Geomorphology of Lighthouse and Turneffe Fore-Reefs: Exploration Using Backscatter

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ABSTRACT

In August 2014, as part of the Mesoamerican Reef Project, Dr. Peter Etnoyer of NOAA and the 2014 Corps of Exploration acquired multibeam sonar data aboard the E/V *Nautilus* using a Kongsberg EM302. The areas of interest included the deep-water eastern flank, or fore-reef of Lighthouse Reef Atoll and the southern fore-reef of Turneffe Reef: 2 of 3 atolls that lie on Belize's continental margin. With depths reaching 4,000 meters, the atolls lie on submarine ridges just west of the Yucatan Basin. The deep waters of these escarpments have potential for being suitable habitats for deep-sea corals to thrive. Through this research, it is our hope to benefit future ROV exploration by mapping areas of interest in search of deep-sea coral habitats. Furthering research of these atolls is crucial for understanding the delicate, threatened ecosystems of deep-sea corals.

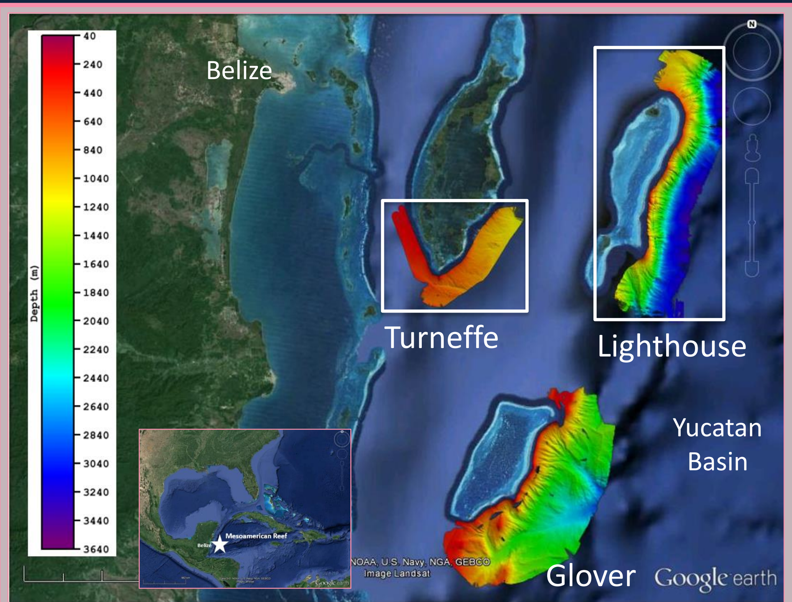


Figure 1. Overview of study area showing the southern fore-reef of Turneffe Reef Atoll, the eastern fore-reef of Lighthouse Reef Atoll and the eastern flank of Glover Reef. The inset map shows the location of the Mesoamerican reef off Belize.

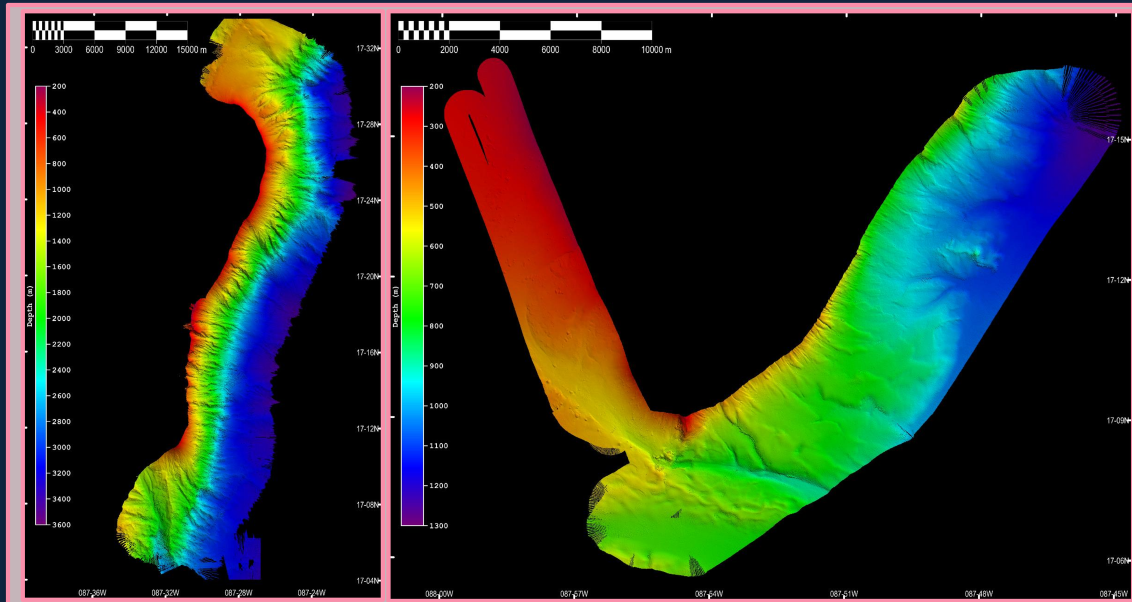


Figure 2. Bathymetry of Lighthouse Reef (left) with a depth range of 200 to 3,600 m and Turneffe Reef (right) with a depth range of 200 to 1,300 m. Images were created using a 10 m Swath Angle BASE Surface overlain with a 5 m BASE surface at Lighthouse and a 3 m BASE surface at Turneffe.

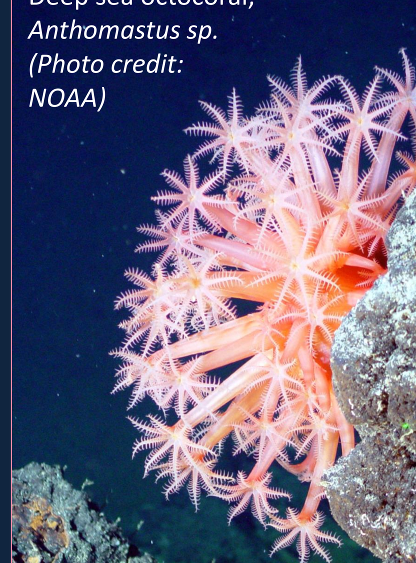
BACKGROUND

Deep sea corals (sometimes referred to as cold water corals) are known to form in areas with a topographically enhanced bottom composed of a hard substrate on which attachment is possible (Attenborough, 2015). Preferring cold water and below storm surges, deep-sea corals often position themselves in exposed rocky areas within canyons, scours, and steep escarpments. They are most often found at depths between 400 and 600 m and between 1800 and 2100 m. The Mesoamerican Reef is an area of interest in search of deep-sea corals, as it proves rocky outcrops and the nearby Caribbean current keeps sediment in suspension and gives the corals nourishment.

Advancement in the understanding of delicate deep water ecosystems is crucial in order to protect the region's biodiversity. Providing stakeholders (e.g., the fishing industry) information on the locations of these habitats can keep coral species from harm. The threat to this ecosystem is not to be taken lightly and pressure on these fragile ecosystems will affect the health of many marine organisms such as finfish and shellfish, manatees and sea turtles, as they provide a habitat for an array of species. Overfishing, use of anchors, and illegal fishing practices harm these ecosystems, which take up to thousands of years to mature (Burke 2005). The purpose of this study is to identify potential hard-bottom habitat for future exploration of deep coral habitat.

METHODS

- Multibeam sonar data were acquired aboard the E/V *Nautilus* using a Kongsberg EM302 (Fig. 1).
- Sonar data were post-processed using CARIS HIPS & SIPS 8.1 to produce 10 m and 5 m Swath BASE surfaces for Lighthouse Fore-Reef, and 10 m and 3 m Swath BASE surfaces for Turneffe Fore-Reef (Fig. 2).
- Backscatter data were processed to determine relative hardness of the fore-reef flanks and escarpments. Statistics were calculated and histograms containing the amount of data at each intensity. Sediment analysis processed and analyzed for areas of interest (Fig. 3).
- Backscatter data were classified into three categories: green for hard-bottom, purple for mixed sediment and red for soft sediment. Hard-bottom was then classified into 3 sub-categories (Fig. 4).
- Slope images were created in BASE Editor to determine areas of steep vertical relief. Slope images were then overlain on the 2D bathymetry surfaces (Fig. 5).
- Backscatter data were exported into Excel to determine statistics of both areas of study (Fig. 6).
- Results formed from these parameters were used to determine areas of further study and conclusions made regarding the use of backscatter and sediment analysis in further studies.



Deep sea octocoral, *Anthomastus sp.* (Photo credit: NOAA)

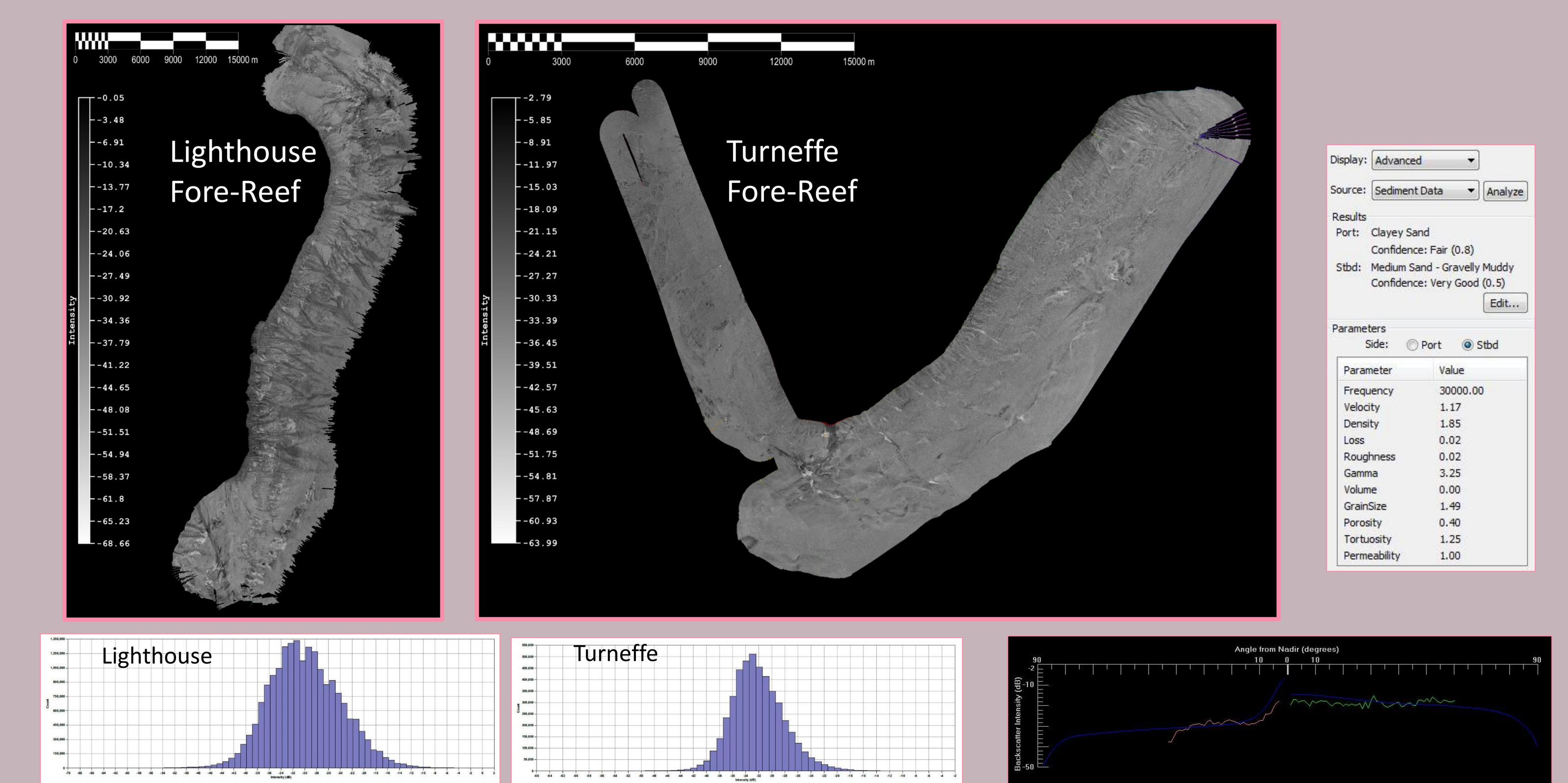


Figure 3. Backscatter of Lighthouse Fore-Reef (left) and Turneffe Fore-Reef (center) with their associated intensity histograms as well as an example of Sediment Data Analysis (upper right) and the corresponding graph (lower right) that was processed for areas of interest. This information gives insight to possible substrate as well as swath width, intensity, and angle from nadir.

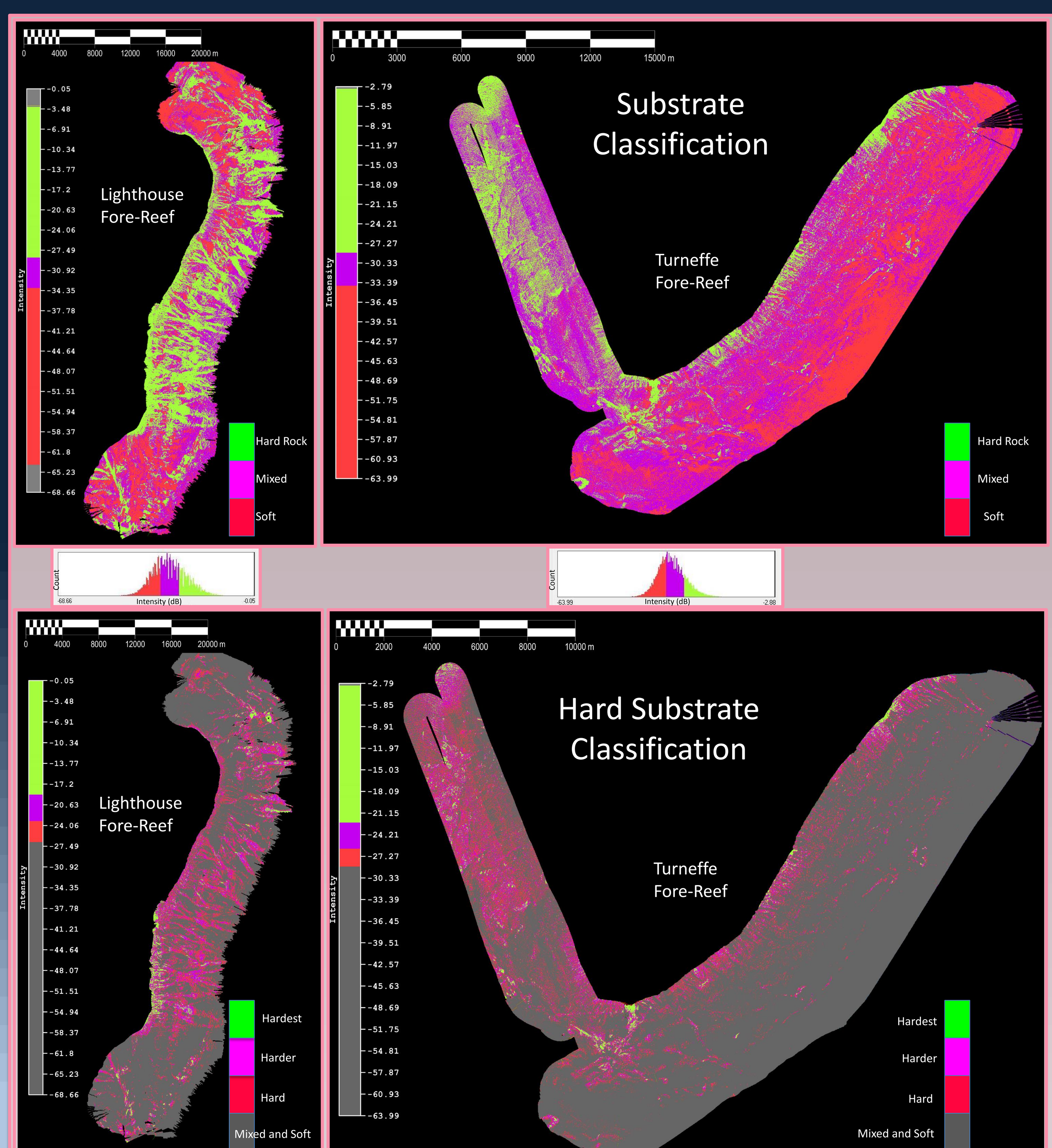


Figure 4. Classification of Lighthouse and Turneffe Fore-Reefs into 3 categories: hard substrate, mixed and soft sediment (top images). Hard substrate was further classified into 3 categories of hard, harder and hardest (lower images).

RESULTS

Bathymetric analysis shows steep escarpments with largely stratified topography, common for this area. The bathymetry alone, however, is not enough to determine where deep-sea corals could potentially inhabit. Once processed and classified, the backscatter became more useful for highlighting areas of soft and hard substrates: Lighthouse shows a minimum intensity of -68.66 dB representing a soft substrate with a maximum intensity of -0.05 dB, representing a hard substrate. Turneffe shows a slightly narrower range with a minimum of -63.99 dB (soft) and a maximum of -2.88 dB, representing the hardest substrate. Sub-classification of the hard-bottom areas further narrowed areas of interest. Lighthouse Atoll's fore-reef shows more areas of hard-bottom with a larger hard to soft substrate ratio. Using BASE Editor, slope was calculated and overlain on the bathymetry and areas of hard substrate were analyzed with slope to determine if conditions were suitable for deep-sea corals. The histograms show that Lighthouse fore-reef is generally steeper than Turneffe, with a maximum slope of 80^{o} and a mean of 18.9^{o}, whereas Turneff has a maximum slope of 76.0^{o} with a mean of 6.7^{o}. Sediment analysis was conducted using CARIS Sediment Analysis tool, however was proven inconclusive for this study.

Table 1. Statistics for backscatter data.

	Minimum (db)	1st Quartile (db)	Median (db)	3rd Quartile (db)	Maximum (db)	Mean (db)	St. Dev. (db)	St. Error Mean (db)	N
Lighthouse	-68.66	-34.15	-30.20	-25.89	-0.05	-29.94	6.05	0.001	19,379,023
Turneffe	-63.99	-34.83	-32.47	-29.71	-2.88	-32.13	4.05	0.001	4,623,969

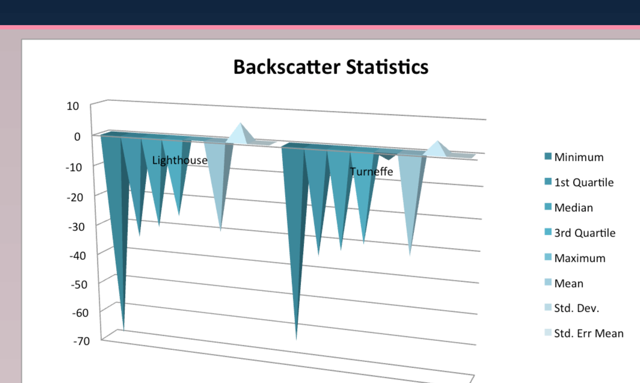


Figure 6. Statistical Analysis of Backscatter.

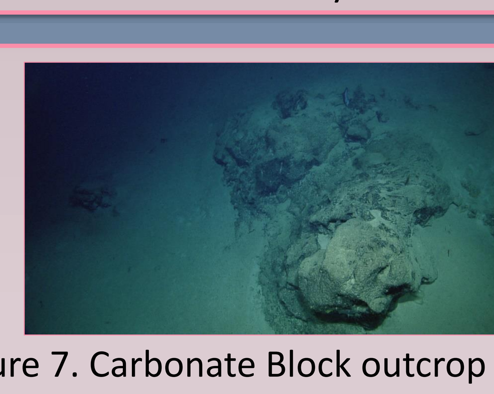


Figure 7. Carbonate Block outcrop most likely transferred downslope represents numerous outcrops in these areas (Etnoyer, 2015).

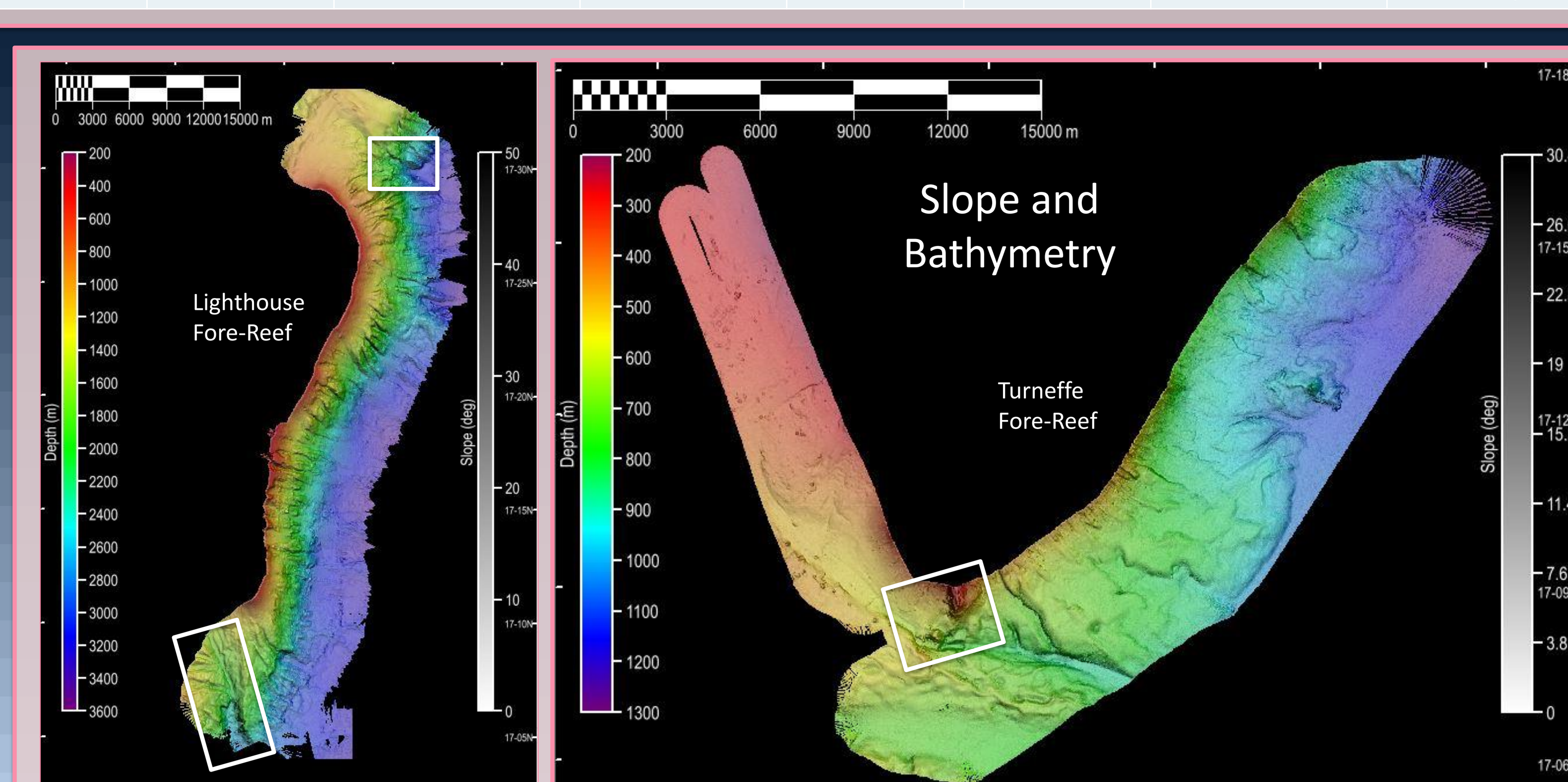


Figure 5. Bathymetry overlain with slope (above) and corresponding slope histograms. White boxes indicate areas of steep bathymetry that have the hardest substrate (Fig. 4), and are suggested as areas for further exploration and ground-trothing in search of deep coral habitat.

DISCUSSION & CONCLUSIONS

Turneffe Atoll's fore-reef consists of broad areas of hard substrate, whereas the highly variable and complex bathymetry of Lighthouse Atoll's fore-reef has small patches of hard-bottom within soft substrate which suggests carbonate block outcrops (Fig. 7). Backscatter data show large areas of mixed sediment, however, it is plausible that a thinner layer of sediment is covering a rocky substrate. Carbonate shoals of Lighthouse and Turneffe Atolls are known to be composed primarily of grainstone and packestones of the Holocene (Purdy, 2003), although the extent of coverage of loose sediment is unclear. Since deep-sea corals need a hard substrate for attachment, this study identifies three suggested focus areas that include both significant hard substrate and steep slope: on the northern and southern portions of Lighthouse Atoll, and the off the southern point of Turneffe, shown by the white boxes on Figure 5. These areas include the requirements for deep-sea coral habitat: substrate hardness, vertical relief and depths between 400 and 600 m at Turneffe and between 1800 m and 2100 m at Lighthouse.

Along with identifying possible locations of deep-sea coral habitats, this research has provided insight to the accuracy and use of backscatter. Analysis of the angle from nadir may show the possible inaccuracies of backscatter, as intensity generally decreases as angle increases.

Additional research and ground-trothing of the seafloor is necessary to determine substrate characteristics. This study reveals that based on slope, bathymetry, and backscatter combined with knowledge of the area's deep sea environment, this research is crucial to our understanding of these dynamic, threatened systems, and will aid in furthering our knowledge of the use of backscatter in seafloor mapping.

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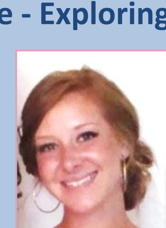

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