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Red Snapper Abundance, Growth, and Movement at Different Structural Configurations in the Rio Grande Valley Artificial Reef

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RED SNAPPER ABUNDANCE, GROWTH, AND MOVEMENT AT DIFFERENT STRUCTURAL CONFIGURATIONS IN THE RIO GRANDE VALLEY ARTIFICIAL REEF

A Thesis

by

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ABSTRACT

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The Rio Grande Valley (RGV) artificial reef was built with the goal of providing habitat for reef fish at various life stages. This study used fish trapping to analyze red snapper and grey triggerfish size and abundance in the RGV reef. Mark-recapture of red snapper was utilized to determine growth, movement, and site fidelity within the reef. Nine configurations of patches consisting of varying combinations and densities of concrete pyramids and low-profile modules were surveyed, as well as additional sites of cinder block palettes and concrete railroad ties. Red snapper and triggerfish abundance per trap hour varied significantly by site type. Red snapper total length and triggerfish fork length were significantly smaller at low-profile cinder block platforms compared to mixed sites and pyramid sites. A recreational tagging study yielded a 9.7% return rate. Growth rates for recaptured red snapper within the RGV reef were 0.234 mm/day and 1.207 g/day.

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CHAPTER I

INTRODUCTION

In the northwestern Gulf of Mexico (GoM), the natural structure is characterized by relic shell reefs, shell hash, and relic submerged barrier islands (Wells et al. 2009). However, natural habitat is quite sparse, with natural reefs covering just 1-3% of the northwestern GoM from the Rio Grande to Pensacola, much of which is low relief under 1.5 m (Parker et al. 1983), and thus is easily destroyed by dredging and trawling (Wells et al. 2008). Recreationally and commercially valuable fish species in the GoM, including snapper (Lutjanidae) and triggerfish (Balistidae), rely on structured habitats at critical stages of their lives, particularly as juveniles and young adults (Coleman et al. 2000; Gallaway et al. 2009). More specifically, red snapper (*Lutjanus campechanus*) is regarded as one of the most highly valued species in the GoM, supporting a multi-billion dollar commercial and recreational fishing industry (Rindone et al. 2015). Red snapper have been affected by overfishing throughout the years and endured a population crash in the 1980s. Since then, fisheries managers have been working to rebuild the collapsed population with the goal of a fully recovered stock by the year 2032 (Strelcheck & Hood, 2007). Federal managers have introduced targets for the total allowable catch to curb fishing pressure in federal waters in both recreational and commercial fisheries, as well as implementing size limits, trip limits, limited entry, seasons, and quotas (Hood et al. 2007). Most states have adopted federal regulations in state waters, except for Texas and Florida, which independently manage their state water fisheries. Currently, Texas state waters allow fishing of red snapper year-round, while federal waters only allow a short season starting June 1 of every year. In 2018, the red snapper population was reported as no longer overfished (SEDAR, 2018), but several factors hinder a full recovery including intense fishing pressure, lack of habitat availability, and high juvenile mortality of age 0-1 fish due to predation and bycatch in the shrimp fishery (Gallaway et al. 2009; Shipp & Borton2009; Cowan et al. 2011). Consequently, fishery managers are still working to rebuild the population to the biomass target level (SEDAR, 2018).

In 1984, the United States implemented the National Fishing Enhancement Act (NFEA) calling for the use of artificial reefs to enhance recreational and commercial fisheries, which has likely improved the recovery of the red snapper population (Szedlmayer & Schroepfer, 2005). Artificial reefs are any manmade, hard structures such as oil platforms, submerged ships, or concrete structures that are intentionally placed underwater to provide habitat for aquatic life. These structures provide several benefits to red snapper and other reef fish, including increased recruitment, growth, and shelter from predation in an otherwise barren area (Alevizon & Gorham, 1989). Red snapper are categorized as reef fish and their reef dependency begins shortly after they leave their planktonic life stage (Szedlmayer & Howe, 1997). Thus, interest in artificial reef development became a strategy to provide habitat for commercially and recreationally valuable reef fish. The recent development of artificial reef programs in the GoM has driven widespread research efforts to determine how significant these reefs are for valuable fisheries (Gallaway et al. 2009, Topping & Szedlmayer, 2011, Shipp & Bortone, 2009). The present-day red snapper fishery is heavily dependent on catches at artificial reefs (Gallaway et al. 2009, Jorgenson 2009), yet information regarding their early life stages among artificial reefs is lacking, especially in Texas state waters. Red snapper require a variety of different habitat types throughout their lifetime. Juvenile red snapper find refuge from predators among low-relief natural or artificial reef structures such as concrete or oyster shell rubble (Rooker et al. 2004; Dance et al. 2021). They grow rapidly at a relatively linear rate until they reach about eight to ten years, after which growth slows substantially (Svedlmeyer & Shipp 1994; Wilson & Nieland 2001). As red snappers age and grow, they undergo an ontogenetic shift and move from low-relief areas to higher-relief habitats in deeper water (Galloway et al., 2009), which commonly includes artificial reef structures. Other studies also support that red snapper require various substrate sizes ranging from low-profile rubble to high-profile structures throughout their life cycles (Wells et al. 2008; Gallaway et al. 2009). There have been observed benefits to deploying low-profile materials that act as a suitable alternative to natural reefs and relic oyster beds (Lingo & Szedlmayer, 2006; Alder, 2018). However, more research is necessary to determine the ideal arrangement of artificial structures for producing a habitat for the various life stages of red snapper in such a way that the reef is recruiting and growing the fish, and not just attracting them from other areas.

Along with red snapper, grey triggerfish (*Balistes capriscus)* are also highly valued and particularly common at artificial reefs in the GOM (Plumlee et al. 2020). These fish recruit to nearshore environments at various life stages for refuge and food. Grey triggerfish are considered an overfished stock (Gallaway et al. 2009; SEDAR 2015; Simmons & Szedlmayer 2011), although little is known concerning the importance of structured habitats for grey triggerfish (Herbig & Szedlmayer 2016). Thus, it is important to study the benefit and functions of nearshore artificial reefs for various reef species. Understanding which configurations are most beneficial to providing adequate nursery, juvenile, and adult habitat is vital for improving the management of these vulnerable fisheries.

Various factors such as species- or life-stage-specific behavior traits, fishing mortality associated with the artificial reef, and reef profile, density, location, and spacing determine how an artificial reef is likely to benefit reef fish populations (Bohnsack 1989; Pickering & Whitmarsh 1997; Strelcheck et al. 2005). Factors affecting the assemblages of fish on artificial reefs in the northern GOM are known to have similar drivers to other reef systems, where vertical relief and available surface for colonizing are recognized as influential factors, as well as differences in reef structure (Rooker et al. 1997; Perkol-Finkel et al. 2006; Boswell et al. 2010). Large artificial structures used to create complex, high-relief artificial reefs such as decommissioned ships and oil rigs are recognized to support highly diverse fish communities off the coast of Texas (Ajemian et al. 2015) as well as throughout the GOM (Boswell et al. 2010). Meanwhile, the deployment of smaller concrete structures with lower relief, like pyramids and reef balls, have become increasingly popular to supplement the lack of natural hard structure off the Texas coast, as smaller habitat can provide compact, low-relief patches where commercially valuable juveniles can recruit and grow (Arney et al. 2017; Plumlee et al. 2020).

Several studies report an increase in the diversity of benthic reef fish through an increase in habitat complexity (Luckhurst & Luckhurst 1978, Depczynski & Bellwood 2004), and the specific habitat requirements of several juvenile reef fish species, like small crevices and isolated reef patches may not be met by the sole deployment of pyramids alone. Although studies have shown the benefit of placing low-profile material on the seafloor (Lingo & Szedlmayer, 2006; Alder, 2018), further studies are needed to determine the optimal spacing of low-profile materials, and whether deploying both high and low-profile structures in the same area adds any benefit to fish communities on artificial reefs.

To determine the effects of artificial reef design and configuration, many studies employ sampling surveys and tagging methods to examine the fish community. Individual sampling techniques have their own strengths and weaknesses when targeting specific species or size ranges of fish. Fish traps are an effective tool for sampling fishes associated with complex structures (Newman & Williams 1995) as they appear to sample a wider range of size classes and species than vertical long lines, but they are size-selective based on the size of the trap, the trap opening, and mesh size (Wells et al. 2008). Several studies have used the deployment of baited fish traps for estimating catch per unit effort and for obtaining a target species for mark-recaptures studies (Svedlmeyer & Moss, 2004; Brandt & Jackson 2013; Wells et al. 2008; Svedlmeyer & Jaxion-Harm, 2014).

Conclusions about the resource value of a particular habitat can be drawn from assessments of growth, movement, and site fidelity of reef fish from mark-recapture studies (Lindberg et al. 1990). Thus, tagging studies are frequently used in artificial reef research to study the benefit of artificial habitat to reef fish (Watterson et al. 1998, Patterson & Cowan 2003, Strelcheck et al 2007). While it is well known that red snapper have a high affinity for artificial structure, studies of their movements (i.e., residency and site fidelity) on artificial reefs have yielded conflicting results (Szedlmayer & Shipp, 1994; Szedlmayer, 1997; Watterson et al. 1998; Fable, 1980; Patterson et al. 2001; Szedlmayer & Schroepfer, 2006). Tagging studies have played a fundamental role in understanding fisheries ecology by providing estimates on stock composition, movement rates, and migration patterns, as well as growth, mortality, and abundance estimates (Hightower & Gilbert 1984; Nielson 1992; Hilborn 1990; Szedlmayer & Shipp 1994). Tagging studies for red snapper in the GOM have primarily focused on movement, as high site fidelity over extended periods could indicate whether artificial structures contribute to an increase in production or simply attract fish from elsewhere (Szedlmayer & Schroepfer, 2006). There is substantial individual variation in site fidelity and movement patterns among studies. Past mark-recapture tagging events had the majority (76 – 97%) of red snapper remain at their original tagging site for extended periods of time (Fable 1980; Szedlmayer & Shipp, 1994). However, other studies showed much greater movements of red snapper with distances up to 352 km and a mean distance moved of 29 km, and only 36% of the recaptured fish remained at their original tagging site (Watterson et al. 1998; Patterson et al. 2001). In the cases where red snapper traveled hundreds of km, the presence of hurricanes played a significant role in furthering the red snapper movement (Patterson et al. 2001). While mark-recapture studies show some varying results, ultrasonic telemetry studies confirm that Red snapper tend to be long-term residents on artificial reefs (Szedlmayer, 1997; Szedlmayer & Schroepfer, 2005). In the present study, t-bar anchor and dart tags are used as they are suitable for the body shape and size of red snapper (Nielson, 1992) and have shown high tag retention rates with no signs of infection or stress (Szedlmayer & Shipp, 1994).

Objectives and Hypotheses

This study used fish trapping at multiple configurations of pre-fabricated concrete low-profile and mid-profile artificial reef modules at the Rio Grande Valley reef (RGV reef), as well as a recreational mark-recapture study of red snapper at the RGV reef. The results of fish trapping were examined to investigate the effects on fish abundance and size among habitat configurations and module densities, while the results of the mark-recapture red snapper provided red snapper growth rates, site fidelity, and fishing pressure on the RGV Reef. The resulting information will be used to further understand the optimal artificial reef design to support the various life stages of reef fish.

Objective 1: Compare red snapper and triggerfish abundance per trap hour among the different patch configurations.

Hypothesis: The abundance per trap hour of both species will be significantly higher at the sites with more material.

Objective 2: Compare the size of red snapper and triggerfish among the different patch configurations.

Hypothesis: The total length of red snapper and the fork length of triggerfish caught will significantly differ in total length among the different patch configurations. The trap will not capture juvenile fish under 100 mm due to its mesh size. However, age 0 fish recruit to low-relief reefs and grow to lengths approaching 100 mm and begin looking for higher relief at age 2 (Gallaway et al., 2009). Therefore, the low-profile modules will have significantly smaller fish lengths than the pyramid sites and mixed sites.

Objective 3: Determine the site fidelity of red snapper in the Rio Grande Valley artificial reef.

Hypothesis: Based on previous studies, it is likely that the majority of red snapper tag returns will be in the vicinity of the original tag location on the RGV reef. However, some fish will likely have left the reef with a wide range of distance travelled, as some studies have shown movement over 100 km from its tagged location (Beaumariage, 1969; Szedlmayer & Shipp, 1994).

Objective 4: Determine the average growth rate of red snapper in the RGV artificial reef.

Hypothesis: Red snapper growth rate will be about 0.2 mm per day, based on a previous study on artificial reefs in coastal Alabama that found a growth rate of 0.206 mm per day (Topping & Szedlmayer, 2011).

CHAPTER II

METHODS

Study Site

This study was conducted in the northwestern GoM at the Rio Grande Valley (RGV) reef. The RGV reef was established in 2015 with a vision to provide graduated steppingstones of increasingly complex and taller habitats to carry red snapper and other reef species through their life cycles. The reef has around 23,000 tons of material, mostly recycled concrete, and continues to grow in structural deployments. Sampling sites for this study were located in the Coastal Management Plan (CMP) experimental reef zone, a 1.37 km^2 area of the reef (Figure 2), as well as one additional replicated site type within the larger 6.7 km^2 reef composed of six pallets of cinder blocks and 25-ton railroad ties in each patch. The experimental reef zone consisted of 51 sites laid out in a randomized complete block design with nine configurations of the concrete pyramid and low-profile modules with five to six replicates of each configuration (Table 1, Figure 2**)**. Sites were deployed in 2018 by Texas Parks & Wildlife Department, and each site is 50 × by 50 m and is separated from the nearest site by 100 m. Red snapper, except when emigrating to a different location, stay within 100 mof their home reef patch, according to Szedlmayer & Schroepfer (2005) and Topping & Szedlmayer (2011). Therefore, the 100 m separation between the experimental reef sites in this study should have prevented conspecific interaction. The pyramids were 3 × 3 × 3 m and had cinderblocks embedded in their walls, producing many cavities in addition to one large triangular cavity (Figure 3). The low-profile modules provide 0.5 m of vertical relief and concrete squares measuring 1.8 × 1.8 m with fixed cinder blocks and limestone (Figure 4). The RGV reef including was open to year-round fishing under Texas state regulations.

Table 1: The locations and structural material at the 60 study sites sampled in the Rio Grande Valley Reef in the Gulf of Mexico.

Site name	Material Type	Latitude	Longitude
16-PY	16 Concrete Pyramids	26°16'18.30"N	97° 3'24.00"W
16-PY	16 Concrete Pyramids	26°16'24.70"N	97° 3'50.20"W
16-PY	16 Concrete Pyramids	26°16'41.20"N	97° 3'29.40"W
16-PY	16 Concrete Pyramids	26°17'3.90"N	97° 3'36.70"W
16-PY	16 Concrete Pyramids	26°16'52.53"N	97° 3'23.25"W
16-PY	16 Concrete Pyramids	26°16'41.00"N	97° 3'42.40"W
16-MX	16 Concrete Pyramids & 16 Low-Profile Modules	26°16'35.70"N	97° 3'23.40"W
16-MX	16 Concrete Pyramids & 16 Low-Profile Modules	26°16'52.96"N	97° 3'36.47"W
16-MX	16 Concrete Pyramids & 16 Low-Profile Modules	26°17'10.06"N	97° 3'23.34"W
16-MX	16 Concrete Pyramids & 16 Low-Profile Modules	26°16'47.10"N	97° 3'49.32"W
16-MX	16 Concrete Pyramids & 16 Low-Profile Modules	26°16'17.96"N	97° 3'37.05"W
16-MX	16 Concrete Pyramids & 16 Low-Profile Modules	26°16'58.58"N	97° 3'49.14"W

Table 1, cont.

16-LP	16 Low-Profile Modules	26°16'24.50"N	97° 3'30.40"W
16-LP	16 Low-Profile Modules	26°17'3.80"N	97° 3'29.50"W
16-LP	16 Low-Profile Modules	26°17'10.24"N	97° 3'48.95"W
16-LP	16 Low-Profile Modules	26°16'35.34"N	97° 3'30.52"W
16-LP	16 Low-Profile Modules	26°16'46.82"N	97° 3'42.80"W
4-PY	4 Concrete Pyramids	26°17'10.16"N	97° 3'36.65"W
4-PY	4 Concrete Pyramids	26°16'52.83"N	97° 3'36.11"W
4-PY	4 Concrete Pyramids	26°16'46.83"N	97° 3'42.81"W
4-PY	4 Concrete Pyramids	26°16'35.35"N	97° 3'29.78"W
4-PY	4 Concrete Pyramids	26°16'29.56"N	97° 3'36.37"W
4-PY	4 Concrete Pyramids	26 °16’ 23.5” N	97°3’ 23.76” W
4-MX	4 Concrete Pyramids & 4 Low-Profile Modules	26°17'4.10"N	97° 3'23.40"W
4-MX	4 Concrete Pyramids & 4 Low-Profile Modules	26°17'4.40"N	97° 3'42.80"W
4-MX	4 Concrete Pyramids & 4 Low-Profile Modules	26°16'52.49"N	97° 3'49.31"W
4-MX	4 Concrete Pyramids & 4 Low-Profile Modules	26°16'46.61"N	97° 3'23.49"W

Table 1, cont.

4-MX	4 Concrete Pyramids & 4 Low-Profile Modules	26°16'35.34"N	97° 3'43.26"W
4-MX	4 Concrete Pyramids & 4 Low-Profile Modules	26°16'23.79"N	97° 3'36.65"W
4-LP	4 Low-Profile Modules	26°16'58.40"N	97° 3'23.60"W
4-LP	4 Low-Profile Modules	26°16'58.67"N	97° 3'42.70"W
4-LP	4 Low-Profile Modules	26°17'9.96"N	97° 3'29.52"W
4-LP	4 Low-Profile Modules	26°16'41.10"N	97° 3'23.73"W
4-LP	4 Low-Profile Modules	26°16'29.55"N	97° 3'36.64"W
4-LP	4 Low-Profile Modules	26° 16' 17.94"N	97° 3' 43.46 " W
1-PY	1 Low-Profile Module	26°16'58.30"N	97° 3'30.20"W
1-PY	1 Low-Profile Module	26°17'9.87"N	97° 3'43.12"W
1-PY	1 Low-Profile Module	26°16'23.85"N	97° 3'43.14"W
1-PY	1 Low-Profile Module	26°16'18.11"N	97° 3'49.73"W
1-PY	1 Low-Profile Module	26°16'29.59"N	97° 3'24.04"W
1-MX	1 Concrete Pyramid & 1 Low-Profile Module	26°16'52.96"N	97° 3'29.68"W
1-MX	1 Concrete Pyramid & 1 Low-Profile Module	26°17'4.60"N	97° 3'49.29"W
1-MX	1 Concrete Pyramid & 1 Low-Profile Module	26°16'35.25"N	97° 3'49.43"W
1-MX	1 Concrete Pyramid & 1 Low-Profile Module	26°16'29.28"N	97° 3'30.13"W
1-MX	1 Concrete Pyramid & 1 Low-Profile Module	26°16'29.02"N	97° 3'10.28"W

Table 1, cont.

1-LP	1 Low-Profile Module	26°16'58.57"N	97° 3'36.67"W
1-LP	1 Low-Profile Module	26°16'47.21"N	97° 3'36.65"W
1-LP	1 Low-Profile Module	26°16'41.01"N	97° 3'37.12"W
1-LP	1 Low-Profile Module	26°16'41.19"N	97° 3'50.17"W
1-LP	1 Low-Profile Module	26°16'18.10"N	97° 3'30.80"W
Mixed	6 Palettes of Cinder Block & 25 Tons of Railroad Ties	26°17' 8.09"N	97 3' 9.51"W
Mixed	6 Palettes of Cinder Block & 25 Tons of Railroad Ties	26°17' 8.87"N	97 '2 12.87"W
Mixed	6 Palettes of Cinder Block & 25 Tons of Railroad Ties	26°17'7.57"N	97° 3'4.48"W
Mixed	6 Palettes of Cinder Block & 25 Tons of Railroad Ties	26°17' 10.31"N	97°03' 6.08" W
Mixed	6 Palettes of Cinder Block & 25 Tons of Railroad Ties	26°17'9.31"N	97°2'45.31"W
Mixed	6 Palettes of Cinder Block & 25 Tons of Railroad Ties	26°17'8.55"N	97° 2'57.70"W
Mixed	6 Palettes of Cinder Block & 25 Tons of Railroad Ties	26°17' 8.49"N	97°02' 51.64" W
Mixed	6 Palettes of Cinder Block & 25 Tons of Railroad Ties	26°17'7.19"N	97°02'47.41" W
Mixed	6 Palettes of Cinder Block & 25 Tons of Railroad Ties	26°17'7.19"N	97°02'47.41"W

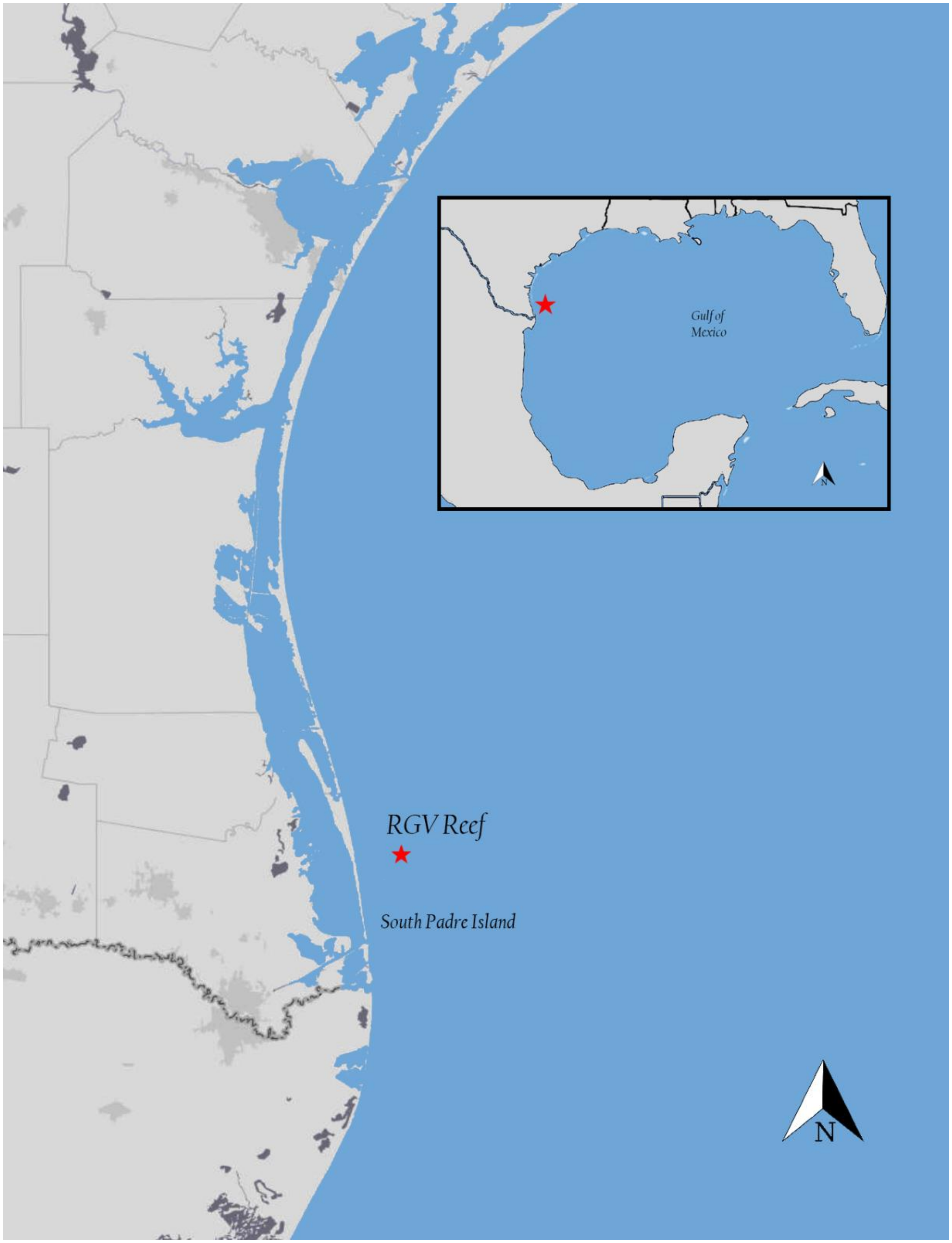

Figure 1. Rio Grande Valley artificial reef (PS-1105) location 12 km from South Padre Island

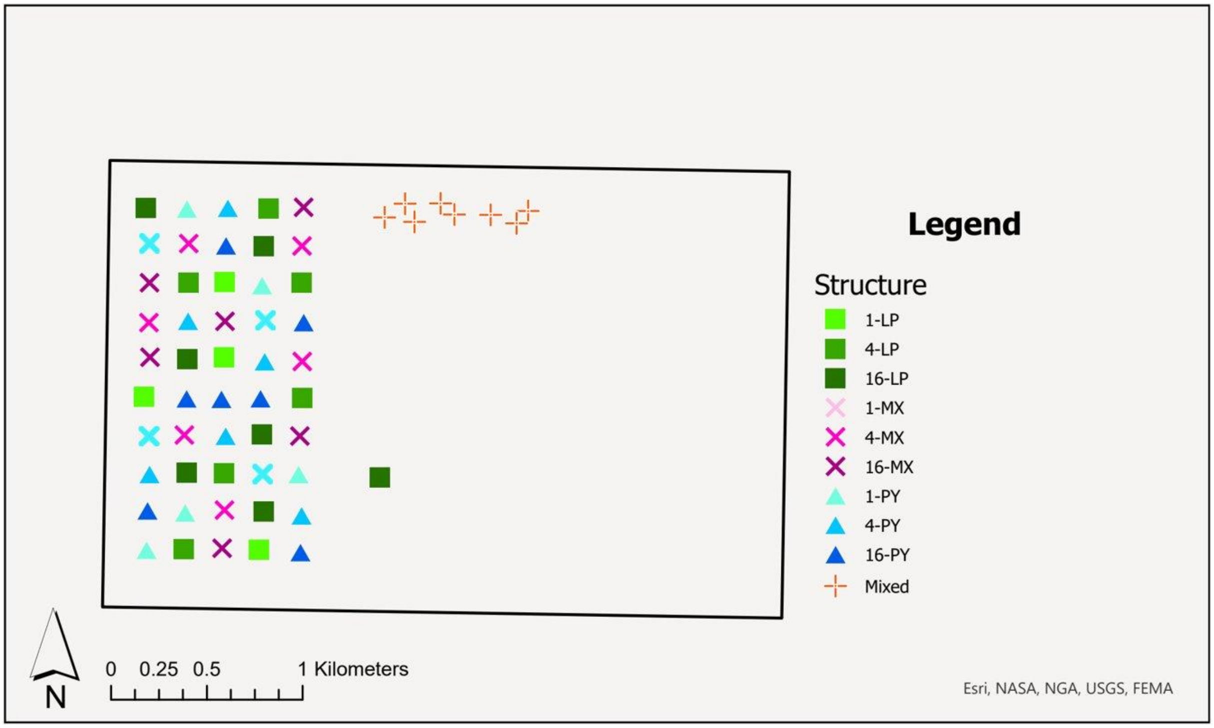

Figure 2. Map of study sites including the different structural configurations in the Rio Grande Valley artificial reef.

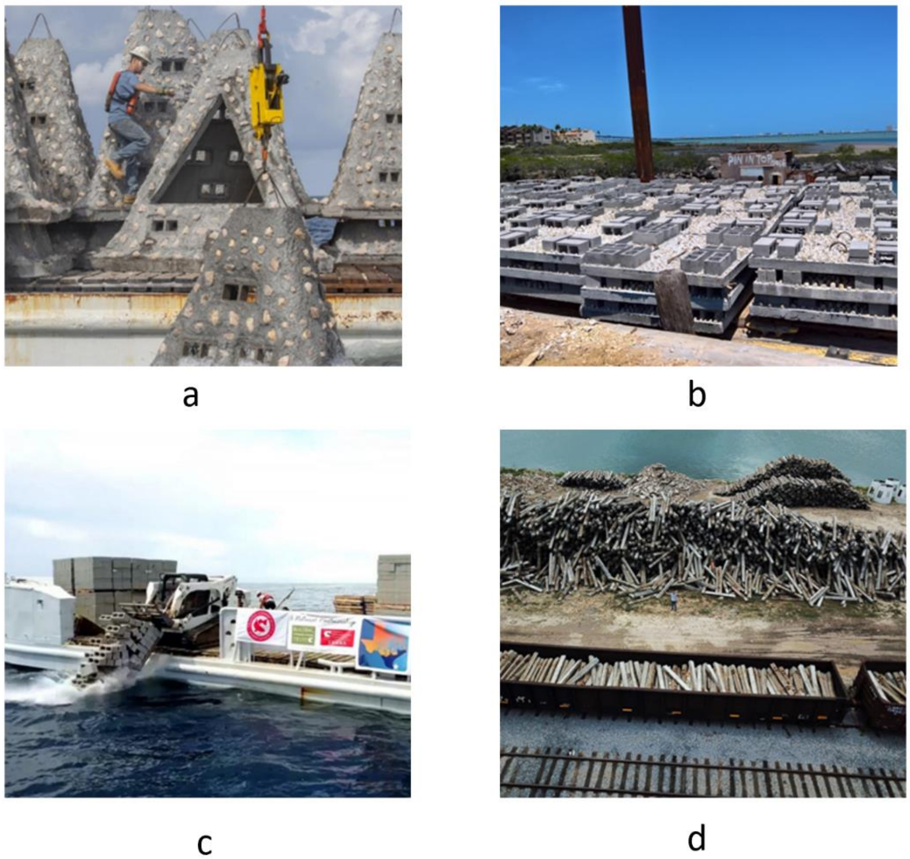

Figure 3. Concrete reefing pyramids, low-profile modules, cinder block palettes and railroad ties that make up the different structural configurations on the Rio Grande Valley artificial reef:

a) Concrete reefing pyramids deployed at the PY and MX sites.
b) Low-profile modules deployed at the LP and MX sites.
c) Cinder block palettes deployed at the mixed sites.
d) Railroad ties deployed at the mixed sites.

Fish Trapping

Three 94 cm x 63.5 cm x 60.9 cm Promar collapsible multipurpose traps with 1.27 cm mesh size and two 15.24 cm openings (Promar & Ahi USA, Gardena, California, model no. TR-302, Figure 4) were baited with menhaden and squid. They were deployed around the center point of the 51 experimental patch sites, including nine different patch configurations (Table 1), as well as nine additional mixed sites with six cinderblock palettes and 25 tons of railroad ties. Each set of traps remained underwater for one hour at every site. Once retrieved, all captured fish were identified, measured, and released. All species were measured by total length to the nearest mm, except for triggerfish, which were measured by fork length to the nearest mm. In addition, every captured red snapper (*Lutjanus campechanus)* was weighed to the nearest gram with a digital fish scale (Dr. Meter YW-S068 digital hanging scale), tagged, and vented (expanded swim bladder punctured) before releasing on site. All sites were resampled four to twelve months later, where the same trapping methods were implemented again.

a

b

Figure 4. Promar collapsible fish trap and Floy n-94 dart tags used in this study:

a) Promar collabsible fish trap.

b) Floy FT – 2 – 94 dart tag inserted in red snapper.

Fish Tagging

Red snapper caught during fish trapping surveys, as well as red snapper caught via hook and line on charter boats on the RGV Reef were tagged. Juvenile red snapper below 250 mm were tagged with Floy T-bar anchor tags via a Hall print tagging gun, while fish above 250 mm were tagged via a needle applicator with Floy FT – 2 – 94 tags. Tags were placed below the dorsal fin and anchored between the pterygiophores to prevent tag loss. Each tag included a phone number and the text "$ reward" to incentive anglers to report the tag return. Additionally, separately labeled tags were distributed to volunteer anglers aboard private and charter boats, who tagged undersized red snapper and report the location coordinates. Tag return information was recorded, including the tag number of the fish, the date the fish was caught, and total length and weight when obtainable, as well as the location of recapture whenever possible (GPS coordinates).

Statistical Analyses

All collected trap data were evaluated in SPSS (IBM, Chicago, IL, USA)., where a one-way ANOVA was used to determine the significance of the site types on red snapper abundance per trap hour and the total length, as well as triggerfish abundance per trap hour and fork-length. The abundance of fish was converted to abundance per rap hour by dividing the number of each species caught at each sampling location by the number of intact traps retrieved. This was done to account for the occasional occurrence of a lost, stuck, or torn fish trap. Square root transformations were applied to the abundance per trap data to improve conformity to the assumptions of ANOVA based on Kolmogorov-Smirnov normality tests, equality of variances tests, box-plots and Q-Q plots. Tukey's honest significance difference test was used for post-hoc analyses. For the mark recapture study, red snapper that were tagged with the n-94 Floy t-bar anchor tags were omitted from the total tags accounted for. This was because only one of these tags was reported, likely due to the small size of the fish (TL < 250 mm) not entering the targeted fishery yet. Red snapper growth in mm and g were determined from the slope of a linear regression line, since red snapper tags were small, and their growth is fairly linear for the first few years of life (Szedlmayer & Shipp 1994; Patterson et al. 2001; Wilson & Nieland 2001). Changes in total length and change in weight were regressed against days at liberty to calculate average growth per day. Finally, Fulton's condition factor (K) was determined using the formula of $K=(100 * Wt/TL^3)$, which is commonly used as a quantitative indicator of the general health of a fish, based on the principle that individuals exhibiting higher weight at a certain length, are in better condition (Lloret et al. 2013), where a value of $K > 1$ suggests fish are in good health.

CHAPTER III

RESULTS

Fish Trapping

Throughout the entirety of the study, 2,745 fish were caught in traps. 18 different species were caught. The majority were grey triggerfish which made up 57 % of the total fish caught and red snapper which made up 31 % of the fish caught (Table 2). The average total fish per trap hour among all sampling sites was 5.827 ± 0.836 (mean ± SE). Fish communities differed significantly between site types (PERMANOVA: Pseudo-F_9 = 4.776, P = 0.001). Site types 1 and 4 LP were significantly different than all other site types except for 1 MX and 1 PY (all P < 0.005, Figure 5). 16 PYR was significantly different than 1 MX and 1 PYR (P < 0.043), while 16 MX was also different than 1 PYR (P = 0.05). Mixed sites were also significantly different than sites 1 PYR, 1 MX, 4 PYR, and 16 LP (all P <0.048). SIMPER results indicated that fish community dissimilarity at 1 and 4 LP sites was primarily driven by lower abundance of grey triggerfish and red snapper and a higher abundance of catfish. The 16 structure mixed and pyramid sites' dissimilarities were mostly driven by their lower abundance of red snapper and higher abundance of triggerfish than at the 1 structure sites.

Total fish abundance was greatest at mixed (railroad ties and cinderblocks) sites, but only significantly differed from 1 and 4 LP sites (ANOVA: $F_{9, 110}$ = 3.887, P <0.001, Figure 6). Most sites were dominated by age 1 red snapper, but 4 and 16 LP had the highest proportions of age 0 red snapper. Furthermore, no age 3 and older red snapper were caught at all at the low profile only sites (Figure 6). Red snapper abundance was significantly different by structure type (ANOVA: F9, 110 = 2.349, P = 0.018), and was highest at 1 PYR site (Figure 7). Triggerfish abundance showed significant differences as well (ANOVA: $F_{9,\,110}$ = 5.667, *P* <0.001) with the highest abundance seen at mixed sites and high-density structure sites (Figure 8). In addition, red snapper total length varied significantly by structure type (ANOVA: $F_{9,\,660}$= 21.543, *P* < 0.001) where 4 and 16 LP sites were significantly smaller than all sites except for 1 LP sites (Figure 9). Triggerfish fork length significantly varied by site as well (ANOVA: $F_{9,\,1204}$= 25.530, *P* < 0.001), and 4 and 16LP sites were smaller than all other structure types (Figure 10). Lastly, the mean condition factor (K) for all red snapper was 1.552 ± 0.23.

Table 2. Fish caught in traps and subsequent size ranges on the Rio Grande Valley artificial reef.

Species	N	Minimum	Maximum	Mean ± S.E.M.
Grey Triggerfish	1554	109	490	235.57 ± 1.26
Red Snapper	854	120	543	231.47 ± 2.04
Tomtate	146	116	420	193.87 ± 3.11
Catfish	93	218	347	262.78 ± 3.11
Pigfish	37	113	281	215.22 ± 5.76
Atlantic Croaker	20	175	262	195.61 ± 5.59
Pinfish	14	110	225	188.71 ± 9.25
Cubbyu	7	160	211	186.83 ± 7.3
Filefish	5	114	185	154 ± 13.2
Lane Snapper	4	188	287	239.25 ± 24.54
Amberjack	1	NA	NA	206
Damselfish	1	NA	NA	120
Grunt	1	NA	NA	265
Gulf Kingfish	1	NA	NA	275
Blue Runner	1	NA	NA	305
Scorpionfish	1	NA	NA	200
Perch	1	NA	NA	129
Moray Eel	1	NA	NA	NA

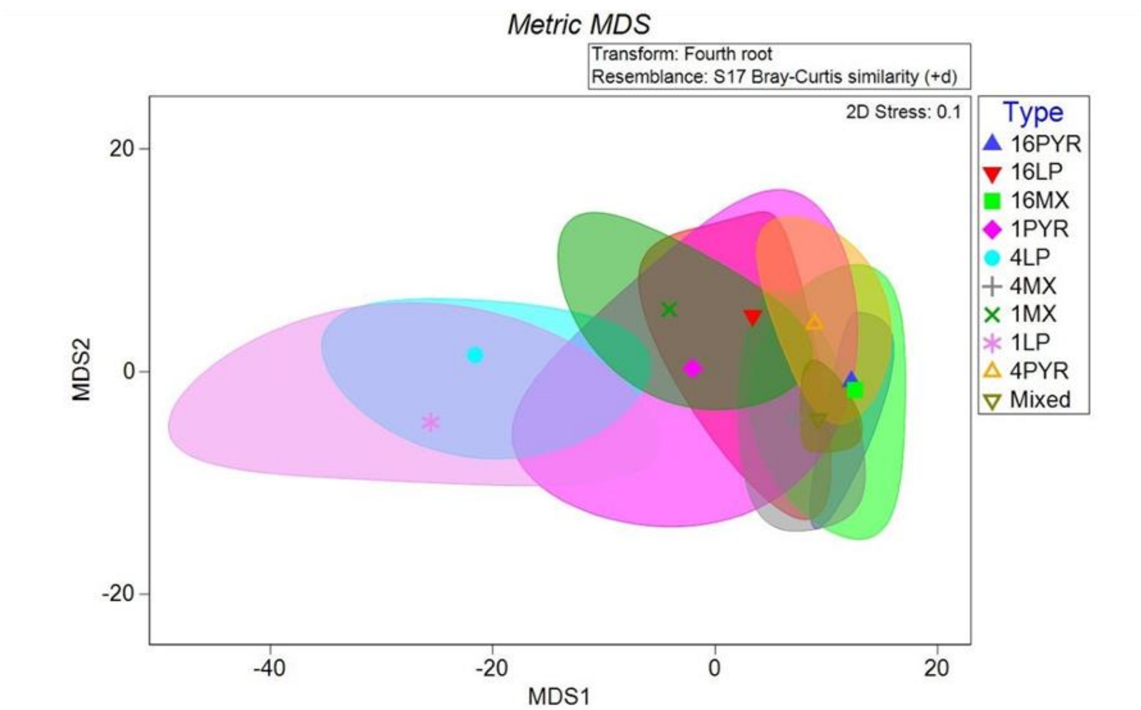

Figure 5. Bootstrapped metric multidimensional scaling plot with 95% confidence interval boundaries comparing the fish community for LP, MX, PYR site types and Mixed sited on the Rio Grande Valley artificial reef.

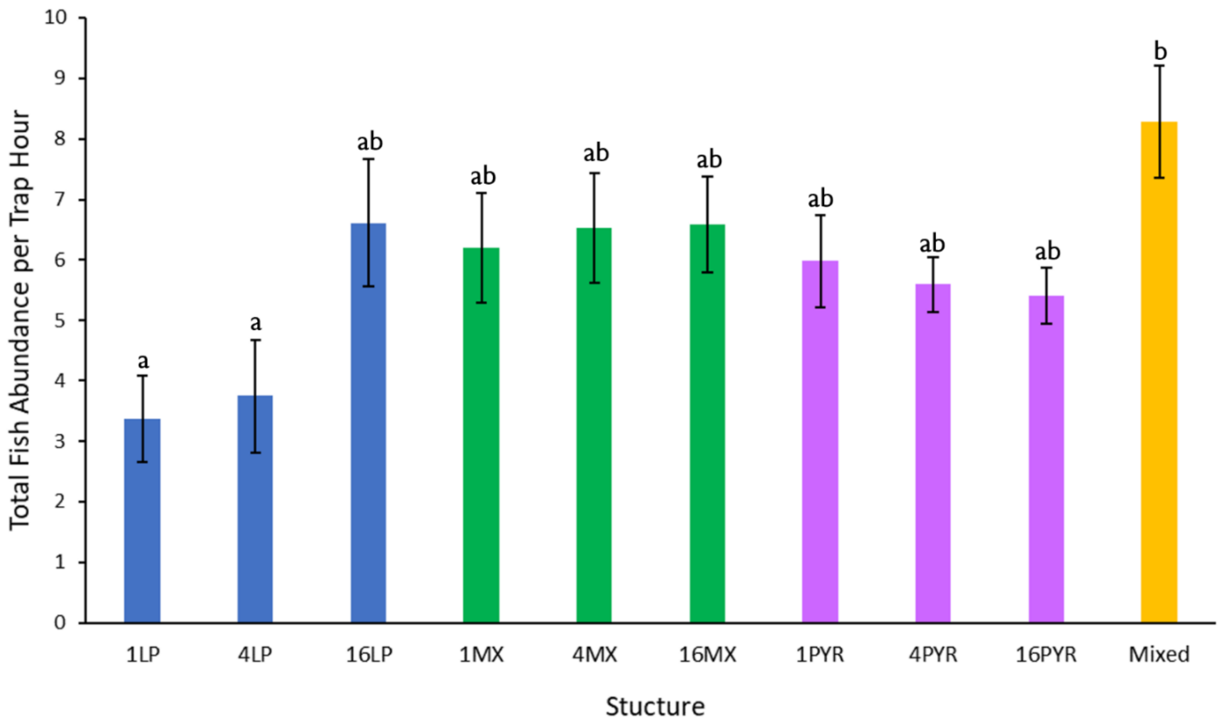

Figure 6. Fish abundance (mean ± SE) based on fish caught per trap hour for various structure types at the RGV reef in the Gulf of Mexico. Bars which do not share the same letter were significantly different (*P* < 0.05) according to pairwise tests with Tukey's HSD.

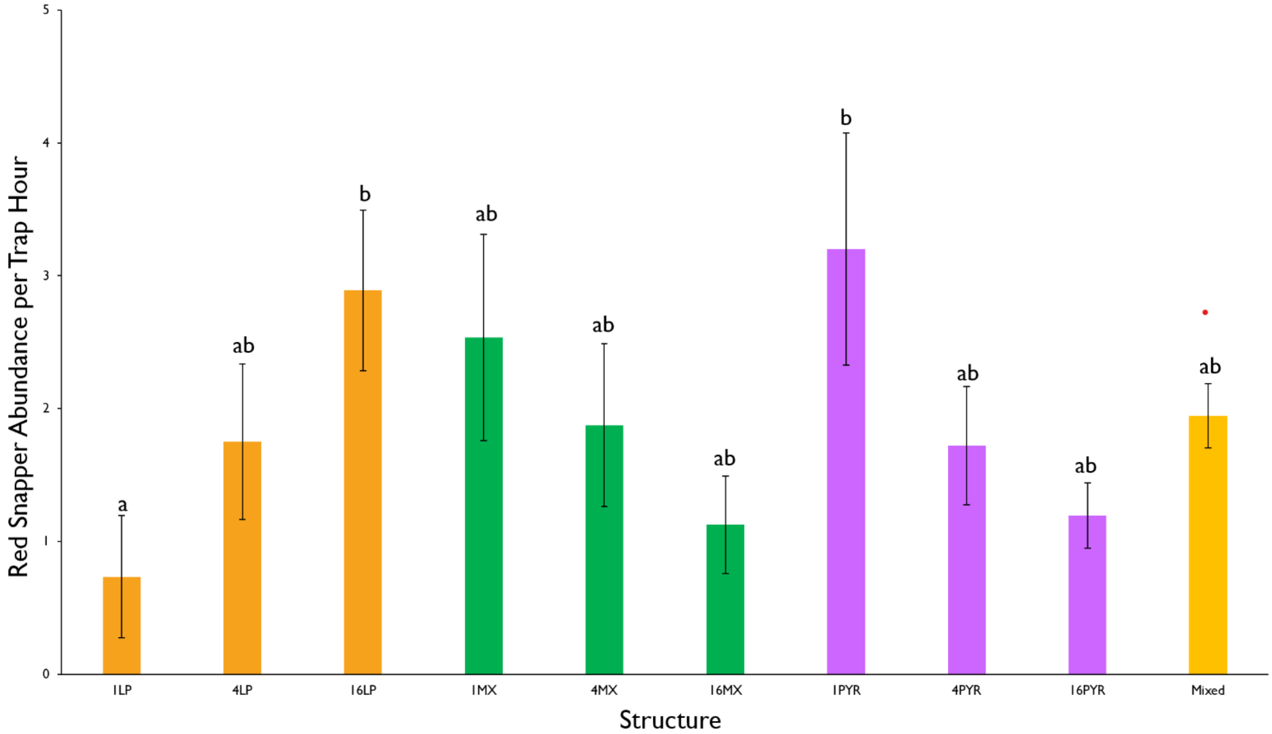

Figure 7. Red snapper (mean ± SE) based on fish caught per trap hour for various structure types at the RGV reef in the Gulf of Mexico. Bars which do not share the same letter were significantly different (P < 0.05) according to pairwise tests with Tukey's HSD.

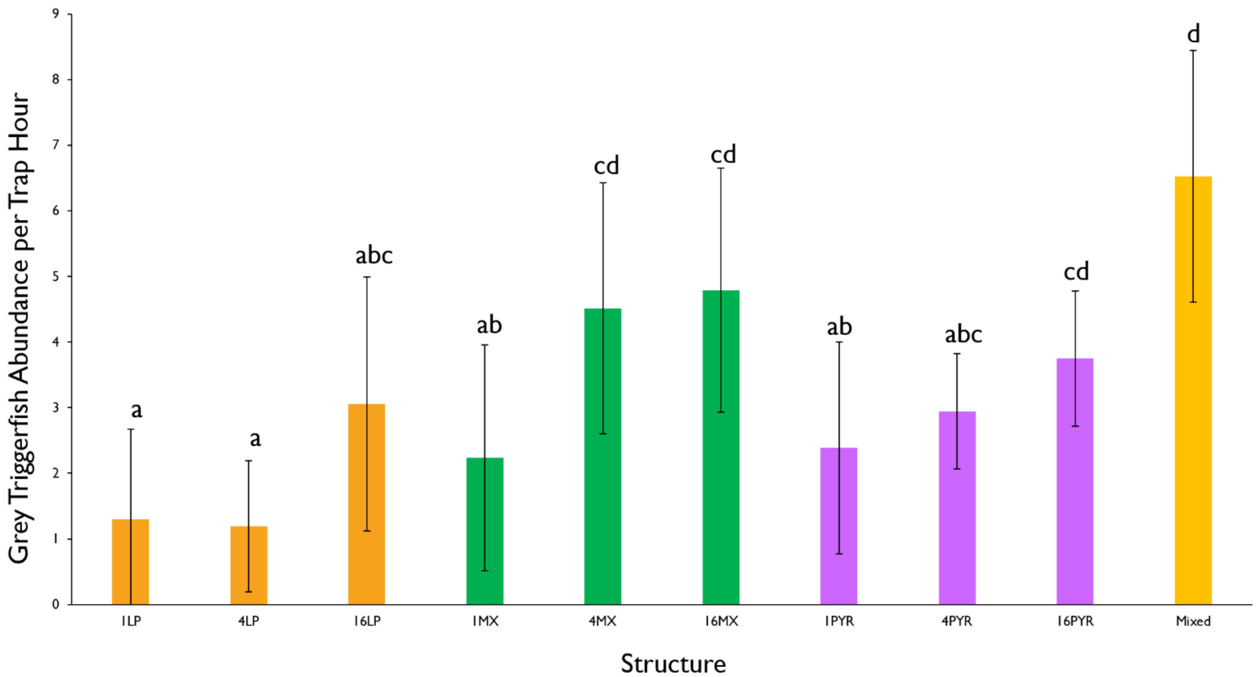

Figure 8. Grey triggerfish abundance (mean ± SE) based on fish caught per trap hour for various structure types at the RGV reef in the Gulf of Mexico. Bars which do not share the same letter were significantly different ($P < 0.05$) according to pairwise tests with Tukey's HSD.

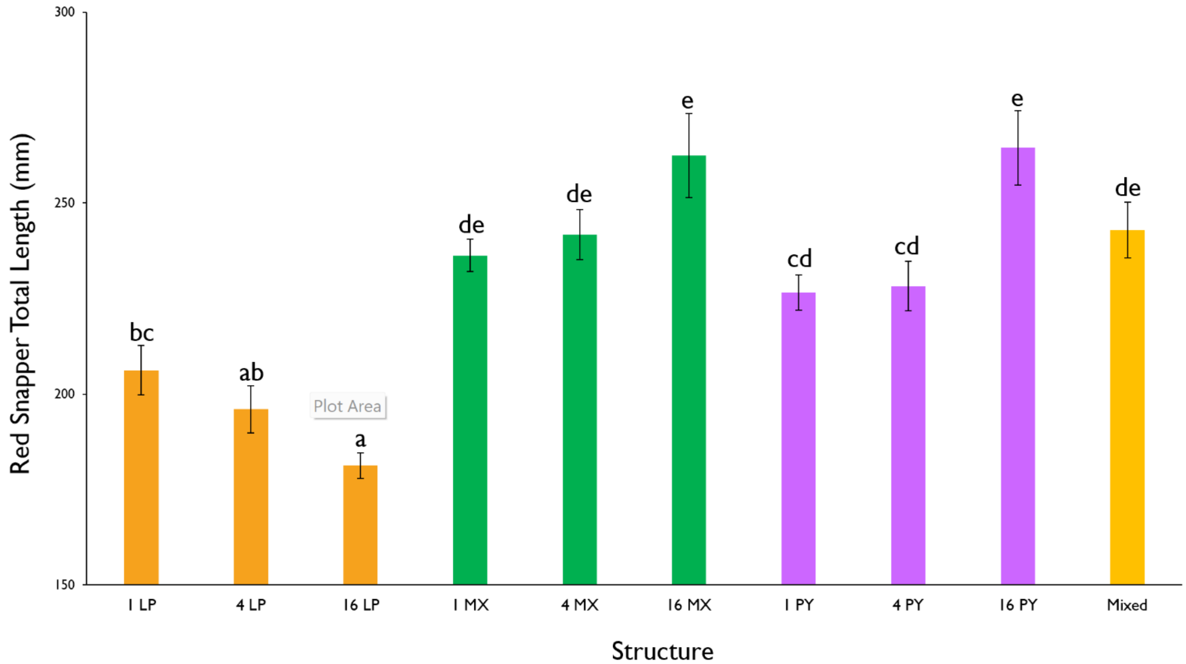

Figure 9. Red snapper total length by site type on the RGV Reef in the Gulf of Mexico. Bars which do not share the same letter were significantly different ($P < 0.05$) according to pairwise tests with Tukey's HSD.

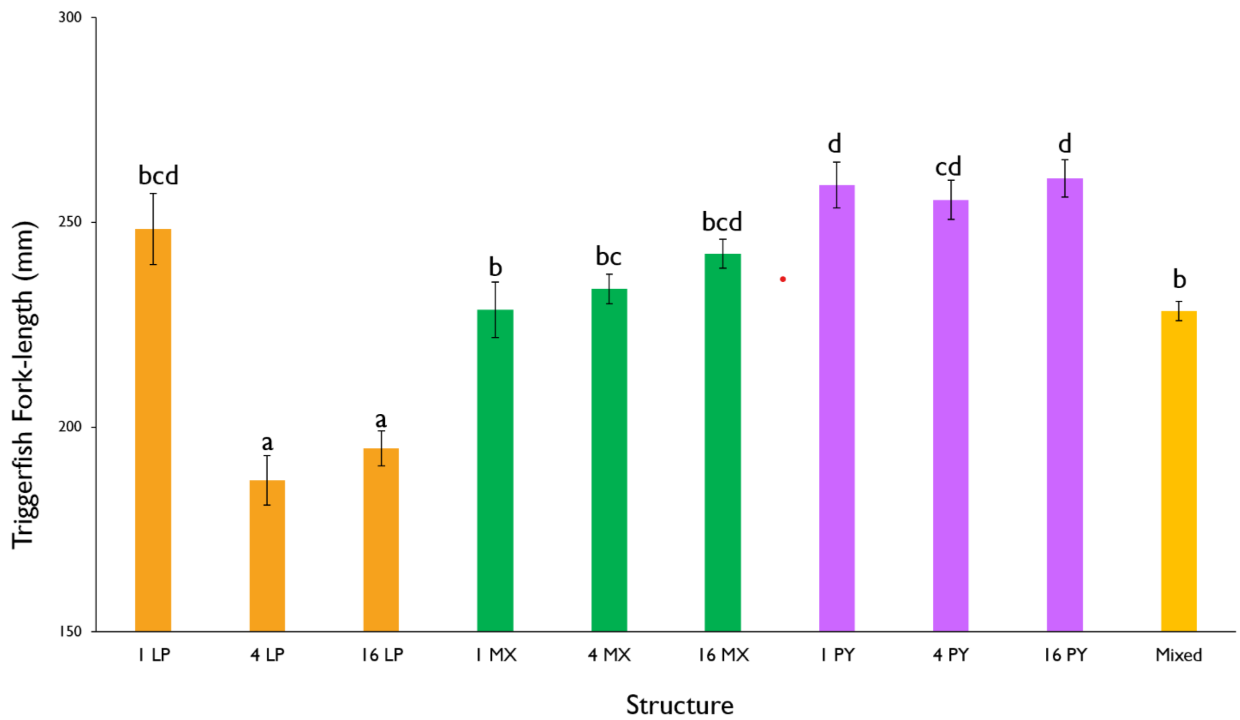

Figure 10. Grey triggerfish fork length by site type on the RGV Reef in the Gulf of Mexico. Bars which do not share the same letter were significantly different ($P < 0.05$) according to pairwise tests with Tukey's HSD.

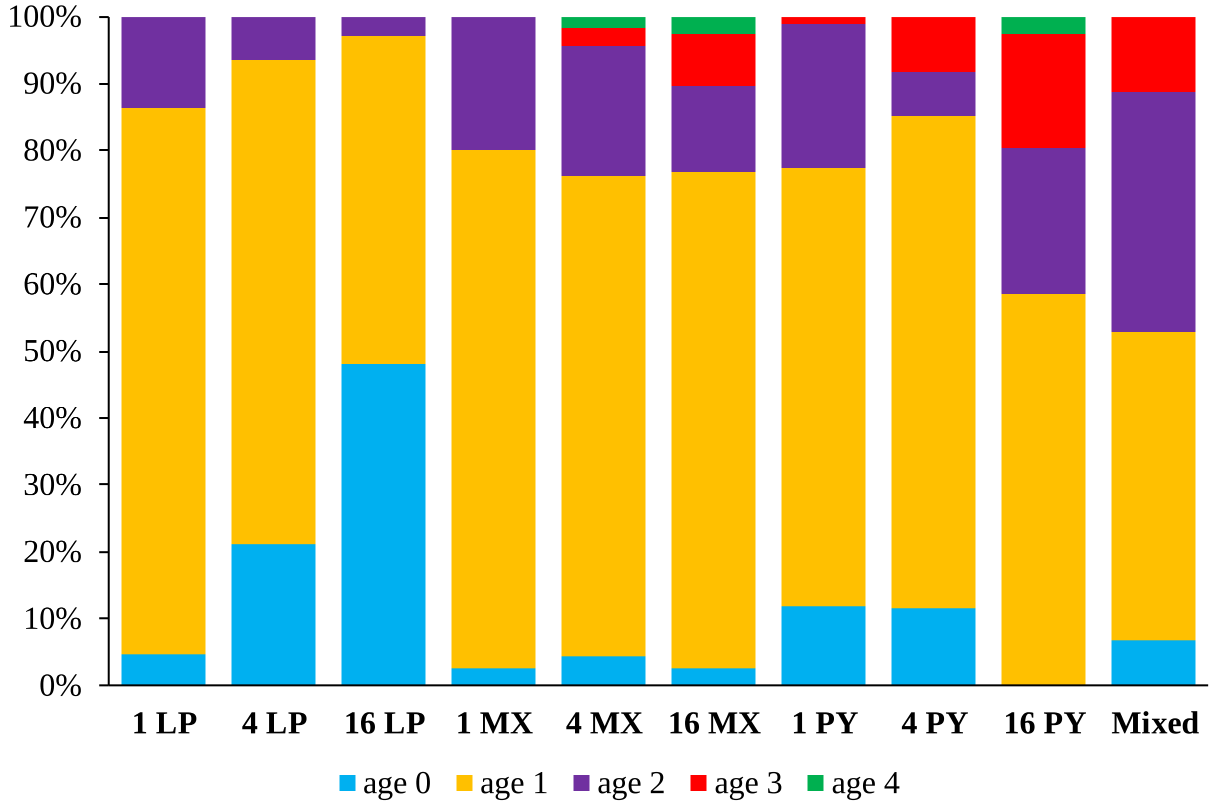

Figure 11. Red snapper age class proportion by structure at different sites on the Rio Grande Valley artificial reef. Age classes were determined by total length based on Manooch and Potts (1997).

Mark-Recapture

Regarding the recreational tagging study, a total of 1,529 red snapper were tagged, and 148 recaptured reports have been made, totaling a 9.7 % tag return rate. The mean days at liberty were 139.07 ± 10.14 days, while the longest time at liberty was 563 days. The mean total length at recapture was 371.15 ± 5.65 mm. Furthermore, out of a total of 98 recaptured fish where location coordinates were known, the mean distance traveled was 0.47 ± 0.05 km. The maximum distance traveled was 2.06 km. All tag returns reported regardless of whether the exact coordinates were known, were within the RGV reef. Red snapper growth rate based on linear regression was 0.2485 mm day -1 (Figure 12) and 1.207 g day-1 (Figure 13). The mean condition value (K) for recaptured fish when weight was obtainable was 1.37 ± 0.106.

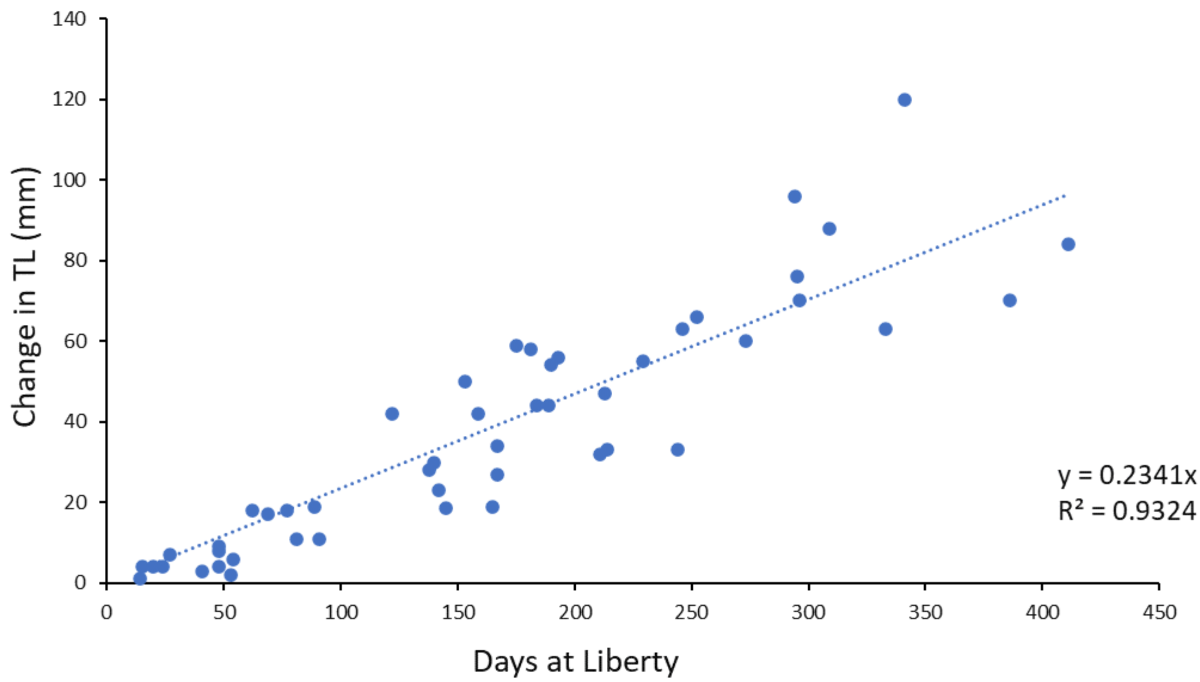

Figure 12. Change in the total length of recaptured red snapper on the Rio Grande Valley artificial reef regressed against days at liberty. The slope indicates a growth rate of about 0.234 mm per day.

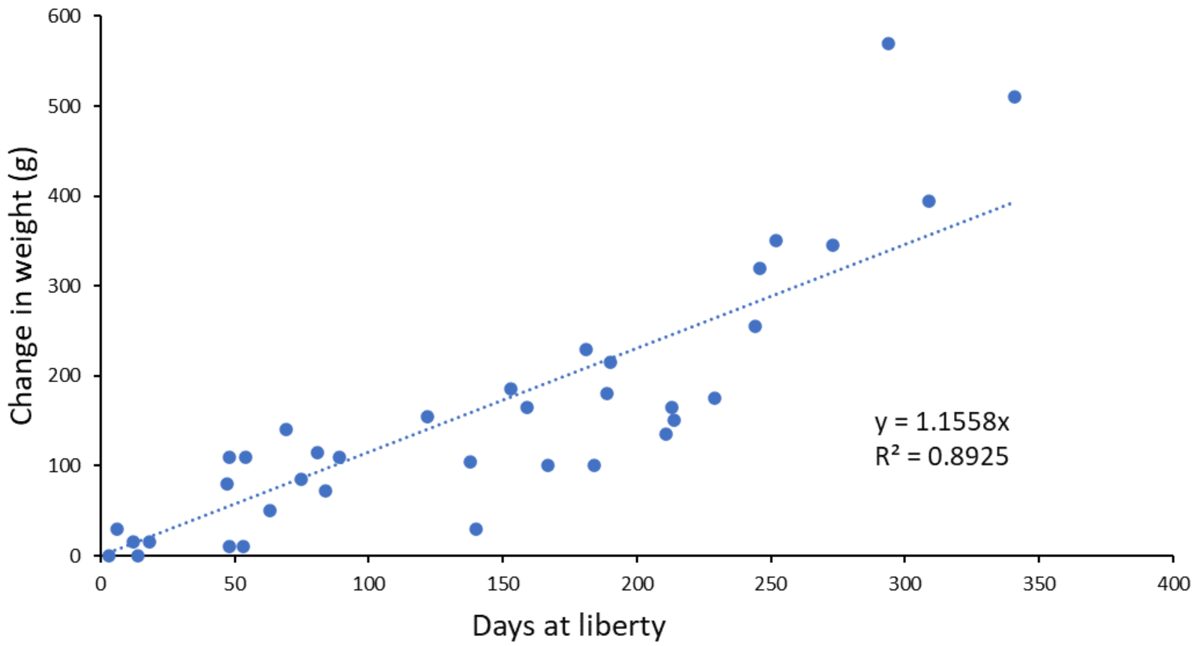

Figure 13. Change in the weight of recaptured red snapper on the Rio Grande Valley artificial reef regressed against days at liberty. The slope indicates a growth rate of 1.207 g per day.

CHAPTER IV

DISCUSSION

Fish Trapping

Enhancement of red snapper and grey triggerfish fisheries is a major factor in artificial reef management plans in the Gulf of Mexico. While fish traps have been known to collect smaller-sized, yet more diverse fish assemblages than other sampling methods (Wells et al. 2008), triggerfish was by far the most abundant species in the traps at 57%. This may suggest that triggerfish dominate this nearshore reef more than in other areas. For instance, Plumlee et al. (2020) found the reverse when they used similar fish traps to characterize fish assemblages in a nearshore reef off the northern Texas coast. They found that red snapper dominated the fish traps, making up 52.6 % of the fish captured at low-profile concrete structures, while triggerfish only made up 19.7%.

Grey triggerfish abundance per trap hour supported the first hypothesis, which stated that the abundance per trap hour of red snapper and grey triggerfish will be significantly higher at the sites with more material. These findings match previous studies that found grey triggerfish prefer reefs with larger footprints, as they feed on encrusting organisms (Bortone et al. 1997; Plumlee et al. 2020). Red snapper caught in our traps did not further support hypothesis one, as abundance did not differ significantly by site type (except for 1 LP) and catch per unit effort actually decreased with the increase in structure amount at MX and PY sites. Previous studies have reported similar findings, where fish abundance per unit area decreased as patch size increased (Schroeder, 1987). Bohsnack (1994) also found smaller reefs tend to have higher population densities than larger reefs, while larger reefs have higher overall biomass due to larger individuals. Traps in the present study had a substantially higher average catch per unit effort than Plumlee et al. (2020) up the coast, where traps deployed at a nearshore reef on low-profile concrete structures reported an average of 1.9 fish per trap hour. Their deployed traps were over a much larger area, while we had a rate of 5.87 fish per trap hour over the smaller RGV reef patch sites. This is likely why 16 PY sites had significantly larger red snapper than 1 and 4 PY but had the lowest catch per unit effort.

The low-profile sites, however, had higher catch per unit effort at the larger structure sizes and were consistent with the hypothesis stating that the LP sites would have significantly smaller fish lengths than the MX and PY sites. This comes as no surprise, as it is well documented that juvenile red snapper and other associated reef fish dominate low-profile structures (Rooker et al. 2004; Lingo & Szedlmayer 2006; Piko & Szedlmayer 2007), especially when isolated from more complex reefs with larger adult fish and predators (Mudrak & Szedlmayer 2012; Arney et al. 2017; Dance et al. 2021). The MX sites versus the PY sites did not alter average fish length much, and the MX or mixed sites did not appear to be effective juvenile habitats for red snapper. This is likely due to predation and competition from other larger present fish at the sites containing mid-profile structures. Gray triggerfish are territorial and have been observed chasing and attacking red snapper (Simmons & Szedlmayer 2018). The removal of gray triggerfish from artificial reef sites leads to smaller size classes of red snapper in the area (Simmons & Szedlmayer 2018). Piko & Szedlmayer (2007) reported that the abundance of juvenile red snapper was significantly higher at caged artificial reefs where predators were excluded using concrete blocks and shells. At low-profile reefs, age-1 red snapper limit recruitment of age-0 red snapper (Workman 2002), and other studies have observed larger Red Snapper aggressively guarding complex habitats against smaller red snappers (Mudrak & Szedlmayer, 2012). This is supported by our age class percentages among sites, as 16 LP had the highest proportion of age 0 red snapper with no presence of age 3 and up fish. Thus, it is likely that the benefits of low-profile modules for juvenile red snapper habitat are lessened when placed near mid-profile or high-profile structures that attract larger fish.

Mark-Recapture

When re-deploying the fish traps at each sampling site for a second time, one of the goals was to recapture some of the original tagged fish put out during the first trapping round. However, only one of the original tagged red snapper was recaptured, although we did catch additional tags that were put out by volunteer anglers. We did not recatch any of the smaller, n-94 T-bar anchor-tagged fish, and only one out of 575 of the small n-94 tags was reported at all. The fish tagged with a t-bar anchor tag had a mean total length of 203 mm, which is well under the legal recreational size limit of 381 mm. This likely explains the lack of return calls since they are too small to be targeted by the recreational fishery. However, the reason none of these smaller fish were recaught in the traps remains unclear. Previous studies have reported high tag retention rates of t-bar anchor tags (Svedlmeyer & Shipp 1994; Phelps & Rodrigues 2011; Hammel et al. 2012). When held in laboratory tanks, Svedlmeyer & Shipp (1994) reported 100

% retention in red snapper after 6 months, while Phelps and Rodrigues (2011) found 90% retention after 150 days. Similar results were found in studies with other fish species such as 81 % retention in African sharptooth catfish (Booth & Weyl 2008) and 100 % in shovelnose sturgeon (*Scaphirhynchus platorynchus*, Hammel et al. 2012). Furthermore, the one tag that was reported from this mark-recapture study supports was at liberty for 310 days. One possible explanation for the lack of t-bar recapture could be due to the high natural mortality rate of small, juvenile red snapper (Gallaway et al. 2007; Rooker et al. 2004), although the complexity of the various structures should have increased the survivability of juveniles, based on previous findings, mostly due to decreased predation (Connell & Jones 1991; Hixon & Beets 1993) and elimination of trawling (Wells et al. 2008). Another potential reason could simply be that there was a very large population of red snapper at this size with a high turnover rate.

Despite the unsuccessful recapture of the smaller tagged fish, recaptures from the larger, dart-tagged fish demonstrated that the growth and site fidelity of young adult red snapper on a nearshore Texas artificial reef complex was similar to many previous studies. In mark-recapture studies of red snapper, little movement, and high site fidelity were observed around artificial reefs (Beaumariage, 1969; Fable, 1980; Szedlmayer & Shipp 1994; Watterson et al. 1998; Strelcheck et al. 2007). Beaumariage (1969) tagged 1,372 red snapper, and 97% of recaptured fish were at their original tagging site, while Fable (1980) had just one recapture off the original tagging site. Among red snapper recaptured by Szedlmayer and Shipp (1994), 76% remained within two kilometers of the original tagging site. Watterson et al. (1998) reported red snapper movements up to 265 km likely due to the occurrence of hurricane Opal. Fish that were not at liberty during the hurricane also showed high site fidelity within 1 km. Most telemetry findings also indicate high site fidelity and residency times around artificial reefs, especially in long-term studies. Two studies of three years had mean red snapper residence close to two years and 72 % to 82 % site fidelity per year; (Topping & Szedlmayer 2011; Williams-Grove & Szedlmayer 2016).

The growth of red snapper in the Gulf of Mexico has been well studied (Patterson et al. 2001; Fischer, 2004; Strelcheck, 2005). The growth of tagged fish on the RGV reef was almost identical to the growth rate of 0.238 mm per day found at a nearshore Alabama artificial reef (Patterson et al. 2001), as well as the growth rate reported by other researchers (Render, 1995; Szedlmayer & Shipp 1994). While several studies have used mark-recapture to determine growth in length, there is a lack of literature that includes an increase in weight over days at liberty for red snapper or other fish in the Lutjanidae family. The overall length-weight relationships of tagged and recaptured red snapper on the RGV Reef, however, appear to indicate that they are in good health (Razi & Noori 2018).

Mark-recapture results are commonly used to estimate exploitation rates from heavily fished areas and may help direct local management efforts (Patterson 2007). These studies rely heavily on the willingness of anglers to provide location, measurement, and dates of recapture to estimate tag return rate (Green et al. 1983). This study, like many others, reports a very conservative tag return rate (Diamond & Cambell 2007). Although our angler volunteers were extremely cooperative with the tagging program, there were several occurrences where we heard about tags that were never reported or were lost before reporting. Providing a higher return reward could improve the assumption that all captured tags are reported (Sackett et al. 2018). Overall, judging by the tag return rate from this study, and given the fact that Texas state waters are open year-round with a bag limit of four red snapper per person, we consider the RGV reef to be under moderate to heavy fishing pressure.

CHAPTER V

CONCLUSION

This study showed that the abundance red snapper did not increase with greater structural density, which is comparable to previous studies that have found that fish per unit area decreased as patch size increased (Schroeder, 1987; Bohnsack et al. 1994). The size of fish did increase with higher structural density though, especially when the site was mid-profile pyramids without mixed-in low-profile modules. The abundance of triggerfish, however, did increase with artificial structure density, although the abundance did not increase proportionally to the higher structure amounts. Triggerfish lengths did not appear to be affected by structure type as much as red snapper, and they also appeared to be dominating the population on most of the sampled structure sites, especially the mixed railroad ties and cinderblock pallet sites.

Despite the high competition from gray triggerfish, the catch per unit effort of red snapper in traps was still greater than from published studies at other nearshore reefing areas further up the coast. Based on the age proportions among structure types, we conclude that the RGV reef is functioning as intended by providing habitat for age 0 – 4 and older red snapper. However, the results from the present study suggests it may not be possible to effectively create a habitat in a single reef patch that is suitable for juvenile red snapper as well as adult red snapper and gray triggerfish due to competition between small red snapper and larger fish. The high-density low-profile habitats separate from mid to high-profile structures are the best nursery habitat for juvenile age 0 red snapper, since they have the highest abundances of juvenile fish without the presence of larger fish. Given the expense of deploying artificial reefs, low-density groups of low-profile modules may not be worthwhile additions since they only support low abundances of fish compared to the higher-density (16 LP) structures. Thus, new reefs should incorporate higher material densities when it comes to placing low-profile material. However, low- to mid-density high profile structure like the pyramids used in this study, have different benefits depending on the management goal. For red snapper, high-density structure sites like 16 PY had lower catch per unit effort than low-density sites, but they also tended to have larger red snapper.

The current mark-recapture study on the RGV reef suggests that red snapper appear to stay within the reef confines over extended periods of time with limited movement (<2 km), which supports many previous studies reporting high site fidelity of red snapper on artificial reefs. Furthermore, red snapper displayed similar growth rates found in other GOM artificial reefs. While this study documented favorable numbers for abundance, growth, and site fidelity, additional research is needed to better define the "health" of snapper at this and other reef sites in the Northwest Gulf of Mexico. This project is the first to include a linear model of weight gain regressed against days at liberty, which could be used in future assessments of snapper "health" at artificial reef sites. Although assessing the health of red snapper was not a goal of this study, the calculated condition factor (K), along with the typical growth rates found, suggest that the RGV reef is providing enough resources to sustain healthy populations of red snapper. Lastly, the fish tag return rate highlights the importance of these easily accessible nearshore reefs for anglers. This study demonstrates that the monitoring of fish at various types of artificial reef materials can be used in the adaptive management of artificial reef design to maximize targeted habitat production and retain healthy populations of commonly targeted fish species.

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Marybeth Weihbrecht is from Mechanicsburg, Pennsylvania and attended Juniata College where she earned her Bachelor of Science in Environmental Science in 2019. After graduating, she worked as a divemaster in Mexico assisting with coral outplanting and monitoring. She went on to become an instructor and taught PADI dive courses before going to gradate school at the University of Texas at Rio Grande Valley. From there, she earned her master of Ocean, Coastal, and Earth Sciences in the spring of 2023. She now works at Texas Parks and Wildlife on the restoration and artificial reef team as a natural resource specialist and dive safety officer.

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