Characterization of a South Texas Mesophotic Reef Epibenthic Community

Caracterización de la Comunidad Epibéntica de un Arrecife Mesofótico en el Sur de Texas

Caractérisation de la Communauté Épibenthique d'un Récif Mésophotique au Sud du Texas

MARIA COOKSEY and DAVID HICKS*
University of Texas Rio Grande Valley
*One West University Boulevard, Brownsville, Texas 78520 USA. *David.Hicks@utrgv.edu.*

ABSTRACT

Benthic community composition was characterized at Southern Bank (27˚ 26' 30" N, 96˚ 31' 30" W), a 1.0 sq. km, mid-continental shelf relic coral-algal reef off the coast of South Texas that rises from a regional depth of 82 m to 59 m below the sea surface. Remotely operated vehicle (ROV) surveys were conducted in September 2014 to collect video and biological specimens of the benthic invertebrate community, with particular focus on antipatharians, scleractinians and octocorals. Percent cover and abundance were estimated from 50 randomly extracted frame grabs of the sea floor. Video identifications of coral species were assisted by simultaneous collections of specimens and subsequent morphological and genetic analyses. Algae was the dominant biotic cover (39.1%). Among macrofauna, encrusting sponges (46.0%), antipatharians (23.2%), and crinoids (6.7%) had the highest substrate cover. Coral cover was primarily antipatharians (76.7%; *Stichopathes* spp. [47%], *Antipathes furcata* [23%], and *Antipathes atlantica* [22%]), followed by scleractinians (22.6%; *Madracis brueggmani* [84%] and *Agaricia fragilis* [10%]), and octocorals (1.7%). The most abundant corals were *Stichopathes* spp. (2.0 ind./m^2) and *Antipathes furcata* (0.7 ind./m^2). Benthic abundance data was georeferenced and correlated to bank microtopography in order to create a habitat suitability map which can be used to predict biodiversity at other the mesophotic banks in South Texas.

KEY WORDS: Species distribute modeling, benthic communities, benthic invertebrates, habitat mapping, mesophotic

INTRODUCTION

Scattered on the continental shelf off of the South Texas coast in the United States, between the Brazos-Colorado and Rio Grande river deltas in the northwestern Gulf of Mexico, lie a series of hard bottom banks which are remnants of coral-algal reefs that perished approximately 10,000 years ago (Rezak et al. 1985). The hard bottom structures, which now lie in between the 60 to 80 m depth contours with crest depths ranging from 70 to 58 m, are now collectively known as the South Texas Banks. Although the growth of hermatypic corals has been stifled due to the Banks' depth and the presence of a persistent nepheloid layer, marine life still aggregates on these sparse habitats, referred to as mesophotic reefs. Mesophotic reefs like the South Texas Banks are understudied and consequently, rarely protected habitat. Although the geology and biological inventory have been described at some of the South Texas Banks, this study is the first quantitative survey being used to characterize the benthic invertebrate community

In the past, mesophotic zones in the northwestern Gulf of Mexico were studied primarily to learn about the geology of the area in the interest of oil exploration (Nash et al. 2013). Recently, the decline in healthy shallow water coral reef ecosystems around the world has rekindled the interest in mesophotic reefs for their relative natural protection from anthropogenic interaction (Baker et al. 2015). Mesophotic reefs may be able to act as a refuge to displaced fauna from shallow water reefs, or as a temporary stopover for fauna migrating to other shallow reefs (Kahng et al. 2010). In 2008, the Gulf of Mexico Science Forum discussed the National Oceanic and Atmospheric Administration (NOAA)'s "Island in the Stream" concept, which has identified the South Texas Banks as a possible site of a Marine Protected Area (MPA) (Ritchie and Keller 2008). This concept considers the connectivity of the entire Gulf of Mexico due to the loop current, and aims to protect the productivity of the Gulf by targeting "islands" of high biodiversity. Unfortunately, during the Panel Discussion it was revealed that the South Texas Banks were no longer being considered for protection because not enough information about the relic reefs was available.

This study aims to characterize the benthic invertebrate communities of Southern Bank (27˚ 26' 30" N 96˚ 31' 30" W), a 1.0 sq. km relic coral-algal reef located 75.9 km from the Texas coast. Southern Bank is one of the most studied of the South Texas Banks, but quantitative data on benthic invertebrate communities is still lacking. Researchers Bright and Rezak (1976) used manned submersibles on Southern Bank to find abundant populations of antipatharian seawhips (*Stichopathes* spp.), comatulid crinoids, large demosponges, coralline algae, and alcyonarian fans. Further studies at Southern Bank relied on dredging and submersibles, and while Southern Bank was found to host 420 identified taxa–making the bank more diverse than any of the other studied mid-shelf banks in South Texas, it was not clear if this calculated diversity is truly indicative of the benthic population or if it is a result of increased sampling effort (Bright and Rezak 1976, Dennis and Bright 1988, Nash et al. 2013, Rezak et al. 1985, Rezak et al. 1990). Unfortunately, the regional depth, the persistent nepheloid layer, and strong currents make direct observational surveys of the South Texas Banks a challenge. The quandary between the need for more quantitative data on the South Texas Banks and the inherent difficulties in sampling a mesophotic reef present the need for a regional habitat suitability model.

This study aims to decipher the ecological connections between the South Texas Banks' topography, environmental factors, and biodiversity. Although all benthic cover is examined in this study, particular attention was paid to "ecosystem engineering" antipatharian and octocoral species. Although they are ahermatypic, the target corals provide ancillary structure to the rocky outcrops and influence the distribution of other mesophotic fauna (Wagner et al. 2012). The scleractinian corals *Madracis brueggmani* and *Agaricia fragilis* were also observed on Southern Bank; these hermatypic species typically construct a low profile that doesn't provide much structure to the banks, but their distribution is intrinsically important as they are some of the only hard coral species that have been found at the South Texas Banks. The objective of this study is to create a species distribution model for antipatharian, octocoral, and scleractinian species across Southern Bank. However, due to a low sample size of octocorals observed at Southern Bank during this study (n = 4), a species distribution model for octocorals could not be created.

METHODS

This study incorporates geographic and geomorphic data collected during a two-week expedition to locate and map several South Texas Banks, which was conducted by a research team aboard the Schmidt Ocean Institutes' oceanographic R/V *Falkor* in September 2012 (Hicks et al. 2014). The ship was equipped with a Kongsberg EM 710 multibeam echosounder and subsea acoustic positioning system which allowed researchers to collect bathymetric data from the relic coral-algal reefs (Schmidt Ocean Institute 2012). The raw data was cleaned and converted for use in ArcGIS using EIVA Navimodel version 4.0 to create a 2-m resolution bathymetric image (Figure 1).

Video footage of the ocean floor was collected using an underwater remotely operated vehicle (ROV Deep Ocean Triggerfish T4H, ROV hereafter) on the University of Texas-Rio Grande Valley's research cruise aboard the M/V *Fling* in September 2014. The ROV was equipped with two horizontal and two vertical thrusters, a manipulator arm for specimen collection, Tritech MicroNav Ultra Short Base Line acoustic tracking system, two GoPro Hero 3+ cameras, a 380K pixel navigation camera, and a black and white rear-facing camera. Benthic community videos for analysis were taken in 1080p with a GoPro Hero3+ camera (hereafter benthic camera) in an I-Torch iPix deepwater housing mounted on the bottom of the ROV's frame. Two lasers 10-cm apart were situated within the field of view of the camera to scale benthic images.

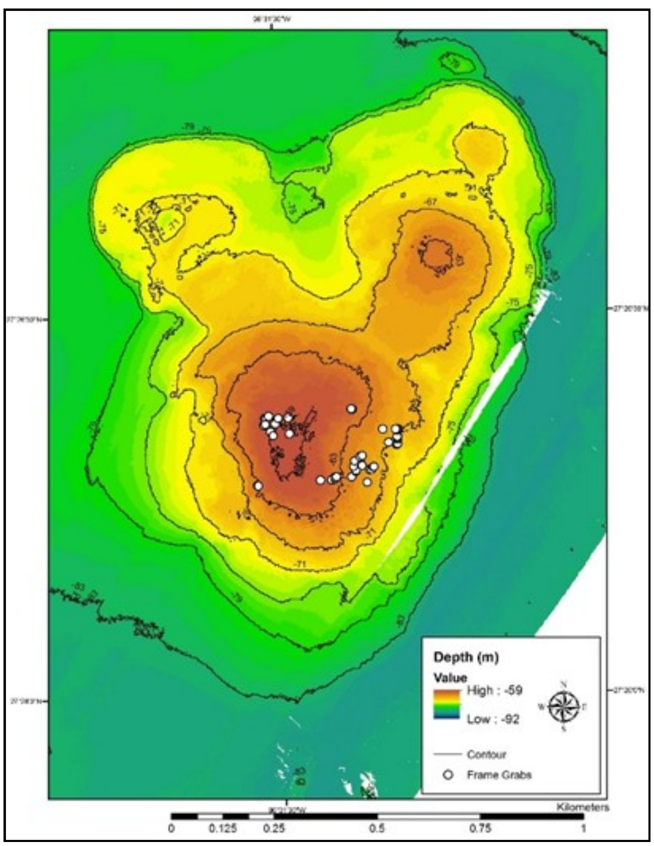

Figure 1. Bathymetric map of Southern Bank, with locations of benthic frame grabs denoted as white dots.

Video from the benthic camera was edited to eliminate blurry and unusable frames. The subsequently edited videos were divided into 2 minute segments and 5 frames were selected at random from segments until a total of 50 suitable frames were collected. Only frames where the lasers take up approximately 10% of the screen were chosen for further analysis as this scale allows for a majority of mega-invertebrates to be identified while providing the largest field of view. A grid with 100 crosshairs was overlaid onto each image and the subject under each crosshair was identified, resulting in percent cover. Benthic organisms observed in the videos were identified to the lowest possible taxon using morphological characteristics from video surveys and collected specimens. In addition to percent cover, a count was taken of all individual organisms and colonies within the frame grab. Percent cover and density counts were weighted according to each photo's area, which were calculated using the10-cm lasers as a guide.

Time and date metadata from the benthic videos were used to determine the time that each of the frame grabs was taken. This time was matched with data from the Tritech MicroNav USBL acoustic tracking system to reveal the position of the ROV. To eliminate error from errant pings, a linear regression was performed on the 2 pings directly before and after the closest ping time, analyzing a total of 5 pings to calculate one extrapolated coordinate.

Benthic percent cover data were square root transformed to downweight groups with high abundances and standardized prior to statistical analysis. The characteristic biotic cover, macrofauna, and coral type for each of the major substrate categories were identified using the SIMPER analysis. Each of these multivariate analyses were calculated using PRIMER (v7+) statistical package (Clarke and Gorley 2015).

Bathymetric data were brought into ArcGIS and the Benthic Terrain Modeler (BTM) tool was used to create surfaces representing the slope, terrain ruggedness (VRM), curvature, aspect, depth and fine- and broad-scale BPI (a factor calculated in BTM) (Wright et al. 2012). These predictor surfaces were standardized for geographic extent, spatial resolution (2 m), and coordinate system, and saved in ASCII format. The size of each of the background surfaces was chosen to ensure that the entirety of Southern Bank was contained, but that an excessive amount of area outside of the bank was not included. The coordinates of frame grabs with recorded target species presence were compiled and converted to the same coordinate system as all of the predictor variables.

The distributions of antipatharians and scleractinians across Southern Bank were predicted using Maxent (v3.3.3k) (Phillips et al. 2010). Maxent (maximum entropy) explores the relationship between species presence locations and environmental covariates in order to create a habitat suitability model across a landscape. Maxent only utilizes species presence data, which works under the assumption that the data represents a random sample of space (Merow et al. 2013). Despite depending on species presence only, Maxent has consistently outperformed other models in tests for accuracy and it produces realistic suitability models, even with low sample sizes (Hernandez et al. 2006, Tittensor et al. 2009). Maxent predicts the distribution of species by assuming that there is equal probability on a landscape that the species will inhabit that cell (null hypothesis), and then narrows the habitat down to areas that fit within the constraints of the added environmental variables (Elith et al. 2011).

The Maxent Java software package was used in this study to model the habitat suitability of Southern Bank species distribution at Southern Bank for 1) *Stichopathes spp.* 2) antipatharians (omitting *Stichopathes spp.*, see Table 1 for list) and 3) scleractinians (Table 1). Although *Stichopathes spp*. is a member of the Antipathidae family, *Stichopathes* were found at densities much higher than its other antipatharian conspecifics (Table 1). The same seven environmental variables were used for all of the models and defined as continuous variables: slope, curvature, terrain ruggedness, aspect, broad-scale BPI, fine-scale BPI and depth. Each model ran until it reached a maximum of 1000 iterations, or until the convergence threshold of log loss fell below 0.00001, whichever came first. The regularization multiplier was tested at various values before it was determined that it should be kept at the default value of 1. Predictions were tested using 10-fold cross validation with random seeding. A jackknife test was used to determine the influence each variable had on the model.

A logistic output was created for this study to model the probability that our target species can be found at that cell, on a scale of 0-1. This model was created with the assumption that the prevalence of the species (tau) is equal to 0.5. Each model was assessed using the area under the receiver-operator curve (AUC) value, which measures the predictive accuracy of a model on a scale of 0 to 1. To calculate an AUC, Maxent ranks the locations of randomly chosen presence locations and compares these rankings to those of randomly chosen background points. AUC values close to 1 represent models that make good predictions whereas values close to 0.5 are no better than random (Merow et al. 2013).

Table 1. Taxonomic categories as entered into Maxent in order to create habitat suitability models for each bank. Average densities of corals (ind./m^2) were used in to determine that *Stichopathes spp*. should be separated into its own category

Maxent Category	Species included	Average Density (ind./m^2)
Stichopathes	*Stichopathes spp.*	2.04
Antipatharians	*Antipathes furcata*	0.65
	Antipathes atlantica	0.53
	Plumapathes spp.	0.10
	Tanacetipathes spp.	0.03
	Aphantipathes spp.	0.02
Scleractinians	*Madracis brueggmani*	N/A
	Agaricia fragilis	0.02

RESULTS

Fifty frame grabs of the sea floor were analyzed by percent cover and abundance. Flora and fauna covered 44.9% of the sea floor with algae making up the dominant biotic cover type 39.13(%). Encrusting sponges (46.03%), antipatharians (23.22%) and crinoids (6.74%) made up the majority of macrofauna cover. Antipatharians dominated the coral cover at Southern Bank (75.66%), primarily because of the coverage provided by *Stichopathes spp.* (47.34%), *Antipathes furcata* (22.94%) and *Antipathes atlantica* (21.89%). Scleractinians provided 22.66% of the coral cover, due to *Madracis brueggmani* (83.75%) and *Agaricia fragilis* (10.00%). Octocorals only comprised of 1.68% of the coral cover.

Six species of Antipatharian were found in the frame grabs (*Stichopathes* spp., *Antipathes furcata*, *Antipathes atlantica*, *Tanacetipathes* spp., *Plumapathes* spp, and *Aphantipathes* spp.). *Stichopathes* spp. was the most abundant coral found on Southern Bank (2.02%, 2.04 ind./m^2), followed by *Antipathes furcata* (1.30%, 0.65 ind./m^2) (Table 1). There were three Scleractinian species observed in the frame grabs; *Madracis brueggmani*, *Agaricia fragilis* and an unidentifiable Caryophyllidae. The sprawling growth form of the *Madracis brueggmani* makes it unfeasible to be individually counted, and so it is omitted from the abundance count. *Agaricia fragilis* was the most abundant Scleractinian otherwise, with a density of 0.02 ind./m^2. Only one octocoral, Ellisella spp., was observed at Southern Bank, which had a density of 0.46 ind./m^2 (Table 1).

Southern Bank was found to have a maximum depth of 92 m and a minimum depth of 59 m (Table 2). Using a 2 m cell resolution and a 3 x 3 mesoscale analysis, the slope was determined to have a range of 0 to 30.6 degrees. Curvature values at Southern Bank ranged from -725 to 550, and terrain ruggedness ranged in values from -4E-8 to 0.31. The unitless variables of BPI were calculated using inner and outer radii of 25 m and 50m for fine-scale, and 250 m and 500 m for broad-scale. The full range of aspects of surfaces (0 - 360 degrees) was also computed for Southern Bank.

At Southern Bank 34 presence samples were used to create a distribution model for *Stichopathes spp.* with an AUC value of 0.975 and a standard deviation of 0.010 (Figure 2). Depth was the highest contributor to the model (89.8%). Not surprisingly, the highest probability of finding a *Stichopathes spp.* was at the crest of Southern Bank, and the lowest on the mud plains surrounding the bank.

The antipatharians (*Antipathes furcata, Antipathes atlantica, Tanacetipathes spp., Plumapathes spp,* and *Aphantipathes spp.*) were combined to create a distribution model because they individually had low sample sizes and similar densities. The resulting logistic model had an average AUC of 0.971 ± 0.010 (Figure 3). Depth was again the variable that contributed the most to the model

(89.8%), with an AUC of 0.974 when run alone. Depth had an inverse relationship with probability of presence. Broad BPI also had a high AUC value by itself (0.959), but only contributed 4% to the model. Because depth had less of an effect overall on the Antipatharian species distribution model than on the *Stichopathes spp.* model, the logistic model for Antipatharians is more spread out over the face of the bank and more affected by the microtopology.

The scleractinian distribution habitat suitability model was created by combining presence samples of *Madracis brueggmani*, *Agaricia fragilis*, and another unidentified stony coral species (Figure 4). The logistic model only predicted better than random chances (> 0.5) of finding a Scleractinian at the two highest areas at Southern Bank (Figure 4). The AUC of the logistic model was 0.988 ± 0.014, suggesting it is a suitable model. The probability that scleractinians would be found at Southern Bank was most affected by depth (60.2%), broad-scale BPI (31.8 %) and fine-scale BPI (4.6%). Aspect and terrain ruggedness did not have any effect on the model (0%), and curvature had a very low contribution to the distribution (0.1%).

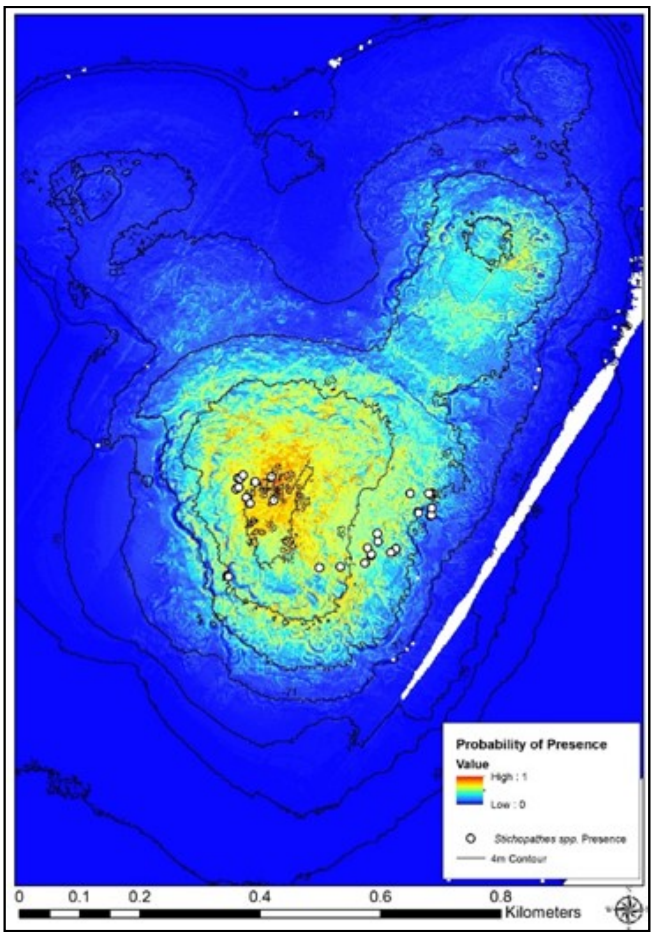

Figure 2. Map showing the probability that *Stichopathes spp*. would be found at Southern Bank. White dots indicate confirmed *Stichopathes* presence.

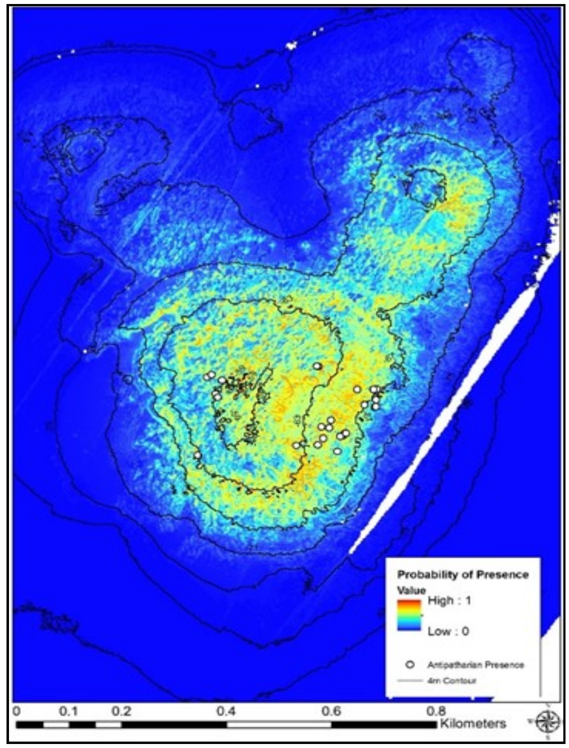

Figure 3. Map showing the probability that antipatharians would be found at Southern Bank. White dots indicate confirmed Antipatharian pres-

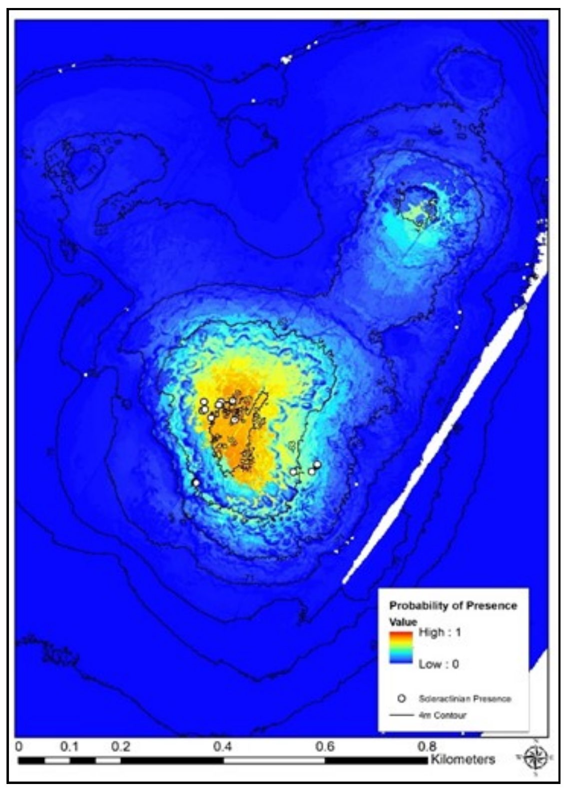

Figure 4. Map showing the probability that scleractinians would be found at Southern Bank. White dots indicate confirmed Scleractinian presence.

Table 2. Mesoscale benthic terrain variables at Southern Bank.

Environmental Variable	Unit	Range for Southern Bank
Depth	Meters (m)	-92 to -59
Slope	Degrees	0 to 30.6
Curvature	Unitless	-725 to 550
Terrain Ruggedness (VRM)	Unitless	-4E8 to 0.31
Aspect	Degrees	0 to 360
Fine-Scale BPI	Unitless	-7 to 7
Broad Scale BPI	Unitless	-9 to 13

DISCUSSION

Mesophotic reefs are, by definition, low-light environments in deep water. The difficulties of surveying the mesophotic reefs in the northwestern Gulf of Mexico are compounded by the nepheloid layer and unpredictable currents. Furthermore, data collection on the South Texas Banks is limited not by the interests of marine scientists and resource managers, but by the difficulty and high cost of surveying the mesophotic ecosystems. Maxent habitat suitability modeling is a boon for marine scientists due to its ability to identify the potential distribution of target species based on multiple environmental and topographical variables. Each of the models created in this study had an AUC value of over 0.90, which Maxent software creators classify as signifying an "excellent" model (Phillips et al. 2006). Although species-based management is not appropriate at the South Texas Banks, by knowing the potential ranges and distribution of habitat-forming species such as *Stichopathes spp.,* or any of the Antipatharians or Scleractinians that were modelled at Southern Bank, scientists can better infer the biodiversity of other mesophotic species at the bank- and ecosystem-level. With the use of these species distribution models, future ROV surveys can be planned to focus on areas with potentially high biodiversity, reducing the amount of errant exploration time. The biological information from this study should provide critical insight about the range of diversity across these five South Texas Banks at a high enough resolution that they may be included in considerations of habitat protection should the occasion arise again. Furthermore, the coral presence data used in this study can be used in order to train Maxent to predict the diversity of other South Texas Banks from bathymetric data, which may play an important part in reducing costs and sea time in future exploration efforts. With the paucity of information about mesophotic reefs both on a global and regional scale, data gathered in future exploration efforts will be critical to the protection of these unique environments and the important ecosystem services that they provide.

ACKNOWLEDGEMENTS

Thank you to the NOAA Environmental Science Cooperative Center for supporting Maria Cooksey and this research, and to Shell for sponsoring our travel to GCFI to present this work. Many thanks are due to the crew and science team aboard the M/V *Fling* for their help collecting data, and to Ashley Moreno and Vannessa Trevino (University of Texas Rio Grande Valley) for their help processing data. Also, special thanks to Emma Hickerson and Marissa Nuttall of the Flower Gardens National Marine Sanctuary for their guidance and support.

LITERATURE CITED

Baker E.K., K.A. Puglise, and P.T. Harris. 2015. *Mesophotic Reefs - A Life Boat for All Reefs?* The United Nations Environment Programme and GRID-Arendal, Nairobi and Arendal. 112 pp.

Belopolsky, A.V. and A.W. Droxler. 1999. Uppermost Pleistocene transgressive coralgal reefs on the edge of the South Texas shelf: Analogs for reefal reservoirs buried in Siliciclastic shelves. *Gulf Coast Section of the Society for Sedimentary Geology (GCSSEPM) Foundation Annual Research Conference* **19**:41-50.

Bright, T.J. and R. Rezak. 1976, January 23. A Biological and Geological Reconnaissance of Selected Topographical Features of the Texas Continental Shelf. *American Zoologist* **30**(1):23-35.

Clarke, K. and R. Gorley. 2015. PRIMER. PRIMER-E Ltd, Plymouth, UK

Dennis, G. D. and T. J. Bright. 1988. Reef fish assemblages on hard banks in the northwestern Gulf of Mexico. *Bulletin of Marine Science* **43** (2):280-307.

Elith, J., S.J. Phillips, T. Hastie, M. Dudík, Y.E. Chee, and C.J. Yates. 2011. A statistical explanation of MaxEnt for ecologists: Statistical explanation of MaxEnt. *Diversity and Distributions* **17**(1):43-57.

Hernandez, P.A., C.H. Graham, L.L. Master, and D.L. Albert. 2006. The effect of sample size and species characteristics on performance of different species distribution modeling methods. *Ecography* **29** (5):773-785.

Hicks, D., L. Lerma, J. Le, T.J. Shirley, J.W. Tunnell, Jr., R. Rodriguez, and A. Garcia. 2014. Assessing fish communities of six remnant coralgal reefs off the South Texas coast. *Proceedings of the Gulf and Caribbean Fish Institute* **66**:244-254.

Kahng, S. E., J. R. Garcia-Sais, H. L. Spalding, E. Brokovich, D. Wagner, E. Weil, R. J. Toonen. 2010. Community ecology of mesophotic coral reef ecosystems. *Coral Reefs* **29**(2): 255–275

Merow, C., M.J. Smith, and J.A. Silander. 2013. A practical guide to MaxEnt for modeling species' distributions: what it does, and why inputs and settings matter. *Ecography* **36**(10):1058-1069.

Nash, H.L., S.J. Furiness, and J.W. Tunnell, Jr. 2013. What is known about species richness and distribution on the outer-shelf South Texas Banks? *Gulf and Caribbean Research* **25**:9-18.

Phillips, S.J., R.P. Anderson, and R.E. Schapire. 2006. Maximum entropy modeling of species geographic distributions. *Ecological Modelling* **190**(3-4):231-259.

Phillips, S.J., M. Dudík, and R.E. Schapire. 2010. *MAXENT* (Version 3.3.3k).

Rezak, R., T.J. Bright, and D.W. McGrail. 1985. *Reefs and Banks of the Northwestern Gulf of Mexico: Their Geological, Biological and Physical Dynamics.* John Wiley & Sons, New York, New York, USA. 259 pp.

Rezak, R., S.R. Gittings, and T.J. Bright. 1990. Biotic assemblages and ecological controls on reefs and banks of the northwest Gulf of Mexico. *American Zoologist* **30**(1):23-35.

Ritchie, K.B. and B.D. Keller. 2008. A scientific forum on the Gulf of Mexico: The Islands in the Stream concept. *Marine Sanctuaries Conservation Series* NMSP-08-04. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Sanctuary Program, Silver Spring, Maryland USA. 105 pp.

Schmidt Ocean Institute. 2012. *R/V Falkor* Specifications.

Tittensor, D.P., A.R. Baco, P.E. Brewin, M.R. Clark, M. Consalvey, J. Hall-Spencer, and A.D. Rogers. 2009. Predicting global habitat suitability for stony corals on seamounts. *Journal of Biogeography* **36**(6):1111-1128.

Wagner, D., D.G. Luck, and R.J. Toonen. 2012. The Biology and Ecology of Black Corals (Cnidaria: Anthozoa: Hexacorallia: Antipatharia). *Advances in Marine Biology* **63**:67-132.

Wright, D.J., M. Pendleton, J. Boulware, S. Walbridge, B. Gerlt, D. Eslinger, and D. Sampson. 2012. *Benthic Terrain Modeler (BTM) v 3.0.* Environmental Research Institute, NOAA Coastal Services Center, Massachusetts Office of Coastal Management.