**Final Report – 10/1/2003-4/31/2004**

# *Characterization of a mid-shelf bank in the northwestern Gulf of Mexico as essential habitat of corals and reef fishes*

**Sponsor Grant No**. NA03NMF4410351

**Submitted by**

Jay R. Rooker[1], Ronald L. Hill[2], Tim Dellapenna[3]

[1]Department of Marine Biology, Texas A&M University, 5007 Ave U, Galveston, TX 77551

[2] NOAA/NMFS/Southeast Fisheries Science Center, 4700 Ave U. Galveston, TX 77551

[3]Department of Marine Science, Texas A&M University, 5007 Ave U, Galveston, TX 7755

**Project Sponsor**
Dr. Wayne Swingle
Executive Director-Gulf of Mexico Fisheries Management Council
The Commons at Rivergate, 3018 North U.S. Highway 301
Suite 1000
Tampa, Florida 33619-2272

**April 25, 2005**

**Award:** $55,000

## Project Summary

Compared to low-relief soft-sediment environments that dominate the continental shelf in the northwestern Gulf of Mexico, hard banks support diverse fish and coral communities that represent important naturally occurring aggregation areas for exploited populations (Rezak et al. 1985, Dennis and Bright 1988). Most of these banks are unmonitored (Asch and Turgeon 2003, Coleman et al. 2004a) and their importance to critical life stages of fish resources has not been quantified. In this project, we are studying Sonnier Bank (approximate location: 28°20'N, 92°27'W) to evaluate its importance as habitat for corals and fish populations. Sonnier Bank has a number of bathymetric peaks where fish aggregate, and we have used a number of approaches to quantify the habitat as well as the biota on this bank, including ROV and SCUBA surveys. We have observed a variety of unique habitats with side scan sonar including: uplifted caprock with aprons of coarse grained debris (possibly coral debris), highly sculpted lumps with steeply dipping ridges, and isolated patches of coral heads. The benthic community appears to be similar to that described 20 years ago by Rezak et al. (1985), except that we have observed some bleaching of *Millepora* coral and this was not reported previously. We have observed a diverse community of fishes and many of these were in families that represent important exploited populations (snappers, groupers, jacks and grunts). The most abundant exploited species observed with SCUBA were rock hind, gray snapper, vermilion snapper, greater amberjack, crevalle jack, and tomtate. With the exception of rock hind, these species were more abundant at greater depths than we could survey with SCUBA. In addition, we found red snapper, lane snapper, and dog snapper in the deeper areas associated with the peaks. We also observed graysby and *Mycteroperca* spp. (yellowmouth grouper), but these were rare. Using bootstrap approaches (re-sampling simulation procedures) with our preliminary data, we have determined that with a reasonable amount of sampling effort (around 30 visual survey counts) we can detect moderate to large changes in abundance of most of these species. This is important knowledge if the need to monitor fish populations on Sonnier Bank becomes a management objective. In addition, we have seen encouraging results comparing SCUBA with ROV that suggests it may be possible to convert counts made with ROV to a measure that is equivalent to what might be observed with SCUBA and subsequently estimate density. Thus, ROV may be an effective tool for quantifying and monitoring fish abundances at highly structured habitats that are in areas that are too deep for SCUBA surveys and when more destructive surveying approaches are undesirable. Still, these findings are preliminary and we need to precisely identify the limitations of the ROV approach in order make recommendations on how to apply this survey technique.

## Research Objectives:

1) characterize and quantify economically important fish populations at Sonnier Bank to support evaluation of this area as essential habitat

2) map benthic habitat characteristics on a finer scale than what is currently available for Sonnier Bank and characterize benthic coral communities

3) develop approaches with ROV that can be used to study deep structurally complex areas that are inaccessible to SCUBA and that can be applied at other banks in the Gulf of Mexico

**Accomplishments:**

*1) Hypsographic analysis of Sonnier Bank to support surveys*

As this project was beginning, high resolution bathymetric data on Sonnier Bank were made available by the USGS (Beaudoin et al. 2002). These data were collected with multi-beam sonar, and we used GIS software to visualize the bank and identify features of interest. The bathymetry data were used to quantify the area that could be surveyed with SCUBA. Most of this area was at a single peak, which has become the focal point of this study (Figure 1). These data also provided a first look at the sonar reflectivity of the bottom, which gives an indication of the level of consolidation of the sediment (i.e., higher reflectivity = hard substrate). A simple visual analysis of the multi-beam sonar data clearly demonstrated that peaks at Sonnier Bank were associated with high reflectivity and likely represented bedrock outcroppings that were covered with coral (Figure 2). In addition, these data were too coarse to observe finer scale habitat structure that is important for reef fishes, emphasizing the need for the side scan sonar work that we conducted. We calculated hypsographic functions for the 2- and 3-dimensional area of the bank, and this function shows that the important areas of the bank (i.e., the peaks at which the fish biota area concentrated) represent a small proportion of the entire geological feature: about 1 $km^2$ at depths < 58 m compared to ~10 $km^2$ for the entire bank (Figure 3).

*2) Side scan sonar cruise*

In June of 2004, we conducted a four day cruise to survey all of Sonnier bank with side scan sonar and Chirp seismic equipment. This work was conducted from the *R/V Marie Hall*, (University of Texas Medical Branch in Galveston). Two of these days were travel days to and from the site. Our side scan sonar work and seismic survey were completed by the afternoon of the second day at Sonnier Bank; therefore, we traveled ~30 miles to the south to McGrail bank to conduct some preliminary seismic surveys that would support the second year of this study in which we plan to survey the fish and coral community at McGrail. We have provided the side scan sonar and seismic data to the Flower Garden Banks National Marine Sanctuary office.

*3) Identification of habitat features from side scan sonar data*

The highest peaks were difficult to image with side scan sonar due to underwater cliffs at these locations, which cast shadows in the sidescan sonar field and obscure some of the features. We invariably observed high reflectivity on the tall peaks consistent with uplifted caprock and coral. Interspersed between the tall peaks were large patches of rubble and coral heads of varying densities. We observed some of these deeper rubble areas with the ROV and confirmed the presence of boulders and rubble encrusted with various corals, sponges and algae. The more gradually sloping peaks were usually characterized by an apron of coarse grained debris, which most likely represents coral debris. Small isolated patches of coral heads in deep water were also observed.

Side scan sonar data revealed a great diversity of habitats at Sonnier Bank (Figure 4). For the following explanations see Figure 4: A) coral cap with an apron of coarse-grained coral debris on the fringe; B) coral cap surrounded by fine-grained mud (low reflectivity, the arrow shows a sonar shadow that emphasizes the height of this feature); C) densely populated coral cap surrounded by high reflection sand patches and low reflection mud patches; D) individual coral heads in a sand patch; E) densely populated and a sparsely populated rubble and boulder areas (the upper left area was explored with the ROV); F) image of the focal site for this study (arrows show shadows that result from wave noise caused by particularly large waves and a large shadow cast by the crest of this feature); G) coral cap with apron of coarse debris surrounded by fine grained mud; H) coral and fractured cap rock - as a salt diapier pushes up through the sediment it often fractures lithified sedimentary rock which creates the circular surface expression of the feature; I) surface expression of the salt diapier (arrow shows the nadir or blind spot directly beneath the side scan sonar tow fish); J) petroleum pipeline; K) coral cap surrounded by fine grained debris.

### *4) Sub-bottom profiling with Chirp seismic survey*

In the middle of the ring of peaks that outlines the salt dome with which this geological feature is associated, Rezak et al. (1985) described a fairly persistent nephloid water column layer (i.e., layer of turbid water). Therefore, we hypothesized that this deeper area between the peaks may represent a depositional area for sediments or an area where sediments may accumulate on the bank. In the areas immediately surrounding the bank, Rezak et al. (1985) described steeply dipping sediment strata, consistent with the geology of a salt dome (Figure 5). With the Chirp seismic survey, we also observed these steeply dipping sediment strata surrounding the bank, and in the interior of the bank we observed only nominal layer of soft sediment. This indicated that sediment is accumulating only briefly in these deeper areas. In addition, because the sub-surface strata surrounding the bank terminate at the sediment water interface, the entire area appears to be an erosive environment. This obviously contributes to the nephloid layer described by Rezak et al. (1985). As the turbidity can be detrimental to corals, a better understanding of the physical processes at Sonnier Bank could help to explain spatial patterns in the benthic community.

### *5) Custom fabrication of a laser array for the ROV*

One of the difficulties using ROVs to quantify abundance of fishes or benthic organisms is that distances cannot be easily determined from video. To help quantify distances underwater from the ROV video surveys, we designed a laser mounting system for the ROV. The primary goal of this system was ranging, or determining distance from the ROV to an object underwater. By calculating the ranges to locations in the field of view, we can then measure the length of ROV transects and quantify the area searched with the ROV. We can then use these area measurements to calculate density from fish counts. In addition, we designed our laser mounting system so that it could be adjusted with a range of angles, and so that we could measure the sizes of fish with computer aided video analysis.

The system we designed used three lasers: two in parallel and one at an angle to the others. The parallel lasers were red and the third laser was green. The three lasers were mounted on the same plane, and the green laser was essential because it allowed us to distinguish between the individual lasers and convert distances measured on the video to real distances. Our mounting system used lasers marketed for SCUBA divers; therefore, these lasers were already mounted in separate underwater housings. Also, these lasers have been used successfully for related applications by NOAA-fisheries researchers. The mounting system was fabricated from high-grade aluminum and custom fitted by a local machinist to our ROV (see schematic in Figure 6). The system is fully adjustable throughout a range of laser angles and the angle of the plane of the lasers relative to the camera angle can be adjusted as well. From our initial deployments, the system appears to be rugged as the angles of the lasers did not change during handling the ROV in moderate seas and from occasional collisions with objects underwater.

### *6) Laser array deployment*

We have made several observations of the lasers that are relevant to our objective of quantifying fish abundances with the ROV. We immediately noticed that many of the small fish in close proximity to the ROV were antagonized by or attracted to the laser spots. These fishes were usually damselfishes and wrasses, but sometimes small rock hind would attack the laser spots. Larger fishes, such as the snappers and jacks, were uninterested in the spots. In addition, while we were measuring a rock hind with the lasers, we observed that this fish ate a bluehead wrasse that was attracted to the laser spots. We expect that these interactions will usually be limited to smaller fishes that are not the focus of this study, and because these interactions usually took place close to the ROV we do not expect that attraction of fishes from outside the field of view will bias counts of our target species. We have been able to measure fish size for a few individual fishes using the laser system, but these opportunities have been highly variable. This is because it is prohibitively time consuming to follow each individual that we observe and position the ROV perpendicular to the fish. Presently, we have not attempted to quantify search area or transect distances using the laser array. Instead, we have concentrated on comparisons between ROV and SCUBA (see below). Measuring search area and transect distances are major objectives for future surveys.

### *7) SCUBA visual surveys*

We conducted two initial SCUBA visual surveys of the highest peak, which crests at a depth of approximately 18 m. Our first trip, 9-11 August 2004, we conducted initial visual surveys and benthic habitat characterizations using quadrats (see below). The SCUBA visual survey approach followed Bohnsack and Bannerot's (1986) method where target fish species observed in an imaginary cylinder of radius 7.5m were counted. The cylinder was visualized by the divers by setting out 15m lengths of line on the bottom. All fish species observed were quantified by the divers in order to provide a characterization of the fish community. These observations combined with exploratory ROV observations were used to generate a list of the fish species composition at Sonnier Bank. Our second trip, 24-27 August 2004, provided a better opportunity for quantitative visual surveys. Based upon our initial observations and to maximize the number of cylinder counts, target species were limited to four families: Serranidae, Lutjanidae, Haemulidae, and two genera of Carangidae (*Seriola* and *Caranx*). These fish families were chosen because they represent major groups of exploited fish populations at this site. Diving was conducted with nitrox (oxygen enriched air) to maximize time at depth for divers, and count durations were limited to 5 minutes per cylinder to maximize the number of cylinder counts per dive. We selected the uppermost area of the peak with depths ranging from 18 to 29 m, and we distributed sampling locations evenly across the peak, covering an area of approximately 0.006 km$^2$ (n=33).

### *8) Exploratory ROV surveys*

Exploratory surveys with the ROV were conducted on an opportunistic basis. On each survey, we explored areas >30 m and also habitat features that were identified with the side scan sonar. We were limited by the length of the ROV tether and the anchorage of the boat; therefore, most of the areas that we searched were deeper parts of the focal site and areas immediately adjacent to this site.

### *9) Benthic surveys with quadrats*

We assessed the species composition of the sessile benthic community using a standard 1 $m^2$ frame (quadrat) with lines that divided the quadrat into 100 squares. Each square, or cell, was 100 $cm^2$. The quadrat was placed on the bottom, and the diver counted the number of cells in which each species was observed. On each dive, a starting location was haphazardly chosen for the first quadrat, and the locations of subsequent quadrats were determined by swimming a random distance and direction from the previous location. We surveyed 40 quadrats across the crest of the main peak.

The substrate of the surveyed peak was completely encrusted with sessile benthic organisms, and no bare substrate was observed. Previously, the benthic community of this area was described as a *Millepora*-sponge community (Rezak et al. 1985), and this characterization was still accurate for our surveys, twenty years later. From 40 quadrat surveys with depths ranging from 17 to 27 m, the dominant benthic organisms were fire coral (*Millepora alcicornis*), several species of sponges (primarily *Agelas clathrodes*, *Ircinia strobilina*, and *Neofibularia nolitangere*) and crustose coralline algae (Figure 7). We also observed a number of other sessile benthos and we are still working to confirm identifications with experts (Table 1). Notably, some bleached *Millepor*a was observed, and this phenomenon was not reported previously by Rezak et al. (1985).

### *10) Species summary list*

We identified a number of species that were both of tropical origin and representing economically valuable resources (Table 2). Out of our target groups, five species were regularly observed during the SCUBA surveys: Atlantic creolefish (Serranidae: *Paranthias furcifer*, n=1823), tomtate (Haemulidae: *Haemulon aurolineatum*, n=315), rock hind (Serranidae: *Epinephelus adscensionis*, n=128), gray snapper (Lutjanidae: *Lutjanus griseus*, n=118), and vermilion snapper (Lutjanidae: *Rhomboplites aurorubens*, n=73). From Carangidae, three species targeted by recreational anglers were regularly observed, greater amberjack (*Seriola dumerili*, n=18), crevalle jack (*Caranx hippos*, n=33), and horse-eye jack (*Caranx latus*, n=4), and these were combined into a single category (i.e., large jacks) for the analyses. Other species from target groups (though some are important exploited populations) were present only in small numbers or in single groups and were not included in the analyses. These latter species were, bar jack (*Caranx ruber*, n=45), lane snapper (*Lutjanus synagris*, n=20), cottonwick (*Haemulon melanurum*, n=8), mahogany snapper (*Lutjanus mahogoni*, n=7, though this identification is unverified), graysby (*Epinephelus cruentata*, n=6), Rainbow Runner (*Elagatis bipinnulata*, n=4), dog snapper (*Lutjanus jocu*, n=2), yellowtail snapper (*Ocyurus chrysurus*, n=2), ceasar grunt (*Haemulon carbonarium*, n=2, though this identification is unverified), and red snapper (*Lutjanus campechanus*, n=1).

### *11) Otolith microstructure analysis*

We opportunistically sampled with hook-and-line to collect otoliths and determine size distributions of species observed during SCUBA and ROV operations. This approach selected for larger higher trophic level species, and we also deployed traps (see below) to supplement information on size and age structure. Each fish was measured and otoliths were extracted and stored in plastic vials. In the laboratory, we cleaned each otolith with dilute hydrogen peroxide and then rinsed each otolith thoroughly with deionized water. For each fish, the right or left saggitus was chosen at random, and then embedded in epoxy resin. Using a low-speed diamond saw we cut a thin transverse section and mounted this on a glass slide with thermoplastic glue. We polished the section to expose the core area and used transmitted light microscopy to view the section and count opaque annuli. Samples we collected were from vermilion snapper (*n*=28), tomtate (*n*=21), rock hind (*n*=13), red snapper (*n*=4), lane snapper (*n*=3) and Atlantic creolefish (*n*=1).

The assigned ages, based upon annulus counts, showed overlapping distributions for most of the species, with ages typically between 4 and 10 years (Figure 8). For all the species, younger ages are believed to be present based upon diver observations of smaller individuals, but the gear selected for larger fish. There were two notably old fish: one tomtate that was 19 years old and one Atlantic creolefish that was 26 years old. There was nothing particularly unusual about these individuals (e.g., with respect to morphology), except that it was unusual to catch Atlantic creolefish with hook-and-line. We are not aware of any published information documenting such high longevity for tomtate, and further we are not aware of any ageing information on Atlantic creolefish. From the few samples of otoliths that we have collected from other species, the age-structure of these populations is not well defined, but appears to be comparable to other published information from the Gulf of Mexico and northwestern Atlantic. The development of age-structure data will be important for predicting population level responses to exploitation or different management actions that may affect fish populations at Sonnier Bank.

### *12) Precision and detectable difference analysis of preliminary data*

To evaluate the SCUBA visual survey approach, we conducted a re-sampling exercise to estimate the relationship between sample size and standard error of mean counts. We simulated sample sizes of 2, 5, 10, 20, 60, 100, and 500 to estimate standard error, and for each sample size, the data were re-sampled 10,000 times with replacement. Count data are typically treated as a Poisson variable, but with this large number of re-sampling iterations, presumably the arithmetic mean and variance will properly describe the re-sampled distribution as per the central limit theorem. We modeled a power function between standard error and sample size to interpolate standard errors of intermediate sample sizes. To evaluate the sensitivity of our cylinder count approach for detecting changes in abundance, we determined the minimum detectible difference (given a 5% chance of Type-I error and 90% chance of detecting a difference; see Zar 1984, p. 135) across ranges of sample size (from 5 to 50) and density (from 0.25 to 2 times the observed mean count). We were also interested whether depth and/or the person making the count had any significant effect on the count. For this exercise we conducted a Poisson regression of observed species count on person with depth as a covariate.

The highest densities observed during SCUBA visual surveys were for Atlantic creolefish followed by tomtate and rock hind (Table 3). The surveyed depths ranged from 16 to 32 m with a mean of 23 m, and most counts were made at depths <29 m (only one count was made at 32 m). In the Poisson regression, there were no significant depth trends for any of the species, though there was a slight increase in mean count with depth for all species except rock hind (Figure 9). In addition for all species, there were no interactions between depth and diver, and there were no significant differences between the four divers. There was significant over dispersion in our data; therefore, we scaled the covariance matrix by the deviance (Kleinbaum et al., 1998). Note that there was one outlying observation, a single large school of tomtate (n=160), and this was not included in the Poisson regression analysis. This outlier was included in the re-sampling analysis.

As expected, the standard errors estimated from the re-sampling procedure declined with sample size, and the highest standard errors were observed for Atlantic creolefish and tomtate (Figure 10). High standard errors for these species reflected frequently observed aggregations of Atlantic creolefish and the one large school of tomtate that was recorded. A large school of tomtate was also reported by two other divers, but it was not inside the survey cylinders and was not counted. For counts of rock hind, gray snapper, vermilion snapper, and large jacks there was little improvement in standard error by increasing sample size from 20 to 50 (Figure 10). Due to the low overall frequencies of observations of large jacks and vermilion snapper, these species were not included in the minimum detectable difference calculations. Based upon the estimated minimum detectable differences, the SCUBA visual surveys would be most sensitive at detecting changes in abundance of the most stationary species (rock hind) and the most abundant species (Atlantic creolefish). Increases in sample size and/or increases in abundance improved detection, and with respect to observed mean counts and our sample size of 33, the density would have to decline by 66% for rock hind and 88% for Atlantic creolefish before we would detect a statistical difference in mean cylinder count (Figure 11). For gray snapper and tomtate, the proportional declines would have to be much larger: 1.6-fold and 1.8-fold, respectively (Figure 11).

The results of this preliminary data analysis indicated that a target sample size for SCUBA surveys of around 30 cylinder counts provided reasonable precision (s.e. < 2) for estimating abundance of low density species (<4 per cylinder). Though this essentially represents most of the area of Sonnier Bank that is accessible for SCUBA surveying, it is a level of sampling that could reasonably be conducted on a regular basis. The two most abundant species, tomtate and Atlantic creolefish, exhibited high variability, and increases in sample size indicated substantial improvements in precision across the range of simulated sample sizes up to 500. Such large sample sizes are unreasonable for conducting SCUBA surveys, but at least for high abundance species like Atlantic creolefish, we expect to be able to detect moderate to large changes in abundance with the same level of sampling.

Two species, which we predicted our SCUBA survey approach would have the greatest sensitivity to detect changes in abundance, were rock hind and Atlantic creolefish, and of these only rock hind would be expected to have significant exploitation from commercial or recreational fishing. Due to recent concern in the Gulf of Mexico about the impacts of recreational fishing (Coleman et al. 2004b), we posed the question, what does the minimum detectable difference at a sample size of 30 (cylinder counts) reflect in terms of numbers of rock hind removed by fishing? Given a total survey area of ~7000 $m^2$ and a minimum detectable difference of 2.5 rock hind per cylinder (cylinder area = 176 $m^2$), anglers would have to catch approximately 100 rock hind. Current federal regulations limit recreational catch of rock hind to 5 per person per day; therefore, if each angler catches her limit, we would detect the change in abundance after approximately 20 angler trips. This amount of effort might be masked in the short term because rock hind from adjacent areas can move to replace those that are caught. Still, the equivalent (or greater) fishing effort of 20 angler trips where bag limits are reached is a highly plausible level of fishing that could take place during typical monitoring intervals (monthly or bi-monthly).

*13) Comparison SCUBA-ROV surveys*

On selected dives, the locations of the cylinder counts were marked temporarily with a small float that was tethered to a lead weight. Between dives, we deployed the ROV to record a video survey of the area that was marked previously during the SCUBA operations. The markers also helped divers minimize cylinder overlap. Our approach with the ROV was to follow the markers, searching the area around each marker. The video was subsequently analyzed and we counted target species that were identified in the video transect. The count of each species from the ROV video was divided by (normalized to) the number of marked areas that were searched.

Though the rank order of abundance of target species was the same between SCUBA visual surveys and ROV video transects, the counts per marked area from the ROV were many times lower (Table 3). These differences were due, at least in part, to a smaller search area and limited field of view with the ROV. We are currently working on an approach to better quantify search area with the ROV in order make better comparisons with SCUBA visual surveys. In general, the behavior of the fish in the video recordings was similar to that observed by the divers. For the low abundance species there was promising relationship between the two approaches (Figure 12), and it may be possible to convert ROV species counts to a measure of equivalent SCUBA visual survey density. In addition, the most abundant species, Atlantic creolefish, did not follow the same trend. There may be a more complex relationship between ROV and SCUBA counts across different orders of magnitude in abundance, or there may be no useful relationship between the two counts beyond a specific density. Still, these are few data and more comparative work is needed to define the limits of the ROV approach.

14) Manuscript and presentation of work to GCFI

We have presented this work at the 2004 annual meeting of the Gulf and Caribbean Fisheries Institute in St. Petersburg, FL. A manuscript was submitted with this presentation (below), and is currently being reviewed by the editors for publication in the proceedings of this conference. This meeting provided a timely venue for sharing our results with a group of researchers and managers that are interested in related issues.

Kraus, R. T., R. L. Hill, J. R. Rooker, and T. Dellapenna. *in review* Preliminary characterization of a mid-shelf bank in the northwestern Gulf of Mexico as essential habitat of reef fishes. Proceedings of the Gulf and Caribbean Fisheries Institute

## Literature Cited

Asch, R. G., and D. D. Turgeon. 2003. Detection of gaps in the spatial coverage of coral reef monitoring projects in the US, Caribbean, and Gulf of Mexico. Revista de Biologia Tropical 51:127-140.

Beaudoin, J.D., Gardner, J.V., and Hughes Clarke, J.E. 2002. Cruise Report; R.V. Ocean Surveyor Cruise O1–02–GM; bathymetry and acoustic backscatter of selected areas of the outer continental shelf, northwestern Gulf of Mexico: U.S. Geological Survey Open-File Report 02-410 [URL http://geopubs.wr.usgs.gov/open-file/of02-410].

Bohnsack, J. A., and S. P. Bannerot. 1986. A stationary visual census technique for quantitatively assessing community structure of coral reef fishes. NOAA Technical Report, NMFS 41. 15 p.

Coleman, F. C., P. B. Baker, and C. C. Koenig. 2004a. A review of Gulf of Mexico marine protected areas: Successes, failures, and lessons learned. Fisheries 29:10-21.

Coleman, F. C., W. F. Figueira, J. S. Ueland, and L. B. Crowder. 2004b. The impact of United States recreational fisheries on marine populations. Science 305:1958-1960.

Dennis, G. D., and T. J. Bright. 1988. Reef fish assemblages on hard banks in the northwestern Gulf of Mexico. Bulletin of Marine Science 43:280-307.

Gust, N., J. H. Choat, and J. L. Ackerman. 2002. Demographic plasticity in tropical reef fishes. Marine Biology 140:1039-1051.

Kleinbaum, D. G., L. L. Kupper, K. E. Muller, and A. Nizam. 1998. Applied regression analysis and other multivariable methods. Brooks/Cole Publishing Company, Pacific Grove, 798 p.

Panfili, J., H. de Pontual, H. Troadec, and P. J. Wright. 2002. Manual of Fish Sclerochronology. Ifremer-IRD coedition, France. 463 p.

Rezak, R., T. J. Bright, and D. W. McGrail. 1985. Reefs and Banks of the Northwestern Gulf of Mexico. John Wiley & Sons, Inc., New York. 259 p.

Zar, J. H. 1984. Biostatistical Analysis. Prentice-Hall, Inc., New Jersey. 718 p.

Table 1. Preliminary list of sessile benthos observed from quadrat surveys and with ROV at Sonnier Bank.

| | common name | scientific name |
|---|---|---|
| Sponges | | |
| | orange elephant ear | *Agelas clathrodes* |
| | black ball sponge | *Ircinia strobolina* |
| | brown sponge | *Anthosigmella varians* |
| | touch-me-not sponge | *Neofibularia nolitangere* |
| | brown sponge | unknown |
| | purple rope sponge | unknown |
| | gray round sponge | unknown |
| | tan sponge | unknown |
| | green sponge | unknown |
| Coral | | |
| | fire coral | *Millepora alcicornis* |
| | star coral | *Stephanoecia* sp. |
| | star coral | *Madracis* sp. |
| | blue/green coral | unknown |
| Macroalgae | | |
| | crustose coralline algae | unknown |
| | Y-branching | *Dictyota* sp. |
| | fan leaf | *Lobophora variegata* |
| | red filamentous cyanobacteria | |
| Other benthos | | |
| | red encrusting tunicate | unknown |
| | hermit crab | unknown |
| | zig-zag mussel | unknown |
| | sea cucumber | unknown |
| | bryzoan/hydrozoan | unknown |

Table 2. Preliminary list of fishes observed from SCUBA surveys and with ROV at Sonnier Bank.

| common name | scientific name |
|---|---|
| Target Groups: | |
| **Serranidae** | |
| Atlantic creolefish | *Paranthias furcifer* |
| Graysby | *Cephalopholis cruentata* |
| Rock hind | *Epinephelus adscensionis* |
| Yellowmouth grouper | *Mycteroperca interstitialis* |
| **Lutjanidae** | |
| Dog snapper | *Lutjanus jocu* |
| Gray snapper | *Lutjanus griseus* |
| Lane snapper | *Lutjanus synagris* |
| Mahogany snapper | *Lutjanus mahogoni* |
| Red snapper | *Lutjanus campechanus* |
| Vermilion snapper | *Rhomboplites aurorubens* |
| Yellowtail snapper | *Ocyurus chrysurus* |
| **Haemulidae** | |
| Ceasar grunt | *Haemulon carbonarium* |
| Cottonwick | *Haemulon melanurum* |
| Tomtate | *Haemulon aurolineatum* |
| **Carangidae** | |
| Almaco jack | *Seriola rivoliana* |
| Bar jack | *Caranx ruber* |
| Blue runner | *Caranx crysos* |
| Crevalle jack | *Caranx hippos* |
| Greater amberjack | *Seriola dumerili* |
| Horse-eye jack | *Caranx latus* |
| Rainbow runner | *Elagatis bipinnulata* |
| African pompano | *Alectis ciliaris* |
| Other Species: | |
| **Balistidae** | |
| Gray triggerfish | *Balistes capriscus* |
| Black durgon | *Melichthys niger* |
| **Scombridae** | |
| King mackerel | *Scomberomorus cavalla* |
| **Kyphosidae** | |
| Bermuda chub | *Kyphosus sectatrix* |
| **Mullidae** | |
| Spotted goatfish | *Pseudopeneus maculatus* |
| **Pomacentridae** | |
| Yellowtail reeffish | *Chromis enchrysura* |
| Bicolor damselfish | *Stegastes partitus* |
| Blue chromis | *Chromis cyanea* |
| Sunshinefish | *Chromis insolata* |
| **Triakidae** | |
| Smooth dogfish | *Mustelus canis* |
| **Carchinidae** | |
| Sandbar shark | *Carcharhinus plumbeus* |
| Silky shark | *Carcharhinus falciformis* |
| **Pomacanthidae** | |
| French angelfish | *Pomacanthus paru* |
| Queen angelfish | *Holacanthus ciliaris* |
| Blue angelfish | *Holacanthus bermudensis* |
| Rock beauty | *Holacanthus tricolor* |
| **Acanthuridae** | |
| Doctorfish | *Acanthurus chirurgus* |
| **Scaridae** | |
| Redband parrotfish | *Sparisoma aurofrenatum* |
| **Labridae** | |
| Spanish hogfish | *Bodianus rufus* |
| Spotfin hogfish | *Bodianus pulchellus* |
| Creole wrasse | *Clepticus parrae* |
| Puddingwife | *Halichoeres radiatus* |
| Bluehead | *Thalassoma bifasciatum* |
| **Holocentridae** | |
| Longspine squirrelfish | *Holocentrus rufus* |
| Squirrelfish | *Holocentrus adscensionis* |
| **Monacanthidae** | |
| Unicorn filefish | *Aluterus monoceros* |
| Orangespotted filefish | *Cantherhines pullus* |
| **Chaetodontidae** | |
| Reef butterfly | *Chaetodon sedentarius* |
| Spotfin butterfly | *Chaetodon ocellatus* |
| Banded butterflyfish | *Chaetodon striatus* |
| **Albulidae** | |
| Bonefish | *Albula vulpes* |

Table 3. Mean counts (and 95% C.L.s) from visual surveys and ROV video surveys for selected species.

|  | SCUBA Visual Survey[a] |  |  | ROV[b] |
|---|---|---|---|---|
|  | Mean | Lower C.L. | Upper C.L. |  |
| Atlantic creolefish | 54.6 | 38.4 | 77.6 | 3.8 |
| tomtate | 4.6 | 2.9 | 7.2 | 1.9 |
| rock hind | 3.8 | 3.0 | 4.9 | 1.0 |
| gray snapper | 3.4 | 1.9 | 6.1 | 0.8 |
| vermilion snapper | 2.2 | 1.0 | 4.9 | 0.2 |
| large jacks | 1.7 | 0.9 | 3.3 | 0.1 |

[a] Estimates from Poisson regression (*n*=33).

[b] Count from video per number of marked areas that were searched (*n*=28).

Figure 1. Oblique bathymetric view of Sonnier Bank showing focal sites of the survey. Depth is exaggerated 5 times, and the bank is approximately 4km across. Depth contour at the focal point crest is at 20m and 5m contours are shown. Data were obtained from USGS and processed with ArcMap and ArcScene.

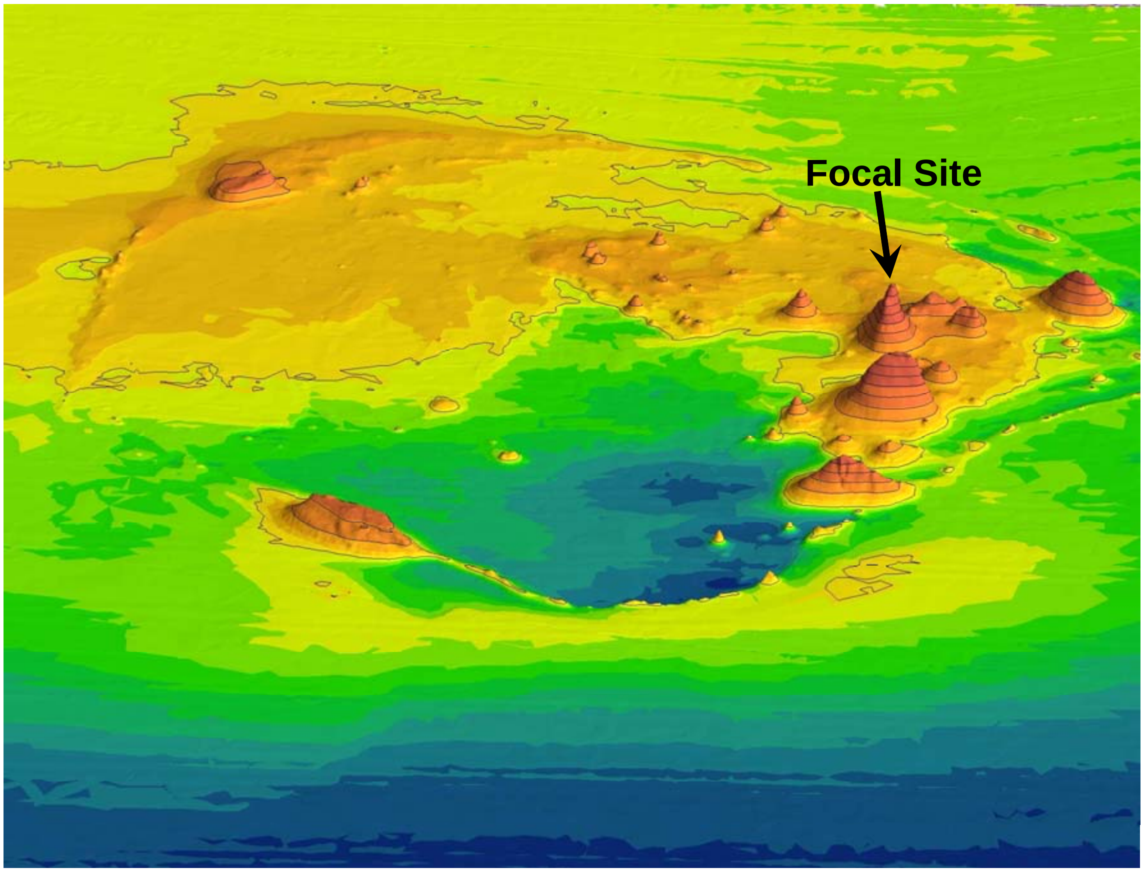

Figure 2. Planar view of Sonnier Bank showing 55m depth contour (black line) and areas of low (gray) and high backscatter (white) from USGS multi-beam sonar.

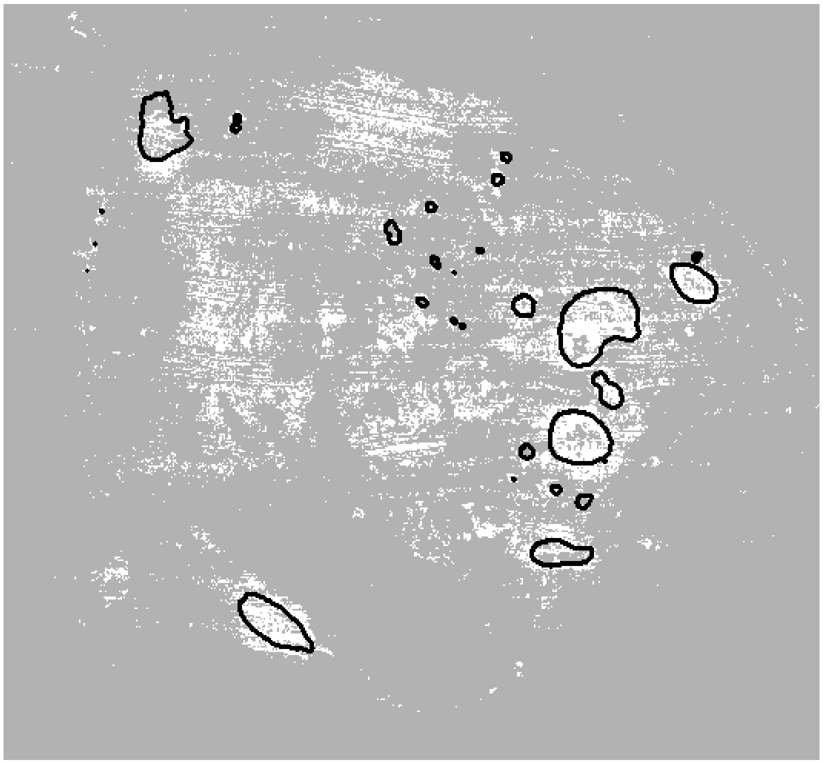

Figure 3. Hypsographic plot of depth on cumulative area (both 2-dimensional and 3-dimensional area, as denoted in the key). Horizontal dashed line represents maximum depth of SCUBA visual surveys, and inset plot shows hypsographic function for the entire bank. These plots were calculated from the bathymetry data of Beaudoin et al. (2002). The steepness of the highest peaks is emphasized by the divergence of the 2-dimensional and 3-dimensional cumulative areas. In the inset plot, these two functions are essentially the same, demonstrating that the high-relief peaks represent a very small fraction of the entire bank.

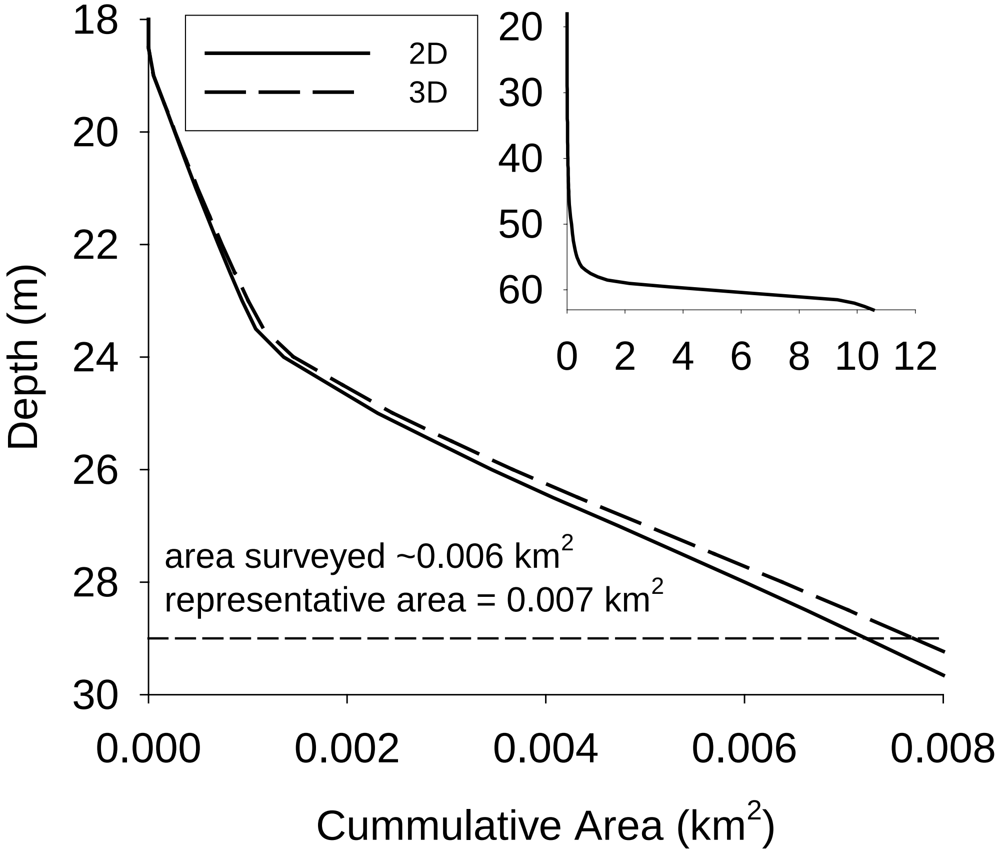

Figure 4. Selected side scan sonar images from Sonnier Bank illustrating a variety of features and habitat types (see text for description of individual panels). The shading from dark-gray to white indicates the strength of the back-scatter intensity, and the lighter the shading the more consolidated and harder the substrate. These images are oriented north to south and area scaled to the same distance.

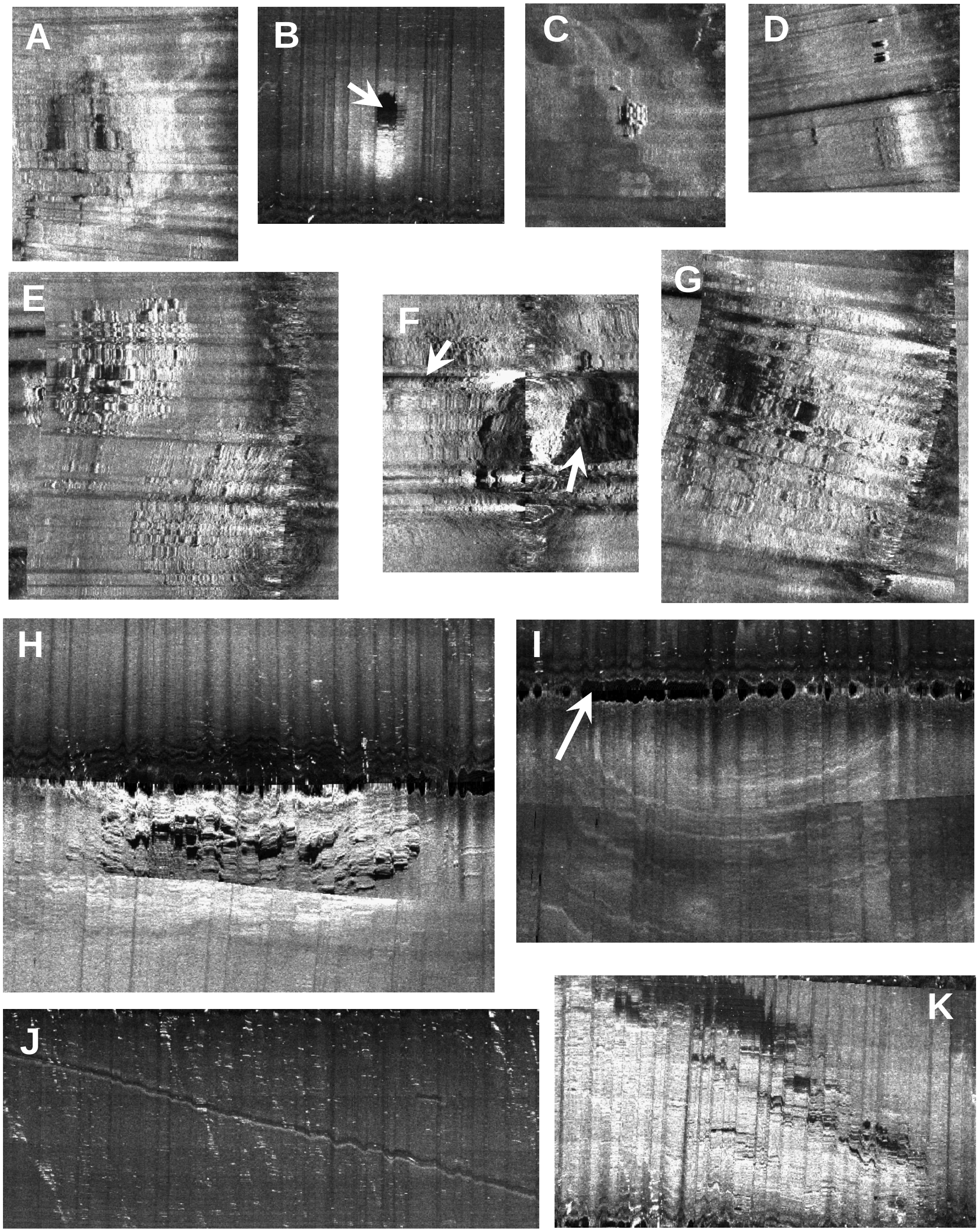

Figure 5. Chirp seismic data demonstrating depth of soft-sediment (short arrows) and sediment strata surrounding (longer arrow) Sonnier Bank.

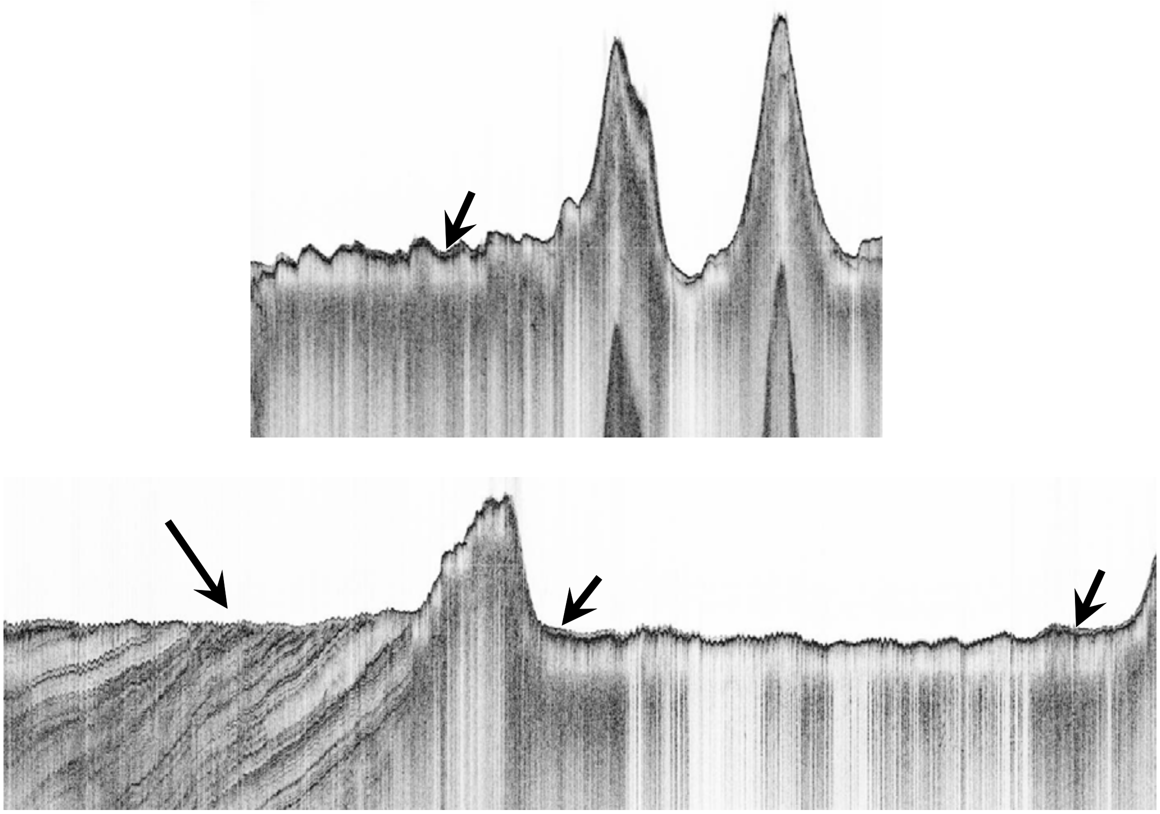

Figure 6. Schematic of the laser array that was fabricated for this project. U-bolt and strap fastener were built to encircle the cylindrical camera housing of the ROV.

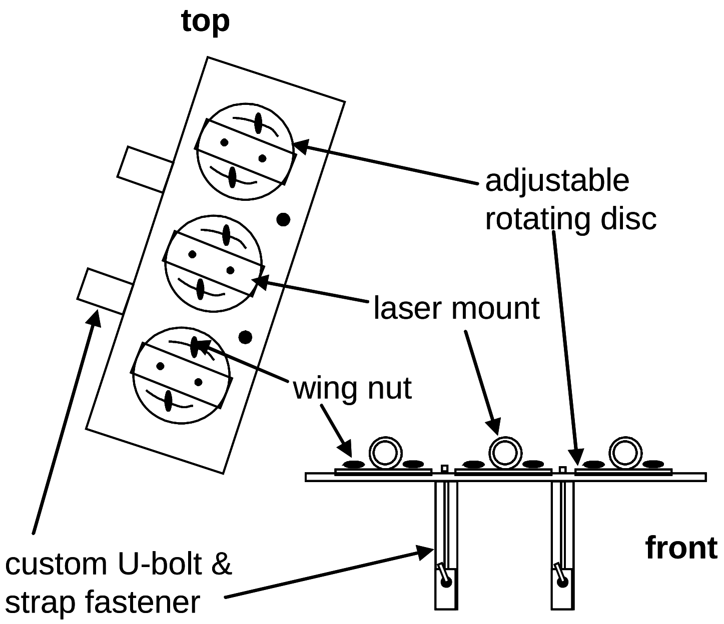

Figure 7. Incidence of major benthic organisms observed at Sonnier Bank and quantified with quadrats (see text). The box plots give median, 10th, 25th, 75th, and 90th percentiles for each taxonomic group, and the dots represent outliers.

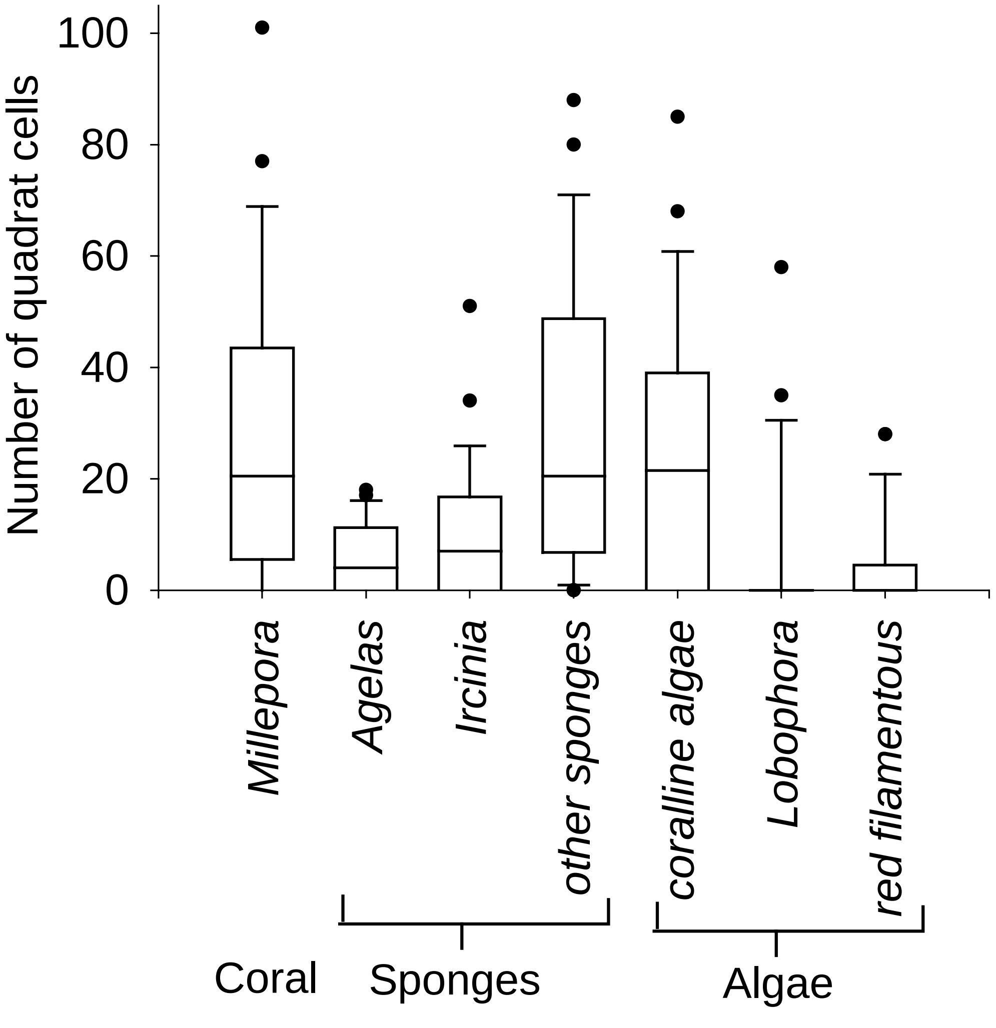

Figure 8. Age-distribution of species captured by hook-and-line at Sonnier Bank. Ages were determined by annulus counts from thin sections of otoliths.

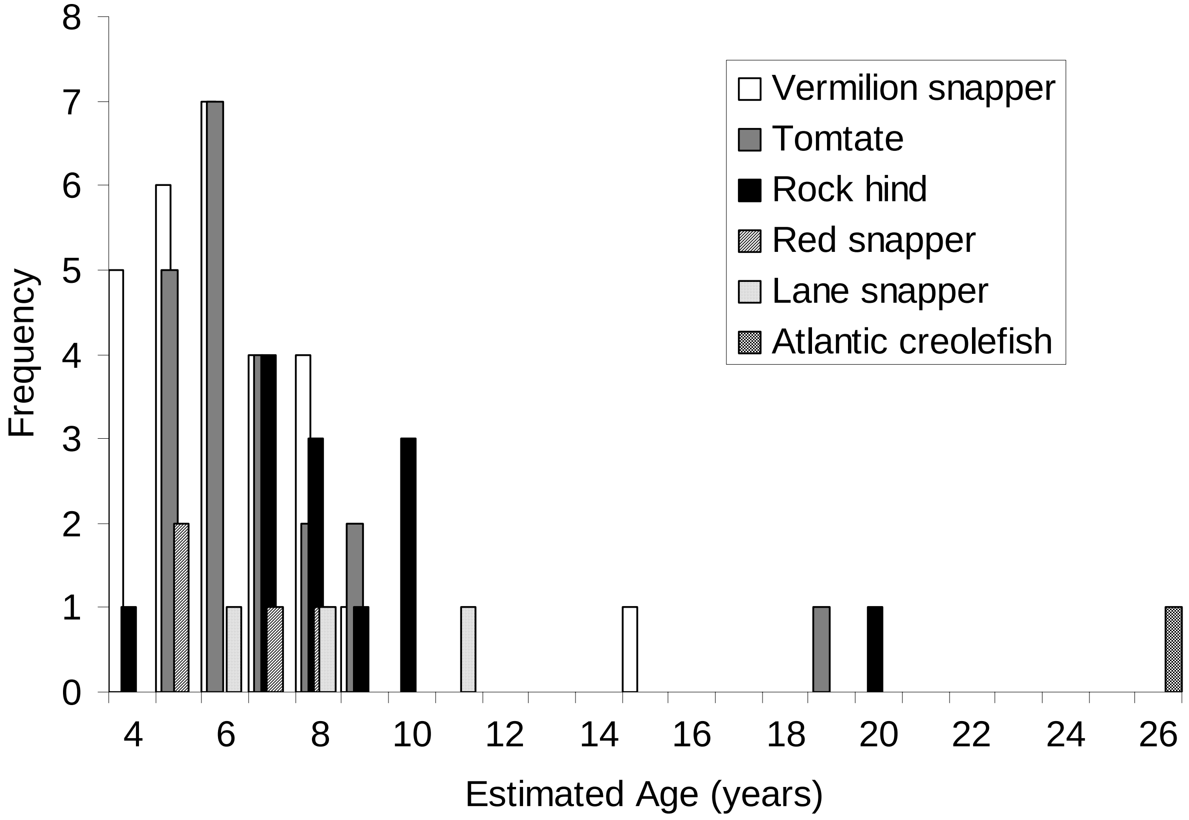

Figure 9. Observed cylinder counts as a function of depth for 6 target species at Sonnier Bank. The line shows value predicted from Poisson regression.  Note the scale on the vertical axis varies by species.

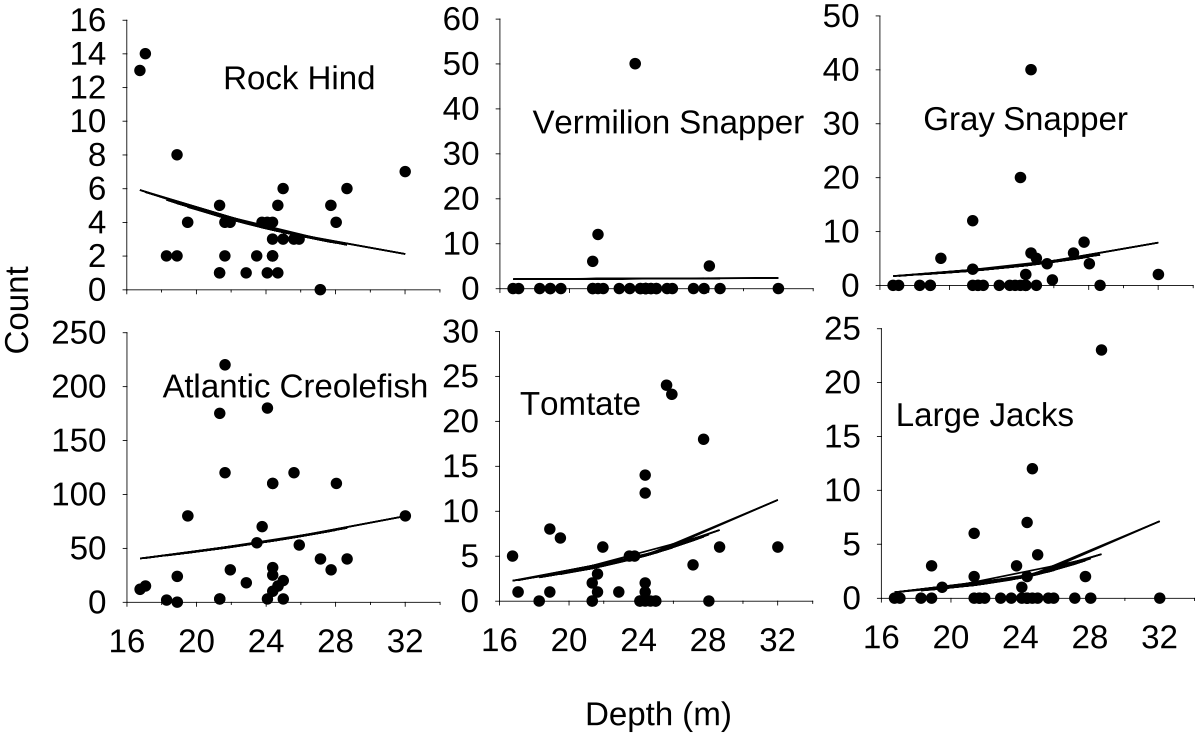

Figure 10. Re-sampling analysis results showing standard error as a function of sample size for selected species observed at Sonnier Bank. Dashed curves show power functions that were fitted to the data.

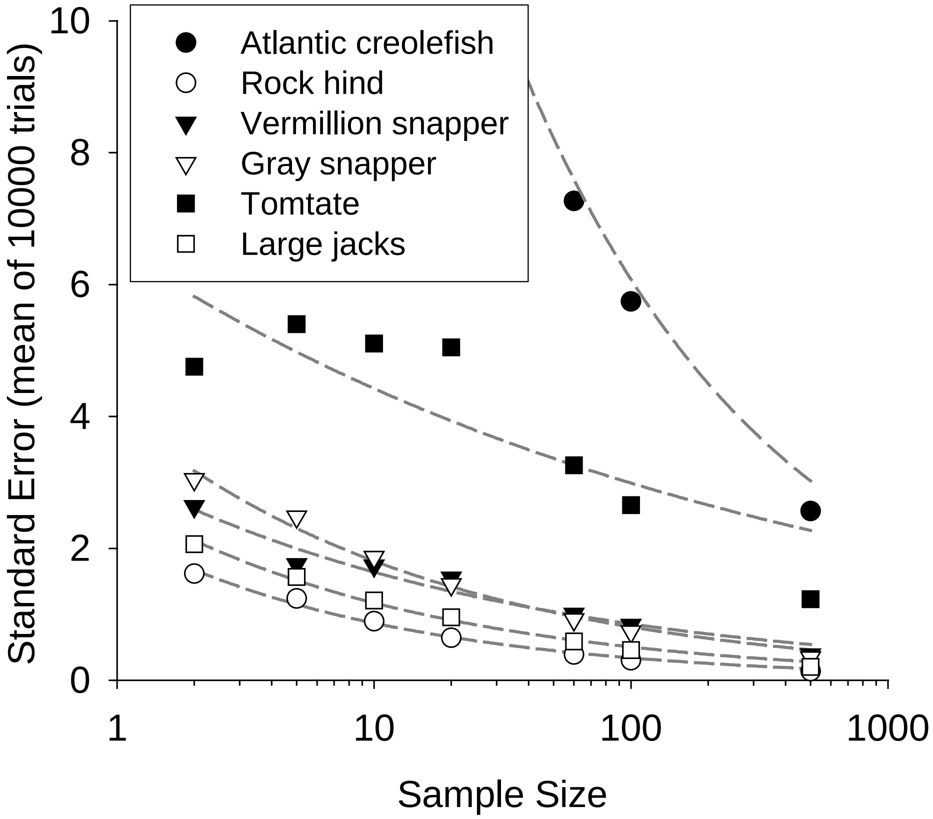

Figure 11. The minimum detectable difference (plotted as a proportion of the mean count) as a function of mean count and sample size for selected species observed at Sonnier Bank.

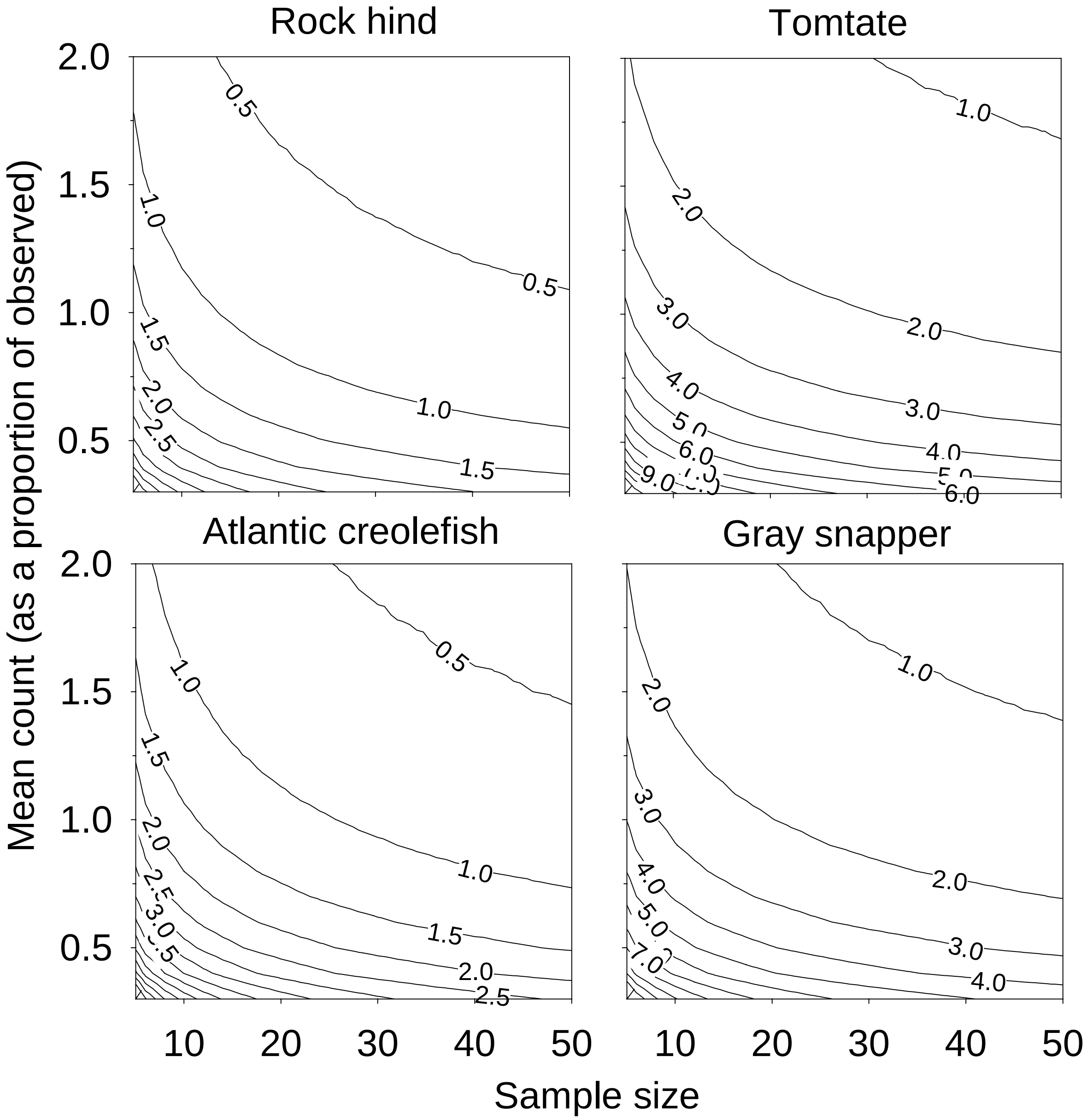

Figure 12. Comparison of mean species counts (Poisson) from SCUBA visual surveys with counts of the same species with ROV (count was normalized by the number of SCUBA sites). The equation of the line fitted to the five species with the lowest counts is: y=0.6x – 1.1