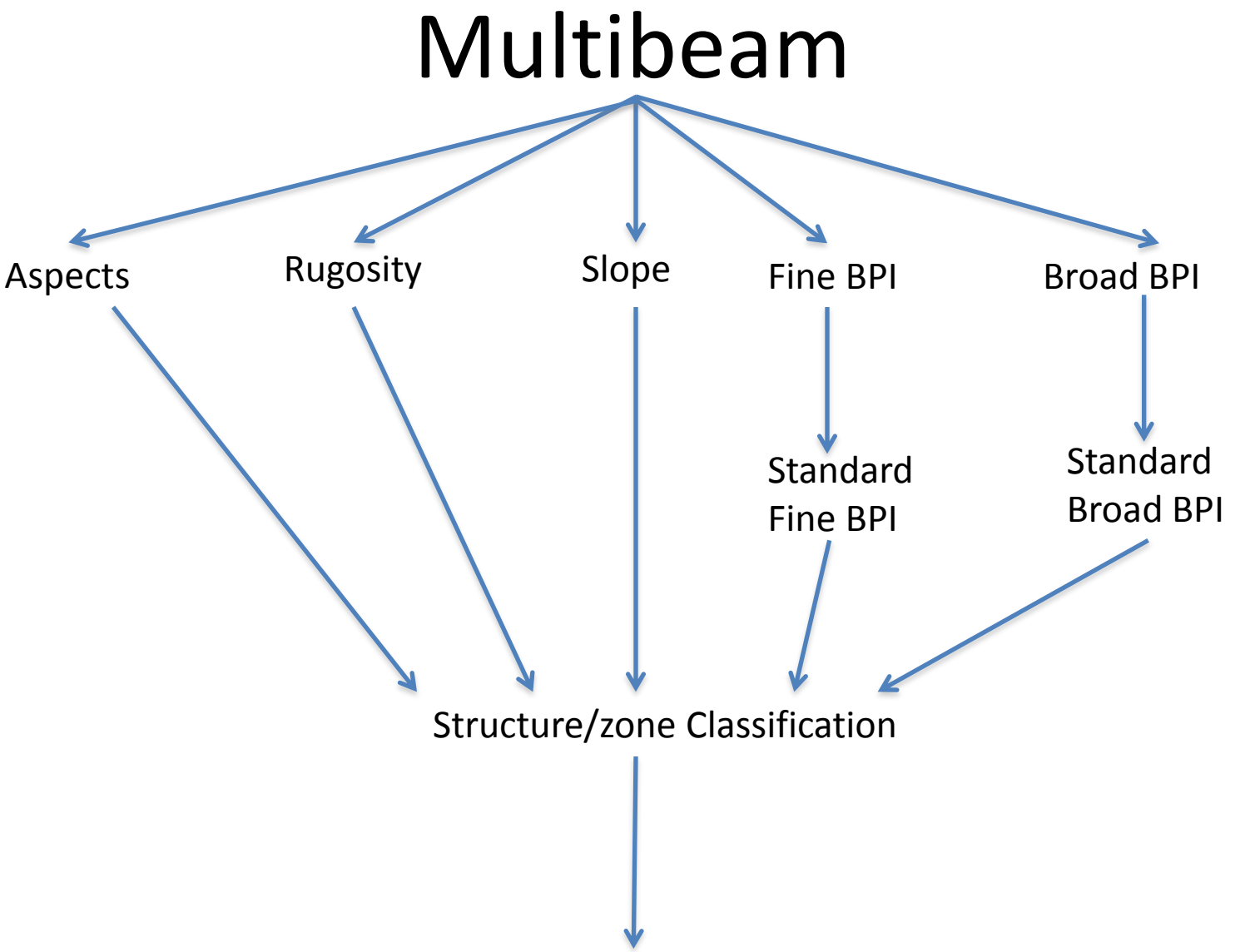

AAR
Mean
Mean±SE
Mean±SD
Outliers
Injury frequency levels 2 to 4 per sample
3.0
2.5
2.0
1.5
1.0
0.5
0.0


RTR
Injury frequency levels 2 to 4 per sample
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1997
1998
1999
2011
Year

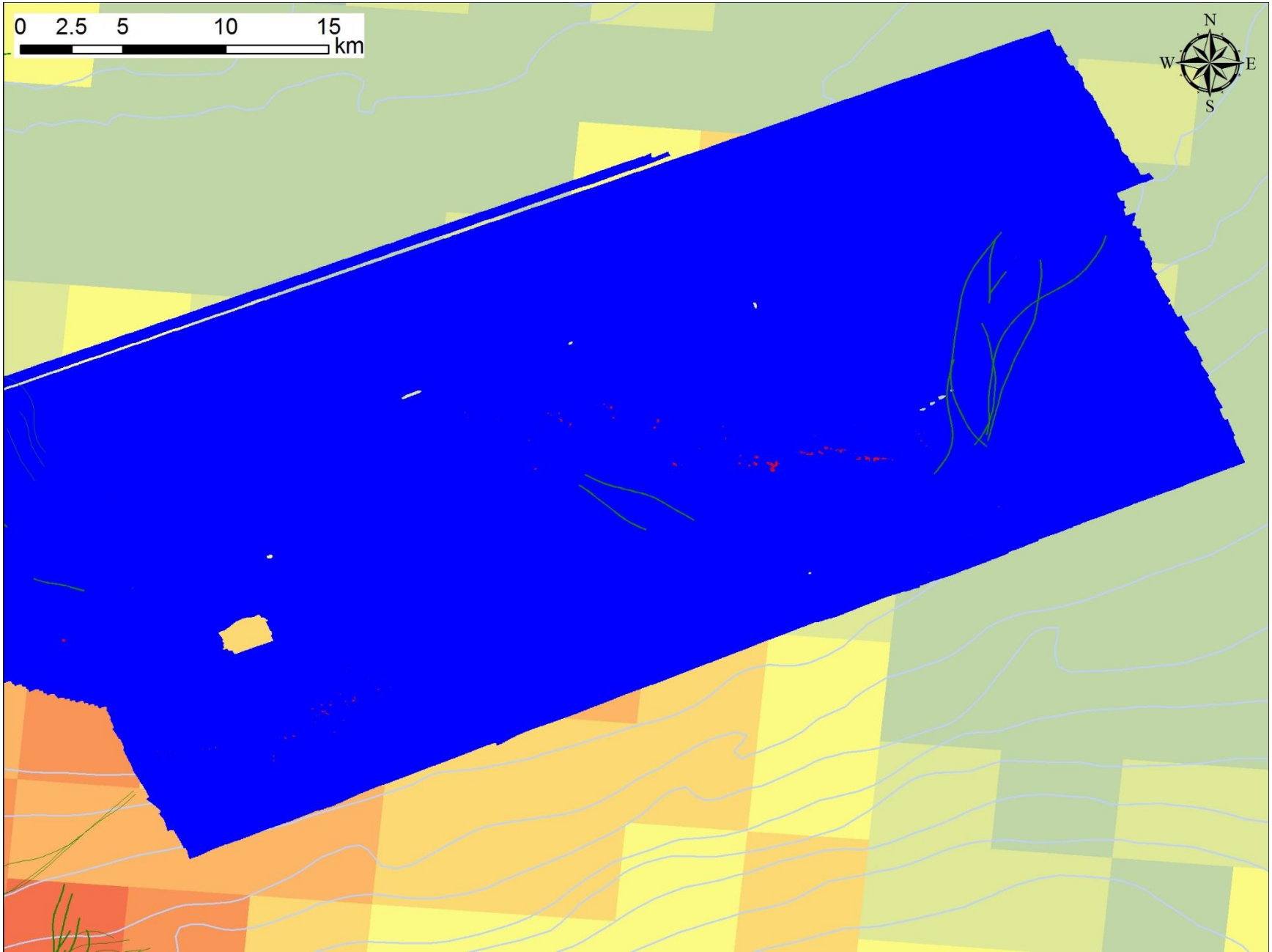


Etnoyer et al. 2015


a
2011
b
2014
c
2011
d
2014
Etnoyer et al. 2015


Multibeam
Aspects
Rugosity
Slope
Fine BPI
Broad BPI
Standard
Fine BPI
Standard
Broad BPI
Structure/zone Classification
Habitat Classification by zone and structures

Predicted coral habitats



Summary

- Deepwater Horizon surface oil covered an average area of 11,200 km^2 with an average volume of 22,600 m^3.
- Impacted area and volume changed dynamically within a cumulative footprint of 149,000 km^2.
- Peak magnitudes of oil detected with SAR occurred on 23 May and 18 June, when wind speeds were <5 m s^{-1}.
- Over this interval, volume of floating oil decreased by 21% while its ocean-area increased by 49%, principally due to dispersant applications and burning.
- A decrease in surface oil volume with a concurrent larger increase in the area covered by that oil will have changed the ecological impact of the oil—one effect was wide-spread injuries to mesophotic corals, which were exclusively impacted by surface oil.
- We see little sign of recovery in the most heavily injured corals.
- The mesophotic coral ecosystem remains under-quantified in this region, but back-scatter and bathymetric analysis indicates that we have studied less that 5% of the potentially impacted area.
- Marine Sanctuary protection would be a major advance for this important resource.