A comparison of site fidelity and habitat use of red snapper (lutjanus campechanus) to evaluate the performance of two artificial reefs in South Texas utilizing acoustic telemetry

Andres Garcia
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A COMPARISON OF SITE FIDELITY AND HABITAT USE OF RED SNAPPER
(Lutjanus campechanus) TO EVALUATE THE PERFORMANCE OF TWO
ARTIFICIAL REEFS IN SOUTH TEXAS UTILIZING ACOUSTIC TELEMETRY

BY

ANDRES GARCIA

A THESIS PRESENTED TO THE FACULTY OF THE COLLEGE OF SCIENCE,
MATHEMATICS AND TECHNOLOGY IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE IN THE FIELD OF BIOLOGY

Approved by:

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Graduate School
University of Texas at Brownsville
November 2013
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A Thesis Presented to the Faculty of the College of Science, Mathematics and Technology

University of Texas at Brownsville

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

In the field of Biology

by

Andres Garcia

November 2013
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Abstract

Evaluation of artificial reefs is becoming an increasingly important component of fisheries management. This is particularly true for the northwestern Gulf of Mexico where natural hard substrate is limited and 359 petroleum platforms are scheduled for removal in 2013 due to the “idle iron” policy. This study compared the performance of two artificial reef configurations off the south Texas coast, the Texas Clipper and South Padre Island Near Shore Reefs that differ in material, depth, and distance from shore, with respect to behavior of red snapper, *Lutjanus campechanus*, an important recreational and commercial species. Red snapper were implanted with depth sensing and identification telemetry tags. Receivers were moored at each site to record presence and vertical movements of the fish. In order to better understand the function of these two artificial reefs, comparisons of behavior during day and night periods, as well as residency time were performed to characterize red snapper-artificial reef interactions. In addition, a mark and recapture study using external dart tags was also used to estimate fishing pressure at each site. Acoustic ping number for day and night periods was significantly higher at the near-shore site as well as angler tag return rate, while the offshore site provided more usable vertical habitat based on daily recorded depth profiles for each fish. This evaluation of which reef configuration type provides the better usable habitat for red snapper may serve as a reference for future artificial reef planning along the Texas coast.
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I. INTRODUCTION

Artificial Reefs in the Gulf of Mexico

Alterations to the flat open mud, sand, and shell bottom for the sake of conservation and fisheries enhancement are changing the underwater landscape below the waves in south Texas. Where there is little to no hard bottom available, artificial reefs are creating the complex habitat that benefits both invertebrate and vertebrate marine species (Seaman, 2000). One of the goals of artificial reef placements is to increase the commercial and recreational fishing opportunities for the surrounding communities (Adams et al., 2009; Stephan et al., 1990). The majority of artificial reefs are constructed of highly durable and stable materials to withstand the harsh oceanic environment elements. Artificial reefs can now be found around the world from small scale designs such as culvert pipes, concrete blocks, and ceramic modules, to large scale structures, such as ships and oil platforms, all providing additional structure and habitat to the local environment (Seaman & Sprague, 1991). Currently, south Texas has four artificial reef sites that cover approximately 3.5 km² (860 acres) (Texas Parks and Wildlife Department (TPWD) Artificial Reef Program, 2013).

In the past, the majority of the artificial reefs in the Gulf of Mexico were a by-product of the offshore oil and gas industry in the form of thousands of steel platforms (Kasprzak, 1998). These artificial reefs have provided numerous locations for fishermen and divers alike to engage in recreational activities. However, the removal of these artificial reefs are currently being conducted due federal mandates such as the “Idle Iron Initiative”, which states that platforms no longer useful for operations must be removed because of the potential liability due to toppling during storms and resulting
environmental and navigational hazards that they would cause (Bureau Of Safety And Environmental Enforcement, 2012). With the removal of hundreds of these unintentional artificial reefs every year, a significant amount of hard substrate and recreational destinations are being lost at a rapid pace. In fact, during the one year course of the study, I personally witnessed two removals, of the hundreds that would share the same outcome.

These oil and gas platforms were artificial reefs purely as a by-product of their function to extract petroleum resources from the seafloor; with the removal of so many in a short period, fisheries managers and conservation groups are now tasked with investing funds specifically for the development of artificial reefs. The cost of these reef deployments can range in the millions of dollars per site. Thus, it is important to understand what parameters of an artificial reef improve its function for holding fishes and augmenting habitat to provide for conservation and increased recreational opportunities.

**Texas Artificial Reef Program**

The Texas Artificial Reef Program (TARP) was established in 1989 and is considered to be one of the strongest in the United States (TPWD, 2007). The Texas legislature enacted the Artificial Reef Act of 1989. This act directed the TPWD to “promote, develop, maintain, monitor, and enhance the artificial reef potential in state and federal waters adjacent to Texas” (Stephan et al., 1990). The TARP currently has 66 artificial reefs along the Texas coast. The sinking of 12 obsolete WWII Liberty Ships in 1975-76 formed the foundation of TARP. In addition to these reefs, T2 tanks, barges, tugboats, petroleum platforms, and land based materials such as concrete culverts and
bridge materials comprise the TARP (TPWD, 2007). Two recent additions to the artificial reef program in south Texas are the USTST Texas Clipper (PS-1122 - Texas Clipper hereafter) and the South Padre Island Near-shore Reef (PS-1047) which will be referred to as the “Port Mansfield Reef”, due to its proximity to that port location. While the intent of these reefs is the same, they differ in structure, material, location used, depth, and distance from shore. The Texas Clipper is one large, steel ship structure lying at a 40 m (132 ft) depth, 31.5 km (17 nmi) offshore, the Port Mansfield Reef consists of several concrete culverts distributed at 20 m (65 ft) deep and 13 km (7 nmi) offshore.

Artificial reefs are structures like the Texas Clipper and the culverts which were deployed on the seafloor are acknowledged as habitat for fish and influence biological or physical processes on its surroundings (Seaman, 2000). These benefits provide the development of interactive food webs among the complex communities of the artificial reef. Not only do the Texas Clipper and the culverts provide hard substrate, but they also attract invertebrate species collectively known as biofouling such as barnacles, corals, sponges, clams, bryozoans and hydroids to the hard surfaces that they need to thrive. In addition, these structures provide habitat and foraging opportunities for several species of reef fish including red snapper, *Lutjanus campechanus* (Poey, 1860).

**Natural Hard Bottom**

Near shore along the south Texas coast, naturally occurring hard bottom is limited, with the exception of small banks such as Seven-and-a-half Fathom Reef. Natural hard banks are relic carbonate shelves that protrude from the sea floor (Dennis & Bright, 1988). Because the Gulf of Mexico receives large river deposits of silt and clay, a
nepheloid zone is formed and maintained with the resuspension of these particles caused by underwater currents. As a result, little hard substrate extends above the nepheloid zone, thus reducing coral growth and further minimizing the creation of any hard surface (Dennis & Bright, 1988). The deployment of artificial reefs instantly creates hard substrate that can be colonized by both sessile and nektonic species.

Diver surveys conducted over summer and fall 2013 at the Port Mansfield Reef site indicate differences in species richness and abundance at sites with concrete culverts as compared with areas of mud and sand flats (C. Froehlich, pers.com., 14 June 2013). The placement of the concrete and steel structures provides hard substrate habitat that is lacking in many areas. In addition, vertical relief may be an aspect of artificial reefs that is also important to create a complex ecosystem with many levels of species stratification. Due to the variety of materials available for the construction of artificial reefs, the question remains: which type of artificial reef can provide the ideal reef habitat for fishes?

Red Snapper

Because red snapper have a life history seeking hard structure, placement of oil and gas platforms have allowed for further distribution of red snapper in the Gulf of Mexico (Gallaway et al., 2009; Shipp & Bortone, 2009). With the help of otolith ageing researchers have been able to document that this long lived demersal fish can live up to 59 years (Louisiana Sea Grant November 2013). Red snapper are highly associated and documented on both platforms and other artificial reefs (Szedlmayer, 2007). The

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spawning season for red snapper occurs between the months of April and September. Their eggs and larval stages are planktonic and drift with the prevailing currents (Bradley & Bryan, 1975; Collins et al., 1996; Futch & Burger, 1976; Render, 1995). After the planktonic phase, they quickly settle into areas that have low relief structure and shell substrate (Lingo & Szedlmayer, 2006; Piko & Szedlmayer, 2007; Rooker et al., 2004; Szedlmayer & Conti, 1999; Szedlmayer & Howe, 1997; Workman & Foster, 1994). Red snapper juveniles quickly outgrow their primary habitat and move to more complex structures with higher relief (Gallaway et al., 2009; Szedlmayer & Lee, 2004). Artificial reef sites and other hard structures like the Texas Clipper and Port Mansfield Reefs typically hold large numbers of red snapper throughout the year (pers. obs.), thus add to the structures preferred by juvenile and adult red snapper (Workman & Foster, 1994).

**Red Snapper Fishery**

Red snapper has long been a key species within the recreational fishery that generates $2.8 billion in Texas annually (NOAA, 2009), and is very valuable elsewhere (i.e. Florida and Mexico). Commercial fishing for red snapper target artificial reefs both near shore and off shore to make their quotas (Gallaway, 1984; Nieland & Wilson, 2003). In 2010 the red snapper brought in a $2.9 million commercial landing and dockside value, making it a valuable finfish species in Texas (NOAA, 2010). Artificial reefs may increase available red snapper habitat thus, red snapper continues to play a vital role in Texas fishery and economy (Shipp & Bortone, 2009). Because red snapper are so popular as food fish, the red snapper’s reproductive and developmental biology make it particularly susceptible to overexploitation and has posed a serious fisheries management
problem (Coleman et al., 2000). In fact, red snapper in the Gulf of Mexico has been in decline since the 1970’s (Goodyear & Phares, 1990). For these reasons, management of the red snapper fishery is important in order to stabilize these late maturing, and long-lived fish. One potential answer to this problem lies with the increases in available habitat provided by artificial reefs.

**Red Snapper Management and Regulations**

Because of the years of severe over-fishing and the impacts of shrimp trawls, red snapper has become one of the most highly managed and regulated fisheries in the United States (Cowan et al., 2011; Hood et al., 2007). Now agencies and organization such as National Marine Fisheries Service (NMFS) and the Gulf of Mexico Fishery Management Council, as well as the TPWD are striving to set mandates, regulatory efforts, and limits to help turn this fishery around. By implementing the following regulations, steps to rebuilding red snapper stocks are underway: 1) applying a total allowable catch quota on the commercial and recreational red snapper sectors; 2) setting bag limits for the recreational red snapper sector; 3) placing minimum size limits on the commercial and recreational red snapper sectors; and 4) applying by-catch reduction devices on shrimp trawls (Cowan et al., 2011; Hood et al., 2007). Red snapper fishing is regulated by the state of Texas within the first 16.7 km (9 nmi) from shore. The current size limits and bag limits for recreational fishing in Texas State waters are a minimum length of 38 cm (15 in) and a bag limit of 4 red snapper/day (d). Federal red snapper season is regulated by the NMFS. Federal waters begin at 16.7 km (9 nmi) off Texas waters with seasons
varying from year to year and dependent on yearly quotas. In 2013, the season ran from June 1st to June 29th. Federal recreational size limits for red snapper consist of a minimum 40 cm (16 in) size limit and a bag limit of 2/d. For commercial fishing, the minimum size limits are reduced to 33 cm (13 in) and a commercial quota of 2 million kg (~ 4.4 million lbs). State and federal artificial reefs and the regulations that apply to each are beneficial to the extent that they manage the red snapper population however; there are still mortality issues with undersized discarded fish. With the release of the undersized red snapper comes the high chance of mortality from pressure related injuries, especially at the deeper depths (i.e., greater than 10 m) which are common in federal water artificial reef sites (Diamond et al., 2007).

The decision-making behind these requirements may vary as an artificial reef can be built from less costly materials such as the culverts at the Port Mansfield Reef site to more costly ones such as the Texas Clipper Reef ship. As a result of a behavioral preference from several reef fishes, certain materials and configurations might be more beneficial to reef fishes than others and can be selected to tailor to the fishes needs and provide a durable, long lasting habitat.

Because the placement of these artificial reefs is distributed in both shallower and deeper depths, it is also important to understand other implications that may affect the utilization of these reefs by divers and anglers alike. Research on diel movements of red snapper on artificial reefs has found that movement away from a reef typically occurs during night hours (Peabody, 2004; Szedlmayer & Schroepfer, 2005). Through gut analysis, it is thought that red snapper remain at a reef during the day feeding on water column and at night move to open sandy, muddy bottoms to feed on benthic prey groups,
therefore diel movement are highly associated with feeding patterns (McCawley et al., 2006; Ouzts & Szedlmayer, 2003). It is important to further understand this diel movement behavior associated with an artificial reef configuration as no published studies to date have investigate it.

With ample literature on the life history and common association with reefs (i.e., Gallaway et al., 2009; Hood et al., 2007; Seaman, 2000; Schroepfer & Szedlmayer, 2006; Szedlmayer, 2007; Szedlmayer & Shipp, 1994), the red snapper makes a good candidate to assess the performance of artificial reefs such as the Texas Clipper and Port Mansfield Reefs. However, the main concern in artificial reef studies is not always which fish species to study but what method(s) of monitoring should be used to give the most and valuable data about the utilization of the reef by fishes.

**Acoustic Telemetry**

Tracking red snapper movement in the Gulf of Mexico has been used extensively to understand site fidelity, residency, movement between structures and stock mixing between populations (Szedlmayer, 1997; Schroepfer & Szedlmayer, 2006; Topping, 2009). In the past, estimation of movement, residency, and site fidelity of fishes utilized external tags. This type of study must rely on the recapture of tagged fishes, thus making the study fishery dependent. Accuracy and willingness of anglers to provide location, measurement, and dates of recapture are all required to estimate tag return rate (Green et al., 1983). Factors such as these may reduce the accuracy and reliability of a study focused on obtaining the site fidelity and residency. For the purpose of this study, site fidelity will be defined as the tendency to return to a previously occupied location.
(Switzer, 1993) and residency is defined as the presence within the maximum remote receiver range (Szedlmayer & Schroepfer, 2005). Acoustic telemetry has some drawbacks; however, it provides information that is impossible for a mark-recapture study, such as the time when movements occurred within a site, before an individual was recaptured. Because it is not fishery dependent, continuous acoustic data can be used to study diel behaviors, movement, residency, and habitat use of individual fish (Eklund & Schull, 2001). Research can be prolonged due to long-lived batteries which can continuously relay continuous data. However, subjects must stay within the range of the receiver to collect data for the study.

Acoustic telemetry transmitters emit ultrasonic sounds normally in the frequency range of 30-300 kHz (George, 2007). These frequencies travel well through the water medium and are not audible to most fish (Bowles et al., 2010). This method of passive tracking consists of either continuous signals or intermittent signals from an implanted subject, depending on the desired objective of research. Acoustic signals are detected by receivers which can be deployed at the chosen study site. Depending on the type of transmitter, it can include supplemental sensors that can transmit different parameters including: depth, temperature, salinity, dissolved oxygen, heart rate, tail beats, and swimming speed (reviewed by Arnold & Dewar, 2001). This approach for tracking movement, although limited in range, has the benefit of not disturbing the research subjects during observation, therefore making it the most reliable method yet to survey fish populations. Studies conducted by Szedlmayer & Schroepfer (2005) showed that acoustic telemetry within the northeastern Gulf of Mexico greatly improved the ability to estimate the movements of red snapper. Acoustic telemetry methods are increasingly
providing researchers with tools to better understand the spatial behavior and movement of fish and minimizing the errors of misidentification (Lucas & Baras, 2000). Placing a single receiver in the precise location can analyze site fidelity, and foraging areas (Klimley & Holloway 1999). Based on these studies, acoustic telemetry is the preferred method for collecting fish data on artificial reefs. Acoustic telemetry has been used to estimate long term site fidelity of red snapper on artificial reefs in the Gulf of Mexico (Schroepfer & Szedlmayer, 2006), as well as the distributions, residency time, and homing abilities of the yellow fin tuna, *Thunnus albacores* (Bonnaterre, 1788) at Las Reunion Island in the Indian Ocean (Marsac & Cayré, 1998).

**Artificial Reef Performance**

Artificial reefs are open to the public and can be accessed by private and public charters as well as commercial fishermen, and are therefore vital contributors to the economy. However, the inflow of recreational dollars from these sites could be presumed to depend on accessibility and cost; anglers and divers may be more willing to visit near shore state reef sites rather than more distant and more costly offshore reefs which have similar reef species (Nieland and Wilson, 2002). As a result of a behavioral preference from several reef fishes, certain materials and construction of these artificial reefs are selected to tailor to the fishes needs and provide a durable, long-lasting habitat. The decision-making behind these requirements may vary as an artificial reef can be built from less costly materials, such as the culverts at the Port Mansfield Reef site, to more costly ones, such as the Texas Clipper Reef ship. One lingering question about artificial
reefs is: are they fish aggregative devices or do they actually add to the available habitat and population size (Bohnsack, 1989)?

In terms of monitoring, it is important to understand reef site fidelity, residency, and diel and seasonal movement patterns of these fishes in order to evaluate the performance. The objective of this study was to compare the performance of two different artificial reef placements that differed in relation to red snapper habitat use, site fidelity, residency, behavioral patterns, and angler use using acoustic telemetry and external tagging techniques.

Hypotheses

To assess the performance of two artificial reef configurations, the following hypotheses were tested: 1) Due to the arrangement of the culvert reef and abundant open sand to forage in compared to the large single structure of the Texas Clipper, red snapper will be present and detected more often at the Port Mansfield Reef site than at the Texas Clipper reef site. 2) Because there is limited vertical relief available at Port Mansfield in comparison to the Texas Clipper, daily depth ranges recorded from red snapper at Port Mansfield will be less than those at the Texas Clipper. 3) Because red snapper are known to forage away from reef structures at night in other studies. 3) Depth ranges recorded from red snapper will be significantly different between light and dark periods at both the Texas Clipper and the Port Mansfield Reef sites.
II. METHODS AND MATERIALS

Study Area

Site 1 was the Texas Clipper (PS-1122) a 145 m (473 ft) steel ship was deployed ~32. km (17.23 nm) from the Brazos Santigo Pass at a depth of 40m (132 ft) (Fig. 1). The ship has 7,100 m² (~ 76,000 ft²) of hard exterior surface which promotes the inhabitation of both nektonic and fouling species. The Texas Clipper extends vertically past the nepheloid zone. The Texas clipper has 40 m of vertical relief and large groups of red snapper are commonly observed.

Site 2 was the South Padre Island Reef (PS-1047) near shore reef positioned ~12 km (6.5 nm) south east of the Port Mansfield Pass becoming one of the newest additions to the near shore reefing program (TPWD, 2011) (Fig. 1). Consisting of 4,800 culverts and a 30 m (100 ft) tug boat which covers an estimated area of (0.64km²) (TPWD, 2011). Located closer to shore and sitting at a depth of 20 m (65 ft), most of the culverts and tugboat remain within the nepheloid layer year-round. Vertical relief at the reef ranges from 2 m high culverts to 4 m at the tug boat. Structures are at a depth of 20 m, approximately half the depth of the Texas Clipper site. Both the Texas Clipper and the Port Mansfield Reef are known to have numerous red snapper and have repeatedly been documented by diver surveys in high abundance (pers.obs.).
Equipment

The acoustic telemetry components consisted of VR2W, receivers and V9P transmitter tags manufactured by VEMCO LTD, which serves as the transmitter for the acoustic system, functions as a continuous “pinger”, pulsing randomly within 3 min intervals to avoid signal collision (Fig. 2B & 2D). All transmitters operated at 69 kHz to transmit alphanumeric identification and depth data. The tags measured 9 mm in diameter and 44 mm in length and had an estimated tag life of 322 d. Additionally, dart tags with contact information were placed externally on every red snapper in case any were caught by the public (Fig. 2 C).

The VR2W receiver is a submersible multifunction omnidirectional hydrophone, which detects ID presence, data logging internal memory. Each receiver has a storage capacity of 1.6 million detections, with a maximum 1 km detection range and a 15 month battery life span. All data were downloaded via Bluetooth and processed using VEMCO VUE software. Depth and times recorded from each artificial reefs were sorted with excel and compared with scatter plots and line graphs.

Transmitter Implantation

Underwater surgery techniques similar to Starr et al. (2000) were used to implant 12 acoustic tags in red snapper at the Texas Clipper and 19 at the Port Mansfield site, between March 2012 and August 2012. All surgeries were performed 18 m below the surface of the water. Underwater fishing techniques were employed on SCUBA at depths between 20-30 m to capture red snapper in various sizes at both sites. This approach was
used in order to reduce stress levels on the fish caused by the changes in atmospheric
depression (barotraumas) and temperature if they were brought to the surface (Starr et al.,
2000). Specimens were strapped down and measured for total length (TL) on a surgery
table similar to Starr et al. (2000). Once the red snapper was securely strapped to the
table, a 15 mm incision was made halfway between the pelvic girdle and anus, mid-line
of the peritoneal cavity in an upward fashion in order to avoid cutting any internal organs
(Fig. 2F). The gas sterilized transmitter was gently pushed into the incision and quickly
sutured with Ethicon 2-0 absorbable monofilament thread (Fig. 2E). Each snapper was
dart-tagged. After tagging, each fish was placed in an expandable mesh chamber and
monitored for recovery. All fish were released within 10 min of implantation. All fish in
this study were handled according to protocol approved by the Institutional Animal Care
and Use Committee at the University of Texas at Brownsville (Artificial Reef Monitoring
& Research, 20011-004-IACUC).

**Deployment of Receivers**

Deployment of the acoustic receivers occurred in March 2012 at Texas Clipper
and in August 2012 at the Port Mansfield site. Each receiver was attached to a 4.6 m
stainless steel chain by three stainless steel hose clamps, held upright in the water column
by three round buoys with an buoyancy of 7500 g. Antifouling paint was applied to the
receiver apparatus prior to deployment to deter attachment of marine algae and organisms
known as fouling community. Receivers were placed approximately 3.5 m above the reef
structure and 17 m below the surface with the hydrophone pointing down in areas that
were predicted to be protected from shrimp trawlers and safe for receiver attachment and
relocation by divers. Two receivers were placed at the Texas Clipper at a distance of 122 m from each other, one near the stern and one near the bow (Fig. 3A). At the Port Mansfield Reef, one receiver was placed in a culvert area and the other was set at the tug boat at a distance of 580 m (Fig. 3B). Deployment and retrieval of receivers were done by SCUBA divers. Data from the receivers was downloaded monthly or as weather permitted between March 2012 and February 2013.

**Dart Tag Deployment**

Floy dart tags were also implanted in fish without acoustic tags at each site. Red snapper were caught on hook and line and were brought slowly to the surface. During the tagging procedure fish were measured for TL and vented with a standard fisherman’s snapper venting tool. Fish were lowered back down to the sea floor using a BlackTip™ catch and release device. In addition, a large mesh open ended cylinder was added to the device to prevent predation by Great barracudas (*Sphyraena barracuda*) (Walbaum, 1792) during the release process.

**Ground Truthing Pinger Range**

To test the detection range of the VR2W receiver and the V9-P pingers, two bare pinger tags were dropped at several locations near the artificial reefs approximately 20 m below the surface during the months of November and December 2012. Each tag was left
to soak for the duration of the dive trips, to allow the VR2W to detect at least one
hour of pings. This allowed me to determine the possible detections range of the
receivers.
Acoustic data were used in the analysis of site fidelity, residency, and light and dark depth movements. All raw data were sorted by receiver, transmitter, and then by date. Data were separated by their respective sites Texas Clipper and Port Mansfield (example in Fig. 4). All data were reviewed to remove any depth data that displayed patterns that indicated a fish was dead (e.g. no vertical movement was observed from maximum depth for two days). Additionally, transmitter (Tag 5594) from the Texas Clipper displayed depth malfunction on July 7, 2012 and was removed from any depth analysis, but was used for fish presence analysis only. All data were reviewed to determine the possible fates of each fish (presumed dead, undetermined, alive, and captured by fishermen) for the Texas Clipper Reef (Table 1) and Port Mansfield Reef (Table 2). Depth and presence data were binned by 1 h intervals to calculate average depth and presence for each fish.

All statistical analyses in this study were performed with SPSS 19 (IBM SPSS, 2010). Data analyzed with t-test, ANOVA, and ANCOVA were visually examined for normality with a Q-Q plot and side by side box plots to test for normal distribution and homogeneity of variance and Levene’s test for equality of variances. All analyses were tested at a significant level ($\alpha$) of 0.05. Additionally, the assumption of homogeneity of the slopes was tested before proceeding with an ANCOVA.
**Comparison of Site Fidelity**

Acoustic data were analyzed to develop short term and long term site fidelity for each site as follows: short term site fidelity detections were binned to 1 h intervals from 24 hr periods. To evaluate the long term site fidelity of red snapper, presence of each fish, data was binned into 10 d periods within the 200 d time frame. Fish were assumed present during a previous period if they were detected during a later period. Presence data for each site was calculated at each 10 d period as a proportion of the total remaining. Proportional data from both sites over time were best fit with a logarithmic function. Linear regression was used to analyze the relationship of fish presence to 10 d time period at each site. To meet the assumptions of normality in the linear regression and ANCOVA, a log transformation was applied to the data after it was increased by a constant of one to avoid negative and zero values. Linear regression and analysis of covariance were performed on the transformed data to determine the relationship of the fish presence over time at the two reef sites and to determine any significant effects of reef site.

**Comparison of Residency**

To analyze the residency time for each of the red snapper at their respective sites, actual residency (number of days detected) was divided by the possible residency (number of days fish was at large after being implanted with transmitter) to result in a relative residency percentage. To calculate the residency for all sampled red snapper, possible detections were divided by actual detections, yielding the proportion of time spent around the two respective sites. Percent residency of red snapper between the two
sites were compared with an independent t-test ($\alpha=0.05$) to estimate the potential effects the site may have had on the residency of the red snapper.

**Comparison of Daily Depth Use**

To compare depth use at the Texas Clipper and Port Mansfield Reef sites, daily depth ranges were calculated for each fish. An average was taken from the daily ranges to produce the average daily depth ranges that would be graphed. To analyze the depth use patterns between the two sites, average daily depth ranges for fish at each site were analyzed with an independent t-test ($\alpha=0.05$). In addition, proportional data based on depth range divided by average vertical relief at each site was compared with a Mann-Whitney U test.

**Comparison of Light and Dark Ranges**

To investigate the depth use of red snapper during light and dark periods at each reef site, data from two warm months (August and September) and two cold months (January and February) were used (Fig. 5). Ten days of data were selected from periods. At the Texas Clipper and Port Mansfield sites, 10 d consecutive average depth ranges were analyzed with a two- way ANOVA, to identify which variable(s) (period (month), and light vs. dark interval) contributed to the differences among average depth ranges of individual red snapper. Interaction effects between light vs. dark intervals and period (month) were examined for a significant at ($\alpha = 0.05$). A post hoc Tukey’s HSD test was used to identify any differences between month periods.
Angler Tag Returns

Dart tags were intended to track movement of a red snapper away from a site, but were primarily used to observe the fishing pressure at each site. To analyze fishing pressure at each site, Floy tag return rate was expressed as the number of returns relative to the number of tags deployed at both the Texas Clipper and the Port Mansfield Reefs.
IV. RESULTS

Throughout the study, 30 red snapper were acoustically monitored at two different artificial reefs between the months of March 2012 to February 2013 (Fig. 6 & 7). Body size of acoustically tagged fish overlapped between the two sites and ranged from 31 - 45 cm at the Texas Clipper and 36 – 47 cm at the Port Mansfield site. Out of 11 red snapper at the Texas Clipper, 8 fish (72%) did not remain at the site: 4 undetermined, 3 died, and 1 sensor malfunction (Table 1). Nineteen red snapper were implanted at the Port Mansfield site, 8 fish (42%) did not remain at the end of the study: 6 undetermined, and 2 caught by fishermen (Table 2).

Comparison of Site Fidelity

After 200 d, 27% of the tagged red snapper remained at the Clipper and 58% remained at the Port Mansfield site. Long term site fidelity over the 200 d followed a negative logarithmic pattern that showed a decrease in proportion of fish over time. Linear regressions of the log-transformed proportion data (Fig. 8) were significant and visual examination of the residual plots for each regression displayed a good fit to the data for the Texas Clipper (F = 72.77, p < 0.001, $r^2 = 0.78$) and Port Mansfield Reef sites (F = 225.36 P < 0.001, $r^2 = 0.92$). The slopes of each regression showed a significant negative relationship to fish proportion remaining over time (Fig. 8). For the ANCOVA comparison of mean proportion remaining by site, the assumptions of homogeneity of slopes were met (ANCOVA, F =1.32, p =0.2577) The ANCOVA results revealed a
significant difference in the mean proportion remaining over the 200 d period between the two reef sites (ANCOVA F = 182.25, p < 0.001).

**Comparison of Residency**

At the Texas Clipper, 40% of the snapper had long-term residency (100-210 d), 40% stayed resident for an intermediate term (20-99 d), and 20% remained at the tag site for only a short time (1-19 d) after release. The longest and shortest residencies at the Texas Clipper were 208 and 9 d respectively. Of the 11 fish included in the Clipper study site, 2 were tagged as early as March of 2012 while the remaining 9 were tagged in the months of July-August of 2012. Average (± SE) residency on the Texas Clipper was 69 ± 20 d and had a range of 8 to 208 d.

In comparison with the Texas Clipper, the Port Mansfield red snapper exhibited higher residency with 58% (100-210 d) long-term residency, 42% stayed resident for (20-99 d), and none in the short term period (1-19 d). The longest residency was 180 d and the shortest was 21 d. Within the course of the study, an average residency of 61 ± 14 d was observed at the Port Mansfield site. Though the actual average of days detected at the Texas Clipper was greater than Port Mansfield, when the possible number of residency days for each fish at both reef sites were taken into account, the percent residency (actual/possible) was greater by 8% at the Port Mansfield Reef versus the Texas Clipper.

Thus, an independent t-test revealed a significant difference between the residency percentages of the red snapper at the Port Mansfield and Texas Clipper Reefs (t 0.05 (28) = -2.464, p = 0.020).
Comparison of Daily Depth Use

When comparing the overall average depth ranges use of red snapper at the Texas Clipper and Port Mansfield, a significant difference between reef sites in respect to the overall depth ranges of red snapper was observed (independent t-test, $t_{0.05(11)} = 3.647$, $P = 0.004$), Levene’s test indicated unequal variances ($F = 6.47$, $p = .017$), so degrees of freedom were adjusted from 27 to 11.20. Average daily depth ranges for the Texas Clipper were $(10 \pm 1 \text{ m})$ and for the Port Mansfield Reef $(5 \pm 0.4 \text{ m})$. The proportional depth ranges, based on average vertical relief at each site were significantly different between sites (Mann-Whitney $U_{(28)}=9$, $Z=3.92$, $p < 0.001$). Proportionally, red snapper at the Port Mansfield Reef used 2.5X more vertical relief, than at the Texas Clipper (Fig. 9).

Comparison of Light and Dark Behavior

The four month, 10 d periods of continuous light and dark depth ranges collected from each red snapper revealed various results. The two way ANOVA showed no significant effects of the factors light vs. dark interval ($F = 1.96$, $p =0.175$), time period (month) ($F =0.292$, $p = 0.830$), or interaction (light/dark*time period) ($F = 3.45$, $p = 0.075$) at the Texas Clipper. The two way ANOVA showed a significant effect of time period (month) on red snapper average depth range at the Port Mansfield Reef ($F_{(3)} = 106.72$, $p < 0.001$) and no significant effect of light vs. dark interval or interaction (light/dark*time period). A post hoc test on time period (Tukey’s HSD, $p < 0.001$) showed a significant difference only in the month of February as compared to the three additional months (August, September and January).
Angler Tag Returns

Six dart tags were returned throughout this study from the Port Mansfield site. The Texas Clipper had only three reported. Thus, the tag return rate for the Texas Clipper and Port Mansfield Reef was 4.8 and 8.4 percent respectively (Fig. 10). No red snapper were observed to travel between sites and each red snapper was caught from the site where it was initially tagged. Two of the returns from Port Mansfield included the VP2 transmitters.
V. DISCUSSION

The objective of comparing the performance of two popular south Texas artificial reef sites was successfully achieved through analysis of continuous telemetry, with respects to site fidelity, residency, and light and dark behavior of red snapper. Like the work of Szedlmayer & Schroepfer (2005) and Schroepfer & Szedlmayer (2006) the use of acoustic telemetry was a key in assessing long term residency and site fidelity of red snapper on artificial reefs, like in this study. The use of a similar underwater tagging method implemented by Starr et al. (2000), allowed for underwater surgical implantation of 30 individual red snapper (Texas Clipper 11, Port Mansfield 19) resulting in a study period of 327 d between March 25, 2012 to August 28, 2012, where the longest actual detection time was 208 d and included several fish residing on the reefs for over 100 d.

Site Fidelity

The results of the linear regressions and ANCOVA showed a significant difference between sites in terms of fish remaining over 200 d. While both sites exhibited similar trends and a loss of site fidelity, similar to the findings of Peabody (2004), the Port Mansfield site lost fewer snapper proportionally, in the first month and still retained 50% of the fish at the end of 200 d. These results are more in agreement with Szedlmayer & Schroepfer (2005), where 67% red snapper in their study had long term residency of 117-595 d. If the duration of this study would have been extended, similar results might have been observed. While the sample sizes were different at each site (Texas Clipper 11 and Port Mansfield19), these were dependent on the amount of fish captured and no-
decompression limits of divers during each visit, especially at the Texas Clipper. The 
increased survival of tagged fish in comparison to other studies, a comparison of the 
performance of the two reef sites was made possible. The published battery life of the 
VP-2 tags was 322 days and the fish with the longest period of detection was 208 d, thus 
it is unlikely that the effects of the battery life played a role in the disappearance of any 
fish. Additionally the duration of the study was less than that of the battery life.

Past studies such as Szedlmayer & Schroepfer (2005), Peabody (2004), and 
Diamond et al. (2007) utilized hook and line to collect specimens from the surface and as 
a result collected larger sample sizes (n= 87 to 320) compared to this study’s (n=133). 
Unlike traditional surface fishing, red snapper experience no barotrauma and are less 
susceptible to predation when caught underwater with hook and line as performed in my 
study. Despite the benefits of this unique sampling method, many factors can limit the 
success of collecting specimens and contributed to a smaller sample size. Among one of 
the factors is the influence of inconsistent weather patterns and fluctuating diving 
conditions. Sampling was difficult at times at both sites, especially at the Texas Clipper 
(depth - 40 m), where only 11 fish were tagged. Multiple attempts to implant red snapper 
were made during the course of the study; however, aside from weather, deep depths and 
limited bottom time constricted the number of fish tagged. For instance, the maximum 
depth at Port Mansfield is 20m, half the maximum depth at the Texas Clipper and 
because red snapper are a demersal species, underwater fishing at a shallower depth was 
greatly facilitated during the tagging procedure as it increased the bottom time for divers 
and resulted in a higher number of tagged red snapper at the Port Mansfield site. In 
efforts to a set out a few more transmitters in red snapper, one additional sampling day
was devoted to the Texas Clipper Reef, making this the only exception to equal sampling efforts, including (diver effort) at both sites.

**Residency**

Residency percentages for red snapper were different between the Texas Clipper and Port Mansfield artificial reef sites. This could be because the two reefs differ in depth, construction, layout, and vertical relief, thus creating two heterogeneous habitats. Since the Texas Clipper is a single structure, the residency times of red snapper could have been affected by what Gallaway et al. (2009) noted on oil and gas platforms where larger fish cause young and smaller red snapper to move up or off the reef due to competitive exclusion. In the case of the Port Mansfield reef which is at a depth of 20 m, haphazardly dropped culverts on average stay below 3 m of vertical relief as well as the one sunken tug boat with 4 m of vertical relief over the mud, sand and shell hash bottom (pers. obs.). According to the studies of Gallaway et al. (2009), Lingo & Szedlmayer (2006), and Piko & Szedlmayer (2007), the Port Mansfield Reef has the complexity sought out by red snapper and allowing them to move from their juvenile habitat of low shelves and shell, thus linking it with a higher abundance of red snapper. Consequently, the sizes of the snapper tagged at Port Mansfield are around the type of habitat is linked to the red snapper life history stages (Gallaway et al., 2009; Szedlmayer, 2007). Additionally, live natural hard bottom near the areas where culverts were deployed has been reported by divers during roving surveys at the Port Mansfield Reef site (pers. obs.). These types of habitats exist on the shallow inner-shelf and are an important reef habitat for many types of reef fish including red snapper (Parker et al., 1983; Schroeder et al.,
1988). When comparing the time spent within the range of the receiver/site by the red snapper, the Port Mansfield Reef site displayed higher red snapper presence on consecutive days. One explanation for a higher residency at the Port Mansfield vs. the Texas Clipper Reef site could be predator abundance. Throughout the study, there was a high abundance of barracuda reported at the Texas Clipper compared to the Port Mansfield site (pers. obs.). Some other factors that may have attributed to reduced detections of red snapper at the Texas Clipper are: the thermocline, nephloid layer, or the steel hull of the ship (Peabody, 2004). All of these reasons might hinder the detection of transmitters implanted in red snapper; however, detections of transmitters were not hindered when test tags were deployed away from the Texas Clipper on several occasions.

**Average Daily Depth Use**

Red snapper in the Gulf of Mexico have become synonymous with artificial reefs. The vertical relief of artificial reefs varies with location and constructed materials. However, the vertical relief of each reef has usually been overlooked, though it may be an essential component of performance of an artificial reef. This study investigated red snapper depth use in relation to the vertical relief provided by each reef. The daily average range utilized by all tagged red snapper at the Texas Clipper was less than the vertical relief provided by the ship (Fig. 9) and diver surveys throughout the study reported sightings of red snapper regularly at 24 m and below. In contrast to the Texas Clipper where less than the maximum relief was utilized, Port Mansfield red snapper used more than the maximum relief provided by the culverts and nearby tug boat, and at
times even exceeded the height of the structures, with the exception of four of the 19 red snappers (Fig. 9). The differences in daily average ranges between red snapper at the Texas Clipper and Port Mansfield may have been attributed to the overall depth of the site (Texas Clipper 40 m (132 ft), Port Mansfield 20 m (65 ft)). Nevertheless, the red snapper at Port Mansfield exceeded the vertical relief of the site, indicating that a reef site’s vertical relief may not be sufficiently tall enough for the red snapper. Considering that the average daily depth range for all fish within this study averaged 7.1 ± 0.6 m with the maximum in one fish of 16 m. The results of this study suggest an ideal vertical relief for red snapper falls somewhere between the depth ranges of the Port Mansfield and Texas Clipper reef sites 7-16 m (~23-52 ft). This optimum vertical relief should be considered when planning artificial reefs where red snapper habitat is a primary focus.

Light and Dark Depth Ranges

Seasonal and diel variation often leads to different behavioral patterns in the animal kingdom, and below the surface of the water is no exception. The average daily depth ranges of red snapper during light and dark periods were analyzed to assess whether they were exhibiting a narrower range to evade highly visual predators (i.e. barracuda) or to forage on the bottom. Curiously, no significant differences were found for depth use between light and dark periods at either site. The ANOVA results from the Port Mansfield site and Tukey’s post hoc test revealed that February was the only month that showed significance within the four periods. The absence of a thermocline in February at the Port Mansfield reef, which was observed by the research dive crew on site, could explain the change in depth range utilized by red snapper due to their
preference of deeper and cooler waters usually associated with a thermocline (Gallaway et al., 1999).

**Angler Tag Return**

While labor intensive, the additional steps of underwater surgery effectively eliminated the effects of barotrauma seen in fish brought to the surface and this study achieved a 100% survival rate in acoustically tagged fish based on a 10 d minimum recording duration. In the efforts to obtain additional information from each site, few of the 133 external dart tags were reported for either site. Even though the Texas Clipper and the Port Mansfield reef sites are highly targeted by anglers, only three red snapper with external dart tags were reported caught at the Texas Clipper and six at the Port Mansfield Reef. Port Mansfield had a year-round fishing season and a bag limit of 4/person, the Texas Clipper had a one month fishing season with a bag limit of 2/person (June 1-29) during the year of this study and more anglers were consistently observed at Port Mansfield during my visits. While the short red snapper fishing season could be a reason for a lower tag reporting rate at the Texas Clipper, a fishing pressure difference does not appear to be a good explanation for the missing fish at the Texas Clipper. It is interesting to note that the tag return proportion mirrored the results of acoustically tagged fish remaining after the 200 d, where the Texas Clipper Reef had approximately half the remaining proportion of the Port Mansfield Reef. While release mortality of discarded fish due to predation and barotrauma of could have contributed to these lower numbers at the Texas Clipper, other explanations such as predation and fish movements away from the site appear more likely.
A greater tag return rate at the Port Mansfield artificial reef site may indicate a higher fishing pressure, and could be attributed to the year-round red snapper season in state waters compared to a one month season at the Texas Clipper because it sits in Federal waters. Because the Port Mansfield site had a higher reporting rate of tags by private boat anglers, it may be that anglers in Port Mansfield are more willing to report tagged red snapper. During one tagging event at the Texas Clipper, video documentation revealed several barracudas lying in wait, for snapper to be reeled up and away from the reef, attacking and consuming snapper before reaching the surface. Yet, it is highly possible some red snapper may have gone unreported by anglers, as well as the possibility that some snappers lost their external dart tags as two returned snapper with implanted transmitters were reported with no external tag present. Dunning et al. (1987) found that the retention of external dart tags was significantly lower than anchor and internal tags in striped bass (*Morone saxatilis*) (Walbaum, 1792), especially within the first 18 d.

Management Implications

Throughout the last several decades, red snapper have been overfished and overexploited. To counteract some of these effects, placement of artificial reefs have long been used to increase fish populations by government and private parties. However, the aim of this study was to assess the performance of two artificial reefs utilized by red snapper, a recreational and commercially important species to the state of Texas. After comparing the Texas Clipper to the Port Mansfield Reefs in terms of site fidelity, residency, use of vertical relief, the effects of barotrauma and fishing pressure, Port
Mansfield appears to be more beneficial reef to the red snapper found at these sites. Reefs placed in shallower water may lead to a higher survival rate after undersized red snapper are returned to the water because of decreased effects of barotrauma (Diamond et al., 2007). Planning scattered or dispersed reefs may help reduce rapid depletion of a red snapper population, as it is thought that some reefs may only be acting as fishes attraction devices and not adding to the production of fishes. Bohnsack (1989) was the first to introduce the question of attraction vs. production. He shared two possibilities, in reference to how artificial reefs interact with reef fish: 1) artificial reefs may be creating an essential habitat needed to increase production of the reef fish in areas isolated from natural reefs, or 2) artificial reefs may act only as an attraction device due to a fish’s behavioral preference as fishes may gain new resources from an existing reef. Regardless of what the Port Mansfield site might be promoting, it experiences heavier fishing pressure with several fishing boats present during diver surveys in comparison to the Texas Clipper. This is because the Port Mansfield reef is more easily accessed, it resides in state waters, and red snapper season is open year round. This pressure may lead to higher mortality through fishing, but on the contrary it may contribute to the local economy. Considering that the high residency and site fidelity of red snapper at these two reef sites, it is important to manage state and federal regulations in order to keep the red snapper populations healthy for future generations.

**Conclusions**

Though research conducted on red snapper populations in the northwest Gulf of Mexico is extensive, less research has been done on red snapper in south Texas. This study may set a baseline for future red snapper research on artificial reefs in south Texas.
Additionally, this study provides evidence that these artificial reefs promote high site fidelity and residency of red snapper for more than 200 d at each reef type. The results of this study were similar to those of other studies done off the coast of Alabama on oil and gas platforms where site fidelity and residency were determined to be high (Schroepfer & Szedlmayer, 2006; Szedlmayer & Schroepfer, 2005; Szedlmayer, 1997).

The value of artificial reefs such as the Texas Clipper and Port Mansfield may play an integral role in red snapper development and may be advantageous to the growth of red snapper (Gallaway et al., 2009). Additional placement of artificial reefs may lead to compounding positive effects that continue to benefit many reef fishes besides the red snapper, as well as benefiting divers, anglers, and commercial fishermen.

Different approaches to this study could have facilitated the collection of data. A few approaches to consider is a larger sample size of red snapper with transmitters and collection of thermocline data samples may provide supplementary information on the performance of the artificial reef. Moreover, an increase in the deployment of dart tags may shed more light on the effects of fishing pressure on these artificial reefs in south Texas. With the question of attraction vs. production, additional information such as: reproductive status, recruitment and growth rates on natural vs. artificial substrate would aid in determination of what these artificial reefs do. A summary table of the performance of the two artificial sites was created (Table 3). The aim of this study was achieved: to compare the performance of these underwater oases in terms of how red snapper exhibit extended site fidelity, residency, vertical relief utilization, and fishing pressure and I found them to be beneficial to waters of south Texas.
VI. LITERATURE CITED


Delineation of essential habitat for juvenile red snapper in the northwestern Gulf of Mexico. Transactions of the American Fisheries Society, 128(4), 713–726.


doi:10.1007/s002270050469


VII. TABLES

**Table 1:** Descriptive statistics and fates of implanted red snapper at the Texas Clipper Reef (TC). Standard error = SE.

<table>
<thead>
<tr>
<th>Fish ID</th>
<th>Transmitter</th>
<th>Implantation date</th>
<th>Total Length (cm)</th>
<th>Actual Residency (d)</th>
<th>Possible Residency (d)</th>
<th>Fate</th>
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<tr>
<td>TC1</td>
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<td>TC2</td>
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<td>9</td>
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</tr>
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<td>37.8 ± 1.3</td>
<td>69.3 ± 20.0</td>
<td>218 ± 16.7</td>
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Table 2: Descriptive statistics and fates of implanted red snapper at the Port Mansfield Reef (PM). Standard error = SE.

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<th>Fish ID</th>
<th>Transmitter</th>
<th>Implantation date</th>
<th>Total Length (cm)</th>
<th>Actual Residency (d)</th>
<th>Possible Residency (d)</th>
<th>Fate</th>
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<td>45</td>
<td>160</td>
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Average ± SE: 42.0 ± 0.8, 115.9 ± 14.0, 177.7 ± 0.7
**Table 3:** Performance summary of the Texas Clipper and the Port Mansfield Reefs in regards to high site fidelity, high residency, vertical relief, red snapper survival, barotruama effects, and high fishing pressure.

<table>
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<th>Performance Measures</th>
<th>Texas Clipper</th>
<th>Port Mansfield</th>
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<td>High site fidelity</td>
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<td>High residency</td>
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<tr>
<td>Max vertical relief used</td>
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<td>Red snapper survival</td>
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<td>✔️</td>
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<td>Barotruama effects</td>
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<tr>
<td>High fishing Pressure</td>
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<td>✔️</td>
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4 5
Figure 1: Artificial reef sites located along the Texas coast, including Texas Clipper (PS-1122) and Port Mansfield (PS-1047) study sites where red snapper were tagged. Line running south to north marks the state waters line out 9 nm off the coast of Texas coast. Map adapted from TPWD Artificial Reef Program interactive reef map.
Figure 2: Supplement pictures of equipment used in study. A) Mini underwater fishing pole with snapper rig (see arrow), B) VR2W Receiver, C) insertion needed and Floy dart tag, D) VP2 Transmitter, E) suture, scalpel, and cutting hemostats, F) V-shaped table and in situ surgery.
Figure 3: Diagram of sites with placement of the receivers at each site and approximate distance between each receiver in meters at A) Texas Clipper, and B) Port Mansfield Reefs. Both receivers at each site had overlapping detection ranges with a maximum detection range of 1km (Vemco).
Figure 4: Representative raw depth data of two consecutive weeks depicting typical vertical movement of a red snapper recorded by the VR2W at A) Texas Clipper and B) Port Mansfield artificial reef sites. Dotted line represents the height of the vertical relief of the structure at each site.
Figure 5: Average light and dark depth ranges (with standard error bars) utilized by red snapper at the Texas Clipper (TC) and Port Mansfield reefs (PM) during months of August and September 2012, January and February 2013. TC, PM sample size (n) = August 6, 12; September 3, 16; January 3, 7; February 3, 7. Means calculated from 10 d periods of sampled at 3 min intervals. Star indicating significant difference at p < 0.001.
Figure 6: Total length in centimeters of average (with standard error bars) red snappers implanted with transmitters at Texas Clipper and Port Mansfield artificial reef sites. Sample size (n) = TC (11) and PM (19).
Figure 7: Daily detections of individual red snapper at A) Texas Clipper (TC) (March 2012–February 2013) and B) Port Mansfield (PM) (August 2012–February 2013) reefs; refer to Tables 1 & 2 for details.
Figure 8: Linear regressions with log transformed data of red snapper detection at the Texas Clipper and the Port Mansfield reef site over 200 d. Solid circles the Texas Clipper Data and squares represent Port Mansfield data.
Figure 9: Average daily depth ranges (with standard error bars) utilized by individual red snapper throughout the study at the A) Texas Clipper (TC) and B) Port Mansfield reefs (PM) for the exception of TC3, as pressure sensor malfunctioned. Right axis represents percentage of the height of the vertical relief at both sites utilized by the red snapper. Dotted line represents the height of the vertical relief of the structure at each site.
Figure 10: Percent dart tags returns calculated from number returned tags/ number tags deployed at the Texas Clipper (3/56) and Port Mansfield reef (6/77) sites.