Classifying Interrelationships Between Deep-Sea Coral and Local Geomorphology on a Blake Escarpment Intraslope Terrace, Southeast U.S. Continental Margin

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BACKGROUND

On June 17, 2018, the National Oceanic and Atmospheric Administration conducted Dive 04 as part of the *2018 Windows to the Deep Expedition*. EX1806 Dive 04 focused on a zone 300 km offshore of the southeastern United States in an area known as the Blake Escarpment (Fig. 1A). The Blake Escarpment rapidly descends from depths ranging 500-1000 m to depths exceeding 5000 m (Dillon 1988). Live video observations of the escarpment taken by ROV *Deep Discoverer* discovered large assemblages of corals and associated benthic organisms. Throughout the dive, coral family diversity and abundance varied as the ROV ascended a scarp with large sediment-draped terraced ledge features, defined as the intraslope terrace. The geology of the intraslope terrace is observed to have erosional rock slabs coated by a carbonate manganese crust. Erosional substrates and environments such as these have been found to provide substrates for cold-water coral (Edinger 2011). Throughout the dive, the five coral orders observed were Actinaria, Antipatharia, Scleractinia, Zoantharia, Alcyonacea, and Pennatulacea with the highest occurrences in Antipatharia, Scleractinia, and Alcyonacea. Through remote telepresence communication, scientists, globally, were able to posit organism identification, contextualizing the benthic habitat in real time. The purpose of this study is to estimate coral biodiversity and abundance in relation to geology through visual observations of an understudied, unique geomorphologic area.

ABSTRACT

From May 22 through July 2, 2018, NOAA and partners, aboard the NOAA Ship *Okeanos Explorer* conducted a telepresence enabled ocean exploration expedition, *Windows to the Deep 2018*, on the Southeast U.S. Continental Margin to collect baseline information about understudied or unknown deep-water habitats. Video footage collected during EX1806 Dive 04 along a steeply terraced section of the Blake Escarpment, referred to as an intraslope terrace, revealed over 25 different deep-sea coral familiae and genera, living within a variety of associated habitats. Intraslope terraces are characterized by flat-lying strata with outcropping edges that result in a stair-step like slope. Active benthic communities thrive in geologic environments with high slope and high backscatter intensity, features often described in association with intraslope terraces. Utilizing video footage of observed deep-sea coral, a semi-quantitative study was conducted of genera abundance as it relates to observed substrate character. Diversity and abundance of familiae and genera were compared to the substrate's backscatter intensity along the ROV dive track. Results were summarized through projection of approximate location onto visualizations depicting bathymetry and backscatter, revealing a pattern of varying biota diversity and frequency according to geologic environment.

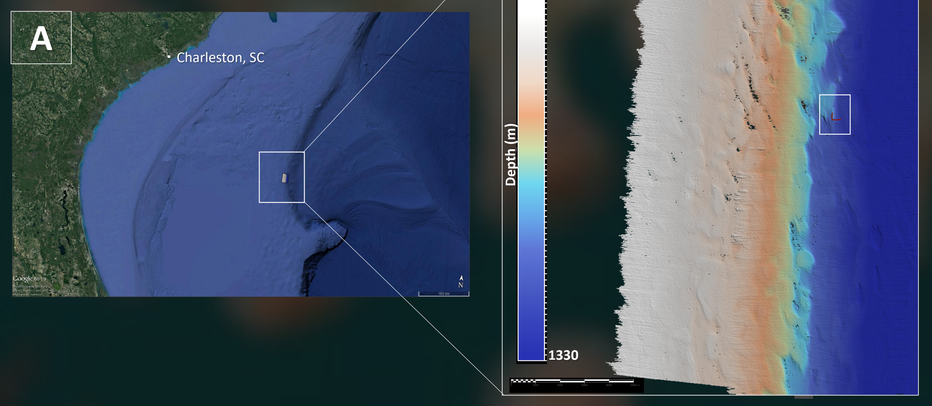

Figure 1. A) Google Earth Image depicting the site of Dive 04 approximately 300 km southeast of Charleston, South Carolina.
B) 15m CUBE bathymetric surface with dive track highlighted in red.

METHODS

- Multibeam sonar data were collected during June-July of 2018 on EX1806 aboard the NOAA Ship *Okeanos Explorer* with a Kongsberg EM302 multibeam sonar.
- During DIVE 04 high-resolution video imagery of benthic habitats and associated organisms were collected by ROV *Deep Discoverer.*
- CARIS HIPS and SIPS 11.2 was used to post-process raw multibeam sonar data and to render high-resolution CUBE bathymetric surface at 15 m resolution (Fig. 1B) .
- ROV dive videos were examined in the citizen science visualization platform, Ocean Video Labs (OVL) (Fig. 3).
- Using the Shannon Index, species diversity was quantified in four different geologic zones: sediment flats (1325-1305 m), intraslope terrace wall (1305-1260 m), intraslope terrace scarp overhang (1260-1250 m), and the rock flats on top of the scarp (1250-1245m).

Figure 2. Shannon Index equations utilized to determine species diversity. Equitability assumes a value between 0 and 1 with 1 being complete evenness.

$$H = -\sum_{i=1}^{S} p_i \ln p_i$$

$$E_H = H / H_{max} = H / \ln S$$

	CORAL	1	2	3	4	T
Antipatharia	*Alternatipathes*				2	2
	Bathypathes	3	7	30	12	52
	Heteropathes americana	1	1			2
	Leiopathes		1	1	8	10
	Parantipathes	2		2		4
	Stauropathes	14	14		2	30
	Stichopathes	17	22	7	21	10
	Taxipathes		1	2		3
Zoantharia	Unidentified Black Coral	1	13	11	12	37
Scleractinia	Branching- *Solenosmilia*	6	33	25	10	74
	Cup- *Desmophyllum*	1	7	21		29
	Enallopsammia rostrata		3			3
Zoantharia	Zoanthidae	1	2	2	2	7
	Anthoptlium			1		1
	Anthomastus		2	5		7
	Candidella		1			1
	Chrysogorgiidae	1	1	1		3
	Cladarisis		1			1
	Clavularia			1		1
	Corallium	1				1
	General Isididae	1	7	18	18	44
	Jasonisis				3	3
	Keratoisis		1			1
	Metallogorgia			1	2	3
	Paramuricea			2		2
	Pennatulacea				2	2
	Primnoid		1			1
	Thouarella	1				1
	Unidentified Octocoral		7	3	3	13

Table 1. Coral observations from each geomorphologic zone Antipatharia (gray), Scleractinia (purple), Zoantharia (blue) and Octocorallia (green).

Figure 3. 3D surface of the intraslope terrace at Dive 04. Pie charts record coral observations at areas of differing geomorphology. The dive track (white) began at the sediment flats and ascended up the intraslope wall before reaching the top of the scarp. The ROV hugged the scarp's overhang before continuing onto the rock flats at the top.

RESULTS

The recorded totals of observed coral (Table 1) visualized distinct patterns:

- Highest diversity (Equitability Index 0.864) was observed on the **rock flats** with the lowest diversity (0.741) in the **sediment flats (Table 2).**
- **Antipatharia** were in the highest abundance (4A) throughout the dive but were noted to be larger in size at the top of the terrace on the rock flats (Fig 4B).
- The least diverse order observed, the **Scleractinia**, were found to have high abundance (>30% of all observed) on scarp overhangs while having low abundance in the flats (<15% of all observed) Fig 4C).
- **Octocorallia** had the highest diversity, which increased concurrently with slope as the ROV ascended the intraslope terrace (Fig 4D).

Figure 4. A-D Total coral observations in orders Antipatharia, Scleractina, and class Octocorallia from Dive 04 with top 3 genera/familiae listed from highest percentage to lowest.

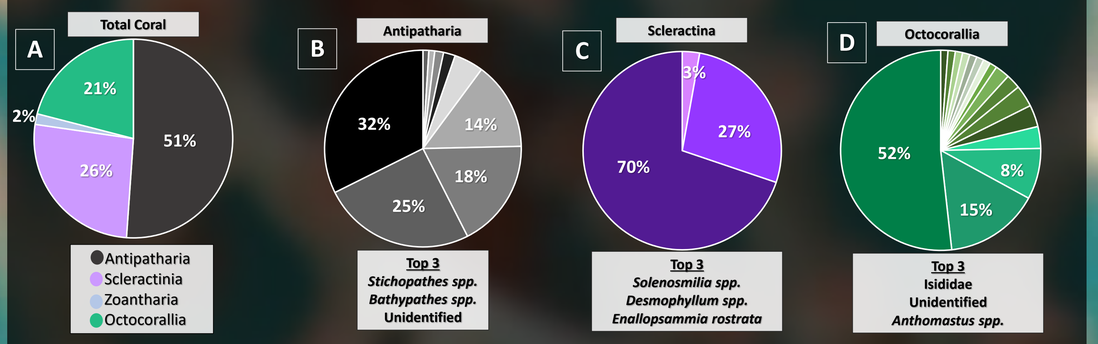

Figure 5. Total coral observations across the geologic gradient.

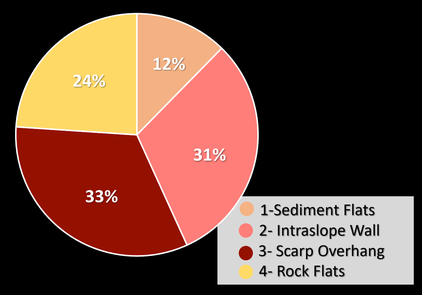

Table 2. Shannon Index and Equitability values illustrating diversity at the different geologic zones.

Zone	Shannon Index (H)	Equitability Index
1	1.90	0.741
2	2.31	0.786
3	2.22	0.783
4	2.22	0.864
Overall	3.53	0.855

DISCUSSION-CONCLUSION

Overall, deep-water coral species diversity and abundance is observed to be variable according to geologic substrate revealing a positive trend with an increase in slope.

- **Antipatharia** was found in the highest abundance likely because of *Stichopathes ssp.'s* ability to root in the unconsolidated sediments. **Scleractina** strongly favored overhangs, however its skeleton complex also provided substrate to other coral. *Solenosmilia spp.* in particular seemed to be acting as a deep water reef-building coral. **Octocorallia** showed a positive trend in abundance and diversity as slope increased. Ocean current flow is likely to be higher on top of the terraced slope which might contribute to increased observations of Octocorallia.
- Size of solitary colonies were observed to increase as the ROV ascended the slope which indicates the geology has been able to remain *in situ* for and extended amount of time, supporting the slow growing corals.

This intraslope terrace is observed to be highly diverse due to its high overall Equitability Index of 0.855 (Table 2), which could indicate The Blake Escarpment may host additional zones of unique faunal assemblages.

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