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Short communication

Size selectivity of sampling gears targeting red snapper in the northern Gulf of Mexico

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Abstract

The ability to estimate fish abundance accurately 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), length-specific bias, and relative catchability (q-ratio) of four different gear types for 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 a standard otter trawl, a small fish trap, a chevron trap, and a stationary 4-camera underwater video array during six quarterly sampling cruises performed in 2004 and 2005. The sizes of snapper captured by trawls ranged from 30 to 250 mm total length (TL) (ages 0 and 1 yr). Trawls captured the most red snapper per unit area and had q-ratios of 3:1 to 5:1 relative to small fish traps for juvenile red snapper. 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 yr). The q-ratio of the chevron trap relative to the underwater video array was approximately 3:1. Our comparison demonstrated the chevron trap is most effective for sampling adults, while trawls were the most effective gear for sampling age-0 yr fish.

Keywords: Gear selectivity; Red snapper; Reef; Traps; Trawls; Underwater video

1. Introduction

Proper gear selection for the specific objectives of a study is one of the most important considerations in any sampling design. The use of multiple sampling gears within a single study 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.

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, towed nets (e.g., seines, trawls) have low and highly variable catch efficiencies that can greatly reduce the success of 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 (Stoner, 2004).

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 is particularly desirable for estimating fish abundance when depth constraints and physical complexity of bottom topography exist

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(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) of assessing relative fish abundance as they are non-destructive and the equipment can be deployed and retrieved rapidly from depth.

Natural low-relief reef habitats in the form of 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 the size selectivity associated with each gear and to compare the relative catchability (q-ratio) between gears that collected similar sizes of red snapper.

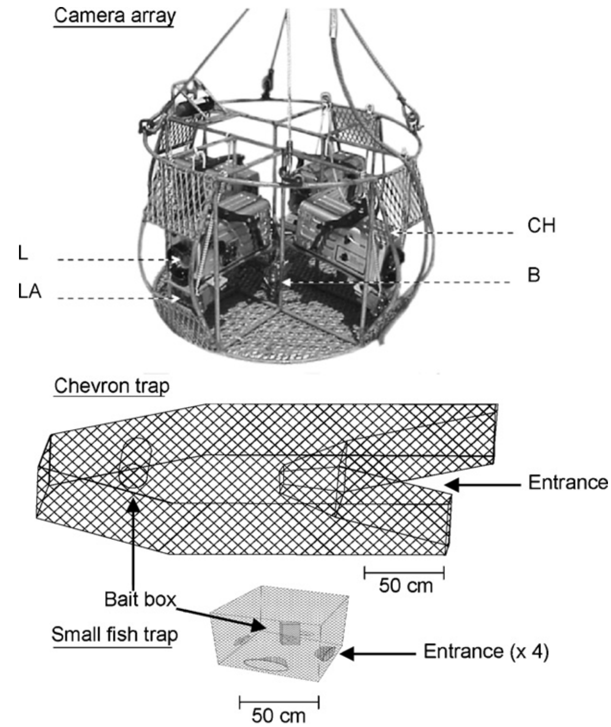

Fig. 1. Baited underwater camera array, chevron trap, and small fish trap used to observe and collect red snapper and the fish community. Cameras were mounted inside aluminum underwater camera housings (CH) and positioned orthogonal to one another. Lenses (L) and laser arrays (LA) were positioned to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

2. Materials and methods

2.1. 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 (Schroeder et al., 1988), and are located in water depths between 25 and 32 m.

2.2. Gear types

Four different gear types were used to sample red snapper quarterly in 2004 and 2005. Gear types included an otter trawl, a small fish trap, a chevron trap, and a stationary 4-camera underwater video array. Standard National Marine Fisheries Service (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. An addition to the standard trawl was a 0.7 cm mesh cod end lining that was sewn inside the cod end to increase gear selectivity for smaller individuals. The small fish trap (dimensions: 64 cm width × 60 cm length × 43 cm height, mesh: 2.2 cm plastic coated wire) and the chevron trap (dimensions: 150 cm width × 180 cm length × 60 cm height, opening: 10 cm × 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 and was deployed for a 30 min period (Fig. 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 m^3 (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. Traps and the camera array were each baited with a single Atlantic menhaden (*Brevoortia tyrannus*), which was replaced after each deployment. All sampling was performed during daylight hours (30 min after sunrise to 30 min before sunset).

2.3. Data analysis

Estimates of catch per unit area (A) were calculated for each gear type at each survey station. Sampling areas were calculated for each gear type and resulted in an estimated 9813 m^2 covered by each trawl sample, and 7854 m^2 by each trap and underwater video sample. We calculated the area sampled by the traps and video array by assuming a circular area of influence with a 50 m radius (Lokkeborg et al., 1995). Catch per unit area (A_i) for each gear relative to the total catch was calculated as the catch of gear i divided by the area sampled by that gear expressed as a proportion of the catch per area sampled over all gears:

$$A_i = \frac{\text{catch}_i/\text{area sampled}_i}{\sum_i \text{catch}_i / \sum_i \text{area sampled}_i}$$

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 based on age estimates obtained from sagittal otoliths (Wells, 2007). 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.

To compute the q-ratio (relative catchability) between two gears, we began with the catchability equation from Arreguin-Sanchez and Pitcher (1999):

$$A_i = q_i s_i N$$

where q is the catchability coefficient of the gear, s is the probability of gear selection, and N is the operative population the gear is sampling. We assumed the operative population size (N) and selectivity (s) were equal between gears that captured similar sizes of red snapper within the same habitat. Therefore, by reorganization, the relative catchability equals:

$$\frac{q_i}{q_j} = \frac{A_i}{A_j}$$

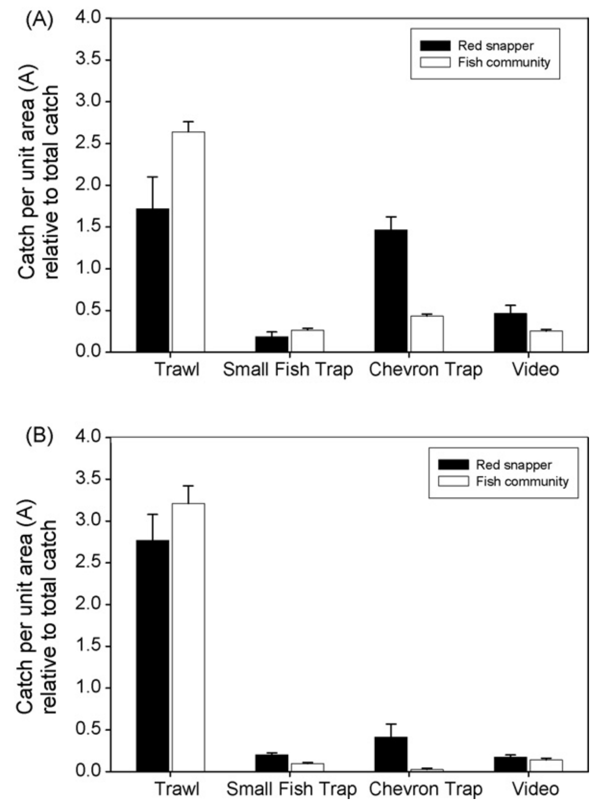

Fig. 2. Catch per unit area (A_i) (±1 S.E.) relative to the total catch by gear type at Southeast Banks (A) and 17 Fathom Hole (B) for red snapper (black bars) and the fish community (white bars) (excluding red snapper).

3. 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 (Fig. 2). 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) (Fig. 2). 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 five-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: $P < 0.05$; Fig. 3). The smallest red snapper were collected using the trawl (primarily between 30 and 250 mm TL), followed by the small fish trap (125–250 mm TL), the underwater video array (125–350 mm TL), and the largest red snapper were consistently collected using the chevron trap (150–440 mm TL) (Fig. 3). Age-0 yr red snapper were most abundant in trawl samples (ranging from age-0 to age-4 yr), and only age-0 yr and age-1 yr red snapper were found in small fish trap samples. Red snapper observed using the underwater video ranged from age-0 to age-3 yr, and the chevron trap sampled red snapper primarily between ages 1 and 5 yr. The trawl sampled the widest size range of all gears, while the small fish trap appeared to be the most size selective (Fig. 3). Qualitatively, size distributions between red snapper and all other fishes showed high overlap by gear type (Fig. 3); however, non-significant size differences were observed with the small fish trap at each sampling location (KS tests: SEB: $P = 0.2798$, 17FH: $P = 0.1744$).

Relative catchability estimates were computed between gears deployed over the same habitat and for which similar size classes of red snapper were vulnerable. Specifically, relative catchability comparisons were made between the trawl and small fish trap, and between the underwater video and chevron trap. Catchability estimates were obtained using the average catch of each gear type during all quarters. Relative catchability comparisons of red snapper indicate that the trawl and chevron trap have high relative catchabilities for juvenile (ages 0–1 yr) and adult (ages 2–5 yr) 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 approximately three to five times more effective at sampling juvenile red snapper than the small fish trap (ages 0–1 yr). In addition, the q-ratio of the chevron trap

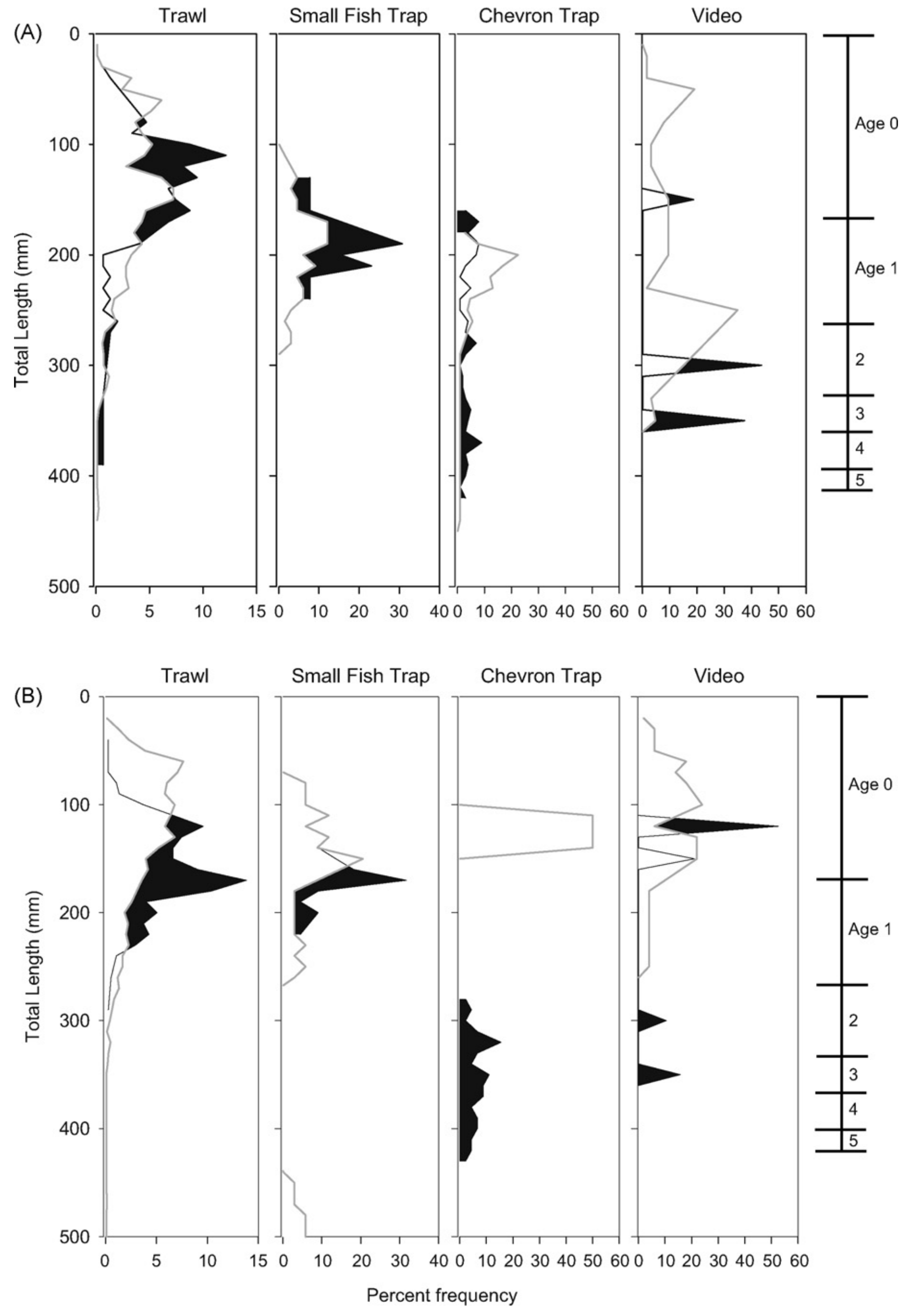

Fig. 3. Size frequency distributions of red snapper (black) and the fish community (white) (excluding red snapper) collected by each gear type at Southeast Banks (A) and 17 Fathom Hole (B). Age-at-size bins are also shown for red snapper.

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 yr).

4. Discussion

Our results show that numerically trawls 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 relative 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 consequence of the relative availability of many age-0 yr red snapper versus the fewer older fish that survive to older ages (age-2 yr 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 similarly size-selective across species.

Assumptions about the operative area sampled by the stationary gear types clearly affected our catchability estimates. We assumed the stationary gears sampled 50 m radii using estimates from other studies (Lokkeborg et al., 1995; Lokkeborg, 1998), but this 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 appropriate 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 assumption of equal selectivity between gears targeting similar sizes of red snapper may also affect our relative catchability estimates. Selectivity of the video array will be 1.0 as all fish within the viewing volume will be detected. In contrast, both traps and trawls likely have lower selectivities due to both avoidance and gear escapement. Nonetheless, our catchability estimates are conservative because the chevron trap was found to be between three and five times more effective at sampling larger red snapper. Given considerable gear escapement occurred and could be accounted for, the chevron trap would have a higher relative catchability than estimated in our study.

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). The trawls were likely sampling small red snapper both on and 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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References

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

Bailey, H.K., Cowan Jr., J.H., Shipp, R.L., 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 Mex. Sci. 2, 119–131.

Bohnsack, J.A., Bannerot, S.P., 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., Hastings, R.W., Oglesby, J.L., 1986. Quantification of reef fish assemblages: comparison of several *in situ* methods. Northeast Gulf Sci. 8, 1–22.

Bradley, E., Bryan, C.E., 1975. Life history and fishery of the red snapper (*Lutjanus campechanus*) in the northwestern Gulf of Mexico: 1970–1974. Proc. Gulf Caribb. Fish. Inst. 27, 77–106.

Cappo, M., Speare, P., De'ath, G., 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. J. Exp. Mar. Biol. Ecol. 302, 123–152.

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

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

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

Greene, L.E., Alevizon, W.S., 1989. Comparative accuracies of visual assessment methods for coral reef fishes. Bull. Mar. Sci. 44, 899–912.

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

Hayes, D.B., Ferreri, C.P., Taylor, W.W., 1996. Active fish capture methods. In: Murphy, B.R., Willis, D.W. (Eds.), Fisheries Techniques. American Fisheries Society, Maryland, pp. 193–220.

Lokkeborg, S., Olla, B.L., Pearson, W.H., Davis, M.W., 1995. Behavioural responses of sablefish, *Anoplopoma fimbria*, to bait odour. J. Fish Biol. 46, 142–155.

Lokkeborg, S., 1998. Feeding behavior of cod. *Gadus morhua*: activity rhythm and chemically mediated food search. Anim. Behav. 56, 371–378.

Moseley, F.N., 1966. Biology of the red snapper, *Lutjanus aya* Bloch, of the northwestern Gulf of Mexico. Publ. Inst. Mar. Sci. 11, 90–101.

Newman, S.J., Williams, D.M., 1996. Variation in reef associated assemblages of the Lutjanidae and Lethrinidae at different distances offshore in the central Great Barrier Reef. Environ. Biol. Fish. 46, 123–138.

Orth, R.J., van Montfrans, J., 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. Mar. Ecol. Prog. Ser. 41, 283–294.

Otway, N.M., Craig, J.R., Upston, J.M., 1996. Gear-dependent size selection of snapper, *Pagrus auratus*. Fish. Res. 28, 119–132.

Parker, R.O., Colby, D.R., Willis, T.D., 1983. Estimated amount of reef habitat on a portion of the U.S. South Atlantic and Gulf of Mexico continental shelf. Bull. Mar. Sci. 33, 935–940.

Patterson, W.F., Wilson, C.A., Bentley, S.J., Cowan Jr., J.H., Henwood, T., Allen, Y.C., Dufrene, T.A., 2005. Delineating juvenile red snapper habitat on the northern Gulf of Mexico continental shelf. In: Barnes, P.W., Thomas, J.P. (Eds.), Benthic Habitats and the Effects of Fishing, Am. Fish. Soc. Symp., vol. 41, pp. 277–288.

Rademacher, K.R., Render, J.H., 2003. Fish assemblages around oil and gas platforms in the Northeastern Gulf of Mexico: developing a survey design. In: Stanley, D.R., Scarborough-Bull, A. (Eds.), Fisheries, Reefs, and Offshore Development, Am. Fish. Soc. Symp., vol. 36, pp. 101–122.

Rooker, J.R., Landry, A.M., Geary, B.W., Harper, J.A., 2004. Assessment of a shell bank and associated substrates as nursery habitat of postsettlement red snapper. Est. Coast. Shelf Sci. 59, 653–661.

Rozas, L.P., Minello, T.J., 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., Douglas, W.A., 1981. Precision and accuracy of visual census techniques for fish assemblages on coral patch reefs. Environ. Biol. Fish. 6, 333–339.

Schroeder, W.W., Shultz, A.W., Dindo, J.J., 1988. Inner-shelf hardbottom areas, northeastern Gulf of Mexico. Gulf Coast Assoc. Geol. Soc. Trans. 38, 535–541.

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

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

Szedlmayer, S.T., Shipp, R.L., 1994. Movement and growth of red snapper, *Lutjanus campechanus*, from an artificial reef area in the northeastern Gulf of Mexico. Bull. Mar. Sci. 55, 887–896.

Wells, R.J.D., 2007. The effects of trawling and habitat use on red snapper and the associated community. Ph.D. dissertation. Louisiana State University, Baton Rouge, LA.

Whitelaw, A.W., Sainsbury, K.J., Dews, G.J., Campbell, R.A., 1991. Catching characteristics of four fish trap types on the Northwest shelf of Australia. Aust. J. Mar. Freshw. Res. 42, 369–382.

Willis, T.J., Millar, R.B., Babcock, R.C., 2000. Detection of spatial variability in relative density of fishes: comparison of visual census, angling, and baited underwater video. Mar. Ecol. Prog. Ser. 198, 249–260.

Workman, I., Shah, A., Foster, D., Hataway, B., 2002. Habitat preferences and site fidelity of juvenile red snapper (*Lutjanus campechanus*). ICES J. Mar. Sci. 59, S43–S50.