Geomorphic Characterization of Submarine Canyons within Govers Reef
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Abstract
Multibeam sonar data from Golvers Reef atoll were collected by the NOAA Coastal Center for Environmental Health using a Kongsberg EM302 onboard the E/V Nautilus in August of 2014. Grovers Reef atoll is part of the Mesoamerican reef and is just south of Lighthouse Reef and Turneffe Reef atolls. 2D and 3D bathymetric images were generated using CARIS HIPS 9.0. This study focuses on utilizing quantitative indices to characterize Grovers Reef canyon geomorphology. Characterization analysis focuses on indices using length, channel relief and area. BASE Editor 4.1 was also utilized to examine canyon slope and aspect. Submarine canyons extend from the atoll’s edge at depths of approximately 50 m to 2900 m where the areas and widths increase significantly. Geomorphic characterization of submarine canyons can yield new information about canyon formation and sediment transport.

Background
Grovers Reef is an atoll within the Caribbean Mesoamerican reef system off the coast of Belize, and is one of only 15 atolls within the Atlantic Gyres (Gischler, 1994). The reef’s eastern flank contains many submarine canyons which reach depths exceeding 2900 m. Some of the canyon segments are nearly 1000 m wide and have yet to be formally characterized. According to Haung et al., (2014) submarine canyons are important geomorphic features because of how they impact sediment transport, ocean currents, benthic ecosystems and ecology. In addition, an expedition led by NOAA’s Dr. Peter Etnoyer in cooperation with the Ocean Exploration Trust showed that there are many areas within the eastern flank of the reef that are possible deep coral habitat sites (Etnoyer et al., in press). This study aims to characterize the submarine canyons at Grovers Reef using quantitative analysis to generate indices and novel methods of classifying and defining submarine canyons. This approach could be useful for future research that aims to classify and characterize submarine canyons that are likely to contain deep coral habitats.

Results
Canyon profiling shows that Northern Canyon is more dynamic than Southern (Figure 4). Rose diagram analysis shows a slight difference in the two canyon’s orientation (Figure 7), (Table 1). The Northern Canyon thalweg was shown to be less skewed than the Southern Canyon (Table 3). The Northern Canyon was shown be slightly more sinuous than the Southern Canyon (Table 3, Figures 2a and 2b).

A strong, positive correlation exists between canyon channel relief and width for both the Northern and Southern canyons. The Southern Canyon was shown to have a more positive gradient than the Northern Canyon (Table 3). The Northern Canyon has a consistently smaller planar area which was expected given its relatively sinuous than the Southern Canyon (Table 3), (Figures 2a and 2b).

Discussion and Conclusions
Geomorphic characterization of submarine canyons is vital to gaining a greater understanding of submarine canyon formation, sediment discharge volume and rates, deep ocean currents, and deep marine habitats. This study examined and employed multiple methods and techniques to characterize and classify the Northern and Southern Canyons within Grovers Reef. Tools like the Rose diagram (Figure 7) and Google Earth were used to show the canyons’ overall orientation, which is useful when characterizing canyons that are close together. Both canyons were shown to have similar sinuosities even though their dominant orientations are different. In addition, Google Earth was used to find the planar area of each canyon, which was useful in showing how each canyon’s slope and overall shape are related (Figure 5). Multiple indices were calculated which serve as useful tools for measuring relative differences between the canyons’ morphologies. The width and relief of both of the canyons in this study are strongly correlated, with an $R^2$ value of 0.819 (Figure 6). All of the different analyses and methods used in this study can be applied to any submarine canyon. This study serves as a guide to future research into submarine canyons, particularly studies of sediment transport and erosion, benthic ecosystems and further geomorphologic characterization.

Methods
• The Ocean Exploration Trust’s E/V Nautilus was used to acquire data using a Kongsberg EM302 multibeam sonar system. Dr. Peter Etnoyer (NOAA National Centers for Coastal Ocean Science Center for Coastal Environmental Health and Biomolecular Research) was the lead scientist for the expedition.
• CARIS HIPS and SIPS 9.0 was used to post process raw data and create a 20 m resolution BASE surface.
• HIPS was also used to generate contour maps and profiles. Profile locations were selected using the canyon mouth as a starting point with profile orientations oriented perpendicular to the thalweg.
• Slope map was generated using CARIS BASE Editor 4.1.
• Profiles for each canyon were characterized using measurements of width to channel relief (P), thalweg skewness (S), profile area, gradient (G), sinuosity (Si), and orientation.

Discussion and Conclusions
Geomorphic characterization of submarine canyons is vital to gaining a greater understanding of submarine canyon formation, sediment discharge volume and rates, deep ocean currents, and deep marine habitats. This study examined and employed multiple methods and techniques to characterize and classify the Northern and Southern Canyons within Grovers Reef. Tools like the Rose diagram (Figure 7) and Google Earth were used to show the canyons’ overall orientation, which is useful when characterizing canyons that are close together. Both canyons were shown to have similar sinuosities even though their dominant orientations are different. In addition, Google Earth was used to find the planar area of each canyon, which was useful in showing how each canyon’s slope and overall shape are related (Figure 5). Multiple indices were calculated which serve as useful tools for measuring relative differences between the canyons’ morphologies. The width and relief of both of the canyons in this study are strongly correlated, with an $R^2$ value of 0.819 (Figure 6). All of the different analyses and methods used in this study can be applied to any submarine canyon. This study serves as a guide to future research into submarine canyons, particularly studies of sediment transport and erosion, benthic ecosystems and further geomorphologic characterization.