Essential Habitat of Reef Fishes

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ABSTRACT

The continental shelf of the northwestern Gulf of Mexico has many, widely scattered, high-relief, bathymetric features (or banks) that represent important naturally occurring aggregation areas for exploited fish species (especially snappers and groupers). While a few of these banks are protected and monitored as national marine sanctuaries (e.g., Flower Garden Banks), most are unprotected and poorly studied. Here, we present initial results of a study of one such bank, Sonnier Bank, where we are developing survey approaches with sidescan sonar, seismic devices, SCUBA, ROV (remotely operated vehicle), and fish traps. Sonnier Bank appears as a ring of topographic peaks, covering approximately 12.6 km^2. At the shallowest depths (< 30 m) we have observed a diverse community of unexploited reef fishes associated with millepora coral and sponges. In this shallower environment, rock hind (*Epinephelus adscensionis*) were the dominant serranid. The deeper (45 to 60 m) bathymetric features of Sonnier Bank had the greatest numbers of exploited reef fish species. Sidescan and ROV surveys identified these areas as more gradually sloping with large pieces of rubble (1 to 4 m in diameter). Notable aggregations of vermilion snapper (*Rhomboplites aurorubens*), red snapper (*Lutjanus campechanus*), and gray snapper (*L. griseus*) were present, and yellowmouth grouper (*Mycteroperca interstitialis*) and graysby (*Cephalopholis cruentata*) were also observed. Our ongoing efforts include the calibration of a laser array for measuring distances with ROV video/ images, and comparisons of fish counts and measurements between divers and the ROV. The development of approaches with ROV may be an effective way to quantify and monitor commercially important snappers and groupers in these deeper, structurally-complex habitats.

KEY WORDS: Visual survey, ROV, Sonnier Bank

Caracterización Preliminar como Habitat Esencial de Peces de Arrecife en un Banco Continental de Profundidad Intermedia en el Noroeste del Golfo de México

La plataforma continental en el noroeste del Golfo de México poseé muchas estructuras de alto relieve batimétrico (bancos) muy dispersas que representan importantes sitios de congregación de muchas especies comercialmente importantes (particularmente huachinangos y meros). Mientras que un número limitado de estos bancos son protegidos y monitoreados como santuarios marinos nacionales (e.g., Flower Garden Banks), la mayoría no reciben protección y son poco estudiados. Aquí presentamos los resultados iniciales del estudio de uno de estos bancos, el Banco Sonnier, en el cual estamos desarrollando técnicas de monitoreo que incluyen el sonar lateral, aparatos sísmicos, buceo autónomo, sumergible de control remoto (ROV), y trampas de peces. El Banco Sonnier asemeja un anillo de picos y ocupa aproximadamente 12.6 km^2. En su profundidad mínima (< 30 m) hemos observado una diversa comunidad de peces de arrecife no explotados asociados con corales *millepora* y esponjas. En esta profundidad menor, el serranido mas abundante es el *Epinephelus adscensionis*. En el Banco Sonnier, el mayor número de especies comercialmente importantes están asociadas con estructuras batimétricas de mayor profundidad (45 a 60 m). El sonar lateral y el monitoreo con ROV identifica estas areas como zonas con pendientes mas pronunciadas en el que se encuentran grandes estructuras (1 a 4 m de diámetro). Ahí se congregan gran numero de *Rhomboplites aurorubens*, *Lutjanus campechanus*, y *L. griseus*, así como *Mycteroperca interstitialis* y *Cephalopholis cruentata*. Actualmente estamos calibrando un grupo de lasers con el objetivo de utilizar las imagenes obtenidas con el ROV para medir distancias, asi como realizando comparaciones entre los censos de peces obtenidos por varios buzos y mediante el ROV. El desarrollo de tecnologías associadas con el ROV puede eventualmente convertirse en una forma efectiva para censar y monitorear especies comercialmente importantes de huachinangos y meros en estas aguas mas profundas y estructuralmente complejas.

PALABRAS CLAVES: Plataforma continental, habitat esencial de peces de arrecife, Golfo de México

INTRODUCTION

The continental shelf of the northwestern Gulf of Mexico is dominated by low-relief, soft-sediment environments that are punctuated by small, high-relief, hard-substrate areas. These hard bottom features are often associated with salt diapers (or salt-domes) and are called banks (Rezak et al. 1985). Banks associated with the mid-shelf and shelf edge support diverse communities (Rezak et al. 1985, Dennis and Bright 1988) and are important naturally occurring aggregation areas for exploited fish populations. With the exception of the Flower Garden Banks National Marine Sanctuary, most of the banks in the northwestern Gulf of Mexico are unmonitored, and their importance as essential fish habitat is unquantified (Asch and Turgeon 2003, Coleman et al. 2004a). Part of the problem has been that the biota of these habitats is not easily sampled with conventional survey gears (e.g., otter trawls). In addition if these habitats might later be designated as marine protected areas, the use of sampling approaches that perturb sessile benthic communities would not be desirable.

We are currently studying one mid-shelf bank in the northwestern Gulf of Mexico, Sonnier Bank (approximate location: 28°20'N, 92°27'W), to evaluate it as essential habitat of coral and reef fish species and to develop survey approaches with SCUBA and ROV (remotely operated vehicles) that can be applied to monitor other similar banks in this region. The biota of Sonnier Bank has been described by Rezak et al. (1985), and high-resolution bathymetry has recently been mapped with multi-beam sonar (Beaudoin et al. 2002) (Figure 1). To date, we have conducted side-scan sonar surveys of Sonnier Bank to characterize benthic habitats (results are not presented here), and we have initiated SCUBA and ROV assessments of one of the main bathymetric peaks. For this preliminary data, our objectives are:

i) To evaluate the precision of visual surveys for quantifying abundance of exploited fish populations,
ii) To compare current sessile benthic community composition with that observed two decades ago (see Rezak et al. 1985), and
iii) To estimate age-structure of species that were sampled from this peak with hook-and-line.

METHODS

Sonnier Bank appears as a ring of siltstone, claystone, and sandstone outcroppings. We conducted two initial surveys of the highest peak, which crests at a depth of approximately 18 m. Our first trip, 9-11 August 2004, was abandoned prematurely due to hurricane Bonnie; therefore, the results presented here are primarily from our second trip, 24-27 August 2004.

The SCUBA visual survey approach followed Bohnsack and Bannerot's (1986) method where target fish species observed in an imaginary cylinder of radius 7.5 m were counted. The cylinder was visualized by the divers by setting out 15 m lengths of line on the bottom. Due to the fish identification experience of the divers and our desire 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 in this region. Diving was conducted with nitrox (oxygen enriched air) to maximize time at depth for divers, and count durations were limited to five 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 ($n = 33$).

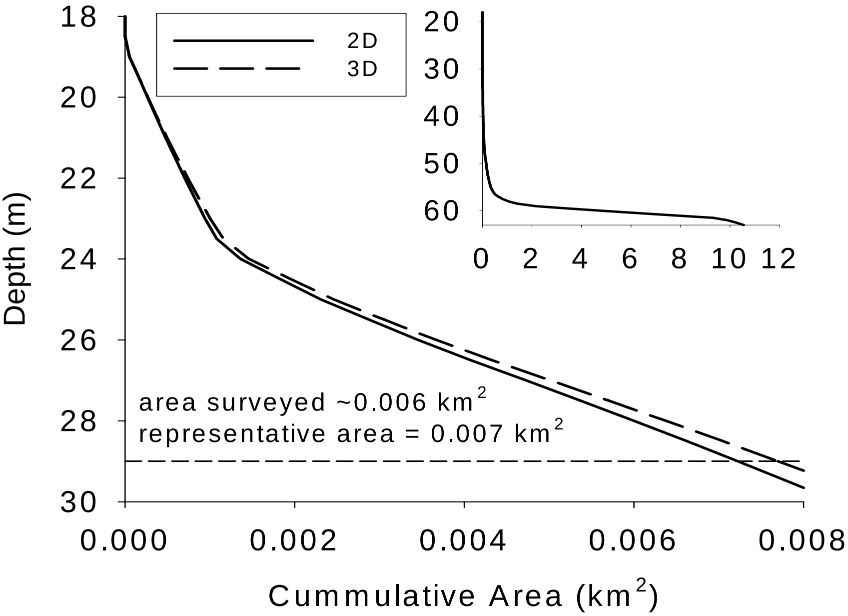

Figure 1. Hypsographic plot of depth on cumulative area (both 2-dimensional and 3-dimensional area, as denoted in the key). Horizontal dashed line represents maximum depth of SCUBA visual surveys, and inset plot shows hypsographic function for the entire bank. These plots were calculated from the bathymetry 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.

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, an ROV with forward- and down-looking digital camera was deployed 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. We also fabricated a laser array that was mounted on the ROV. Three lasers were arranged to allow us to measure the distance of objects from the ROV (two red lasers in parallel and one green laser at an angle). As part of our development of this ROV survey approach, we plan to use the lasers to quantify the size of the search area, but for this paper we report only observations on the reactions of fish to the lasers. For comparison with the SCUBA visual survey results, counts of target species from the video transects were normalized to the number of marked areas that were searched.

The species composition of the sessile benthic community was assessed by divers 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.

The age-structure of reef fish populations has been shown to vary significantly between reefs, and this phenomenon may have implications for understanding population dynamic responses to exploitation (e.g., Gust et al. 2002). We were interested in developing information on age-structure of fish populations at Sonnier Bank; therefore, with hook-and-line, we collected otolith samples from several species. We then counted annuli in otolith thin-sections, using standard otolith preparation and light microscopy techniques (see Panfili et al. 2000).

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 10000 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. There was significant over dispersion in our data; therefore, we scaled the covariance matrix by the deviance (Kleinbaum et al. 1998). We set a significance level of alpha = 0.05 prior to statistical hypothesis testing.

RESULTS

Out of our target groups, five species were regularly observed during the SCUBA surveys: Atlantic creolefish (Serranidae: *Paranthias furcifer,* n = 1,823), 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).

The highest densities observed during SCUBA visual surveys were for Atlantic creolefish followed by tomtate and rock hind (Table 1). 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 (in Table 1) except rock hind. In addition for all species, there were no interactions between depth and diver, and there were no significant differences between the four divers. 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.

Table 1. 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).

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 2). 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 2). 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 3). For gray snapper and tomtate, the proportional declines would have to be much larger: 1.6-fold and 1.8-fold, respectively (Figure 3).

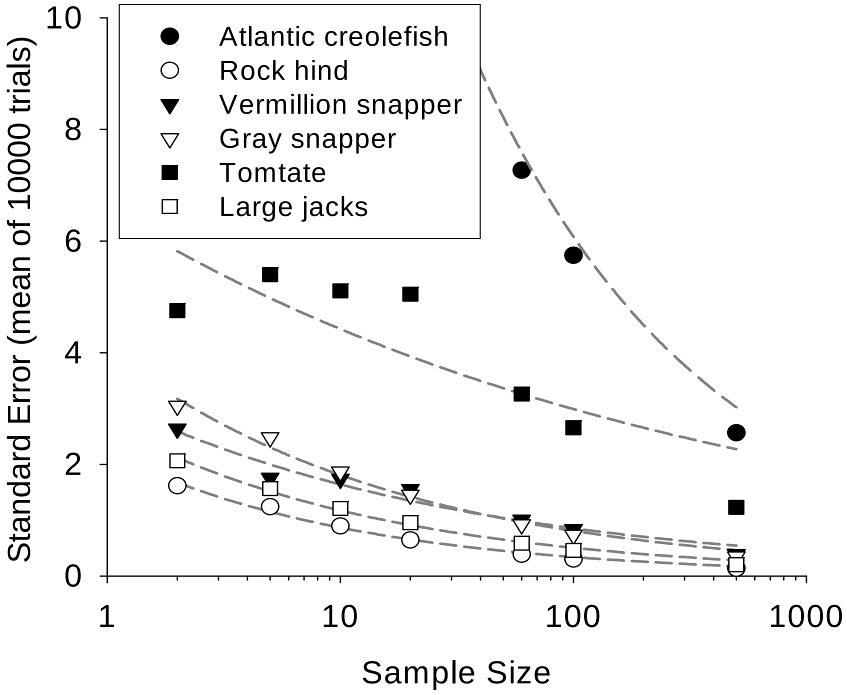

Figure 2. Re-sampling analysis results showing standard error as a function of sample size for selected species observed at Sonnier Bank. Dashed curves show power functions that were fitted to the data.

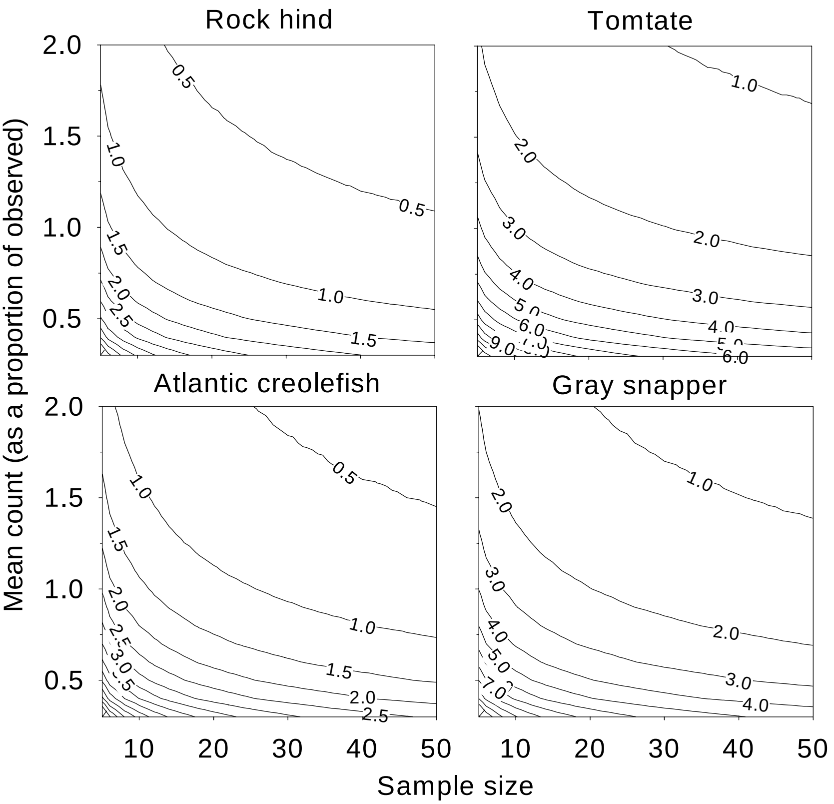

Figure 3. The minimum detectable difference (plotted as a proportion of the mean count) as a function of mean count and sample size for selected species observed at Sonnier Bank.

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 1). 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 areas 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. In addition, there was a notable reaction of some fishes to the spot projected by the green laser. For example, damsel fishes (primarily *Stegastes* spp.), bluehead wrasse (*Thalasoma bifasciatum*), and smaller rock hind frequently attacked the green laser spot when it was projected on the bottom while close to the ROV (< 4 m), and on one occasion, a rock hind was observed to eat a juvenile bluehead that was attracted to the laser spot.

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 4). Notably, some bleached *Millepora* was observed, and this phenomenon was not reported by Rezak et al. (1985).

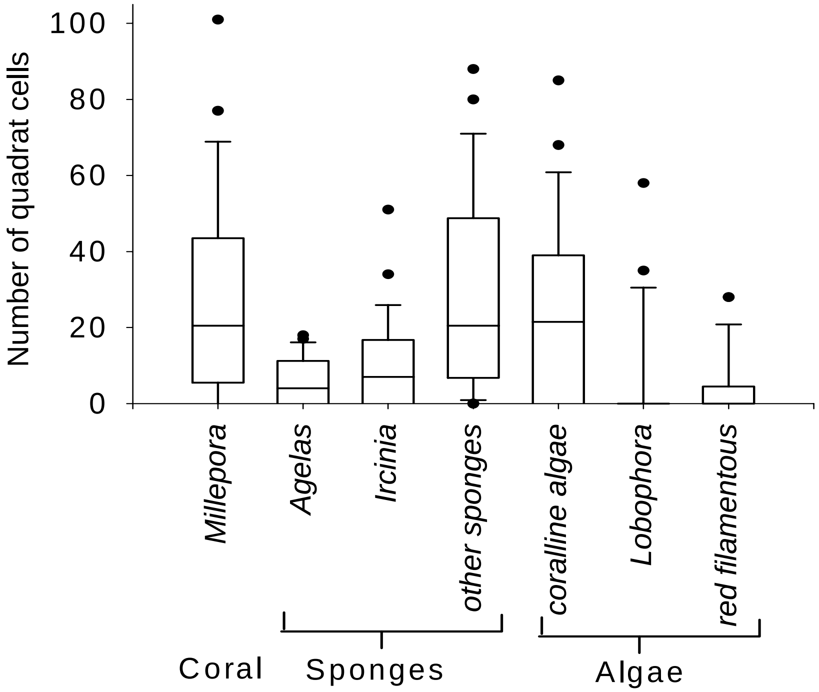

Figure 4. Incidence of major benthic organisms observed at Sonnier Bank and quantified with quadrats (see text). The box plots give median, 10th, 25th, 75th, and 90th percentiles for each taxonomic group, and the dots represent outliers.

Some of the same species observed with SCUBA and ROV were captured with hook-and-line for otolith analysis (Figure 5). The assigned ages, based upon annulus counts, showed overlapping distributions for most of the species, with ages typically between 4 and 10 years. 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.

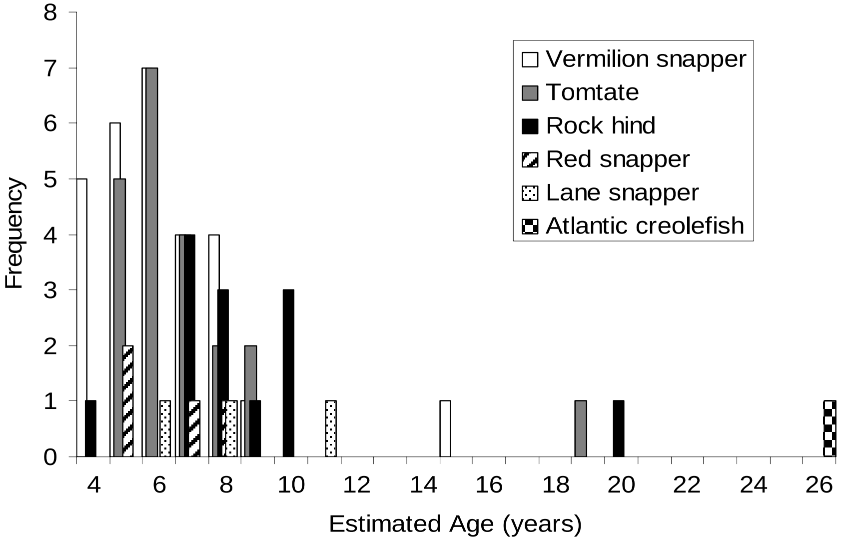

Figure 5. Age-distribution of species captured by hook-and-line at Sonnier Bank. Ages were determined by annulus counts from thin sections of otoliths.

DISCUSSION

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.

The two species, which we predict 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 ~7,000 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 five 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).

Our explorations of deeper areas (>30 m) around this main peak with the ROV, indicated that densities of lutjanids (most notably, *L. griseus*) and tomtate increased substantially, approaching similar levels to that observed for Atlantic creolefish on the crest of this peak and in accordance with the increasing (but non-significant) depth trend in the Poisson regression analysis. These deeper areas that are not accessible by SCUBA are clearly more important for the majority of exploited fish populations at Sonnier Bank, and our future efforts will concentrate on quantifying these populations by developing approaches with the ROV. Though the laser spots seem to attract or antagonize some smaller fish, the effects were most evident in the immediate vicinity of the ROV, and we have not seen any indications that this effect will bias counts of species from our target groups. Ongoing efforts to better quantify the search area of the ROV with the laser array will be a crucial part of this work.

Some other observations from these initial surveys that warrant additional study were:

i) The bleached patches of *Millepora* coral that were either not observed or recorded previously by Rezak et al. (1985), and
ii) The presence of unusually old tomtate and Atlantic creolefish.

These fish may merely represent coincidental captures of unusually old individuals. 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.

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