Mesophotic Reef Fish Communities of Two South Texas Relic Coral-Algal Banks: North Hospital and Hospital

Comunidades de Peces de Arrecifes Mesofóticos de dos Bancos Coralinos-Algales Reliquia del Sur de Texas: "North Hospital" y "Hospital"

Communautés de Poissons de Récifs Mésophotiques de Deux Bancs Reliques Coralliens-Algals au Sud du Texas: "North Hospital" et "Hospital"

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ABSTRACT

Mesophotic ecosystems (30-150 m depths) are poorly understood due to the inherent difficulties associated with working below recreational SCUBA diving limits. Nonetheless, baseline studies of the community structure, biodiversity and, geographic connectivity of mesophotic reef habitats are essential with increasing threats from climate change, ocean acidification, and invasive species. Multibeam sonar, side scan sonar, and ROV technologies were used in this study to examine the fish communities of two mesophotic ecosystems in Northwestern Gulf of Mexico: North Hospital (27°34'30"N, 96°28'30"W) and Hospital (27°32'30"N, 96° 28'30"W) banks. These banks are remnant structures of a relict coral reef paralleling the South Texas shoreline that was extant during the late Pleistocene. Reef fish were identified and enumerated from ROV transect video footage. Side scan sonar was used to quantify water column fish aggregations along transects at each reef site. Collectively, forty species in 20 families were identified including invasive *Pterois volitans*. North Hospital's reef fish community had higher species richness (S = 38) and Shannon's diversity (H' = 1.94) compared to Hospital (S = 18 & H' = 1.46). The reef fish communities were 97.5% dissimilar. The three most common species at Hospital Bank were *Lutjanus campechanus* (32%), members of the family Gobiidae (23.6%), and *Lutjanus griseus* (7%). The three most common species at North Hospital Bank were *Chromis insolata* (46.6%), *Chaetodon sedentarius* (7.4%), and *L. campechanus* (7%). Approximately 3.5 times more fish were observed per km in ROV and sonar transects at North Hospital than Hospital. Side scan sonar indicated that the majority of fish abundance occurred in high slope areas at 11-20m below the reef crest at both banks.

KEY WORDS: Mesophotic reef, Gulf of Mexico, reef fish communities, habitat suitability mapping, *Pterois volitans*

INTRODUCTION

Mesophotic coral ecosystems (MCEs) are found in the intermediate depths of the photic zone between 40-150 m. Research and monitoring of MCEs are critical to our understanding of fish biodiversity and stocks of commercially important species (Bongaerts et al. 2015) particularly with increasing threats from climate change, ocean acidification, and invasive species. Fish inhabiting MCEs include both shallow water reef species and species specifically restricted to mesophotic depths (Bongaerts et al. 2015, Hicks et al. 2014). In the lower portion of mesophotic ecosystems, the abundance and richness of mesophotic reef fish increase while the abundance and richness of shallow water reef fish decrease (Benjarano et al. 2014).

The South Texas Banks are a MCE consisting of at least 14 major structures that are the remnants of a relict coral reef paralleling the South Texas shoreline. This reef was extant during the late Pleistocene and now extends from Matagorda Bay south to the Rio Grande off the South Texas coastline between the 60 to 80 m contours and known to fisherman for their abundance in Lutjanid and Serranid species (Nash et al. 2013). The South Texas Banks were first examined by Parker and Curray (1956) who described the benthic fauna as tropical in nature. Our knowledge of the fish communities of these banks stems primarily from a series of government/technical reports from the 1970s and 1980s intended to provide baseline data in support of petroleum exploration (reviewed by Nash et al. 2013). To date, a total of 97 fish species have been reported from the South Texas Banks (Hicks et al. 2014).

In 2008, the South Texas Banks were proposed as a potential candidate to become a marine protected area (MPA). However, they were eventually excluded from consideration due to the lack of knowledge about the mesophotic reef community (Richie and Keller 2008). The goal of this study is to identify and describe the mesophotic reef fish communities at two of the South Texas Banks. Specifically, to:

i) Quantify the density and relative abundance of mesophotic reef fish on North Hospital and Hospital banks using ROV video and side scan sonar data,
ii) Compare the variations in community composition of reef fish amongst the banks, and
iii) To develop species distribution models to identify fish biodiversity hotpots.

METHODS

Study Area

This study specifically focused on the mesophotic fish communities at two South Texas Banks in the northwestern Gulf of Mexico: Hospital and North Hospital (Figure 1). Hospital Bank is a hard bottom feature with an area of 2.41 sq. km having three distinct terraces, and crest and regional depths of 58 and 77 m, respectively (Nash 2013). North Hospital Bank is described as a hard bottom area of 1.42 sq. km arising from a regional depth of 71 m to a height of 57 m below the sea surface, and having four distinct terraces (Nash 2013). Hospital Bank and North Hospital banks are separated by 1 km.

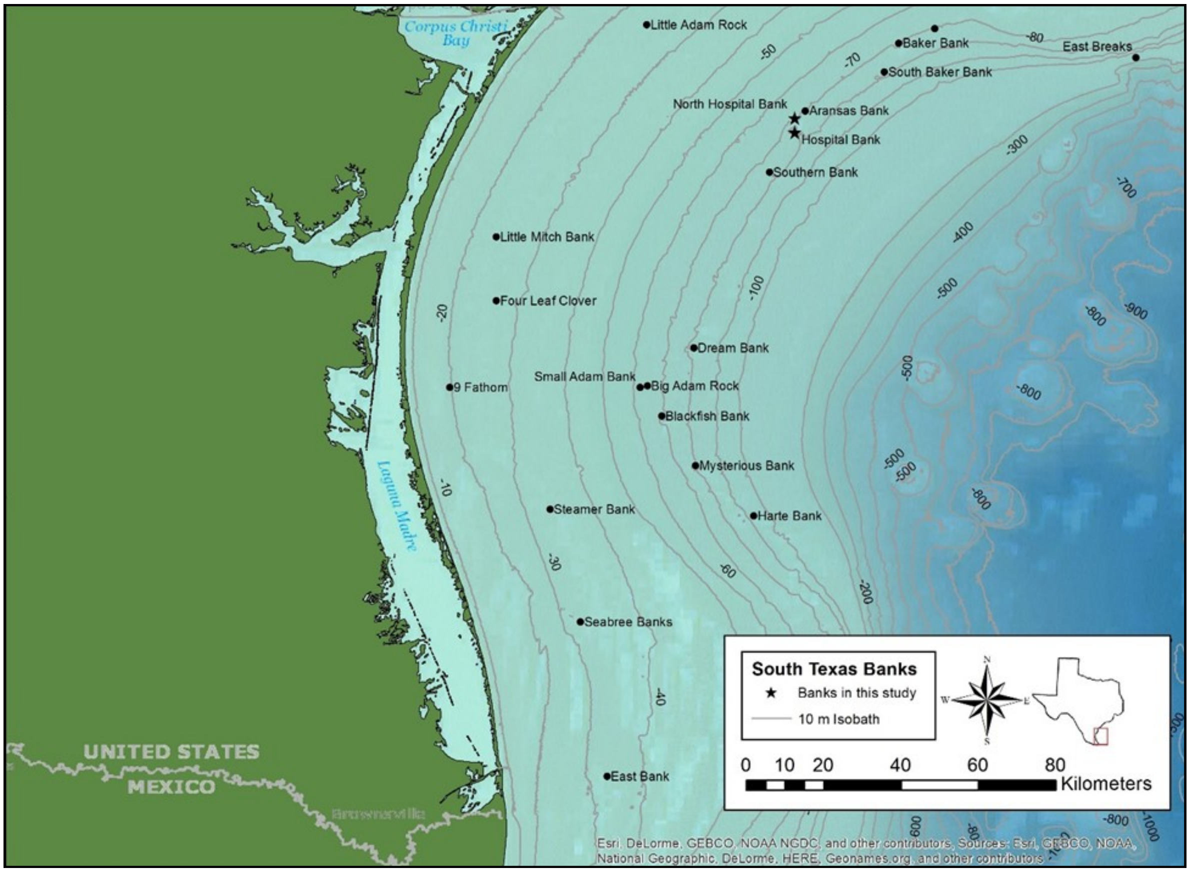

Figure 1. Locations of the South Texas Banks in the northwestern Gulf of Mexico. The banks surveyed in this study (North Hospital and Hospital) are indicated by stars.

Data Collection

Ichthyofaunal surveys were conducted in September 2014 using a Deep Ocean Engineering Triggerfish T4H remotely operated vehicle (ROV) piloted from the M/V *Fling* (Freeport, Texas). The ROV was equipped with two digital GoPro Hero 3+ video cameras (one facing forward and one facing downward), an integrated 380K pixel forward-facing tilt-and-pan navigation camera, a black and white rear-facing camera, and external LED lights. A Blueview P900-90 multibeam sonar unit with a 90-degree field of view was mounted onto the front of the ROV and parallel to the navigation camera. Before each ROV dive, a pair of waypoints were selected from georeferenced multibeam bathymetric maps and set onto opposite sides of each bank, providing a single transect along which the ROV was maneuvered. The transect path was monitored using the ROV's Ultra-Short Base Line (USBL) positioning system (Tritech MicroNav) during each dive. In addition to ROV dives at each bank, side scan sonar data was collected using a CMAX CM2 (C-MAX Ltd., England) operating at 325 KHz. Two passes were made at each bank over their entire lengths which extended 1.8 km for the central transect and 1.5 km for the outer edge transect at North Hospital Bank and 2.3 km for the central transect and 2.2 km for the outer transect at Hospital Bank (Figure 2). Side scan data was processed using SonarTRX (Leraand Engineering Inc., USA) to produce image clips including the water column. Transects were divided into 25 m clips and fish returns were quantified using the count tool in Adobe Photoshop CS6 along with average reef depth and slope within each clip. Fish counts from each transect and reef bank were compared for fish abundance (scaled to 1 km) and percent of abundance binned to 5m depth increments below the reef crest.

Comparing Bank Communities

A PERMANOVA analysis was used to compare fish communities among Hospital and North Hospital banks. For this analysis, each bank's ROV video was divided into 1-minute segments from which 50 segments were randomly selected. All demersal and pelagic fish that entered the field of view from the front facing GoPro video were enumerated and identified to the lowest possible taxon. Species counts from each 1-minute video segment were converted to densities (ind./100 m^2) by dividing by the area surveyed. The area surveyed was estimated by multiplying the average field of view width (m) by the linear distance (m) traveled in each 1-minute video segment. The distance traveled (m) was calculated from the starting and ending coordinates of each video segment. The field of view was estimated using sizes of individual fish and other objects simultaneously captured in the field of view with the onboard multibeam sonar unit. Prior to multivariate analyses, a square root transformation was applied to the abundance data in order to avoid the excessive weight of numerically dominant species in the multivariate analysis. A similarities percentages (SIMPER) analysis was used to identify the characteristi---c species of each bank community and identify which species are responsible for the dissimilarities between banks. All multivariate analyses were performed using PRIMER (v7).

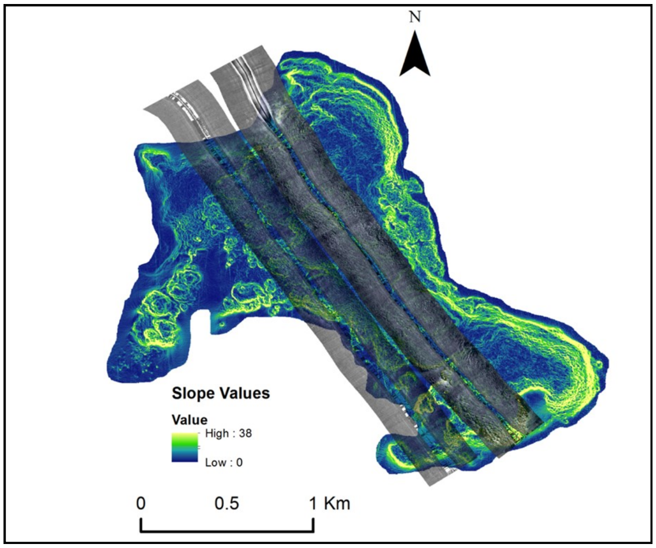

Figure 2. Multibeam map indicating slope values of Hospital Bank overlaid with the side scan sonar transects including the water column along the center of the reef and along the slope of the reef.

Habitat Suitability

In September 2012, bathymetric data was collected using a Kongsberg EM 710 multibeam swath mapping system by the Schmidt Ocean Institute's R/V *Falkor* during a two-week cruise to the South Texas Banks (Hicks et al. 2014). This bathymetric data was utilized to classify benthic environments using the Benthic Terrain Modeler (BTM) ArcGIS extension (Wright et al. 2012). Specifically, BTM was used to generate the morphometric environmental variables of aspect, broad- and fine-scale bathymetric position index (BPI), depth, slope, and terrain ruggedness associated with Hospital and North Hospital banks. Each variable was projected to the same coordinate system (WGS 1984 UTM Zone 14N), cropped to the same geographic extent, and set to a spatial resolution of 2 m. Lastly, each of the BTM output rasters were converted to an ESRI ASCII (.asc) file for use in the MaxEnt software package.

MaxEnt, a maximum entropy modelling program, was used to predict the likelihood of a species occurring at a given location utilizing fish presence-only data and the group of environmental predictors generated from the bathymetry data by BTM. MaxEnt uses the principle of maximum entropy to produce species distribution models and approximates the target's distribution when the probability is most spread out or closest to uniform distribution (Merow et al. 2013; Pittman and Brown 2011). After finding the target's maximum distribution, MaxEnt constrains the distribution of the study organism based on the prevailing environmental conditions at locations where the species is present (Pittman and Brown 2011). Pittman and Brown (2011) found MaxEnt to have higher mapping accuracy compared to Boosted Regression Tree when creating species distribution models for different fish species. Maxent has also been shown to work well with small sample sizes since its optimization routine is guaranteed to converge on the maximum entropy solution.

In this study, MaxEnt was used to create species distribution model to predict the distribution of the sunshine fish (*Chromis insolata*, Cuvier, 1830) and commercially important reef fish: red snapper (*Lutjanus campechanus*, Poey 1860) and grey snapper (*Lutjanus griseus*, Linnaeus 1758) across both North Hospital and Hospital banks. For this analysis, the front-facing GoPro video from each bank was reviewed in its entirety and the presence and location of targeted fish species were recorded. The resulting species presence data was used to create a logistic model that was cross-validated with 10 reiterations to ensure accuracy in predictions. The six BTM environmental variables listed above were set as continuous and a jackknife analyses were used in order to measure the importance of each environmental variable on species distribution. Each model was assessed using the area under the receiver-operator curve (AUC) which represents the probability that a randomly chosen location based on the presence data will be ranked as a more suitable habitat than a randomly chosen pseudo-absence area. A model that performs no better than random will result in an AUC value of 0.5, whereas a model with an AUC above 0.9 is considered to be highly accurate.

RESULTS

A total of 852 pelagic and demersal fishes were counted during the ROV surveys across both banks representing 40 species and 20 families (Table 1). Pomacentridae (47%) was the most common family on both banks followed by Lutjanidae (13%) and Serranidae (9%, Figure 3). A total of 452 ind. / km were observed from the 1.71 km ROV transect at North Hospital compared to 129 ind. / km observed from the 0.56 km transect at Hospital (i.e., 3.5X more individuals were observed at North Hospital). North Hospital's reef fish community had higher species richness (S = 38) and Shannon's diversity (H' = 1.94) compared to Hospital (S = 18 & H' = 1.46). The three most common species at North Hospital Bank were *C. insolata* (46.6%), reef butterflyfish, *Chaetodon sedentarius* (Poey 1860, 7.4%), and *L. campechanus* (7%) (Table 1). The three most common species at Hospital Bank were *L. campechanus* (32%), members of the family Gobiidae (23.6%), and *L. griseus* (7%) (Table 1). A night dive was performed at Hospital where a total of 9 individuals were observed over a 207 m transect including *C. insolata,* Blue Angelfish

(Holacanthus bermudensis, Goode, 1876), Bigeye *(Priacanthus arenatus,* Cuvier, 1829*)*, and members of the family Gobiidae. Hospital and North Hospital reef fish communities were found to be significantly different (Psuedo-F = 12.337, df = 1, 98; p = 0.001). The overall dissimilarity between the reef fish communities of Hospital and North Hospital was 97.5%. SIMPER analyses indicated the most reoccurring fish captured in the 1 min video segments at Hospital were *L. campechanus* with an average abundance of 10.1 ind./100 m^2 and species of the family Gobiidae with an average abundance of 1.2 ind./100 m^2 (Table 1). While the most reoccurring fish species at North Hospital was *C. insolata* with an average abundance of 16.9 ind./100 m^2 (Table 1).

A total of 4,580 fish were observed from four side scan sonar transects (two at each bank) over a combined distance of 7.8 km. Approximately 3.4 times more fish were observed per km in the water column at North Hospital Bank compared to Hospital Bank (Table 2). A greater number of fish were positioned over the high slope value areas towards the edges of each bank (Figure 4). Fish counts along the outer edge transects were 59% higher per km at North Hospital and 71% higher per km at Hospital compared to the central transects, indicating a preference for the slopes (Table 2). A majority of the fish in the water column were found in regions that averaged 11 to 15 m below the reef crest at North Hospital and regions 16 to 20m below the reef crest at Hospital (Table 3).

A logistic model predicting the distribution of *C insolata* at North Hospital and Hospital Bank was created with an average AUC of 0.97 (Figure 5). Based on this model, *C. insolata* distribution is affected most by depth (94.8% of variation), which is reflected in the predicted suitable habitat; *C. insolata* are predicted to be found at the shallowest terraces at North Hospital which encompasses an expansive area compared to the predicted distribution at the slightly deeper peaks of Hospital. The distribution of commercial species *L. campechanus* and *L. griseus* were predicted using a logistic model with an AUC of 0.96 (Figure 6). Although the depth differences do affect the distribution of commercial species at North Hospital and Hospital Banks (accounting for 70.7% of variation), broad BPI also played a significant role in the prediction of species distribution (12.2%), with *L. campechanus* and *L. griseus* showing a particular affinity for the crests of the banks.

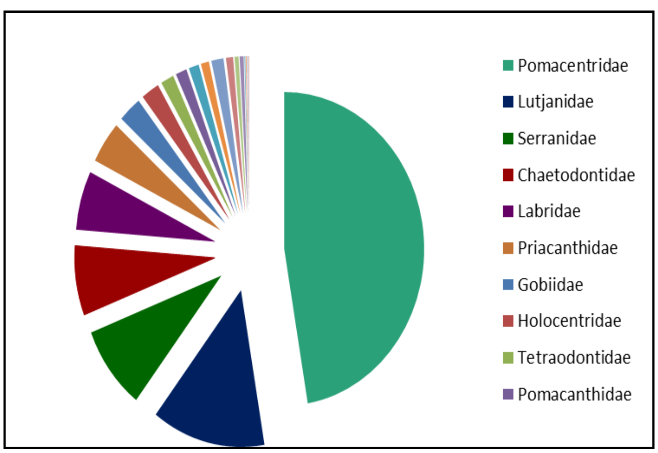

Figure 3. The distribution of fish families identified in ROV video transects at North Hospital and Hospital banks in the northwestern Gulf of Mexico.

Table 2. Fish abundance (fish / km) conducted with side scan sonar by transect for North Hospital and Hospital Banks in the northwestern Gulf of Mexico.

Transect	Fish/ km
North Hospital Center	777
North Hospital Slope	1237
Hospital Center	217
Hospital Slope	372

Table 3. Percent of fish abundance counted from side scan sonar images in relation to reef depth range (depth below the reef crest) at North Hospital Bank and Hospital Banks in the northwestern Gulf of Mexico.

Depth from reef crest (m)	North Hospital	Hospital
0 to 5	6%	7%
6 to 10	1%	9%
11 to 15	67%	23%
16 to 20	8%	39%
21 to 25	2%	16%
26 to 30	16%	6%

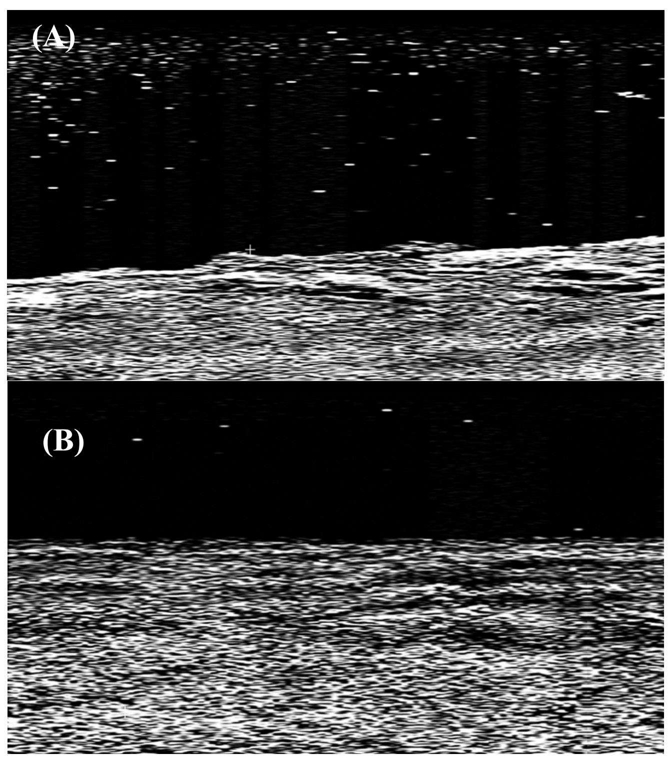

Figure 4. Representative fish aggregations observed with side scan sonar at the (A) slope and (B) crest of Hospital Bank in the northwestern Gulf of Mexico.

Table 1. Fish species percent relative abundance and density (ind. /100 m^2) from Hospital and North Hospital banks in the northwestern Gulf of Mexico. Densities are shown only for those species observed in a random sample of 50 1-minute video segments from each bank. Relative proportions are shown all fish observed along the entire 1.71 km transect at North Hospital and the 0.56 km transect at Hospital. A '–' indicates no density data for a given fish species. * denotes first record from the South Texas Banks.

	Hospital		North Hospital	
Taxa	Relative abundance (%)	Density (ind./100 m^2)	Relative abundance (%)	Density (ind./100 m^2)
Carangidae				
Caranx crysos		-	0.3	-
Seriola dumerili		-	0.1	-
Seriola rivoliana	1.4	0.27		-
Carcharhinidae				
Carcharhinus sp.	5.6	-	0.8	0.55
Chaetodontidae				-
Chaetodon sedentarius	5.6	0.78	7.4	4.41
Gobiidae	23.6	2.27	0.6	-
Holocentridae				
Holocentrus adscensionis	2.8	0.13	0.8	0.06
*Myripristis jacobus**	1.4	0.21		-
Sargocentron bullisi		-	0.9	0.17
Labridae				
Bodianus pulchellus	1.4	0.08	6.7	3.97
Halichoeres bathyphilus		-	0.4	0.1
Lutjanidae				
Lutjanus campechanus	32.0	10.09	7.0	0.21
Lutjanus griseus	7.0	0.49	3.5	1.11
Lutjanus synagris		-	0.3	0.34
Rhomboplites aurorubens		-	0.1	-
Malacanthidae				
*Caulolatilus chrysops**		-	0.1	-
Muraenidae				-
Gymnothorax moringa		-	0.1	-
Ostraciidae				-
Acanthostracion quadricornis		-	0.1	0.25
Pomacanthidae				
Holacanthus bermudensis		-	0.8	0.14
Holacanthus ciliaris	1.4	0.14		-
Townsend Angelfish	1.4	0.15	0.3	-
Pomacentridae				
Chromis enchrysura	1.4	0.07	2.2	1.29
Chromis insolata	4.2	0.46	46.6	16.89
Chromis scotti		-	2.6	-
Stegastes variabilis		-	0.3	-
Priacanthidae				
Heteropriacanthus cruentatus		-	0.5	-
Priacanthus arenatus	2.8	0.33	1.7	0.15
Pristigenys alta	2.8	0.1	2.1	0.29
Ptereleotridae				
Ptereleotris calliura		-	1.0	-
Rachycentridae				
Rachycentron canadum		-	0.1	-
Sciaenidae				
Equetus lanceolatus	1.4	0.06	0.5	0.1
Pareques umbrosus		-	0.3	-
Scorpaenidae				
Pterois volitans	1.4	0.07	0.4	0.2
Serranidae				
Liopropoma eukrine		-	2.1	1.29
Paranthias furcifer		-	0.3	-
Pronotogrammus martinicensis		-	5.3	4.43
Serranus annularis		-	0.1	-
Serranus phoebe	1.4	0.13	1.6	0.57
Sphyraenidae				
Sphyraena barracuda		-	0.5	-
Tetraodontidae				
Canthigaster jamestyleri		-	1.6	0.62
*Canthigaster rostrata**		-	0.1	0.11

DISCUSSION

Our knowledge of the fish diversity on the South Texas Banks has increased greatly since the first qualitative survey of the banks in 1988 where 66 fish species were reported (Dennis and Bright 1988). Currently, a total of 100 fish species have been identified from the South Texas Banks, including the three additional species from this study including sharpnose pufferfish (*Canthigaster rostrata,* Bloch, 1786)*,* spotted moray (*Gymnothorax moringa,* Cuvier, 1829)*,* and blackbar soldierfish (*Myripristis jacobus,* Cuvier, 1829). Forty species from 20 families were reported in this study between Hospital and North Hospital banks. Similarly, Hicks et al. (2014) reported 45 species from six of the South Texas Banks (Aransas, Baker, Blackfish Ridge, Dream, Harte, and Mysterious). In this study, North Hospital Bank had the greater species richness (S=38), and higher than that reported by Hicks et al. (2014) for six South Texas Banks surveyed in 2012. Hicks et al. (2014) reported species richness values ranging from 13 at Blackfish Ridge to 31 at Baker Bank. Hospital Bank had the lower species richness (S = 18) in this study but similar to that reported from Aransas Bank (S = 28) and Dream (S = 23) (Hicks et al. 2014). Collectively, these results generally support predictions made by Nash (2013), where macroscale geographic variables were used to predict that North Hospital would have greater biodiversity than Aransas, Dream and Hospital banks which were predicted to have similar biodiversity and greater than that of Blackfish Ridge. The exception being that Baker Bank had relatively high biodiversity (Hicks et al. 2014) compared to Nash's (2013) prediction. It is worth noting that the most abundant fish species observed in this study, *Chromis insolata*, was reported by Dennis and Bright (1988) as being rare on the South Texas Banks. Similarly, Tunnell et al. (2009) and Hicks et al. (2014) also noted a dominance of *Chromis insolata* at the combined eight banks surveyed, perhaps indicating a shift towards a more tropical assemblage than previously reported. Previously, Bright and Rezak (1976) indicated Yellowtail Reef Fish (*Chromis en-*

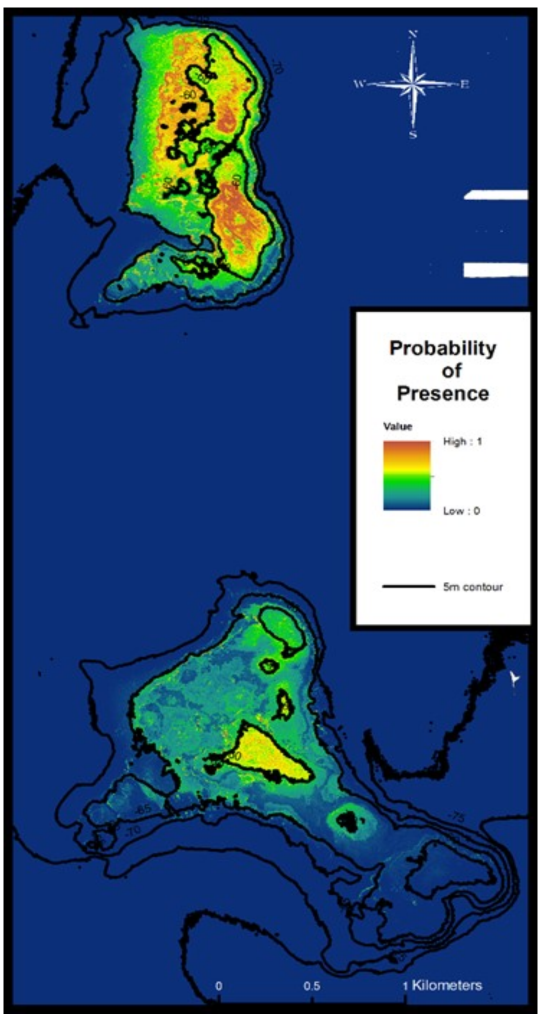

Figure 5. Modeled distribution of *Chromis insolata* across North Hospital (27°34'30"N, 96°28'30"W) and Hospital (27°32'30"N, 96°28'30"W) banks in the northwestern Gulf of Mexico using MaxEnt.

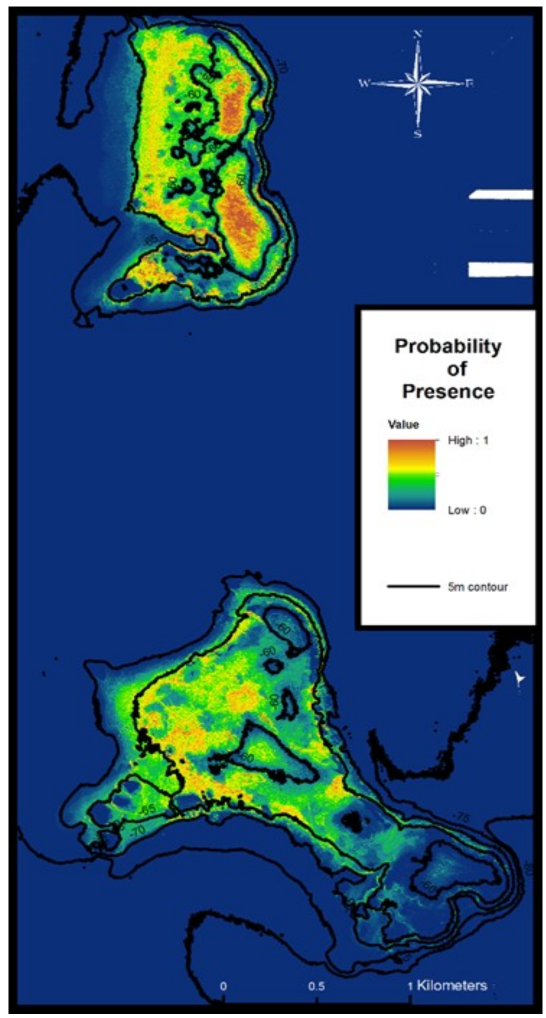

Figure 6. Modeled distribution of commercial species (*Lutjanus campechanus* and *Lutjanus griseus*) across North Hospital (27°34'30"N, 96°28'30"W) and Hospital (27°32'30"N, 96°28'30"W) banks in the northwestern Gulf of Mexico using MaxEnt.

chrysura, Jordan & Gilbert 1882), Spotfin Hogfish (*Bodianus pulchellus*, Poey 1860) and Bigeye (*Priacanthus arenatus*, Cuvier 1829) as the characteristic fish species of the South Texas Banks.

In this study, a total of four invasive lionfish (*Pterois volitans,* Linnaeus 1758) were recorded: one at Hospital and three at North Hospital. The only other report of *P. volitans* on the South Texas Banks was at Baker Bank in 2012 (Hicks et al. 2014). Thus, these two studies have likely captured the initial *P. volitans* invasion of the mesophotic reefs off the South Texas coast. However, no studies were conducted between 2009 and 2014 on these Banks. The first report of *P. volitans* in the Northwestern Gulf was by recreational SCUBA divers at the Flower Garden National Marine Sanctuary (FGBNMS) in 2010. The first sighting during a scientific survey at the FGBNMS occurred in 2012 (Clark et al. 2014, Nuttall et al. 2014). *P. volitans* was also recorded from fish surveys at Sonnier Bank, Stetson Bank, and on adjacent oil rigs in 2010 (Clark et al. 2014). With continual monitoring of the South Texas Banks, we will have a better understanding of how *P. volitans* will influence mesophotic fish communities in the Gulf of Mexico.

Fish assemblages in the Northwestern Gulf are highly affected by a persistent nepheloid layer (Tunnell et al. 2009). This layer is created by the silt and clay particles released by the Mississippi and Atchafalaya rivers (Dennis and Bright 1988). Low light conditions resulting from the nepheloid layer influence the development of hard-bottom communities, reducing algal and scleractinian growths, and subsequently reducing available habitat and food resources (Rezak et al. 1985). At mesophotic coral reefs where light is limiting, planktivores and piscivores have been shown to be positively correlated with depth, whereas invertivores and herbivores are negatively correlated with depth (Benjarano et al. 2014, Clark et al. 2014). North Hospital's two most dominant species, *C. insolata* and *Pronotogrammus martinicensis* are known planktivores. *L. campechanus,* which had the highest relative abundance on Hospital, is a known piscivores and planktivore. Piscivores prefer high relief habitats (Clark et al. 2014) and may explain the greater abundance of water column fish in high slope areas observed in this study.

The fish communities of North Hospital and Hospital banks were markedly different both in species composition and relative abundances as determined by both ROV and side scan sonar analyses. Hard coral cover (Scleractinia) has been shown to be a primary factor to influence species richness of fish on reefs (Kahng et al. 2010). While some hard coral growths have been reported from Hospital and North Hospital, their distribution is limited and similar among the two banks (Cooksey 2016). Dunn and Halpin (2009) states rugosity as the main driver of species richness on hard bottom habitats like mesophotic reefs. However, rugosity was also similar for North Hospital and Hospital banks (0.00193 and 0.00182, respectively). The two predictive Maxent models indicated that the distributions of *C. insolata* and commercial fish species were affected most by depth. While the crest depths of the two banks differ by only 1 m, the relative proportion of shallower (e.g., 60 m) terrace habitat at North Hospital is far greater than Hospital (Figures 5 and 6) and most likely accounts for the differences in fish communities.

ROV video surveys, MaxEnt modelling, and side scan surveys converge on the same general conclusions regarding the two reefs – that North Hospital was the more suitable habitat and held more fish and fish species than Hospital. Our MaxEnt model predicted a high probability of commercially important fish to be found around the outer perimeters of both banks (Figure 6) which coincided with our observations using side scan sonar. The large aggregations of fish observed along the slopes may be taking advantage of the lee waves and vortex currents that are likely formed there (Nakamura 1985). This is similar to what Hamner (1988) reported from the Great Barrier Reef where planktivorous fish formed large aggregations referred to as a "wall of mouths" up-current of the reef slope. Previous surveys using split beam sonar at the Flower Gardens Banks also noted the highest biomass of fish along the reef slopes (Clark et al. 2014). The steeper slopes of North Hospital Bank are likely to produce lee waves and vortex currents which may result in increased nutrient inputs that may partially explain differences in fish abundance. However, further studies are necessary to understand long term fish abundance patterns and how they correlate to the current patterns at each reef. The results of this study demonstrated that side scan sonar can be used as a complementary tool to assess fish populations in relation to the bathymetry of MCEs.

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