A Comparison of Multiple Gear Types in Sampling Red Snapper on Natural Low-Relief Reefs

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ABSTRACT

The Sustainable Fisheries Act of 1996 called for the identification and evaluation of essential fish habitat. However, the ability to make accurate estimates of fish abundance over a particular habitat is contingent upon the use of appropriate sampling methods. The objectives of this study were to compare the catch per unit area (A), the relative catchability (q-ratio), and the length-specific bias of four different gear types on sampling red snapper (*Lutjanus campechanus*) over natural low-relief reef habitats on the inner continental shelf of the northern Gulf of Mexico. Specifically, our goal was to assess the overall performance of using a standard otter trawl, a crab trap, a chevron trap, and a stationary 4-camera underwater video array during six quarterly sampling cruises performed in 2004 and 2005. Results indicate that trawls collected the most red snapper per unit area and had catchability estimates for juvenile red snapper that were three to five times greater than the crab traps. Additionally, trawls were the most selective gear for collecting juvenile and sub-adult red snapper from 30 to 250 mm total length (TL) (ages 0 and 1). The chevron trap collected the second highest number of red snapper and proved most useful at collecting red snapper from 150 to 440 mm TL (ages 1-5). The catchability of the chevron trap was three times greater than the underwater video array, which was size selective for both 100 to 150 mm TL (age 0) and 300 to 350 mm TL (ages 2-3) red snapper. The ultimate goal of the project was to provide the most appropriate survey methods for future studies that aim to collect red snapper over natural low-relief reef habitats. Our comparison has demonstrated that the chevron trap is most effective for sampling adults, while trawls appeared to be the most effective gear for sampling age 0 fish.

KEY WORDS: gear selectivity, red snapper, reef

Múltiples Tipos de Artes de Pesca y su Eficiencia para Colectar Pargos Colorados en Arrecifes Naturales

La Resolución del Congreso Estadounidense para Pesquerías Sostenibles de 1996 hizo un llamado a la identificación y evaluación de hábitat esencial para peces. Sin embargo, la capacidad para realizar estimaciones precisas en la abundancia de peces es contingente al uso de métodos de muestreo apropiados. Los objetivos de este estudio fueron comparar el área por unidad de muestreo (A), la capturabilidad relativa (q-ratio) y el sesgo en la talla de captura de cuatro tipos diferentes de artes de pesca en el muestreo de pargo colorado (*Lutjanus campechanus*) en arrecifes naturales de bajo relieve de la plataforma continental interna del norte del Golfo de México. Específicamente, nuestra meta fue evaluar el rendimiento general en la captura al utilizar una red estándar de arrastre (*otter trawl*), una trampa de cangrejo, una trampa *chevron*, y un arreglo subacuático de cámaras de video durante seis cruceros de muestreo trimestral realizados en el 2004 y en el 2005. Los resultados indicaron que las redes de arrastre colectaron el mayor número de pargos por unidad de área y presentaron estimados de capturabilidad de pargos de tres a cinco veces mayores que los estimados con trampas de cangrejo. Además, la red de arrastre fue el arte más selectivo en la colecta de pargos colorados juveniles y subadultos de 30 a 250 mm de longitud total (LT) (edades 0 y 1). La trampa chevron colectó el segundo número mayor de pargos y comprobó ser el arte más útil en la colecta de individuos de 150 a 440 mm de LT (edad 1-5). La capturabilidad de la trampa chevron fue tres veces mayor que el arreglo subacuatico de cámaras que resultó ser selectivo para pargos de tallas de 150 mm LT (edad 0) y de 300 a 350 mm LT (edades 2-3). La meta final del proyecto fue proveer los métodos más apropiados para estudios futuros que busquen colectar pargo colorado en hábitats de arrecife natural de bajo relieve. Nuestra comparación ha demostrado que la trampa chevron es la más efectiva en el muestreo de adultos, mientras que las redes de arrastre parecen ser los artes más efectivos en el muestreo de peces de edad 0.

PALABRAS CLAVES: selectividad del arte de pesca, pargo colorado, arrecife

INTRODUCTION

Proper gear selection for the specific objectives of a study is one of the most important considerations in any sampling design. Employing multiple sampling gears has increased, both for characterizing fish communities and for evaluating the relative abundance of single species across multiple habitat types, due to the size-selectivity and bias associated with individual gears (Willis *et al.* 2000, Diaz *et al.* 2003). As such, appropriate gear selection must account for deployment and processing time to aid in a sufficient sample size, while attaining adequate precision.

Characterization of habitat use patterns by organisms associated with reef habitats is difficult due to habitat complexity, the mobility and cryptic nature of many species, and ontogenetic habitat shifts (Sale and Douglas 1981, Bortone *et al.* 1989). Individual sampling techniques each have their own strengths and weaknesses when targeting specific species or size ranges. Otter trawls are a common technique for sampling demersal species, and providing relative abundance estimates of small, cryptic, and burrowing species (Harmelin-Vivien and Francour 1992, Hayes *et al.* 1996). However, low and highly variable catch efficiencies are associated with towed nets (*e.g.,* seines, trawls), and can greatly reduce the success of these mobile gear types (Orth and van Montfrans 1987, Rozas and Minello 1997). Collection devices, such as fish traps, can also be useful for targeting specific species associated with structurally complex habitats, such as coral and rocky reefs (Whitelaw *et al.* 1991, Newman and Williams 1996); however, the inability to define a sampling area and the influence of environmental parameters (*e.g.,* currents, bait plume) can affect gear performance, yet are difficult to quantify.

Underwater video camera arrays have become an increasingly common tool for characterizing marine fish assemblages (Gledhill *et al.* 1996, Willis *et al.* 2000, Cappo *et al.* 2004), and for indexing abundances of single species over a particular habitat type (Ellis and DeMartini 1995). This technique, and other video methods, is particularly desirable for estimating fish abundance when depth constraints and physical complexity of bottom topography exist (Bortone *et al.* 1986, Greene and Alevizon 1989). However, difficulties associated with video censuses are evident, such as biased estimates due to poor visibility, difficulty in species identification, fish movement that results in double counting, or avoidance and under-representation of small, cryptic species (Sale and Douglas 1981, Bohnsack and Bannerot 1986). Nevertheless, video methods offer unique advantages over more traditional methods (*e.g.,* otter trawls, diver counts) of assessing relative fish abundance as they are non-destructive and the equipment can be deployed and retrieved rapidly from depth. Thus, the use of both trawling and visual counts has been suggested to provide a good representation of the relative abundance of fishes due to the high capture success of small, benthic, and cryptic species by trawls, while large, mid-water, and more mobile species are better estimated with visual techniques (Harmelin-Vivien and Francour 1992).

Natural low-relief reef habitats in the form of reef pinnacles, banks, and ledges, as well as many artificial reefs, exist on the inner shelf of the northern Gulf of Mexico (GOM), and have been suggested to be important reef habitat for red snapper and other reef fishes (Parker *et al.* 1983, Schroeder *et al.* 1988, Szedlmayer and Shipp 1994, Patterson *et al.* 2005). However, the structural heterogeneity of these reef habitats makes it difficult to adequately sample a wide size range of the species of interest. Despite the potential importance of natural and artificial reef habitats in the northern GOM for red snapper, to date no studies have adequately addressed the effectiveness and size selectivity of different gear types on red snapper.

The goals of this study were to compare different gear types and their ability to collect red snapper over natural low-relief reef habitats. We were specifically interested in determining which gears sampled the highest catch per unit area (A). As fish grow, their vulnerability to a particular gear changes, which can affect gear efficiency. Different-sized fish are caught with varying efficiencies due to gear selectivity, catchability, or to differences in fish distribution or habitat. Thus, our objective was not to assess gear efficiency across all four gears, but rather to determine the size selectivity associated with each gear and to compare the relative catchability (q-ratio) between gears that collected similar sizes of red snapper.

MATERIALS AND METHODS

Study Site

Two natural low-relief reef habitats on the northern GOM inner continental shelf, located approximately 20 km south of Mobile Bay, Alabama, were chosen for this study. These reefs have been characterized as reef-like outcrops of rock rubble and shell hash supporting a diverse epifaunal assemblage, and are identified by the names Southeast Banks and 17 Fathom Hole on navigation charts (Schroeder *et al.* 1988).

Gear Types

Four different gear types were used to sample red snapper quarterly in 2004 and 2005 on the R/V Caretta, an 18-m research vessel operated by the National Marine Fisheries Service (NMFS) Pascagoula, Mississippi laboratory. Gear types included an otter trawl, a small fish trap, a chevron trap, and a stationary 4-camera underwater video array. Standard NMFS Fall Groundfish Survey trawl gear was used (FGS; SEAMAP Information System, NMFS, Pascagoula, MS), which included a single 12.8-m wide net with 4 cm mesh size, towed at approximately 4.6 km h-1 for 10 min, adjacent to the reef structure. An addition to the standard trawl was a 0.7cm mesh cod end lining that was added to increase gear selectivity for smaller individu-

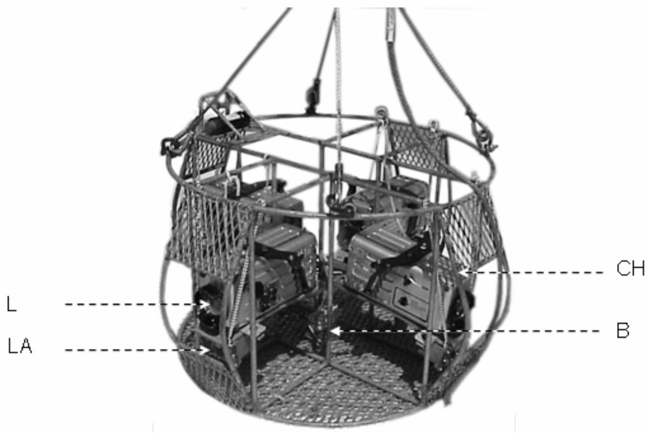

Figure 1. Baited camera array used to collect underwater video of red snapper and the fish community. Cameras were mounted inside aluminum underwater camera housings (CH) and positioned orthogonal to one another. Lenses (L) and laser arrays (LA) were positioned to provide nearly 360° of coverage. A single Atlantic menhaden (*Brevoortia tyrannus*) was placed in the bait box (B) during each deployment.

als. The small fish trap (dimensions: 64 cm width x 60 cm length x 43 cm height, mesh: 2.2 cm plastic coated wire) and the chevron trap (dimensions: 150 cm width x 180 cm length x 60 cm height, opening: 10 cm x 5 cm, mesh: 3.8 cm plastic coated wire) were each soaked on a reef for a two hour period. The camera array consisted of four Sony DCR-VX1000 digital video camcorders housed in aluminum underwater housings (Figure 1). Cameras were positioned orthogonal to one another at a height of 25 cm above the bottom of the camera rig to provide a nearly 360° view. Each camera had a 72.5° viewing angle with an approximate viewing distance of 5 m, resulting in an estimated viewing volume of 70.4 m3 (Rademacher and Render 2003). In addition, two parallel-beam lasers placed 10 cm apart were attached below each camera to aid in estimating lengths of observed fish to the nearest cm. The camera array was deployed for a 30-min period and was baited with a single Atlantic menhaden (Brevoortia tyrannus), which was replaced after each deployment. All sampling was performed during daylight hours (30 minutes after sunrise to 30 minutes before sunset).

Data Analysis

Estimates of catch per unit area (A) were calculated for each gear type (g:, where i=trawl, small fish trap, chevron trap, and video) at each survey station. Sampling areas were calculated for each gear type and resulted in an estimated 9,813 m^2 covered by each trawl sample, and 7,854 m^2 by each trap and underwater video sample. We calculated the area sampled by the traps and video array using an estimate of 50 m as a radius of influence (Lokkeborg *et al.* 1995), using the area of a circle (πr^2). Catch per unit area (A_i) was calculated as the percent catch for each gear type divided by the percent area covered by each gear using the following equation:

$$A_i = ((catch_i / \Sigma\ catch)*100) / ((area_i / \Sigma\ area)*100)$$

Gear-specific vulnerability of red snapper was compared using length-frequency distributions. Red snapper length-frequency data were binned by 10 mm size classes for each gear type and were compared with Kolmogorov-Smirnov (KS) two-sample tests (Sokal and Rohlf 1995). Red snapper also were grouped according to their corresponding age class estimated from length with a von Bertalanffy growth function developed using red snapper from this study (R.J.D.W., unpublished data). In addition, size distributions of the fish community (excluding red snapper) were compared to red snapper sizes by each gear type to assess if the size bias was gear or species-specific.

Relative catchability (q-ratio) estimates were compared between gears that targeted similar sizes of red snapper over the same habitat, thus sampling the same operative population. Catchability estimates were obtained using the average catch of each gear type during all quarters. Specifically, catchability comparisons were made between the trawl and small fish trap, and between the underwater video and chevron trap, using the following equation from Arreguin-Sanchez and Pitcher (1999):

$$C_i = q_i s E_i N$$

where C_i is the total catch by gear type i, q_i is the catchability coefficient of gear type i, s is the probability of gear selection, E_i is the effort (area sampled) of gear type i, and N is the operative population the gear is sampling. We assumed the operative population (N) and the selectivity (s) were equal between gears that targeted similar sizes of red snapper on the same habitat. Thus, for gear i, $C_i = q_i s E_i N$, and for gear j, $C_j = q_j s E_j N$. Therefore solving for the relative catchability (q-ratio) gives the following equation:

$$q_i/q_j = C_i E_j / C_j E_i$$

RESULTS

Data from the six sampling cruises were used to compute gear comparison statistics. A total of 756 red snapper was collected or observed using the four gear types during the study. The total number of red snapper sampled varied by gear type, with the highest percentage of red snapper sampled with trawls (69.3%), followed by the chevron trap (19.3%), the video array (6.8%), and the small fish trap (4.6%).

Estimates of A were greatest with trawls compared to other gear types for both red snapper and other members of the fish community (Figures 2 and 3). The high A calculated from the trawl catches was consistent between reef sites. In addition, estimates of A showed similar patterns when analyzing only red snapper, or the fish community (excluding red snapper) (Figures 2 and 3). The second highest A was calculated from the chevron trap, but the number of red snapper collected per unit of area between reef sites ranged from nearly equal (Southeast Banks) to over 6-fold fewer (17 Fathom Hole) than the corresponding trawl samples. Overall, the small fish trap and underwater video had the lowest estimates of A.

Red snapper length distributions were significantly different among gears, regardless of the sampling location (KS tests: $P<0.05$; Figures 2 and 3). The smallest red snapper were collected using the trawl (primarily between 30-250 mm TL), followed by the small fish trap (150-250 mm TL), the underwater video array (100-150 and 300-350 mm TL), and the largest red snapper were consistently collected

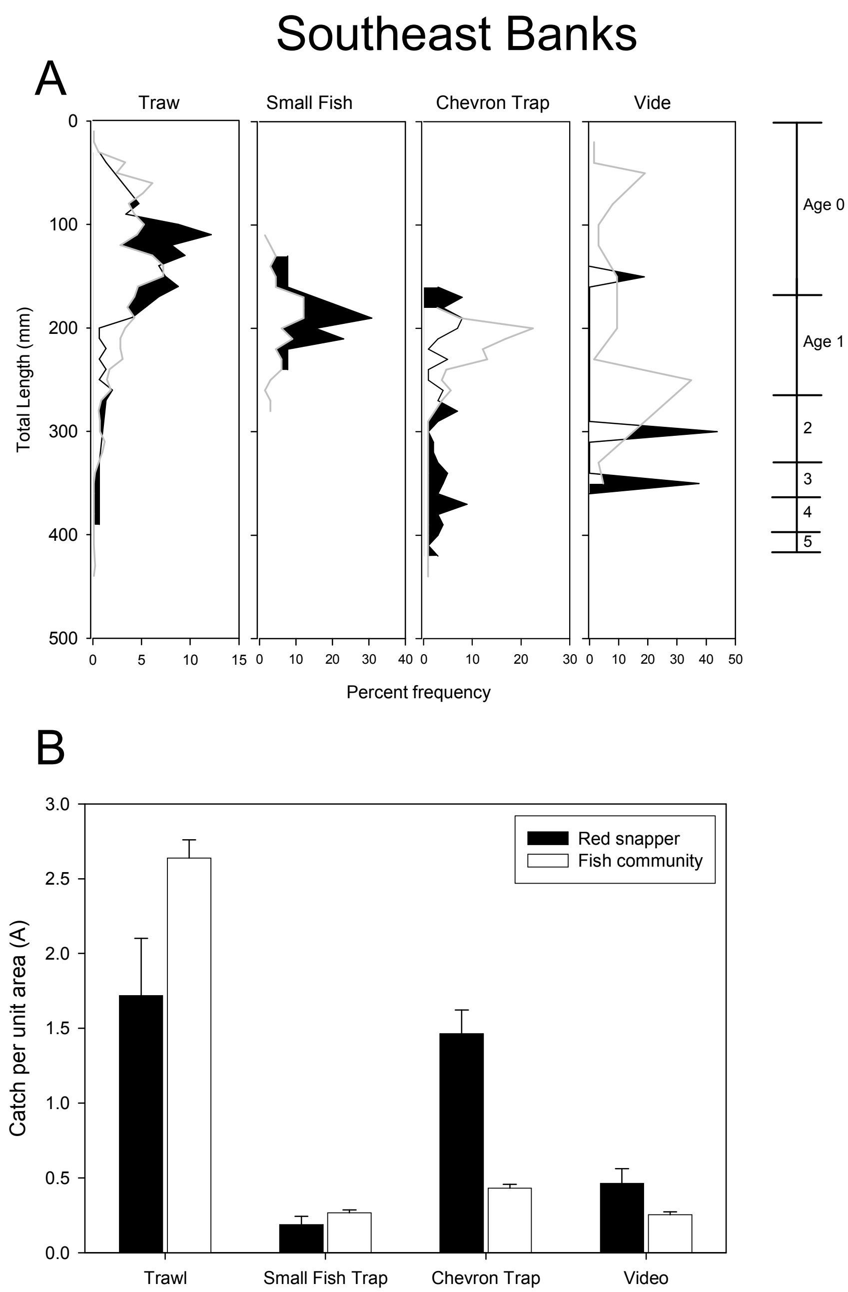

Figure 2. (A) Size frequency distributions of red snapper and the fish community (excluding red snapper) collected by each gear type at Southeast Banks. Age-at-size bins are shown for red snapper and were based upon a von Bertalanffy model from otolith microstructure analysis. (B) Relative catch per unit area (A_i) by gear type at Southeast Banks for red snapper and for the fish community (excluding red snapper) (± 1 SE).

using the chevron trap (150-440 mm TL) (Figures 2 and 3). Further, age 0 red snapper were most abundant in the trawl, and both age 0 and age 1 red snapper were abundant in the small fish trap. Red snapper observed using the underwater video ranged from age 0 to age 3, and the chevron trap sampled red snapper primarily between ages 1 and 5. The trawl sampled the widest size-at-age range of all gears, while the small fish trap appeared to be the most size selective (Figures 2 and 3). Qualitatively, size distributions between red snapper and all other fishes showed high overlap by gear type (Figures 2 and 3); however, non-significant size differences were observed only with the

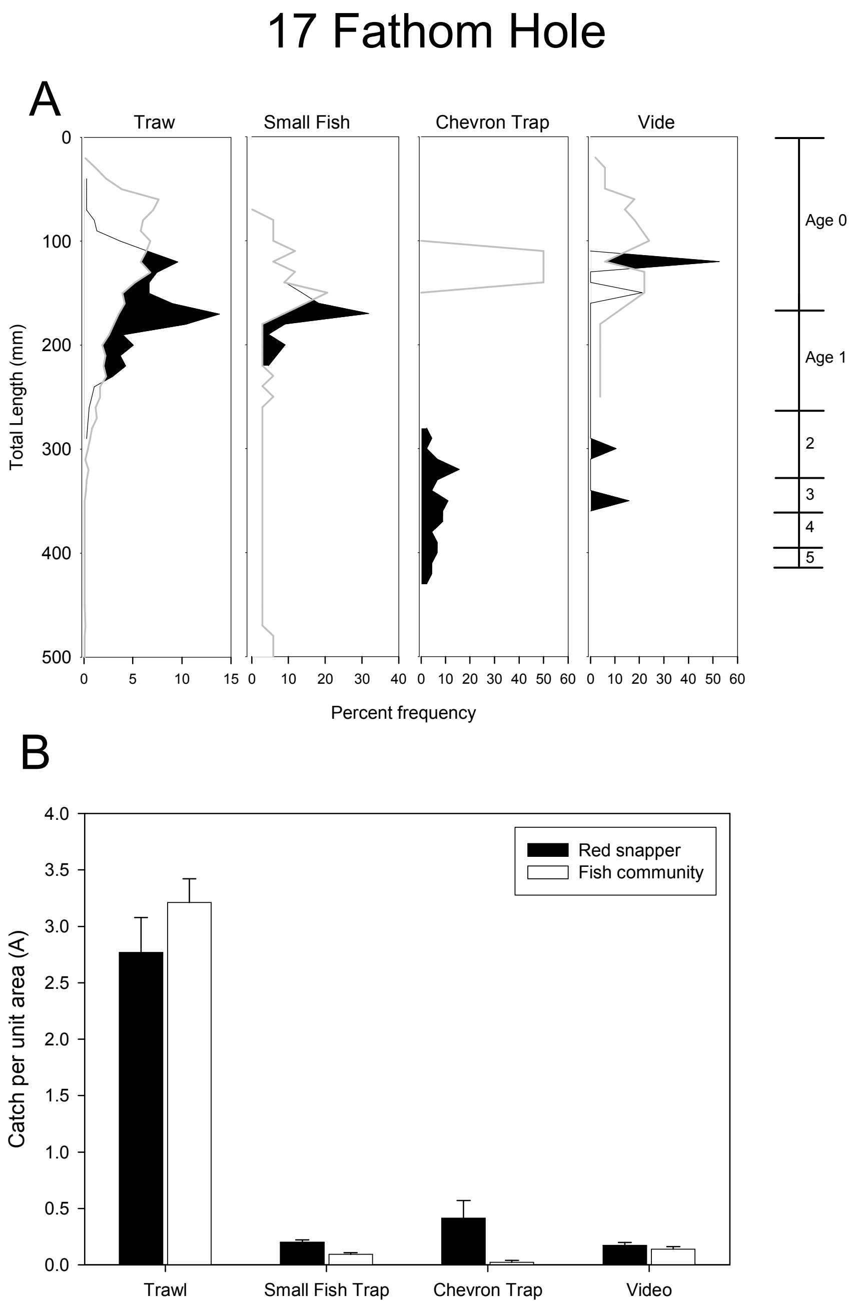

Figure 3. (A) Size frequency distributions of red snapper and the fish community (excluding red snapper) collected by each gear type at 17 Fathom Hole. Age-at-size bins are shown for red snapper and were based upon a von Bertalanffy model from otolith microstructure analysis. (B) Relative catch per unit area (A_i) by gear type at 17 Fathom Hole for red snapper and for the fish community (excluding red snapper) (± 1 SE).

small fish trap at each sampling location (KS tests: SEB: P=0.2798, 17FH: P=0.1744).

Relative catchability (q-ratio) comparisons between gears that target similar sizes of red snapper indicate that the trawl and chevron trap have high catchabilities for juvenile (ages 0-1) and adult (ages 2-5) red snapper, respectively. The q-ratio of the trawl to the small fish trap was 5.6 at Southeast Banks and 2.9 at 17 Fathom Hole, indicating the trawl was between three to five times more effective at sampling juvenile red snapper than the small fish trap (ages 0-1). In addition, the q-ratio of the chevron trap to the underwater video was 3.5 at Southeast Banks and 2.7 at 17 Fathom Hole, thus the chevron trap was approximately three times more effective at sampling larger, older red snapper (ages 2-5).

DISCUSSION

Our results show that trawls numerically sample the most red snapper per unit area when compared to the small fish trap, chevron trap, and underwater video array on natural low-relief reefs in the northern GOM. However, each gear type is size-selective, with the trawl capturing the smallest red snapper and the chevron trap capturing the largest red snapper. Thus, the overall effectiveness of a gear for collecting red snapper over natural low-relief reefs is size dependent. Trawling has the highest catchability for sampling juvenile red snapper, while the chevron trap best estimates the relative abundance of larger red snapper.

The gear-dependent size selectivity in our study is consistent with similar studies that have used multiple gear types (Willis *et al.* 2000). Otway *et al.* (1996) found demersal trawls caught 65% of the entire catch of snapper, *Pagrus auratus*, off Sydney, Australia; however, these fish were significantly smaller than those collected with concurrent longline sampling. In our study, trawls collected the widest size range of red snapper, and appeared effective at collecting the smallest individuals associated with the reef habitat. These results are likely a function of the relative availability of many age 0 red snapper versus the fewer older fish that survive to older ages (age 2 and older). In addition, despite significant differences between the red snapper and fish community size distributions by gear type (except small fish traps), the size distributions demonstrated good concordance in most cases, thus indicating that these gear types are size-selective across species. This finding makes our estimates more robust for the entire fish community.

Assumptions about the operative area sampled by the stationary gear types affects our catchability estimates. We assumed the stationary gears sampled a 50 m radius, but estimates would have underestimated red snapper densities if smaller areas were effectively sampled, and overestimated the counts if effective areas were larger. In addition, we assumed a circular sampling area, but a semicircular area may be more realistic due to the bait plume being affected by directional currents. Thus, studies that aim to compare across mobile and stationary gears need to incorporate the operative sampling area. In addition, studies need to account for the effects that baited gears have on fish behavior and the associated environmental parameters that may affect fish detectability (Stoner 2004).

The use of multiple gear types in this study has shown that a wide size spectrum of red snapper utilize natural low-relief reef habitat on the GOM inner continental shelf. Previous studies investigating red snapper habitat use have shown that sub-adult and adult red snapper are associated with reef habitat, while smaller conspecifics are found over mud, sand, and shell-rubble (Moseley 1966, Bradley and Bryan 1975, Rooker *et al.* 2004, Patterson *et al.* 2005). In addition, differences in age-specific habitat use may be attributed to the agonistic behavior by adults toward younger conspecifics (Bailey *et al.* 2001). Workman et al. (2002) reported that age 0 red snapper preferred reef structures, but recruitment to these structures was limited by the presence of older age 1 conspecifics. The trawls were likely sampling small red snapper adjacent to the reef structure that were either displaced or precluded from the reef by older red snapper; nevertheless, the use of multiple gear types has provided a more complete image of red snapper habitat use than if only one gear type had been used. The use of multiple gear types is therefore essential to understand life histories of species that utilize different habitats.

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LITERATURE CITED

Arreguin-Sanchez, F. and T. J. Pitcher. 1999. Catchability estimates and their application to the red grouper (*Epinephelus morio*) fishery of the Campeche Bank, Mexico. *Fishery Bulletin* **97**:746-757.

Bailey, H. K., J. H. Cowan, Jr. and R. L. Shipp. 2001. Experimental evaluation of potential effects of habitat size and presence of conspecifics on habitat association by young-of-the-year red snapper. *Gulf of Mexico Science* **2**:119-131.

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, Seattle, Washington.

Bortone, S. A., R. W. Hastings, and J. L. Oglesby. 1986. Quantification of reef fish assemblages: comparison of several in situ methods. *Northeast Gulf Science* **8**:1-

22.

Bortone, S. A., J. J. Kimmel, and C. M. Brundrick. 1989. A comparison of three methods for visually assessing reef fish communities: time and area compensated. *Northeast Gulf Science* **10**:85-96.

Bradley, E. and C. E. Bryan. 1975. Life history and fishery of the red snapper (*Lutjanus campechanus*) in the northwestern Gulf of Mexico: 1970-1974. *Proceedings of the Gulf and Caribbean Fisheries Institute* **27**:77-106.

Cappo, M., P. Speare, and G. De'ath. 2004. Comparison of baited remote underwater video stations (BRUVS) and prawn (shrimp) trawls for assessments of fish biodiversity in inter-reefal areas of the Great Barrier Reef Marine Park. *Journal of Experimental Marine Biology and Ecology* **302**:123-152.

Diaz, R. J., G. R. Cutter, Jr., and K. W. Able. 2003. The importance of physical and biogenic structure to juvenile fishes on the shallow inner continental shelf. *Estuaries* **26**:12-20.

Ellis, D. M., and E. E. DeMartini. 1995. Evaluation of a video camera technique for indexing abundances of juvenile pink snapper, *Pristipomoides filamentosus*, and other Hawaiian insular shelf fishes. *Fishery Bulletin* **93**:67-77.

Gledhill, C. T., J. Lyczkowski-Shultz, K. Rademacher, E. Kargard, G. Crist, and M. A. Grace. 1996. Evaluation of video and acoustic index methods for assessing reef-fish populations. *ICES Journal of Marine Science* **53**:483-485.

Greene, L. E., and W. S. Alevizon. 1989. Comparative accuracies of visual assessment methods for coral reef fishes. *Bulletin of Marine Science* **44**:899-912.

Harmelin-Vivien, M. L. and P. Francour. 1992. Trawling or visual censuses? Methodological bias in the assessment of fish populations in seagrass beds. *P.S.Z.N.I: Marine Ecology* **13**:41-51.

Hayes, D. B., C. P. Ferreri, and W. W. Taylor. 1996. Active Fish Capture Methods. Pages 193-220 *in*: B.R. Murphy and D.W. Willis, editors. Fisheries Techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Lokkeborg, S., B. L. Olla, W. H. Pearson, and M. W. Davis. 1995. Behavioural responses of sablefish, *Anoplopoma fimbria*, to bait odour. *Journal of Fish Biology* **46**:142-155.

Moseley, F. N. 1966. Biology of the red snapper, *Lutjanus aya* Bloch, of the northwestern Gulf of Mexico. *Publications of the Institute of Marine Science* **11**:90-101.

Newman, S. J. and D. M. Williams. 1996. Variation in reef associated assemblages of the Lutjanidae and Lethrinidae at different distances offshore in the central Great Barrier Reef. *Environmental Biology of Fishes* **46**:123-138.

Orth, R. J. and J. van Montfrans. 1987. Utilization of a seagrass meadow and tidal marsh creek by blue crabs, *Callinectes sapidus*. I. Seasonal and annual variation in abundance with emphasis on post-settlement juveniles. *Marine Ecology Progress Series* **41**:283-294.

Otway, N. M., J. R. Craig, and J. M. Upston. 1996. Gear-dependent size selection of snapper, *Pagrus auratus*. *Fisheries Research* **28**:119-132.

Parker, R. O., D. R. Colby, and T. D. Willis. 1983. Estimated amount of reef habitat on a portion of the U.S South Atlantic and Gulf of Mexico continental shelf. *Bulletin of Marine Science* **33**:935-940.

Patterson, W. F., C. A. Wilson, S. J. Bentley, J. H. Cowan, Jr., T. Henwood, Y. C. Allen, and T. A. Dufrene. 2005. Delineating juvenile red snapper habitat on the northern Gulf of Mexico continental shelf. Pages 277-288 *in*: P.W. Barnes and J.P. Thomas, editors. Benthic habitats and the effects of fishing. American Fisheries Society, Symposium 41, Bethesda, Maryland.

Rademacher, K. R. and J. H. Render. 2003. Fish assemblages around oil and gas platforms in the Northeastern Gulf of Mexico: developing a survey design. Pages 101-122 *in*: D.R. Stanley and A. Scarborough-Bull, editors. Fisheries, reefs, and offshore development. American Fisheries Society, Symposium 36, Bethesda, Maryland.

Rooker, J. R., A. M. Landry, B. W. Geary, and J. A. Harper. 2004. Assessment of a shell bank and associated substrates as nursery habitat of postsettlement red snapper. *Estuarine, Coastal and Shelf Science* **59**:653-661.

Rozas, L. P. and T. J. Minello. 1997. Estimating densities of small fishes and decapod crustaceans in shallow estuarine habitats: a review of sampling design with focus on gear selection. *Estuaries* **20**:199-213.

Sale, P. F. and W. A. Douglas. 1981. Precision and accuracy of visual census techniques for fish assemblages on coral patch reefs. *Environmental Biology of Fishes* **6**:333-339.

Schroeder, W. W., A. W. Shultz, and J. J. Dindo. 1988. Inner-shelf hardbottom areas, northeastern Gulf of Mexico. *Gulf Coast Association of Geological Societies Transaction* **38**:535-541.

Sokal, R. R. and F. J. Rohlf. 1995. Biometry: the principles and practice of statistics in biological research, 3rd ed., W.H. Freeman and Co., New York, New York. 887 pp.

Stoner, A. W. 2004. Effects of environmental variables on fish feeding ecology: implications for the performance of baited fishing gear and stock assessment. *Journal of Fish Biology* **65**:1445-1471.

Szedlmayer, S. T., and R. L. Shipp. 1994. Movement and growth of red snapper, *Lutjanus campechanus*, from an artificial reef area in the northeastern Gulf of Mexico. *Bulletin of Marine Science* **55**:887-896.

Whitelaw, A. W., K. J. Sainsbury, G. J. Dews, and R. A. Campbell. 1991. Catching characteristics of four fish trap types on the Northwest shelf of Australia. *Austra-*

lian Journal of Marine and Freshwater Research **42**:369-382.

Willis, T. J., R. B. Millar, and R. C. Babcock. 2000. Detection of spatial variability in relative density of fishes: comparison of visual census, angling, and baited underwater video. *Marine Ecology Progress Series* **198**:249-260.

Workman, I., A. Shah, D. Foster, and B. Hataway. 2002. Habitat preferences and site fidelity of juvenile red snapper (*Lutjanus campechanus*). *ICES Journal of Marine Science* **59**:S43-S50.