Characterization of Deep Sea Coral Mounds Beneath the Gulf Stream Off the Southeast U.S. Coast

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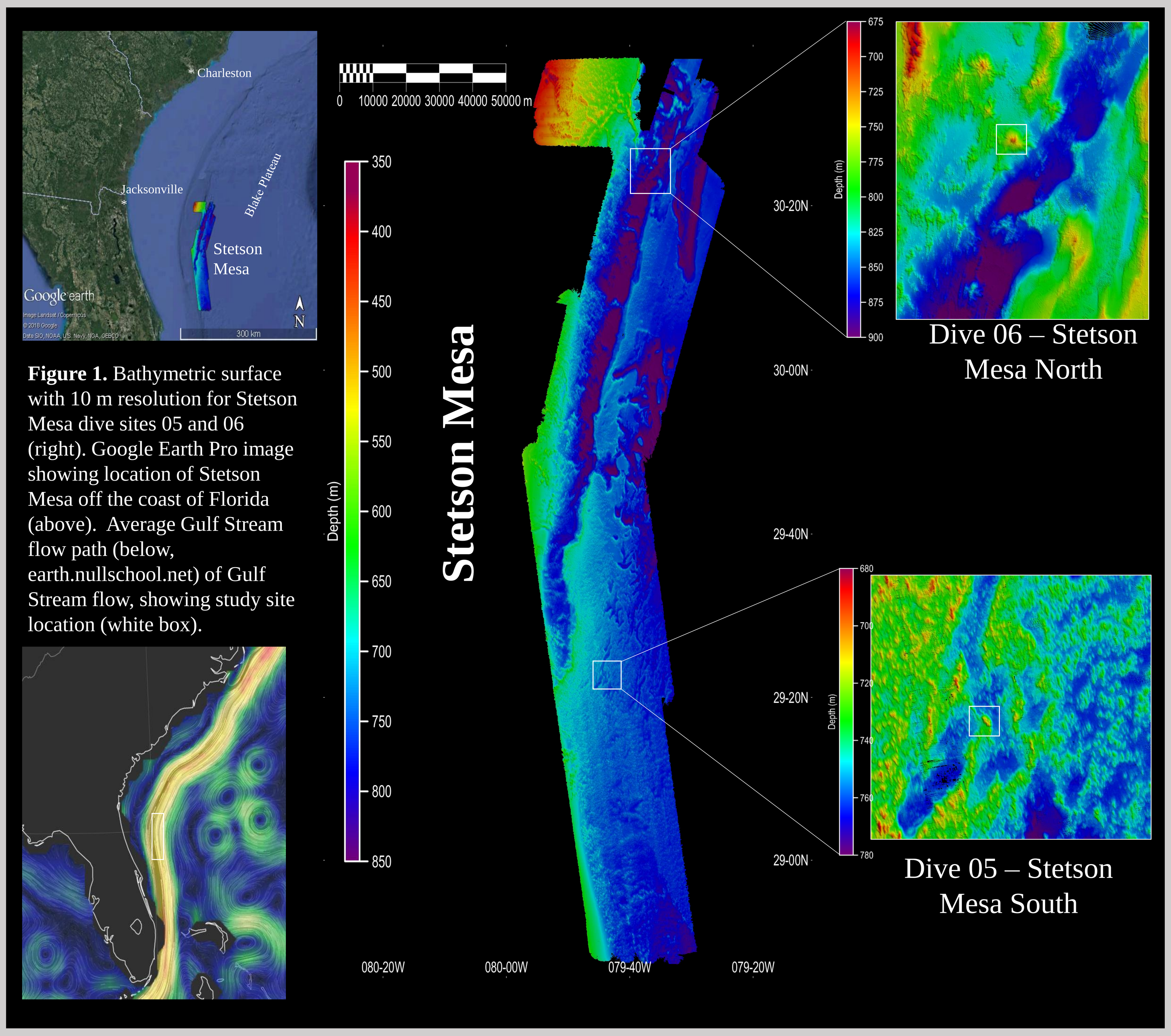


Figure 1. Bathymetric surface with 10 m resolution for Stetson Mesa dive sites 05 and 06 (right). Google Earth Pro image showing location of Stetson Mesa off the coast of Florida (above). Average Gulf Stream flow path (below, earth.nullschool.net) of Gulf Stream flow, showing study site location (white box).

ABSTRACT

Deep-sea coral mounds located beneath the Gulf Stream on the southeastern U.S. continental margin were explored during the NOAA Ocean Exploration and Research (OER) expedition, *Windows to The Deep 2018* (May-June), aboard the NOAA Ship *Okeanos Explorer.* The ROV *Deep Discoverer* dove on multiple mound sites to characterize benthic habitat and ground truth areas that had previously been designated potential deep-sea coral and sponge habitats by the South Atlantic Fisheries Management Council. Bathymetric and backscatter intensity maps were created using multibeam sonar data collected during OER mapping cruises EX1403 and EX1805. This study focuses on the Stetson Mesa, approximately 184 km east of Jacksonville, FL on the western edge of the Blake Plateau where depths range 350 to 900 m. The area's northwest portion is comprised mainly of coral mounds aligned trending northeast, whereas the southern area coral mounds are aligned northwest. Live corals were documented at the shallowest depths of coral mounds explored at ROV dive site 05 (660-780 m depth range) and were abundant at the top of the large single mound at site 06 (675-900 m depth range). Bathymetry, classified backscatter intensity, and slope surfaces were used to examine these live coral habitat areas. Live corals were found at the shallowest depths, not in areas with high backscatter intensity or steep slopes. These results suggest that using bathymetry to identify live deep coral habitat on mounds is more reliable in areas under the Gulf Stream's influence, as opposed to using backscatter intensity or slope.

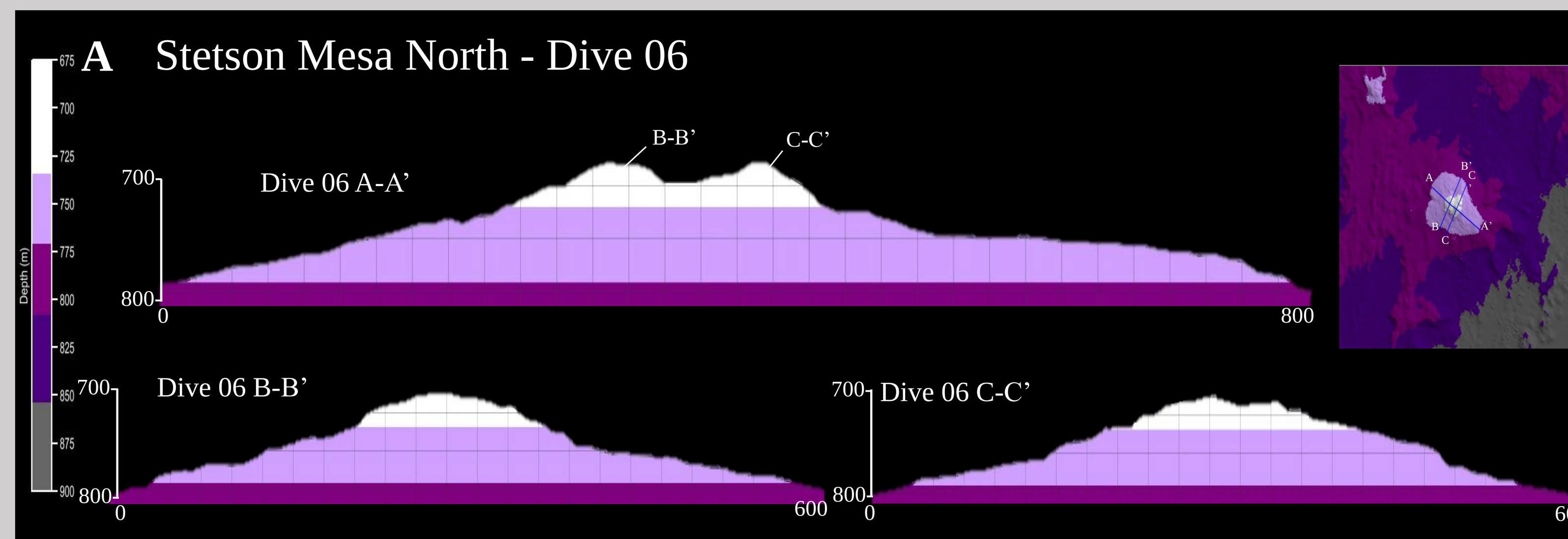


Figure 2.
A) Stetson Mesa North Dive 06 profiles were drawn from the northwest end to southeast of the dive track (A-A') and cross sections were drawn from the southwest to northeast of the dive track (B-B' and C-C'). Profile locations are shown in the upper right.
B) Stetson Mesa South Dive 05 profiles were also drawn from the northwest end to southeast of the dive track (A-A') and cross sections were drawn from the southwest to northeast of the dive track (B-B' and C-C').. Profile locations are shown in the lower right.

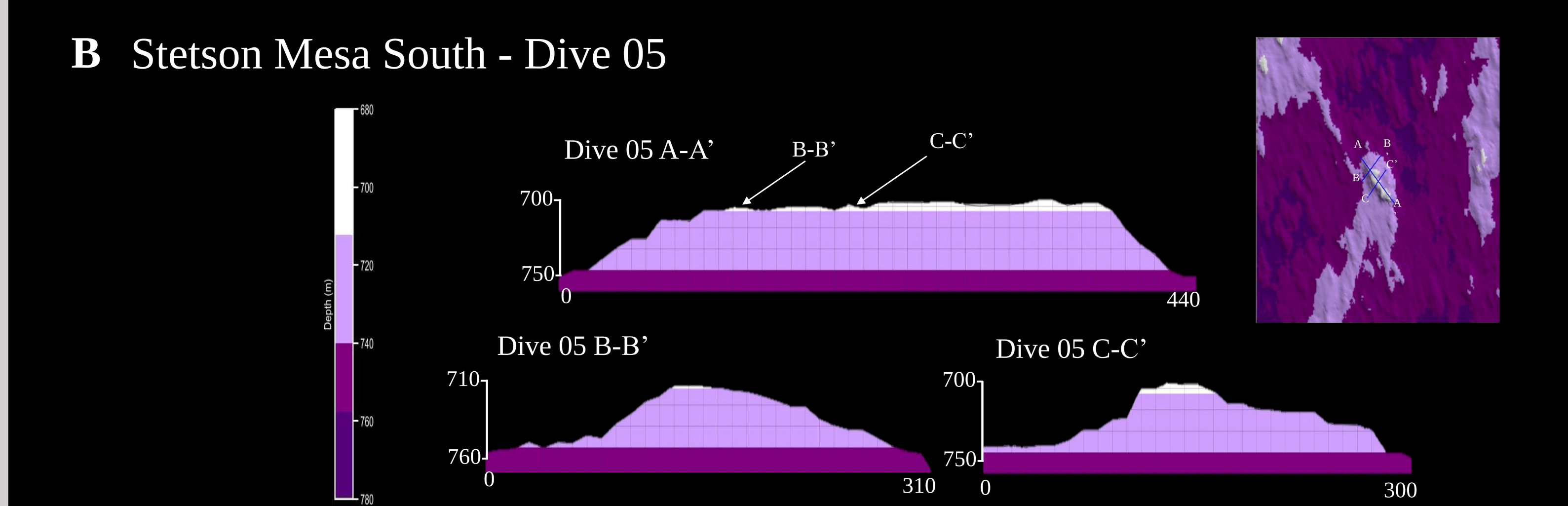


Table 1. Dive 06 and Dive 05 mounds Depth, Slope, and Intensity values for points selected within specific depth ranges.

Dive 06 Crest Depths (715 -734 m)

Depth (m)	Slope (deg)	Intensity (db)
732.30	5.781	-24.111
731.90	12.198	-24.986
731.40	22.382	-20.729
727.20	15.732	-21.249
717.10	15.676	-21.335
722.60	35.754	-21.780
716.70	7.500	-22.178
725.50	22.143	-23.684
717.80	11.641	-23.107
724.20	22.869	-21.712
720.60	10.994	-21.360
725.40	22.544	-22.080
723.80	18.341	-23.454
727.90	18.379	-24.311
720.30	24.328	-23.807
724.30	21.160	-26.397
728.20	24.453	-24.227
728.90	14.011	-25.517
729.20	18.084	-26.217
731.00	17.211	-23.431
729.70	17.199	-21.754
730.30	27.403	-20.344
715.60	29.686	-21.339
727.30	18.233	-22.714
723.30	26.554	-19.638
723.20	29.966	-17.250
718.70	23.281	-20.046
726.60	23.544	-20.677
721.90	22.406	-23.511
722.70	26.895	-22.155
719.40	21.424	-22.864
724.10	7.375	-23.056
716.50	21.196	-21.621
719.60	15.525	-22.574
724.60	22.258	-25.592
722.30	20.203	-22.530
722.40	19.673	-23.094
722.30	25.299	-23.501
717.20	15.794	-18.884

Dive 06 Flank Depths (735 -745 m)

Depth (m)	Slope (deg)	Intensity (db)
740.10	9.578	-24.522
740.00	12.497	-23.238
737.80	15.516	-25.201
736.30	22.470	-23.665
737.30	16.130	-21.458
738.50	13.018	-23.399
739.80	11.785	-24.700
742.90	16.576	-25.002
735.90	24.373	-24.982
735.60	22.919	-24.497
739.30	21.783	-25.287
736.00	17.326	-23.488
736.30	15.333	-24.253
739.20	17.125	-25.506
741.00	20.409	-25.336
741.50	16.569	-24.088
737.30	5.859	-25.405
736.20	9.342	-24.121
739.30	20.875	-23.675
744.30	25.327	-21.327
743.10	22.965	-21.244
742.10	10.154	-24.463
737.70	25.590	-18.261
738.00	19.198	-21.920
736.00	15.617	-22.339
736.60	10.126	-23.975
736.80	7.012	-21.283
738.30	9.211	-20.291
740.00	17.072	-22.160
745.20	21.300	-20.923
743.80	14.430	-20.004
740.50	16.738	-21.137
743.20	17.091	-24.052
740.20	20.156	-22.231
737.20	20.856	-20.150
739.60	27.876	-23.229
736.60	24.723	-22.414
741.50	15.415	-22.066
738.70	13.212	-22.024
741.30	15.456	-25.459

Dive 05 Crest Depths (706 -712 m)

Depth (m)	Slope (deg)	Intensity (db)
711.30	21.828	-27.141
708.30	0.349	-26.389
706.60	10.487	-25.768
708.50	4.211	-26.239
709.50	7.724	-23.325
709.80	10.613	-25.625
709.30	13.699	-25.226
707.30	7.545	-28.497
708.30	5.808	-29.487
708.30	6.669	-25.000
708.20	6.374	-27.543
710.70	10.302	-28.159
709.00	6.833	-27.488
709.50	5.679	-24.461
709.60	2.516	-27.967
710.20	0.529	-25.326
708.40	4.865	-24.275
710.60	7.141	-26.788
711.90	8.817	-23.809
711.80	8.128	-21.696
710.90	4.413	-20.724
712.00	7.329	-22.967
711.60	12.399	-24.656
707.00	13.606	-24.211
708.30	21.612	-24.961
707.00	18.115	-27.563
710.10	15.639	-27.456
709.60	23.537	-23.236
711.50	18.240	-24.448
710.50	17.842	-23.992
710.20	23.361	-25.700
709.30	8.878	-24.417
711.60	25.795	-24.913
708.00	11.813	-27.476
710.70	7.445	-27.038
711.20	7.736	-26.353
711.00	16.746	-27.724
708.50	11.560	-26.999
708.20	9.764	-22.496
710.90	6.110	-26.646
711.70	12.209	-32.315

Dive 05 Flank Depths (712 -730 m)

Depth (m)	Slope (deg)	Intensity (db)
725.90	33.320	-26.746
724.50	36.881	-25.332
730.80	33.972	-24.619
728.90	32.926	-24.312
716.20	19.439	-27.289
728.10	29.803	-24.975
724.30	30.894	-29.046
729.10	37.590	-26.970
724.40	28.884	-26.486
721.60	31.665	-26.067
722.40	35.280	-25.761
724.30	26.807	-23.415
716.20	27.494	-23.958
716.50	29.829	-23.241
721.70	32.758	-26.024
724.90	30.611	-22.429
725.30	24.145	-24.551
723.10	29.360	-27.792
725.50	27.626	-30.179
720.80	18.623	-30.805
716.40	12.918	-27.036
714.90	6.907	-29.002
715.90	10.150	-31.936
719.10	24.270	-24.425
721.10	23.245	-25.414
722.30	11.819	-26.253
720.00	15.924	-27.749
714.00	13.500	-26.202
719.00	14.134	-22.656
717.40	15.408	-23.036
714.80	11.964	-21.511
715.20	5.868	-25.591
713.00	4.043	-22.502
713.90	13.110	-27.908
716.70	27.756	-28.584
727.00	33.190	-29.211
721.60	27.368	-27.348
723.90	21.880	-29.058

Dive Site 06 – Stetson Mesa North

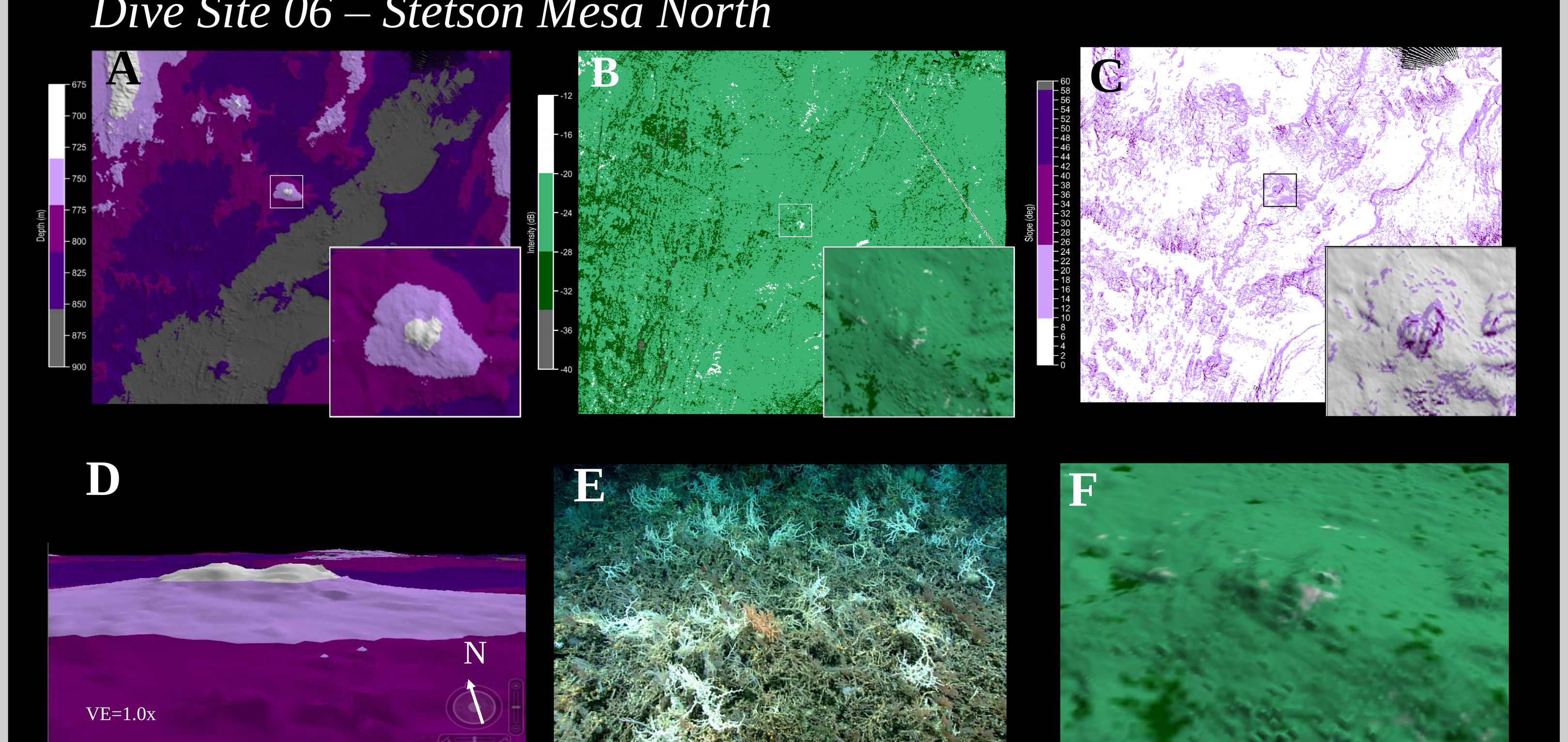


Figure 3. A) Bathymetric surface with 10m resolution. B) Classified backscatter intensity surface, where highest intensities are white. C) Slope surface with steeper slopes in darkest purple. Insets for A-C are enlarged images of Dive 06 Site. D) 3D image of mound explored. E) ROV *Deep Discoverer* image of live *Lophelia pertusa* (white coral) and *Madrepora oculata* (orange coral) found at mound crest. F) 3D image of backscatter draped over bathymetry for Dive 06 mound, showing lack of high intensity backscatter at the shallower depths.

Dive Site 05 – Stetson Mesa South

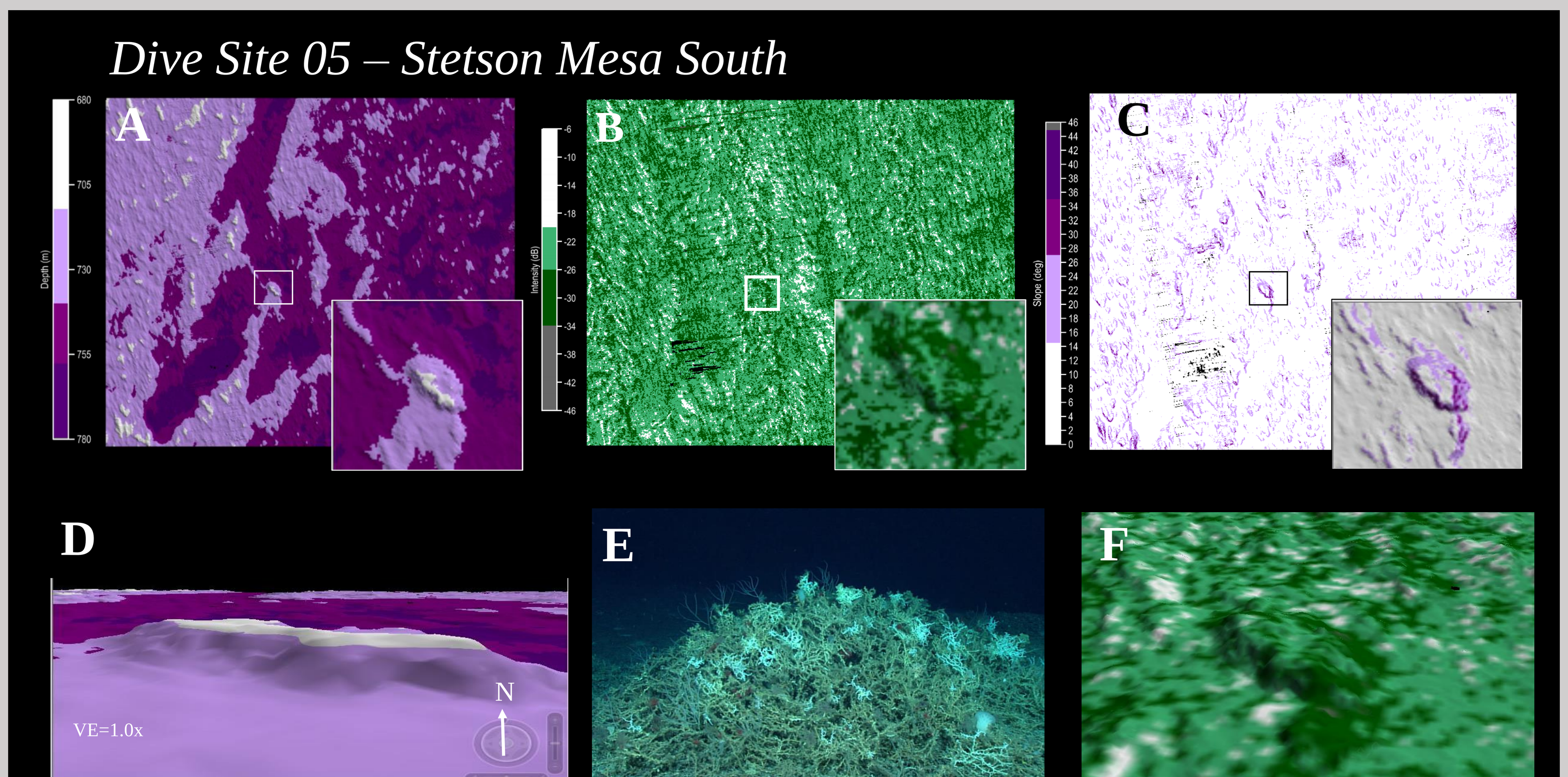


Figure 4. A) Dive Site 05 Bathymetric surface, 10 m resolution. B) Classified backscatter intensity surface, where highest intensities are white. C) Slope surface, with steeper slopes in darkest purple. Insets for A-C are enlarged images of Dive 05 Site. D) 3D image of Dive 05 mound. E) ROV *Deep Discoverer* image of live *Lophelia pertusa* (white coral) located at mound crest. F) 3D classified backscatter intensity draped over bathymetry for Dive 05 mound, showing lack of high intensity at the shallower depths of the mound where live coral are most abundant.

BACKGROUND

Located 185 km east of Jacksonville, FL, the Stetson Mesa is a part of the Blake Plateau on the South Atlantic Bight. An area ~250 km in length was previously mapped by NOAA vessel *Okeanos Explorer* during the *East Coast Mapping Expedition 2014* to understand the features of an area designated deep-sea coral habitat of concern in 2010 by the South Atlantic Fisheries Management Council. Research done on many cold-water corals has pointed to habitats primarily located on hard, dense substrate at depths between 300-800 m and temperatures from 4-12°C (Roberts, 2010). Prior attempts to determine habitat location using multibeam sonar data have relied heavily on finding areas of high backscatter intensity to locate hard substrate, considered 'prime real estate' for cold-water corals such as *Lophelia pertusa*. The purpose of this study was to determine whether slope, backscatter intensity, or depth was the most defining characteristic in determining potential locations for deep-sea coral habitats under the influence of the Gulf Stream.

Figure 6. *Lophelia pertusa* sample collected by DSV *Alvin* during the DeepSEARCH expedition.

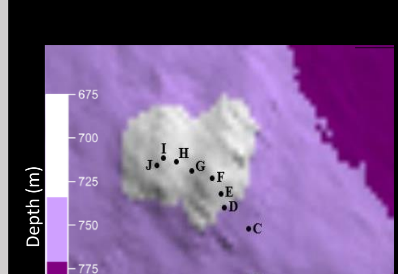
METHODS

- Multibeam sonar data were collected during May 2014 on EX1403 by the NOAA Ship *Okeanos Explorer*, equipped with a Kongsberg EM302 multibeam sonar system.
- For Dive Sites 05 and 06 of the *Windows to The Deep* (ex1806) expedition, the ROV *Deep Discover* covered a section of the Stetson Mesa, located 185 km east of Jacksonville, FL
- Additional areas of the mesa were surveyed during EX1806 before each dive.
- CARIS HIPS and SIPS 10.4 was used to create bathymetric, backscatter and slope surfaces at a 10 meter resolution, as well as cross-sectional profiles.
- Bathymetry was color-classified to highlight mound crests (white) and mound flanks (light purple) for each of the two study areas.
- Slope and intensity measurements were collected within the shallow (crest) and intermediate (flank) depth ranges along ROV dive tracks at sites 05 and 06 (Table 1).
- Table 2 data were collected along the ROV dive tracks for each site.
- Slope vs. intensity was examined for possible correlation.

RESULTS

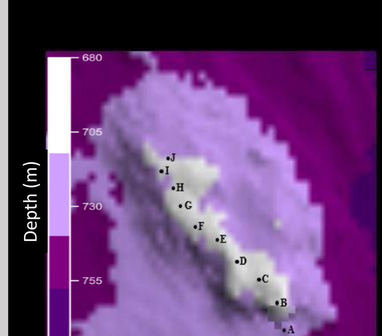
- Dive 06 classified backscatter intensity map showed small pockets of high intensity, but no areas were found directly on the dive track, including areas where live coral were found, on the mound crest, at the shallowest depths (Table 2, Figure 3).
- Dive 05 classified backscatter intensity map showed small areas of high intensity, including a small section east of the dive track (Table 2), however, intensities were low to moderate on the shoalest portion of the coral mound, where greatest abundances of live corals were observed (Figure 4).
- Dives 05 and 06 showed weak to no correlation between slope and backscatter intensity along the mounds' crests and flanks (Figure 4).

Table 2. Dives 06 and 05 track data points.



Along Dive Track - Dive 06

Point	Depth (m)	Slope (deg)	Intensity (db)
A	770.30	16.839	-25.001
B	753.90	16.348	-24.525
C	743.90	8.216	-26.935
D	738.00	18.955	-19.183
E	718.10	27.295	-18.074
F	712.90	10.416	-21.493
G	723.80	11.213	-24.375
H	716.60	26.149	-23.105
I	712.20	7.291	-21.786
J	713.10	15.220	-21.026



Along Dive Track - Dive 05

Point	Depth (m)	Slope (deg)	Intensity (db)
A	729.00	9.466	-30.285
B	708.40	2.940	-30.016
C	708.50	4.211	-26.239
D	706.90	9.694	-27.274
E	708.40	2.340	-28.848
F	709.60	4.293	-24.201
G	709.60	2.516	-27.967
H	710.60	6.028	-26.038
I	710.20	4.502	-22.125
J	713.10	8.816	-17.457

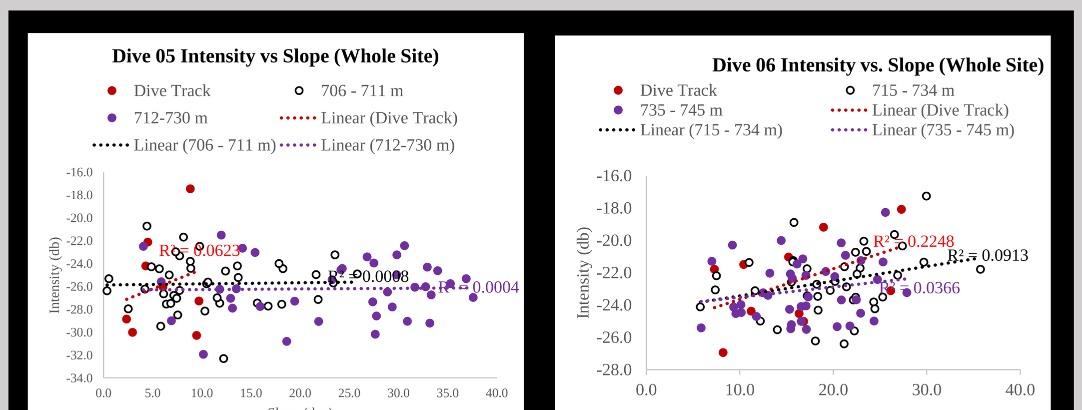


Figure 5. Intensity vs. Slope for the Dive Track, The White Layer depth, and the Purple Layer depths.

DISCUSSION and CONCLUSIONS

Deep sea coral habitat is often found on high slope, hard substrate areas (Roberts et al., 2006). These hard substrate areas often are identified by having high backscatter intensities. While this hard substrate/high high backscatter intensity may be true for areas with warm water corals (Faud, 2010) or deep-sea cold water corals located on intraslope terraces (Coe and Sautter, 2019) and other exposed hardground, neither Dive Site 05 or Dive Site 06 showed high intensities in areas where deep coral were observed along the ROV dive track (Figures 2E & 3E). This finding suggests that as the acoustic signal reaches the mound crest, it is highly scattered through the rugose dead coral framework structure, therefore returning a much weaker intensity (Fig 5). These live coral prefer the shallower depths found at the top of dead coral mounds under the Gulf Stream influence as particulate flow may be greater at these depths suspension feeding. Other organisms living on and within the dead coral framework structure included several different sponge species, crustaceans, echinoderms, and several species of fish. Few coral or other fauna, however, were located in the swales between coral mounds, as these areas were covered in calcareous sediments (NOAA OER, 2018). In conclusion, future proposed ROV dives might consider using mound crests as the best indicator of where larger colonies of live coral, and higher biodiversity can be found on the Stetson Mesa and other areas of the Blake Plateau. There is no shortage of potential mound sites as seen on Figure 1.Within the small subset picture of the area surrounding Dive Site 05, there are approximately 100 mounds to explore this proposed method for finding deep sea coral habitat.

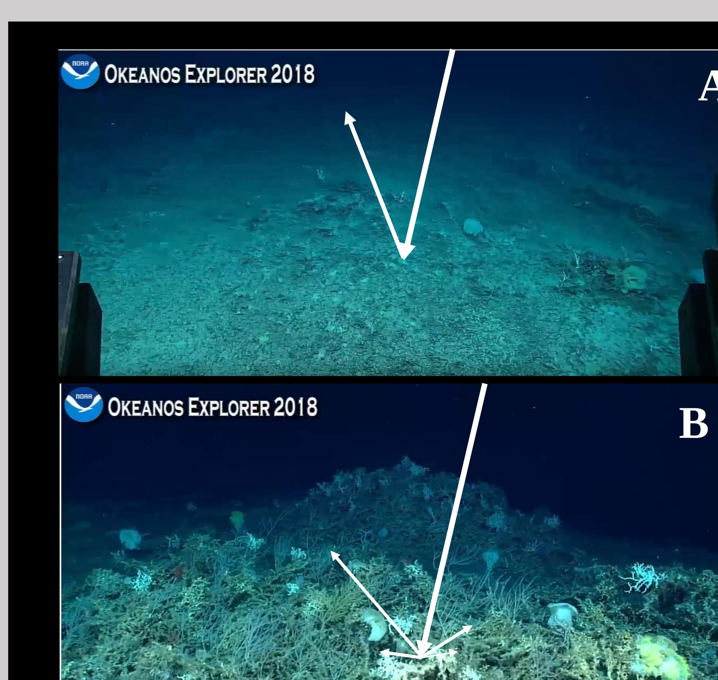


Figure 5. Backscatter return comparisons shown on Dive Site 05 ROV *Deep Discover* video frames. A) Acoustic signal transmitted bouncing off semi-hard, relatively smooth substrate. B) Same signal reflected off high rugosity, porous, semi-hard substrate, resulting in higher scattering and lower intensity return.

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ACKNOWLEDGEMENTS

This research would not have been possible without NOAA Office of Exploration Research and the ship *Okeanos Explorer.* Additionally, we would like to thank CARIS for Academic Partnership, and the support from the CofC School of Science & Math. This project was conducted as part of the College of Charleston BEAMS Program.