Assessing Fish Communities of Six Remnant Coralgal Reefs off the South Texas Coast

Evaluación de Communidad Peces de Seis Remanentes Coralgal Arrecifes de la Coasta Sur de Tejas

Evaluation des Communautés Poissoneuses dans Six Récifs Coraliens Éteints de la Côte Sud du Texas

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ABSTRACT

Community composition and abundances of fish species were examined from six South Texas banks, including from north to south Baker, Aransas, Dream, Blackfish, Mysterious, and a previously undescribed bank referred to herein as Harte Bank. These shelf-edge banks are relic coralgal reefs that existed off the South Texas coast approximately 21,000 to 12,000 years BP but were drowned and buried as a result of Pleistocene deglaciation and subsequent rise in sea level. Today, the remnant peaks of these reefs protrude 14 to 22 m above the surrounding sediment from depths of 58 to 84 m with buried portions extending 20 to 30 m beneath the sea floor. Enumeration and identification of fish species was accomplished by reviewing video footage from an ROV deployed from the R/V *Falkor* of the Schmidt Ocean Institute in September 2012. Multiple ROV transects were made across each of the relic banks. Fish abundances were standardized (relative percentages) to account for differences in sampling effort among the banks. Community assessments were limited at Mysterious Bank due to low visibility resulting from a nepheloid layer suspended across surveyed terrace. Collectively, 45 fish species in 17 families were recorded from Baker, Aransas, Dream, Mysterious, Blackfish, and Harte banks. Five species accounted for 66% of total abundance including *Pronotogrammus martinincensis* (rough tongue bass; 25.5% of total), *Chromis insolata* (sunshine fish; 15% of total), *Stegastes variabilis* (Cocoa damselfish; 10.4% of total), *Lutjanus campechanus* (red snapper; 7.7% of total), and *Chromis scotti* (purple reeffish; 7.3% of total). Diversity generally diminished from north to south along the relic coral bank chain with Baker and Aransas banks having the highest diversity. Community similarity was highest among the northernmost banks and distinct from the southernmost bank.

KEY WORDS: Gulf of Mexico, South Texas Banks, fish assemblages

INTRODUCTION

Reef-building hermatypic corals provide complex habitat supporting high productivity and diversity of associated invertebrate and fish species. However, less is known about the relative importance of these habitats after they go extinct as a result of sea level rise and subsequent decrease in salinity and increased sedimentation. Just off the Texas coast between the 60 - 80 m contours in the northwestern Gulf of Mexico lie a series of relic coral reefs that flourished during the first half of the last sea-level transgression approximately 21,000 to 12,000 years BP (Belopolsky and Droxler 1999) (Figure 1). Collectively referred to as the South Texas Banks, this relic reef complex consists of a band of individual banks extending 140 km between the 60 - 80 m contours of the outer continent shelf (Belopolsky and Droxler 1999). They include at least 14 major topographic features but there are likely many more sites scattered throughout the continental shelf off south Texas (Nash et al. 2013). Today, the remnant peaks of these drowned coralgal reefs protrude 14 to 22 m above the surrounding sediment from depths of 58 to 84 m with buried portions extending 20 to 30 m beneath the siliciclastic mud sea floor (Bright and Rezak 1976, Rezak et al. 1985, Belopolsky and Droxler 1999, Nash et al. 2013). Also included in what is collectively referred to as the South Texas Banks, but not considered in this study, are several low-relief relic barrier island features between the 20 - 30 m contours (Nash et al. 2013) (Figure 1).

The community ecology of shelf-edge South Texas Banks is largely unknown given the inherent difficulty of study at these depths and distance from shore (Dennis and Bright, 1988). Nash et al. (2013) reviewed 14 references containing taxonomic data from 10 south Texas relic coralgal reefs including 7 governmental/technical reports (Abbott and Bright 1975, Bright and Rezak 1975, 1976, Holland 1976, UTMSI 1976, Groover et al. 1977, Rezak and Bright, 1978), 3 peer-reviewed journal articles (Parker and Curray 1956, Dennis and Bright 1988, Rezak et al. 1990), 2 dissertation/thesis (Hoese 1965, Hyde 2000), 1 proceedings article (Tunnell et al. 2009), and 1 book (Rezak et al. 1985). A majority of these were technical reports from the 1970s and 1980s intended to provide baseline data in support of petroleum exploration. Accordingly, these works were dominated by physical and geological data, with relatively little biological data aside from basic faunal inventories (Nash et al. 2013). Only eight of 14 references reviewed by Nash et al. (2013) included information regarding ichthyofauna and quantitative fish assemblage data are completely lacking as often the case in deep-water habitats. However, studies of patterns of abundance are an essential aspect of fisheries management (Connell et al. 1998)

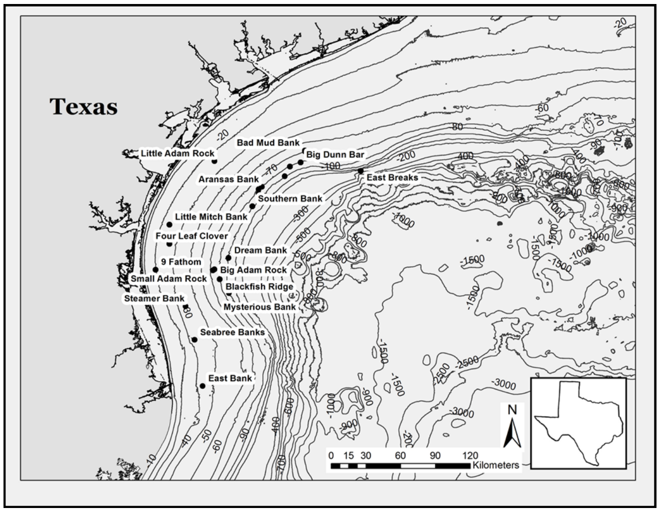

Figure 1. Locations of the South Texas Banks in the northwestern Gulf of Mexico. Relic coralgal banks are those banks between the 60 - 80 m contours approximately 60 - 70 km offshore. Those banks occurring between the 20 - 30 m contours approximately 20 - 30 km offshore are relic barrier island features.

and conservation planning (Nash 2013). Direct observation sampling as opposed to trawl sampling is generally the most effective means of assessing fish populations in deep-reef habitats (Starr et al. 1996). Fortunately, the use of underwater survey vehicles in coastal research has increased allowing for development of sampling methods that go beyond structural data collections (e.g. species lists, water chemistry, bathymetric mapping). The continued exploration of the South Texas relict reefs with the incorporation of such technology will help fulfill the critical gaps in the understanding of these habitats and facilitate the decision making process concerning their potential conservation (Nash et al. 2013). Particularly, as the complex evolution of these geological legacies have given rise to unique environments in terms of substrate, depth, and distance from shore rendering them a chance medley with no equivalent elsewhere in the Gulf of Mexico.

In September 2012, the R/V *Falkor* of the Schmidt Ocean Institute set out on a two-week expedition to explore reefs and banks of the south Texas portion of the Texas-Louisiana continental shelf. The primary objective of the expedition was to conduct high resolution multi-beam mapping of the South Texas banks. Ancillary to the primary objective, a submersible remotely operated vehicle (ROV) performed multiple dive transects at six of the mapped relic reefs for general faunal and habitat characterizations. This study is based upon direct observations from the ROV video recordings. The aim of this study was to document fish species occurrences and relative abundances at six outer shelf reefs including Baker, Aransas, Dream, Blackfish Ridge, Mysterious, and a previously unmapped bank (hereto referred to as Harte Bank) (Table 1, Figure 1). The explicit objectives were:

i) Identifying and quantifying reef associated fish species,
ii) Examining patterns of fish species abundance,
iii) Quantifying topographical extents that the ROV traveled and surveyed, and
iv) Characterizing bank water column parameters.

These data could facilitate judgments regarding the need for conservation of these geological legacies which have no equivalent elsewhere in the Gulf of Mexico.

METHODOLOGY

Ichthyofaunal community observations and bathymetric data were collected during a two week cruise (September 17-29, 2012) aboard the Schmidt Ocean Institute's R/V *Falkor*. The R/V *Falkor*, at 82.9 m, was equipped with CTD/hydro winch operations, Kongsberg EM 710 multi-beam echosounder, and subsea acoustic positioning systems (www.schmidtocean.org). The ship was additionally equipped with a submersible Remotely Operated Vehicle (ROV Global Explorer MK3) having a 3048 m depth rating which was used to assess both habitat and biotic features. The Global Explorer hosted a real-time data logger for recording of hydrographic features (temperature, conductivity, pressure, and salinity) and four semi-conducting parallel lasers at a fixed width of 10 cm apart for distance and scale measurements. Three video recording systems were simultaneously used to provide a 10x magnified 2-dimensional view and two 3x magnified 2-dimensional views that could be overlain to create a composite 3-dimensonal image. An 18 megapixel digital still camera was used to capture high-resolution images of targeted species. (www.globalexplorerrov.com).

Table 1. Coordinates, dates, and physiochemical parameters of South Texas Banks visited during the September 2012 Gulf of Mexico expedition.

Date	Study Site	Latitude; Longitude	Temperature (°C)	Salinity (psu)
September 19, 2012	Baker Bank	27° 45' 00'' N; 96 °14' 00'' W	23.5-24.1	36.4
September 21, 2012	Aransas Bank	27° 35' 30'' N; 96° 27' 00'' W	23.7-23.8	36.4
September 23, 2012	Dream Bank	27° 02' 30'' N; 96° 42' 30'' W	23.1-23.8	36.4
September 26, 2012	Blackfish Ridge	26° 52' 36'' N; 96° 46' 36'' W	22.8-25.7	36.4
September 26, 2012	Mysterious Bank	26° 46' 06'' N; 96° 42' 00'' W	22.4-23.0	36.4
September 27, 2012	Harte Bank	26° 39' 13'' N; 96° 34' 22'' W	19.9-23.0	36.4

Prior to deployment of the ROV, a multibeam echosounder was used to scan the topography and create bathymetric maps. Waypoints were subsequently selected for plotting transect routes across each structure on which the ROV was maneuvered. ROV routes generally began at the base of the each bank slope, ascended to the terrace, across the terrace, and ended at the base of the opposite slope. Deployments commenced early morning and dives lasted approximately six hours. During all dives, the ROV's position was tracked from the vessel via a Sonardyne Ranger 2 ultra-short baseline system. ROV position data were translated into NMEA format using HYPACK (Hydrographic Survey and Processing Software) and stored in the vessels ship computing system (SCS) for further processing.

ROV dives were intended for a general characterization of reef habitat and community features and included collections of sediment cores, rock, and invertebrate specimens and thus, not specifically designed as a fish community survey (i.e., transect lengths varying and were not replicated randomly throughout the banks surveyed). The 3-D video recordings were the primary data used to describe the ichthyofaunal community. Corresponding 10x and digital still images were used to assist in species identifications as necessary. Because all transects varied in length, species abundances were standardized as relative abundance in each bank (number of individuals per species /total number of individuals x 100). Parallel lasers were used to estimate the width of the video's field of view and subsequently the topographic area surveyed. Survey surface area estimates were used to convert species counts to densities (individuals/m^2) for comparisons with future and past studies. However, the width of the visual field varied along each transect due to the ROV's varying pitch and roll angles, and height above the seafloor. Further, the camera was variously set from wide-angle to close-up views depending on subject matter additionally affecting the width of the visual field. Nonetheless, for a majority of the time, observations were made at a constant height and camera zoom providing a visual field width of approximately 2.6 m. Errors resulting from varying field of view would be systematically applied to all banks surveyed and likely small at the scale of each transect.

All multivariate analyses were performed on forth-root transformed standardized abundance data. Non-metric MDS ordinations and cluster analyses derived from Bray–Curtis similarity matrices were conducted to examine differences in the structure of fish communities among the surveyed banks. A SIMPER analysis was used to investigate which species were driving the dissimilarity between surveyed banks. SIMPER calculates the overall percentage contribution of each species to the average dissimilarity between the banks pairwise and lists species in order of importance (Clarke and Gorley 2001). All analyses were conducted in PRIMER 6 and based on guidelines in Clarke and Warwick (2001) and Clarke and Gorley (2006).

RESULTS

ROV transects varied between 270 m and 1,100 m in length. A total distance of 2,778 m of seabed was video-recorded with a total survey area of approximately 7,222.5 m^2. The total time of the video recorded was ~36 hours. Collectively, 45 fish species in 17 families were recorded from Baker, Aransas, Dream, Mysterious, Blackfish, and Harte banks (Table 1). Five species accounted for 66% of total abundance including *Pronotogrammus martinincensis* (rough tongue bass; 25.5% of total), *Chromis insolata* (sunshine fish; 15% of total), *Stegastes variabilis* (Cocoa damselfish; 10.4% of total), *Lutjanus campechanus* (red snapper; 7.7% of total), and *Chromis scotti* (purple reeffish; 7.3% of total) (Table 2, Figure 2). Mean salinity was stable across all study areas at 36.4 psu (Table 1). Mean water temperatures over all dives and study areas ranged from 19.9°C at 98 m on Harte Bank to 24.1°C at 60 m on Baker Bank (Table 1).

Baker Bank was a 1.39 km^2 rectangular feature with the maximum east-west dimension at ~2,584 m and maximum north-south length of ~524 m with a vertical relief of ~16 m. Four ROV waypoints were organized into two non-connecting transects each ascending to the terrace (60 m) from depths of 73 and 76 at the northern and southern slope bases respectively (Figure 3A). Combined, the two transects covered a linear distance of 450.4 m The numerically dominant fish species at Baker Bank in decreasing order of abundance were *Chromis insolata* (21.4% of total), *Stegastes variabilis* (19.0% of total), *Chromis scotti* (15.7% of total), *Lutjanus campechanus* (9.2% of total), *Pronotogrammus martinincensis* (9.1% of total) and *Chaetodon sedentarius* (reef butterflyfish; 5.1% of total) (Figure 2). An Indo-Pacific lionfish (*Pterois volitans*) was observed on the terrace at a depth of ~60 m (Table 2).

Aransas Bank was a 0.51 km^2 circular feature with a maximum diameter of ~700 and vertical relief of ~14 m. Three ROV waypoints were set along one continuous transect (563.8 m) from east to west across the bank ascending from a depth of approximately 70 m at the base of the structure to the terrace crest at approximately 60 m before descending the opposite slope to the base at approximately 69 m (Figure 3B). The predominant fish species in decreasing order of abundance were *Lutjanus campechanus* (25.4% of total), *Chromis insolata* (15.3% of total), *Rhomboplites aurorubens* (vermilion snapper; 14.3% of total), *Chaetodon sedentarius* (6.3% of total), and *Priacanthus arenatus* (Atlantic bigeye; 5.7% of total) (Table 2, Figure 2).

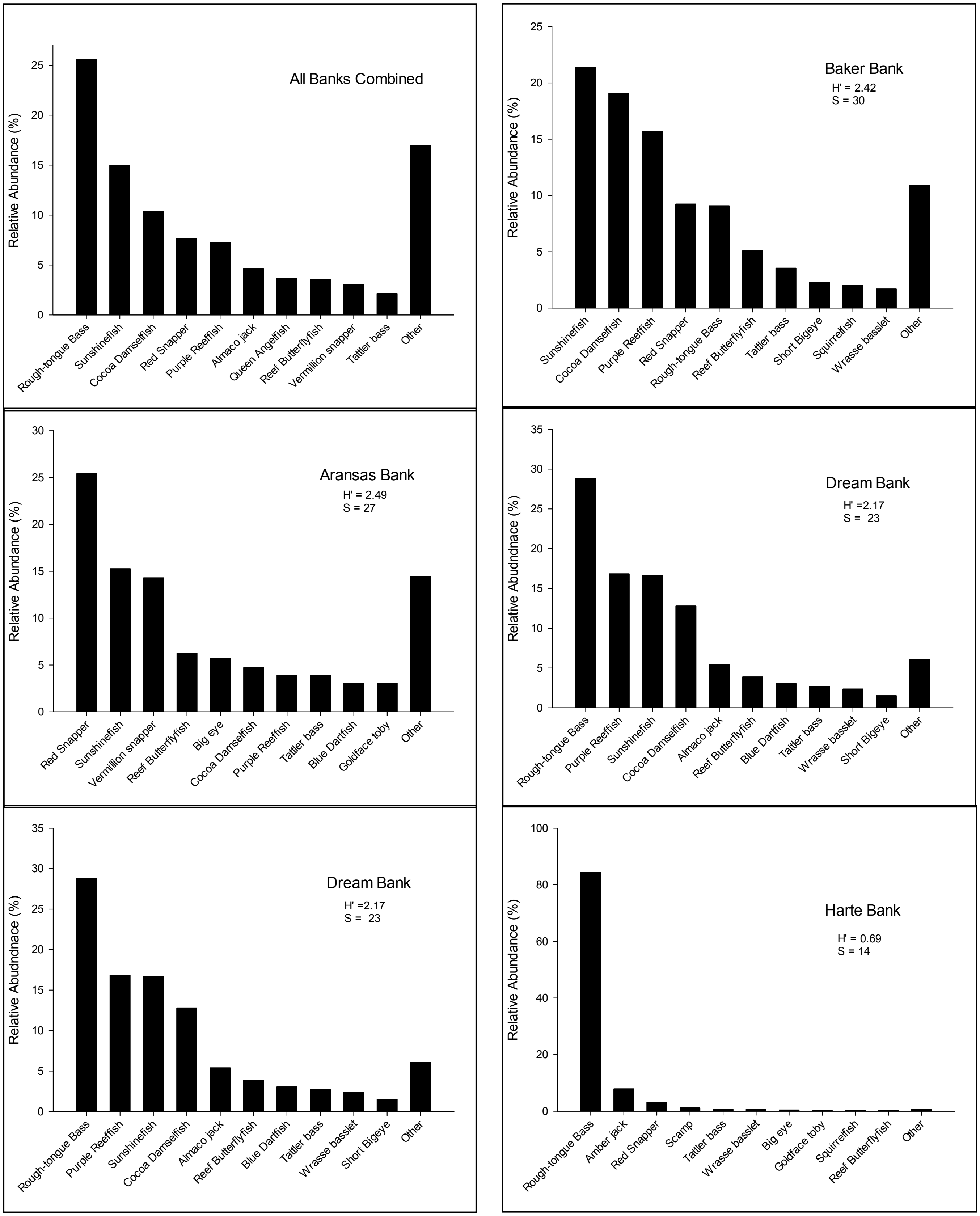

Figure 2. Percent relative abundances of the ten most abundant fish species from Baker, Aransas, Dream, Blackfish, and Harte banks in the northwestern Gulf of Mexico. H' = Shannon's diversity (base *e*) and S = species richness.

Table 2. Fish species percent relative abundance and density (individuals • m^{-2}) from Baker, Aransas, Dream, Blackfish Ridge, Mysterious, and a previously uncharted bank (Harte Bank) in the northwestern Gulf of Mexico. * denotes first record from the South Texas Banks.

	Baker		Aransas		Dream		Mysterious		Blackfish Ridge		Harte Bank	
Taxa	**Relative Abun-dance**	**Density**	**Relative Abun-dance**	**Density**	**Relative Abun-dance**	**Density**	**Relative Abun-dance**	**Density**	**Relative Abun-dance**	**Density**	**Relative Abun-dance**	**Density**
Apongonidae												
**Apogon pseudomaculatus*					0.2	3.64E-04			1.3	1.42E-03	0.2	1.95E-03
Carangidae												
**Caranx lugubris*			0.1	6.82E-04								
Seriola dumerili											7.9	7.13E-02
Seriola rivoliana			0.1	6.82E-04	5.4	1.16E-02			17.7	1.99E-02		
Chaetodontidae												
Chaetodon aya					0.2	3.64E-04						
Chaetodon ocellatus			0.1	6.82E-04								
Chaetodon sedentarius	5.1	2.82E-02	6.3	3.07E-02	3.9	8.36E-03			2.5	2.85E-03	0.2	1.95E-03
Gobiidae												
**Bollmannia boqueronensis*					0.2	3.64E-04						
**Elacatinus oceanops*	0.2	8.54E-04										
Holocentridae												
Holocentrus adscensionis	2.0	1.11E-02	0.4	2.05E-03	0.8	1.82E-03			6.3	7.12E-03	0.3	2.93E-03
**Sargocentron bullisi*	0.2	8.54E-04	0.7	3.41E-03	0.3	7.27E-04						
Labridae												
Bodianus pulchellus	1.5	8.54E-03	1.7	8.19E-03	0.2	3.64E-04			5.1	5.70E-03		
Halichoeres bathyphilus	0.3	1.71E-03	0.4	2.05E-03	0.3	7.27E-04						
Lutjanidae												
Lutjanus campechanus	9.2	5.12E-02	25.4	1.25E-01	0.7	1.45E-03					3.1	2.83E-02
Rhomboplites aurorubens			14.3	7.03E-02	0.8	1.82E-03					0.2	1.95E-03
Microdesmidae												
**Ptereleotris calliura*	0.8	4.27E-03	3.6	1.77E-02	3.0	6.55E-03			2.5	2.85E-03		
Ostraciidae												
**Acanthostracion quadricor-nis*			0.1	6.82E-04								
Pomacanthidae												
**Centropyge argi*	0.9	5.12E-03										
Holacanthus bermudensis	0.3	1.71E-03	1.4	6.82E-03								
Holacanthus ciliaris	0.3	1.71E-03	0.4	2.05E-03					17.7	1.99E-02		
Pomacanthus paru	0.3	1.71E-03	0.3	1.36E-03								
Pomacentridae												
Chromis enchrysura	1.4	7.69E-03	1.7	8.19E-03	0.5	1.09E-03			1.3	1.42E-03		
Chromis insolata	21.4	1.19E-01	15.3	7.50E-02	16.7	3.60E-02			21.5	2.42E-02		
Chromis scotti	15.7	8.71E-02	3.9	1.91E-02	16.8	3.64E-02						
Microspathodon chrysurus	0.3	1.71E-03										
**Stegastes variabilis*	19.1	1.06E-01	4.7	2.32E-02	12.8	2.76E-02			15.2	1.71E-02		
Priacanthidae												
Pristigenys alta	2.3	1.28E-02	1.5	7.50E-03	1.5	3.27E-03					0.2	1.95E-03
Priacanthus arenatus	0.2	8.54E-04	5.7	2.80E-02	1.0	2.18E-03	1.4	1.03E-03	2.5	2.85E-03	0.4	3.91E-03

Table 2. (Continued)

Taxa	Baker		Aransas		Dream		Mysterious		Blackfish Ridge		Harte Bank	
	Relative Abun-dance	Density	Relative Abun-dance	Density	Relative Abun-dance	Density	Relative Abun-dance	Density	Relative Abun-dance	Density	Relative Abun-dance	Density
Sciaenisdae												
Equetus lanceolatus			0.8	4.09E-03								
**Pareques umbrosus*	0.2	8.54E-04	0.3	1.36E-03								
Scorpaenidae												
**Pterois volitans*	0.2	8.54E-04										
Serranidae												
Epinephelus adscensionis	0.3	1.71E-03										
**Liopropoma carmabi*	0.8	4.27E-03										
Liopropoma eukrines	1.7	9.39E-03	0.8	4.09E-03	2.4	5.09E-03	98.6	6.98E-02	3.8	4.27E-03	0.7	5.86E-03
Mycteroperca bonaci	0.2	8.54E-04										
Mycteroperca phenax											1.2	1.07E-02
Pronotogrammus martini-censis	9.1	5.04E-02	2.9	1.43E-02	28.8	6.22E-02			2.5	2.85E-03	84.4	7.61E-01
**Rypticus bistrispinus*											0.1	9.77E-04
Serranus annularis	0.8	4.27E-03										
**Serranus chionaraia*	0.9	5.12E-03			0.3	7.27E-04						
Serranus phoebe	3.5	1.96E-02	3.9	1.91E-02	2.7	5.82E-03					0.7	5.86E-03
Tetraodontidae												
**Canthigaster jamestyleri*	1.1	5.98E-03	3.1	1.50E-02	0.5	1.09E-03					0.3	2.93E-03
Triglidae												
**Prionotus rubio*	0	0	0	0	0.2	9.77E-02	0	0	0	0	0	0

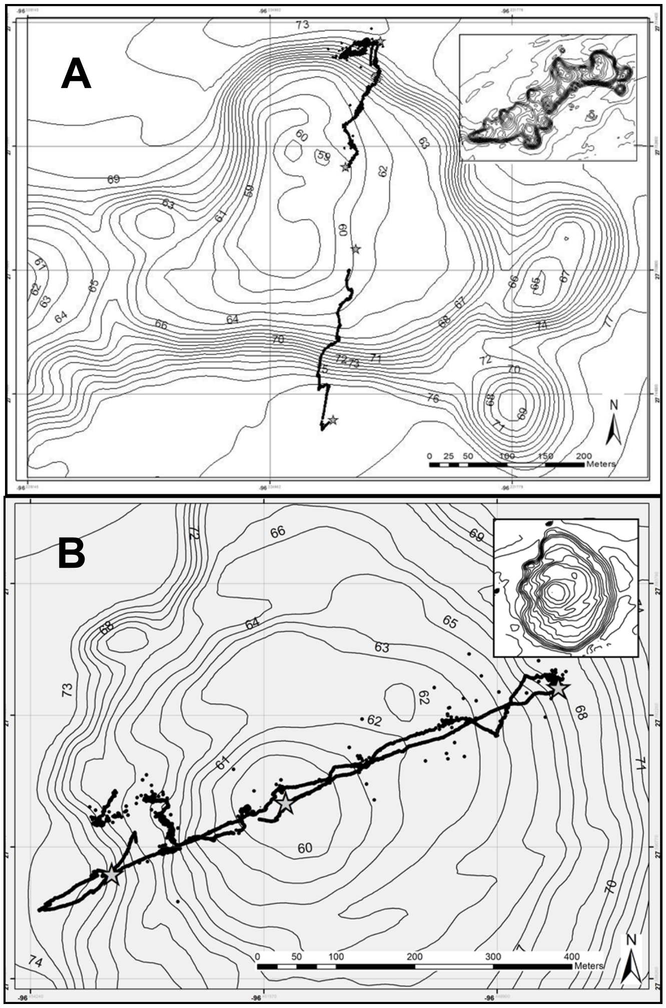

Figure 3. Multibeam bathymetry (meters) of A) Baker and B) Aransas banks in the northwestern Gulf of Mexico. ROV waypoints (stars) and tracks depicted.

Dream Bank was a 2.07 km^2 elliptical feature with a maximum east-west length of 2,179 m and a maximum north-south length of 1,343 m with a vertical relief of ~16 m. Four ROV waypoints were organized into three interconnecting transects having a total length of 1,100 m bisecting the bank from north to south. The survey began and ended at the slope bases at depths of 82 - 83 m ascending to the terrace crest at 69 m (Figure 4A). The predominant fish species observed at Dream Bank in decreasing order of abundance were *Pronotogrammus martinincensis* (28.8% of total), *Chromis scotti* (16.8% of total), *Chromis insolata* (16.7% of total), *Stegastes variabilis* (12.8% of total), and *Seriola rivoliana* (almaco jack; 5.4% of total) (Table 2, Figure 2,).

Blackfish Ridge was a 1.36 km^2 elliptical feature with a maximum east-west length of 1,431 m and a maximum north-south length of 701 m with a vertical relief of ~14 m. Two ROV waypoints at the ends of a single 270 m transect ascending the north side of the feature from a depth of 73 m at the base to the crest of the terrace at 62 m (Figure 4B). The predominant fish species observed at Blackfish Ridge in decreasing order of abundance were *Chromis insolata* (21.5% of total), *Seriola rivoliana* (17.7% of total), *Holacanthus ciliaris* (queen angelfish; 17.7% of total), and *Stegastes variabilis* (15.2% of total) (Table 2, Figure 2).

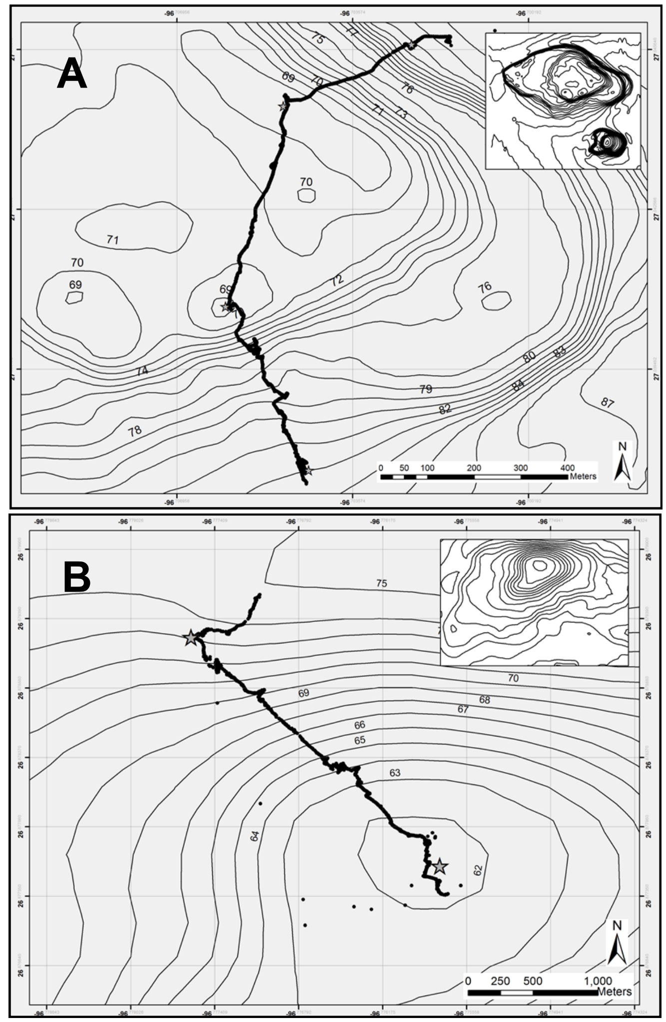

Figure 4. Multibeam bathymetry (meters) of A) Dream and B) Blackfish Ridge banks in the northwestern Gulf of Mexico. ROV waypoints (stars) and tracks depicted.

Mysterious Bank has an irregular shape with numerous patch reefs and discrete terraces. Three ROV waypoints were plotted across one of the discrete structures forming two interconnecting transects with a combined length of 374.6 m (Figure 5A). Mysterious bank was cloaked in a dense nepheloid layer preventing comparable assessments of the fish communities with other surveyed banks. Only two fish species were observed including a single *Priacanthus arenatus* and 68 *Liopropoma eukrines* (wrasse bass) (Table 2).

The previously uncharted Harte Bank was a 0.37 km^2 rectangular feature with a maximum east-west length of ~1,394 m and maximum north-south length of 264 m with a vertical relief of ~16 m. Three waypoints forming two interconnecting transects were set and traversed by the ROV for a total length of 393.7 m surveyed (Figure 5B). Despite being the deepest of the banks surveyed (96 m at the base), a nepheloid layer was absent from the 84 m terrace. Three fish species accounted for more than 95% of the total fish abundance including *Pronotogrammus martinincensis* (84.4% of total), *Seriola dumerili* (greater amberjack; 7.9% of total), and *Lutjanus campechanus* (3.1% of total) (Table 2, Figure 2).

Diversity generally diminished from north to south along the relic coral bank chain with Baker and Aransas banks having the highest diversity (Table 3). Cluster and MDS ordination analyses based on standardized fish species abundances identified three northern banks grouped together at ~70% similarity (Figures 6 and 7). SIMPER analyses showed that the species contributing most to the dissimilarity between banks were *Lutjanus campechanus*, *Rhomboplites aurorubens*, *Stegastes variabilis*, *Pronotogrammus martinincensis*, *Seriola rivoliana*, *Chromis insolata*, and *Chromis scotti* (Table 4).

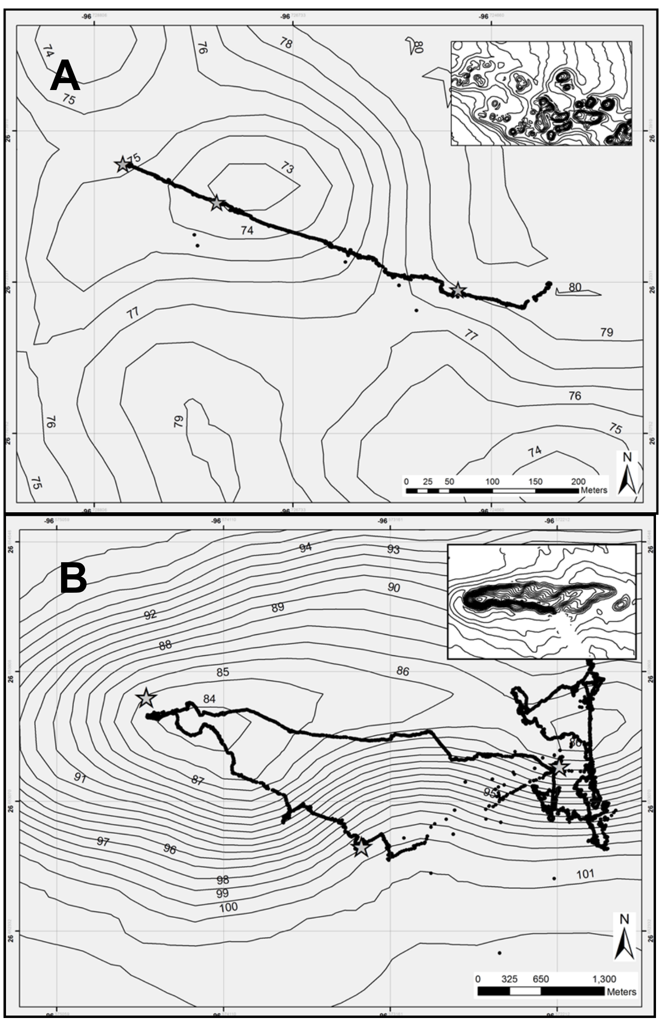

Figure 5. Multibeam bathymetry (meters) of A) Mysterious and B) Harte banks in the northwestern Gulf of Mexico. ROV waypoints (stars) and tracks depicted.

DISCUSSION

A total of 45 fish species were recorded from six relic coralgal banks off the south Texas coast including 16 previously unreported species (Table 2). Dennis and Bright (1988) reported a total of 66 fish species from seven South Texas Banks including three of which surveyed in the current study (Baker, Aransas, and Dream). Fourteen additional fish species were reported in 2008 from Southern and North Hospital Banks by Tunnell et al. (2009). Thus, a total of 97 fish species have been reported from the South Texas Banks. Bright and Rezak (1976) considered *Pronotogrammus martinincensis* (rough-tongue bass) most characteristic fish of the South Texas Banks. Similarly in this study, *Pronotogrammus martinincensis* was the most

Table 3. Shannon's diversity (H', base *e*), Simpson diversity (1-lambda), species richness (S), and evenness (J') of fish communities surveyed at Baker, Aransas, Dream, Blackfish Ridge, Mysterious, and a previously uncharted bank (Harte Bank) in the northwestern Gulf of Mexico.

	S	H'	1-Lambda	J'
Baker	31	2.421	0.8719	0.705
Aransas	28	2.503	0.8764	0.7513
Dream	23	2.173	0.8388	0.693
Mysterious	2	7.575E-2	2.899E-2	0.1093
Blackfish ridge	13	2.163	0.8679	0.8433
Harte	14	0.6922	0.2805	0.2623

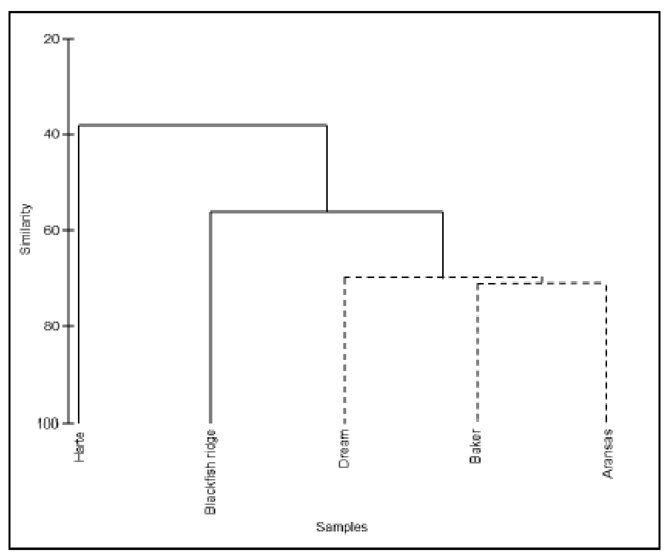

Figure 6. Cluster analysis of samples based on the Bray-Curtis similarity matrix calculated from standardized, fourth-root transformed fish abundances (45 species) from Baker, Aransas, Dream, Blackfish, and Harte banks in the northwestern Gulf of Mexico. Clusters connected by a solid line are significant ($p < 0.05$) by SIMPROV test.

Table 4. Results from similarity percentage (SIMPER) analysis of fish surveys among five South Texas Banks (Baker, Aransas, Dream, Blackfish Ridge, and Harte Bank). Only the top three diagnostic species are listed. Cell values are percent relative abundance in each surveyed bank where values above the diagonal correspond to column headings and those below correspond to row headings.

	Aransas		Dream		Blackfish		Harte	
Baker	*Rhomboplites aurorubens*	14.2 / 0	*Seriola rivoliana*	5.3 / 0	*Seriola rivoliana*	17.3 / 0	*Chromis insolata*	0 / 21.4
	Centropyge argi	0 / 0.9	*Centropyge argi*	0 / 0.9	*Chromis scotti*	0 / 15.7	*Stegastes variabilis*	0 / 19.1
	Serranus chionaraia	0 / 0.9	*Rhomboplites aurorubens*	0.8 / 0	*Lutjanus campechanus*	0 / 9.1	*Chromis scotti*	0 / 15.7
Aransas			*Lutjanus campechanus*	0.7 / 25.6	*Lutjanus campechanus*	0 / 25.6	*Chromis insolata*	0 / 15.4
			Holacanthus bermudensis	0 / 1.4	*Rhomboplites aurorubens*	0 / 14.2	*Pronotogrammus martinicensis*	84.3 / 2.9
			Pronotogrammus martinicensis	29.0 / 2.9	*Seriola rivoliana*	17.7 / 0.1	*Seriola dumerili*	8.0 / 0
Dream					*Holacanthus ciliaris*	17.7 / 0	*Chromis scotti*	0 / 17.0
					Chromis scotti	0 / 17.0	*Chromis insolata*	0 / 17.0
					Serranus phoebe	0 / 2.7	*Stegastes variabilis*	0 / 12.8
Blackfish							*Chromis insolata*	0 / 21.4
							Seriola rivoliana	0 / 17.7
							Holacanthus ciliaris	0 / 17.7

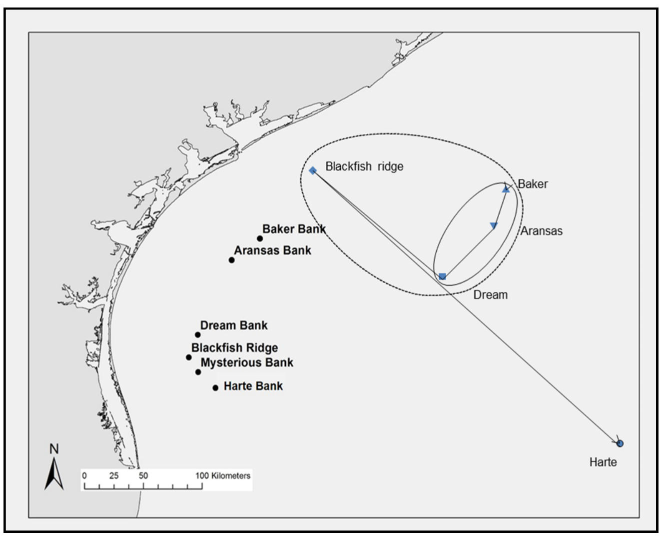

Figure 7. Non-metric multidimensional scaling (MDS) ordination of fish community samples (right) superimposed on map depicting locations of surveyed banks (Baker, Aransas, Dream, Blackfish, and Harte banks) in the northwestern Gulf of Mexico. Ordination of samples based on the Bray-Curtis similarity matrix calculated from standardized, fourth-root transformed fish abundances (45 species). Contours from cluster analysis are defined at a 70% similarity level. Overlay trajectory connects samples from north to south.

abundant and widely distributed fish species representing 25.5% of the total number of fish observed. Dennis and Bright (1988) described four distinct Gulf bank reef fish assemblages; coral reef, algal sponge, drowned reef, and mid-shelf, resulting from similar crest depths, hydrogaphic conditions, and subsequent similar epibenthic communities. Dennis and Bright (1988) characterized the South Texas Bank fish assemblage as a mix of algal-sponge and drowned reef zones. The algal-sponge assemblage is characterized by *Chromis enchrysura*, *Chaetodon sedentarius*, *Serranus annularis*, *Bodianus pulchellus*, *Liopropoma eukrines*, and *Priacanthus arenatus* (Dennis and Bright 1988). The drowned reef assemblage is characterized by *Pronotogrammus martinicensis*, *Serranus phoebe*, *Chaetodon aya*, *Bodianus pulchellus*, *Liopropoma eukrines*, and *Priacanthus arenatus* (Dennis and Bright 1988). Each of these algal sponge and drowned reef assemblage species were observed in the current study. However, with the exception of *Pronotogrammus martinincensis* (rough tongue bass; 25.5% of total), the predominant reef-associated species were *Chromis insolata* (sunshine fish; 15% of total), *Stegastes variabilis* (Cocoa damselfish; 10.4% of total), and *Chromis scotti* (purple reeffish; 7.3% of total) (Table 2, Figure 2). It is worth noting that two of the most abundant fish species observed in this study, *Chromis insolata* and *Stegastes variabilis*, were reported by Dennis and Bright (1988) as being rare on the South Texas Banks. Similarly, Tunnell et al. (2009) also noted a dominance of *Chromis insolata* on Southern and North Hospital Banks, perhaps indicating a shift towards a more tropical assemblage than previously reported.

Rezak et al. (1985, 1990) delineated benthic biotic zones of Gulf reefs and banks based upon levels of reef building activity characterizing the shallower portions (56-70 m) of the South Texas relic carbonate banks having reef assemblages comparable to the Antipatharian-Transitional Zone found at similar depths on mid-shelf bed-rock banks (Stetson, Sonnier, and Claypile) and at greater depths on outer shelf carbonate-capped diapric banks (Flower Garden Banks). The Antipatharian-Transitional Zone variously grades into a Nepheloid Zone at a depth of approximately 70 m (Rezak et al. 1985, 1990). Many low profile banks, including Mysterious (a complex of many banks) and Blackfish Ridge, are noted to suffer from chronic high turbidity and sedimentation from reef crest to base (Rezak et al. 1985, Tunnell et al. 2009). This was generally supported in this study wherein the terraces of all surveyed banks were above the nepheloid layer excepting the low-relief Mysterious Bank which was completely engulfed in a nepheloid layer within the surveyed depths 75 - 79 m. Interestingly, the deeper and southern-most Harte Bank, wherein survey depths ranged 84 - 100 m, was one of the clearer sites surveyed. Dennis and Bright (1988) cited low primary benthic community diversity resulting from the chronic nepheloid layer as the main factor contributing to lower fish species diversity of South Texas Banks when compared to reefs formed on the tops of diapric salt intrusions of the continental shelf edge where shallower crests allow for increased benthic diversity and hermatypic coral activity (e.g., Flower Garden Banks, Stetson, Claypile, Sonnier).

Cluster and MDS ordination analyses based on standardized fish species abundances identified three northern banks (Baker, Aransas, and Dream Banks) grouped together at ~70% similarity (Figures 6 and 7). This is consistent with a similar analysis conducted by Nash (2013) which grouped these three banks based upon geomorphic variables. Similar groupings in both studies are likely a result of the larger terraces of Baker and Dream banks and closer proximity of Baker and Aransas banks. The latter supporting the concept of ecological connectivity (Nash 2013). In contrast, Blackfish Ridge and Harte Bank were distinct from one another and to all other sites in the analysis. Fish biodiversity generally diminished from north to south along the relic coral bank chain with Baker and Aransas banks having the highest diversity and Blackfish and Harte having the lowest diversity (Table 3). Nash (2013) similarly predicted a general southerly decrease in biodiversity based on a multivariate statistical analysis of geomorphic features.

It has been hypothesized that the south Texas relic reef chain may act as 'biotic stepping stones' connecting the coral reefs of the southern and northwestern Gulf (Tunnell et al. 2007). However, critical gaps remain, particularly with regard to the benthic community and its role in providing habitat for other reef-associated species. Indeed, a majority of what is known of the benthic community was obtained using traditional deep-water sampling methods such as dredge and trawl (Abbott and Bright 1975, Bright and Rezak 1976) which lack the spatial resolution and capture efficiency necessary to discern patterns of species abundance (Connell et al. 1998, Mortensen and Buhl-Mortensen 2004). It is likely that these habitats will continue to be threatened by overfishing and oil exploration activities at the edge of the continental shelf. Only through a better understanding of the ecology of these habitats and their role as an ecotone can we better facilitate judgments regarding the need for conservation and protective regulations or if warranted, Marine Protected Area status (Nash 2013, Nash et al. 2013).

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