2013

Acoustic biomass of fish associated with an oil and gas platform before, during, and after "reefing" it in the northern Gulf of Mexico

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Recommended Citation

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ACOUSTIC BIOMASS OF FISH ASSOCIATED WITH AN OIL AND GAS PLATFORM BEFORE, DURING AND AFTER "REEFING" IT IN THE NORTHERN GULF OF MEXICO

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Master of Science

in

The Department of Oceanography and Coastal Science

By
Grace E. Harwell
B.S., Louisiana State University, 2009
December 2013

ACKNOWLEDGEMENTS

I would like to take this opportunity to thank my advisor, Dr. James H. Cowan, Jr. for all of his valuable insight, support, and funding throughout my graduate studies. He has provided me with the unfiltered advice that I continuously needed. He always had time for me, and for that I will always be grateful. I also owe a great amount of my gratitude to my committee members Dr. Kevin Boswell, Dr. Joseph Powers, and Dr. Brian Marx. Dr. Boswell mentored me throughout my training in hydroacoustics, and handled my frequent breakdowns with the composure I was lacking at the time.

Dr. Powers provided valuable insight into fisheries management and stock assessment. I am fortunate to have taken part in his coursework. I may have been the least vocal of his students, but I consumed every bit of the knowledge he provided. His input has had a huge influence on my work.

Dr. Brian Marx made time to counsel me on my statistical work when time was not available. His patience will not be forgotten. I want to thank all of my committee members for the time and effort that they have given to my thesis. This project would not have been possible without the help and support of my fellow lab mates. I am extremely grateful for my lab mates, both old and new. Kirsten Simonsen terrified me at first, but ended up helping me more than I could ever ask for. That is one smart cookie. I would also like to thank Todd Langland, Brittany Schwartzkopf, Hilary Glenn, Marshall Kormanec, Kari Klotzbach, Kristy Lewis and Stephen Potts for their help both in the laboratory and at sea.

To my previous labmates who have moved on to bigger and better things: Dannielle Kulaw, Courtney Saari, Elise Roche, Michelle Zapp Sluis, Steve Garner Andy

Fischer, and of course the irreplaceable Dutch couple: Joris van der Hamm and Kim de Mutsert (who I can only hope to be half the woman she is one day). Finally, I would like to thank my parents, sister, and brother-in law for all of their love and support throughout my graduate studies. I could not have done this without them. This project was funded by Mariner Energy Inc., currently Apache Energy Inc.

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ABSTRACT

With over ~2600 oil and gas platforms (platforms) remaining in the northern Gulf of Mexico (Gulf), the Gulf States have access to one of the most unique fisheries in the world. Because of high abundances of game fishes around platform legs and the popular belief that platforms enhance fish stocks, both Louisiana and Texas have created artificial reef programs based upon the decommissioning of platforms. As oil and gas fields continue to be retired, oil and gas companies may find that "reefing" or toppling a platform may be a more economically viable alternative to complete removal of material. Questions remain about how platforms should be decommissioned and whether the moved material affects fish density by changing habitat complexity. In this study, I define habitat complexity as a change in one or all of three variables: vertical relief, footprint and volume of the structure. The objective of this study was to show which of these variables has the greatest effect on changes in fish density with depth in the water column and distance from the site. Mobile hydroacoustic surveys were taken over a period of four years, yielding target strength (TS) (dB) values and mean volume backscattering strength (MVBS) values that could be converted into fish per cubic meter, or fish density. Upon reefing, fish density at the site increased. There was no significant change in density with distance from the site but depth proved to be an important factor. Overall density increased after reefing, with the most substantial increase shown in between 40-60 m depth within the water column, the layer that contained most of the platform material after reefing. The reefed site decreased in vertical relief but increased in footprint and volume. A regression tree revealed that volume was the variable responsible for the greatest variability among densities. Even though there was a much greater percent

change in overall footprint compared to volume after reefing (1,024% increase in footprint versus 55% increase in volume) volumes are 3 dimensional (m^3 vs. m^2) and the platforms permeable, allowing fish to seek refuge within the site.

THE USE OF HYDROACOUSTICS TO ESTIMATE FISH DENSITY AT AN OIL AND GAS PLATFORM BEFORE AND AFTER IT WAS REEFED

With over ~2,600 oil and gas platforms remaining in the northern Gulf of Mexico (Gulf), the Gulf States have access to one of the most unique fisheries in the world (Boswell et al. 2010). Oil and gas platforms (platforms) act as artificial reefs, and are frequented by commercial and recreational fishers and SCUBA divers (Dauterive 2000). Because of high abundances (3-25 times higher within 16 m than distances further out) of game fishes around platforms (Stanley and Wilson et al. 2003; Wilson 2006; Keenan 2007; Gallaway 2009) and the popular belief that platforms enhance fish stocks, both Louisiana and Texas have created artificial reef programs (Kaiser 2006).

Structures that are used for ‘reefing’ often are comprised only of the jackets (i.e. the decks and machinery have been removed; see Figure1). As of December 31, 2012, there have been 403 such structures ‘reefed’ in the northern Gulf; 302 of these have been placed in one of nine planning areas off the coast of Louisiana. These planning areas were selected based on available scientific information, consultation with participants in the offshore fishery for Penaeid shrimp, and comments obtained from affiliated oil and gas industries, and federal and state agencies (Stephan 1996).

Platform removal is expensive (about $10-15 million per structure) according to the Bureau of Ocean Energy Management (BOEM). Converting a platform to an artificial reef can be a preferable alternative if ‘reefing’ is done correctly. There are three recognized methods to “reef “or topple a platform: tow-and-place, topple-and-place, and partial removal.

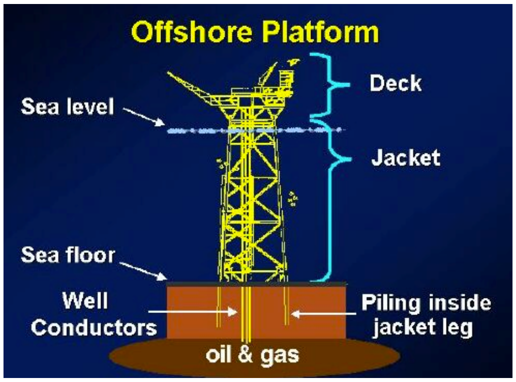

Figure 1. Structural components of an oil and gas platform showing the deck that is removed after decommission, and the jacket left behind that forms the artificial reef (http://www.galvestonlab.sefsc.noaa.gov/platforms).

Oil and gas companies are required by BOEM to remove a platform within one year after it has been decommissioned. By opting out of transporting the decommissioned material inshore, these companies have the potential to save money. Fishing industries, both commercial and recreational, support these conversions in the hopes of attaining sustainable fisheries and increased fishing opportunities (Lindberg 1997).

Despite the support of fishing industries and the emergence of newly reefed habitat, there is limited information available about how platforms affect the distribution of fishes. Large aggregations of fish are commonly found near platforms (Stanley and Wilson 2000; Arena et al. 2007) with density generally decreasing with increasing distance from the site (Boswell et al. 2010; Simonsen 2013) often referred to as a 'reef effect'. In addition to the horizontal shifts in fish density, Stanley and Wilson (2000) reported that fish density also decreased with depth. Several factors contribute to density changes in the water column, some of which include seasonality, time of day, and the presence of a light source (from a standing platform, for example). The goal of my research was to determine if partial removal and “reefing” of a standing platform impacted the magnitude fish density and it’s distribution relative to a nearby control site.

Furthering our understanding of the consequences of “reefing” is becoming increasingly important, as more platforms are being decommissioned and placed on the seafloor for use as fish habitat (Dauterive 2000; Kaiser 2006). Fish density at standing platforms differs from density at reefed platforms (Boswell et al. 2010) and has shown to be higher at standing platforms than reefed platforms (Simonsen 2013; Stanley and Wilson et al. 2003). An important issue to address, however, is whether the vertical relief, footprint, or the total volume of a platform has a greater effect on density. The vertical relief of a structure is simply how far it extends upwards through the water column. The footprint of a reef is a 2-dimensional representation of the structure on the sea floor, measured in square footage, or site pattern + area (Seaman 1996). Footprint takes the 3-dimensional reef and represents it in two dimensions, whereas volume of the reef is measured 3-dimensionally (provided that both footprint and vertical relief information is available). This study will be the first of its kind to examine variables that are believed to drive changes in density once a platform is reefed: vertical relief, footprint, and volume.

In general, reefed platforms reach depths that are, on average, 30 m below the subaqueous height of standing platforms. Vertical relief may play a more significant role in the upper 30 m where large piscivores are common (Nieland and Wilson 2003). The upper 30 m has also been linked to high planktonic productivity and it has been suggested that artificial reefs that extend all the way throughout the water column provide habitat for which these planktonic resources may interact (Rilov and Benayahu 2000). That said, Daigle et al. (2013) showed that phytoplankton was the dominant basal resource fueling platform-dwelling communities at the time of their study, and that no consumer studied specialized on a diet of red macroalgae, which was the dominant type of epiphyte on the platform. If these findings are generally representative, platform-derived benthic algae would not be integral to food-web function on standing and reef function should be similar in areas both favorable to and unfavorable to *in situ* algal growth. These finding are similar to those of Bortone (1998) who showed that low-relief artificial reefs in the shallow Gulf off Pensacola, Florida are sinks for phytoplankton derived carbon. In addition results of a 3 year study (Simonsen 2013) performed coincidently with that of Daigle et al. showed that red snapper diets collected on standing and toppled platforms provided no prey items that were unique to artificial habitats.

To develop my working hypothesis, I have used studies on other types of traditional artificial or natural reefs to draw inference. Studies on both artificial and natural reefs have found that sites that have higher vertical relief support higher numbers of demersal and pelagic fish (Beets 1989; Matthews 1990). Natural reefs characterized by low relief, such as those found off the coast of Alabama, may be less attractive to reef fishes compared to artificial reefs characterized by a high vertical profile (Strelchek et al. 2005).

Arena et al. (2007) examined density on sunken vessels compared to artificial reefs. They found that density was higher on vessel-reefs, with 54% of this abundance contributed by planktivores, and few if any of these fishes was reef dependent. Rilov and Benayahu (2002) concluded that high vertical relief of vessel-reefs provide suitable habitat for the settlement of juveniles higher in the water column. However, volume was not discussed. The volume of the vessel-reef in the Rilov and Benayahu study was larger than that of the artificial reef, as it was not a closed-off structure, allowing more space for fish to find refuge.

A change in platform volume potentially can change habitat complexity. Studies have found that increasing habitat complexity results in an increase in density at a site (Charbonnel 2002). Artificial reefs characterized by low habitat complexity off the coast of France typically harbor low fish densities compared to more complex, multimodular reefs (Charbonnel et al. 2000). Because platforms in the Gulf of Mexico are typically characterized by an average of four legs with multiple beams spanning the legs, these platforms have a high void reef space within which fish may avoid predation.

In this study, I had the opportunity to assess fish density before and after a standing platform was reefed. I use the results of this work to draw conclusions about the importance of vertical relief, footprint, and volume of an artificial reef site, and determine which of these variables best explain changes in density both before and after the site was reefed.

1.1 Materials and Methods

1.1.1 Study Site Design

Eugene Island 314 “J” (28° 16’ 767” N, 91° 43’ 627” W) was a storm-damaged oil and gas platform located approximately 273 km southwest of Port Fourchon, Louisiana (Figure 2). The site is part of a group of platforms in the Eugene Island lease block on the continental shelf. The site is located in approximately 72 m of water and extended fully through the water column before it was reefed. Several years after the site had been damaged, former owners Mariner Energy Inc. (later Apache Energy Inc.)

announced renovation plans in August 2010 Renovation in preparation of reefing the platform began in November 2010.

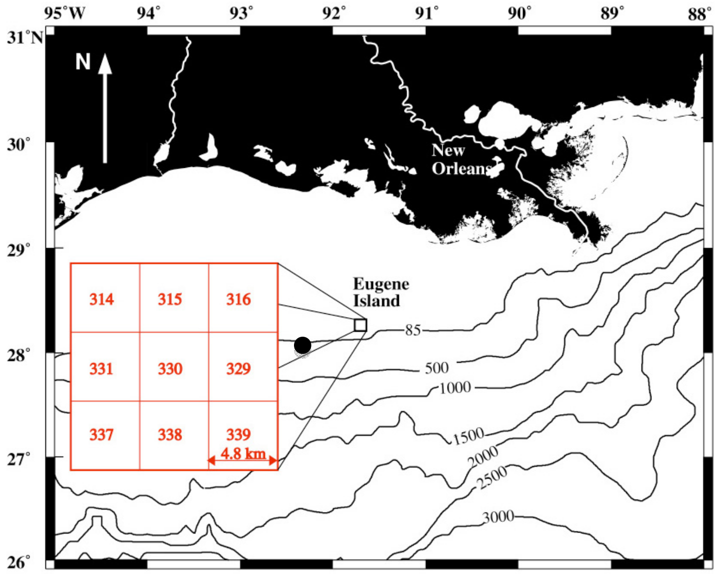

Figure 2. Location of the Eugene Island Block 330 that comprises the study site Eugene Island 314. The block is located on the continental slope in the northern Gulf. The black circle denotes the location of my control site, EI 325.

The platform was reefed by removing the deck, and the upper ~32 m of the jacket of standing platform EI 314 “J” and placing the jacket material on the sea floor approximately 15 m from the original structure. A separate decommissioned platform in the Eugene Island block, platform EI 314 “F”, had it’s deck removed and placed on the sea floor after reefing, thus creating a large and complex structure that made up the reefed study site (Figures 3, 4, and 5).

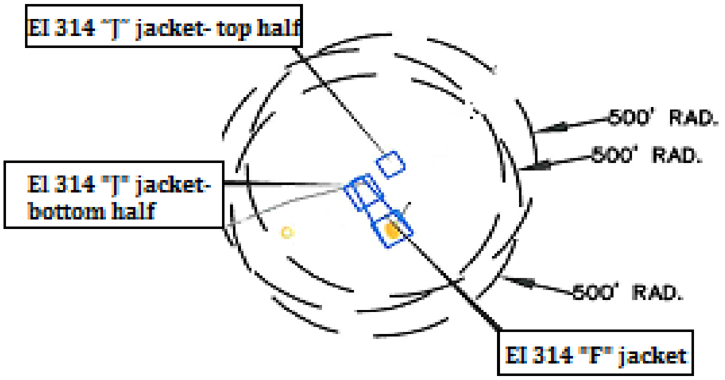

Figure 3. A downward looking drawing of site layout (provided by Bisso Marine for Mariner Energy Inc.).

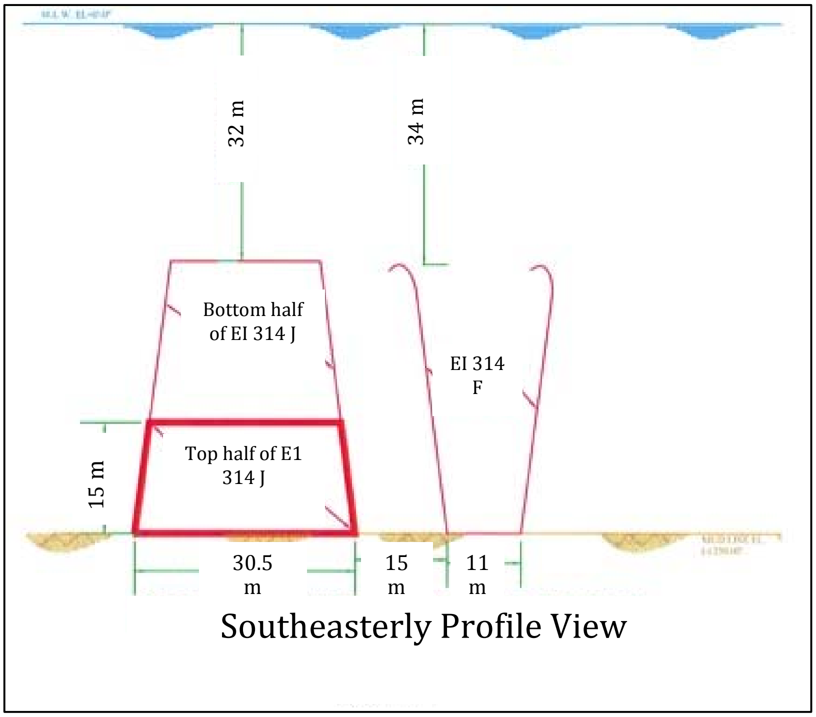

Figure 4. Drawing of the southeasterly profile of the site after reefing (provided by Bisso Marine for Mariner Energy Inc.).

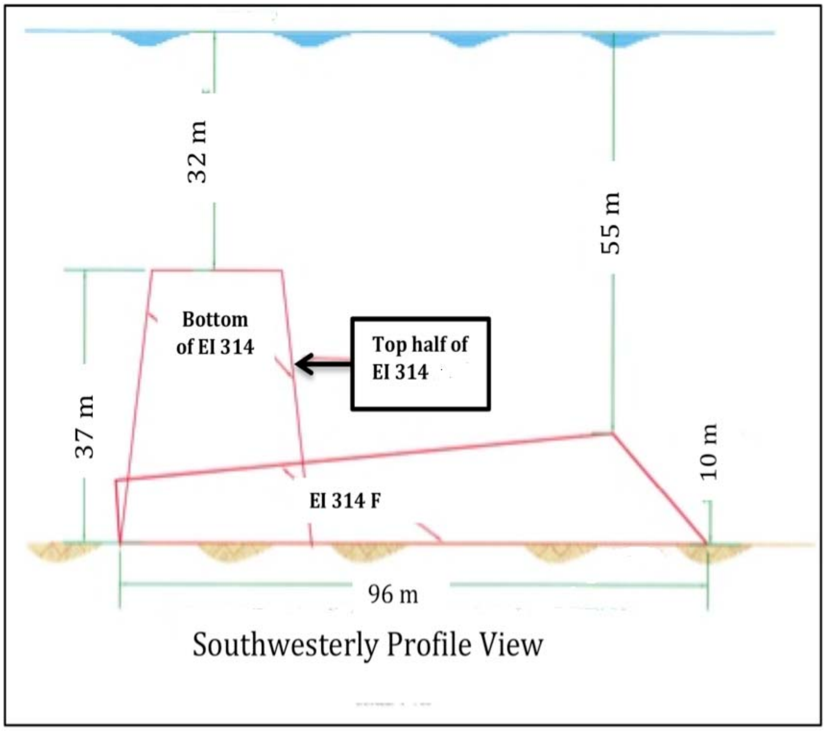

Figure 5. Drawing of the southwesterly profile view of the site after reefing. (provided by Bisso Marine for Mariner Energy Inc.).

The study site's footprint, volume and vertical relief were measured before and after the site was reefed. Surveys taken at a nearby standing platform, Eugene Island 325, act as a control to which I can compare my results (Figure 5). The control site is similar in footprint (5,422 m^2 (control) versus 4,244 m^2 (study) and vertical relief (88 m (control) versus 72 m (study) to my pre-reefed study site.

Generally, fish density was expected to increase with an increase in reef size, although this increase may not be linear (Bohnsack 1994). This suggests that a larger reef (i.e. a larger footprint) does not necessarily equate to higher density. Due to high abundance of fish found in the upper 30 m of the water column around standing platforms, I hypothesized that changes in vertical relief would have a larger affect on reef fish density than changes in footprint or volume of the artificial reef.

1.1.2 Hydroacoustic Survey Design and Techniques

In this study I utilized mobile hydroacoustics to acquire information on reef fish density before and after the site was reefed. Hydroacoustics use different frequencies of sound to measure acoustic backscatter within a volume of water. Data were collected at the site in daylight hours during seven surveys. Four of the surveys at the study site were taken before the November 2010 reefing,, and three were made after the site was reefed. Two additional daytime surveys were taken at a nearby control site, also in the Eugene Island blocks, Eugene Island 325 (EI 325), so that comparisons could be made between the control and the study site before it was reefed (here now referred to as the pre-reefed survey site where applicable). This allowed me to compare changes at the control site with the study site over time (before and after reefing took place). I expected no discernible changes in density at the control site over time because the control site structure was not altered over the course of this study.

Hydroacoustic data were acquired with a BioSonics multi-frequency (70, 120, 200 kHz) split-beam echosounders. However, only echograms from the 70 kHz transducer were used in my analysis, as this frequency most appropriately describes the resonant properties of fishes with swimbladders. Data were collected at a threshold of -65 dB, with a pulse duration of 0.4 ms. Environmental data were collected at each site during each survey with a Sea-Bird SBE 25 conductivity, temperature and depth (CTD) profiler.

Surveys were conducted at an average speed of 4 m s^{-1} and each of the transects around the site was approximately 3 km in length, with the reef structure at the midpoint.

Each survey took from 4-5 hours to complete and were conducted once per survey date. The location of the research vessel was tracked by a wide area augmentation global positioning system (GPS) that was accurate to within 7 m. My hydroacoustic surveys were conducted in a pattern that resembled a ten-lobed tract around the site. This design allowed me to sample on all sides of the of the standing and/or reefed platforms, an important factor considering the density variation that can occur on different sides of a platform (Stanley and Wilson 2000). All surveys were conducted using the same pattern, with each transect line offset 18° from the previous line. Each survey line began at 1.5 km south of the survey site, resulting in 10 transect lines each approximately 3 km long (Figure 6).

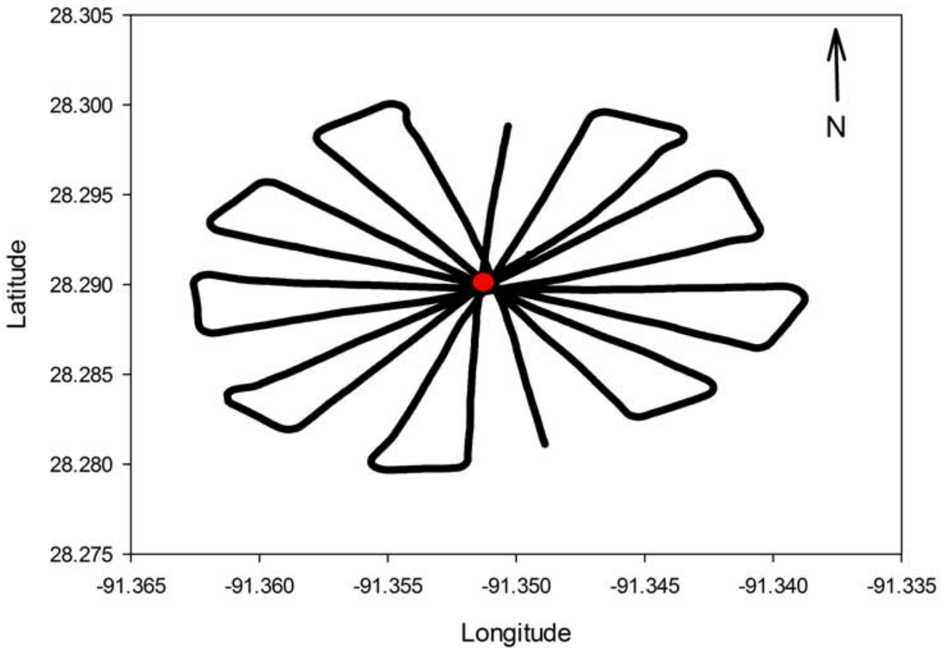

Figure 6. Representation of GPS track showing the survey pattern around the study site indicated by a red dot (reproduced from Simonsen 2013).

1.1.3 Post Processing

Data were processed using Echoview version 5.3, and all echograms were visually inspected; unwanted artifacts were manually removed during post-processing (i.e., seafloor and artificial material, gas seeps, surface bubbles). Transducer ring down and near field effects were eliminated by excluding data within 5 m of the transducer face. A grid of 25 x 20 m cells (equivalent to elementary sampling distance units) was created by dividing the echogram into 25 m horizontal bins and 20 m vertical bins (or layers). Fish density can be averaged within each cell, yielding data on density changes with both distance from the platform and depth in the water column. Environmental data provided by the CTD profiler gave values of salinity and temperature to adjust speed of sound and absorption coefficients per survey.

The data were processed via a user specified analysis pathway (Figure 7) with raw volume backscattering and target strength data handled in a parallel process. Echograms were processed by applying a background noise removal algorithm to the raw volume backscattering data, thus resulting in clean data from the 70kHz transducer. The background noise level is automatically estimated from the data and subtracted from the raw data signal. This method was developed by de Robertis and Higginbottom (2007) and is considered to be the standard technique when applying a Background noise removal algorithm. For this operand, a -100 decibel (dB) threshold was set to remove and eliminate background noise.

Data were then resampled by number of pings with 20 pings per cell. Resampling identifies which samples fall within each cell and applies a mean operation to those samples. The addition of this operator "resamples" the data and links it back to the original resolution so that ping geometries are maintained relative to the raw data (Figure 7).

Following noise removal and resampling, the echo integral (mean volume backscattering strength or MVBS) was derived for 25 x 20 m cells using a cell statistic operator in Echoview, and later used to calculate fish density (fish m^{-3}). The cell statistic operator averages s_v, or the "volume backscattering coefficient" to give the sum of targets, or individuals, over a certain volume to approximate MVBS. The volume backscattering coefficient, s_v, is used to derive the "backscattering cross section" or σ_{sb}, which measures the cross sectional area of the swimbladder of a target. It is from σ_{bs} that target strength (TS) is derived (MacLennan et al. 2002). These conversions from s_v and σ_{bs} to MVBS and TS are necessary because the latter values are in decibels, units that have been used throughout post-processing of data. Mean target strength was derived at the same resolution as the echo integral (25 x 20 m) and was subtracted in the dB domain from MVBS to calculate fish density (fish m^{-3}) or fish per cubic meter per cell ($\underline{FPCM_{cell}}$) on a 25 x 20 m resolution.

$$\text{Fish Density } (FPCM_{cell}) = 10^{(MVBS/10)}/10^{(TS/10)} \qquad (1)$$

This calculation is a measure of fish individuals within a cell. A cell value for example, of 0.017, represents 0.017 fish within that cell. Following this calculation, density estimates were exported from Echoview and used for statistical analysis.

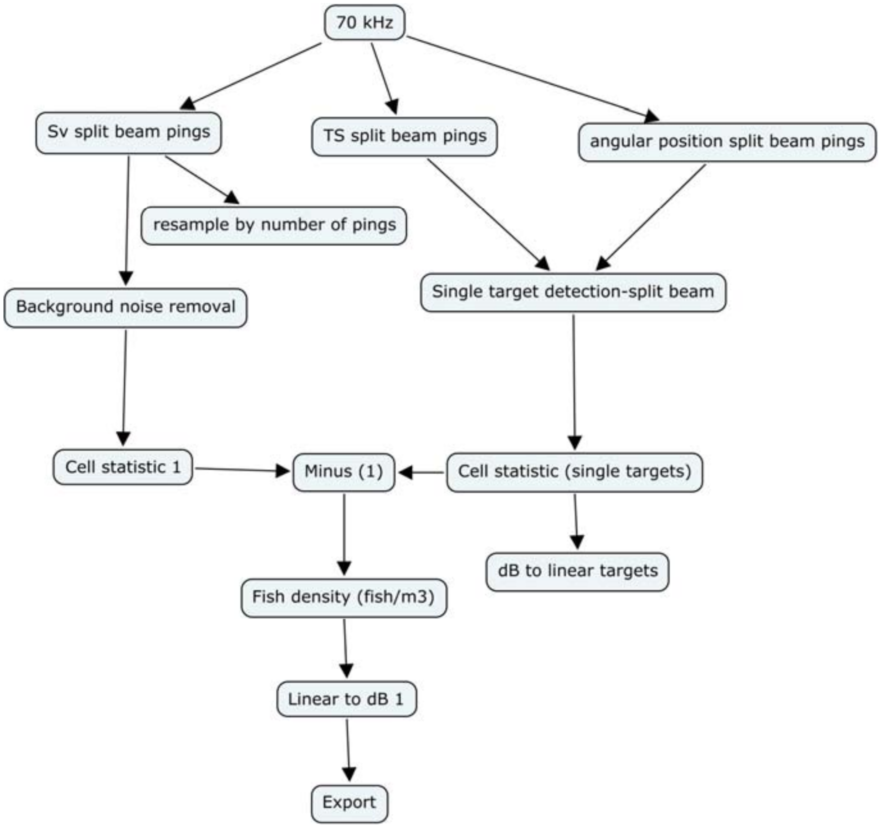

Figure 7. The analysis pathway in Echoview 5 that I used to obtain an estimate of fish m^{-3}.

1.1.4 Data Analysis

To interpret the distribution of fish density in the water column, four 20 m-depth layers were created: 0-20 m, 20-40 m, 40-60 m and 60-80 m, each labeled as 1-4, respectively. To examine distance, four concentric horizontal "bins" were designated around the study sites. Each bin was labeled 1-4, with bin 1 extending 10 m from the edge of the site, bin 2 extending from 10-30 m, bin 3 extending 30-60 m, and bin 4 extending from any distance greater than 60 m from the site. Initially I used up to 15 bins of varying distances, however, no significant changes in biomass were detected from bin-to-bin, so these bins were collapsed into bin 4 (Figure 8).

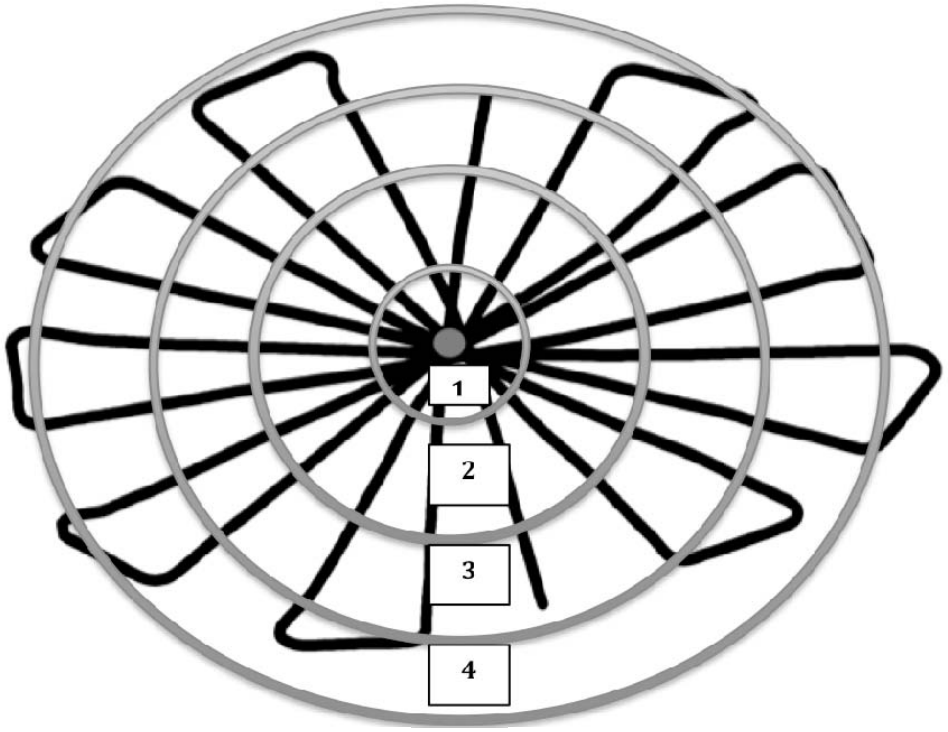

Figure 8. Ten-lobed survey track separated into distance bins 1-4. Grey dot in the middle marks the survey site. Concentric regions are not to scale.

To create distance bins, platform longitude and latitude were determined from each echogram and subsequently converted to northings and eastings. The same conversions were made to latitudes and longitudes corresponding to each individual measurement within each vertical layer. The pythagorean theorem was used to find the distance between a particular measurement and the platform. Fish density estimates at extending distances were then assigned to the appropriate distance bin.

To analyze the data, a Generalized Linear Mixed Model (GLMMIX) was used to determine if mean density changed in relation to distance from the platform, and depth within the water column, at both the control site and the study site before and after reefing. Interactions between and among main effects were included in the model, and I blocked on survey date to reduce error in the model owing to seasonal variability in fish density. I began with all possible interaction interactions (including three-way interactions). The model was reduced by removing interactions that were not significant and the model run again in its reduced form to increase power.

Two surveys taken at the control site in May 2009 and May 2013 were compared to the survey site. This was done to determine if density changed with distance and depth at the control site and pre-reefed study site, as they are similar in footprint, vertical relief and volume. Survey dates at the site conducted before the platform was reefed (December 2009, June 2009, July2009 and March 2010) were grouped as “Before.” Survey dates conducted after the reefing (March 2011, July 2011 and May 2013) were grouped as “After.” The same GLIMMIX was used to compare the two sites as well as density changes before and after reefing. Least squares means (LSmeans) values, and their appropriate standard errors, were used to plot all figures. Significance was set at $\alpha = 0.05$ for all tests.

The three variables of interest, volume, footprint and vertical relief, were calculated for both the standing and reefed platforms using basic geometry and the given dimensions of the site provided by Bisso Marine Inc. A regression tree was used to determine which variable accounted for the greatest variability in fish density after the site was reefed. The regression tree uses recursive binary partitioning to see which variable contributes more to variability within the data. Volume, footprint and vertical relief of a platform are not independent of each other; therefore the assumptions of normality and homogeneity of variance could not be met so a regression tree (a nonparametric approach) was used.

The regression tree bases its selection on the variable with the smallest sum of the squares of the error or SSE. Once the program selects the variable with the smallest SSE, the tree then splits to examine density changes at the study site both before and after reefing occurred.

1.2 Results

The Type 3 tests of fixed effects from the mixed model show whether or not the main effects and their interactions were significant (Table 1). With this output from the full model, I had the option to remove insignificant main effects and interactions, however I chose not to remove them because I believe that they provide insight into the way density changed before and after reefing   For example, the BA*Distance interaction was not significant (Pr > F= 0.5785) but Distance was significant (Pr > F=0.0134), so all interactions involving Distance were kept in the model.

The significant triple interactions (Type*BA*Depth and BA*Depth*Distance) were plotted using LSmeans and standard error. The effect “Type” refers to the study site or control site. The effect “BA” represents data collected before and after reefing occurred. All interactions involving depth were significant. Density changes with depth were examined at the control site and the study site before and after reefing occurred at the study site. The depth distribution of fish density at the control site differed very little before and after the study site was reefed (Figures 9), albeit that statistically significant differences in density with depth are indicated in Table 2.

Table 1. Type 3 fixed effects from the GLIMMIX comparing “Type” (control or study site), “BA” (before or after reefing occurred), Depth, Distance and all interactions.

Type 3 Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
Type	1	5.21	3.91	0.1025
BA	1	5.23	0.08	0.7841
Depth	3	25E3	24.88	<0.0001
Distance	3	25E3	3.57	0.0134
Depth*Distance	9	25E3	11.99	<0.0001
BA*Depth	3	25E3	21.49	<0.0001
BA*Distance	3	25E3	0.66	0.5785
BA*Depth*Distance	9	25E3	19.62	<0.0001
Type*BA*Depth	6	25E3	32.38	<0.0001
Type*BA*Distance	6	25E3	0.83	0.5434

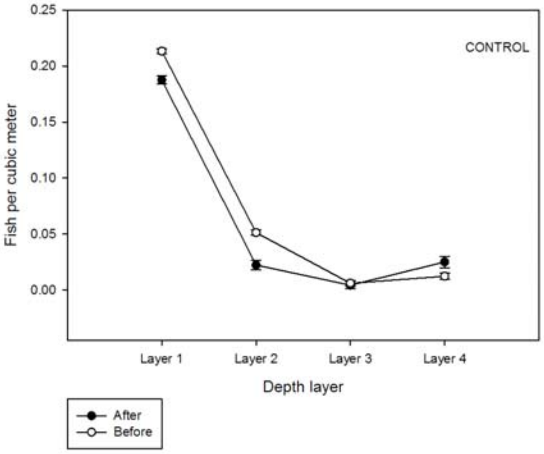

Figure 9. Lsmeans output from the mixed model showing fish per cubic meter with depth layers at the control site, before and after reefing occurred at the study site. Error bars represent standard error.

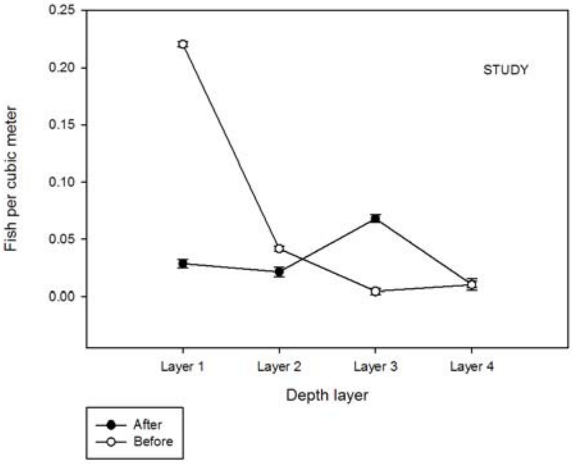

Figure 10. Lsmeans output from the mixed model showing fish per cubic meter with depth layers at the study site, before and after reefing occurred. Error bars represent standard error.

In contrast, the most notable change in depth distribution of fish density at the study site was a significant decline in density in depth layer 1 (Figure 10), and a dramatic increase in depth layer 3 (Table 2). Fish mean density decreased significantly after reefing occurred at the study site (Table 3).

Table 2. Density (fish mean density) at layers 1 and 3 at the study site before and after reefing with percent (%) change: increase (+) or decrease (-).

	Layer 1				Layer 3			
	Density	S.E.	Pr > |t|	% change	Density	S.E.	Pr > |t|	% change
Before	0.2207	0.0023	<0.0001		0.0043	0.0042	<0.0001	
After	0.0285	0.0028	<0.0001	87 (-)	0.0654	0.0051	<0.0001	1428 (+)

Table 3. Fish mean densities at the study site before and after it was reefed. Fish density decreased significantly after reefing. 'S.E.' denotes standard error.

	Density	S.E.
Before	0.06845	0.00568
After	0.04457	0.00511

The second significant interaction was between BA, Depth and Distance. I found that density decreased with distance from the platform and differed both by depth layer and before versus after reefing (Figures 11 and 12).

Total platform volume, footprint and vertical relief were determined for the standing and reefed platforms. Percent increases and decreases were calculated and reported in Table 4. Density trends with volume, footprint and vertical relief were averaged over all surveys taken at the survey site before and after reefing, as well as the two surveys taken at the control site. All data came from the layer of interest, layer 3, because this layer showed the greatest increase in fish density after the site was reefed.

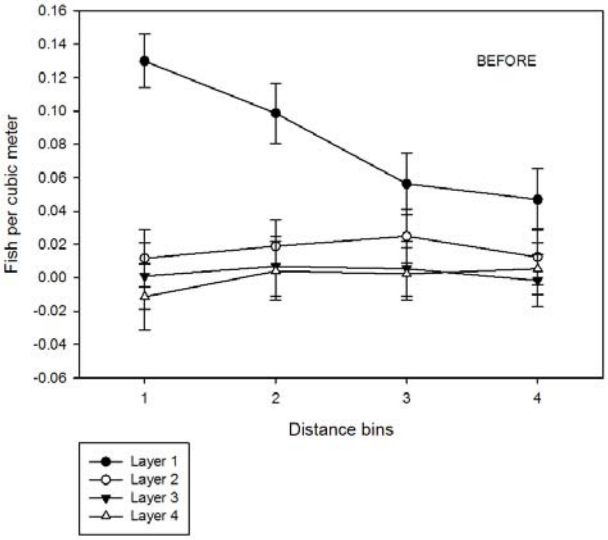

Figure 11. Fish density trends over depth layers and distance bins before the site was reefed.

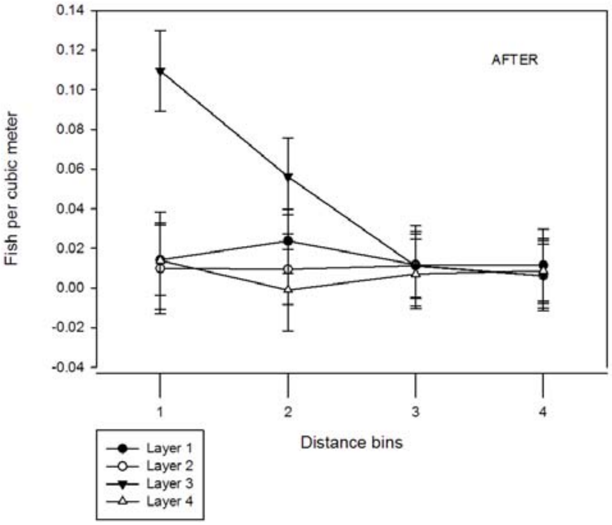

Figure 12. Fish density trends over depth layers and distance bins after the site was reefed.

Table 4. Total volume, footprint and vertical relief of the standing and reefed platforms. Percent change (% change) shows the percent increase (+) or decrease (-) in each factor following reefing.

	Total Volume (m^3)	Total Footprint (m^2)	Total Vertical Relief (m)
Standing	48,962	4,244	72
Reefed	75,771	47,700	33
% change	55(+)	1024(+)	54(-)

After reefing, the largest increase (14-fold) in density was found to be in layer 3. The results from the regression tree using layer 3 densities revealed that enclosed volume was the variable that explained the greatest variability in density (Figure 13). Numbers in the figure represent natural log transformed density values. All data is pooled at the top box, or the parent node. The number in the left box is the lowest density value and the number in the right box is the highest density value. These numbers showed the widest variability, which is why volume was the selected variable.

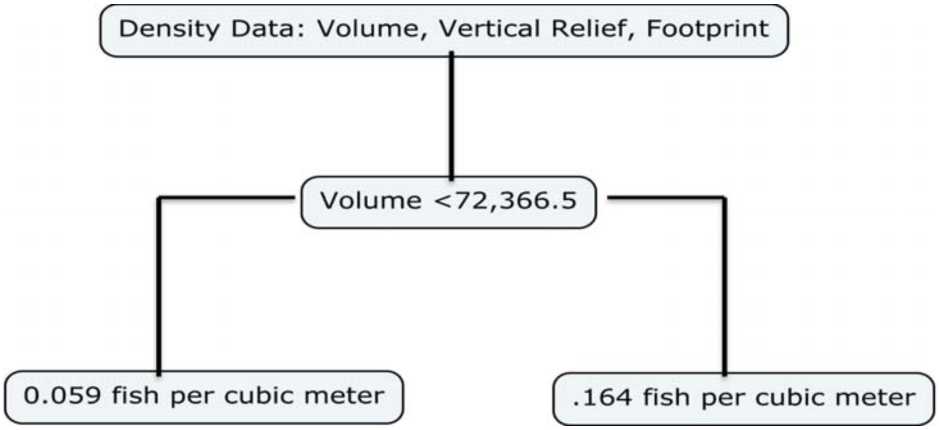

Figure 13. Regression tree showing that volume was the variable that showed the greatest variance among density values.

1.3 Discussion and Conclusions

This study provides new information about how fish density responds before during and after a standing gets reefed. When reefing occurs, the footprint, volume and vertical relief of the structure or structures changes, as does the distribution of fish around the site. As platform decommissioning and removal continues, my results provide insight into how the process of reefing is likely to affect both fish density and fishing opportunities around the structures.

The effects of reef size, especially for structures as large as toppled platforms, has been little studied (Boswell et al. 2010). In a previous Gulf study of a very large artificial reef, vertical relief showed higher fish density in mid- and deeper depths compared to surface waters (Boswell et al. 2010). Other studies investigating patterns of fish distribution associated with complex reef structures also have indicated a precipitous decrease in fish abundance with increasing horizontal distance from the reef structure (Gerlotto et al. 1989; Stanley and Wilson 1996, 1997, 2000; Fabi and Sala 2002; Bremner et al. 2003; dos Santos et al. 2010).

At both my control site and study sites, density decreased with distance from the platform.

A previous study showed that a reefed platform will have higher density in the upper and middle water column (Stanley and Wilson et al. 2003). However, this study showed a much larger increase in the deeper layers within the water column, again likely due to the increase in substrate in deeper layers 3 and 4. Layer 3 reaches from 40 to 60 m deep. The study site is located in approximately 72 m of water. After reefing, the site reached up only from the seafloor (approximately 72 m) to 37 m and the structure was almost exclusively located within layer 3, where fish mean density greatly increased.

Past studies on artificial reefs in the northern Gulf located in a similar depth of water (60 m, where layer 3 ends) showed that the predominant species that comprise the fish community are blue runner (*Caranx crysos*), red snapper (*Lutjanus campechanus*), gray triggerfish (*Balistes capriscus*), Bermuda chub (*Kyphosus sectatrix*), gray snapper (*Lutjanus griseus*), and scamp (*Mycteroperca phenax*) (Stanley and Wilson 2000) with previous studies confirming these species to be dominant (Sonnier et al. 1976; Gallaway et al. 1981; Lewbel 1987; Stanley and Wilson 1996; Stanley and Wilson 1997; Rooker et al. 1997). An ongoing study (Reynolds, Petre and Cowan unpublished), using hydroacoustics coupled with a stereo camera profiling system, clearly shows that the type of fishes located around standing platforms are structured vertically in the water column. Results to date indicate that large piscivores (large jacks and mackerels, several species of sharks, bluefish, blue runners, rainbow runners, etc.) are much more likely to be found in the top 30 m of the water column a platform. Fishes such as snappers, groupers, and other types of reef-associated species are more likely to be present in high numbers at depths between 35-65 m.

Many of these fish have swimbladders that are identified by the 70 kHz transducer during hydroacoustic surveys. Dominant species such as red snapper and gray triggerfish have been shown to make diel movements away from the site during the nighttime for foraging, staying closer to the platform during daylight hours (Simonsen 2013). It is feasible that an increase in substrate (material from the artificial reef) at deeper layers (around 60 m) could provide greater refuge for these species, potentially explaining higher biomass in this portion of the water column despite our surveys being taken in the daytime (i.e. my reefed platform provided more structure in a more dimly lit portion of the water column).

Fish commonly found in the upper portion of the water column, or depth layer 1, are schooling planktivores and large pelagics (Simonsen 2013). Removal of substrate in layer 1 could account for a decline in predatory fish, where they may move off to find another source of substrate in the water column, potentially resulting in the overall decline of predation mortality of other reef-associated species. In fact, preliminary results from the ongoing study by Reynolds, Petre and Cowan, and Campbell et al. (2011) indicate that numbers and biomass of reef-associated species like snappers and groupers are likely controlled from the top down by the numbers and biomass of piscivores in the upper 30 m of the water. If true, this provides fisheries management with the opportunity to use reefed platforms to “target” fish communities of interest. Toppled platforms are more likely to attract reef-associated species like snappers and groupers with less exposure to large piscivores. Decommissioned platforms that are left standing, or cut off just below the sea surface, would favor the piscivores, albeit that predation on reef-associated species would likely remain high.

Initially, I hypothesized that, due to greater density at the shallow depth of layer 1, removal of substrate in this layer would cause an overall decrease in density at the site. Previous studies have shown that a platform reefed by removal of this top layer can result in an overall decrease in density (Simonsen 2013; Cripps 2002) and that platforms in deeper water support lower fish densities both upon toppling and compared to structures in shallower water (Boswell et al. 2010). This study supported those findings, with a significant decrease in total fish density after reefing occurred at the study site. The greatest change in density was found in layer 3, which comprised the highest percentage of the platform volume (approximately 70%). Even though there was a much greater percent change in overall footprint compared to volume after reefing (1,024% increase in footprint versus 55% increase in volume) an increase in volume allows fish to seek refuge within the site. Ultimately, the use of a regression tree indicated that platform volume accounted for the greatest variability among fish densities.

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THE VITA

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