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Investigating the Demise of East Bank Ridge Through Local Fishery Perceptions and Fish Population Metrics

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INVESTIGATING THE DEMISE OF EAST BANK RIDGE

THROUGH LOCAL FISHERY PERCEPTIONS

AND FISH POPULATION METRICS

A Thesis

by

MARISSA R. LAMB

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ABSTRACT

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East Bank Ridge is a natural reef formation located 18 nautical miles off the coast of South Padre Island, covering an area of over 80 km^2, with the southern portion extending into Mexico. There is no previous record of the structural composition or fish community present at the site. The ridge was a well-known fishing site in the local community over the past decades but catch rates have decreased substantially according to personal accounts from local anglers. In this study, areas of reef habitat were identified, and fish presence and abundance metrics were determined at East Bank Ridge. These measures were compared to Sebree Banks, the closest natural reef bank, approximately 20 nautical miles north. Side-scan sonar was used to create a 2D bathymetric image of East Bank Ridge. Split beam sonar was used to define seafloor characteristics of vertical relief, roughness, and rise time at both sites and determine fish biomass and abundance estimates. Comparisons of fish abundance showed Sebree Banks had significantly greater fish abundance when scaled for area surveyed. Generalized Additive Mixed Models showed that vertical relief had the largest contribution to fish presence and biomass at East Bank Ridge. Visual surveys using a remotely operated vehicle were also conducted and nine species were identified at EBR, and six more were seen at Sebree Banks. Additionally, a questionnaire was distributed to local, long-term anglers and shrimpers to provide a baseline of historic fish presence and to identify perceived sources of degradation to East Bank Ridge. According to repondents, the fishery at EBR has declined in abundance especially regarding the Red Snapper fishery and the main threats they identified to the fishery were illegal fishing practices from across the US-Mexico border and shrimp trawling practices. This study provides the first assessment of East Bank Ridge and identifies that the fishery is degraded when compared to a reef bank to the north, the Sebree Banks.

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CHAPTER I

INTRODUCTION

The South Texas Banks

Natural hard bottom habitats are limited and sparsely distributed along the South Texas coastline due to a dominance of terrigenous inputs of soft sand and clay sediments along the western Gulf of Mexico (GoM) (Bright and Rezak 1976, Flint and Rabalais 1981). These soft bottom sediments and a pervasive nepheloid layer in the coastal Texas GoM, further limit natural reef formation (Rezak et al. 1985). The hard-bottom habitats that do exist along the South Texas coast have been classified as the South Texas Banks.

The South Texas Banks (STB) are a series of relict coralgal reefs that sit at about 60-80m depth, extending across a 140-km band that is 50-60 km offshore the present Texas coast (Belopolsky and Droxler 1999). The STB are almost exclusively contained within the South Texas Shelf with an average width of 88.5 km and a gentle seaward slope of 2.3 m/km. The area of the banks is bounded by the Texas coast to the west, 96°W longitude in the east, the Matagorda Bay in the north, and the US-Mexico border in the south (Flint and Rabalais 1981). Approximately 12,000-18,000 years ago these reefs formed on top of low-stand coastal deposits when sea level was approximately 110 m lower than current levels. The reefs persisted as thriving coral reef systems until their demise due to sea level rise about 1000-2000 years later (Belopsky and Drexler 1999, Khanna et al. 2017). The current banks formed over these drowned reef systems and are composed of carbonate substrates layered by fine siliciclastic and terrigenous sediments that compose the surrounding seafloor. The remaining structures extend 14-22 m off the seafloor, providing bathymetric relief and habitat in an otherwise flat and mud-dominated bottom layer (Bright and Rezak 1978, Rezak et al. 1985, Belopolsky and Droxler 1999).

Historically, these banks have been well-known and frequented by local anglers and shrimpers for their abundance of commercially important species and were commonly referred to as the Snapper banks (Nash et al. 2013). However, scientific studies of the STB are limited because access to the banks is difficult due to their depth and distance offshore (Dennis and Bright 1988). In the 1970s and 80s studies of the area were primarily conducted for oil and gas development (Nash et al. 2013, Hicks et al. 2014). More recent studies conducted since 2009 focused on the ecological setting and biological communities of the STB (Tunnell et al. 2009, Weaver et al. 2009, Hicks et al. 2014, Rodriguez et al. 2018, Bollinger et al. 2022). However, many of the banks still remain unexplored.

The exact number of banks considered in the STB varies by publication and defining characteristics (size, depth, location, etc.). Nash et al. 2013 reviewed the findings of 14 literature sources covering the STB, including peer-reviewed journal articles and technical reports that were primarily focused on oceanographic characteristics of the banks for the purpose of possible petroleum exploration (Bright and Rezak 1976, Holland 1976, UTMSI 1976, Groover et al. 1977, Bright and Rezak 1978, Dennis and Bright 1988). Of these 14 sources, only 8 included species accounts for ichthyofauna, and none include any quantitative fish community data (Nash et al. 2013, Hicks et al. 2014). Further studies on the fish and coral communities of five of the mid-shelf banks were conducted using data collected during the September 2012 Schmidt Ocean

Institute R/V Falkor cruise (Hicks et al. 2014, Rodriguez et al. 2018, Bollinger et al. 2022). Little has been done since this expedition as access to the sites is limited, and this expedition only covered five of the banks. The southernmost bank known as East Bank will be the primary focus of this study but has only one citing by name in peer reviewed publications (Nash et al. 2013). The Sebree Banks will be used as a comparison site (Fig. 1), as there is more available information about this site (Bright and Rezak 1976, Rezak et al. 1985, Bollinger and Kline 2017, Getz and Kline 2019).

Local Fishing Practices

Fisheries Management

Many of the South Texas Banks are popular fishing sites for local, commercial, and recreational fishermen and shrimpers. Due to the limited hard bottom substrates in the area, these natural reef formations act as habitat hotspots for a diverse range of marine species, including commercially important taxa such as Red Snapper (*Lutjanus campechanus*) and shrimp (Penaeidae) (Rezak et al. 1985, Weaver et al. 2009, Hicks et al. 2014).

The shrimping industry is Texas' most valuable commercial fishery. Over 90% of the shrimp that are sold are wild caught, as opposed to shrimp that are sourced for aquaculture, or fish farms (Coastal Fisheries Department TPWD 2002). The primary shrimp collection method used by Texas shrimpers is bottom trawling, a process that damages and disturbs bottom structures and habitat. With habitable substrate already a limiting factor in the GOM, increased damage to natural hard-bottom structures from trawling can have large-scale ecological impacts on fishery health (Auster and Langton 1999, Coastal Fisheries Department TPWD 2002).

Trawling and dredging practices can cause direct damage to natural reef structures. The large nets can catch on structures disrupting habitat, and disturbances to the bottom sediments can deplete benthic community composition. This can have further indirect consequences by altering the trophic levels, decomposition rates, nutrient cycling, and sediment resuspension. It is challenging to quantify both the direct and indirect impacts trawling can have because there are so many factors contributing to the disturbance of the habitat (Auster and Langton 1999, Council 2002). Sites in the GoM exposed to commercial trawling events in shell and reef habitats have shown significant differences in invertebrate and fish community structure in as short as two years of exposure (Wells et al. 2008). These practices can reduce habitat complexity even after one trawling event. On sponge-coral hard bottom habitats, a single tow of a trawl net has damaged all species of observed coral and sponges (Van Dolah et al. 1987).

Another important fishery supported by the STB and the surrounding area is the Red Snapper fishery and it has been reported that the majority of known Red Snapper stock is located on natural banks within the northwest region of the GoM (Karnauskas et al. 2017, Streich et al. 2017). In the past, this fishery has been under great fishing pressure, but management efforts starting in 1976 have helped in rebuilding stocks (NOAA 1976, Hood et al. 2007). Shrimp trawling has been one of the largest contributing factors to the decreased snapper populations primarily through bycatch, although the damage to the benthos and low relief structures also destroys juvenile Snapper habitat (Hood et al. 2007, Wells et al. 2008). Red Snapper have shown a high affinity for natural reefs and are found in higher abundance where habitat structure is more complex than sand bottoms (Bradley and Brian 1975). However, Red Snapper abundance is significantly lower in trawled sites when compared to non-trawled areas (Wells et al. 2008).

Obtaining accurate abundance and diversity measures for fisheries can also prove challenging in this area of the Gulf of Mexico. A variety of methods have been used along the STB to assess fish community measures such as trawling, bag seining and long-line fishing (Stanley and Wilson 1991, Rester et al. 2017, Bolser et al. 2021). Less invasive measures have been utilized recently including visual and acoustic surveying. Visual surveys using divers or remotely operated vehicles can be highly effective at determining community structure and diversity. However, visual survey methods are limited by fish attraction/avoidance behaviors, inconsistent visibility, and a prevalent nepheloid layer within the GoM making it difficult to obtain adequate abundance and biomass measures (Stanley and Wilson 2000, White et al. 2022). Active hydroacoustic surveying to determine fish biomass have recently been used within natural and artificial reefs of the GoM because hydroacoustic surveying is not limited by visibility or calm environmental conditions (Stanley and Wilson 1996, Reynolds et al. 2018, Egerton et al. 2021, White et. al 2022, Gilliland et al. 2023).

Active hydroacoustic methods allow for large spatial areas to be surveyed that encompass the entire water column for biomass estimation (MacLennan 1990, Simmonds and MacLennan 2008). The use of different frequencies for surveying allows for density estimations of all scattering biomass within the water column and this can be further refined to isolate only biomass associated with fish (MacLennan 1990, Simmonds and MacLennan 2008). The relative density of fish biomass is best estimated using the nautical area scattering coefficient (NASC) in units of m^2 nmi^{-2} (MacLennan et al. 2002, Simmonds and MacLennan 2008) which is often used as a proxy for biomass density as NASC is considered proportional to the abundance of biological scatterers in the water column (Fennell and Rose 2015, Boswell et al. 2020, Campanella et al. 2021, White et al. 2022, Gilliland et. al 2023). Fish biomass is best isolated by exploiting the variation in backscatter associated with gas filled swim bladders present in many fish species (Benoit-Bird et al. 2003, Simmonds and MacLennan 2008, Boswell et al. 2020). However, these are considered estimates of relative fish density, because without visual confirmation of the fish species associated with the biological backscatter, exact density measures are not possible.

Target strength of fish backscatter can also be isolated to determine length estimates of fish identified in hydroacoustic surveys. Target strength (TS, units of dB re. 1 m^2) is defined as the backscattered acoustic energy that is attributed to a single target (MacLennan et al. 2002, Simmonds and MacLennan 2008). A widely accepted generalized equation to estimate fish length from target strength known as the Love (1971) dorsal- aspect equation allows for general estimates of length associated with swim-bladdered fish identified in hydroacoustic surveying.

Local Ecological Knowledge

Another obstacle to fisheries management is a lack of past knowledge or information on the status of fish populations and fishery stocks. In many fisheries, there are no recorded datasets on past stocks. Often if these historical data do exist, methods and record keeping are limited or inconsistent. This has created an increased use and dependence on Local Ecological Knowledge (LEK) of anglers and community members to provide information on historical changes in local marine stocks and fishery conditions (Johannes et al. 2000, Martins et al. 2018). This can then inform best management practices for fishery monitoring and conservation, while also incorporating the input of the local community that depends on the fishery. This aids in building trust and can increase collaboration between local anglers, commercial/ industry fishers, governing agencies, and conservation organizations (Johannes et al. 2000, Carr and Heyman 2012).

The use and incorporation of LEK has grown over the last couple decades in the ecological science realm, and methods of quantifying and limiting bias in this area have also improved (Carr and Heyman 2012, Beaudreau and Levin 2014). Studies have been conducted to quantify spatial, temporal, and behavioral trends of commercial fish species (MacDonald et al. 2014) and LEK has been used to establish presence and abundance data for threatened and endangered species (Beaudreau and Levin 2014). More commonly, LEK is used to determine trends in abundance over time and help inform management decisions (Johannes et al. 2000, Carr and Heyman 2012). The use of well-conceived and consistent questionnaires is essential in this process to limit areas of bias, but the use of LEK has been shown to match the data obtained by fishery scientists (Rochet et al. 2008). Predetermined questionnaires have been used for decades to assess fish stocks (eg. creel surveys, Wilde et al. 1996), but the goals of these questionnaires have since expanded (Hunt et al. 2013). Behavioral trends of fishermen have been assessed to help inform trends or attitudes about the state of the concerned fishery (Aas and Ditton 1998, Hunt et. al 2013). Input from the local residents fishing at the sites can be the most informative as they are the individuals who see the area and how it changes most. This is done through predetermined interviews and questionnaires that first identify the perceived risks and threats to the fishery (Griffin et al. 2023, Bower et al. 2024). This can then be used to inform possible solutions to address these problems and the attitudes of the anglers (Foster and Vincent 2010, Smith et al. 2022).

East Bank Ridge

East Bank Ridge (EBR) is the focus of this study. The site is one of the South Texas Banks, the southernmost natural reef formation along the Texas coast located near South Padre Island, whose area spans the US-Mexico border. Little is known about this site other than its popularity with local South Padre Island anglers. Over 20 years ago, EBR was well-known for landings of Grouper and Snapper, as seen in nautical fishing charts of the area and noted in published hang journals for local fishing spots (Horner, 2012). Today, EBR is less frequented by local anglers due to a general perception that catch rates have decreased (personal interactions).

One perceived source of the decrease in fish abundance at EBR is thought to be caused by an increase in illegal cross-border fishing practices in the area. As mentioned, the ridge's formations extend past the US-Mexico maritime border, into Mexico waters. In Mexico, the Snapper fishery is not under any defined regulations (NOAA 2021). On the US side, harmful practices such as long-line fishing and gillnets are illegal and regularly enforced to minimize amounts of bycatch. Shrimpers in US waters are also required to use Bycatch Reduction Devices (Coastal Fisheries Department TWPD 2002, Hood et al. 2007). The snapper industry in US waters of the GOM is further regulated by seasonal restrictions, quotas, size limits, and bag/trip limits. These regulations help keep the snapper fishery stocks sustainable in federal and state waters (Hood et al. 2007). With such close proximity to Mexico, where these regulations do not exist, illegal fishing activity from Mexican vessels in U.S. waters within the GoM is an ongoing issue, especially in regard to the Red Snapper industry (Pala et al. 2018, NOAA 2021).

The main governing agency responsible for apprehensions of these illegal fishing practices (poaching, long-line fishing, and gill-net use) is the US Coast Guard (USCG). The

USCG have the authority to enforce regulations and interdict fishing vessels participating in these practices, as well as apprehend fishing vessels that are not permitted or licensed to fish in federal or state waters (NOAA 2021). The Magnuson- Stevens Fishery Management and Conservation Act clearly states that since 1977, no foreign fishing is allowed within federal waters of the GoM unless proper permitting is obtained (NOAA 2007). Despite this long-standing regulation, the instances of USCG interdictions of these practices (primarily long-line fishing) have increased from nine vessel apprehensions in 2010, to 138 vessel apprehensions in 2020 (NOAA 2021, US Coast Guard). All of these apprehensions were of vessels known locally as "*lanchas*" that are small fishing boats commonly used in Mexico (NOAA 2021). No direct studies have been conducted on the impacts this increased activity has had on the surrounding fishery, but in 2018 alone, 26,159 pounds of fish were confiscated, with 10,875 pounds being Red Snapper (Alexander 2019) and these numbers only account for those who were actually apprehended. NOAA issued Mexico a negative certification in the 2021 Report to Congress to encourage increased government action and regulations in Mexico to help further limit this activity (NOAA 2021).

The lack of knowledge on the fish communities at this site and the surrounding areas presents a unique challenge to assessing the current status of the reef. Local fishermen have observed illegal fishing practices in the area, and many will report this to the USCG, however many vessels escape before apprehensions are possible (personal interactions). This is again an area where past knowledge and current assessments are very limited, so incorporating this as a possible source of degradation by assessing LEK will provide insight into impacts it may have at EBR.

Furthermore, the lack of past scientific data on species abundance and diversity measures at EBR prevents a comparison of fish communities over a designated timescale. However, the STB in closest proximity to EBR, known as Sebree Banks (SB), is also a popular fishing site and has similar structure and environmental conditions, but is located further north from the US-Mexico border. Both sites still face the constraints of the GoM marine environments, specifically visibility and accessibility. To combat these limitations, active acoustic surveys and visual surveys are commonly employed in the northern GoM to examine fish biomass and diversity (Stanley and Wilson 2000, Patterson et al. 2014, Ajemian et al. 2015, Streich et. al 2017, Garner et al. 2019, Reynolds et al. 2018, Egerton et al. 2021, White et al. 2022).

This study aims to characterize the current habitat and fish populations present at EBR and identify possible sources of degradation as noted by the local fishing community. This will be used to compare present populations to both locals' knowledge of past fish species presence and the STB in closest proximity to EBR. This will be done through the creation of a bathymetric map of the site, visual surveys, biomass estimation, and a questionnaire provided to local anglers.

Objectives

Objective 1: Characterize EBR through the creation of a 2-D side-scan mosaic based on sonar imaging to identify bathymetric features and classify seafloor characteristics through hydroacoustic surveys and compare with Sebree Bank (SB).

Expected Outcomes for Objective 1

- The mosaic image will identify areas of hard bottom structure and relief throughout the defined perimeter of EBR.

- Sebree Bank will have higher relief and a larger extent of suitable bottom habitat for fish in a more concentrated area when compared to EBR.

Objective 2: Determine current fish species presence, biomass, and fish abundance estimates within East Bank Ridge and compare this to Sebree Bank. This site will be a basis for comparison as it is further north of the US-Mexico border and possibly subject to less degradation. Further determine how seafloor characteristics (relief, rise time, and hardness) impact fish and total biomass presence and relative fish density as measured by the Nautical Area Scattering Coefficient (NASC) at both sites.

Hypotheses for Objective 2

- EBR will have lower fish abundance and diversity than SB. Using ROV video surveys, a lower number of fish species will be identified at EBR, compared to SB when assessing three selected sites of hard bottom structure identified through base mapping and hydroacoustic surveying.
- Fish biomass and abundance will be greater at SB than at EBR when scaled to even measures of number of fish tracks and schools per area and across mean NASC per 10 m transect.
- Total biomass will be higher at SB than at EBR when compared via total NASC per 10 m transect.
- Fish and total biomass presence and fish NASC will increase as relief, rise time, and hardness increase but will show a nonlinear relationship.

Objective 3: Determine local perceptions on the past and current status of fish abundance at EBR, how it has changed, and sources that could have shaped that change based on accounts from local anglers and shrimpers through a predesigned questionnaire.

Hypotheses for Objective 3

- Questionnaire respondents will indicate their frequency of fishing at East Banks has decreased since their first visit.
- Questionnaire respondents will indicate Red Snapper catch rates and size were significantly lower at respondent's most recent visit to EBR compared to their first visit (5-10+ years prior).
- According to respondents, there will be a significant difference in the most common fish species caught at EBR from respondent's first and most recent visits to EBR.
- Questionnaire respondents will indicate illegal fishing and shrimping will be the most significant concerns for possible sources of degradation to EBR.

CHAPTER II

METHODS

Study Area

East Bank Ridge (EBR) is located 30 km east of the coast of South Padre Island (Fig. 1). The area of the ridge studied here spans ~85 km^2 and the southernmost point is 0.15 km from the US-Mexico maritime boundary (N25.99838, W96.85127). The full ridge system extends across the boundary line, but the scope of this study only covered the area located in US federal waters (Fig. 2). Nash et. al, 2013 listed the area of the EBR as 155.4 km^2. The additional 70 km^2 area extends into Mexican waters and was not accessible for the purpose of this study. The depth at EBR ranges from 40-45 m. The structures present are likely composed of cemented silicious clay and sandstone dominated by octocorals and sponges, similar to other reefs in the south Texas banks (Nash et al. 2013, Rodriguez et al. 2018) but no formal record exists for EBR.

Sebree Bank (SB; N26.449967, W97.00945) is the closest natural reef formation to EBR (~34 km north, Figure 1) and was used as a comparison site for hard bottom substrate and fish communities. This site is ~33 m in depth with several natural reef patches that have up to 4 m of relief (Getz and Kline 2019) and covers approximately 20 km^2 (Fig. 2). SB is also known as a popular fishing site for local anglers but is further north than EBR at ~50 km from the US-Mexico maritime boundary line.

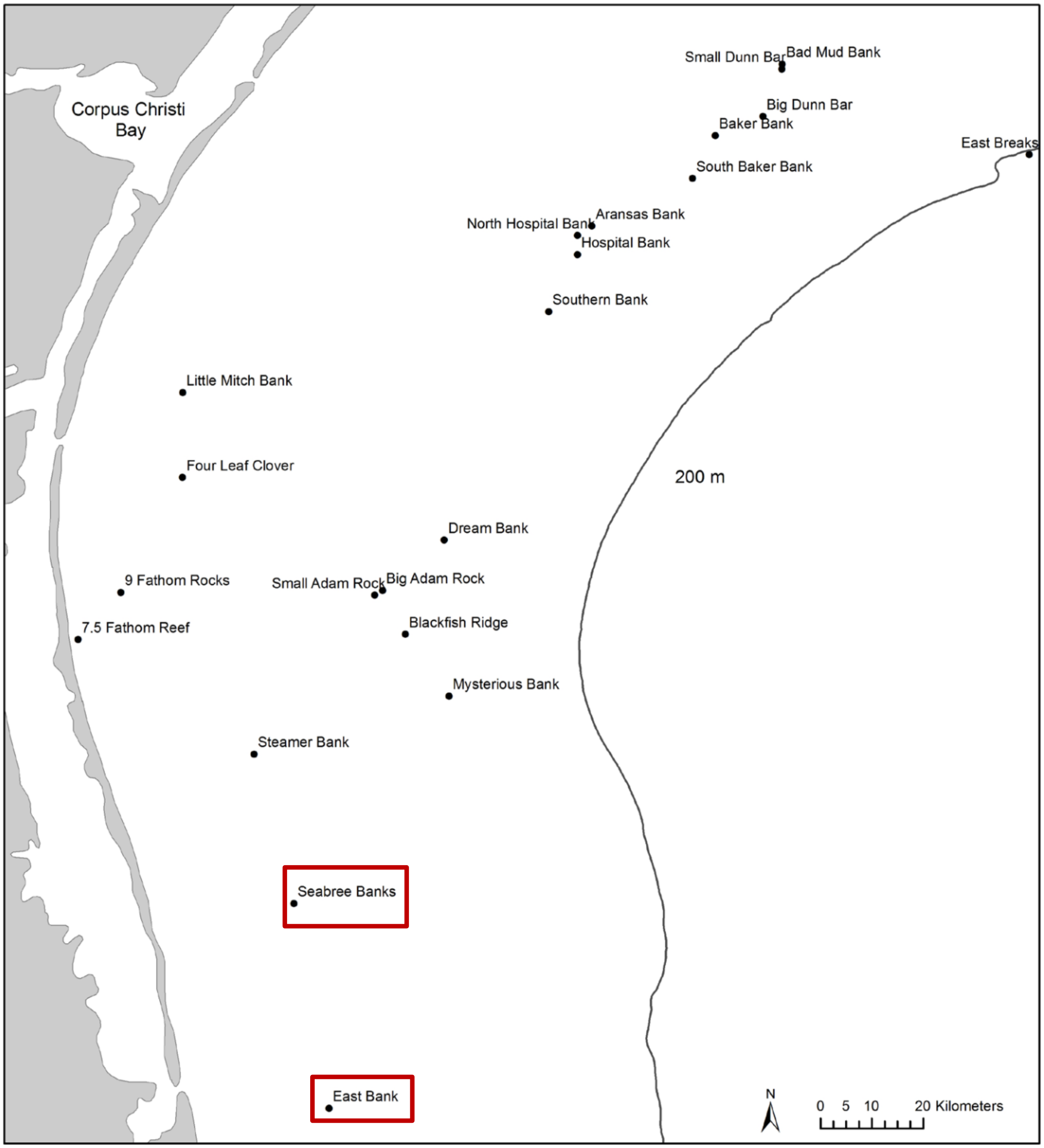

Figure 1: Location of Sebree Banks and East Bank Ridge in relation to other South Texas Banks. Edited from Nash et al. 2013.

Figure 2: Location and perimeter of Sebree Bank and East Bank Ridge.

Base Mapping

A mosaic 2-D bathymetric map of EBR was created through imagery collected with a C-MAX CM2 side-scan sonar system (C-MAX Ltd., Dorset, England). Sonar transects were conducted at 100 kHz over the area shown in Figure 2 with 25% overlap and 800 m swath distance. The side-scan sonar was deployed from the ship deck by a CM2-WIN-300 Winch (C-MAX Ltd., Dorset, England). The boat maintained a speed of (11-14 kph) with the tow fish maintaining an altitude of 15-25 m above the seafloor.

Post-processing of images was conducted in SonarWiz7 (Chesapeake Tehcnology, Inc., Los Altos, California, United States). During post-processing, the water column was removed from the images. Beam angle corrections, gain corrections, and empirical gain normalizations were applied to normalize images. Transect images were then pieced together and trimmed to create a representative map (Fig. 6). GPS location of the map was verified in Google Earth. This image was used to identify bathymetric relief within the defined perimeter of EBR. This was then used to determine transect placement for biomass and abundance data collection and to identify the sites used for visual survey. The percentage and height of relief from this map was also compared to the bathymetric map of Sebree Bank previously published (Fig. 4, Bollinger and Kline 2017). High-relief structures at EBR were identified through the shadow casting shown in the imagery, as shown in Figure 3.

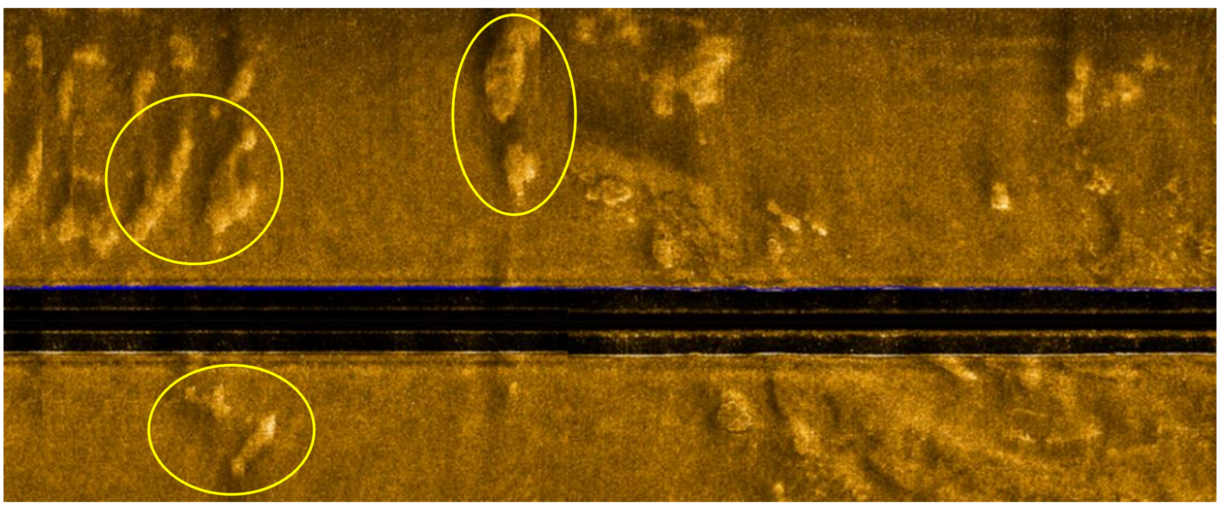

Figure 3: Side- scan sonar mosaic that displays shadow casting used to identify moderate and high relief structures at EBR. Yellow circles surround identified areas of relief.

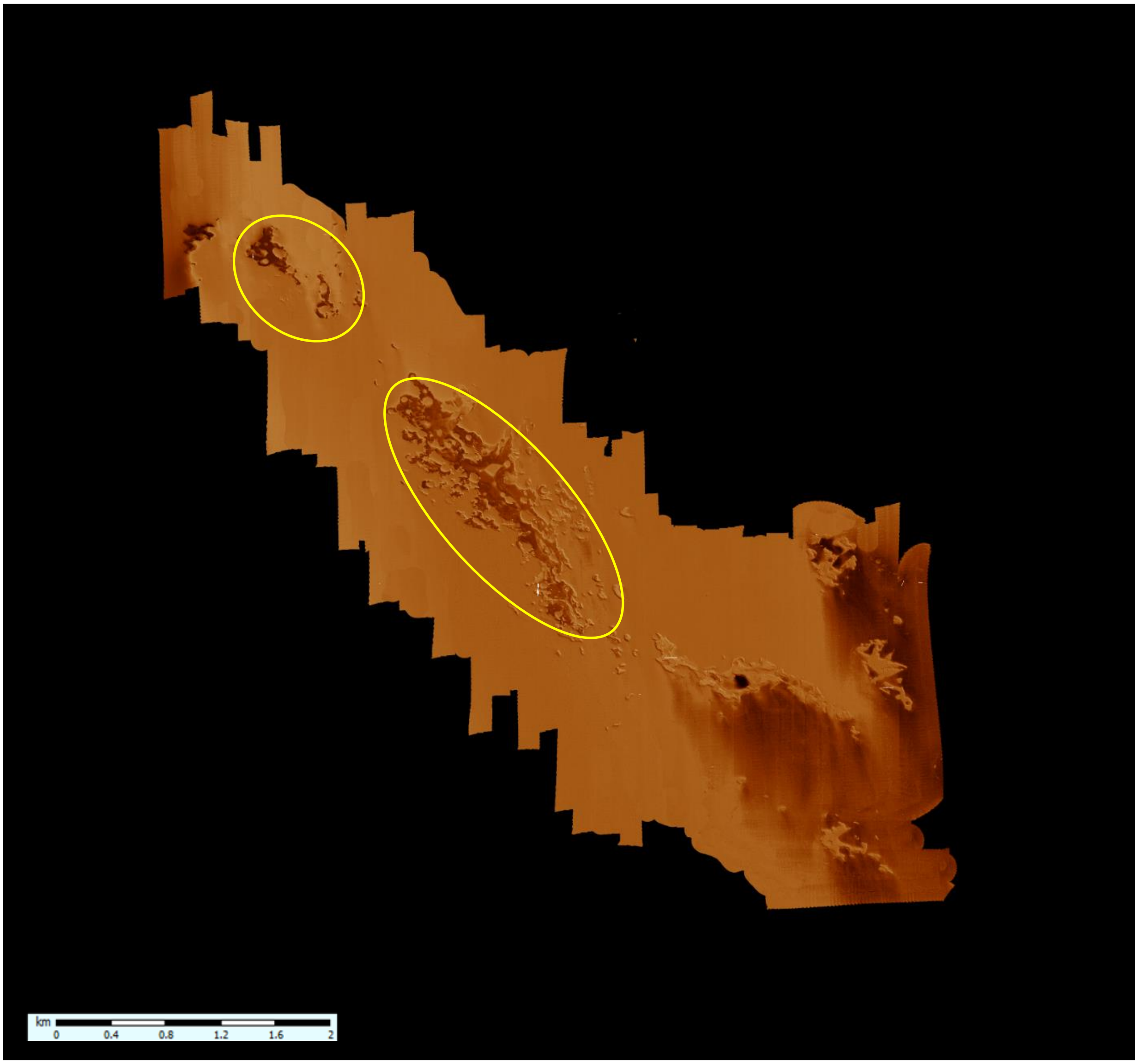

Figure 4: Side-scan 2D bathymetric image of Sebree Banks showing the shadow casting used to identify areas appropriate for surveying. Yellow circles surround identified areas of relief.

Fish Community Surveys

Visual Surveys

Visual fish surveys to determine fish communities were conducted using an Outland Technology 2000 ROV (Outland Technology, Slidell, Louisiana, United States) equipped with high-definition Go-Pro Hero 9 Black cameras (GoPro, San Mateo, California, United States). Six cameras were mounted to the ROV so that video could be taken in the front, back, left, right, and two in the downward view of the ROV. Visual survey sites were identified from imagery created during the bathymetric imaging and split-beam transect surveys. Then areas of possible structure were identified through shadow casting on the base maps of each site that were also surveyed and relief verified during hydroacoustic surveys explained in the next section. Three out of the ten areas of structure were chosen at each site because they had vertical relief verified to be ≥ 1 m through the hydroacoustic surveys. Prior to visual surveys, a weighted marker buoy and line were dropped as close to the identified structure as possible. The ROV was then deployed from the ship deck at each survey site and a vertical video survey was taken along the line, from the surface to the seafloor and back. Additional video was recorded until the appropriate structure was identified. A strong nepheloid layer was present at both sites, therefore videos were analyzed for species identification of fish only. Once visual surveys were completed, the videos were downloaded to Adobe Premier Software. The videos were reviewed, and usable video footage for each site was consolidated down to 65 minutes per camera at SB, and 73 minutes per camera at EBR. Fish were identified to the lowest possible taxon. A species list of identifiable fish was created for both EBR and SB.

Hydroacoustic surveys

Biomass, relative fish abundance, and fish length estimates were determined at EBR and Sebree Bank using a SIMRAD EK80 Portable split-beam sonar echosounder (Kongsberg Maritime, Kongsberg, Norway). Surveys were conducted using a dual sonar transducer that ran a split-beam sonar at 38 kHz and a single beam sonar at 200 kHz. Acoustic surveys were conducted concurrently for both frequencies with a circular beam width of 18^{o}; pulse duration =

0.128 ms, and ping rate = “max”. The transducer was deployed at a depth of 1.5 m using a customized aluminum mount on the starboard side of the survey vessel and aimed downwards. The echosounder was calibrated for each day of data collection using a 38.1 mm tungsten carbide sphere (Part num. 13417, Salem Specialty Ball Company, Inc., Canton, Connecticut, United States) according to standard practices (Demer et al. 2015). Calibration trials were conducted using the calibration function in the SIMRAD EK80 software v23.6.2 (Kongsberg Maritime, Kongsberg, Norway) until a RMS score of less than 0.4 was achieved. Sound speed profiles were determined for each day of data collection using a SonTek Castaway conductivity, temperature, and depth (Xylem Inc., Washington, District of Columbia, United States). Casts for sound speed profiles were conducted prior to sonar data collection and applied to the SIMRAD EK80 settings before data collection began to account for environmental differences in the water column. Data collection occurred over four days in 2022 with two days at each site (10/4, 10/6, 10/16, 12/6). Nine acoustic survey transects were run at each site encompassing a total distance of 7.9 km (volume of 0.2356 km^3) at EBR and 4.3 km (volume of 0.0931 km^3) surveyed at SB.

Post-processing of acoustic data was conducted in Echoview software v13 (Echoview Software Pty Ltd., Hobart, Tasmania, Australia). Calibration settings were applied to imported Echoview file sets according to date of collection. The echograms for raw volume backscattering strength (Sv) from 38 kHz and 200 kHz frequencies were cleaned using Echoview background noise removal and intermittent noise removal filters (DeRobertis and Higginbottom 2007, Ryan et al. 2015). Thresholds for biomass measurements were set to -55 dB and the 38 kHz and 200 kHz echograms were matched by time and ping in Echoview. The bottom line for both frequencies was identified using the Echoview best bottom candidate algorithm and the bottom line was manually inspected to span gaps and ensure proper delineation from the seafloor to the water column. The 200 kHz echogram was then processed to determine seafloor characteristics and the 38 kHz echogram was processed to determine total and fish biomass observed.

In the 200 kHz echogram, the seafloor characteristics were averaged per 10 m cell using the Bottom classification algorithms in Echoview (Hamilton 2001, Anderson et al. 2007). This Bottom classification in Echoview was based on eight variables: depth, roughness, first bottom length, rise time, line depth mean, max SV, kurtosis, and skewness. The bottom echo threshold at 1m was set to -500 dB and the depth normalization for SB was 33 m and 40 m at EBR. Bottom roughness (referred to as bottom_roughness_normalized in Echoview) was determined in the bottom tracking algorithm in Echoview following the classification by Siwabessy et al. (1999) of the roughness index (E1) defined as the energy in the echo of the first acoustic bottom return. This is a proxy measure for the hardness of the seafloor within the first bottom echo and will be referred to as hardness for the statistical analyses. Rise time (referred to as bottom_rise_time_normalized in Echoview) was defined as the mean of the depth normalized rise time of the first bottom echo. This was essentially a measure of the slope along the first bottom echo. Depth, roughness, and rise time were exported for analysis. The processed 38 kHz echogram was integrated into 20 m vertical from the seafloor by 10 m horizontal cells to match the 200 kHz bottom cells and 0.5 m above the designated bottom line was excluded from analysis to account for the acoustic dead zone (Ona and Mitson 1996). The nautical area scattering coefficient (NASC) (MacLennan et al. 2002, Simmonds and MacLennan 2008) was calculated for each cell and was exported for further analysis of total biomass across both sites. Total biomass measurements were used to assess the presence of fish with and without swim bladders as well as non-fish scatterers in the water column.

To isolate only fish biomass, the 38 kHz echograms were further analyzed using the Fish Tracking and School Detection modules in Echoview. First, aggregations of fish were identified using the Echoview school detection module and SHAPES algorithms (Coetzee 2000, Diner 2001). The following detection parameters were used: minimum total school height (2 m), minimum candidate length (2 m), Minimum candidate height (2 m), maximum vertical linking distance (3 m), maximum horizontal linking distance (5 m), and minimum total school length (10 m). Echograms were then visually inspected to ensure proper region boundaries for each identified fish school and to delineate any schools that were not detected through the algorithm. Once all schools were defined into individual regions, a mask of these schools was applied to the 38 kHz target strength (TS) echogram used to identify individual fish tracks. The 38 kHz TS echogram was cleaned using the same filters and the bottom-line candidate from the 38 kHz Sv echogram was applied. The single target detection operand- dual beam (method 2) in Echoview was applied to the 38 TS echogram in conjunction with the angular positioning echogram from the dual beam transducer. This operand detected single targets using the specified algorithm with the TS threshold set to -50 dB, pulse length determination level of 6 dB, normalized pulse length range (0.70-1.5), and maximum standard deviation of the minor and major axes at 0.6 degrees. The operand resulted in a new echogram displaying only single echoes at the provided thresholds for identifiable fish targets. The fish tracking module in Echoview was then used to identify individual fish in the 2D field with Alpha range set to 0.7, beta range at 0.5. Track acceptance parameters were set to a 2 ping and single target minimum and a maximum gap of 5 pings between single targets. Individual fish and their corresponding tracks were then visually inspected to ensure proper identification of a fish with an example shown in Figure 5. The tracks were converted to individual regions and were manually edited to incorporate the associated backscatter of the individual fish. A map of both the fish schools and fish track regions was then created and placed over the cleaned 38 kHz echogram matched with the 200 kHz echogram isolating only the regions of biomass associated with a fish school or track. To eliminate non-fish back scatter from the fish school and track regions before exporting NASC, the 38 kHz Sv values were subtracted from the 200 kHz, creating a new ΔSv echogram. Then, a data range bitmap was applied to the ΔSv echogram for values between − 9.63 and 4.64 dB because this dB range is the accepted range of previously published ΔMVBS200–38 estimates for fish backscatter (De Robertis et al. 2010, Sato et al. 2015, Becker et al. 2021) This bitmap was used to mask the cleaned 38 kHz echogram, removing other scattering objects from the water column and leaving only the fish biomass. The processed 38 kHz echogram was then integrated into the same 20 m horizontal by 10 m vertical cells and NASC was calculated and exported along the same 10 m divisions as the total biomass and bottom characteristic exports.

Next, fish length estimates were determined using the mean target strength of each individual fish track. The TS-length model for the 38 kHz transducers adapted from the Love (1971) dorsal- aspect equation used in this study where (L) is length of the fish and TS is target strength in decibels:

$$L = 10^{(TS+23.9345)/19.4}$$

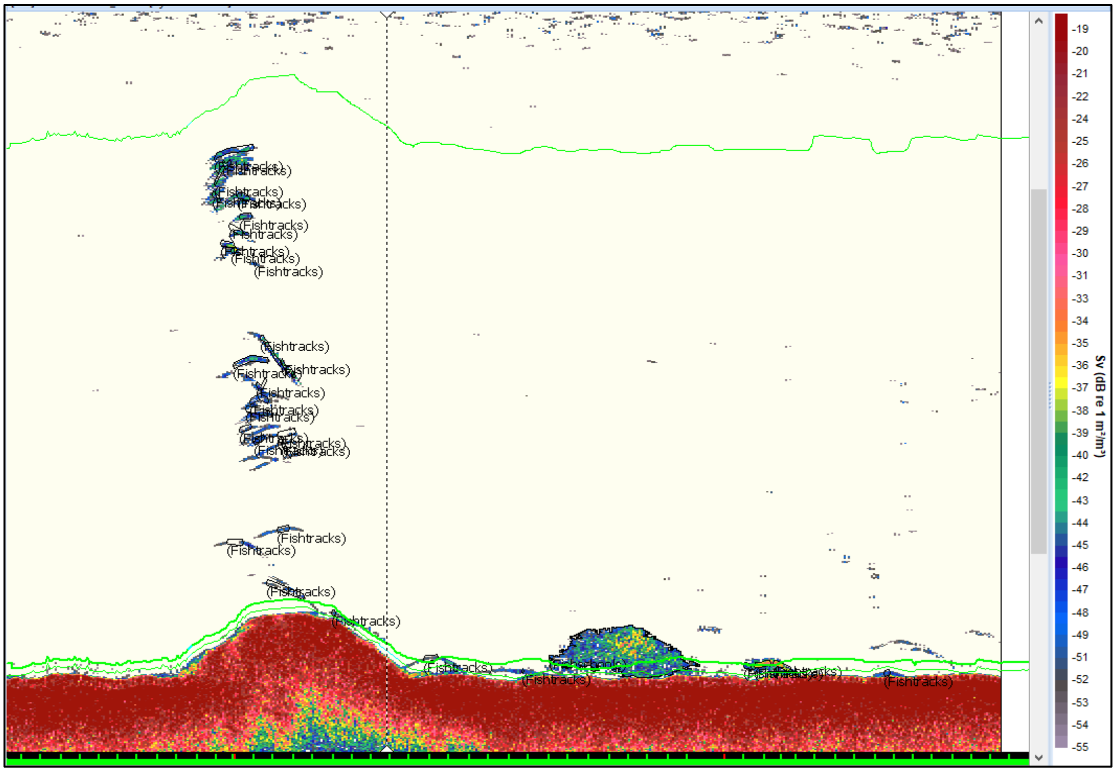

Figure 5: A cleaned 38 kHz Sv echogram from Sebree Banks with identified fish tracks. Fish tracks were used to quantify biomass estimates, individual fish counts, and estimated fish length.

East Bank Ridge Fishery Questionnaire:

To determine past and current fishery information, a questionnaire was distributed to local anglers and shrimpers familiar with EBR. The questionnaire was created using the online survey software Qualtrics and was approved through the UTRGV Institutional Review Board (Institutional Review Board number 220218).

Questionnaire specifications

Survey participants were identified if they met the criteria of having fished at EBR more than once and within the last ten years. Most of the target participants were those who have fished in the area for more than a decade. A list of possible participants was provided by Gary Glick of the local non-profit Friends of RGV Reef. Once all those on this list were contacted, additional participants were identified through phone and email contact with local fishing guides and boat captains. The survey was primarily conducted through phone calls, followed up by an email with a website link to the questionnaire. Initial phone communication was used to ensure participant applicability before they completed the online component. Based on participant preference, the survey was then completed orally or online. For the oral submission, the survey link was opened on a personal device, the questionnaire was orated to the participants, and their provided answers were submitted. For the online submission, the participants were emailed a link to access and submit the questionnaire. The link was distributed to 106 participants and a total of 62 questionnaires were completed.

The survey was divided into three categories: (1) fishing history and activity, (2) fish species presence and abundance, (3) perceived sources of degradation and their impacts. Questions for the first two sections were adapted from MacDonald et al. (2014). Questions for the final section were adapted from Carr and Heyman (2012) and Smith et al. (2022). The first section was used to sort survey answers by fishing activity type and construct a timespan of activity for each participant. The second section provided quantitative and qualitative data about fish species presence and abundance across those time periods to establish perceived trends in fish species caught and catch rates. These questions were set up to assess changes between the respondent's first and most recent visit to EBR. The third section was used to determine the perceived views on the current status of the fish population at EBR and threats to the area. All trend questions were multiple-choice with answers consisting of three to five response options designed on a Likert-type scale. The Likert scale was a one-dimensional scale from which respondents choose the option which best fits their views.

Statistical Analyses

Hydroacoustic Survey Analysis

To prepare the data set for proper comparisons, the mean and standard deviation of depth, relief, and volume surveyed were calculated for the nine transects run at each site. Due to the smaller overall area and shallower depth range at SB, the volume assessed during hydroacoustic surveys was not even between the two study sites. To account for this difference, the total volume surveyed for each site was considered to scale total number of fish tracks, schools, and biomass measurements. These counts were scaled to a count per cubic kilometer using the total volume surveyed across each site. Total fish NASC and total biomass NASC were scaled by the total volume surveyed at each site to allow for proper interpretation of abundance comparisons. The mean NASC for each 10 m cell of the hydroacoustic echogram was calculated and scaled based on the mean volume of area surveyed for each site. Two-sample t-tests assuming unequal variance were conducted in IBM SPSS Statistics v. 29.01.0 (IBM, Chicago, Illinois, United States) to assess differences in the mean NASC values of total biomass and fish biomass, as well as estimated fish length between the two sites.

Further statistical analyses used to compare NASC were run in RStudio v2022.07.2 (Posit Software, Boston, Massachusetts, United States). To account for the distribution of fish biomass showing a complex relationship with seafloor characteristics. Generalized Additive Models (GAMMs) were developed using the ‘gam’ function in the ‘mgcv’ package (https://cran.r-project.org/web/packages/mgcv/index.html). Two separate models were created to assess the presence versus absence of total biomass and fish biomass across the differing seafloor characteristics using binary GAMMs. The 10 m cells were sorted by site and NASC values where the cells that were identified to have biomass or fish backscatter (NASC > 0) was assigned a value of one to indicate a presence and those without remained at zero. Predictor variables for both models included the seafloor characteristics of reef vertical relief (m), bottom hardness and bottom rise time. Depth was converted to a relief measure by subtracting the average depth of each 10 m cell from the maximum depth identified at each site (*SB*=36.9, *EBR*= 42.1m). Bottom hardness and bottom rise time were determined in Echoview. Heading (in degrees) was included to account for directional variation using a cyclic- cubic spline as this is a cyclical variable. Site was included as a categorical fixed effect factor to account for geographical differences between the two areas. Northings and eastings in terms of latitude and longitude were also considered in the initial model building process, but determined the inclusion of heading and analyzing each predictor variable by the individual site would better isolate differences for comparison between the two sites. A test of concurvity was performed in the 'mgcv' package (concurvity()) and heading was tested for correlation across the two sites using the correlation function (cor.test()) in R.

For the presence and absence models, abinomial error distribution was assumed, and a logit function was used. The final binary GAMMs for presence of fish and total biomass NASC was:

PA_NASC = s(Vertical relief by site) + s(Hardness by site) + s(Rise time by site) + s(Heading, bs = "cc") + Site

The ‘by’ argument is an interaction-like term and allows separate splines to be fitted to each of the site locations.

To further assess the relationship between fish abundance and seafloor characteristics another GAMM was created using the NASC values of the isolated fish biomass. All cells that had a NASC value of zero were removed from the dataset for fish biomass before they were fit to the model. The response variable was log-transformed (log(fishNASC)) to meet a normal distribution and a Guassian error distribution was used because this provided the best fit per the ‘gam.check’ function for model diagnostics in the ‘mgcv’ package of R. Site was again included as a categorical fixed effect factor to account for geographical differences and the cubic cyclic spline was applied to heading for the directional component. The final GAMM for fish NASC was:

Fish NASC = s(Vertical relief by site) + s(Hardness by site) + s(Rise time by site) + s(Heading, bs = “cc”) + Site

All three models were further compared using a backward stepwise selection process using approximate significance terms (p-values) of the smooth terms to minimize the Akaike Information Criterion (AIC) (Akaike 1974). Overall model fit was assessed with AIC and percent deviance explained (DE). The relative importance of each variable to the final model was then examined by reducing models with further variable removals and comparing the resulting change in AIC (ΔAIC) to the full model (Dance and Rooker 2019, Gilliland et al. 2023). The partial effects (or fitted effects) plots were used to visualize the relationships between predictor variables and the presence of total biomass, fish biomass, and fish NASC values.

East Bank Ridge Status Questionnaire Analyses

A total of 62 surveys were submitted for analysis with 40 respondents identifying that they have fished at EBR for 6-10+ years. As this was the timeframe of interest to assess a change, the remaining pool of fish community analyses to these respondents was narrowed to these 40 responses. Questions were set up to assess changes between the respondent's first and most recent visit to EBR. Statistical analyses were conducted in IBM SPSS Statistics v. 29.01.0(171).

The related-samples Wilcoxon signed-rank test was used to assess differences in the average catch, Red Snapper catch per unit effort (CPUE), and Red Snapper size. The rank of commonly caught fish species was coded numerically on a scale of 1-3. Species ranked as first most common received a score of three, second most common received a score of two, and third most common received a one. An independent-sample Mann-Whitney U test was conducted in SPSS to determine differences in the ranking of commonly caught fish species from the first and most recent visit to EBR. The U-test was performed for each species choice provided in the survey. The change in the most common species caught across visit time was also analyzed by individual respondents. The score per individual respondent was determined for each fish species listed for their first and most recent visits separately. The change in each fish species score per respondent was then identified to have increased, decreased, or remained the same. If the score for a fish species was higher at the first visit compared to the more recent visit at EBR it was counted as a decrease, while the reverse was counted as an increase, and no change indicated the same score across visit time.

Finally, respondents were asked if they believed the fish abundance at EBR had decreased, increased, or remained the same between their first and most recent visits. If they answered decreased, they were shown questions regarding possible causes for the decrease. Four possible sources of degradation (proximity to artificial reef structures, overfishing by the local community, illegal fishing practices from across the US/Mexico border, and shrimp trawling practices) were provided to respondents and they were asked to rank the level of significance each source had on a Likert scale of significance. Differences in perceived sources of degradation were analyzed using the Kruskal-Wallis one-way analysis of variance by ranks. Pairwise comparisons of the four sources were then assessed using Dunn's (1964) procedure with a Bonferroni correction for multiple comparisons. Each source was compared with one of the other sources for a total of six comparisons.

CHAPTER III

RESULTS

The 2-D bathymetric mosaic of EBR showed areas of relief used for further surveying (Fig.6)

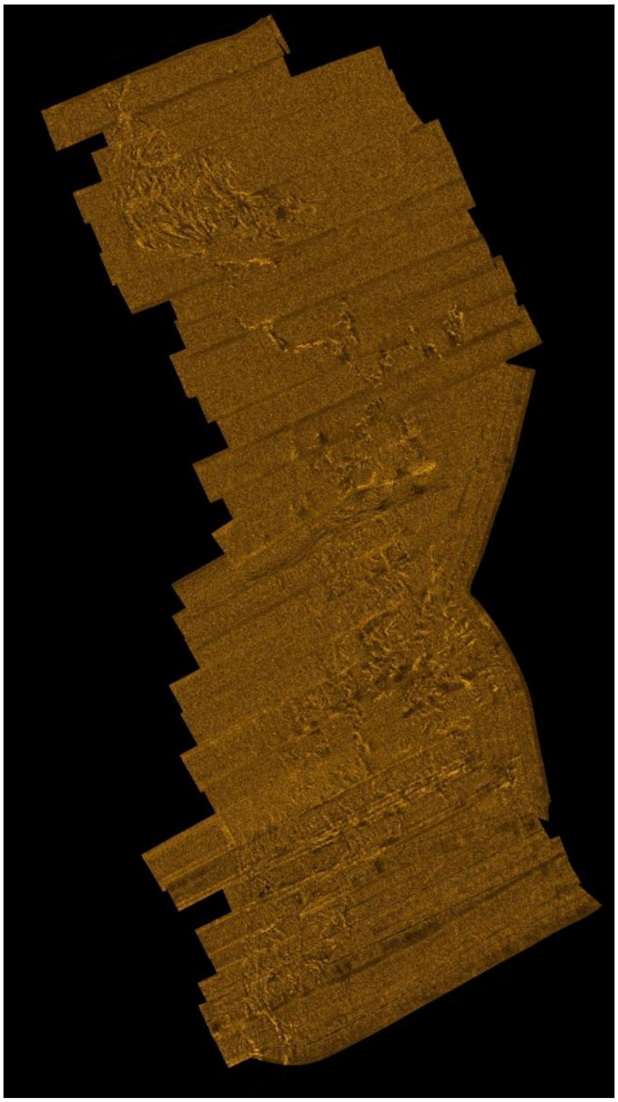

Figure 6: Side-scan 2D bathymetric image of East Bank Ridge showing the shadow casting used to identify areas appropriate for surveying.

Fish Community

Visual Surveys

A total of nine fish species were identified at EBR and fifteen fish species were identified at SB (Table 1). Nine of the species were identified at both of the sites. As expected in the first hypothesis for Objective 2, SB had six species not seen at EBR, and all species identified at EBR were present at SB even with an additional 13 minutes of video footage per camera at EBR.

Table 1: Fish species identified for East Bank Ridge and Sebree Bank Reef in the Gulf of Mexico. Collected from ROV visual surveys between July and September 2023.

East Bank Ridge		**Sebree Bank Reef**	
Common name	**Scientific name**	**Common name**	**Scientific name**
Red Snapper	*Lutjanus campechanus*	Red Snapper	*Lutjanus campechanus*
Grey Snapper	*Lutjanus griseus*	Grey Snapper	*Lutjanus griseus*
Grey Triggerfish	*Balistes capriscus*	Grey Triggerfish	*Balistes capriscus*
Barracuda	*Sphyraena barracuda*	Barracuda	*Sphyraena barracuda*
Goby spp.	*Gobidae spp.*	Goby spp.	*Gobidae spp.*
Cubbyu	*Pareques umbrosus*	Cubbyu	*Pareques umbrosus*
Atlantic Spadefish	*Chaetopdipterus faber*	Atlantic Spadefish	*Chaetopdipterus faber*
Pinfish	*Lagodon rhomboides*	Pinfish	*Lagodon rhomboides*
Bandtail Pufferfish	*Sphoeroides spengleri*	Bandtail Pufferfish	*Sphoeroides spengleri*
		Lookdown	*Selene vomer*
		Lesser Amberjack	*Seriola fasciata,*
		Spotfin Butterflyfish	*Chaetodon ocellatus*
		Blue Runner	*Caranx crysos*
		Blue Angelfish	*Holacanthus bermudensis*
		Cocoa Damselfish	*Stegastes variabilis*

Hydroacoustic Surveys

As expected, the hydroacoustic surveys showed SB had higher scaled fish abundance measurements in all categories when compared to EBR (Table 2). Site differences of depth, relief, and volume surveyed were calculated for the nine transects run at each site (Table 2). At SB, 809 individual fish tracks and 18 schools were identified. A total of 1112 fish tracks and 32 fish schools were detected at EBR. Total fish NASC (*SB*=3620.77, *EBR*=1742.23) when scaled to area was more than double at SB and total biomass NASC (*SB*=333923.6, *EBR*=80831.4) when scaled was over four times higher at SB. SB also had greater counts per km^3 for fish tracks and schools, as expected (Table 2).

Table 2: Fish abundance and abiotic characteristics determined through split-beam and single-beam acoustic surveys at Sebree Bank Reef (SB) and East Bank Ridge (EBR).

Category		**SB**	**EBR**
Abiotic variables	Area of site (km^2)	19.7	84.8
	Volume surveyed (km3)	0.0931	0.2356
	Total number of 10m transects	4285	7880
	Depth range (m)	29.3-36.9	36.1-42.1
	Vertical relief max (m)	7.6	6.0
Fish abundance per $0.1km^3$	Fish tracks	869	472
	Fish Schools	19	14
	Total fish NASC	3620.77	1742.23
	Total biomass NASC	333923.595	80831.4385

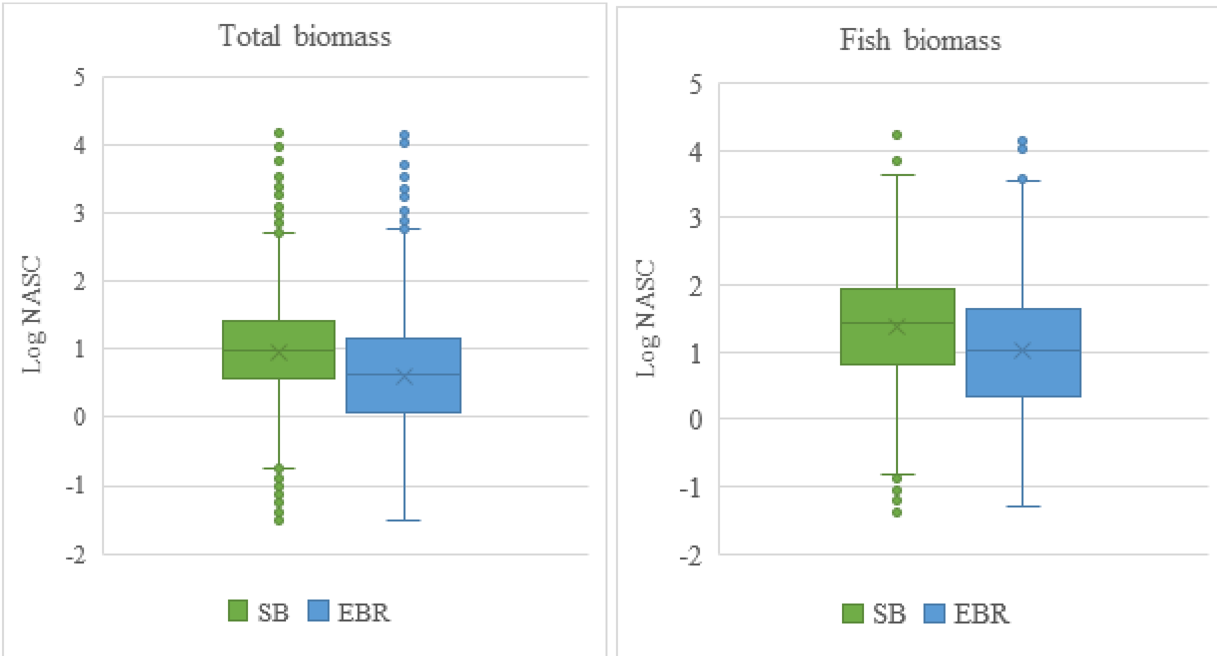

Figure 7: Mean log10 NASC values from 10 m cells of the hydroacoustic echogram for total biomass and fish biomass across the two study sites: East Bank Ridge (EBR) and Sebree Bank Reef (SB).

Log-transformed (Log10) means of total biomass NASC (*SB: M*=0.963, *SD*=0.714, *EBR:M*=0.589, *SD*=0.815) and fish biomass NASC (*SB: M*=1.37, *SD*=0.879, *EBR:M*=1.01, *SD*=0.945) per 10 m transect were significantly higher at SB than at EBR (total biomass: $t(9872) = 25.9$, $p = <0.001$, fish biomass: $t(1323) = 7.26$, $p = <0.001$) (Fig. 7). The estimated length of individual identified fish tracks was significantly longer ($t(1622) = 5.55$, $p = <0.001$) at SB (*M*=0.332, *SD*=0.227) than at EBR (*M*=0.276, *SD*=0.201) (Fig. 8).

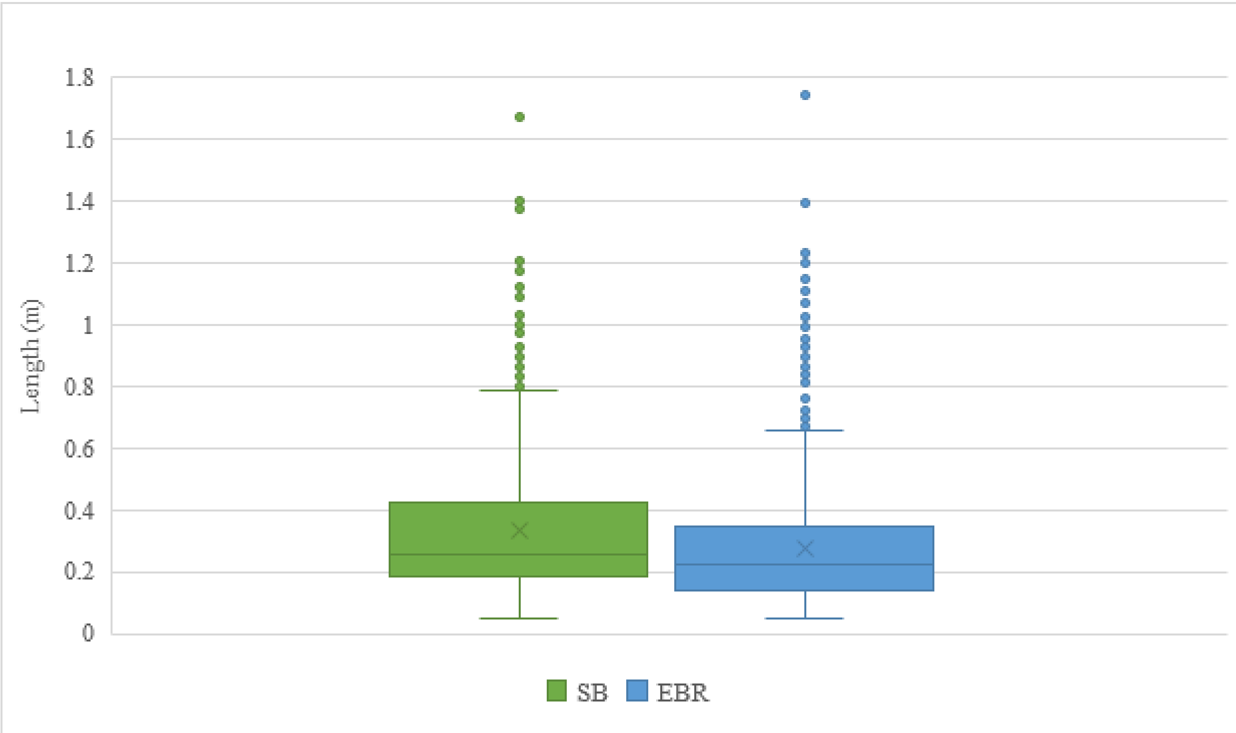

Figure 8: Length of individual fish estimated from 38 kHz split-beam sonar data across the two study sites: East Bank Ridge (EBR) and Sebree Bank Reef (SB). Length estimates were calculated using the Love (1971) dorsal-aspect equation with the maximum target strength of individual fish tracks.

All predictor variables (vertical relief, bottom hardness, and bottom rise time) were retained in the final GAMMs for presence of total biomass, presence of fish biomass, and for the log transformed NASC of fish biomass per 10 m cell surveyed. EBR had 25% lower mean vertical relief across all 10 m cells and 6% lower for cells identified to have fish present. Bottom hardness and rise time were higher at EBR for both models but had less than a 5% change between the sites (Table 3).

Table 3: Mean values of the predictor variables retained in the generalized additive mixed models. Models were fitted for presence of total biomass and fish (presence models) and NASC values of 10 m cells where fish were identified (Fish NASC model) for both of the sites used in this study: East Bank Ridge (EBR) and Sebree Bank Reef (SB). SD = standard deviation.

	EBR		SB	
	Mean	SD	Mean	SD
Presence models				
Vertical relief	2.0471	1.1163	2.7128	1.5465
Bottom hardness	7.6573	0.3395	7.6198	0.4812
Bottom rise time	0.4587	0.0941	0.4370	0.2106
Heading	171.36	70.844	182.03	110.66
Fish NASC model				
Vertical relief	2.5900	1.6359	2.7366	1.4779
Bottom hardness	7.8272	0.3822	7.7389	0.5083
Bottom rise time	0.4553	0.1251	0.5094	0.2732
Heading	169.76	74.061	188.20	98.838

The final presence and absence GAMM models accounted for 21.2% deviance explained (DE) for total biomass and 11.6% DE for fish biomass. In both the presence of total biomass and fish models, all predictor variables were significant, and AIC increased/ DE decreased with the removal of each variable (Table 4).

Table 4: Predictor variables retained in final generalized additive models for presence and absence of total biomass and fish and fish biomass NASC values per 10 m cells. Variables associated with seafloor characteristics include relief, hardness and rise time. The heading variable accounts for variation in direction between the 10m cells. The percent deviance explained (DE) and Akaike's Information Criterion (AIC) value are given for each of the final models. The change in AIC (Δ AIC) and change in DE (Δ DE) when each variable was removed from the final model are provided as a measure of the relative importance of each variable.

	Presence: Total biomass		**Presence: Fish**		**Fish NASC**	
	AIC= 8167.35	DE=21.2%	AIC=7642.03	DE=11.6%	AIC=5854.34	DE=6%
Variable	**Δ AIC**	**Δ DE**	**Δ AIC**	**Δ DE**	**Δ AIC**	**Δ DE**
Vertical relief	157.675	1.8	450.39	4.9	12.855	1.6
Bottom hardness	202.919	2.2	165.958	2.1	1.313	0.33
Bottom rise time	127.335	1.5	5.184	0.2	-1.255	0.02
Heading	451.238	5	72.541	1.1	14.186	2.03

In the total biomass model, heading had the greatest influence on presence (Δ AIC=157.675, Δ DE= 5%), while hardness (Δ AIC=202.919, Δ DE= 2.2%) and relief (Δ AIC=157.675, Δ DE= 1.8%) were the most influential seafloor characteristics in this model (Table 4). According to the response plots, biomass presence was positively associated with hardness values above 8.5 at SB and 8.75 EBR with slight fluctuations in moderate (7-8.5) hardness measures (Fig. 9). Biomass presence was more likely in relief greater than 3m at SB and greater than 5m at EBR (Fig. 9). Rise time showed the least influence on biomass presence (Δ AIC=127.335, Δ DE= 1.5%) and response plots showed a slight positive association with values of rise time over 1.5 at both sites (Fig. 9).

In the fish presence model, vertical relief was most influential on fish presence (Δ AIC=450.39, ΔDE =4.9%). Response plots showed fish were more likely to be present where relief was over ~3.5m at EBR and at 5m the magnitude of the partial effect more than doubled and continued to increase with increased relief. The relationship of presence and relief was more complicated at SB. Fish presence was most likely at ~1 m, 2.5 m, and 5.5 m at SB with a negative association of fish presence expected at over 5.5 m, contradictory to the trend seen at EBR (Fig. 10). Hardness was the next most influential variable on fish presence (Δ AIC=165.958) where response plots showed a presence to be more likely at higher hardness values at SB (7.5-8.5) and EBR (~8). However, a negative association on fish presence was seen at hardness values exceeding 8.5 at SB. At EBR, the hardness response plot showed a trend of fish presence being more likely as hardness increases (Fig. 10). As with the total biomass model, rise time had little influence on the model (Δ AIC=5.184) and showed little association within the response plots for both sites (Fig. 10).

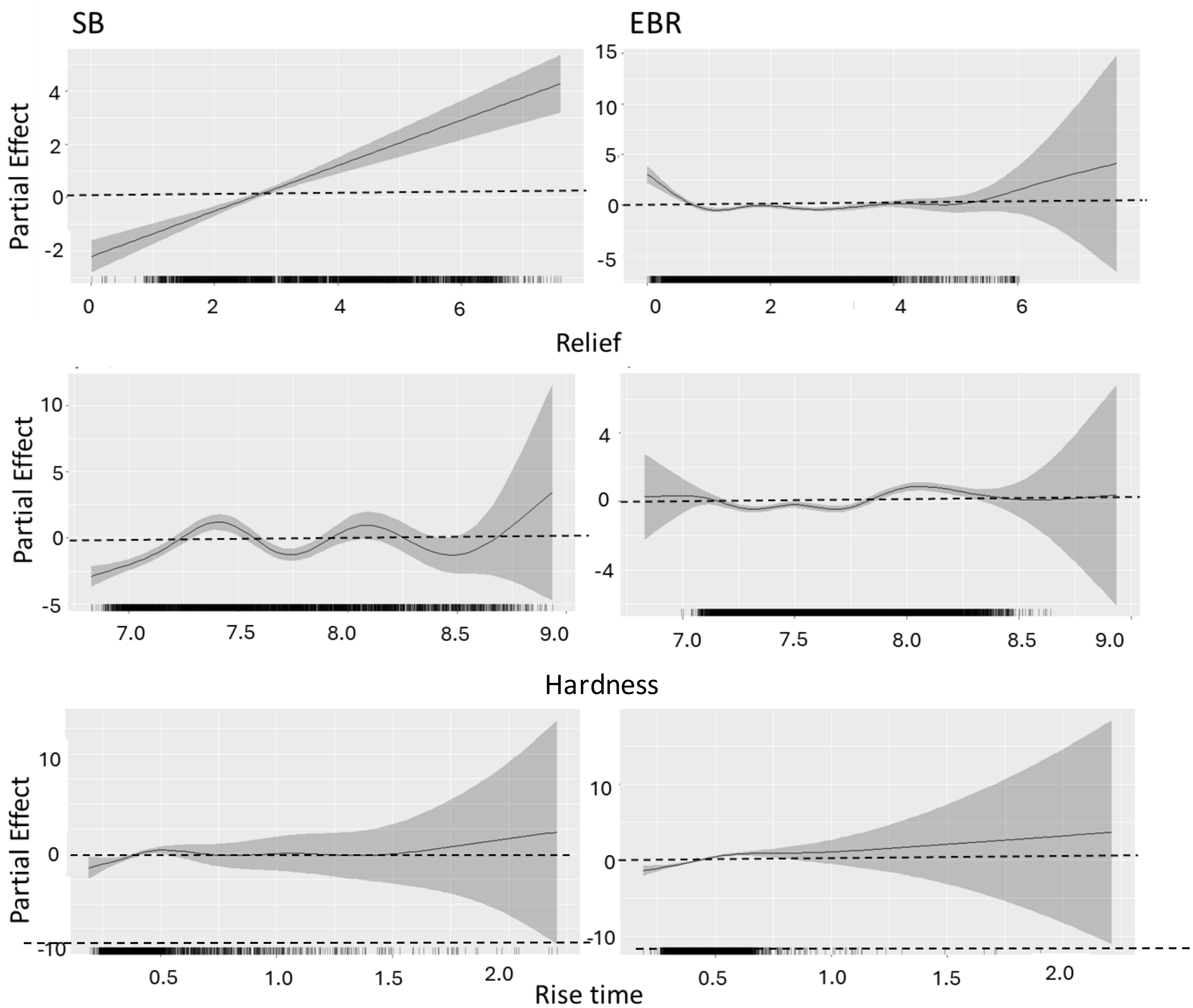

Figure 9: Biomass Presence Generalized Additive Mixed Model. Partial effect plots of the seafloor characteristics retained as predictor variables in the generalized additive model showing influence of relief, bottom hardness, rise time, and heading on the presence of total biomass across the two study sites: Sebree Bank (SB) and East Bank Ridge (EBR). Solid trendlines represent the smoothed partial effect and the y-axis shows the contribution of the smoother. Grey shaded areas show 95 % confidence intervals, dashed lines at y = 0 represent no effect by the smoother, and bottom lines represent the fitted values.

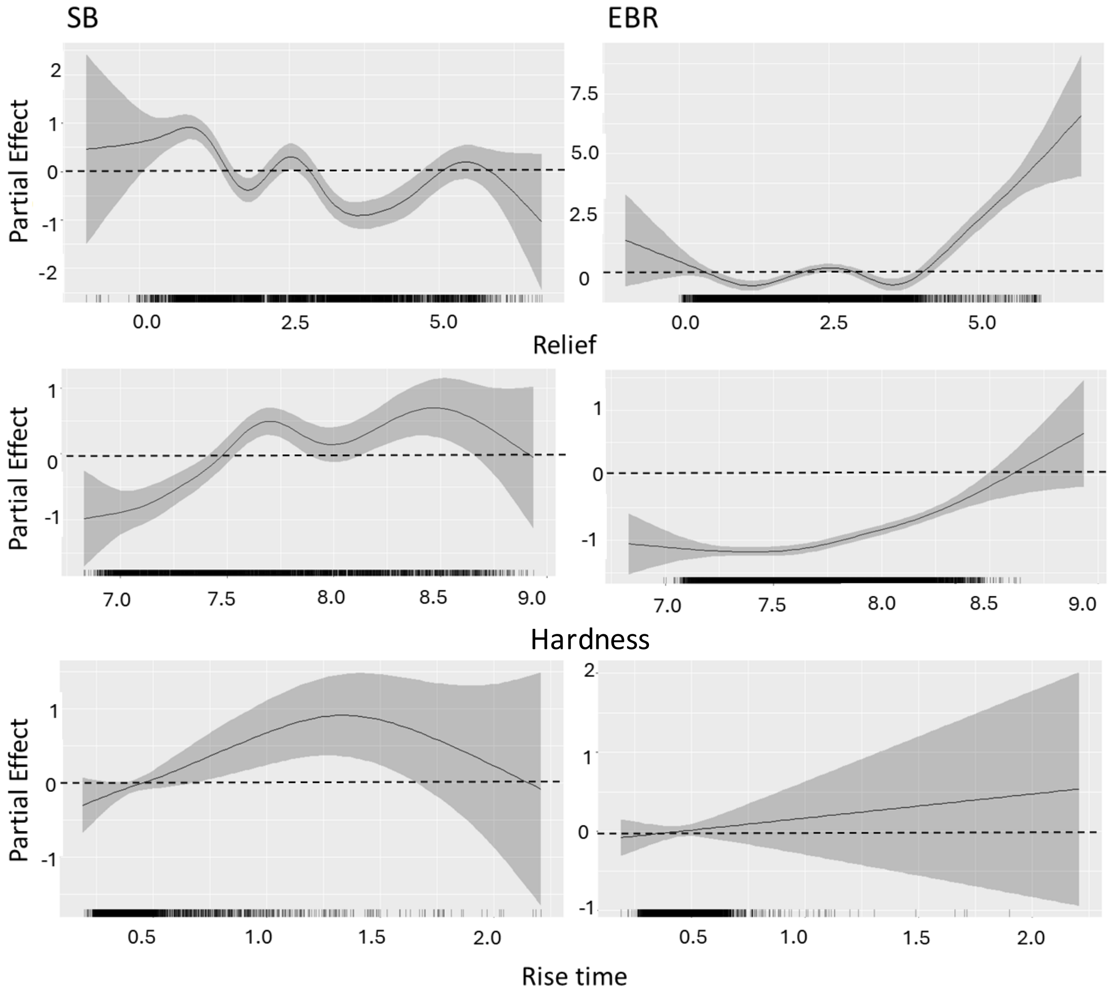

Figure 10: Fish presence Generalized Additive Mixed Model. Partial effect plots of the seafloor characteristics retained as predictor variables in the generalized additive model showing influence of vertical relief, bottom hardness, bottom rise time, and heading on the presence of fish across the two study sites: Sebree Bank (SB) and East Bank Ridge (EBR). Solid trendlines represent the smoothed partial effect and the y-axis shows the contribution of the smoother. Grey shaded areas show 95 % confidence intervals, dashed lines at y = 0 represent no effect by the smoother, and bottom lines represent the fitted values.

The model of NASC fish biomass values had the lowest DE (6%) indicating the predictor variables had minimal influence on the relative fish density. During model building, rise time showed no significance in the model and when removed did show a lower AIC (5853.08) but the DE was higher in the full model (Δ DE= 0.02). A Δ AIC under two units can be considered negligible (Burnham and Anderson 2004, Gilliland et al. 2023), so the complete model was retained for analysis. Hardness (Δ AIC=1.313, ΔDE= 0.33%) and rise time (ΔAIC -1.255, ΔDE= 0.02%) still showed negligible influence on the model. Heading showed the greatest influence (Δ AIC=14.186, ΔDE= 2.03%) and relief was the most influential seafloor characteristic (Δ AIC=12.855, ΔDE= 1.6%). Response for relief at SB showed density estimates were only positively associated with relief less than 2 m, while at EBR the trend showed a nearly linear increase in fish NASC with increasing relief (Fig. 11).

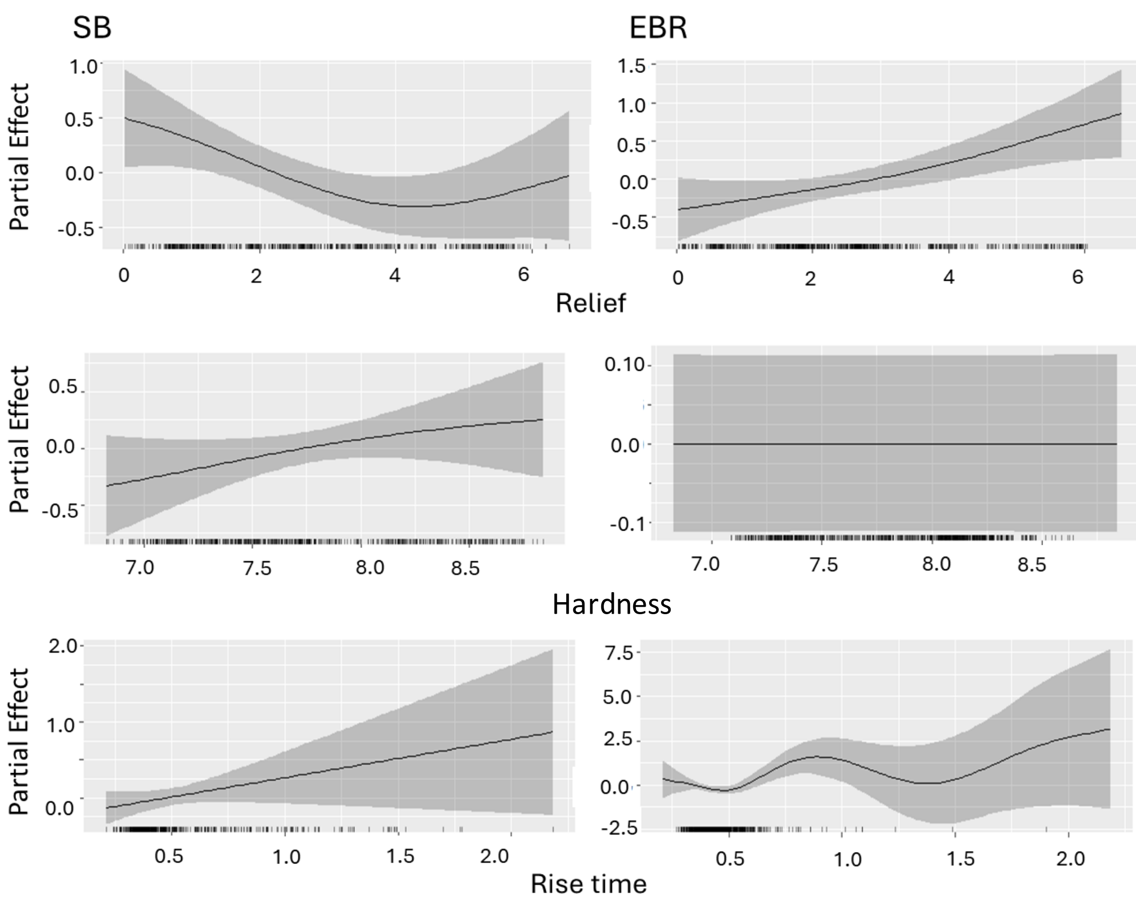

Figure 11: Fish biomass Generalized Additive Mixed Model. Partial effect plots of the seafloor characteristics retained as predictor variables in the generalized additive model showing influence of vertical relief, bottom hardness, bottom rise time, and heading on log transformed mean fish NASC values from 10 m cells of the hydroacoustic echogram across the two study sites: Sebree Bank (SB) and East Bank Ridge (EBR). Solid trendlines represent the smoothed partial effect and the y-axis shows the contribution of the smoother. Grey shaded areas show 95 % confidence intervals, dashed lines at y = 0 represent no effect by the smoother, and bottom lines represent the fitted values.

East Bank Ridge Fishery Questionnaire

Fishing history and activity

The largest percentage of respondents were anglers who had fished in the area for over five years (86.9%). Most respondents identified as recreational or sport fishermen (85.9%), with only 14.3% having experience in shrimping and 7.9% participating in commercial fishing. A majority of respondents (62.5%) said they had been fishing at EBR over 6 years ago and 72.5% said their most recent visit to EBR was within the last five years. The 40 respondents who answered that they had been fishing at EBR for 6-10+ years were further analyzed.

Fish Presence and Abundance

Respondents indicated their average catch rate, catch per unit effort (CPUE) of Red Snapper, and most common size of Red Snapper changed significantly between the first time they visited EBR and their most recent visit to EBR. The average total catch was significantly different from the first to the most recent visit (Wilcoxon signed- rank Z= -2.94, p=0.03, Fig. 8), where 42% of respondents caught 10+ fish at their first visit and only 18% caught 10+ fish at their most recent visit. The reported CPUE of Red Snapper significantly changed (Wilcoxon signed- rank Z= 2.84, p=0.05) between respondent's visits (Fig. 9), with 69.25% of respondents indicating CPUE was high or very high at their first visits, while 37.5% indicated CPUE was low or very low at their most recent visits. The size of Red Snapper on average changed significantly (Wilcoxon signed- rank Z= -2.27, p=0.023) when respondents compared differences between the time of their visit (Fig. 10). Approximately 30% of respondents indicated that the majority of red snapper caught were over 24 inches in length at their first visit to EBR. At the most recent visit, only 4% of respondents indicated the most common size caught was over 24 inches.

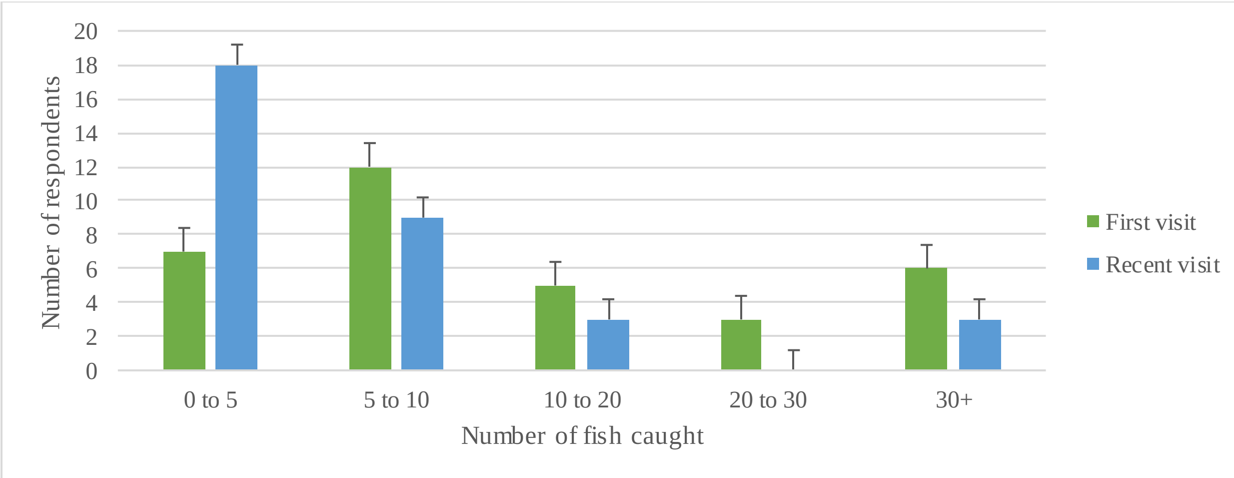

Figure 12: Average number of fish caught according to individual respondents fishing 6-10+ years (N=40) at their first visit and their most recent visit to EBR.

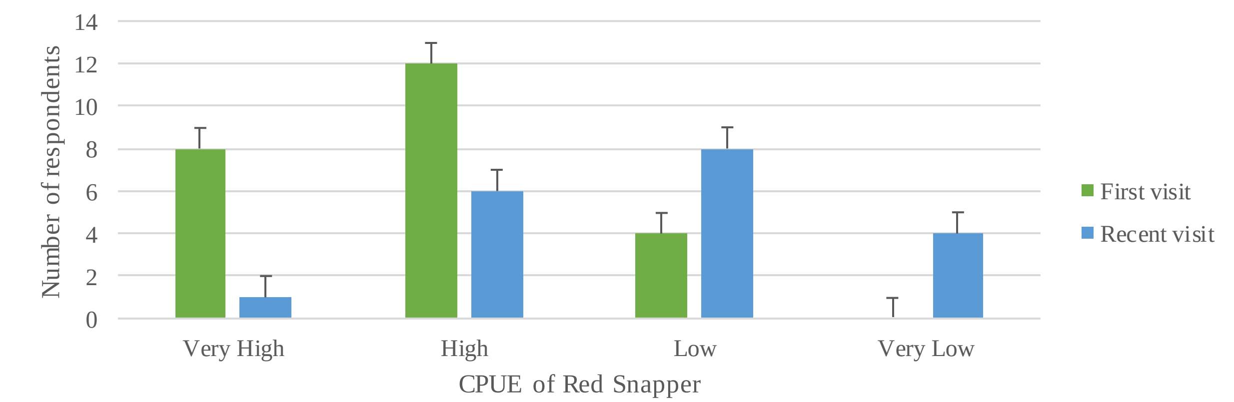

Figure 13: Catch per unit effort (CPUE) of Red Snapper according to individual respondents fishing 6-10+ years (N=40) at their first visit and their most recent visit to EBR

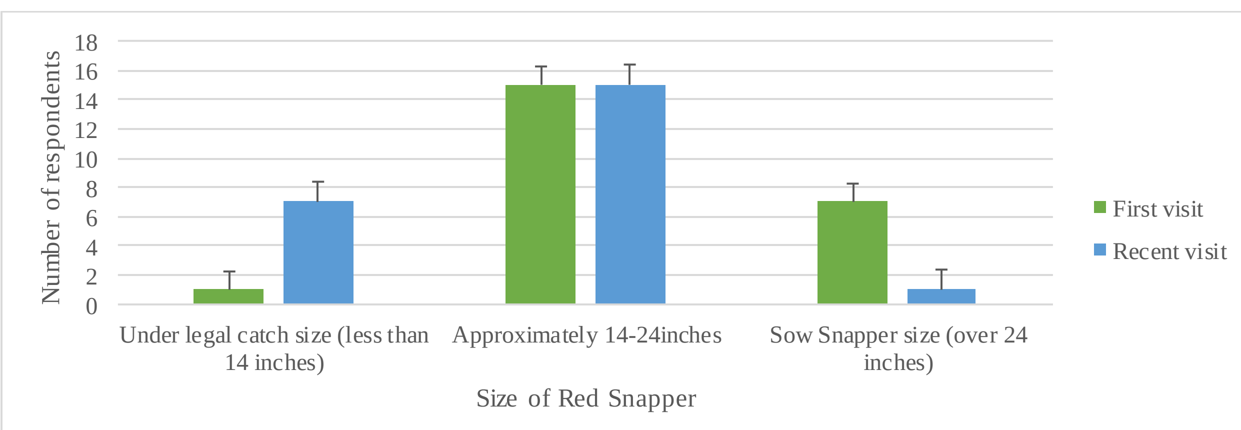

Figure 14: The most commonly measured size of Red Snapper caught according to individual respondents fishing 6-10+ years (N=40) at their first visit and their most recent visit to EBR

Respondents indicated there were no signifcant differences in the species of fish most commonly caught when assessed across the same time scale of first versus most recent visit to EBR. Respondents ranked order the most common species of fish they caught from a provided list (Red Snapper, grey Triggerfish, Grouper, Amberjack, Dolphinfish, Bonito, shark species, tuna species, other) and Red Snapper was identified as most common, followed by Dolphinfish (Fig. 15). The summed score for each respondent showed all listed species except shark and Triggerfish were less common at the most recent vists (Fig. 15).

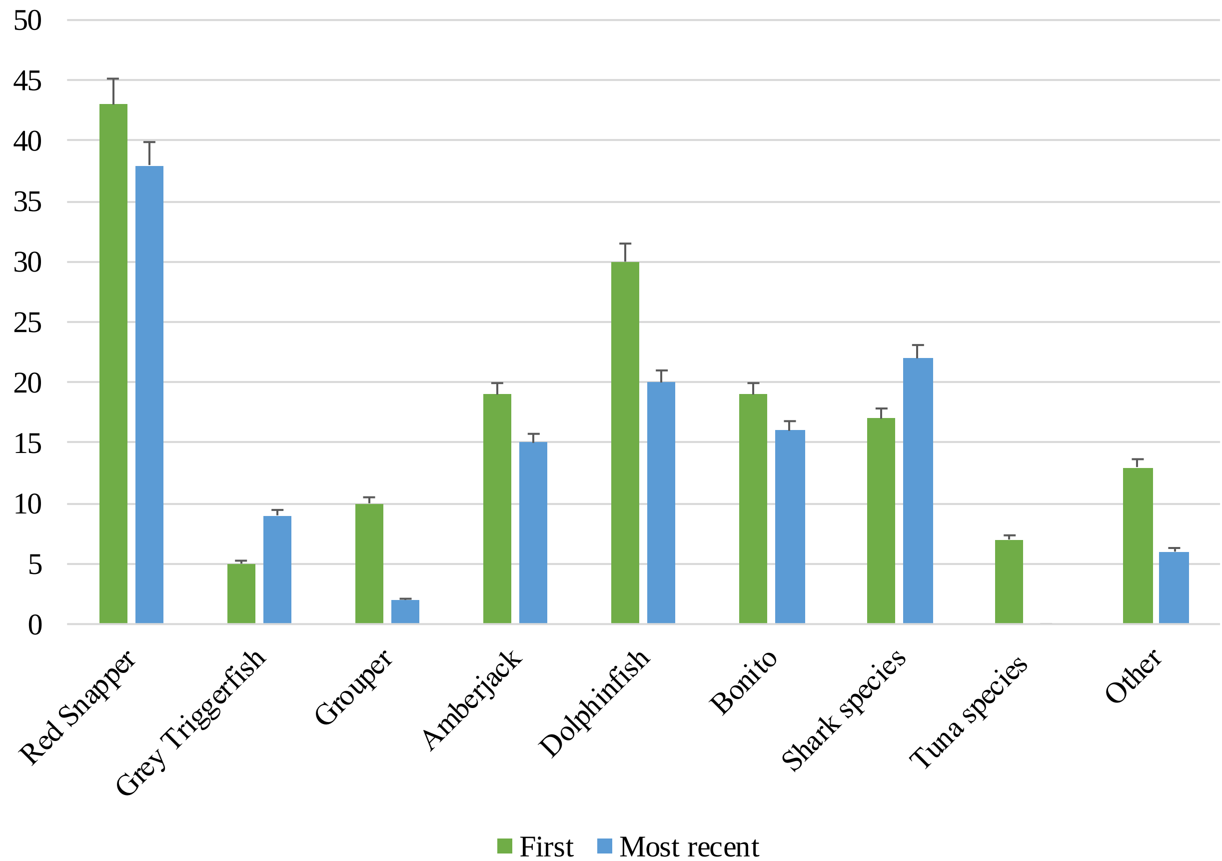

Figure 15: The total rank score for each provided fish species ranked by how commonly the species was caught by respondents for their first and most recent visit to EBR. Respondents were asked to choose from the listed species on the x-axis and rank, in order their, top three most common fish species caught at EBR for their first and most recent visits separately. Total ranks were determined based on the sum of the rank score they were assigned (first most common= 3, second= 2, third =1).

Mann- Whitney U test run per species revealed there were no significant differences in the species rank by the time of visit to EBR (Table 5).

Table 5: Results of individual Mann-Whitney U test for each species provided for most common species caught at EBR according to questionnaire respondents. Tests compared most common species across respondent's first and most recent visit to EBR. Value of significance *($p \leq 0.05$)*. Rank difference is the difference between the total rank score calculated for each fish species from the most recent visit subtracted from the first visit to EBR.

Species	**Rank difference**	**p-value**
Red Snapper	5	0.628
Grey Triggerfish	- 4	0.292
Grouper	8	0.092
Amberjack	4	0.589
Dolphinfish	10	0.303
Bonito	14	0.611
Shark species	-5	0.360
Tuna species	7	0.927
Other	7	0.285

The majority of respondents identified no change in commonality for all fish species choices provided. There were no significant differences in species changes from first and intitial visits to EBR according to questionairrie respondents (Figure 12). Red Snapper had the largest percentage change and 25% of respondents reported a perceived decrease in Red Snapper.

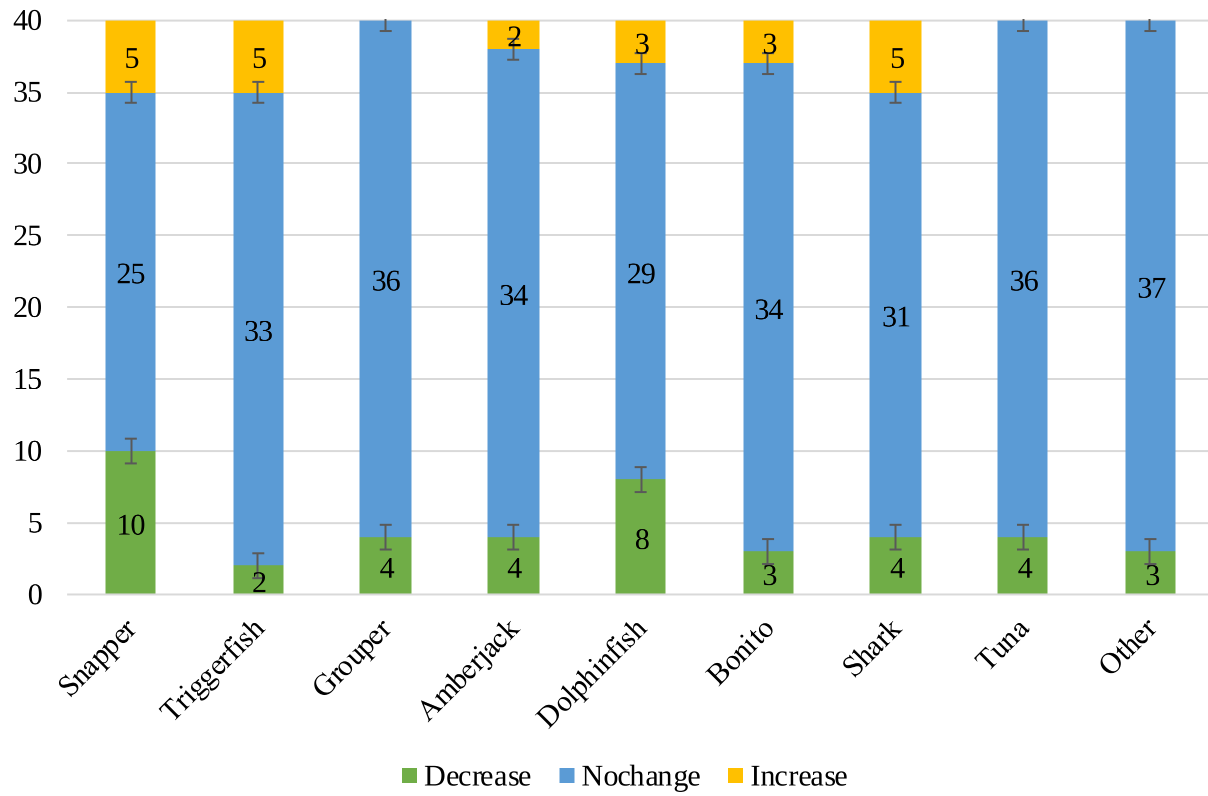

Figure 16: Type of change (decrease, no change, increase) per individual respondent for most common species of fish caught at EBR across time of visit. "Decrease" is defined as ranking the fish species to be more common at the first visit compared to the most recent visit. "No change" is defined as no change in fish species commonality across visits. "Increase" is defined as ranking the fish species as less common at the first visit compared to the most recent visit to EBR.

When asked if they believed fish abundance at EBR has decreased, increased, or remained the same from their first to last visit to EBR, over half of the respondents that answered said abundance had decreased (53%). The respondents who answered that abundance had decreased (*N*=17), ranked the level of significance of the four listed possible degradation sources (Fig. 13).

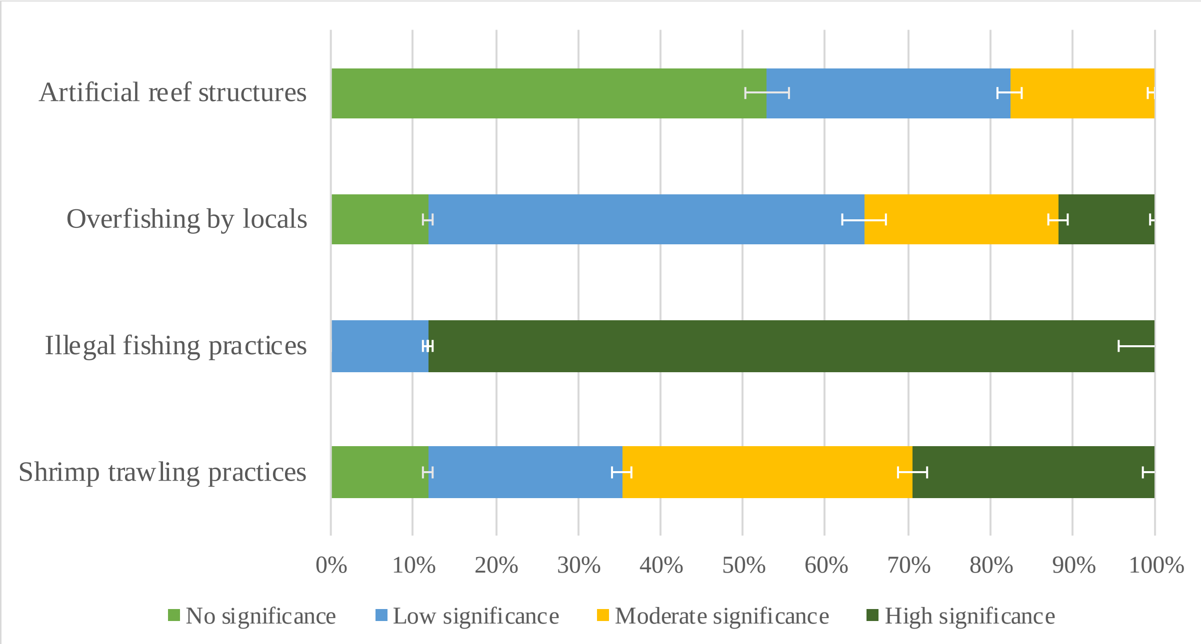

Figure 17: The percentage of respondents (N=17) who ranked each level of significance for the four possible sources of degradation listed to the study site: East Bank Ridge. The respondent pool was isolated to those fishing at EBR for 6-10+ years and identified a decrease in fish abundance at EBR from their first to most recent visits.

The Kruskal-Wallis test revealed there were significant differences in the perceived effects of the four degradation sources listed ($X^2 = 33.514$, p = <0.001). The six comparisons showed illegal fishing practices were ranked significantly higher in impact level compared to the three remaining sources (Table 6).

Table 6: Pairwise comparisons of the four listed degradation sources in the EBR fishery questionnaire using Dunn's (1964) procedure with a Bonferroni correction. Value of significance *($p \leq 0.05$)*. Median rank difference is the difference between median scores for each source.

Source of degradation	**Median rank difference**	**Sig.**	**Adj. Sig.**[a]
Artificial reefs and Local overfishing	1	0.068	0.409
Artificial reefs and Shrimp trawling	2	0.003	0.016*
Artificial reefs and Illegal fishing	3	0.000	0.000*
Local overfishing and Shrimp trawling	1	0.239	1.000
Local overfishing and Illegal fishing	2	0.000	0.001*
Shrimp trawling and Illegal fishing	1	0.008	0.050*

CHAPTER IV

DISCUSSION

Current Status of East Bank Ridge

The results of this study provide the first assessment of East Bank Ridge's present state as a fishery. Overall, estimates of relative fish density obtained from the hydroacoustic surveys suggest that East Bank had fewer fish per scaled volume than Sebree Banks (SB) and according to local anglers, fish abundance has decreased since their initial visits to EBR. Perceptions from local anglers indicate this could be in part due to the increase in illegal fishing practices in this area over the last decade. This is consistent with the findings that SB may support higher fish abundance and diversity, as the site is further north and therefore exposed to less illegal fishing pressure. The comparison of fish abundance related to seafloor characteristics at EBR showed that vertical relief had the greatest influence on fish presence. The likelihood of fish presence at EBR increased with higher relief measures which is consistent with similar studies of other reefs in the GoM (Streich et al. 2017, Garner et al. 2019, Gilliland et al. 2023). This was further supported as relative fish density also increased with relief measures. The base mapping and initial surveying provide baselines for locations of structures, fish diversity, and relative biomass estimates at EBR that can be used in future studies and comparisons of the site and the fishery questionnaire indicated a need for possible management or protective intervention at EBR.

Fish Community

Few high relief structures were mapped at EBR, and structures appeared to be sparsely spread throughout the study area when compared to relatively concentrated areas of relief at SB indicating a larger percentage of hard bottom habitat is present at SB. The maximum vertical relief for SB was 1.6 m greater than at EBR, however mean values of vertical relief across the surveyed transects did not differ greatly between the two sites indicating the average bathymetric relief was similar.

As expected, more fish species were identified at SB and no fish was identified at EBR that was not also seen at SB, indicating similar species overlap. The species identified at both sites are consistent with those documented at artificial reefs in the same area of the GoM (Bollinger and Kline 2017, Angerer 2022) and the neighboring South Texas Banks (Dennis and Bright 1988, Hicks et al. 2014, Thomspon- Grim 2020). Although visibility limitations did not allow for visual counts of fish in relation to identified structures, the visual surveys provided the first list of identified fish species at EBR.

Hydroacoustic survey analyses supported the hypothesis that SB would have greater fish abundance than EBR. Fish counts and biomass estimates when scaled to the area surveyed, were greater at SB than at EBR, indicating a larger population of fish at SB. This was further supported by significantly higher mean values of NASC at SB for both total and fish biomass estimates per 10 m cell. These findings are consistent with previous research that shows a greater concentration of fish will be associated with hard bottom substrate in this area of the GoM (Garner et al. 2019, Thompson-Grim 2020, White et al. 2022).

Fish size estimates were also significantly higher at SB. This indicates SB may support larger sized fish on average when compared to EBR. This is consistent with other studies that have shown fish size based on TS measurements decreases with proximity to reef habitat in the northern GoM (Boswell et al. 2010, Dance and Rooker 2017, Bolser et al. 2022). Previous studies comparing fish abundance at artificial and natural reefs within this area of the GoM have found that smaller reef associated fish species are more abundant at natural reef sites, while larger fishery important species such as Red Snapper tend to have higher densities associated with artificial reef sites (Patterson et al. 2014, Streich et al. 2017, Garner et al. 2019). It is important to note that these sizes are generalized estimates and TS is influenced by the presence or absence of a swim bladder in fish, as well as their orientation to the transducer (Foote 1980, Simmonds and MacLennan 2008). While most fishery important species such as Red Snapper have swim bladders, further ground truthing could aid in determining more accurate size measurements for other species.

The association between fish abundance and marine habitat characteristics is well known and documented in the GoM, especially regarding reef associated fish species (Bright and Rezak 1978, Dennis and Bright 1988, Nash et al. 2013, Spies et al. 2016). Within the northern GoM, fishery important species such as Red Snapper and other reef associated fish species have shown preference for complex habitat and reef structure (Dennis and Bright 1988, Gledhill 2001, Lingo and Szedlmayer 2006) associated with varied seafloor characteristics such as relief (Lara and Gonzalez 1998, Garner et al. 2019, Switzer et al. 2020) and hardness (Bejarano et al. 2011). However, the relationship between fish abundance and seafloor characteristics across SB and EBR was more nuanced and harder to interpret.

The presence of fish was most influenced by vertical relief at EBR, and this was a significant factor across all three models. The association between vertical relief and the density of reef-associated fishes within other natural reef systems of the GoM has been established with hydroacoustic surveys, where areas of highest relief support the greatest relative density of fish biomass (Langland 2015, Garner et al. 2019, Thompson- Grim 2020, White et al. 2022). Only the model of biomass presence followed this trend across both sites, but an increase in fish presence and abundance with higher relief was seen at EBR and is consistent with the pattern associated with relief observed at nearby artificial reefs within the northern GoM (White et al. 2022). In the fish presence model, vertical relief had the strongest influence on both sites, but SB did not show a direct increase in likelihood of fish with increased relief. Gilliland et al. (2023) found that at artificial reefs, the relationship between relative fish density to area and isolation may have a threshold of values, where density estimates increased to a certain point but decreased again at maximum values of area and isolation. The fish presence model indicated a similar threshold of vertical relief may be present at SB, and further comparisons are required to determine a trend. In the same study of artificial reefs, relief was shown to explain over 20% of the pattern associated with relative fish density at sites in North Carolina (Gilliland et al. 2023) and only 1.6% in this study, indicating there are other environmental factors that could be influencing fish presence and abundance at EBR.

Hardness and rise time as defined in these models were used to measure traits associated with possible reef habitat and are similar to measures of habitat complexity such as hardness and slope used in previous studies (Bejarano et al. 2011, Cutter and Demer 2014, Thomspon- Grim 2020). These studies also yielded complex interactions between hardness, slope, and fish presence/ abundance, but determined they are useful measures when describing habitat complexity (Bejarano et al. 2011, Thomspon- Grim 2020). Habitat complexity has been shown to have a positive correlation to fish presence and abundance in other natural reefs of the GoM (Langland 2015, Garner et al. 2019), although this was not obvious in the models developed here. Hardness was a significant factor in all models of this study and the likelihood of fish presence was associated with higher hardness, although the deviance explained in the model was low. Bejarano et al. (2011) found this measure of hardness was a significant predictor in the presence and abundance of a variety of reef associated fish species, especially those that were most common at the site, though this was not apparent at EBR. SB showed a more consistent trend of increased fish presence and density with higher levels of hardness. Rise time had a significant influence on biomass and fish presence but explained less than 2% of the pattern in both models. In the fish presence model, a possible threshold to both hardness and rise time was present at SB, while EBR showed an increase in likelihood of fish presence at increased levels of both the predictor variables. This could be due to limited observations at the higher values of hardness and rise time or indicate other structural characteristics may be associated with fish presence.

The most influential factor in the biomass presence model was the heading covariate indicating the seafloor characteristics have minimal influence on overall biomass presence. This is important to consider because heading was used to account for variation in the transect directions across both sites, but heading can also be associated with other factors such as current flow when measuring fish backscatter (Becker et al. 2023).

Fishery Characterization by Local Community

A majority of respondents to the questionnaire identified a perceived decrease in fish abundance and a concern for the fishery at EBR. Studies using similar questionnaires have identified concerns and threats to small-scale fisheries that can be used to promote or inform management actions (Carr and Heyman 2012, Griffin et al 2023, Bower et. al 2024). Individual accounts and personal reflections from anglers and shrimpers were also telling as their perceptions were not in agreement with each other.

As expected, the participants who had been fishing at EBR for over five years indicated that the catch rate and CPUE of Red Snapper significantly changed since their first visit to EBR, with more respondents indicating more abundant average catch numbers during their initial visits. Participants indicated that the size of Red Snapper has also significantly changed, with more respondents indicating larger size catches occurred more at their initial visits. This finding supports a perceived degradation of the Red Snapper fishery at EBR. With the lack of past scientific data collection on size and abundance of Red Snapper at this site, a decline of the Red Snapper fishery was difficult to quantify over this timescale, but this provides insight into how the people who commonly utilize the local fishery perceive the status of fish stocks at this site. Other studies have shown using LEK in local or small-scale fisheries can accurately inform changes in fish stocks and inform management for specific species (Beaudreau and Levin 2014, Macdonald et al. 2014, Martins et al. 2018, Mederios et al. 2018).

The focus on Red Snapper when assessing abundance and size within this survey can create a biased view of the fishery as a whole. Due to the commercial importance of Red Snapper locally (Cowan et al. 2011), it was best used as an indicator species for abundance as they are a primary targeted fish species that require measurements when caught (Hood et al. 2007). The abundance metrics and size changes were limited to Red Snapper for the purpose of this study as several studies have shown that this species makes up the majority of fish abundance associated with neighboring sites and other STBs (Hicks et al. 2014, Langland 2015, Streich et al. 2017, Garner et al. 2019, Thompson- Grim 2020, Angerer 2022).

While there were no significant differences identified in commonly caught fish species, a perceived decrease in how often a species was caught was seen in all identified species except for Grey Triggerfish and shark species. Triggerfish and shark species were also the only two species that had more respondents indicating an increase in how commonly they were caught than a decrease or no change. This is consistent with the process of "fishing down the marine food web", where targeted fish species such as Red Snapper are overfished or less abundant, so the next most prevalent species are more frequently caught (Pauly et al. 1998). Red Snapper was shown to have the highest percentage of change with 25% of respondents indicating a decrease in their commonality. Garner (2018) found that Red Snapper made up 77% of reef associated fish species caught on recreational fishing charters during open season within the northern GoM, indicating this species is the most likely to be caught by recreational anglers if they are present at a site. These findings further support a perceived decline in the Red Snapper fishery but may also show the potential for shifting the targeted catch to other less desirable fish species such as sharks and triggerfish. Sharks and triggerfish are regulated fish species in the state of Texas and surrounding federal waters, but an apparent increase in these species can also impact angler perceptions of the Red Snapper fishery. When speaking to recreational and commercial fishers, many expressed the sentiment that recently they were catching an overabundance of Triggerfish, but this may just be related to a diminished Red Snapper stock. This could then continue to negatively impact Red Snapper stocks, as these species occupy similar niches and triggerfish have shown to be territorial (Simmons and Szedlmayer 2012, 2018). These types of insights can be further assessed and used to inform new management strategies and restrictions with local and federal agencies such as TPWD and NOAA that currently regulate shark and triggerfish catches (NOAA 2022, TPWD 2023). The popularity of the Red Snapper fishery further creates the opportunity for bias, as the catch-and-release process versus retaining “keeper” fish can influence angler perceptions of abundance on targeted species. Daw (2010) defines a memory bias associated with extreme catches that can exaggerate the trends perceived from LEK, as anglers are more likely to recall memorable events associated with larger fish catches than those that were released. (Orensanz et al. 2015).

There was also discrepancy in the most commonly caught fish species based on the type of fishing activity the respondent was said to have participated in. Recreational anglers identified Red Snapper and other fishery targeted species as the most often caught fish species, while the few respondents who said they participated in shrimping more often identified shark species and even added in whitefish as the most common species in the “other” category. Fishing gear and technique impacts the types of fish caught, so using personal accounts from specialized recreational anglers may not show the full picture of the fish diversity at the site. Increasing the respondent pool to include more shrimpers and other sampling methods should be considered in future studies to fully explore trends in species diversity (Rosa et al. 2014, Griffin et al. 2023, Bower et al. 2024).

Over half of the respondents fishing at the site for over five years agreed that overall fish abundance decreased since their first visits to EBR. These respondents further identified illegal fishing practices as the most significant source of degradation to EBR, as expected based on initial interactions with local anglers. The proximity to US-Mexico may have a large impact on this perception as witness reports and apprehensions have more than doubled over the past decade (Pala et al. 2018, NOAA 2021). Respondents were also asked to identify the number of times they personally had witnessed these types of practices and 50% of respondents had witnessed illegal fishing occurring, with 80% of those reporting they had witnessed this more than once. Personal accounts with respondents supported these responses as they claimed illegal fishing is their largest concern for the South Texas fishery, not just at EBR. Even during data collection and base mapping for EBR, we personally witnessed three shrimp boats actively trawling in the area and a fishing vessel being apprehended for illegal fishing. Recreational anglers also identified shrimp trawling practices to have moderate to high significance to the degradation of EBR. However, only two of the nine shrimpers who responded to the survey indicated a perceived decrease in fish abundance and both of those respondents listed shrimp trawling as having no significance to the degradation. When speaking directly to anglers and shrimpers about the degradation of the fishery at EBR, it was apparent there may be disagreement between the shrimping and recreational fishing community about the present status of the site.

Personal interviews with shrimpers and anglers revealed much stronger opinions about the local fishery and EBR than many of the questions in the questionnaire could formalize or quantify. When assessing LEK regarding a fishery, it is important to consider the reliability of the respondent, how valid their perception is, and their connection to the questions being asked. Maurstad et al. (2007) explained that reliability is the respondent providing information on what they know and believe to be true, while validity is how accurate the information the respondent provided represents a true testable relationship in the fishery. It has been shown that reliability and validity agree most when the respondent is rooted in daily routines and ample practical experience related to the fishery in question (Baelde 2007, Maurstad et al. 2007, Wiber et al. 2012). The criterion for the respondent pool in this questionnaire was isolated to familiarity with

EBR but was not limited by the amount of fishing activity or by number of visits to EBR. Further isolating the activity levels and amount of time fishing within the respondent pool could provide a more accurate depiction especially regarding specific species or diversity. For example, in a study looking at perceived status and threats to a local Atlantic Tarpon fishery, respondents with more days on the water and longer history of fishing the area perceived a greater decrease in abundance then those with less experience (Griffin et al. 2023). This is to be expected in small-scale fisheries such as EBR and needs to be considered when evaluating the perceptions of a fishery with only a small local population that is familiar with the site. There are many factors that can still be associated with these perceptions that can further be influenced by the social, economic, or political landscape associated with the fishery in question (Maurstad et al. 2007, Silvano et al. 2009, Orensanz et al. 2015).

There are inherent biases involved when analyzing LEK data in fisheries that must be considered. Orensanz et al. (2015) outlined one of the most prominent concerns for bias comes from the expectation that fishers will respond based on their vested interests in the matter. This is especially evident when interviews or questionnaires may have an influence on the regulations or opportunities present within the fishery (Daw 2010, Orensanz et al. 2015). This bias was likely observed between shrimpers and recreational anglers when asked about EBR. Recreational and sport fishers who depend on the Red Snapper fishery for their livelihood, or even just enjoyment, primarily identified the degradation of the snapper fishery to be apparent and associated illegal fishing practices as the main threat. This is consistent with their interests, as illegal fishing practices damage their business by diminishing the fish stock. Shrimpers on the other hand, are dependent on trawling practices that may cause damage to natural reef structures, such as EBR They could risk having increased restrictions or distaste from the local community about their practices if it was thought that trawling could be a contributing factor to the degradation of the fishery. The shrimp market in South Texas is already threatened by an increase of imported shrimp, and local shrimpers are currently in the throes of getting their voice heard to promote the local industry (Davila 2023, Qin 2023). Similar biases were seen in previous studies, where the type of fishing activity and even gear type influenced the significance of perceived threats in small-scale fisheries (Griffin et al. 2023, Bower et al.2024). This is important to consider in regard to the apparent decline at EBR and local fisheries in general.

Further Research

While this study provided a basic characterization of EBR on its structure, fish presence and abundance, and local perceptions from local anglers and shrimpers, the findings of this study prompt more questions into the status of the EBR fishery. One initial goal of this study was to obtain and test a sediment sample from EBR to determine the age and composition of the structures. Radiocarbon dating the structure could help determine if degradation at the site is simply based on its age and composition of the structure could help inform if other influences such as the proximity to the Rio Grande basin may have influenced the degradation of the site.

The base mapping can be used to isolate potential areas of study for additional diversity and abundance measures. Further visual surveys to include fish counts or MaxN such as those done on nearby artificial reefs (Ajemain et al. 2015, Angerer 2022) and similar natural reef sites (Patterson et. al 2014, Streich et al. 2017, Garner et al. 2019) would be informative to determine accurate diversity indices. However, the persistent nepheloid layer in this area and active shrimping activity make visual surveying difficult.

Additional surveys and interviews should be conducted regarding EBR and the surrounding fisheries to better understand all perspectives. Due to a limited pool of available respondents familiar with the specificity of the study site, the sample size for a diverse set of fishing activity was small. However, this was expected for such a small-scale fishery and could be further limited by accessibility and changes in the local fishing practices. With the progression and increased abundance of more fine-scale navigational and sonar mapping technology being used in fisheries over the last ten years, finding and isolating fish has become easier for anglers (Shelton et al. 2001, Dassow et al. 2020, Cooke et al. 2021). This influences the areas used for recreational fishing activities, as anglers will rely less on methods of the past such as nautical fishing charts and utilize newer technologies to find and target more precise areas to fish that are more easily accessible, have a greater degree of isolation, or have less abundant populations of fish (Cooke et al. 2021). EBR, in particular, is further offshore than the neighboring artificial reef sites and studies have shown fishery important species such as Red Snapper have higher densities at artificial reef structures (Streich et al. 2017, Garner et al. 2019, Martin 2022).

This study identified potential threats to the fishery that could also be further assessed. Coast guard apprehension records for the specific area were requested, but unable to be obtained, which could illuminate a deeper connection between the increase in illegal fishing in the area and its impact on EBR. Shrimp boat tracks and trawling history could also show the prevalence or lack of shrimping activity and how that may affect the EBR fishery. Determining the threat these activities pose can inform if greater protections or federal management are needed at EBR.

Further research is also required to determine what other factors are contributing to the differences in fish abundance between SB and EBR. The models did show significant differences in presence of fish between SB and EBR, indicating there are factors that are more influential when comparing the two sites. Further measures of complexity should be considered at these two study sites to determine other contributing factors such as percent cover and sediment classification. More recent research aimed at determining percent cover and coral community composition has been conducted at other STBs and could be replicated at SB and EBR (Bollinger et al. 2022, Gniffke 2023). With additional visual surveying, the analyses of this study can be further refined to habitat types with measures of percent cover or be used to target fishery important species (Dance and Rooker 2016, Garner et al. 2019, Brogdon 2022). Other studies within the northern portion of the GoM have shown how environmental factors (eg. salinity, temperature, dissolved oxygen) impact levels of biomass and fish density on reef systems using Generalized Additive Models (Hazen et al. 2009, Rooker et al. 2013, Dance and Rooker 2019). The influence of spatial and temporal characteristics on relative fish density have also been similarly modeled and should be considered in future research at these sites (Rooker et al. 1997, Dance and Rooker 2019, Luzenti et al. 2021, White et al. 2022, Becker et al. 2023).

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CHAPTER V

CONCLUSIONS

This study has provided a baseline assessment for one of the fishery important South Texas Banks (STB), that was otherwise unexplored. The side-scan mosaic provided a bathymetric image that identifies areas of hard bottom structure and moderate relief that can be referenced for further research at this site. The quantitative results of visual and hydroacoustic surveys show that EBR had lower fish species diversity and relative fish density than its northern counterpart of the STB, Sebree Banks. While seafloor characteristics showed significant contribution to these variances, obvious trends were not consistent across presence and absence models of fish and biomass and contributed least to relative fish density. At EBR, higher relief did influence fish presence and larger values of fish biomass. Models also identified further research questions that could help explain these site differences. Although the scope of this study did not include an in-depth analysis of the spatial differences of the two sites, it is important to note that EBR lies directly along the US-Mexico border where illegal fishing practices are prevalent, which is negatively impacting the fishery at EBR.

The results of the questionnaire about the fishery at EBR were consistent with my expectations and findings in the quantitative studies. The majority of respondents identified a decrease in the abundance of Red Snapper from past fishing experiences at the site. Illegal fishing practices in the area were rated as the highest contributing factor to this decrease. While there are discrepancies and biases to address when assessing any local ecological knowledge of anglers and shrimpers, these analyses can be informative especially regarding restrictions and protections associated with fisheries management at this site. Continued studies of EBR are required to determine the extent of the degradation at EBR and if increased management is needed at this site and other STBs to aid in sustaining the fishery in South Texas and the greater GoM.

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APPENDIX A

APPENDIX A

ANGLER QUESTIONNAIRE

1. How long have you been fishing at South Padre Island?
    a. Less than 1 year
    b. 1-5 years
    c. 6- 10 years
    d. 10+ years
2. What type of fishing activity do you currently participate in or have in the past? (select all that apply)
    a. Commercial Fishing
    b. Recreational/ Sport fishing
    c. Shrimping
3. When was the first time you fished at East Bank Ridge?
    a. Less than 1 year
    b. 1-5 years
    c. 6- 10 years
    d. 10+ years
    e. Never
4. When was your most recent visit to East Bank Ridge?
    a. Less than 1 year
    b. 1-5 years
    c. 6- 10 years
    d. 10+ years
    e. Never
5. Since your first trip, has the frequency of your visits to East Bank Ridge:
    a. Increased
    b. Decreased
    c. Remained the same
6. On average, how many fish did you catch per trip when you first fished at East Banks?
    a. 0-5
    b. 5-10
    c. 10-20
    d. 20-30

7. On average, how many fish did you catch per trip at your most recent visit to East Banks?
    a. Same as answers in 6.
8. What are the most common species of fish you have caught in all your fishing trips to
9. East Bank Ridge? (Please select the top three species and rank order them according to the box title):
    a. Red Snapper
    b. Grey Triggerfish
    c. Grouper
    d. Amberjack
    e. Dolphinfish
    f. Bonito
    g. Shark species
    h. Tuna species
    i. Other

   6b. What is the most common size Red Snappers you have caught
    j. Under legal catch size
    k. Approximately legal catch size
    l. 2+ inches over legal catch size
    m. Sow snapper size
10. What was the most common species caught at EBR when you first began fishing there? (Please select the top three species and rank order them according to the box title):
11. What was the most common species caught at EBR at your most recent visit? (Please select the top three species and rank order them according to the box title)
12. Since your first trip to EBR, has the average size of Red Snapper caught:
    a. Increased
    b. Decreased
    c. Remained the same
13. What do you believe the catch per unit effort for Red Snapper was at East Bank Ridge when you first began fishing?
    a. Very High
    b. High
    c. Unsure
    d. Low
    e. Very Low
14. What do you believe the catch per unit effort for Red Snapper is at East Bank Ridge currently?
    a. Same as answers in 13.
15. Do you believe the quantity of fish at East Bank Ridge in recent years has:
    a. Increased
    b. Decreased
    c. Remained the same

16. Because you answered “decreased” above, how significant do you think each of the following factors have been to the relative fish abundance at EBR? (In actual survey these will each be rated on a Likert scale of no to high significance)
    a. Legal fishing practices by local fishermen and shrimpers that could contribute to overfishing
    b. Illegal fishing practices in the area form across the US/ Mexico border
    c. Damage from shrimp trawling practices
    d. Proximity to artificial reef structures
17. Do you believe there are other sources of degradation to the fish populations at East Bank Ridge? If yes, please specify what those are in the space provided
    a. No
    b. Yes:
18. Have you personally witnessed apprehensions of illegal fishing practices by the US Coast Guard or Texas Parks and Wildlife when fishing at East Bank Ridge?
    (If yes, please list how many times)

    15b. To your best recollection, what year did this occur? (please provide a year for each account)

    15c. Did witnessing this have a significant impact on your choice to fish at East Bank Ridge again?

    15d. If you answered yes, rate the level of impact this had: (1-10)

VITA

Marissa Lamb attended the University of Texas at Austin and earned her Bachelor of Science in December of 2014. She started her undergraduate degree on a pre-veterinary track and majored in Ecology, Evolution, and Behavior with a focus in Marine Science coursework. Upon graduation, Marissa began a job at Wildlife Rescue and Rehabilitation in Central Texas. She progressed within this organization, rehabilitating and caring for native and non-native animals in sanctuary and rehabilitative care. While working at the rehabilitation center, Marissa earned her Texas Master Naturalist Certification and trained to become a SCUBA Divemaster. In Summer of 2021, Marissa began working in the Marine lab of Dr. Richard Kline at UTRGV and transitioned into the master's program. Marissa earned her Master of Science in Ocean, Coastal, and Earth Sciences at the University of Texas Rio Grande Valley in May 2024. She will be continuing her education by starting a PhD program at Texas A&M Corpus Christi, working on restoring colonial waterbird islands along the South Texas Coast.

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