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MMS 2006-037

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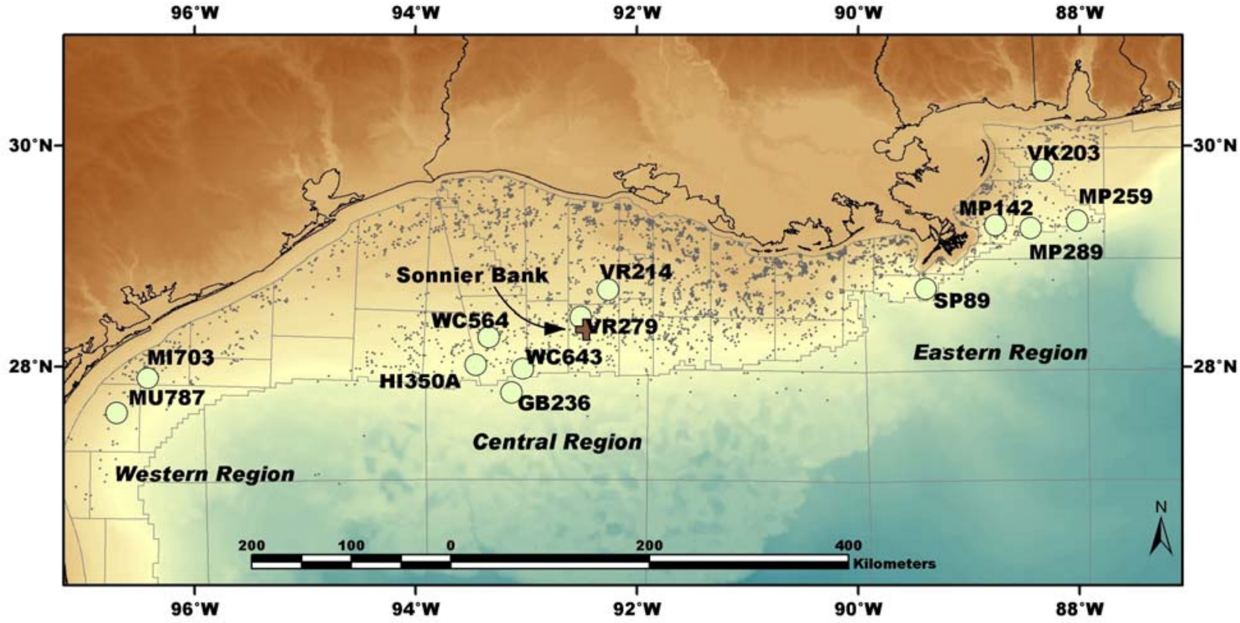
Final Report



U.S. Department of the Interior
Minerals Management Service
Gulf of Mexico OCS Region

Cooperative Agreement
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Louisiana State University

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August 2006

Prepared under MMS Contract
1435-0001-30660-19947
by
Louisiana State University
Coastal Fisheries Institute
School of the Coast and Environment
Baton Rouge, Louisiana 70803

Published by

U.S. Department of the Interior
Minerals Management Service
Gulf of Mexico OCS Region

Cooperative Agreement
Coastal Marine Institute
Louisiana State University

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CITATION

Suggested citation:

Wilson, C.A., M.W. Miller, Y.C. Allen, K.M. Boswell, and D.L. Nieland. 2006. Effects of depth, location, and habitat type on relative abundance and species composition of fishes associated with petroleum platforms and Sonnier Bank in the northern Gulf of Mexico. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2006-037. 85 pp.

ACKNOWLEDGMENTS

The authors wish to thank Mr. Greg Boland in the Environmental Sciences Section of the Minerals Management Service in New Orleans for his guidance during this project. We extend our deepest gratitude to James Cowan, James Geaghan, and Larry Rouse for assistance in research direction, data analysis, and critical review. This research was supported by the Minerals Management Service, U.S. Department of the Interior through the Coastal Marine Institute of Louisiana State University under a cooperative agreement with Louisiana State University.

EXECUTIVE SUMMARY

Scientists and managers continue to ponder both the role of artificial reefs in fisheries management and the effect that artificial reefs have on both healthy and stressed fish populations. This issue is exemplified by the northern Gulf of Mexico (GOM), which has the largest artificial reef complex in the world.

We have spent over a decade studying the fish communities associated with operating oil and gas platforms and with several artificial reefs created from platforms. Although we are still uncertain of the life history consequences of this artificial habitat and its value as compared to the limited natural habitat in the region, we have gained a great deal of knowledge that has advanced this science. Platforms in the region form an extensive resource for recreational and commercial fishery user groups; regional fisheries managers and user groups have reasonable justification to believe that platforms enhance fisheries and organisms dependent on hard substrate. Fish abundance measured as fish biomass at platforms invariably exceeds the measurable fish community associated both with open water bottoms of the GOM and with natural reef and reef-like habitats.

Petroleum platforms differ from traditional artificial reefs in that their vertical profile extends throughout the water column and provides habitat from the photic zone to the substrate. Historically, a major obstacle in deriving scientific data about the effect of deep water artificial reefs (and platforms) on fishes and other nekton was the difficulty in quantifying abundance and species composition associated with these reef communities. We have successfully used two complementary techniques, hydroacoustics and point count visual surveys, to estimate the abundance (biomass) and species composition of fishes at several of these structures (Stanley and Wilson 1995, 1996a, 1997, and 1998) and natural reefs (Wilson et al 2003). In these studies dual-beam hydroacoustics provided estimates of acoustic biomass, density, size distribution, and the near field area of influence. A remotely operated underwater vehicle (ROV) was used to determine species composition.

We have found from 10,000 to 30,000 fishes associated with individual platforms; the lowest numbers were found at the largest and deepest structures, leading us to question the value of deep water structures as artificial reefs. We have also reported that density of fishes around platforms was ten times greater than open water and from two to three times greater than fish density associated with the upper portion of the West Flower Garden Bank off eastern Texas; species composition also differed between these two habitat types. (Wilson et al 2003).

The purpose of this project was to extend our research to address the effect that depth and latitude have on the fish community associated with platforms and to compare the fish community at a natural hard bottom (Sonnier Bank) to that of a nearby standing platform.

The test of these hypotheses is critical both to future Minerals Management Service policy and to platform dependent artificial reef programs. We proposed to describe the fish communities at several platforms along a north-south transect twice a year for each of three years, sampling along a new transect each year. Transects were located east of the Mississippi River in year one, in the central Gulf of Mexico off the Louisiana coast in year two, and the western Gulf of Mexico off the coast of Texas in year three. A contract modification allowed us to add an

additional survey of the Sonnier Bank features to provide for comparison of the fish community at platforms to that of nearby natural substrate.

Across the three regions (east, central and west), we observed a significant difference in fish biomass. Fish biomass per unit area was highest in the central region and lowest along both the eastern and western regions. Fish biomass at platforms in the central region were also dominated planktivores that reside high in the water column. We speculate that increased nutrients from the Mississippi river may allow for increased primary and secondary productivity in the central region. Species richness was higher in the central and western GOM compared to the eastern GOM.

Average acoustic fish size also varied significantly across regions and was again highest in the central region and lowest in the western region (Figure 12a, 13). Targets along the western region averaged 30% smaller than those of the central or eastern regions. Targets along the eastern region were also slightly smaller than target size along the central region.

A comparison of the high-relief pinnacles at Sonnier Bank and the standing platform VR279 again demonstrated that based on our acoustic fish biomass estimates, fish biomass, abundance and size were all substantially greater around the standing platform, particularly in the upper water column. Fish biomass over the low-relief feature at Sonnier Bank showed a greater fish biomass compared to the pinnacles

This research continues to support the premise that standing oil and gas platforms make useful artificial reefs because they support fish densities that can be from 10 to 1000 times greater than the densities found over adjacent sand and mud bottom habitats. Also, fish densities at standing platforms almost always exceed those found both at artificial reefs (both partially removed and toppled) and at natural habitats such as Sonnier Bank. However, the fish species associated with artificial reefs (including standing platforms) differ from those found on natural habitats. Future research efforts might be directed toward determining the reasons for this difference.

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1.0 INTRODUCTION

The benthic environment of the northern Gulf of Mexico (GOM) from Destin, FL to Brownsville, TX is characterized by silt, mud, and sand with very little hard substrate. Parker et al. (1983) estimated that there was approximately 2800 km² of naturally occurring hard bottom in the region. Over the last 60 years, the area of hard substrate in this region has increased through the development of infrastructure for a thriving oil and gas industry. Currently, there are some 4000 oil and gas platforms operating in state and federal waters of the northern GOM (MMS 2005), creating the largest de facto artificial reef system in the world. Combined, these platforms only increase the surface area of hard substrate available in the northern GOM by 4% (Stanley and Wilson 1990, 1991, 1997), but they have altered the available fish habitat and possibly affected regional fisheries by providing hard substrate throughout the water column. Off the coast of Louisiana in particular, the Mississippi River deposits vast amounts of clay and other fine-grained sediment; oil and gas platforms thus provide a large percentage of hard-bottom area for reef-dwelling fishes. For example, Stanley and Wilson (1997, 1998, 2000), determined that a standing platform in about 30 m water depth seasonally provided habitat for 10,000-20,000 fishes, many of which are of recreational and commercial importance. By adding even minimally to the amount of reef available, petroleum platforms have doubtless affected many regional ecosystem processes such as energy (food) availability, habitat, recruitment, competition, and predation (Menge and Sutherland 1987; Doherty and Williams 1988; Bohnsack et al. 1991; Stanley and Wilson 2000).

In response to both the federally mandated removal of obsolete platforms and to the popularity of petroleum platforms as fishing destinations, Louisiana, Texas, and other states along the northern GOM now convert retired oil and gas platforms into artificial reefs (NRC 1996). The Louisiana Artificial Reef Program (LARP) was established in 1986 and is currently administered by the Louisiana Department of Wildlife and Fisheries. The Texas Parks and Wildlife Department established a rigs-to-reef program in 1988. To date, these states have emplaced over 200 platforms as artificial reefs.

The concept of using oil and gas platforms as artificial reefs, i.e. “Rigs to Reefs” (RTR), is strongly supported by recreational and commercial fishers and by supporting organizations such as the Coastal Conservation Association. The scientific community, however, still ponders the ecological impact of artificial reefs in general, and more specifically the effectiveness of petroleum platforms as artificial reefs. How do species composition and density of artificial reef fish communities compare to those found in association with natural substrates? The current paradigm with artificial reefs and platforms is that they improve and/or diversify habitat, increase resources, and modify assemblages of organisms (Seaman and Jensen 2001).

Beyond purely scientific concerns, there are also many management questions concerning the effect of water depth, geographic location, and general reef configuration on fish production at both standing platforms and artificial reefs. For example, for past RTR projects, oil and gas platforms were typically converted into reefs by laying a platform on its side either by toppling in place or by moving a toppled platform to a new location. More recently, the Louisiana Artificial Reef Program has followed the Texas Artificial Reef Program by removing the top portion of a standing platform to a depth (typically 90 feet below surface) sufficient to comply with Coast Guard regulations. This practice is referred to as partial removal. Stanley and

Wilson (1997) proposed that vertical profile is important in maintaining the fish density resident at standing platforms. Wilson et al (2003) later demonstrated that a partial removal did, in fact, retain a larger portion of the population reported at an operating platforms than did a platform toppled in place.

1.1 Past Research

There have been several surveys of fish communities conducted around oil and gas platforms; the extent of this work was reviewed by Stanley and Wilson (2000) and is summarized below. Scientific investigations of fish assemblages at platforms did not start until the mid 1970's. They consisted of visual surveys performed with SCUBA divers, with remotely operated underwater vehicles (ROV), and with stationary cameras. The majority of these projects were short term (Sonnier et al. 1976; Gallaway et al. 1981; Continental Shelf Associates 1982; Gallaway and Lewbel 1982; Putt 1982). The results of this early research described the fish density and species composition found at each platform, and how they varied among platforms, water depths, and times of year. The results however are difficult to compare due to sampling problems associated with limited visibility, gear bias, diver avoidance by fish, and a lack of standardized survey methodology. Although visual surveys are the method of choice to survey natural and artificial reefs (Bortone and Kimmel 1991), the presence of SCUBA divers affects the density and possibly the species composition of fishes at a site (Sale and Douglas 1981; Brock 1982; Bohnsack and Bannerot 1986; Stanley and Wilson 1995).

The composition of the platform fish community has also been shown to change with location and water depth. Previous researchers have noted a zonation of the assemblage of fishes associated with platforms and have divided the shelf waters of the northern GOM into three zones: coastal (water depth < 27 m), offshore (water depth 27 to 64 m) and bluewater (water depth > 64 m) (Gallaway 1980; Gallaway et al.1981; Gallaway and Lewbel 1982). This was more recently confirmed by Stanley and Wilson (2000), who reported that, at a platform in 219 m of water, pelagic bluewater fishes were found principally in the upper 100 m of the water column and fish density was essentially zero below 100 m depth. At a platform situated at a water depth of 60m, they found fishes throughout the water column, but fish density was highest near the surface and adjacent to the bottom; the fish community was characterized as reef-associated shelf species. At a nearshore platform at 20 m depth, fishes were found throughout the water column and the population was characterized as estuarine.

Several investigators evaluated and established guidelines for using acoustics to survey platform communities. Gerlotto et al. (1989) demonstrated that towed hydroacoustics could be used to measure fish densities near petroleum platforms off Cameroon. Scientists at Louisiana State University's Coastal Fisheries Institute combined visual surveys and quantitative dual beam hydroacoustics to document the assemblage of fishes associated with four petroleum platforms in the northern Gulf of Mexico (Wilson and Stanley 1991; Stanley and Wilson 1995, 1996a, 1997, 2000; Wilson et al 2003).

Regardless of methodology used, investigators have consistently reported that platforms harbor large numbers of fishes, and that abundances and species compositions vary greatly temporally and with proximity to structure (Sonnier et al. 1976; Continental Shelf Associates 1982; Gallaway and Lewbel 1982; Putt 1982; Stanley and Wilson 1996b, 1997, 2000). Gerlotto et al.

(1989) reported that fish densities were 5 - 50 times higher immediately adjacent to a platform than 50 m away. Stanley and Wilson (1996a, 1997) reported that fish densities were 3-25 times higher within 16m of a standing platform on the continental shelf. Stanley and Wilson (1997) reported that at 30 m away from a platform, fish densities were comparable to the open waters of the northern GOM. Long-term studies have also reported that fish populations at platforms are highly variable through time. Putt (1982) reported that fish density varied by a factor of two from month to month, while Stanley and Wilson (1996a, 1997, 2000) reported that monthly and seasonal abundances varied by up to a factor of five.

Wilson et al (2003) conducted hydroacoustic and ROV surveys of the West Flower Garden Bank (WFGB) and compared fish abundance and composition at this natural reef to that found at nearby artificial reefs and a platform. They reported three distinct reef fish assemblages at the WFGB in association with three major biotic zones (coral reef, algal-sponge, and drowned reef) (Dennis and Bright 1988). Based on hydroacoustics, fish biomass (biomass), was highest over the shallowest portion of the WFGB (upper terrace) where biomass was similar to that found at a nearby artificial reef. Biomass was, however, not as high as that found at a nearby operating oil and gas platform . Species composition associated with the upper terrace of the WFGB was similar to that observed on the outer slope of Caribbean coral reefs, but the WFGB exhibited a much lower diversity (253 primary species reported at Caribbean reefs versus 84 found at the WFGB). The fish community along the upper terrace was also different than that at nearby artificial reefs or operating oil and gas platforms. Wilson et al (2003) pointed out that the low vertical structure of fish habitat found at the WFGB is substantially different from the extreme high-relief vertical profile found at a platform.

1.2 Goals of This Study

The importance of standing platforms in holding significant reef fish populations has been well established. However, we lack an understanding of how the fish community varies along the longitudinal and latitudinal range of platforms in the northern GOM. Additionally, there is little research comparing the fish communities at artificial and natural reefs, offering similar vertical relief. This research project was designed to assist MMS, the National Marine Fisheries Service, and the artificial reef programs of Louisiana and Texas in making decisions regarding the deployment and placement of platforms as artificial reefs, especially with respect to deep water artificial reefs.

We proposed to examine the affects of geographic location and water depth on the abundance and species composition of fishes associated with petroleum platforms in the northern GOM. In particular, we sought to determine how the fish community around platforms changes along a longitudinal gradient traversing the northern GOM continental shelf and slope. We also wanted to pinpoint the depth at which the fish community became uncoupled from the benthic substrate and fishes associated with the structure in the upper water column. Our null hypothesis was that fish communities do not vary significantly along a longitudinal gradient in the northern GOM.

Our plan was to continue to build upon our platform based hydroacoustic research in the northern GOM by describing the fish community associated with a total of 15 platforms of similar size and age. The study sites included five sites east of the Mississippi River (Eastern), five in the north central GOM (Central), and five in the northwestern GOM (Western). Each of five platforms were to be sampled twice annually; platforms were to range in water depths from 30 to 200 m at intervals of approximately 40 m. The reality was that platform placement did not accommodate the intended design of the project. The lack of platforms off Texas forced us to reduce the number of platforms visited on the Western GOM to two, but afforded us the opportunity to add mobile hydroacoustic and ROV surveys of the Sonnier Bank pinnacle complex to our study.

The goals of this study were therefore to: 1) identify species composition at each site, 2) estimate (acoustic) biomass and target size distribution associated with each site, 3) determine the effects of orientation, depth, and distance away from each site on biomass, 4) determine if there is a pattern or trend in fish community composition and abundance related to region and/or depth, and 5) to determine whether a natural reef having an extreme vertical profile supports a fish community similar to that found at an artificial reef of comparable vertical relief.

This report is presented in four sections. The following Materials and Methods (Section 2) gives site descriptions and explains the equipment, site specific sampling design, and acoustic and statistical analysis. Results (Section 3), are separated into the results for the standing platforms and Sonnier Bank. A collective Discussion (Section 4) is used to compare and synthesize the results.

2.0 METHODS AND MATERIALS

2.1 Site Descriptions

This research project was designed to effectively sample and compare the fish populations associated with standing oil and gas platforms located within each of three regions of the northern Gulf of Mexico: an eastern region including platforms east of the Mississippi River, a central region including platforms off Louisiana, and a western region including platforms off southeastern Texas (Figure 1). The platforms in each of these regions were located at water depths ranging from 30 m to over 200 m with the objective of selecting one platform in each of five increasing depth zones. Once the study had begun, it was decided to examine two additional sites: a natural reef with vertical characteristics similar to a platform (Sonnier Bank) and an nearby oil platform (VR 279) at the same water depth. All sampling was variously conducted from 1998 to 2003 beginning with the eastern region (Table1).

2.1.1 Eastern Region

Platforms selected in the eastern region included; Viosca Knoll 203 (VK 203) (located 29.7815°N and 88.3331°W, water depth 37.2 m, operated by Murphy Oil Inc.), Main Pass 142 (MP 142) (located 29.2872°N and 88.2872°W, water depth 61.1 m, operated by Chevron), Main Pass 289 (MP 289) (located 29.2585°N and 88.4415°W, water depth 97.5 m, operated by Shell Oil), Main Pass 259 (MP 259) (located 29.3257°N and 88.0201°W, water depth 119.5 m, operated by SOCO Inc.), South Pass 89 (SP 89) (located 28.7031°N and 89.3910°W, water depth 139.0 m, operated by Exxon Inc.) (Table 1, Figure 1).

2.1.2 Central Region

Platforms selected in the central region included five, according to original survey design plus one (VR 279) that was added because of its proximity to Sonnier Bank. The VR 279 platform allowed the comparison of fish population composition between a platform and nearby natural reef system. The platforms in this region were: Vermillion 214 (VR 214) (located 28.6963°N and 92.2623°W, water depth 38.7 m, operated by Chevron), Vermillion 279 (VR 279) (located 28.4495°N and 92.5099°W, water depth 54.9 m, operated by W&T Offshore, Inc.), West Cameron 564 (WC 564) (located 28.2699°N and 93.3433°W, water depth 57.3 m, operated by Chevron), High Island A350 (HI A350) (located 28.0188°N and 93.4585°W, water depth 93.0 m, operated by Shell Oil), West Cameron 643 (WC 643) (located 27.9814°N and 93.0342°W, water depth 114.3 m, operated by Texaco), and Garden Banks 236 (GB 236) (located 27.7611°N and 93.1377°W, water depth 208.8 m, operated by Chevron) (Table 1, Figure 1).

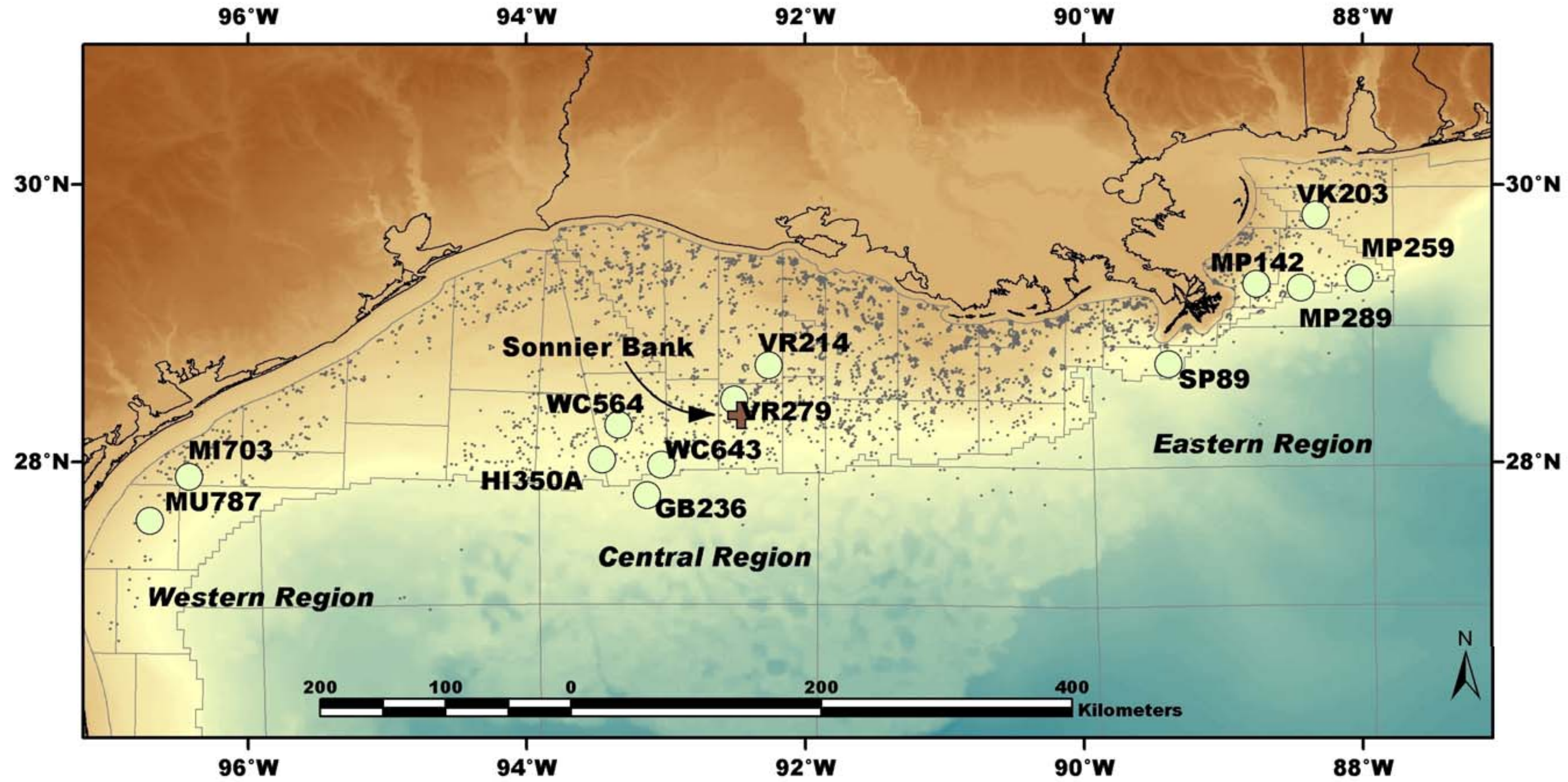

Figure 1. Overview map of study platforms, regions, and location of Sonnier Bank. Graded color background indicates depth and elevation.

Table 1

General Information about the Oil and Gas Structures Surveyed with Stationary Dual Beam Hydroacoustics.

Site	Visit (mm/yy)	Region	Depth (m)	Installed	Piles	Conductors	Latitude(N)	Longitude(W)
VK 203	05/98, 01/99	Eastern	37.2	1993	6	3	29.7815	88.3331
MP 142	07/98	Eastern	61.3	1969	4	0	29.2872	88.2872
MP 289	07/98, 12/98	Eastern	97.5	1968	6	17	29.2585	88.4415
MP 259	06/98, 12/98	Eastern	119.5	1994	6	10	29.3257	88.0201
SP 89	05/98, 10/98	Eastern	139.0	1978	8	8	28.7031	89.3910
VR 214	01/00, 04/00	Central	38.7	1971	4	15	28.6963	92.2623
VR 279	06/03	Central	54.9	1996	4	10	28.4495	92.5099
WC 564	05/99	Central	57.3	1976	4	5	28.2699	93.3433
HI A350	06/99	Central	93.0	1976	8	20	28.0188	93.4585
WC 643	03/00, 02/01	Central	114.3	1975	8	16	27.9814	93.0342
GB 236	05/99, 02/99	Central	208.8	1980	8	13	27.7611	93.1377
MI 703	2002	Western	39.0	1981	8	5	27.8956	96.4280
MU 787	2002	Western	46.0	1993	4	8	27.5772	96.7080

2.1.3 Western Region

We had intended to select five platforms in the western region, but a lack of suitable platforms in the desired depth ranges limited the western region to only two sites. This was when the decision to survey Sonnier Bank and an adjacent platform (VR 279) was made. The platforms in this region are Matagorda Island 703 (MI 703) (located 27.8956°N and 96.4280°W, water depth 39 m, operated by British Petroleum), and Mustang Island 787 (MU 787) (located 27.5772°N and 96.7080°W, water depth 46 m, operated by British Petroleum) (Table 1).

2.1.4 Sonnier Bank

Sonnier Bank is located approximately 250 km southeast of Galveston, TX, near the edge of the continental shelf at 28.3305°N and 92.4659°W (Figure 2). The physical structure of the reef complex is unique for this region of the northern Gulf of Mexico. The main body of the reef system is comprised of five steeply sloped pinnacle features whose profile and scale resemble a standing platform that comes to within 20 m of the ocean surface. At 30m below the water surface, the footprints of artificial reefs created by both partially removed, and toppled platforms, are similar to that found at Sonnier (Figure 3). Below this depth, the Sonnier Bank pinnacles spread out more toward the bottom.

2.2 Survey Designs

Dual beam hydroacoustic surveys were conducted with three stationary arrays of four transducers at the standing platforms. At Sonnier Bank, a mobile acoustics survey was conducted with a single transducer mounted on a v-fin tow body (towfish). The arrays at the standing platforms were composed of upward-oriented, downward-oriented, and outward-oriented (horizontal) transducers at each site after Stanley and Wilson (1997).

2.2.1 Standing Platforms

The standing platforms were surveyed with stationary dual beam hydroacoustic equipment developed during past research (Wilson and Stanley 1991; Stanley and Wilson 1995, 1996b, 1997, 1998). Array 1 (Figure 4a) was designed to measure in situ target strength distribution and density of fishes immediately adjacent to each side of the platform. It consisted of four downward-oriented transducers (120 kHz) placed approximately 5 m below the surface, one on each side of the platform. Array 2 (Figure 4b) was designed to measure the density of the fish within the upper portion of the water column. This array utilized four upward-oriented transducers suspended on heavy monofilament line 20 m below the waterline. Array 3 (Figure 4c) consisted of four transducers oriented horizontally at 20 m water depth with each transducer facing away from the platform. The downward and upward oriented transducers provided acoustic coverage from a depth of 1 m to within 0.5 m of the substrate. The outward-oriented transducers allowed the simultaneous measurement of fish biomass and abundance out to 80 m away from the platform. Stationary hydroacoustics allows for the collection of many samples or "snapshots" of density and size distribution over time; each “snapshot” consisted of 5 minute blocks of acoustic data. Previous analysis of acoustic data in segments from 1 to 15 minutes has shown that variances of density estimates are not significantly different after a five-minute duration.

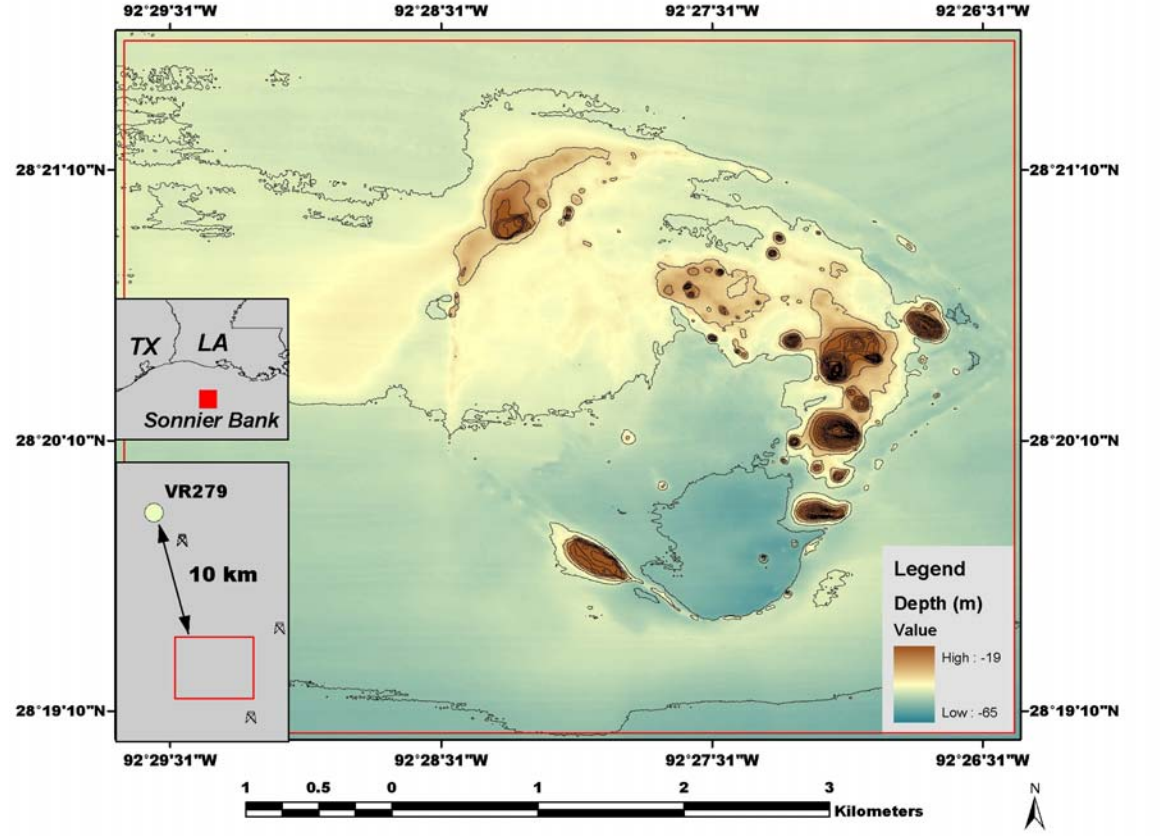

Figure 2. Bathymetry of Sonnier Bank. Top inset shows the overview location of Sonnier Bank. The bottom inset shows the proximity of the nearest study platform (VR 279) with respect to Sonnier Bank.

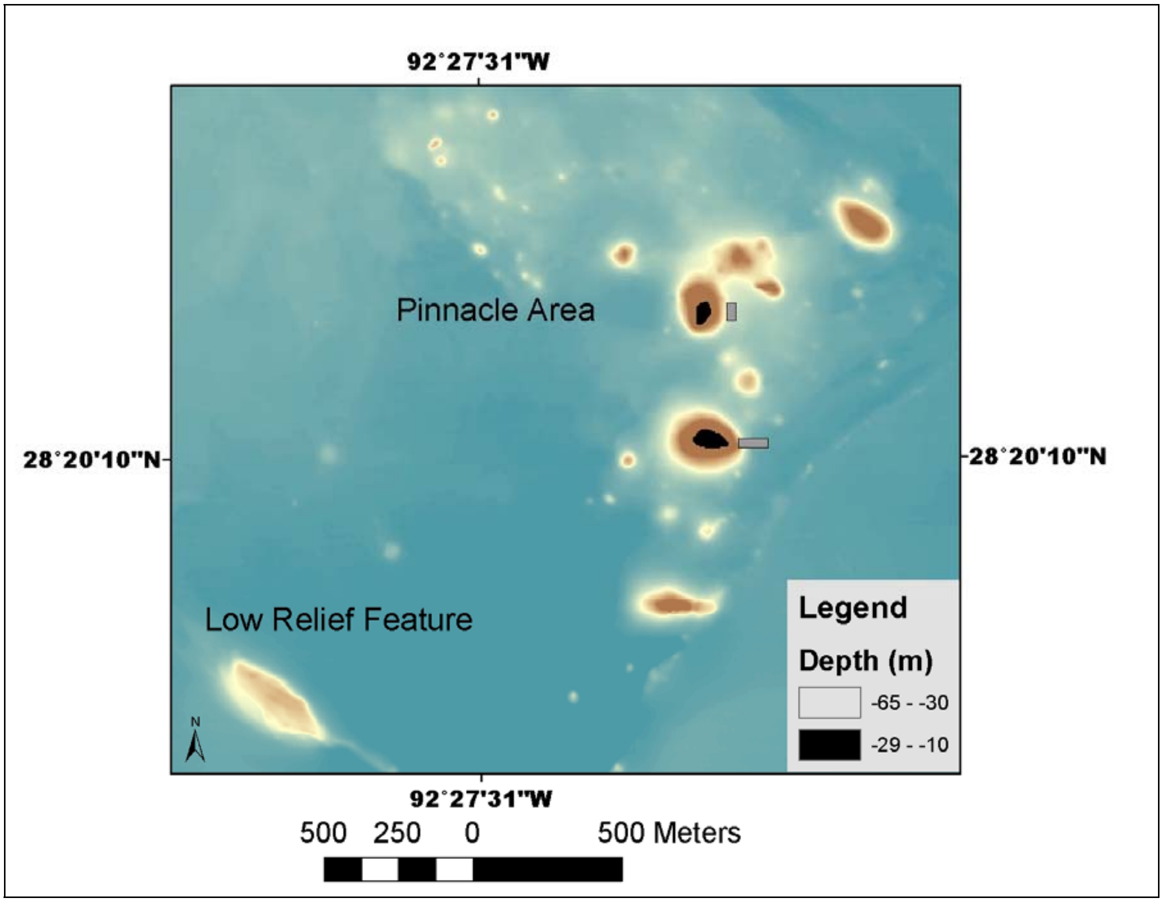

Figure 3. **Figure shows the footprint of the Sonnier Bank pinnacles (black areas) compared to the footprints of a partially removed platform (top grey rectangle) and toppled platform (bottom grey rectangle) at the same depth below surface (30m). Also pictured is the low-relief feature in the southwest corner.**

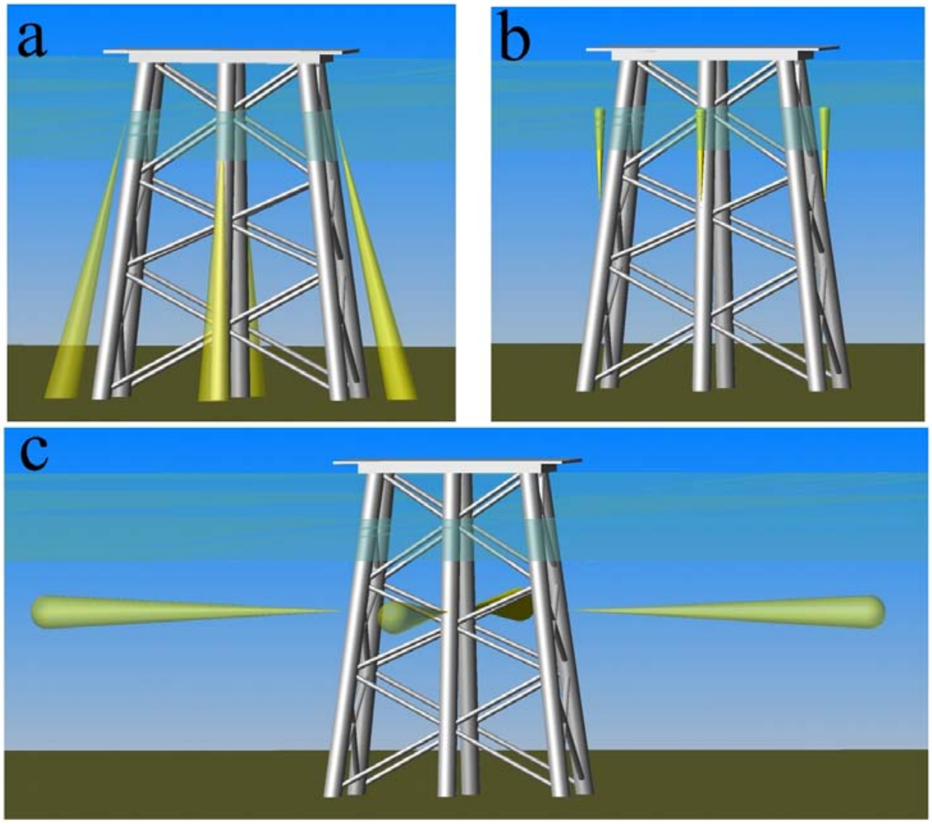

Figure 4. Configuration of hydroacoustic beams. Note that platform and beam dimensions are to scale. Water surface is indicated with a semi transparent green plane.

Acoustic sampling was accomplished during four two-hour intervals distributed over the solar day (dawn, noon, dusk, and midnight). Within each interval, data were collected in 15 minutes segments with a twice repeated progression through the transducers on each side (north, west, south, and east) of the platform. Each 15 minute segment was further divided into three sub-segments of five minutes each resulting in six observation periods per side per sampling interval. Up and down vertical data were pooled in 10 m depth strata from the surface to the substrate; horizontal data were pooled in 10 m distance strata from the platform out to 70 m. We made no attempt to acoustically sample within the underwater confines of the platform itself due to the interference of the metal piles and cross members.

2.2.2 Sonnier Bank

A towed transducer (Wilson et al. 2003) was used to estimate the acoustic biomass,density and size frequency distribution of fishes associated with the natural reef site during the summer of 2002. A 120 kHz downward-oriented transducer was towed from the stern of the research vessel M/V Spree. The towfish was towed at approximately 2 m/sec, 5 m out from the stern and 3 m below the surface to keep the transducer out of the prop wash. The use of a towed downward-oriented transducer enabled the calculation of density and size distribution of fishes from a depth of 5 m to 1 m above the bottom. Navigational data were collected with a Garmin V Plus global positioning system (GPS); the GPS antenna was held above the towfish with a telescoping mast. The navigation data stream, which updated once per second, was incorporated into the acoustic data string, and saved on a laptop computer.

The survey design for the Sonnier Bank reef complex was divided into three separate sections that were completed over a four day period (Figure 5). The entire Sonnier Bank complex was first surveyed with 22 north-south transects spaced 200 m apart. A small low-relief feature in the southwest region of the complex was surveyed with 24 north-south transects spaced 40 m apart. The high-relief pinnacle series on the east side of the complex was surveyed with 28 north-south transects spaced 40 m apart. The tighter line spacing over the two special interest regions of the reef provided much finer detail for resolving bottom relief and for providing better estimates of acoustic biomass over each targeted habitat.

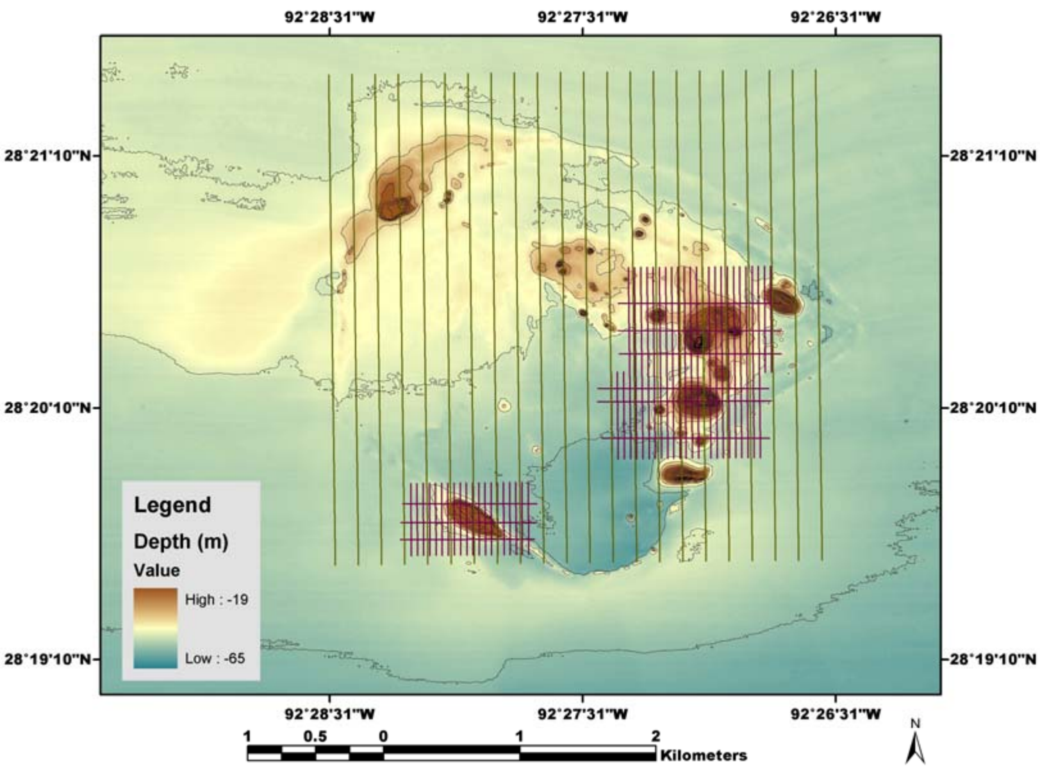

Figure 5. Overview of Sonnier Banks bathymetry intended track lines of the hydroacoustic survey conducted in May 2002.

2.3 Acoustic Data Collection and Processing

Acoustic data were collected with a Biosonics model DT5000 scientific echosounder following the methods outlined in Wilson et al (2003). All data were collected with 120 kHz transducers factory calibrated with a - 42 dB tungsten sphere. The source level of the acoustic system was 223 dB/Pa at 1 m; acoustic sampling rate was five pings/sec with a pulse duration of 0.4 msec. Received signals, adjusted for spreading loss by applying a 40 log R time varied gain, were digitized and recorded on a computer hard drive and later transferred to CD digital media. The data collection minimum and maximum thresholds were set to -55 dB and -20 dB, respectively, corresponding to a 2.9 cm minimum and a 1.9 m maximum length, based on a dorsal perspective, for target detection (Love 1971).

Perhaps the most important development, other than improvements in the data collection equipment, has been the evolution of sophisticated hydroacoustic analysis packages that enable the user to manipulate many variables during post-processing. In the late 1990's an innovative advance in analysis software, Echoview, which has been described as revolutionizing hydroacoustic data analysis (pers. comm., I. Higginbottom, Biosonics, Inc., 2003), became available. The most recent version of this analysis package, Echoview 3.10, allows one to extract a variety of target specific variables resulting in improved acoustic biomass and single target size estimates. Echoview also permits removal of acoustic noise, clear separation of the acoustic bottom from fish targets, and access to powerful visualization techniques.

Digitized hydroacoustic data collected at each survey site were processed with Echoview 3.10 (Sonar Data, Pty Ltd.). The factory settings for Echoview are intended for use with data generated with a 38 kHz single beam transducer, not the 120 kHz transducers that we employed. Several adjustments in the Echoview programming were necessary for proper handling and analysis of our data. The first step in processing the data files was to enter both the correct transducer frequency (120 kHz for this study) and the environmental parameters, such as water temperature and salinity, at each site into the speed of sound calculator to produce the corrected speed of sound and absorption coefficient. The appropriate calibration offset, transmitted pulse length, frequency, and two-way beam angle (Table 2) were input for calibrating echo positions. The proper values for these variables are critical for correct placement of echo returns in the beam; changes in speed of sound, for example, will shift the position of a target returning an echo nearer to or farther from the transducer, thus affecting either vertical or horizontal spacing of the targets.

A grid was applied to the data establishing 5 min by 10 m bins (or strata) that were used for all subsequent analyses. Parameters for color display minimum and for color display range were set to match the data collection threshold (–55 dB for this study). The echogram display limits, corresponding to the water depth at each site for the downward-oriented transducers and the maximum range desired for the horizontal and upward-oriented transducers were specified The minimum analysis threshold was set to the minimum collection threshold (–55dB), the maximum analysis threshold was set to the maximum collection threshold (–20dB), and the time-varied threshold (TVT) was adjusted to reduce as much noise from the far edge of the data record as was possible (Table 2). The time-varied threshold is specific for each study site as the amount of noise affecting data quality is directly influenced by the varying environmental conditions among sites.

Table 2

Parameter Settings for Echoview Analysis.

Site	Visit	Temp (^oC)	Salinity (ppt)	Absorption Coefficient	Speed of Sound (m sec $^{-1}$)	Time-Varied Threshold (dB)
VK 203	1	29	34	0.046545	1523.05	-87
VK 203	2	18	28	0.040584	1510.52	-90
MP 259	1	28	34	0.046151	1535.57	-84
MP 259	2	22	34	0.046692	1525.7	0
MP 289	1	28	34	0.045288	1540.08	-100
MP 289	2	22	34	0.046692	1525.7	0
MP 142	1	28	34	0.045288	1540.08	-95
SP 89	1	26	34	0.047124	1518.67	-90
SP 89	2	28	34	0.045288	1540.08	-100
GB 236	1	26	36	0.047427	1536.64	0
GB 236	2	22	36	0.045199	1509.81	0
WC 564	1	27	35	0.047033	1538.92	-90
WC 643	1	19	36	0.047124	1518.67	0
WC 643	2	18	34	0.045031	1525.3	0
VR 214	1	19	36	0.047124	1518.67	0
VR 214	2	21	36	0.0478	1526	0
HI A350	1	27	35	0.047033	1538.92	0
MU 787	1	19	36	0.047124	1518.67	-100
MI 703	1	19	36	0.047124	1518.67	-95
VR 279	1	18	34	0.045031	1514.64	-91

Data files were first played through Echoview with the bottom tracking feature turned on; the bottom exclusions were then visually inspected and adjusted to ensure the bottom and platform legs were not included in the analyzer window. After the bottom had been edited, each echogram was scrutinized for "bad data" such as mid-water platform inclusions, air entrainment, and any other non-biological returns (e.g. gas seeps). All of these areas were manually identified, designated as "bad data" regions, and excluded from data analysis and echo integration.

Software updates and new features for Echoview are released frequently, allowing users to remain on the cutting edge of hydroacoustic data analysis and presentation. Echoview has been used previously to estimate single target sizes (Higginbottom et al. 2000, Lawson et al 2001, Abe et al. 2002, Sellers 2003, Goss et al. 2004), to discriminate aggregated fish species and single targets (Lawson et al. 2001, Logerwell and Wilson 2002, Woodd-Walkera et al. 2002, Churnside et al. 2003, Gerlotto et al. 2004,), and to visualize fish movement (Higginbottom et al. 2000, Abe et al. 2002, Buelens et al. 2003).

The many output variables generated in Echoview make it one of the most versatile and powerful software packages available for analysis of hydroacoustic data. Two primary outputs are routinely used for statistical analysis: 1) mean volume backscatter (Sv), reported herein as dB/m3, commonly used as an approximation of fish biomass and 2) target strength (TS), an acoustic measure (in dB) of target size, generally used to derive estimates of fish length. Target strength values are generated for targets that are identified and tracked for at least six consecutive pings with the single target detection algorithm. Both Sv and TS are logarithmic in their scales and as such are not directly amenable to the calculation of mean values; thus each is converted to an arithmetic, or linear, form prior to such manipulations. Fish energy (FE), the linear counterpart of Sv, is converted with the equation

$$FE = 10^{Sv/10} \qquad \text{(Eqn 1).}$$

Similarly, sigma, the linear equivalent of TS, is calculated with the equation

$$sigma = 10^{TS/10} \qquad \text{(Eqn 2).}$$

Once either a mean sigma or a mean FE has been calculated, this number can then be converted back to yield mean TS and mean Sv, respectively.

Fish density was calculated as the mean Sv (from mean FE) of a known volume (m^3) of water divided by the mean TS (from mean sigma) of that same volume of water. Fish density is calculated with the equation:

$$\text{Fish density } (\# \ m^{-3}) = 10^{Sv/10} / 10^{TS/10} \qquad \text{(Eqn 3).}$$

Density estimates are dependent on accurate estimates of the mean TS of the targets. Analyses with Echoview version 3.10 of data from fixed transducers at standing platforms produced useful density estimates; however, analyses of the towed transducer data from Sonnier Bank required modification for accurate density comparisons. The accuracy of mean TS increases with repeated acoustic samples of individual targets (pers. Comm.., J. Dawson, Biosonics Inc., 2003). Given that the Sonnier Bank surveys were based on a vessel moving at 2 m/sec and transmitting acoustic pulses (pings) at a rate of five pings/sec, the probability of hitting a target multiple times was very low. In many cases data collection and subsequent processing produced a Sv, but no TS, for the same volume of water. In such cases a mean sigma was calculated for a specific linear distance within a stratum and used as a proxy for TS to calculate densities in those cells where TS was lacking. The assumption was that mean fish sizes within several adjacent cells within the same stratum would be roughly equivalent.

2.4 Data Analysis

2.4.1 Statistical Analysis

Split-plot randomized block design ANOVA (SAS Institute Inc. 2002) were performed to test for differences among acoustic variables including Sv (fish biomass), TS (fish numbers), and fish density. We used the SAS software procedure Proc Mix, which has several advantages over earlier software, to run the analyses. In addition to providing better estimates for random components, it provides the investigator with other options like the ability to test for, and to fit, non-homogeneous variances and to specify covariance structures.

The dependent variable, FE (converted from Sv as above), was log transformed (ln (fish energy x 10^9+ 1)) to allow for the high number of observations in which Sv was zero. Data from the standing platforms were initially analyzed with the following class variables: year of survey, platform, number of conductors on platform, region (East, Central, and West), time of day (TOD; dawn, noon, dusk, and midnight), platform side (north, south, east, and west) ten meter depth or distance stratum (strata), dissolved oxygen, and logical interactions. After several trials year, region, platform, and dissolved oxygen were dropped from the test model as they reduced the degrees of freedom, but did not improve the model. For the Sonnier Bank data class variables included depth stratum and a bottom depth threshold (-50 m) indicating over or away from a pinnacle. Tukey's standardized range tests (Ott 1982) were used to compare the means of significant variables. Statistical tests were reported as significant at $\alpha \leq 0.05$.

In order to compare the effects of class variables on fish biomass, TS, and Sv, we applied statistics that generated least square means rather than elementary arithmetic means. In our earlier studies we used arithmetic means; however, in unbalanced designs with more than one effect (characteristic of acoustic surveys), the arithmetic mean for a group will not accurately reflect the "typical" response for that class variable since it does not take other effects into account. Given the large number of zero values and the various "effects" included in our final models, we used least square means in Proc Mixed of SAS (SAS Institute Inc. 2002) to illustrate the responses observed in our analysis. Thus those statistical comparisons of biomass, TS, and Sv illustrated in the various figures herein are based on least square means generated with the above procedure. This is confounding as it constrains our ability to compare and illustrate differences among our earlier studies (Stanley and Wilson 2000, Wilson et al. 2003) and this study. We therefore confine comparative conclusions to habitats considered in this study.

ANOVA, as above, was also used to analyze TS (as sigma) at all sites. Class variables used in the analysis of standing platforms were the same as those stated above and they too were reduced down to region, time of day, platform side, ten meter depth or distance stratum (strata), and logical interactions. Sonnier Bank class variables included depth stratum and a bottom depth threshold (-50m) indicating over or away from a pinnacle (bump). Tukey's standardized range tests (Ott 1982) were used to compare the means of significant variables. Statistical tests were reported as significant at $\alpha \leq 0.05$.

2.4.2 Fish Abundance Estimation

The total fish abundance estimates were calculated for comparison to previous studies. Total abundance at each platform was calculated by determining a 20 m near-field area of influence of each reef site or platform, then multiplying mean density values by stratum and side by the volume of water on each side of or over the platform (Stanley and Wilson 1998). Fish density within the center of each platform was not measured with acoustics due to interference by structural members and was assumed to be the average of the density estimates of the four sides of the platform. Fish abundance in the center of the platform was calculated by multiplying the estimated fish density of the center by the volume of water in the center of the platform. Fish abundance estimates at Sonnier Bank were based on the average density by stratum over the whole area and separately at each pinnacle assuming a 20 m area of influence, although that is an arbitrary area of influence used here solely for comparative purposes.

2.5 Visual Surveys

Visual surveys were conducted with a Deep Ocean Engineering Phantom HD2 ROV or a VideoRay Pro II ROV with standard visual census techniques and recording video on S-VHS or digital tape with the method described by Bohnsack and Bannerot (1986) and previously reported by Stanley and Wilson (1998) and Wilson et al. (2003). Cryptic fishes (fish length < 10 cm) that stayed within half a meter of either the bottom or the platform were not included in the video surveys results as could not be accurately assessed in the acoustic surveys. Point counts were conducted to identify individual fish to the lowest taxonomic level. Results and data were expressed as percent composition by species and stratum at each site. At standing platforms, the ROV was deployed from the water surface to the bottom, stopping every 10 m for approximately 5 minutes.

During the Sonnier Bank survey, the ROV was deployed from the M/V Spree. The ROV was deployed to dive and capture video of the species composition associated with the two most distinctive habitat types found in the Sonnier Bank system. The vessel was moored to the high-relief pinnacle feature during ROV deployment at this site. At the deeper, low-relief feature, the vessel could not be moored and was allowed to drift during ROV deployment. During the survey, the ROV would descend to the bottom, stopping every 10m for approximately 1 minute. Once on the bottom the ROV was flown approximately 40m along random transects along these features and the surrounding natural bottom.

2.6 Environmental Data

Environmental data collected in the East and part of the Central regions consisted of temperature (+/- 0.1 ^{o}C), salinity (+/- 0.1 ppt) and dissolved oxygen (+/- 0.5 ppm); parameters were measured with a Seabird SBE 19 meter. Current speed (+/- 0.1 m/s) and direction (+/- 1 degree) were measured an InterOcean S4 meter during each hydroacoustic data collection period for the East region only. Subsequent discussions with other users of the S4 current meters and review of InterOcean literature concerning deployment of the S4 in environments with large amounts of ferrous metal or magnetically impeded regions led us to stop using it due to reported inaccuracies caused by metal in the data reception field. The recommended deployment technique for this type of environment suggests that the S4 should be rigidly mounted to or near the structure and calibrated for the magnetic interference at that particular site. We did not have the ability to provide this type of mounting system for such a dynamic survey. We deployed the S4 from a temporary winch, lowering the unit through the water column where it was allowed to swing and spin freely adjacent to the steel platform. These data were not addressed in this analysis.

3.0 RESULTS

3.1 Field Operations

During the course of this study, three or four scientists participated in 23 excursions to platforms off the Louisiana and Texas coastlines and spent up to five days at each location. Technology advancements in the acoustic equipment and improvements in ROV technology allowed us to reduce both the amount of gear required for sampling and the effort required for deploying the sampling equipment. By the end of this project our four transducer hydroacoustic system and ROV could be housed in a single 6 x 6 x 6 foot aluminum container designed for lifting by crane or forklift.

Transducer deployment at platforms has also become easier over time. As the project progressed the technique of deploying the transducer system evolved to improve safety and data quality as well as to reduce the manpower required for data collection. The original method of deployment involved large aluminum frames suspended from the platform that held the transducers in such a fashion that allowed the transducer to fire upward through the center of the frame without interference. Though effective, this method was very cumbersome and potentially hazardous to deploy, especially in rough weather. This evolved to a heavy, single point monofilament bridle that allowed the transducer to be lowered easily, accurately, and safely. With the use of the acoustically invisible monofilament, the technique evolved further to use a small hand winch to raise and lower each transducer.

The original method to deploy the downward and horizontal transducers involved the use of as many as 16 four-foot sections of aluminum pipe for each of the four transducers. The gear had to be assembled and moved manually with each deployment. This method required no less than four people to deploy and was often plagued by poor data quality due to excessive transducer motion when sea conditions got rough. This led to a modification of the upward-oriented deployment method, hand winches and single stainless steel cable suspension systems. The transducers were attached to lead ballasted base plates that were attached to four point cable bridles. These bridles proved to be crucial as they allowed the angle of the transducers to be adjusted to match the angle of the legs of the platform before they were lowered into the water. This provided an optimal acoustic view throughout the entire water column. The advantage of the system was that it provided a much smaller cross-section in the wave zone, so it had the effect of de-coupling the wave and surge motion from the transducer. This was evident immediately when viewing the echograms: the return from the bottom was now a smooth line instead of a wavy line caused by the sea surface motion. The use of the hand winch system also reduced the required number of persons for safe deployment from four to three. The deployment and retrieval in an emergency could be handled by as few as two people.

One of our original objectives was to collect current data during acoustic sampling. During the first year of the project we had intermittent success with the S4 current meter. Although frequently collected, the data were influenced by the large metal legs and cross members of the platform; subsequent discussions with a physical oceanographer (Dr. Bjorn Kjerve, Texas A&M University) confirmed this type of current meter is subject to the influence of large metal objects and likely would not be dependable for data collection around platforms. We therefore discontinued data collection using the S4 current meter and decided not to incorporate the current data collected during the first year of the project.

3.2 Platform Results

The long-term data set, which included acoustic data from up to two trips to each of 12 different platforms, was pooled for statistical analysis as our primary objective was to determine if there were effects of latitude and longitude on the fish communities around platforms. Variables included region, water depth of platform, time of day, month, year, platform side, conductor number, piles, and depth stratum in 10 m intervals and their logical interactions. Analyses of the data using a split plot analysis of variance (SAS Institute Inc. 2002) were conducted iteratively using Proc Mixed by removing insignificant variables. Runs were continued until the Akaike Information Criteria (AIC) value was lowest. The dependent variables in the data analysis included volume backscatter (Sv), density, and target strength (TS).

The vertical and horizontal data sets were analyzed separately. The vertical data set was used to analyze the effect of various parameters on acoustic fish density and biomass and acoustic target size adjacent to the platform. The horizontal data set was used to analyze the effect of distance from a platform on the resident fish communities.

3.2.1 Acoustic Volume Backscatter (Fish Energy)

Volume backscatter (Sv) is a measurement of the amount of reflected acoustic energy that is returned to a transducer. It is a proxy of fish biomass m^{-3}. For statistical analysis and comparison to previous studies Sv was converted to fish energy using Equation 2 in Materials and Methods. For graphical purposes, fish energy means were calculated and then converted back to Sv for display.

Volume backscatter ranged from -100 (default for 0) to -32 dB over the course of study. Following several iterations of analysis of variance, we determined that location off the coast (East, Central, or West), depth stratum, platform side, and time of day were significant at influencing the changes observed in Sv. Platform age was not significant; although number of conductors and platform depth were significant, removing them from the model reduced the AIC coefficient (Table 3). We surmised that this was likely due to the fact that they were confounded by platform location and depth stratum.

Throughout the study, we found a general trend of lower acoustic biomass east of the Mississippi River and off of Texas. The highest biomass was found in the central GOM (Figure 6a, 7). Due to large variability in the data set the central and western area estimates of acoustic biomass were, however, not significantly different. We found a decrease in fish biomass with increasing water depths. When examining all platforms together, the highest biomass was in the top 50 m of the water column with the lowest biomass occurring below 50 m (Figure 6b). Fish biomass also varies significantly with platform side and time of day. Acoustic fish biomass was highest on the west side of the platforms and lowest on the north side (Figure 6c). Fish biomass was lowest at noon, increasing through midnight when it was highest, and then dropped off at dawn (Figure 6d).

Depth elicited the largest range of variation in acoustic biomass. The range of variation for acoustic biomass due to variation in location and time of day were approximately equal, and the range of variation was lowest due to side of platform (Figure 8).

Table 3

Results of Split Plot Design Analysis of Variance Showing the Effect of Region (Location), Time of Day (TOD), Platform Side (Side), and Depth Stratum (Stratum) on the Dependent Variable Fish Energy

Type 3 Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
Location	2	36	5.39	0.0089
TOD	3	27000	205.25	<.0001
Side	3	27000	15.51	<.0001
Stratum	10	36	8.66	<.0001

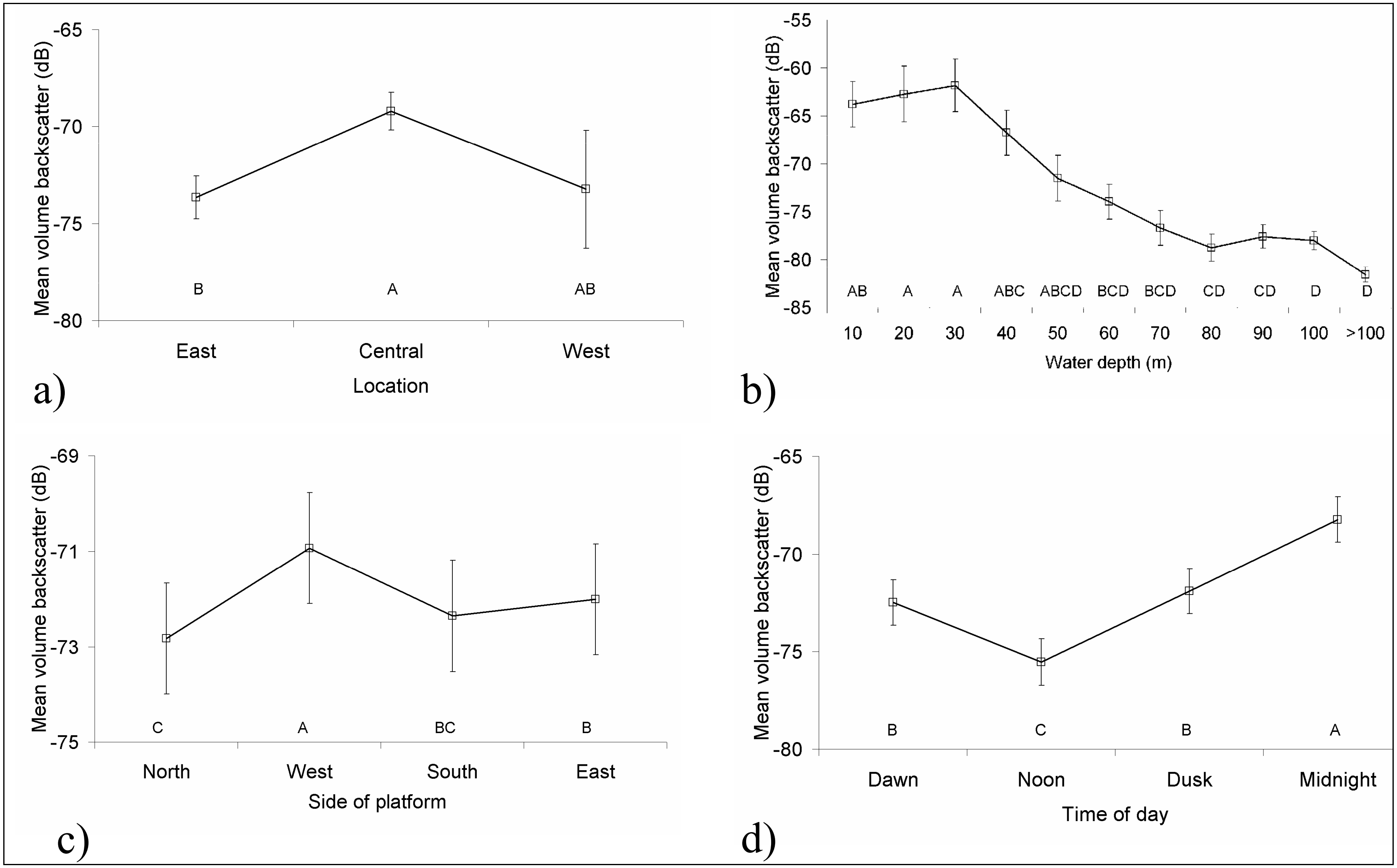

Figure 6. LS mean volume backscatter (Sv in dB ± 1 SE) by a) region, b) depth, c) side and d) time of day for platforms in the northern Gulf of Mexico. Means with same letters are not significantly different at α= 0.005.

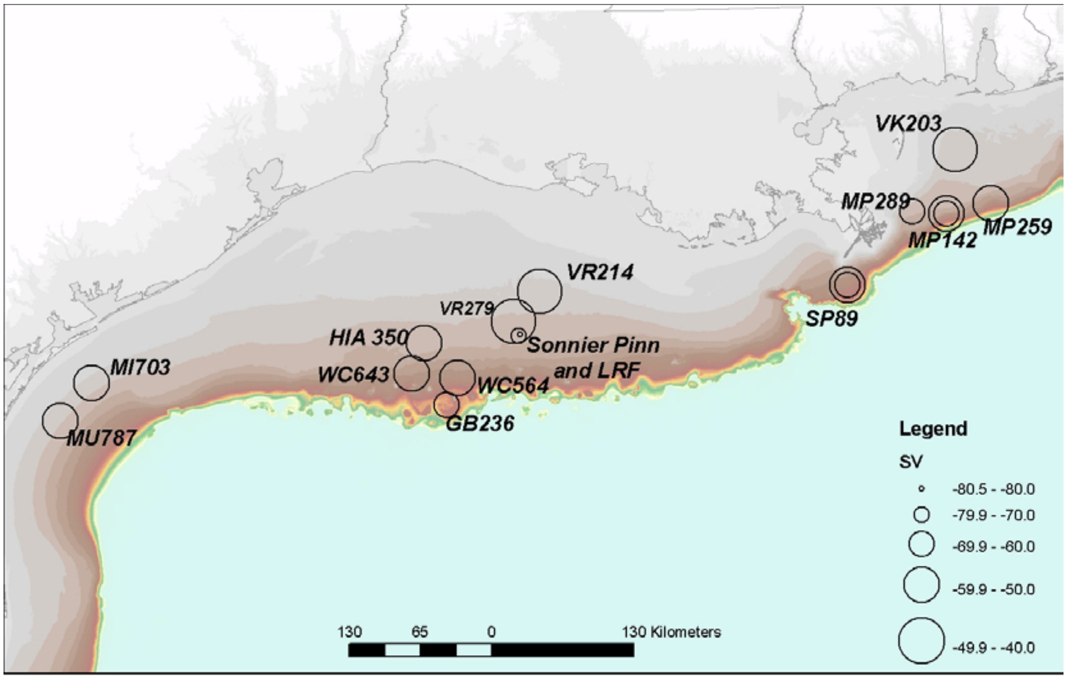

Figure 7. Least squares mean volume backscatter (Sv) at all study locations. Note that data from Sonnier Bank are included.

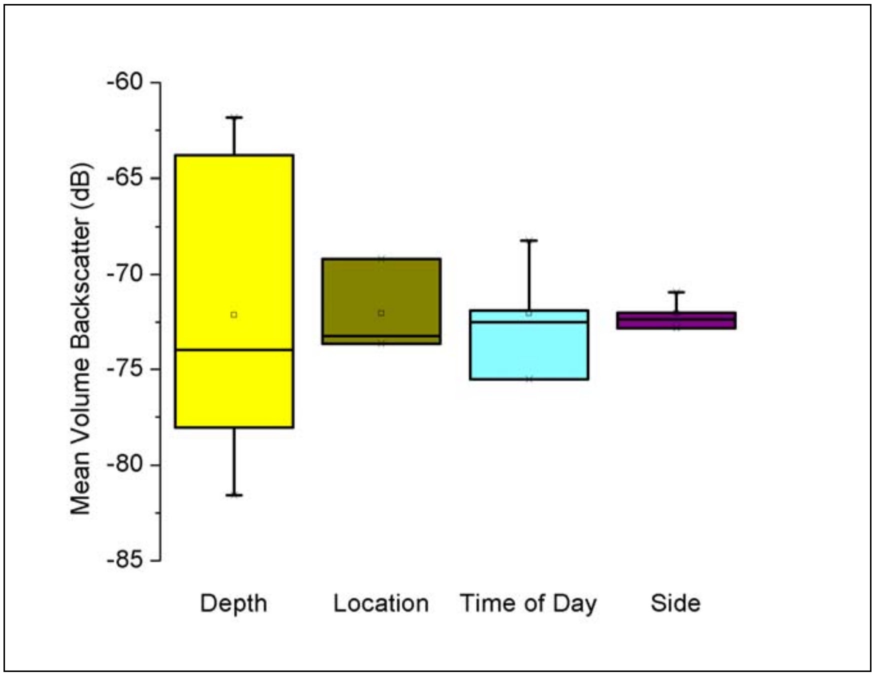

Figure 8. Range of variation in acoustic biomass at all study platforms due to depth, location, time of day, and side.

3.2.2 Density Estimates

Fish density is a gross approximation of the number of fish per cubic meter based on the average reflected acoustic energy (Sv) over a sampling period divided by the average target strength (TS) encountered over that same five minute block of time. Throughout the study, fish density ranged from zero to over eight fish per cubic meter. Fish density varied with time of day, platform side and depth stratum, but was not influenced by location (Figure 9a), platform age, number of conductors, or number of legs (Table 4), but some shallow water platforms appeared to hold larger numbers of fish (Figure10).

Fish density data followed the general pattern of acoustic biomass and was highest near the surface; the overall project average was one fish per 10 cubic meters and approached zero near the bottom. Below 50 m fish densities were not significantly different (Figure 9b). Fish density also varied with platform side and time of day. Fish density was significantly lower on the north side of the platforms than the west, south or east sides (Figure 9c). Fish density was lowest at noon and dusk and highest at dawn and midnight (Figure 9d).

Again, depth revealed the largest range of variation in acoustic biomass. The range of variation for acoustic biomass due to variation in time of day and side were approximately equal, and the range of variation was lowest due to location (Figure 11).

Table 4.

Results of Split Plot Design Analysis of Variance Showing the Effect of Region (Location), Time of Day (TOD), Platform Side (Side), and Depth Stratum (Stratum) on the Dependent Variable Fish Density.

Type 3 Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
Location	2	15	0.16	0.8565
TOD	3	27000	7.71	<.0001
Side	3	27000	8.16	<.0001
Strata	10	15	4.62	0.0041

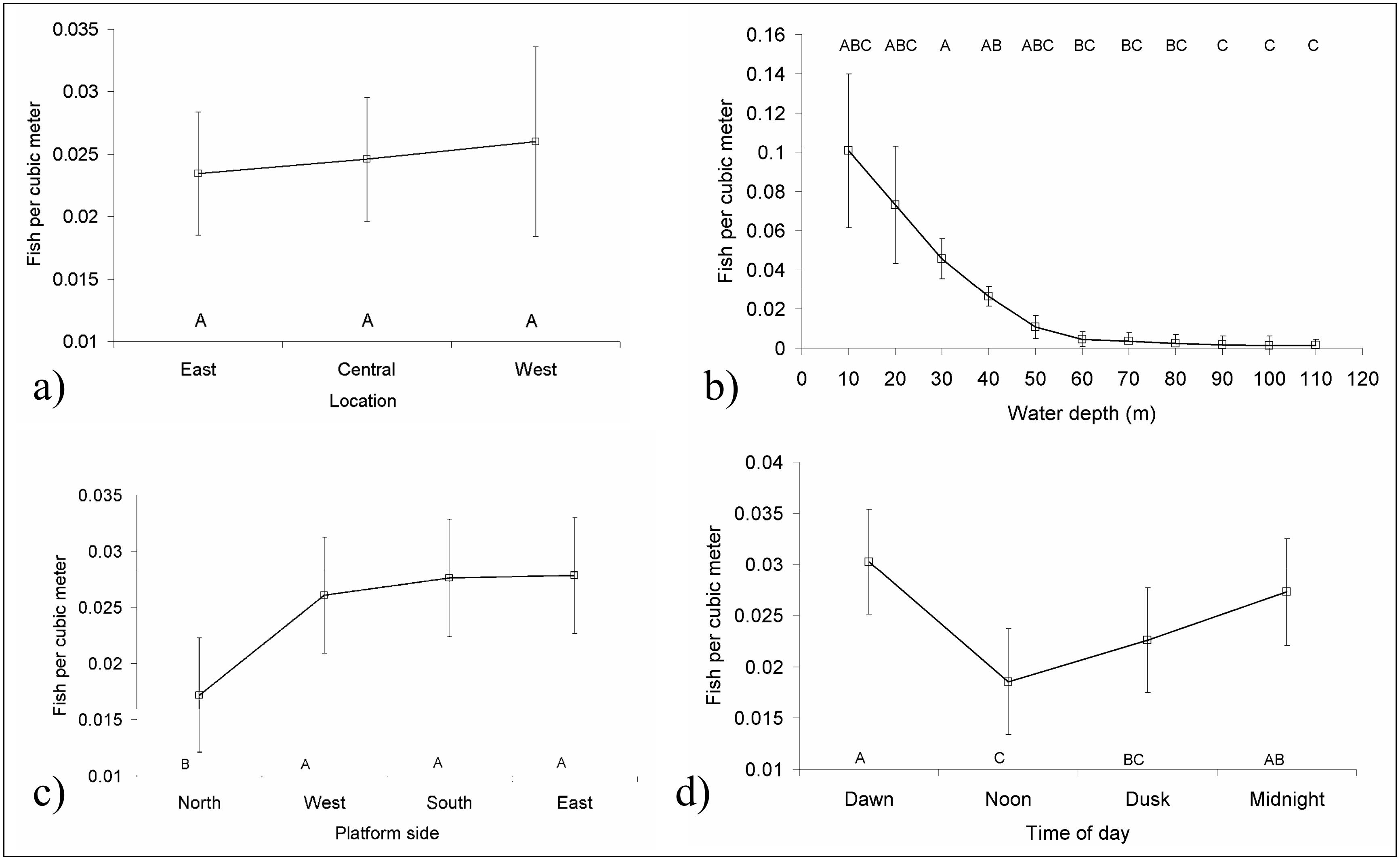

Figure 9. LS mean fish per cubic meter (± 1 SE) by a) region, b) depth, c) side and d) time of day for platforms in the northern Gulf of Mexico. Means with same letters are not significantly different at α= 0.005.

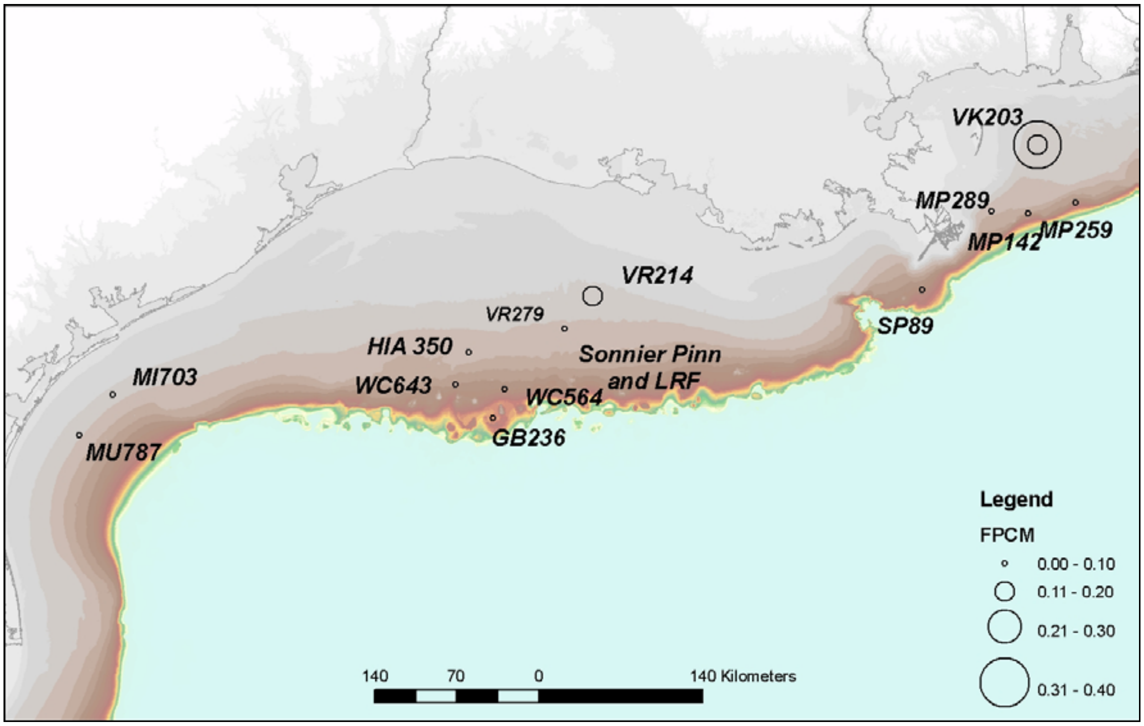

Figure 10. Least squares mean fish density (fish m^{-3}) at all study locations. Note that data from Sonnier Bank are included.

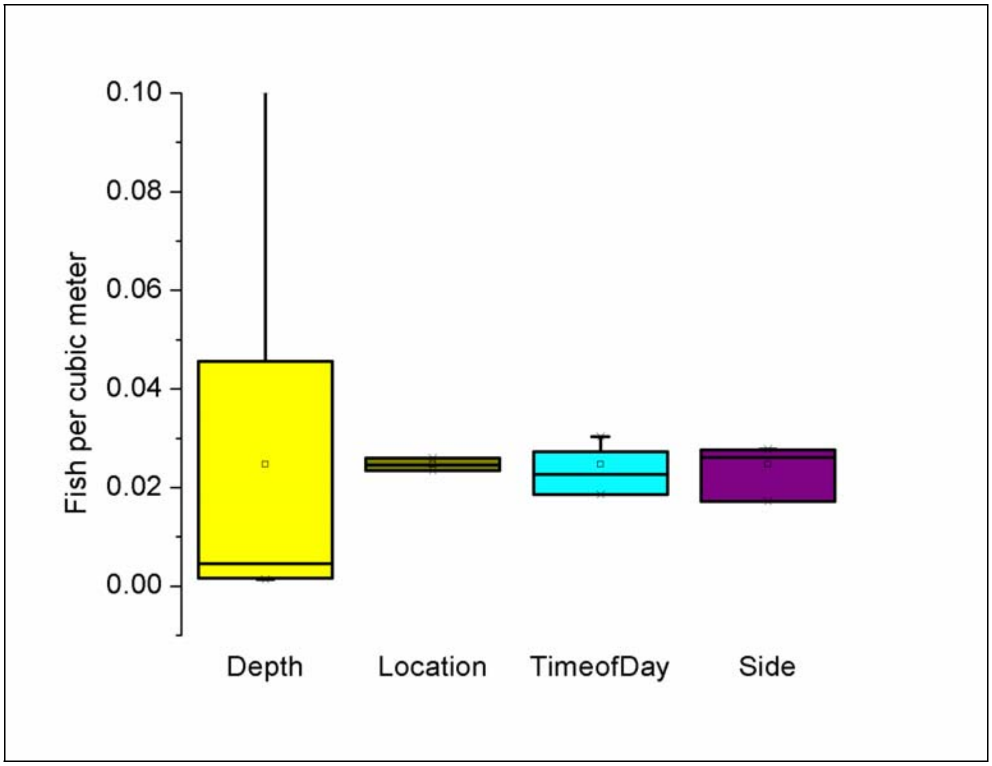

Figure 11. Range of variation in fish density at all study platforms due to depth, location, time of day, and side.

3.2.3 Target Strength (TS)

Target strength is an acoustic measure of fish size. Individual targets are identified in the reflection of an acoustic ping and tracked over consecutive pings. Target strengths can vary depending on target orientation and are therefore considered to be a rough approximation of target size. However, by tracking, measuring, and averaging the acoustic reflection of a target over multiple pings we can achieve a reasonable estimate of target size. We used target strength as a dependent variable to test for relationships between trends and target size for the independent variables outlined above. Throughout the study, target strength ranged from –20 dB to –53 dB. Target strength was significantly affected by region, time of day, platform side, and depth stratum.

Mean acoustic target size varied with region, water depth, platform side, and time of day (Table 5). Fish were smallest along the western region, largest along the central region, and the central and eastern regions were very similar (Figure 12a, 13). The few fish encountered at the deeper strata were much larger than fish near the surface and there was a general trend of increasing fish size with increased water depth although smallest fish size was between 10 and 20 m water depth (Figure 12b). All platforms sides exhibited statistically different target strength with the largest size occurring on the east side of platforms and the smallest sizes occurring on the north side (Figure 12c). Fish size varied slightly with time of day and was largest during the daylight hours and smallest at midnight (Figure 12d). Target strength showed the greatest variation with depth and location. Time of day and side showed smaller ranges in variability, respectively (Figure 14).

An alternate method to examine the spatial distribution of target strength and fish is illustrated in Figure 15. Figure 15 is a plot of the target strength data from HI A350 that shows high concentration of single targets at 30 and 18 meters water depth. Targets near the surface showed a large variation in sizes. Targets at 30 m were dominated by smaller size classes; and targets occurring at deeper depths tended to be exclusively larger in size.

Table 5

Results of Split Plot Design Analysis of Variance Showing the Effect of Region (Location), Time of Day (TOD), Platform Side (Side), and Depth Stratum (Stratum) on the Dependent Variable Target Strength.

Type 3 Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
Location	2	72	3.44	0.0375
TOD	3	500000	2260.42	<.0001
Side	3	500000	175.08	<.0001
Stratum	11	44	26.37	<.0001

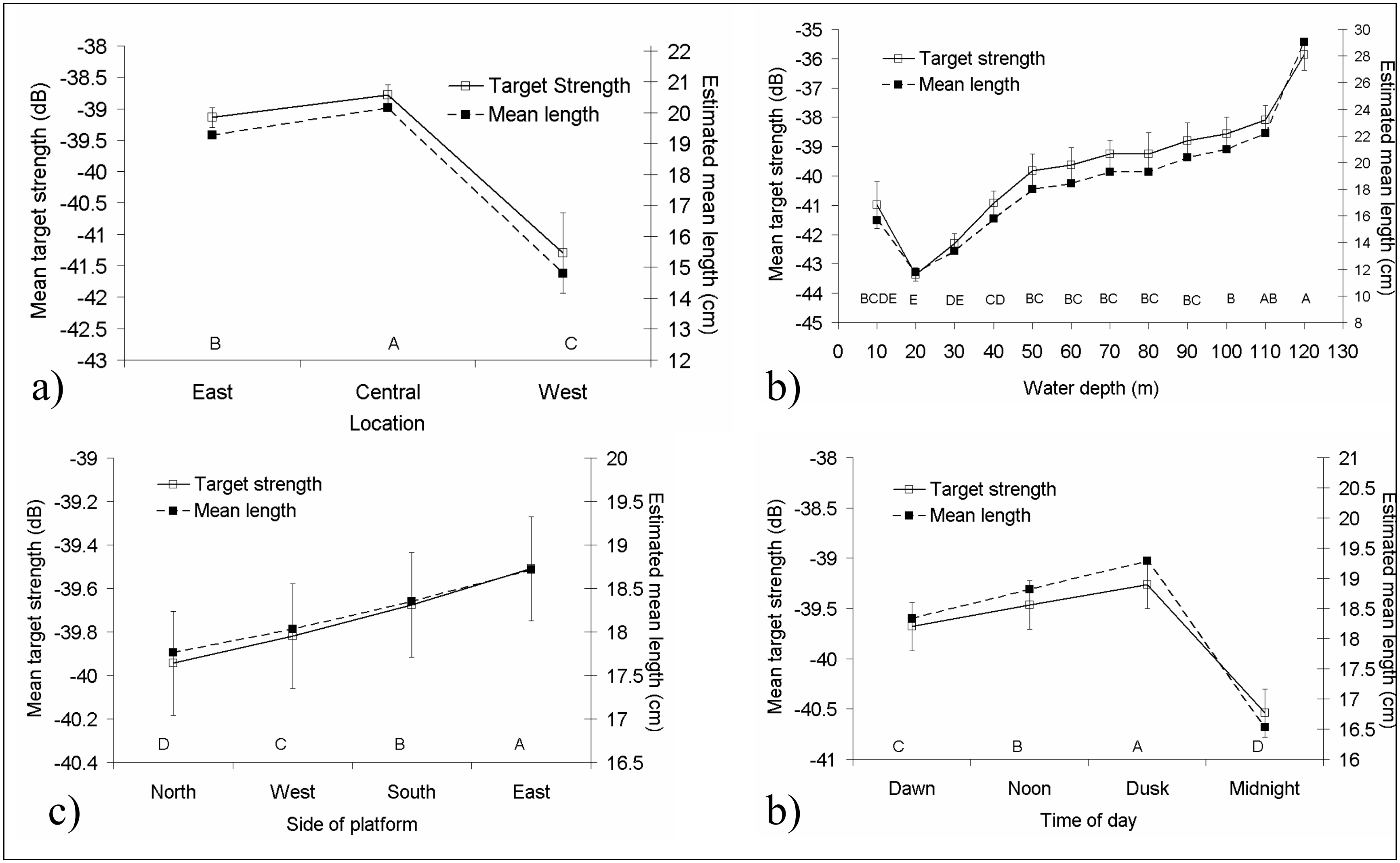

Figure 12. LS mean target strength (dB ± 1 SE) by a) region, b) depth, c) side and d) time of day for platforms in the northern Gulf of Mexico. Means with same letters are not significantly different at α= 0.005.

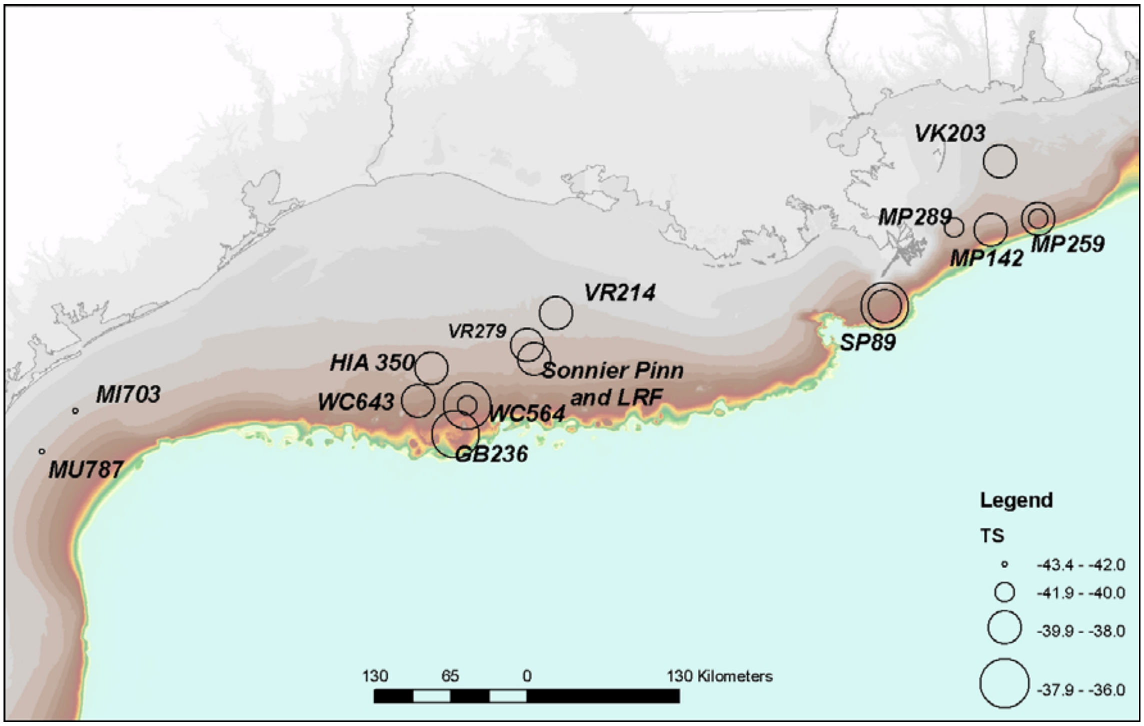

Figure 13. Least squares mean target strength at all study locations. Note that data from Sonnier Bank are included.

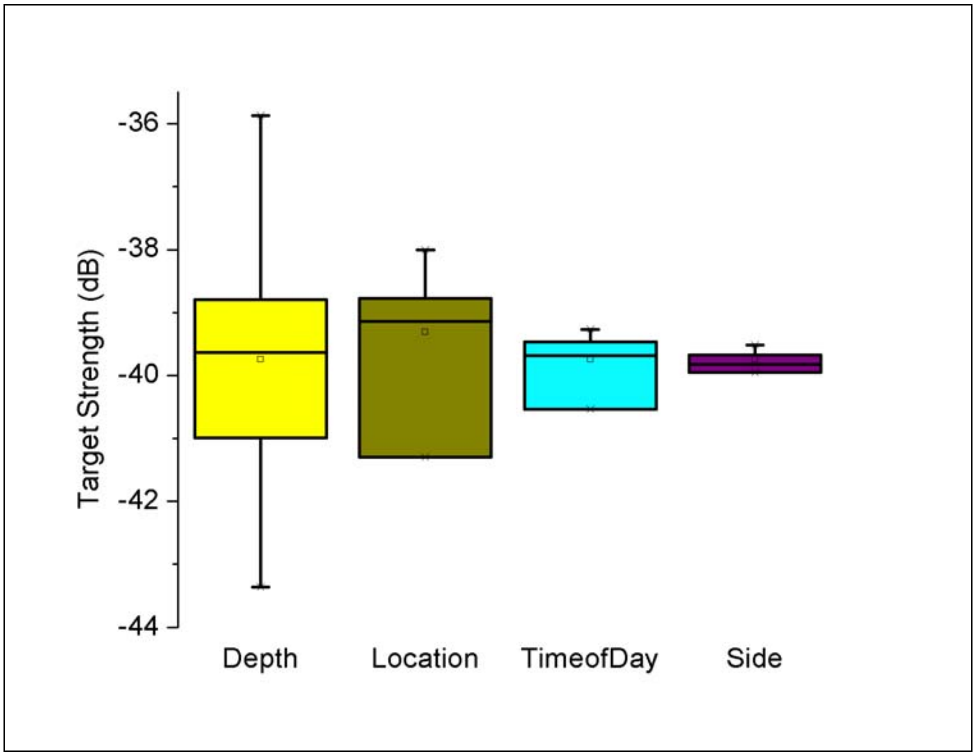

Figure 14. Range of variation in target strength at all study platforms due to depth, location, time of day, and side.

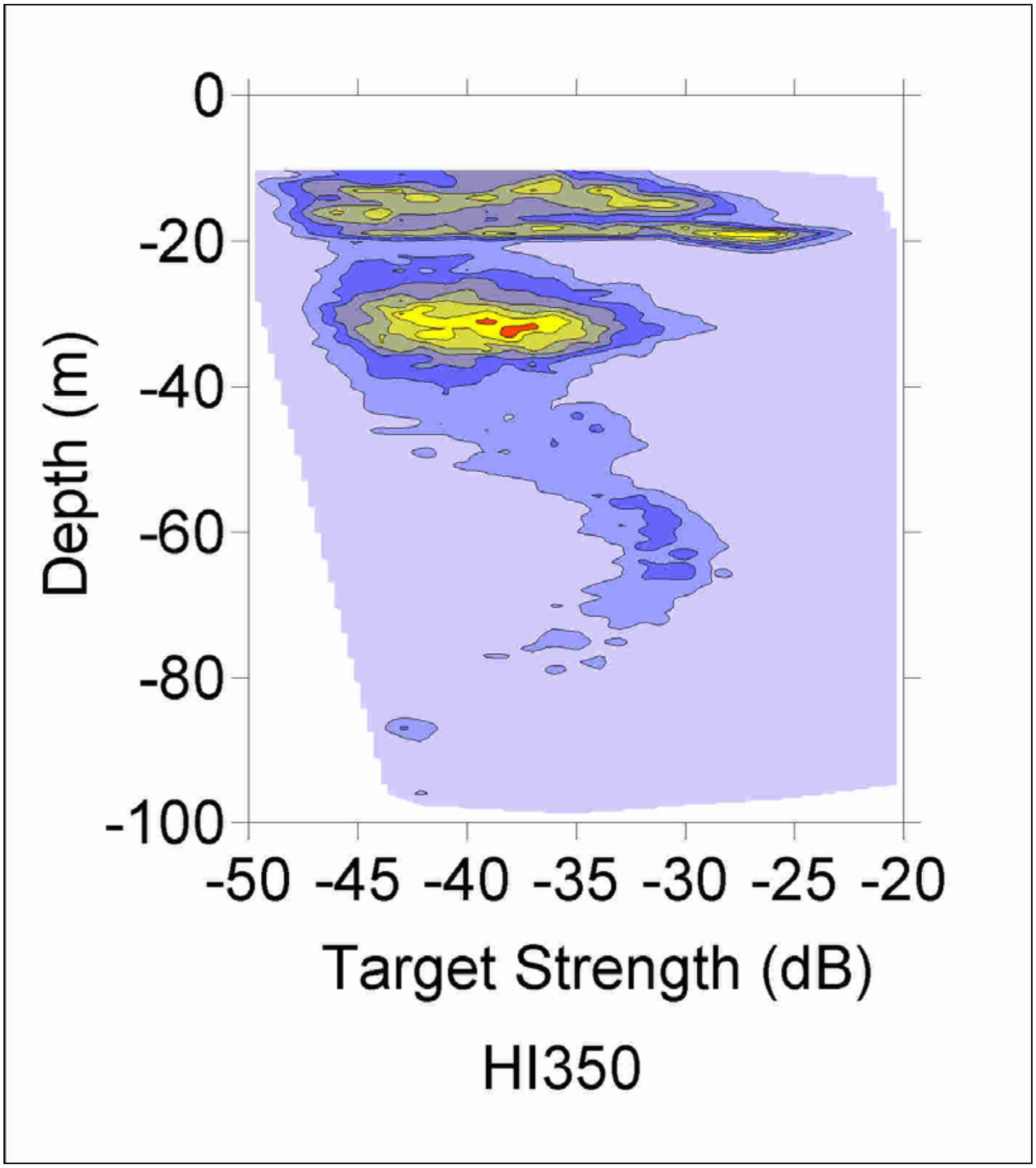

Figure 15. Alternate method to examine the spatial distribution of target strength and fish at HIA 350. Blue indicates lower occurrence of a given target strength and red indicates a higher occurrence of a given target strength.

3.3 Platform Results - Horizontal

3.3.1 Volume Backscatter

Acoustic reflectivity of targets such as fish can vary greatly depending upon target orientation. A vertical aspect, either upward or downward, provides the most meaningful perspective from which to infer size and biomass data. The data collected with the horizontal oriented transducers are useful for comparative purposes to determine area of influence, relative biomass changes with distance from the platform, as well as the effect of side and time of day on the same parameters. Acoustic biomass was significantly affected by distance from the platform, transect location, side of the platform, and time of day (Table 6).

Acoustic biomass varied among platforms depending on region: acoustic biomass was highest in the central region and lower in the eastern and western regions (Figure 16a). Acoustic biomass was highest from 10 to 20 m away from the platforms studied and then dropped off to very low levels beyond 70 m (Figure 16b). Although there were no statistical differences, acoustic biomass gradually declined from 20 m out to 80 m, which was the limit of our ability to collect acoustic data. Acoustic biomass also varied significantly with platform side and was highest on the west side and lowest on the south side (Figure 16c). Acoustic biomass varied with time of day and was highest at midnight and lowest at noon (Figure 16d).

Table 6

Results of Split Plot Design Analysis of Variance Showing the Effect of Region (Location), Time of Day (TOD), Platform Side (Side), and Depth Stratum (Stratum) on the Dependent Variable Sv for Horizontal Hydroacoustic Data.

Type 3 Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
Location	2	32	5.23	0.0109
TOD	3	17000	130.77	<.0001
Side	3	17000	70.9	<.0001
Stratum	7	32	6.02	0.0002

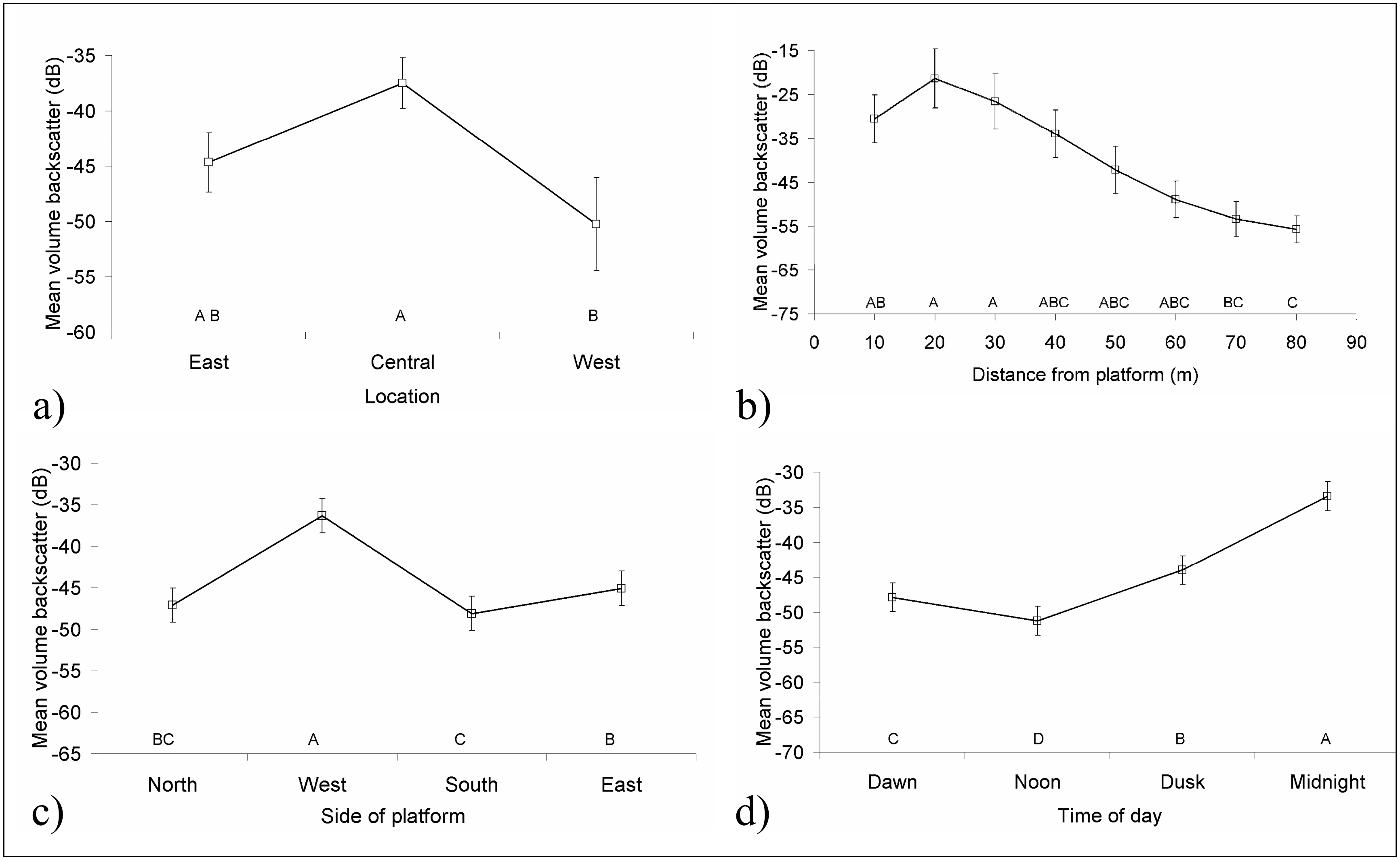

Figure 16. Horizontal LS mean volume backscatter (Sv in dB ± 1 SE) by a) region, b) depth, c) side and d) time of day for platforms in the northern Gulf of Mexico. Means with same letters are not significantly different at α= 0.005.

3.4 Platform Species Composition and Abundance

Examination of the ROV video surveys from most sites provides some patterns that can be recognized across the GOM and may lend insight into the population structure at platforms in various water depths throughout the three major regions of the study area: eastern, central, and western.

Gulf wide, 39 different species were observed by ROV survey. Species richness appeared to be higher in the central and western GOM (Figure 17). Shannon-Wiener Diversity Index did not show a remarkable pattern with either longitude or distance from shore (Figure 18).

Consistent with past studies by Stanley and Wilson (2000), we found fish populations to be generally dominated by planktivores such as blue runner, Bermuda chub, and Atlantic creolefish, These species were always most abundant in the upper water column at depths less than 30 m (Tables 7-23). To more carefully examine the patterns of fish functional groups through the GOM, we assigned each observed fish species to one of four categories based on its presumed role in the functioning of reef ecosystems (Table 7). We then determined the proportion of each of these functional groups at each platform based on ROV abundance observations.

As already noted, planktivores dominated the observed fish abundance at most platforms. In the central GOM, however, planktivores appeared to compose a larger proportion of the population compared to fish at platforms in either the eastern or western regions (Figure 19). Grazers were important at several platforms in each region of the GOM, but they tended to be found at platforms that were closer to land or located in shallower depths (Figure 20). In the eastern GOM, carnivores and top predators composed a remarkably large proportion of observed fish populations (Figure 21, 22).

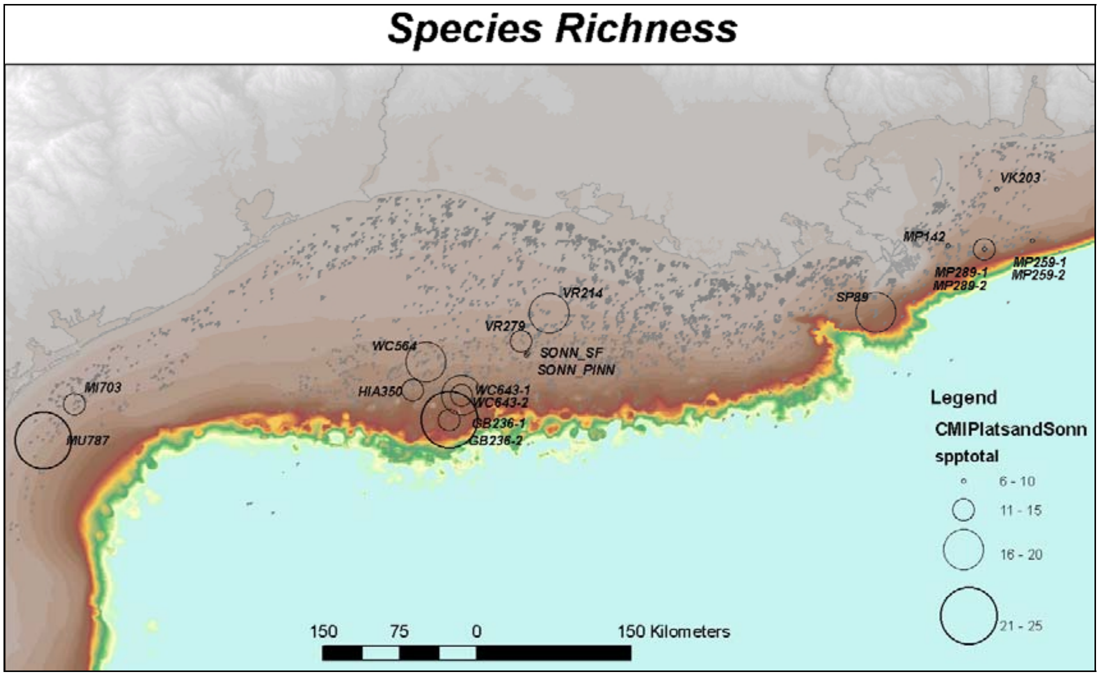

Figure 17. Map of species richness observed by ROV surveys at all study platforms and visits. Note that results from Sonnier Bank (SONN_SF and SONN_PINN) are also included.

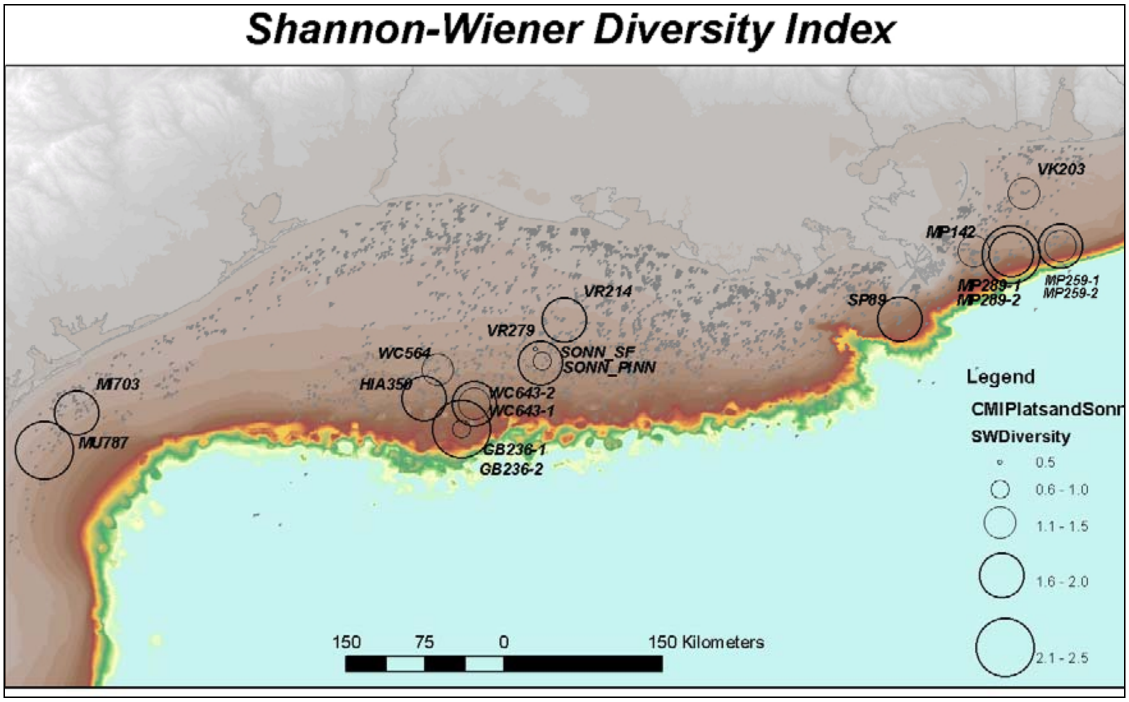

Figure 18. Map of Shannon-Wiener Diversity Index observed by ROV surveys at all study platforms and visits. Note that results from Sonnier Bank (SONN_SF and SONN_PINN) are also included.

Table 7

Fish Functional Group Assignments Based on ROV Survey Observations.

Planktivores	Carnivores (lesser predators)	Top predators	Grazers
Blue runner	Bluefish	Greater amberjack	Florida pompano
Atlantic spadefish	Red snapper	Great barracuda	Lookdown
Atlantic creolefish	Almaco jack	Scamp	Sheepshead
Bermuda chub	Rainbow runner	sharks	Blue angelfish
Round scad	Bar jack		Gray triggerfish
	Crevalle jack		Queen angelfish
	Lesser amberjack		Spanish hogfish
	Cobia		
	Gray snapper		
	Vermilion snapper		
	Horse-eye jack		
	Rock hind		
	Lane snapper		

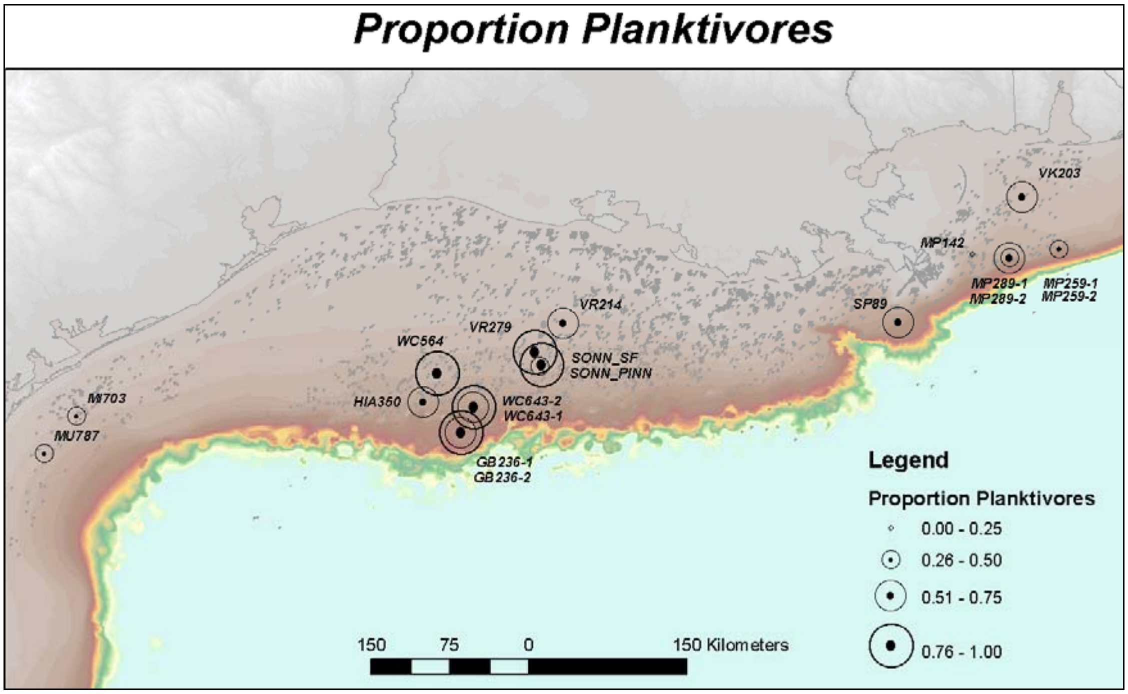

Figure 19. Map of the proportion of planktivores at all study platforms and visits. See Table 7 for planktivore definition. Note that results from Sonnier Bank (SONN_SF and SONN_PINN) are also included.

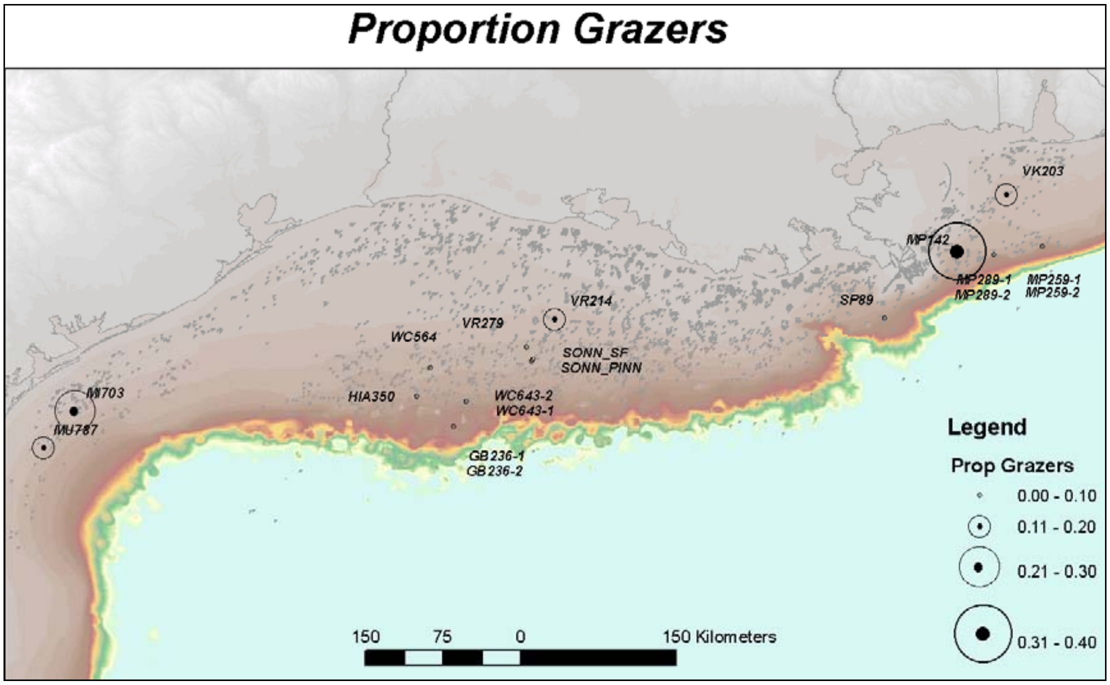

Figure 20. Map of the proportion of grazers at all study platforms and visits. See Table 7 for planktivore definition. Note that results from Sonnier Bank (SONN_SF and SONN_PINN) are also included.

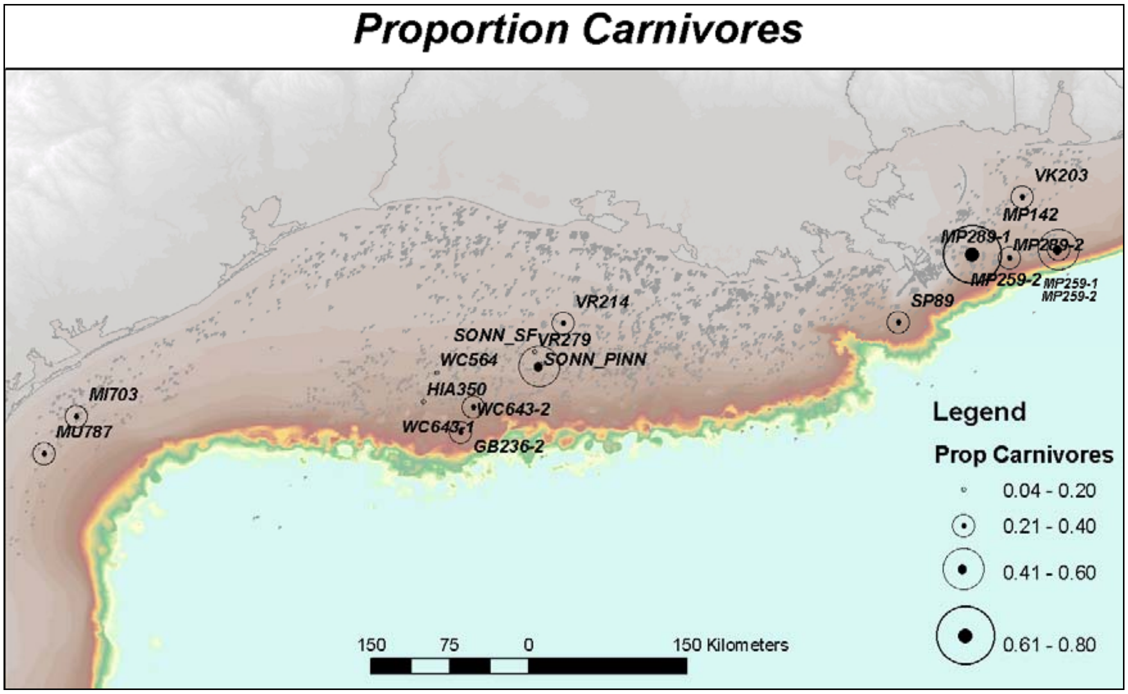

Figure 21. Map of the proportion of carnivores at all study platforms and visits. See Table 7 for carnivore definition. Note that results from Sonnier Bank are also included.

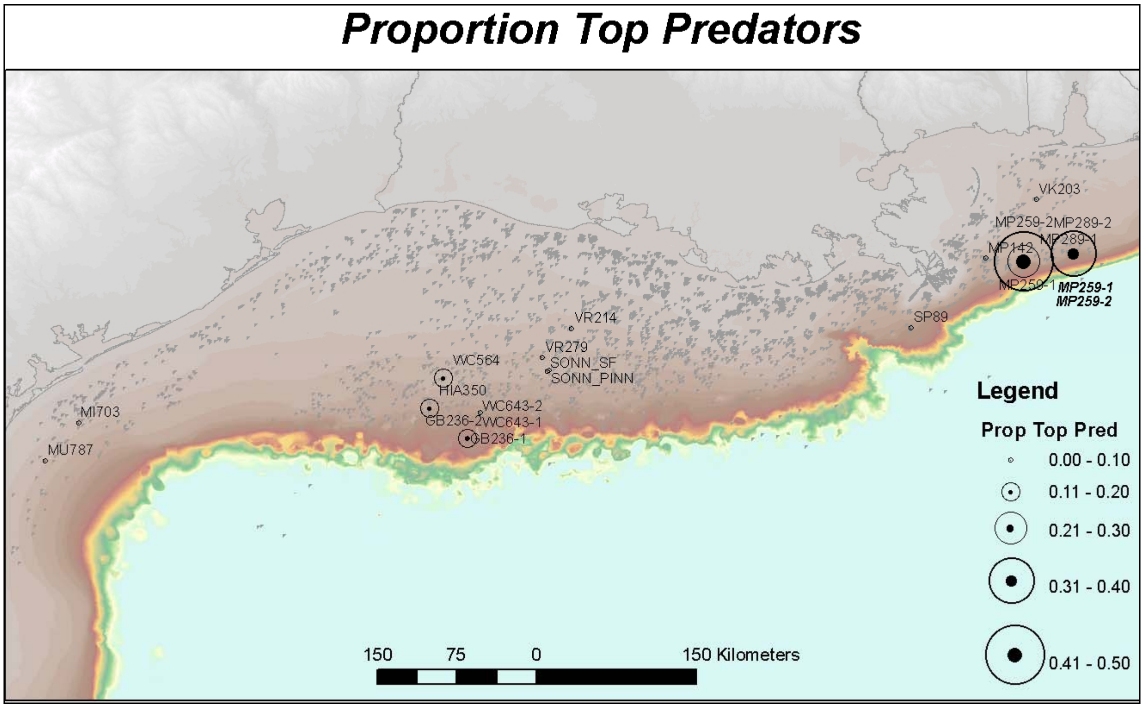

Figure 22. Map of the proportion of top predators at all study platforms and visits. See Table 7 for top predator definition. Note that results from Sonnier Bank are also included.

Table 8

Number of Fishes By Species Observed during ROV Video Surveys by Depth at VK 203, Visit 2, 1/1999.
(This platform lies in the eastern region. Max depth at the platform is 37 m. Blanks = no data.)

Common Name	**Scientific Name**	***0-10***	***10-20***	***20-30***	***30-40***	***Total***	***% Composition***
Blue runner	*Caranx crysos*	186	146	130	0	**462**	**44.6%**
Atllantic spadefish	*Chaetodipterus faber*	113	23	48	0	**184**	**17.7%**
Bluefish	*Pomatomus saltatrix*	33	122	2	0	**157**	**15.1%**
Florida pompano	*Trachinotus carolinus*	0	30	89	0	**119**	**11.5%**
Red snapper	*Lutjanus campechanus*	0	0	99	4	**103**	**9.9%**
Other							**1.2%**
Greater amberjack	*Seriola dumerili*	2	9	1	0	**12**	**1.2%**
Total		**334**	**330**	**369**	**4**	**1037**	**100.0%**

Table 9

Number of Fishes by Species Observed during ROV Video Surveys By Depth at MP 259, Visit 1, 6/1998.
(This platform lies in the eastern region. Max depth at the platform is 119 m. Blanks = no data.)

Common Name	**Scientific Name**	***0-10***	***10-20***	***20-30***	***30-40***	***40-50***	***50-120***	***Total***	***% Composition***
Greater amberjack	*Seriola dumerili*	0	26	41	**45**	4	0	**116**	**32.0%**
Almaco jack	*Seriola rivoliana*	0	0	22	**48**	0	0	**70**	**19.3%**
Blue runner	*Caranx crysos*	5	**45**	0	0	0	0	**50**	**13.8%**
Atlantic creolefish	*Paranthias furcifer*	0	0	**42**	0	0	0	**42**	**11.6%**
Bermuda chub	*Kyphosus sectatrix*	0	**35**	0	0	0	0	**35**	**9.7%**
Rainbow runner	*Elagatis bipinnulata*	0	0	**32**	0	0	0	**32**	**8.8%**
Other									*4.7%*
Gray triggerfish	*Balistes capriscus*	2	0	**3**	0	0	0	**5**	**1.4%**
Great barracuda	*Sphyraena barracuda*	0	2	**3**	0	0	0	**5**	**1.4%**
Cobia	*Rachycentron canadum*	2	0	2	0	0	0	**4**	**1.1%**
Scamp	*Mycteroperca phenax*	0	0	0	**3**	0	0	**3**	**0.8%**
Total		**9**	**108**	**145**	**96**	**4**	**0**	**362**	100.0%

Table 10

Number of fishes by Species Observed during ROV Video Surveys by Depth at MP 259, Visit 2, 12/1998.
(This platform lies in the eastern region. Max depth at the platform is 119 m. Blanks = no data.)

Common Name	**Scientific Name**	***0-10***	***10-20***	***20-30***	***30-40***	***40-50***	***50-60***	***60-120***	***Total***
Bar jack	*Caranx ruber*	0	38	28	0	0	0		**66**
Greater amberjack	*Seriola dumerili*	0	0	0	0	0	33		**33**
Great barracuda	*Sphyraena barracuda*	1	1	5	0	4	21		**32**
Blue runner	*Caranx crysos*	0	26	0	0	0	0		**26**
Other									
Almaco jack	*Seriola rivoliana*	0	0	0	0	0	7		**7**
Ocean triggerfish	*Canthidermis sufflamen*	0	0	0	0	0	2		**2**
Total		**1**	**65**	**33**	**0**	**4**	**63**		**166**

Table 11

Number of Fishes by Species Observed during ROV Video Surveys by Depth at MP 289, Visit 1, 6/1998.
(This platform lies in the eastern region. Max depth at the platform is 98 m. Blanks = no data.)

Common Name	**Scientific Name**	***0-10***	***10-20***	***20-30***	***30-40***	***40-50***	***50-60***	***60-70***	***70-80***	***80-100***	***Total***	***% Composition***
Bermuda chub	*Kyphosus sectatrix*	0	**60**	43	0	0	0	0	0		**103**	**30.8%**
Atlantic creolefish	*Paranthias furcifer*	9	4	**43**	9	4	0	0	0		**69**	**20.7%**
Scamp	*Mycteroperca phenax*	2	2	0	15	10	**16**	7	5		**57**	**17.1%**
Almaco jack	*Seriola rivoliana*	0	0	6	**8**	0	1	0	7		**22**	**6.6%**
Crevalle jack	*Caranx hippos*	0	**14**	0	0	0	0	0	0		**14**	**4.2%**
Greater amberjack	*Seriola dumerili*	0	0	2	**6**	2	3	1	0		**14**	**4.2%**
Rainbow runner	*Elagatis bipinnulata*	0	**12**	0	0	0	0	0	0		**12**	**3.6%**
Great barracuda	*Sphyraena barracuda*	0	**6**	2	2	0	0	0	0		**10**	**3.0%**
Lesser amberjack	*Seriola fasciata*	0	2	0	0	**7**	0	0	0		**9**	**2.7%**
Cobia	*Rachycentron canadum*	0	3	2	2	1	0	0	0		**8**	**2.4%**
Other												*4.8%*
Gray snapper	*Lutjanus griseus*	**6**	0	0	1	0	0	0	0		**7**	**2.1%**
Horse-eye jack	*Caranx latus*	0	0	**3**	0	0	0	0	0		**3**	**0.9%**
Ocean triggerfish	*Canthidermis sufflamen*	0	0	0	1	**2**	0	0	0		**3**	**0.9%**
Gray triggerfish	*Balistes capriscus*	0	0	0	**2**	0	0	0	0		**2**	**0.6%**
Remoras	Echeneidae	0	0	0	**1**	0	0	0	0		**1**	**0.3%**
Total		**17**	**103**	**101**	**47**	**26**	**20**	**8**	**12**		**334**	**100.0%**

Table 12

Number of Fishes by Species Observed during ROV Video Surveys by Depth at MP 289, Visit 2, 12/1998.
(This platform lies in the eastern region. Max depth at the platform is 98 m. Blanks = No Data.)

Common Name	**Scientific Name**	***0-10***	***10-20***	***20-30***	***30-40***	***40-50***	***50-60***	***60-100***	***Total***	***% Composition***
Bermuda chub	*Kyphosus sectatrix*	**57**	0	0	0	0	0		**57**	**30.2%**
Greater amberjack	*Seriola dumerili*	0	8	0	**16**	14	2		**40**	**21.2%**
Great barracuda	*Sphyraena barracuda*	0	8	**14**	12	1	0		**35**	**18.5%**
Almaco jack	*Seriola rivoliana*	0	1	**28**	0	0	0		**29**	**15.3%**
Blue runner	*Caranx crysos*	0	0	**16**	0	4	0		**20**	**10.6%**
Other										*4.2%*
Scamp	*Mycteroperca phenax*	0	0	**4**	2	0	0		**6**	**3.2%**
Gray triggerfish	*Balistes capriscus*	0	1	0	0	0	0		**1**	**0.5%**
Sharks		0	1	0	0	0	0		**1**	**0.5%**
Total		**57**	**19**	**62**	**30**	**19**	**2**		**189**	**100.0%**

Table 13

Number of Fishes by Species Observed during ROV Video Surveys by Depth at MP 142, Visit 1, 7/1998.
(This platform lies in the eastern region. Max depth at the platform is 61 m. Blanks = no data.)

Common Name	**Scientific Name**	***0-10***	***10-20***	***20-30***	***30-70***	***Total***	***% Composition***
Gray Snapper	*Lutjanus griseus*	**34**	16	3		**53**	**63.1%**
Lookdown	*Selene vomer*	0	**12**	0		**12**	**14.3%**
Sheepshead	*Archosargus probatocephalus*	**9**	2	0		**11**	**13.1%**
Blue Angelfish	*Holacanthus bermudensis*	0	**4**	0		**4**	**4.8%**
Other							*4.8%*
Great Barracuda	*Sphyraena barracuda*	0	**3**	0		**3**	**3.6%**
Gray Triggerfish	*Balistes capriscus*	0	0	**1**		**1**	**1.2%**
Total		**43**	**37**	**4**		**84**	**100.0%**

Table 14

Number of Fishes by Species Observed during ROV Video Surveys by Depth at SP 89, Visit 2, 10/1998.
(This platform lies in the eastern region. Max depth at the platform is 139 m. Blanks = no data.)

Common Name	**Scientific Name**	***0-10***	***10-20***	***20-30***	***30-40***	***40-50***	***50-60***	***60-70***	***70-80***	***80-140***	***Total***	***% Composition***
Atlantic creolefish	*Paranthias furcifer*	15	251	9	**629**	289	320	0			**1513**	**36.8%**
Blue runner	*Caranx crysos*	177	**534**	255	116	255	5	0			**1342**	**32.6%**
Vermilion snapper	*Rhomboplites aurorubens*	0	0	0	0	156	**318**	1			**475**	**11.5%**
Horse-eye jack	*Caranx latus*	0	26	10	**115**	67	3	0			**221**	**5.4%**
Red snapper	*Lutjanus campechanus*	0	0	2	0	15	**107**	55			**179**	**4.3%**
Round scad	*Decapterus punctatus*	**123**	44	0	0	0	0	0			**167**	**4.1%**
Other												*5.3%*
Blackfin tuna	*Thunnus atlanticus*	0	0	0	0	0	**61**	0			**61**	**1.5%**
Greater amberjack	*Seriola dumerili*	0	0	1	6	0	**21**	11			**39**	**0.9%**
Bermuda chub	*Kyphosus sectatrix*	2	**33**	5	6	0	0	0			**46**	**1.1%**
Great barracuda	*Sphyraena barracuda*	2	**7**	0	1	1	1	0			**12**	**0.3%**
Gray snapper	*Lutjanus griseus*	**16**	12	0	9	0	0	0			**37**	**0.9%**
Gag	*Mycteroperca microlepis*	0	0	0	0	0	0	**7**			**7**	**0.2%**
Gray triggerfish	*Balistes capriscus*	0	3	0	0	0	**5**	0			**8**	**0.2%**
Atllantic spadefish	*Chaetodipterus faber*	0	0	0	0	**2**	1	0			**3**	**0.1%**
Sharks		0	**2**	0	0	1	0	0			**3**	**0.1%**
Almaco jack	*Seriola rivoliana*	0	0	0	0	0	1	1			**2**	**0.0%**
Rainbow runner	*Elagatis bipinnulata*	0	**2**	0	0	0	0	0			**2**	**0.0%**
Total		**335**	**914**	**282**	**882**	**786**	**843**	**75**			**4117**	**100.0%**

Table 15

Number of Fishes by Species Observed during ROV Video Surveys by Depth at VR 214, Visit 2, 4/2000.
(This platform lies in the central region. Max depth at the platform is 39 m. Blanks = no data.)

Common Name	**Scientific Name**	***0-10***	***10-20***	***20-30***	***30-40***	***Total***	***% Composition***
Blue runner	*Caranx crysos*	124	**153**	22	4	**303**	**51.9%**
Gray snapper	*Lutjanus griseus*	2	**20**	17	19	**58**	**9.9%**
Red snapper	*Lutjanus campechanus*	0	0	9	**39**	**48**	**8.2%**
Atlantic spadefish	*Chaetodipterus faber*	4	10	12	**14**	**40**	**6.8%**
Gray triggerfish	*Balistes capriscus*	1	4	**16**	15	**36**	**6.2%**
Bermuda chub	*Kyphosus sectatrix*	**28**	0	0	0	**28**	**4.8%**
Sheepshead	*Archosargus probatocephalus*	0	5	5	**13**	**23**	**3.9%**
Almaco jack	*Seriola rivoliana*	0	3	**8**	4	**15**	**2.6%**
Other							*5.7%*
Lookdown	*Selene vomer*	**13**	0	0	0	**13**	**2.2%**
Blue angelfish	*Holacanthus bermudensis*	0	0	0	**4**	**4**	**0.7%**
Cobia	*Rachycentron canadum*	0	0	**4**	0	**4**	**0.7%**
Blue tang	*Acanthurus coeruleus*	0	**2**	0	1	**3**	**0.5%**
Atlantic creolefish	*Paranthias furcifer*	0	0	0	**3**	**3**	**0.5%**
Crevalle jack	*Caranx hippos*	0	3	0	0	**3**	**0.5%**
French angelfish	*Pomacanthus paru*	0	0	0	**2**	**2**	**0.3%**
Squirrelfish	*Holocentrus ascensionis*	0	0	0	**1**	**1**	**0.2%**
Total		**172**	**200**	**93**	**119**	**584**	**100.0%**

Table 16

Number of Fishes by Species Observed during ROV Video Surveys by Depth at WC 564, Visit 1, 5/1999.
(This platform lies in the central region. Max depth at the platform is 58 m. Blanks = no data.)

Common Name	**Scientific Name**	***0-10***	***10-20***	***20-30***	***30-40***	***40-50***	***50-60***	***Total***	***% Composition***
Blue runner	*Caranx crysos*	68	116	217	**375**	0		**776**	**63.3%**
Atlantic creolefish	*Paranthias furcifer*	0	7	22	**210**	8		**247**	**20.1%**
Greater amberjack	*Seriola dumerili*	2	14	14	**42**	12		**84**	**6.9%**
Great barracuda	*Sphyraena barracuda*	**24**	6	2	0	0		**32**	**2.6%**
Bermuda chub	*Kyphosus sectatrix*	**20**	0	0	0	0		**20**	**1.6%**
Other									*5.5%*
Red snapper	*Lutjanus campechanus*	0	0	**10**	8	0		**18**	**1.5%**
Cobia	*Rachycentron canadum*	**5**	2	4	0	0		**11**	**0.9%**
Blackfin tuna	*Thunnus atlanticus*	0	**9**	0	0	0		**9**	**0.7%**
Crevalle jack	*Caranx hippos*	0	0	**7**	0	0		**7**	**0.6%**
Almaco jack	*Seriola rivoliana*	0	0	**5**	0	0		**5**	**0.4%**
Blue angelfish	*Holacanthus bermudensis*	0	**5**	0	0	0		**5**	**0.4%**
Bar jack	*Caranx ruber*	0	**4**	0	0	0		**4**	**0.3%**
Sharks		**3**	0	0	0	0		**3**	**0.2%**
Horse-eye jack	*Caranx latus*	**2**	0	0	0	0		**2**	**0.2%**
Scamp	*Mycteroperca phenax*	0	1	0	0	1		**2**	**0.2%**
Warsaw grouper	*Epinephelus nigritus*	0	0	0	**1**	0		**1**	**0.1%**
Total		**124**	**164**	**281**	**636**	**21**		**1226**	**100.0%**

Table 17 .

Number of Fishes by Species Observed during ROV Video Surveys by Depth at HIA 350, Visit 1, 6/1999.
(This platform lies in the central region. Max depth at the platform is 93 m. Blanks = no data.)

Common Name	**Scientific Name**	***0-10***	***10-20***	***20-30***	***30-40***	***40-50***	***50-60***	***60-70***	***70-100***	***Total***	***% Composition***
Blue runner	*Caranx crysos*	92	33	182	0	0	0	0		**307**	**30.9%**
Bermuda chub	*Kyphosus sectatrix*	280	0	0	0	0	0	0		**280**	**28.2%**
Atlantic creolefish	*Paranthias furcifer*	0	0	94	53	0	0	0		**147**	**14.8%**
Scamp	*Mycteroperca phenax*	0	0	2	17	7	37	10		**73**	**7.3%**
Red snapper	*Lutjanus campechanus*	0	0	0	0	11	50	2		**63**	**6.3%**
Almaco jack	*Seriola rivoliana*	5	1	22	9	0	0	0		**37**	**3.7%**
Greater amberjack	*Seriola dumerili*	0	2	4	4	2	8	1		**21**	**2.1%**
Bar jack	*Caranx ruber*	11	9	0	0	0	0	0		**20**	**2.0%**
Other											*4.6%*
Great barracuda	*Sphyraena barracuda*	6	10	2	0	0	0	0		**18**	**1.8%**
Crevalle jack	*Caranx hippos*	0	9	0	0	0	0	0		**9**	**0.9%**
Rainbow runner	*Elagatis bipinnulata*	0	9	0	0	0	0	0		**9**	**0.9%**
Gray triggerfish	*Balistes capriscus*	1	0	1	2	4	0	0		**8**	**0.8%**
Gag	*Mycteroperca microlepis*	0	0	1	0	0	1	0		**2**	**0.2%**
Total		**395**	**73**	**308**	**85**	**24**	**96**	**13**		**994**	**100.0%**

Table 18

Number of Fishes by Species Observed during ROV Video Surveys by Depth at WC 643, Visit 1, 3/2000.
(This platform lies in the central region. Max depth at the platform is 114 m. Blanks = no data.)

Common Name	*Scientific Name*	*0-10*	*10-20*	*20-30*	*30-40*	*40-50*	*50-60*	*60-70*	*70-80*	*80-90*	*90-100*	*100-110*	*Total*
Blue runner	*Caranx crysos*	7	206	**332**	0	0	0	0	0	0	0		**545**
Atlantic creolefish	*Paranthias furcifer*	0	12	99	0	64	15	**219**	5	33	1		**448**
Vermilion snapper	*Rhomboplites aurorubens*	0	0	**200**	0	0	0	0	0	0	0		**200**
Horse-eye jack	*Caranx latus*	0	0	0	0	0	0	**61**	27	46	50		**184**
Greater amberjack	*Seriola dumerili*	0	0	0	0	29	7	22	1	**54**	25		**138**
Other													
Great barracuda	*Sphyraena barracuda*	3	**4**	3	0	0	0	0	0	0	0		**10**
Queen angelfish	*Holacanthus ciliaris*	0	0	1	0	**4**	3	2	0	0	0		**10**
Blue angelfish	*Holacanthus bermudensis*	0	0	0	0	**4**	0	**4**	0	0	0		**8**
Scamp	*Mycteroperca phenax*	0	0	0	0	0	0	**5**	1	0	1		**7**
Gray triggerfish	*Balistes capriscus*	0	0	0	0	0	0	**6**	0	0	0		**6**
Blue tang	*Acanthurus coeruleus*	0	0	0	0	**3**	0	1	0	0	0		**4**
French angelfish	*Pomacanthus paru*	0	0	0	0	0	0	**2**	1	0	0		**3**
Rock hind	*Epinephelus adscensionis*	0	0	0	0	0	0	**1**	**1**	0	0		**2**
Almaco jack	*Seriola rivoliana*	0	0	**1**	0	0	0	0	0	0	0		**1**
Squirrelfish	*Holocentrus ascensionis*	0	0	0	0	0	0	**1**	0	0	0		**1**
Total		**10**	**222**	**636**	**0**	**104**	**25**	**324**	**36**	**133**	**77**		**1567**

Table 19

Number of Fishes by Species Observed during ROV Video Surveys by Depth at WC 643, Visit 2, 2/2001.
(This platform lies in the central region. Max depth at the platform is 114 m. Blanks = no data.)

Common Name	Scientific Name	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100-110	Total	% Composition
Blue runner	*Caranx crysos*	373	205	**398**	0	0	0	0	0	0	0	0	**976**	**40.5%**
Atlantic creolefish	*Paranthias furcifer*	1	4	23	101	60	0	**212**	108	122	0	31	**662**	**27.5%**
Bermuda chub	*Kyphosus sectatrix*	109	32	**243**	86	0	0	0	0	0	0	0	**470**	**19.5%**
Crevalle jack	*Caranx hippos*	0	0	0	32	48	38	**52**	1	0	0	0	**171**	**7.1%**
Other														*5.4%*
Greater amberjack	*Seriola dumerili*	0	0	**13**	10	5	3	9	1	0	0	1	**42**	**1.7%**
Great barracuda	*Sphyraena barracuda*	0	6	10	**11**	7	4	1	1	0	0	0	**40**	**1.7%**
Blue angelfish	*Holacanthus bermudensis*	0	0	0	1	3	1	**4**	3	0	0	0	**12**	**0.5%**
Spanish hogfish	*Holocentrus ascensionis*	0	0	**6**	5	0	0	0	0	0	0	0	**11**	**0.5%**
Cobia	*Rachycentron canadum*	0	0	0	0	0	0	**4**	**4**	0	0	0	**8**	**0.3%**
French angelfish	*Pomacanthus paru*	0	0	0	**2**	**2**	1	0	0	0	0	0	**5**	**0.2%**
Scamp	*Mycteroperca phenax*	0	0	0	0	0	0	0	0	2	0	**3**	**5**	**0.2%**
Gray triggerfish	*Balistes capriscus*	**1**	0	0	**1**	0	0	0	0	0	0	0	**2**	**0.1%**
Rock hind	*Epinephelus adscensionis*	0	0	0	**2**	0	0	0	0	0	0	0	**2**	**0.1%**
Bar jack	*Caranx ruber*	0	0	0	0	0	0	**1**	0	0	0	0	**1**	**0.0%**
Filefishes	Balistidae	0	0	0	**1**	0	0	0	0	0	0	0	**1**	**0.0%**
Gag	*Mycteroperca microlepis*	0	0	0	**1**	0	0	0	0	0	0	0	**1**	**0.0%**
Total		**484**	**247**	**693**	**253**	**125**	**47**	**283**	**118**	**124**	**0**	**35**	**2409**	**100.0%**

Table 20

Number of Fishes by Species Observed during ROV Video Surveys by Depth at GB 236, Visit 1, 5/1999.
(This platform lies in the central region. Max depth at the platform is 209 m. Blanks = no data.)

Common Name	**Scientific Name**	***0-10***	***10-20***	***20-30***	***30-40***	***40-50***	***50-60***	***60-70***	***70-80***	***80-210***	***Total***	***% Composition***
Atlantic creolefish	*Paranthias furcifer*	1	10	132	234	**341**	136	71	0		**925**	**75.1%**
Almaco Jack	*Seriola rivoliana*	0	0	1	21	**65**	11	21	3		**122**	**9.9%**
Blue Runner	*Caranx crysos*	9	**46**	0	0	0	0	0	0		**55**	**4.5%**
Bermuda Chub	*Kyphosus sectatrix*	**36**	0	0	0	0	0	0	0		**36**	**2.9%**
Greater Amberjack	*Seriola dumerili*	**9**	7	6	5	4	2	0	0		**33**	**2.7%**
Other												*4.9%*
Great Barracuda	*Sphyraena barracuda*	**21**	10	1	0	0	0	0	0		**32**	**2.6%**
Bar Jack	*Caranx ruber*	0	**10**	2	0	0	0	0	0		**12**	**1.0%**
Gray Triggerfish	*Balistes capriscus*	0	0	0	**4**	1	0	0	0		**5**	**0.4%**
Queen Angelfish	*Holacanthus ciliaris*	2	**3**	0	0	0	0	0	0		**5**	**0.4%**
Lesser Amberjack	*Seriola fasciata*	0	0	0	0	**3**	0	0	0		**3**	**0.2%**
Scamp	*Mycteroperca phenax*	0	0	0	0	0	0	**2**	1		**3**	**0.2%**
Total		**78**	**86**	**142**	**264**	**414**	**149**	**94**	**4**		**1231**	100.0%

Table 21

Number of Fishes by Species Observed during ROV Video Surveys by Depth at GB 236, Visit 2, 2/2000.
(This platform lies in the central region. Max depth at the platform is 209 m. Blanks = no data.)

Common Name	***Scientific Name***	***0-10***	***10-20***	***20-30***	***30-40***	***40-50***	***50-60***	***60-70***	***70-80***	***80-90***	***90-100***	***100-110***	***110-210***	***Totals***	***% Composition***
Blue runner	*Caranx crysos*	48	0	22	45	0	**169**	0	0	0	0	0	0	**284**	**23.0%**
Bermuda chub	*Kyphosus sectatrix*	**224**	0	0	0	0	0	0	0	0	0	0	0	**224**	**18.1%**
Greater amberjack	*Seriola dumerili*	5	4	15	2	2	19	**44**	23	10	15	11	13	**163**	**13.2%**
Almaco jack	*Seriola rivoliana*	0	12	**48**	0	6	**48**	39	0	7	0	0	0	**160**	**12.9%**
Atlantic creolefish	*Paranthias furcifer*	0	9	0	0	0	0	**47**	30	24	4	0	0	**114**	**9.2%**
Scamp	*Mycteroperca phenax*	0	0	0	0	2	5	8	**22**	7	7	0	3	**54**	**4.4%**
Horse-eye jack	*Caranx latus*	0	**37**	0	0	0	0	0	0	0	0	0	0	**37**	**3.0%**
Queen angelfish	*Holacanthus ciliaris*	0	2	0	3	3	**8**	6	4	3	4	0	0	**33**	**2.7%**
Blue angelfish	*Holacanthus bermudensis*	0	0	0	1	0	0	0	3	11	9	4	0	**28**	**2.3%**
Great barracuda	*Sphyraena barracuda*	0	8	1	**9**	5	2	1	0	0	0	0	0	**26**	**2.1%**
Gag	*Mycteroperca microlepis*	0	0	0	3	**9**	2	1	4	2	1	0	3	**25**	**2.0%**
Sheepshead	*Archosargus probatocephalus*	0	0	0	6	**15**	0	0	0	0	0	3	0	**24**	**1.9%**
Rock hind	*Epinephelus adscensionis*	0	0	0	0	2	5	1	**6**	2	1	0	0	**17**	**1.4%**
Other													0		*5.2%*
Black jack	*Caranx lugubris*	2	0	**11**	0	0	0	0	0	0	0	0	0	**13**	**1.1%**
French angelfish	*Pomacanthus paru*	0	0	0	0	0	1	2	2	**3**	1	0	0	**9**	**0.7%**
Spanish hogfish	*Bodianus rufus*	0	0	0	0	0	**9**	0	0	0	0	0	0	**9**	**0.7%**
Gray triggerfish	*Balistes capriscus*	0	0	0	0	0	0	1	**3**	2	0	0	0	**6**	**0.5%**
Blue tang	*Acanthurus coeruleus*	0	0	0	1	**2**	**2**	0	0	0	0	0	0	**5**	**0.4%**
Dog snapper	*Lutjanus jocu*	0	0	0	0	**2**	0	0	0	0	0	0	0	**2**	**0.2%**
Bar jack	*Caranx ruber*	0	0	0	**1**	0	0	0	0	0	0	0	0	**1**	**0.1%**
Filefishes	Balistidae	0	0	0	0	0	0	0	**1**	0	0	0	0	**1**	**0.1%**
Gray snapper	*Lutjanus griseus*	0	0	0	**1**	0	0	0	0	0	0	0	0	**1**	**0.1%**
Total		**279**	**72**	**97**	**72**	**48**	**270**	**150**	**98**	**71**	**42**	**18**	**19**	**1236**	**100.0%**

Table 22

Number of Fishes by Species Observed during ROV Video Surveys by Depth at VR 279, Visit 1, 6/2003.
(This platform lies in the central region. Max depth at the platform is 55 m. Blanks = no data.)

Common Name	**Scientific Name**	***0-10***	***10-20***	***20-30***	***30-40***	***40-50***	***50-60***	***Total***	***% Composition***
Blue runner	*Caranx crysos*	28	**1240**	760	0	0	0	**2028**	**90.6%**
Red snapper	*Lutjanus campechanus*	0	3	**27**	**27**	0	10	**67**	**3.0%**
Almaco jack	*Seriola rivoliana*	0	7	**28**	8	0	0	**43**	**1.9%**
Other									*4.5%*
Gray triggerfish	*Balistes capriscus*	0	11	**13**	7	0	0	**31**	**1.4%**
Greater amberjack	*Seriola dumerili*	0	0	8	**9**	0	0	**17**	**0.8%**
Vermilion snapper	*Rhomboplites aurorubens*	0	**14**	1	0	0	0	**15**	**0.7%**
Bermuda chub	*Kyphosus sectatrix*	0	**9**	2	0	0	0	**11**	**0.5%**
Crevalle jack	*Caranx hippos*	0	**11**	0	0	0	0	**11**	**0.5%**
Gray snapper	*Lutjanus griseus*	0	1	**5**	0	0	1	**7**	**0.3%**
Atlantic creolefish	*Paranthias furcifer*	0	0	**5**	0	0	0	**5**	**0.2%**
Black drum	*Pogonias cromis*	0	0	0	0	0	**1**	**1**	**0.0%**
Ocean triggerfish	*Canthidermis sufflamen*	0	0	**1**	0	0	0	**1**	**0.0%**
Snowy grouper	*Epinephelus niveatus*	0	0	0	**1**	0	0	**1**	**0.0%**
Total		**28**	**1296**	**850**	**52**	0	**12**	**2238**	**100.0%**

Table 23

Number of Fishes by Species Observed during ROV Video Surveys by Depth at MI 703, Visit 1, 10/2002.
(This platform lies in the western region. Max depth at the platform is 39 m. Blanks = no data.)

Common Name	Scientific Name	*0-10*	*10-20*	*20-30*	*30-40*	*Total*	*% Composition*
Blue runner	*Caranx crysos*	0	**45**	0	3	**48**	**26.7%**
Gray snapper	*Lutjanus griseus*	0	0	2	**40**	**42**	**23.3%**
Lookdown	*Selene vomer*	0	0	0	**35**	**35**	**19.4%**
Great barracuda	*Sphyraena barracuda*	5	9	0	0	**14**	**7.8%**
Red snapper	*Lutjanus campechanus*	0	0	4	**5**	**9**	**5.0%**
Sheepshead	*Archosargus probatocephalus*	2	2	**3**	2	**9**	**5.0%**
Bermuda chub	*Kyphosus sectatrix*	**8**	0	0	0	**8**	**4.4%**
Lane snapper	*Lutjanus synagris*	0	0	0	**6**	**6**	**3.3%**
Other							*5.0%*
Atlantic spadefish	*Chaetodipterus faber*	**3**	0	0	0	**3**	**1.7%**
Gag	*Mycteroperca microlepis*	0	0	0	**3**	**3**	**1.7%**
Gray triggerfish	*Balistes capriscus*	1	0	0	1	**2**	**1.1%**
Rock hind	*Epinephelus adscensionis*	0	0	**1**	0	**1**	**0.6%**
Total		**19**	**56**	**10**	**95**	**180**	**100.0%**

Table 24

Number of Fishes by Species Observed during ROV Video Surveys by Depth at MU 787, Visit 1, 10/2002.
(This platform lies in the western region. Max depth at the platform is 46 m. Blanks = no data.)

Common Name	**Scientific Name**	***0-10***	***10-20***	***20-30***	***30-40***	***40-50***	***Total***	***% Compostion***
Blue Runner	*Caranx crysos*	0	3	**144**	0	0	147	**20.9%**
Creole-fish	*Paranthias furcifer*	35	**92**	0	0	0	127	**18.1%**
Lookdown	*Selene vomer*	0	0	**107**	0	0	107	**15.2%**
Red Snapper	*Lutjanus campechanus*	1	0	1	27	**53**	82	**11.7%**
Gray Snapper	*Lutjanus griseus*	0	2	0	**31**	26	59	**8.4%**
Great Barracuda	*Sphyraena barracuda*	**16**	14	7	0	0	37	**5.3%**
Atlantic Spadefish	*Chaetodipterus faber*	0	0	0	**28**	5	33	**4.7%**
Greater Amberjack	*Seriola dumerili*	0	0	0	2	**13**	15	**2.1%**
Remoras	Echeneidae	**15**	0	0	0	0	15	**2.1%**
Rock Hind	*Epinephelus adscensionis*	3	**5**	3	0	2	13	**1.9%**
Bar Jack	*Caranx ruber*	**12**	0	0	0	0	12	**1.7%**
Spanish Hogfish	*Bodianus rufus*	4	**7**	0	0	0	11	**1.6%**
Cobia	*Rachycentron canadum*	**9**	0	0	0	0	9	**1.3%**
Others								5.0%
Scamp	*Mycteroperca phenax*	3	0	**5**	0	0	8	**1.1%**
Gray Triggerfish	*Balistes capriscus*	3	1	0	**4**	0	8	**1.1%**
Sheepshead	*Archosargus probatocephalus*	**5**	0	0	0	1	6	**0.9%**
Bermuda Chub	*Kyphosus sectatrix*	**4**	0	0	0	0	4	**0.6%**
Gag	*Mycteroperca microlepis*	0	0	0	0	**4**	4	**0.6%**
French Angelfish	*Pomacanthus paru*	0	0	0	**2**	0	2	**0.3%**
Blue Angelfish	*Holacanthus bermudensis*	**1**	0	0	0	0	1	**0.1%**
Crevalle Jack	*Caranx hippos*	0	0	0	0	**1**	1	**0.1%**
Sharks		**1**	0	0	0	0	1	**0.1%**
Total		**112**	**124**	**267**	**94**	**105**	**702**	**100%**

3.5 Sonnier Bank

The Sonnier Bank mobile survey was conducted during the summer of 2003 on board the R/V Spree. Acoustic transects closely matched the intended transects (Figure 23). Based on our survey design and the additional bathymetry data from the higher resolution survey of the low-relief pinnacles and high-relief pinnacles areas, we were able to conduct an analysis of the whole Sonnier Bank as well as a targeted analysis of the low and high-relief features, and further compare these results to those for a nearby standing platform. The high-relief pinnacle feature is a natural geological formation that resembles the high vertical profile of platforms; allowing a more detailed comparison of the relative importance of natural vs. artificial reefs for fish habitat.

The low-relief feature was characterized by one oval shaped mound 300 m by 600 m and rising approximately 13 m up from the bottom. Two tall pinnacles, each rising to within 20 m of the surface, characterized the pinnacle region and several smaller pinnacles located around the tall features. The tall pinnacles bear a resemblance in size and steepness to standing platforms or partially removed platforms used as artificial reefs. The low-relief mound is similar in extent and vertical profile to platforms that have been toppled onto the side for artificial reefs (Figure 3).

For data analysis, we examined the effects of water depth, quadrant (relative region within each sample area), and proximity to areas of vertical relief on acoustic fish biomass and acoustic size of targets.

3.5.1 Broad-Scale Survey Results of Sonnier Bank

As found in the platform surveys, acoustic biomass measured during the broad-scale survey of Sonnier Bank varied significantly with depth, proximity to areas of vertical relief, and the interaction of the two variables above (Split plot ANOVA $P<0.0001$). Low acoustic biomass was found in deep waters and also in waters distant from any features with vertical relief. Much higher biomass was found over both low and high-relief features. Detailed sampling of these areas was able to provide more accurate biomass estimates over these features compared to the broad scale survey results.

For the purpose of analysis of the low and high-relief pinnacle areas, a sample unit consisted of two linear meters of hydroacoustic data broken out into 10 m depth strata from 5 m below the surface to within 0.5m of the bottom.

3.5.2 Low-Relief Pinnacle Area of Sonnier Bank

Based on visual observations of the acoustic data, we noticed that there were more numerous acoustic targets over and around the low-relief feature as well as in the Northwest region of the sampling area. Consequently, we examined the effects of water depth, quadrant (relative region within each sample area), and proximity to the low-relief feature on acoustic fish biomass and acoustic size of targets. Water depth, quadrant, and proximity to the low-relief feature were all significant in the volume backscatter model as was the interaction of feature within region (Table 24).

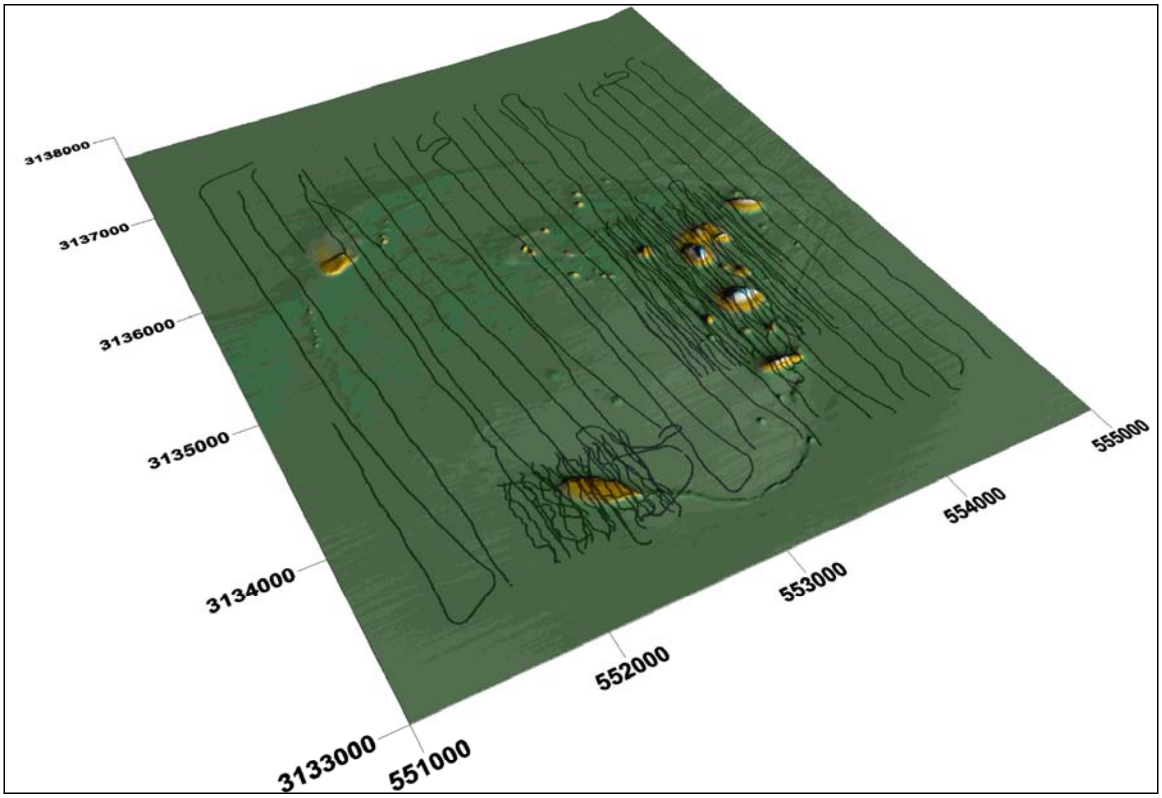

Figure 23. Actual survey track lines for hydroacoustic survey conducted in May 2003 of Sonnier Bank projected over bathymetry.

Table 25

Results of Split Plot Design Analysis of Variance Showing the Effect of Depth (in 10 m Strata), Feature (Low or High-Relief Feature), and Quadrant (General Quadant in Sample Area) on the Dependent Variable Sv for Horizontal Hydroacoustic Data.

Type 3 Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
Depth	5	15	14.51	<.0001
feature	1	42E3	64.01	<.0001
Quadrant	3	15	377.85	<.0001
region(feature)	3	42E3	213.14	<.0001

Acoustic fish biomass varied with depth in the low-relief survey area; biomass was highest in waters greater than 30 m and lowest at the surface (Figure 24). Fish biomass was significantly higher in the northwest and northeast quadrants and lower in the southwest and southeast quadrants (Figure 25). Mean volume backscatter was higher immediately over the low-relief feature (-72 dB) than away from it (-74 dB).

Target strength varied with water depth and quadrant (Split plot ANOVA $p<0.0001$), but there was no difference in target strength associated with the low-relief feature. Target strength was higher near the bottom and lowest near the surface (Figure 26).

Fish density was highly variable over the survey area, but in general followed the pattern observed in volume backscatter. Fish density varied significantly with water depth, quadrant, and proximity to the low-relief feature. Fish density ranged from zero to over two fish per cubic meter. Fish density was highest in the 20 m stratum and dropped off to less than 0.001 fish per cubic meter near the bottom (Figure 27).

3.5.3 High-Relief Pinnacle Area of Sonnier Bank

The acoustic survey of the high-relief features in the Sonnier Bank area produced results that were similar to the low-relief area; however, the general magnitude of acoustic biomass estimates and densities were lower. Water depth, quadrant, and proximity to the high-relief features were all significant in the volume backscatter model as was the interaction of feature within quadrant. Mean volume backscatter was higher near the bottom and lowest at the surface in the high-relief pinnacle survey area (Figure 28). Mean volume backscatter over the high-relief pinnacles was -80.5 dB compared to -83 dB away from the pinnacle. Target strength data from the high-relief pinnacle area were fairly consistent averaging from -40 to -43 dB and exhibited a positive trend with increasing depth where targets were smaller near the surface and largest near the bottom (Figure 29).

Fish density data varied significantly with water depth and region. Estimated fish densities were highest in the 20 m strata and lowest near the bottom (Figure 30).

3.5.4 Species Composition

An ROV survey was conducted at both the small relief and high-relief pinnacle areas. The ROV was flown around, over, and away from geological features in each of the sampling areas. The resultant species composition data are shown in Tables 25 and 26. The high-relief pinnacle region was clearly dominated by Atlantic creolefish and Bermuda chub (planktivores), whereas Atlantic creolefish, vermillion snapper, and red snapper (planktivores and carnivores) were dominant and equally abundant at the low-relief feature.

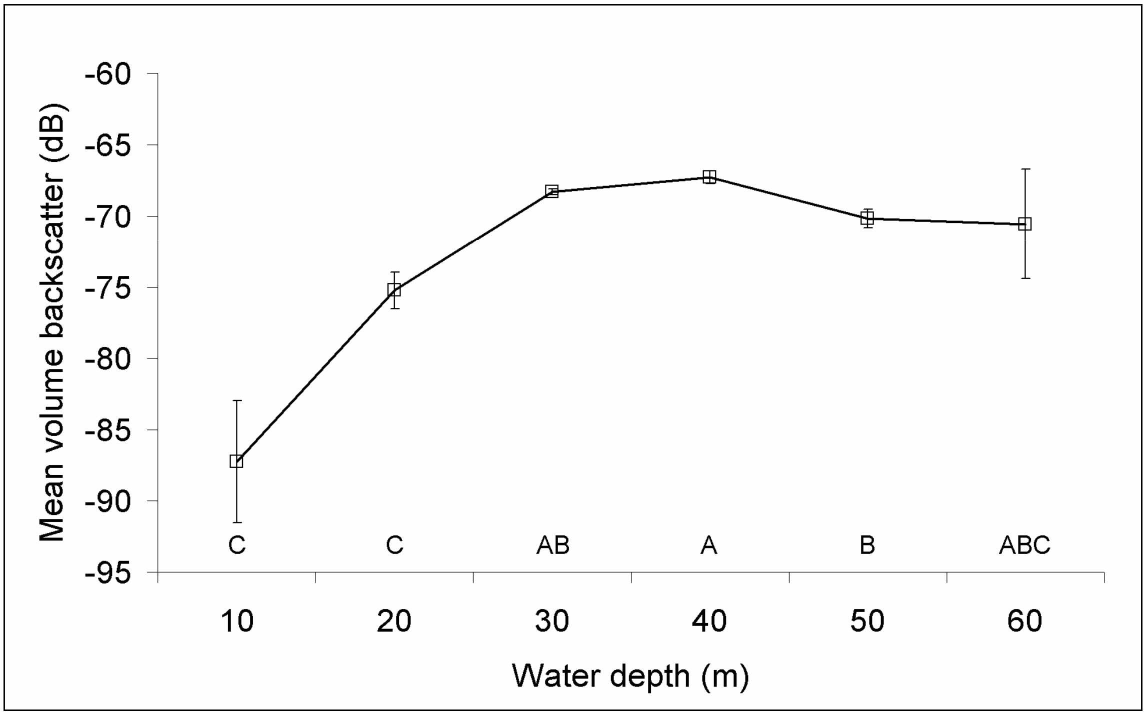

Figure 24. LS mean volume backscatter (Sv in dB ± 1 SE) at depth (m) for the small feature at Sonnier Bank, northern Gulf of Mexico. Means with same letters are not significantly different at $\alpha = 0.005$.

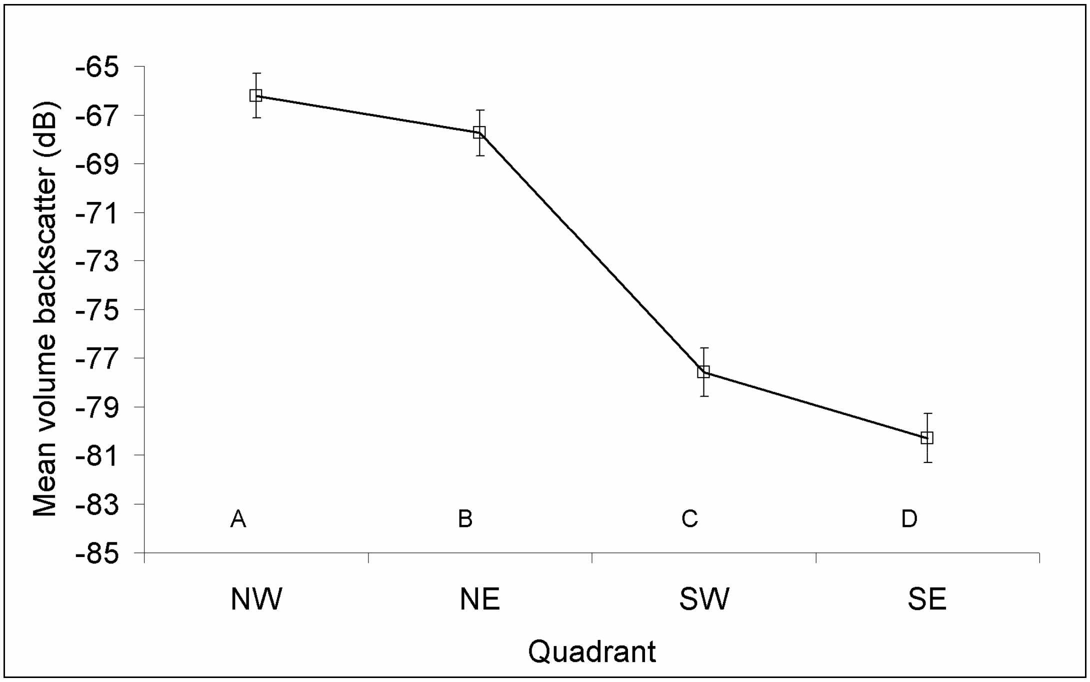

Figure 25. LS mean volume backscatter (Sv in dB ± 1 SE) at directional quadrant for the small feature at Sonnier Bank, northern Gulf of Mexico. Means with same letters are not significantly different at $\alpha = 0.005$.

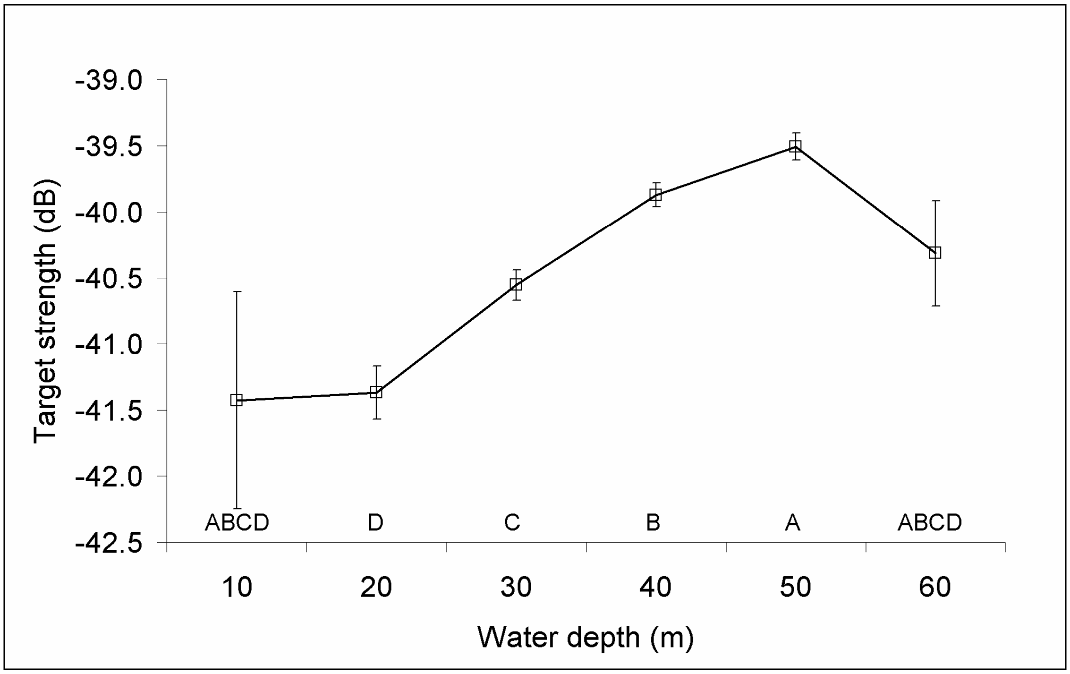

Figure 26. LS mean target strength (dB ± 1 SE) at depth (m) for the small feature at Sonnier Bank, northern Gulf of Mexico. Means with same letters are not significantly different at α= 0.005.

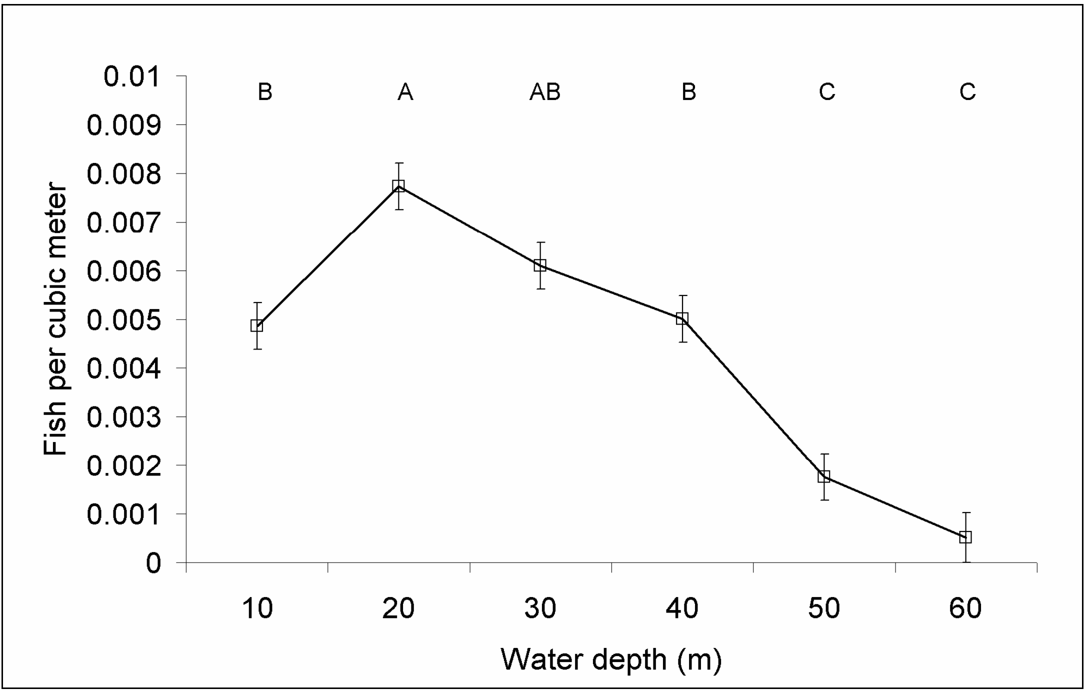

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Figure 27. LS mean density (fish per cubic meter) at depth (m) for the small feature at Sonnier Bank, northern Gulf of Mexico. Means with same letters are not significantly different at α= 0.005.

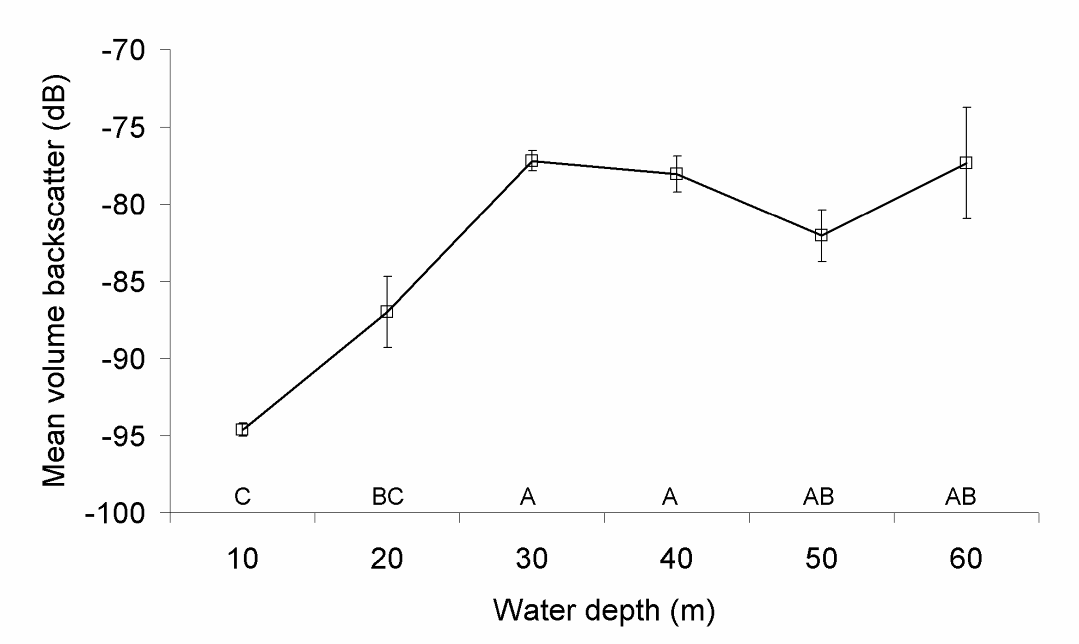

Figure 28. LS mean volume backscatter (Sv in dB ± 1 SE) at depth (m) for the pinnacle feature at Sonnier Bank, northern Gulf of Mexico. Means with same letters are not significantly different at α= 0.005.

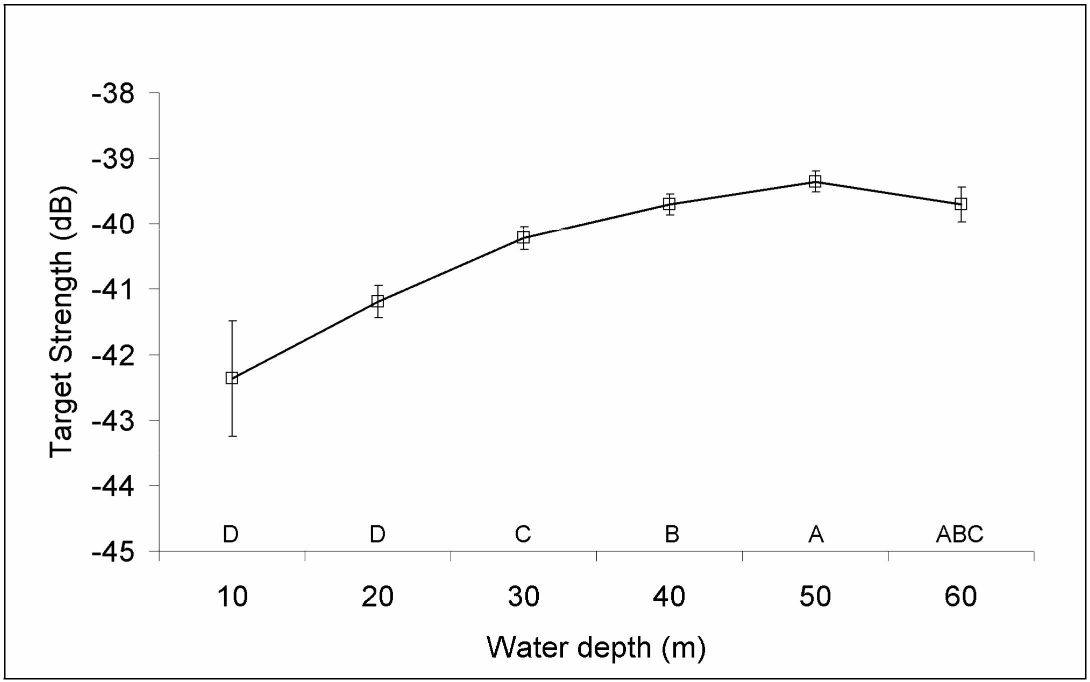

Figure 29. LS mean target strength (dB ± 1 SE) at depth (m) for the pinnacle feature at Sonnier Bank, northern Gulf of Mexico. Means with same letters are not significantly different at α= 0.005.

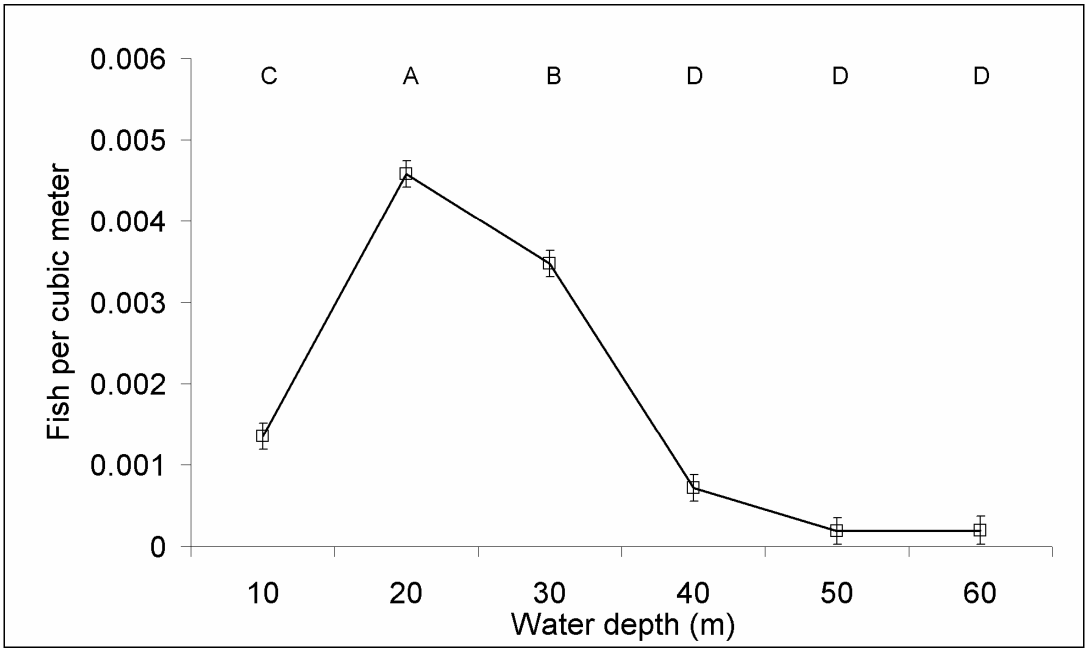

Figure 30. LS mean density (fish per cubic meter) at depth (m) for the pinnacle feature at Sonnier Bank, northern Gulf of Mexico. Means with same letters are not significantly different at α= 0.005.

Table 26

Number of Fishes by Species Observed during ROV Video Surveys by Depth at Sonnier Bank Low-Relief Feature, 5/2002.
(Blanks = no data.)

Common Name	Scientific Name	0-10	10-20	20-30	30-40	40-50	50-60	Total	% Composition
Atlantic creolefish	*Paranthias furcifer*	0	0	0	0	0	**57**	**57**	**31.5%**
Red snapper	*Lutjanus campechanus*	0	0	0	0	0	**38**	**38**	**21.0%**
Vermilion snapper	*Rhomboplites aurorubens*	0	0	0	0	0	**37**	**37**	**20.4%**
Little tunny	*Euthynnus alletteratus*	0	0	**23**	0	0	0	**23**	**12.7%**
Gray triggerfish	*Balistes capriscus*	0	0	2	2	0	**6**	**10**	**5.5%**
Spanish hogfish	*Bodianus rufus*	0	0	0	0	0	**7**	**7**	**3.9%**
Other									*5.0%*
Scamp	*Mycteroperca phenax*	0	0	0	0	0	**3**	**3**	**1.7%**
Queen angelfish	*Holacanthus ciliaris*	0	0	0	0	0	3	**3**	**1.7%**
Gray snapper	*Lutjanus griseus*	0	0	0	0	**2**	0	**2**	**1.1%**
Almaco jack	*Seriola rivoliana*	0	0	0	0	0	**1**	**1**	**0.6%**
Total		**0**	**0**	**25**	**2**	**2**	**152**	**181**	**100.0%**

Table 27

Number of Fishes by Species Observed during ROV Video Surveys by Depth at Sonnier Bank Pinnacle Feature, 5/2002.
(Blanks = no data.)

Common Name	**Scientific Name**	***0-10***	***10-20***	***20-30***	***30-40***	***40-50***	***50-60***	***Total***	***% Composition***
Atlantic creolefish	*Paranthias furcifer*	0	618	**1291**	66	0	0	**1975**	**78.4%**
Bermuda chub	*Kyphosus sectatrix*	**295**	0	0	0	0	0	**295**	**11.7%**
Vermilion snapper	*Rhomboplites aurorubens*	0	0	0	0	**215**	0	**215**	**8.5%**
Other									*9.9%*
Blue angelfish	*Holacanthus bermudensis*	0	0	2	0	0	**6**	**8**	**0.3%**
Gray triggerfish	*Balistes capriscus*	0	**3**	1	0	**3**	0	**7**	**0.3%**
Greater amberjack	*Seriola dumerili*	0	2	**3**	2	0	0	**7**	**0.3%**
French angelfish	*Pomacanthus paru*	0	0	**4**	0	2	0	**6**	**0.2%**
Queen angelfish	*Holacanthus ciliaris*	0	0	**3**	0	0	0	**3**	**0.1%**
Spanish hogfish	*Bodianus rufus*	0	0	0	0	0	**3**	**3**	**0.1%**
Almaco jack	*Seriola rivoliana*	0	0	0	0	0	**1**	**1**	**0.0%**
Cobia	*Rachycentron canadum*	0	0	**1**	0	0	0	**1**	**0.0%**
Total		**295**	**623**	**1304**	**68**	**220**	**10**	**2520**	**100.0%**

3.6 Comparison of Sonnier Bank High-Relief Pinnacle Area and VR 279

Sonnier Bank is located approximately 10 km to the southeast of the platform situated at VR 279. Maximum depth at both localities is 70 m, although we were only able to resolve the data for the upper 60 m of the water column. A comparison of biomass at the two high-relief features (Sonnier Bank pinnacle and VR279) showed inverse trends: at VR 279, mean biomass decreased with depth, while mean biomass at the Sonnier Bank pinnacle increased with depth (Figure 31, 34). LS means biomass was substantially lower at all depths at Sonnier Bank compared to VR 279 (Figure 34). Mean target strength increased marginally with increasing depth at both sites, but the higher values at VR 279 (Figure 32, 35) indicated that fishes associated with the platform are also generally larger than those at the pinnacle. Fish densities in the upper 20 m of the water column at VR 279 (Figure 33) were vastly higher than those found at the pinnacle (Figure 37). Densities of fishes at both sites were similarly low at depths of or below 30 m. The composition of fish functional groups found at VR 279 and the pinnacle feature were quite similar (Figure 38), being heavily dominated by planktivores. The dominant planktivorous species at the features were, however, quite different. Blue runners dominated at VR 279 while Atlantic creolefish dominated at the pinnacle feature. At the low-relief feature, carnivores were the dominant functional group followed by planktivores and a number of grazers.

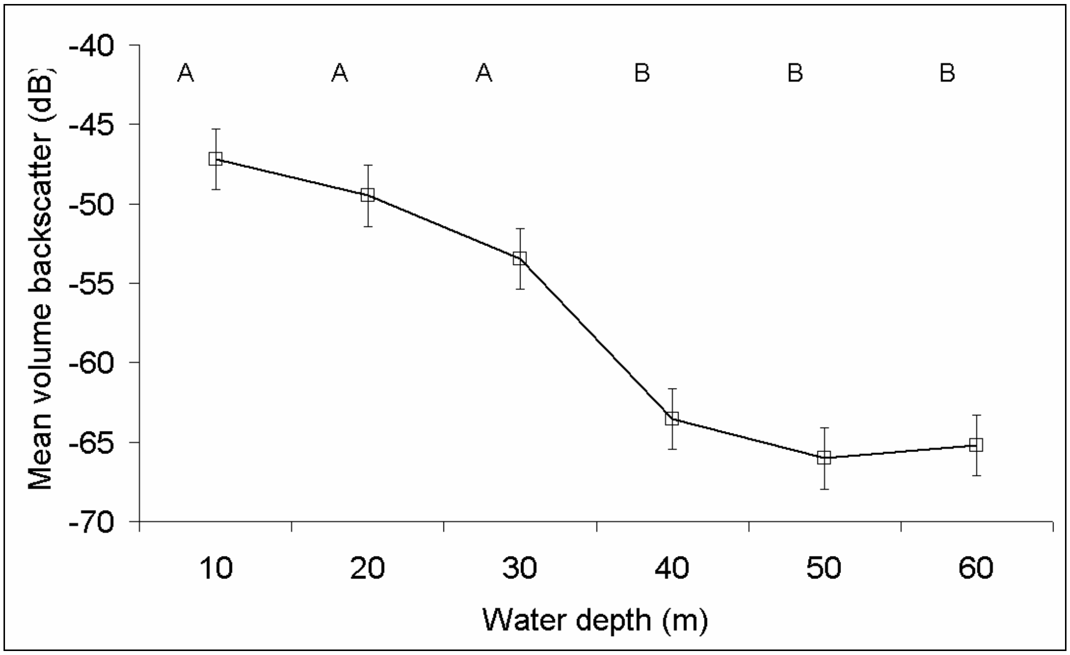

Figure 31. LS mean volume backscatter (SV in dB ± 1 SE) at depth (m) at VR 279, northern Gulf of Mexico. Means with same letters are not significantly different at $\alpha = 0.005$.

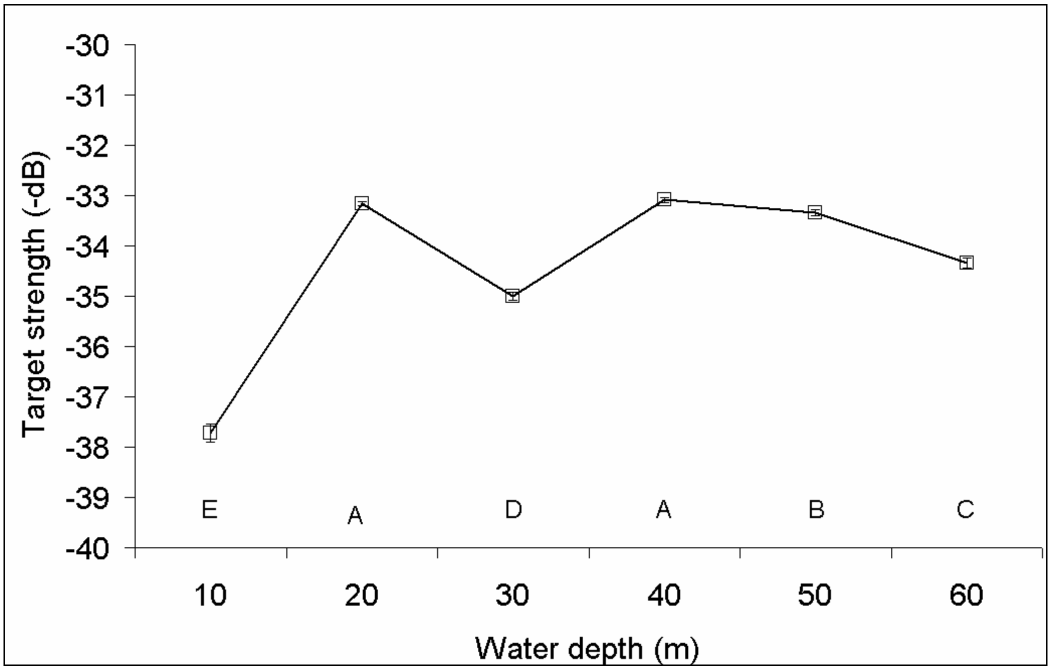

Figure 32. LS mean target strength (dB ± 1 SE) at depth (m) at VR 279, northern Gulf of Mexico. Means with same letters are not significantly different at $\alpha = 0.005$.

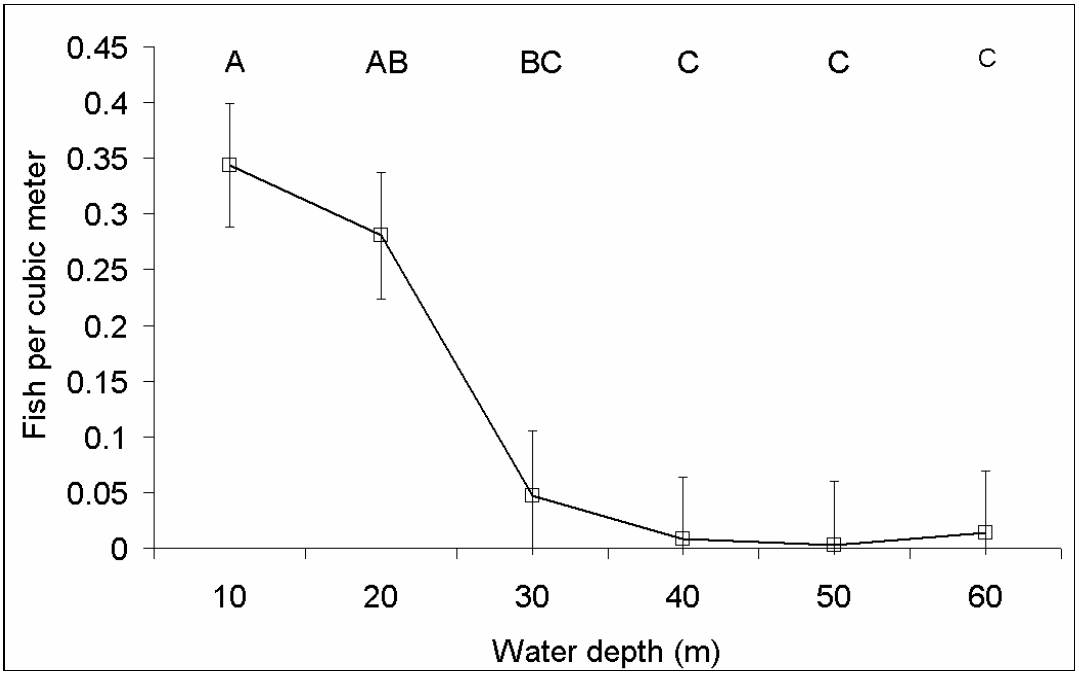

Figure 33. LS mean density (fish per cubic meter) at depth (m) at VR 279, northern Gulf of Mexico. Means with same letters are not significantly different at α= 0.005.

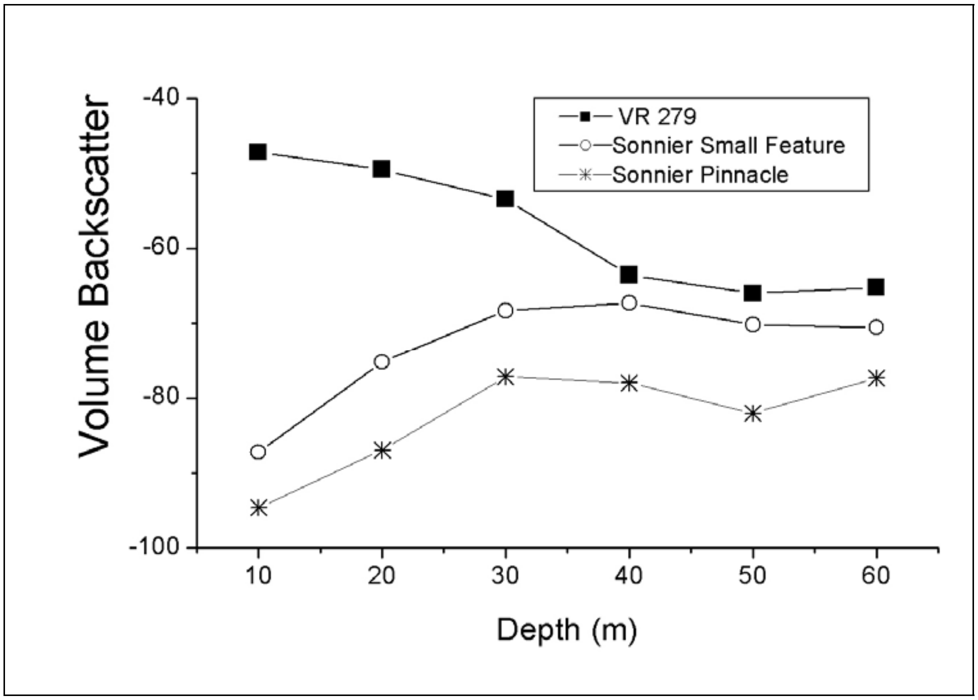

Figure 34. LS mean Volume backscatter (Sv) at the standing platform (VR279) compared to Sv at the small feature and pinnacle feature at Sonnier Bank.

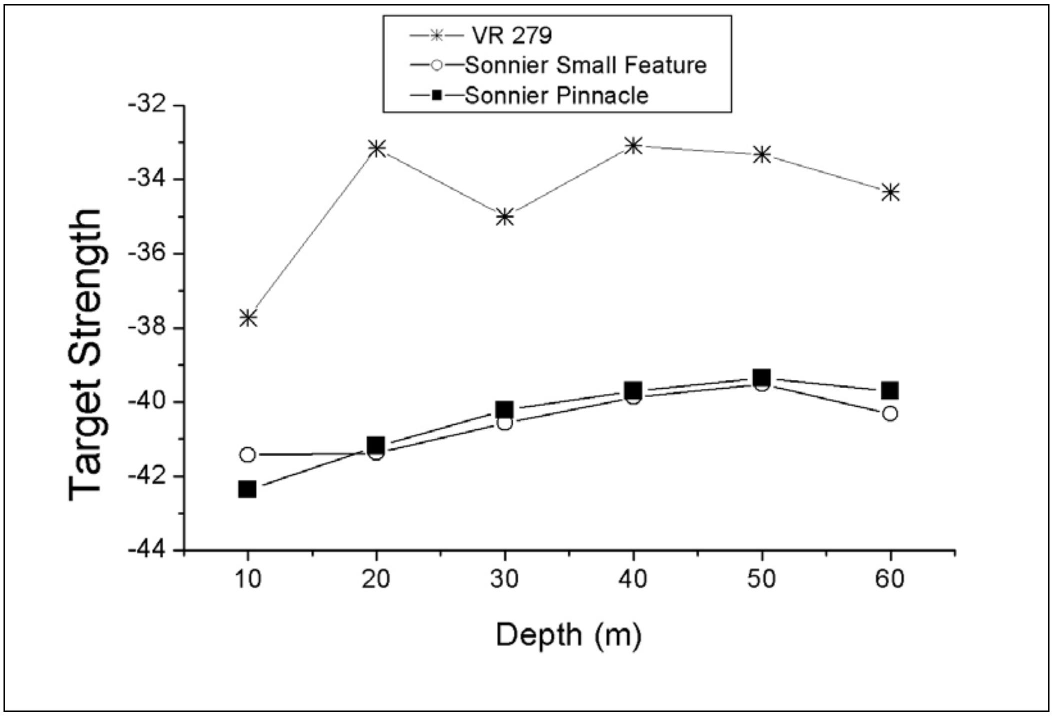

Figure 35. LS mean Target Strength (TS) at the standing platform (VR279) compared to TS at the small feature and pinnacle feature at Sonnier Bank.

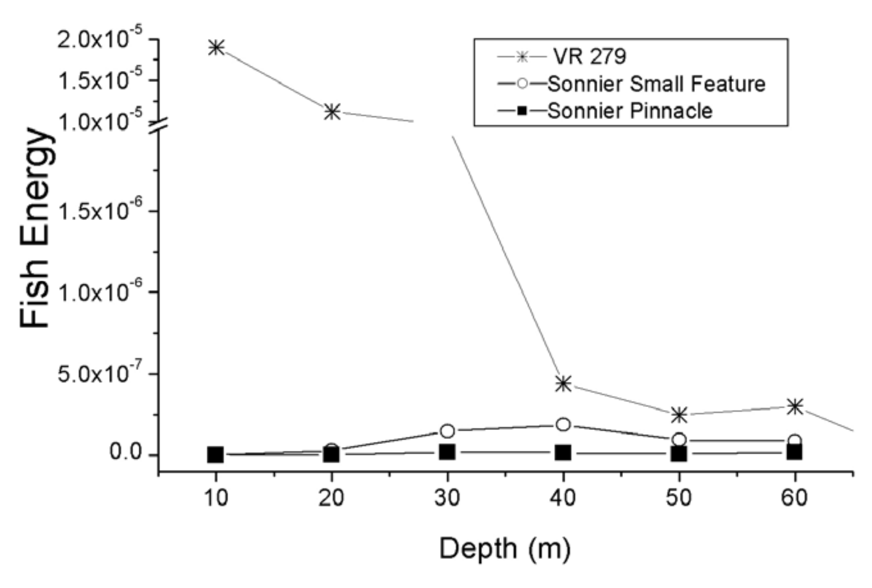

Figure 36. Fish Energy at the standing platform (VR279) compared to Sv at the small feature and pinnacle feature at Sonnier Bank.

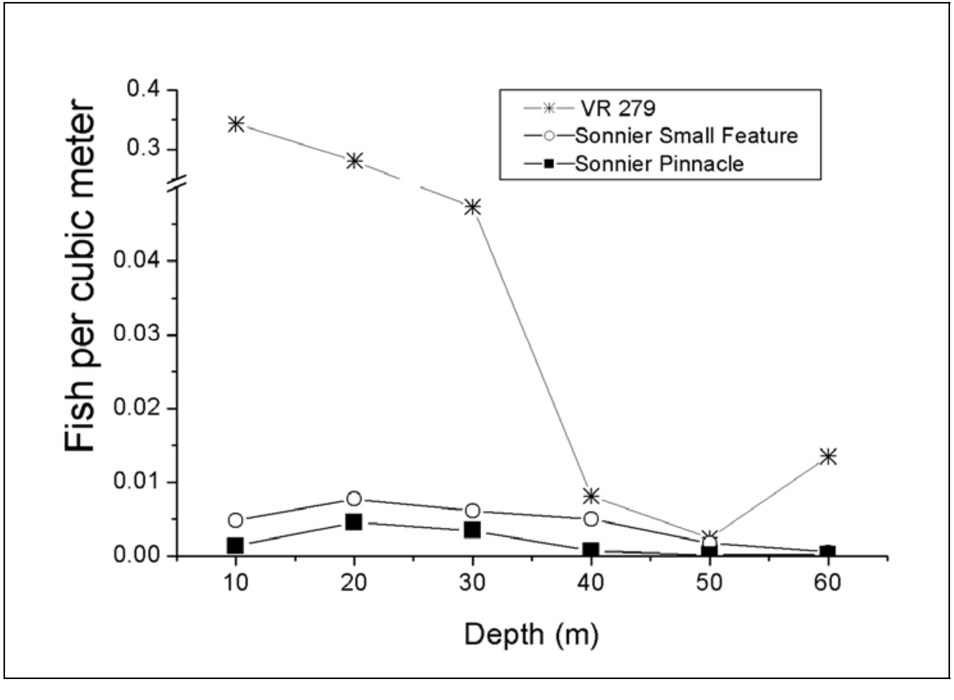

Figure 37. Fish Density at the standing platform (VR279) compared to Sv at the small feature and pinnacle feature at Sonnier Bank.

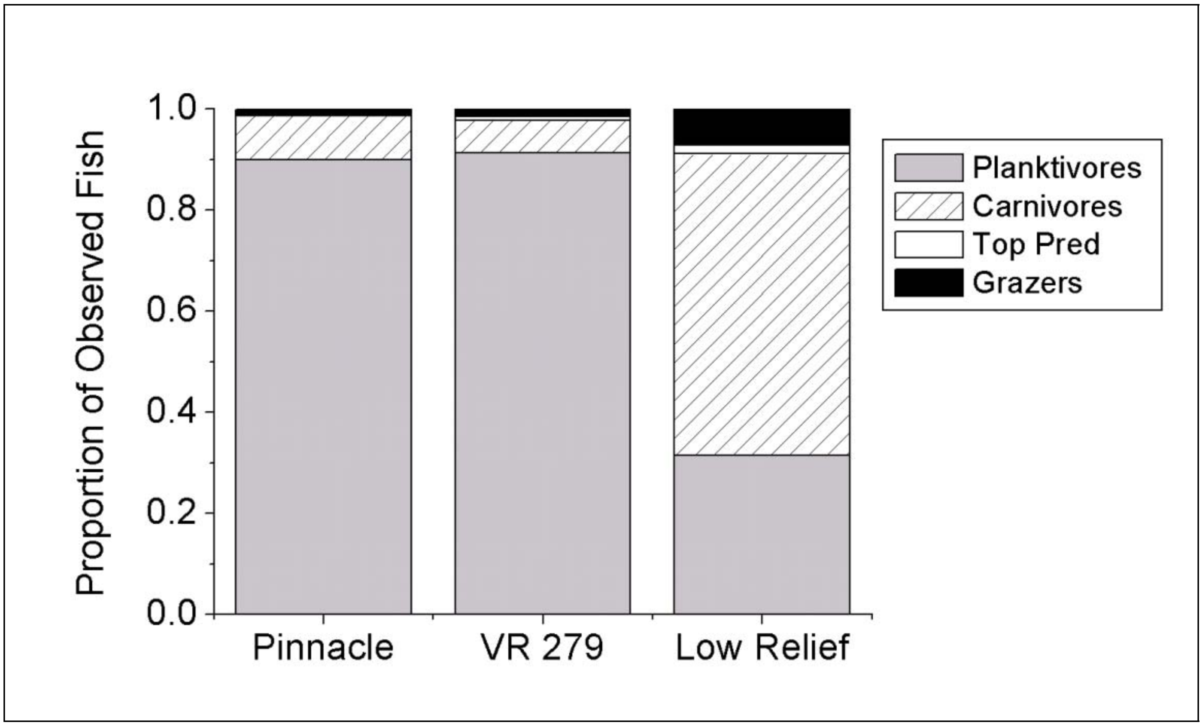

Figure 38. Comparison of the proportion of each fish functional group found at Sonnier Pinnacle, Sonnier low-relief feature, and VR279.

4.0 DISCUSSION

4.1 Technical and Analysis Logistics

This project, intended to last three years, has taken seven years to complete. During this extended period of time we experienced significant changes in personnel, technology for data collection, data processing, and data analysis. Through the course of the project, several of the cooperating oil and gas companies merged, leading to changes in our internal industry contacts and offshore field personnel. A lightning strike during the first year of the project crippled data collection as it destroyed several transducers and cables and they had to be replaced. In the second year poor planning on our part led to the failure of a lift strap for moving our gear from a platform to the boat; our offshore box struck the water, split open, and immediately sank to the bottom. Thanks to the generosity of Chevron we recovered the equipment. However we suffered another setback: it took roughly six months to replace the equipment that was damaged by saltwater. One platform was lost to hurricane damage, another was sold and turned into an un-manned facility and another was shutdown permanently before a second visit could be executed. Problems encountered during this study reinforce how complicated it is to work in the marine environment, even when facilitated by access to oil and gas platforms and associated infrastructure.

The current hydroacoustic technology has become very portable, durable, and easy to use. Target discrimination and analysis have also been greatly improved. The greatest advancement we recently encountered was the addition of Echoview processing software. There are a number of features to this new software that greatly enhance our ability to derive useful data from the acoustic returns. For example, Figure 39 illustrates an echogram image from the Sonnier Bank mobile acoustic survey; the software automatically defines the bottom, which is color-coded by bottom hardness, and the blue scale in intensity of the targets above the bottom illustrates target size. The software automatically analyzes those targets between the surface and the identified bottom. The operator can also select a specific area in the echogram for analysis or manually edit out areas of poor data or poorly defined bottom. Figure 40 is an echogram of an area of Sonnier Bank where we encountered numerous gas seeps. We edited these bad data regions to exclude them from the final analysis.

No standard method has been either prescribed or endorsed for analysis of hydroacoustic data. An obvious advantage of this is the ability both to tailor analyses to answer a specific question and to allow for analytical improvements as technology and research advance. The disadvantage, however, is that comparability among projects is reduced. The development of novel analysis techniques has provided significant improvements in processing acoustic data, resulting in a dataset of much higher resolution, but these improvements may also necessitate significant change in our approach to analysis. With Echoview, for example, we can isolate both bad data regions and questionable data from the final analysis (Figure 38). By removing the bad data regions we effectively change the overall sample size in the analysis. The appropriate method for treating observations with different sample sizes is to weight each observation by its respective sample size; therefore the means of those observations are inherently weighted. In previous studies, we have not used the weighted means technique because this option was not available in older analysis software.

When we compared weighted versus non-weighted means, we observed differences in the magnitudes of biomass estimates. The trends observed in the data were, however, consistent regardless of the method used for deriving the mean (weighted or non-weighted). To maintain comparability with previously reported analyses (Wilson and Stanley 1991, Wilson et al. 2003), we chose to analyze the data without weighting for differences in sample size. It is likely that a complete re-analysis of the current dataset using weighted means would provide biomass estimates that are more accurate than those reported here, but the overall trends among sites would not differ from this analysis.

Hydroacoustics is an extremely useful technology for comparing and estimating fish biomass, particularly that biomass associated with specific habitats. However, the users must be cognizant of the limitations of data derived from hydroacoustics. The resultant data should be construed as an estimate of the acoustic biomass; without extensive groundtruthing, those estimates are not precise, but relative. Similarly, estimates of target strength are an average of all the acoustic returns during the sample period in a particular depth stratum. Consequently, when the acoustic biomass is divided by the average target strength to estimate fish density, one must recognize that the error associated with that estimate is fairly large .

4.2 Patterns in Acoustic Variables

The results of this multiyear research project continue to reinforce our earlier conclusions that there is a relatively high fish biomass associated with operating oil and gas platforms when compared to other habitats in the northern Gulf of Mexico. We continue to observe the general trend that fish biomass around platforms is consistently higher than that of the adjacent soft bottom habit from the coastal waters of Louisiana out to the edge of the outer continental shelf (OCS). This general pattern was true along the eastern, central, and western regions.

Unlike previous techniques used to assess fish biomass in specific habitats, hydroacoustics affords us the ability to be very specific in spatial and temporal perspectives. We observed a significant difference in fish biomass across the three regions. Fish biomass per unit area was highest in the central region and lowest along both the eastern and western regions (Figure 6a, 7). The lower sample size along the western region lead, however, to higher variability of this estimate. This higher biomass in the central region is largely due to a very high planktivore abundance. It was interesting to note that a number of variables were not significant in the various models. Several sites had been on location for over 20 years, yet platform age was not significant in statistical models. We also did not observe a statistical effect of number of legs, or number of conductor guides, although these variables were confounded by platform identity and depth.

We continue to find fish around oil and gas platforms vary predictably with platform side, time of day, and especially, depth. Fish biomass is highest near the surface waters and declines with increased water depth. At water depths greater than 100 m, fish biomass is not statistically different from zero (Figure 6b). This continues to reinforce the fishery value of platforms, in particular platforms at water depths less than 50 m. Although several factors were statistically significant, depth consistently explained a large degree of variation in fish biomass, target strength and abundance. Fish biomass was highest at midnight and dawn and lowest at noon (Figure 6d). The fact that fish biomass is highest during the hours of darkness is evidence either that the lights at a platform create a halo effect attracting fishes to the platform or crepuscular fish emerge from within the confines of the platform at night and become acoustically visible. Platform side also significantly affected fish biomass; in the current study fish biomass was consistently and statistically higher on the west side (Figure 6c). Stanley and Wilson (1997, 2000) reported the same observation but offered no explanation.

Our experimental design allowed us to analyze a change in acoustic fish biomass with distance away from the platforms sampled. Our objective was to gain some insight into the "reef effect": how far all way from a platform (artificial reef) is there a measurable effect of the artificial habitat. We found that fish biomass was highest within 20 m of the platforms sampled and that biomass decreased with increased distance. However, we report that the range of influence of platforms over those sampled extends out beyond the 20 m reported by Stanley and Wilson (1997) and is more on the order of 50 m. This may in fact be a visual cue that varies with water clarity.

We also compared target strength, which is an acoustic estimate of fish size. Although the target strengths reported are five minute averages of fish size over 10 m depth range, we did observe some statistical differences worth reporting. Average acoustic fish size varied across regions and was highest in the central region and lowest in the western region (Figure 12a, 13). In fact, targets along the western region averaged 30% smaller than those of the central or eastern regions. Targets along the eastern region were also slightly smaller than target size along the central region. Mean target size varied with the depth and was largest near the bottom and smallest near the surface (Figure 12b). The larger reef associated species tend to be near the bottom as reported by Stanley and Wilson (1997). Mean target size was statistically lower at midnight and greatest at dusk (Figure 12d). The higher biomass and smaller target size at midnight suggests that the smaller, crepuscular organisms were, in fact, emerging from the confines of the platform at night. Mean target size also varied with platform side and targets were largest on the east side and smallest on the north side (Figure 12c); this is an observation we cannot explain.

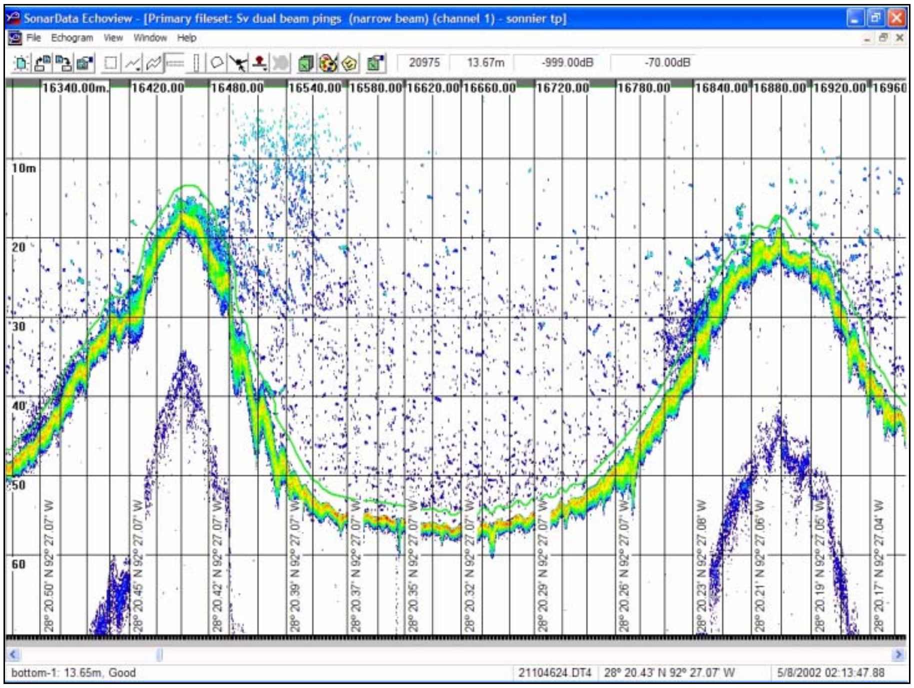

Figure 39. Hydroacoustic echogram of Sonnier Bank pinnacle feature illustrating the high density of fish associated with the two pinnacle features.

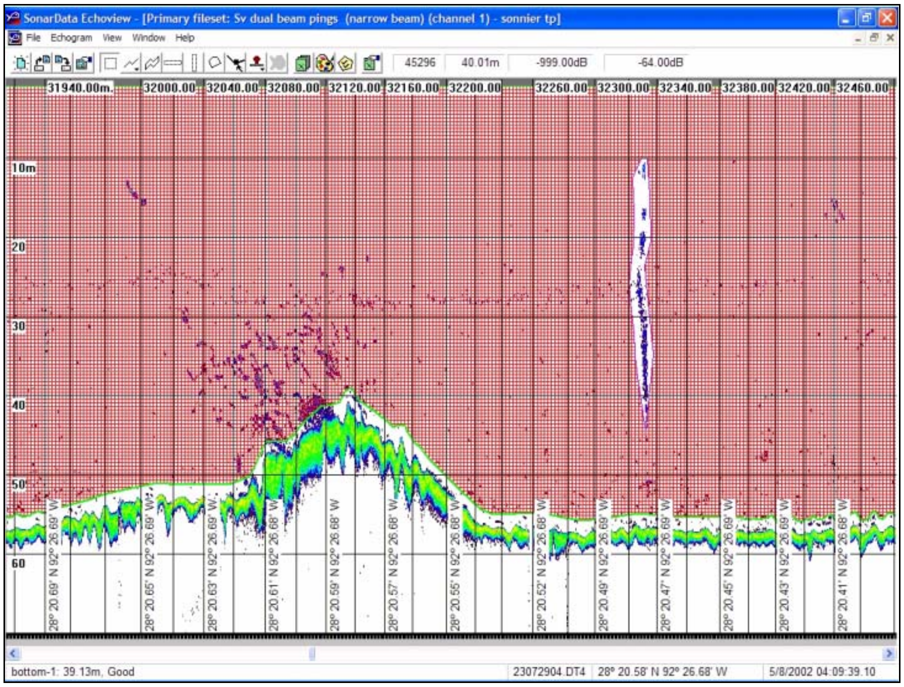

Figure 40. Hydroacoustic echogram of Sonnier Bank small feature illustrating a few acoustic targets associated with the small feature and a natural gas plume. The echogram illustrates how the natural gas and can be eliminated from analysis.

4.3 Patterns in Species Composition

Species richness was higher in the central and western GOM compared to the eastern GOM. This observation may be tied to the proportion of functional groups observed in each of these regions. The fish fauna in the eastern GOM showed a much higher proportion of carnivores and top predators. Platforms in this region are also located very close to edge of the continental shelf and a very steep shelf slope. Open water carnivores and top predators that are not strictly reef-associated species may be opportunistically visiting platforms in this region to take advantage of abundant prey resources. We speculate that this heavy predation pressure may, in fact, restrict the diversity of reef associated prey species that are able to effectively reside at platforms.

The proportions of species (Figures 19-22) in the functional groups delineated in Table 7 show that these groups are differentially distributed across the study area. The westward flow of the nutrient-rich Mississippi River plume likely contributes to the proportional dominance of planktivores in the Central region off southwestern Louisiana (Figure 19). These nutrients support greater primary and secondary production that in turn support larger populations of planktivorous fishes. The East and West regions are comparatively nutrient poor and would be expected to support fewer planktivores. Grazer species (Figure 20) were only abundant at one locality (MP142) and were otherwise confined to those localities both closest to shore and at the shallowest depths. We suspect that the distribution of grazers is largely affected by the inshore distributions of their preferred crustacean and molluscan prey species that may be replaced by other species at greater depths. Carnivorous species (Figure 21) and top predators (Figure 22) show similar patterns in the proportional abundances. Both are proportionally abundant in the East region and show lesser proportions at the deepwater platforms in the Central and West regions. The carnivores include many species targeted by both commercial and recreational fishers, so their numbers may be affected by local fishing pressure. Amberjacks and groupers are obligate deepwater species; thus they would be expected at those platforms at the greatest depths. Barracudas and sharks are less specific in their depth requirements and are to be found in varying numbers at most platforms throughout the study area. Every platform in the northern Gulf may have at least one barracuda that has taken up residence; however, our experience both as scientists and as fishers has shown that barracudas are especially abundant at the platforms at the edge of the OCS.

Red snapper are an important species for both commercial and recreational interests in the northern GOM and as such warrant some special discussion in light of our findings in this study. Of all the habitats included in this study, red snappers were proportionally most dominant at the low-relief feature at Sonnier Bank. This finding is similar to that reported by Wilson et al. (2003) for toppled and partially removed artificial reef structures.

Red snappers were proportionally abundant at several platforms in all three regions of the study area (Figure 41); most of these platforms were at the shallowest depths included in the survey design. Few red snappers were observed at those platforms at the edge of the OCS. The movements of red snapper over their potential 50 year lifespan can help to explain some of the observed distribution. After spending the best part of their first two years in shallow, inshore waters, red snapper begin an offshore migration in search of more suitable, deepwater habitats that might include reefs, lumps, depressions, and wrecks (Nieland and Wilson 2003). In the northern Gulf, these suitable habitats include the many oil and gas platforms that have been sited at moderate depths in the nearshore waters. After a residence at the platforms of perhaps 5-8 years, the red snapper migrate away from the platforms and spend the rest of their lives in a relatively solitary existence at natural or anthropogenic, non-platform structures in deeper waters toward the edge of the OCS (Nieland and Wilson 2003).

4.4 Comparison of Sonnier Bank and a Standing Platform

A mobile hydroacoustic survey has allowed us, for the first time, to compare hydroacoustic biomasses of a natural, high-profile hard bottom feature (Sonnier Bank pinnacle) with that of an adjacent oil and gas platform (VR 279). Although similar in form in many respects, the obvious difference between the Sonnier Bank pinnacle and VR 279 is their respective profiles in the water column: the summit of the Sonnier Bank pinnacle is at a depth of about 20 m while VR 279 spans from the bottom to the surface. Unlike the most of the platforms surveyed to date, including VR 279, acoustic biomass at the Sonnier Bank pinnacle was highest near the bottom and lowest at the surface (Figures 32 and 35). Even though the Sonnier Bank pinnacle rises very high in the water column, biomass near the surface was, still very close to zero. Structure-oriented, epipelagic species, such as blue runner, that were found in abundance at VR 279, were absent from the Sonnier Bank pinnacle.

Although the dominant species differ substantially between the pinnacle and VR 279, the proportion of fish observed in each functional group were remarkably similar. At both locations, the ichthyofauna was overwhelmingly dominated by planktivores. We conclude therefore that, planktivores will dominate fish abundances at a feature given a certain vertical extent. This remains true whether the feature is natural or artificial in nature. This certain vertical extent does *not* however, necessarily translate into higher fish biomass. Fish biomass reported at the pinnacle was, in fact, much lower even than biomass reported at the low-relief feature (Figurer 36, 37).

The low-relief feature at Sonnier Bank held a higher fish biomass per unit area compared to the pinnacle area. We speculate that at least part of this observation can be explained by the spatial configuration of the two areas. The “pinnacle feature” is actually a field of four major high-relief features separated from the nearest high-relief feature by approximately 500 m. Fish in this region were not only tightly clustered around the feature, but were also found dispersed between two features, and may move readily between the pinnacle features (Figure 39). The low-relief feature, is a single, more isolated feature at least 1km distant from the nearest feature having significant relief (Figure 3). Fish may therefore remain more closely associated with the low-relief feature.

The low-relief feature seems to provide a habitat that is most similar in species composition, to toppled or partially removed artificial reefs. The species found at both toppled and partially removed platforms also hold a significant fraction of carnivores and top predators. Wilson et al.

(2003) reported that the most abundance species at a partially removed platform (HIA 355) were greater amberjack, red snapper, almaco jack and Spanish hogfish.

This research continues to support the premise that standing oil and gas platforms do make useful artificial reefs because they support fish densities that can be from 10 to 1000 times greater than the densities found over adjacent sand and mud bottom habitats. Also, fish densities at standing platforms almost always exceed those found both at artificial reefs (both partially removed and toppled) and at natural habitats such as Sonnier Bank. However, the fish species associated with artificial reefs (including standing platforms) differ from those found on natural habitats. Future research efforts might be directed toward determining the reasons for this difference.

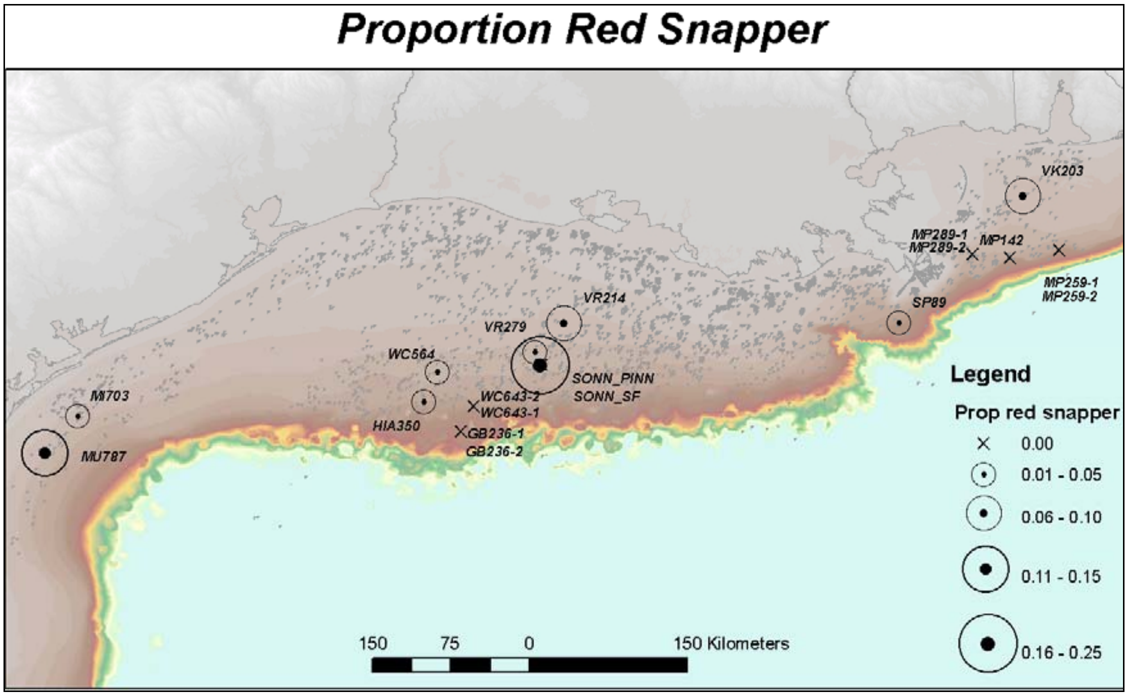

Figure 41. Proportion of red snapper observed at each study platform based on ROV surveys. Note that data from Sonnier Bank (SONN_PINN and SONN_SF) are also included.

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The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

The Minerals Management Service Mission

As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS), collect revenue from the Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the **Offshore Minerals Management Program** administers the OCS competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil and other mineral resources. The MMS **Minerals Revenue Management** meets its responsibilities by ensuring the efficient, timely and accurate collection and disbursement of revenue from mineral leasing and production due to Indian tribes and allottees, States and the U.S. Treasury.

The MMS strives to fulfill its responsibilities through the general guiding principles of: (1) being responsive to the public's concerns and interests by maintaining a dialogue with all potentially affected parties and (2) carrying out its programs with an emphasis on working to enhance the quality of life for all Americans by lending MMS assistance and expertise to economic development and environmental protection.