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Distribution, Abundance, and Age Structure of Red Snapper (*Lutjanus campechanus*) Caught on Research Longlines in U.S. Gulf of Mexico

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Two pilot surveys were conducted in the northern Gulf of Mexico (Gulf) to determine the feasibility of sampling red snapper (*Lutjanus campechanus*) populations in offshore waters with bottom longline gear. The first pilot survey off Mississippi–Alabama was conducted in May 1999 and yielded a total of seven snapper from 60 stations. The second pilot survey was off Texas in June 2000 and yielded a total of 76 snapper from 44 stations. The catch per unit effort was 0.12 red snapper/100 hook hr [coefficient of variation (CV) = 0.54] in 1999 and 1.73 red snapper/100 hook hr (CV = 0.21) in 2000. Otoliths were removed from all collected red snapper, and ages were assigned with an average percent error of 3.71%. Red snapper from the 1999 survey ranged from 405 to 873 mm total length (TL) (545 mm TL median) and from 3 to 19 yr (median age 5 yr). The red snapper from Texas ranged in size from 380 to 903 mm TL (755 mm TL median) and ranged in age from 3 to 53 yr (median age 11 yr). Based on the results of the pilot surveys, expanded longline surveys targeting red snapper were conducted in 2001 and 2002; these surveys yielded 86 snapper and 75 snapper, respectively. The 2001 snapper ranged from 427 to 950 mm TL (770 mm TL median) and from 3 to 37 yr (median age 12 yr). The 2002 snapper ranged from 409 to 950 mm TL (815 mm TL median) and from 4 to 44 yr (median age 13 yr). Twelve red snapper were captured in the eastern Gulf (east of the Mississippi River), and their ages ranged from 3 to 19 yr (median age 6 yr). The 232 red snapper that were caught in the western Gulf ranged in age from 3 to 53 yr (median age 12 yr). A difference in catch rates by depth was also noted with most red snapper captures occurring in the 55–92 m depth range.

The red snapper (*Lutjanus campechanus*) is considered by many to be the premier food fish in the Gulf of Mexico (Gulf). A commercial fishery for red snapper has existed for more than 150 yr, but with improving fishing techniques and technologies, the species has become increasingly vulnerable to commercial and recreational exploitation. Federal management of red snapper began in 1984 with the implementation of the Reef Fish Fishery Management Plan, and a series of management actions to rebuild the stock have followed since that time. Currently, the red snapper is considered to be overfished, and controversy continues regarding what actions are necessary to recover the species to former abundances. For an in-depth summary of red snapper management issues see Goodyear (1995) and Schirripa (1998).

In March 1999, the Gulf of Mexico Fisheries Management Council recommended that "National Marine Fisheries Service (NMFS) research priority be given to items regarding red snapper including analysis of the fate of offshore stocks and estimates of fecundity, and that results be applied to the red snapper model as applicable." In response to this request, NMFS Southeast Fisheries Science Center, Mississippi Laboratories, scheduled two 14-d surveys to evaluate the feasibility of using longline gear to capture red snapper in sufficient numbers for age and growth studies and estimations of distribution and abundance. The first study was conducted off the Mississippi–Alabama coast and the second was conducted in waters off Texas. Both surveys occurred in deeper waters (64–146 m) where larger and older red snapper were suspected to occur. Based on the results of these studies, an offshore snapper–grouper component was added to annual shark longline surveys conducted by the NMFS Mississippi Laboratories. The shark longline surveys have been conducted since 1995 and fished depths from 9 to 55 m (Grace and Henwood, 1997). The 2001 survey was expanded offshore to depths of 366 m to include areas where red snapper were encountered during the 1999 and 2000 surveys.

Numerous studies have used otoliths to age red snapper from the Gulf of Mexico and provide basic information on growth and annulus formation (Futch and Bruger, 1976; Bortone and Hollingsworth, 1980; Nelson and Manooch, 1982; Szedlmayer and Shipp, 1994; Ren-

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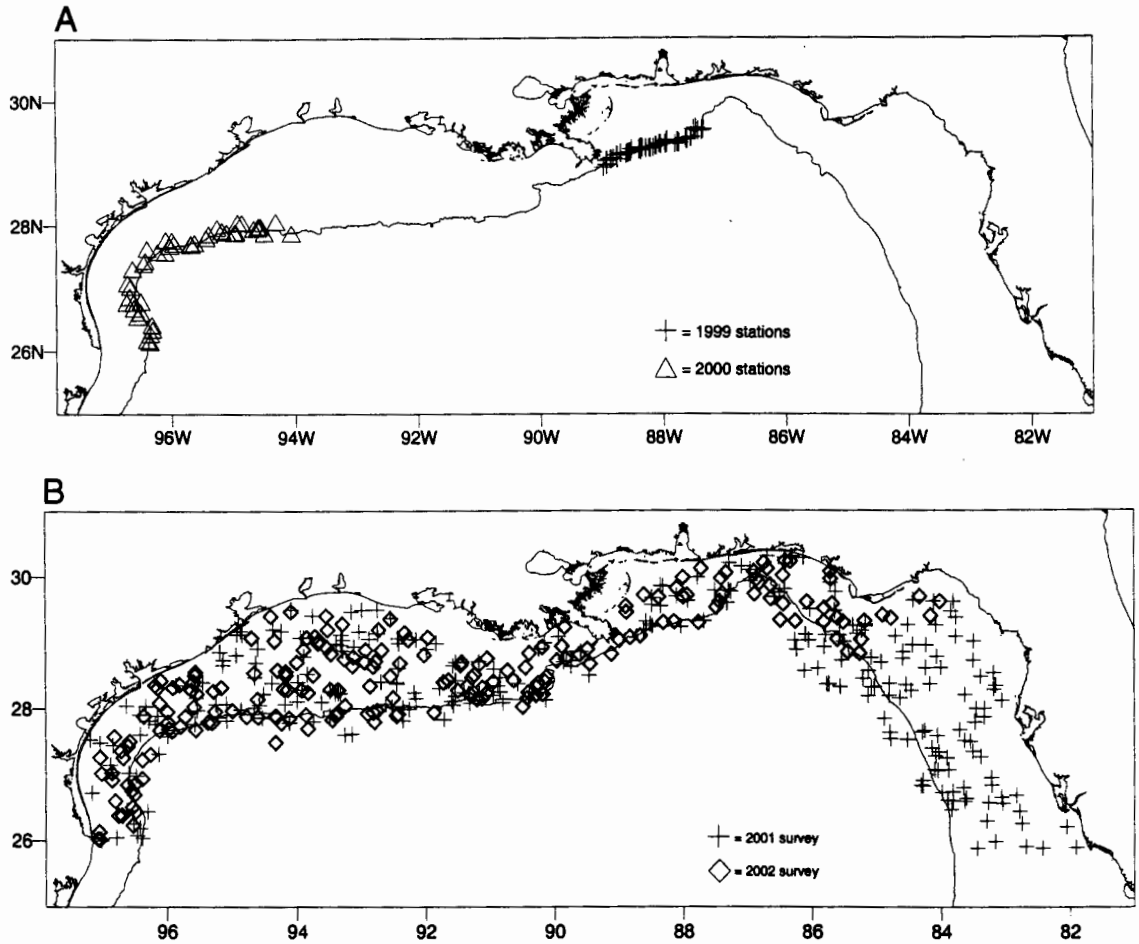

Fig. 1. (A) Station locations for snapper longline cruise in 1999 (60 stations) in north-central Gulf of Mexico and 2000 (44 stations) in north-western Gulf of Mexico. Depths of sampling locations range from 64 to 146 m. (B) Station locations for 2001 (277 stations) and 2002 (212 stations) NMFS longline surveys in the U.S. Gulf of Mexico. Depths of sampling locations range from 9 to 366 m.

der, 1995; Patterson et al., 2001; Wilson and Nieland, 2001). In common, these studies targeted red snapper taken largely by hook and line gear and sampled across the breadth of the continental shelf as well as from the western to eastern Gulf. This article will address the number, size, and age of red snapper caught during these surveys and the regional differences in abundance.

Materials and Methods

The 1999 study was conducted aboard the National Oceanic and Atmospheric Administration (NOAA) Ship *Ferrel* in the north-central Gulf from 89°W to 87°W at depths ranging from 64 to 146 m, an area not considered to be part of the historical snapper fishing grounds (Prytherch, 1983) (Fig. 1A). Six random stations per 10-min block (stratum) were selected by longitude and depth for a total of 12 blocks and 72 stations. The bottom was surveyed to evaluate topographic conditions before each longline set, and each set was made parallel to the depth contour. The longline gear consisted of 409- to 455-kg test monofilament mainline with 2.44-m, 182-kg test gangions and #15/0 circle hooks. One hundred hooks baited with Atlantic mackerel (*Scomber scombrus*) were set at each station and soaked for 1 hr. The hour began when the last high flier (4-m pole at the beginning and end of the mainline to identify the location of the gear) was deployed and ended when the first high flier was retrieved. All captured fish were weighed (kg), measured (mm) (total length [TL] and fork length [FL]), and sagittal otoliths were removed for ageing.

The 2000 study occurred aboard the NOAA Ship *Gordon Gunter* in the northwestern Gulf from 94°W to 97°W longitude above 26°N latitude at depths ranging from 64 to 146 m (Fig.

TABLE 1. Red snapper (*Lutjanus campechanus*) captures during 1999–2002 National Marine Fisheries Service longline surveys with age and length ranges of snapper by survey.

Survey year	Total no. of snapper	Stations caught at/ total no. of stations	Total weight of snapper (kg)	Largest snapper (kg)	Length range (mm)	Median length (mm)	Age range	Median age
1999	7	4/60	20.4	8.5	405–873	545	3–19	5
2000	76	21/44	463.5	10.2	380–903	755	3–53	11
2001	86	28/277	556.0	11.8	427–950	770	3–37	12
2002	75	37/212	534.0	11.2	409–950	815	4–44	13

1A), an area where large red snapper have historically been observed and harvested with longline gear (Prytherch, 1983). Six random stations per 20-min block (stratum) were selected by longitude (or latitude) and depth for a total of 12 blocks and 72 stations. The stratum size was increased in the 2000 study to cover the entire Texas coast in the time allotted for the survey. Thus, effort expended in the 2000 survey was designed to be the same as in the 1999 survey, but the area covered was approximately doubled. The bottom was surveyed as in the 1999 study and sets were made parallel to the depth contour. The mainline was 409- to 455-kg test monofilament, but the gangions were changed to 318 kg test and 3.66 m in length to compensate for the greater freeboard of the *Gordon Gunter*. The set procedure was again a 1-hr soak time and 100 hooks baited with Atlantic mackerel.

In 2001, the annual longline survey was expanded to cover the entire U.S. Gulf over depths ranging from 9 to 366 m (Fig. 1B). Effort was proportionally allocated based on shelf width within 60 nautical mile statistical zones (81°–82°W, 82°–83°W, 83°–84°W, ..., etc.) and stratified by depth with effort distributed as follows: 50% of effort 9–73 m, 40% of effort 73–183 m, and 10% of effort 183–366 m. Longline gear was the same as used in the 2000 study, and the NOAA Ship *Oregon II* served as the survey platform. The 2002 longline survey also followed this survey design, as will future surveys.

Catch per unit effort (CPUE = number of red snapper per 100 hook hr) was calculated for each survey by depth and by survey. The coefficient of variation (CV = coefficient of variation for the mean = standard error of the mean/mean) was also calculated for each CPUE.

Sagittal otoliths were removed from all red snapper captured, and otoliths were processed and sectioned according to the methods of Cowan et al. (1995). The sectioned otoliths were viewed under a dissecting microscope with reflected light (×25), and two readers (GRF and RJA) made independent annulus counts (opaque zones). Ages (years) were assigned based on the number of annuli and edge condition. Those individuals with advanced translucent edges (judged at least 2/3 complete) were advanced 1 yr in age in the expectation that opaque zones would have formed soon. With this conventional approach, an annual age cohort is based on a calendar year (Jearld, 1983). Reproducibility of age estimates based on initial independent readings was determined with average percent error (APE) (Beamish and Fournier, 1981). When counts disagreed, otolith sections were reexamined jointly by the two readers. Any unresolved counts and illegible otoliths were excluded from the analyses.

RESULTS

Red snapper were caught during each survey. The largest snapper was caught during the 2001 survey at 11.8 kg; the largest total weight in snapper of 556 kg was also captured during this survey. Ages ranged from 3 to 53 yr, with the oldest snapper caught during the 2000 survey (Table 1).

Two independent counts of red snapper annuli resulted in an APE of 3.71% (%CV = 5.25). After undergoing a review of differences to achieve reader agreement and to improve the likelihood of assigning a correct age, the "final" ages were assigned and used to characterize the age structure.

Red snapper catches varied geographically and with depth. Regional differences were observed across the Gulf with only 12 red snapper caught in the eastern Gulf (east of the Mississippi River; 269 stations), whereas 232 red snapper were caught in the western Gulf (west of the Mississippi River; 324 stations) (refer to Fig. 2A,B). Differences in age and size of fish were also noted with older, larger red snapper in the western Gulf (up to 53 yr; median 12 yr, median TL 784 mm) and younger, smaller fish

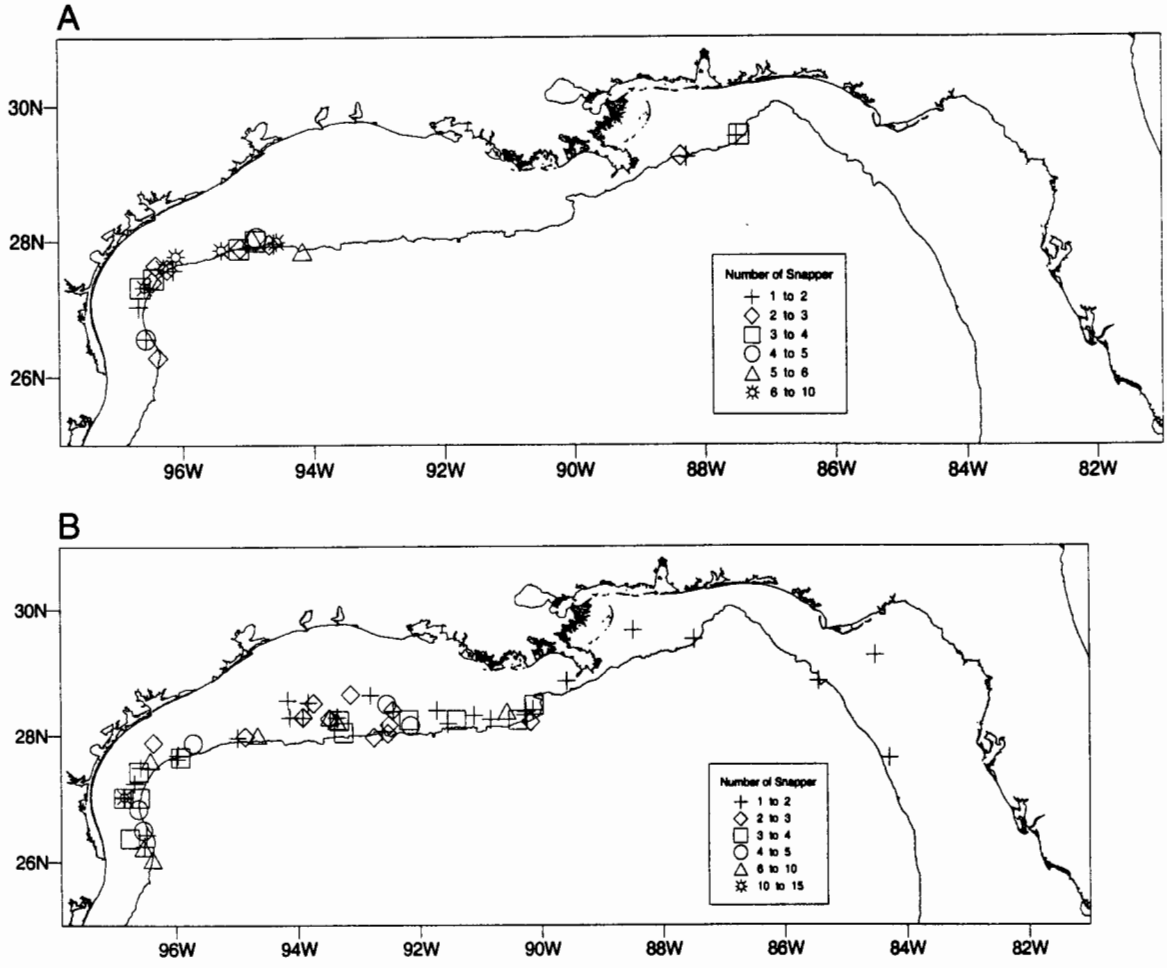

Fig. 2. (A) Red snapper locations for 1999 (seven snapper: four stations) and 2000 (76 snapper: 21 stations) longline surveys in the U.S. Gulf of Mexico. Depths of sampling locations ranged from 64 to 146 m. (B) Red snapper locations for 2001 (86 snapper: 28 stations) and 2002 (75 snapper: 37 stations) longline surveys in the U.S. Gulf of Mexico. Depths of sampling locations ranged from 9 to 366 m.

in the eastern Gulf (up to 19 yr; median 6 yr, median TL 625 mm) (Figs. 3, 4).

A breakdown of CPUE by depth for all longline surveys revealed that red snapper were more abundant at depths ranging from 55 to 92 m, with catches dropping off both inshore and offshore (Fig. 5). Red snapper CPUE was much greater in the 2000 survey conducted off Texas than during the 1999 survey off Mississippi–Alabama. Mean CPUE for Texas catches was 1.73 red snapper (CV = 0.21) compared with mean CPUE of 0.12 red snapper (CV = 0.54) for the 1999 survey. For comparative purposes, using only data from 64- to 146-m depths and dividing the Gulf into eastern and western components, the 2001 annual Gulf-wide longline survey yielded CPUE estimates of 0.08 red snapper (CV = 0.74) for the eastern Gulf and 1.38 (CV = 0.27) for the western Gulf. The 2002 survey yielded CPUE estimates of 0.12 red snapper (CV = 0.68) for the eastern Gulf and 0.72 (CV = 0.27) for the western Gulf.

Discussion

The longline surveys indicated several patterns of red snapper distribution and differences in age and size structure attributable to geography and depth. An early study (Prytherch, 1983) of longline catches from the then-young commercial longline fleet in the early 1980s also revealed very similar geographic results for a similar depth range. [Fishing practices in the commercial fishery were different from the 1999–2002 surveys. The commercial fishery targeted relief and other "hotspots," hooks were set closer together, soak time and bait also varied (Prytherch, 1983).] Based on commercial longline CPUE (same units: red snapper per 100 hook hr) from the Prytherch study, red snapper was the most

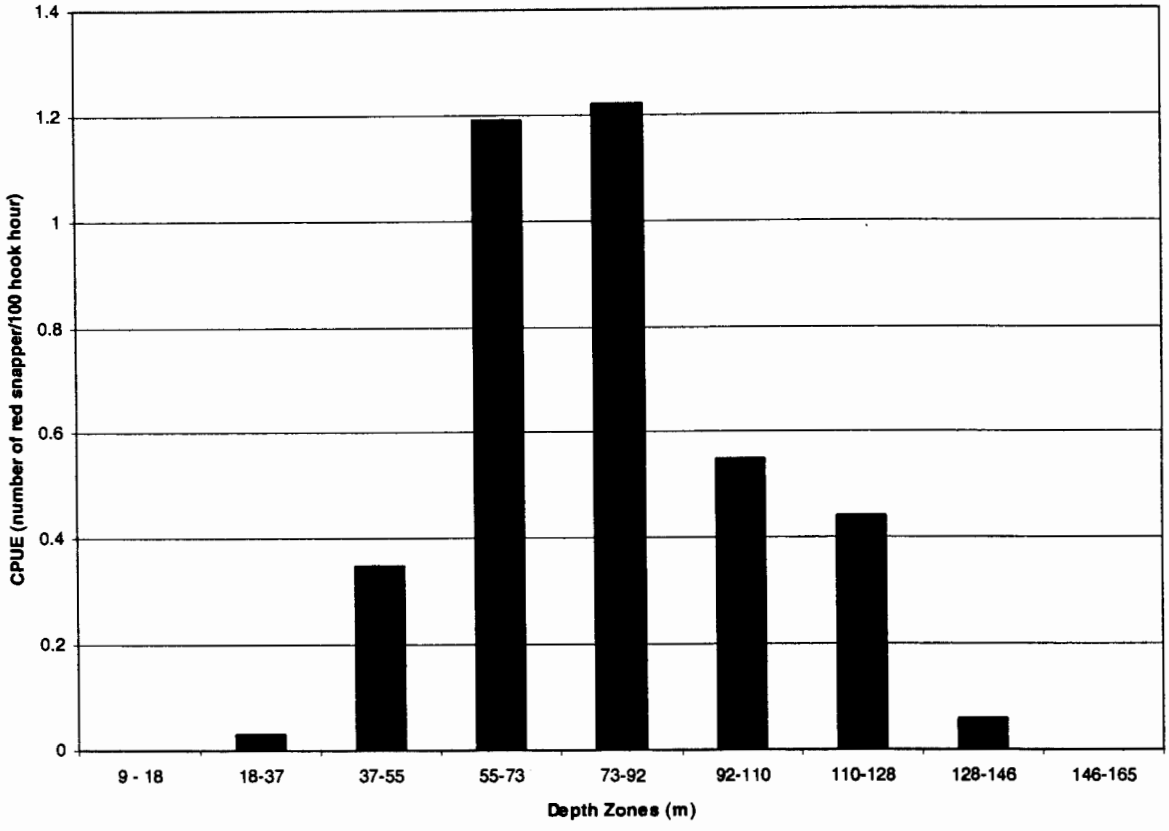

Fig. 3. Length of red snapper caught during NMFS research longline surveys from 1999 to 2002 in depths of 9–366 m in the eastern Gulf of Mexico (Mississippi, Alabama, Florida) (12 snapper) and in the western Gulf of Mexico (Louisiana and Texas) (232 snapper).

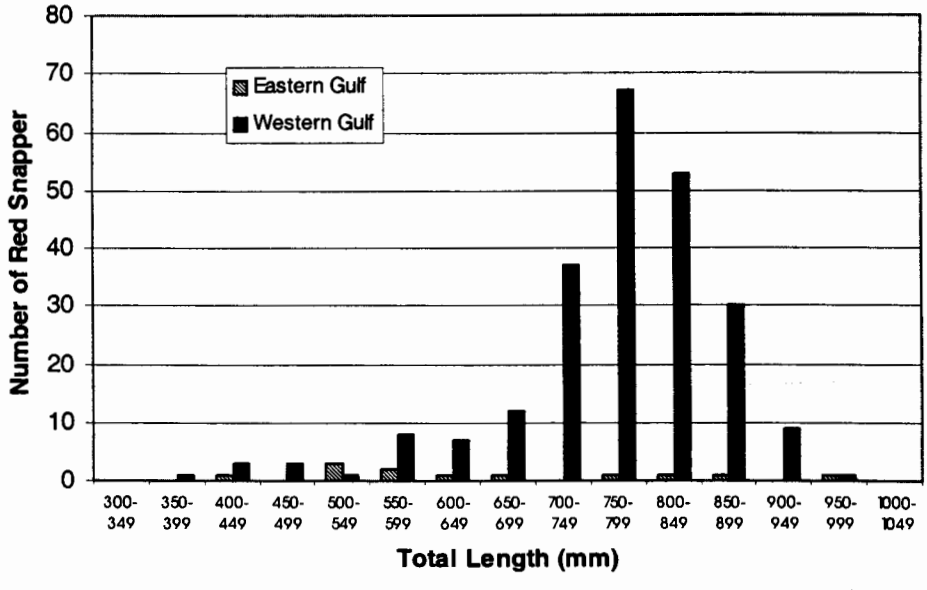

Fig. 4. Age of red snapper caught during NMFS research longline surveys from 1999 to 2002 in depths of 9–366 m in the eastern Gulf of Mexico (Mississippi, Alabama, Florida) (12 snapper) and in the western Gulf of Mexico (Louisiana and Texas) (232 snapper).

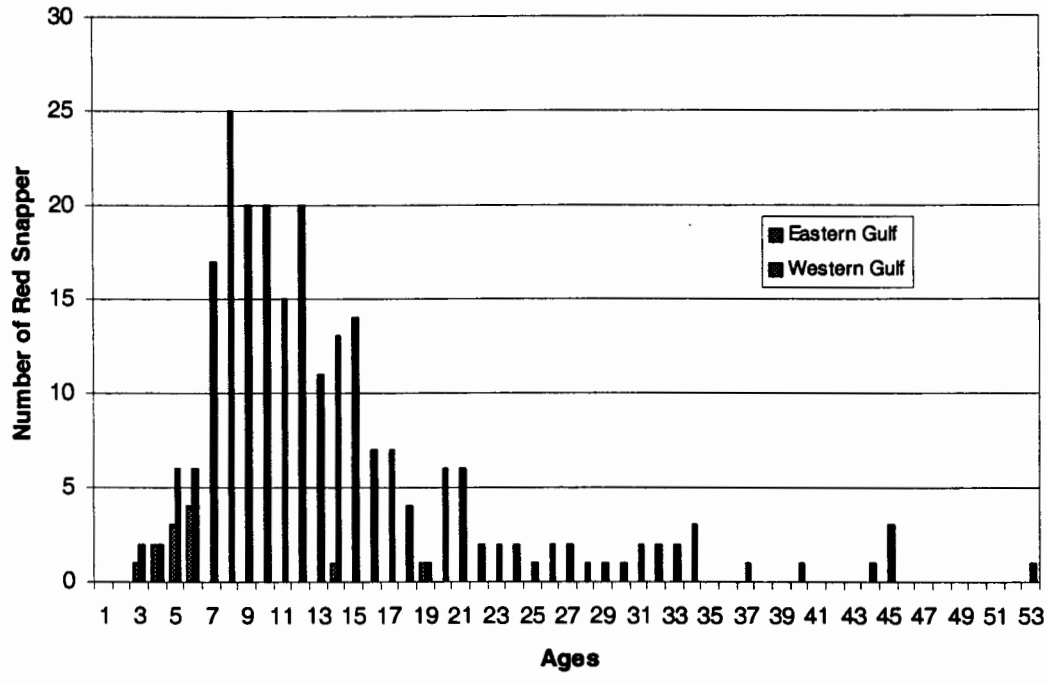

Fig. 5. Depth distribution by CPUE (number of red snapper/100 hook hr) for red snapper (593 stations) caught during NMFS research longline surveys from 1999 to 2002 in depths of 9–366 m.

abundant "food fish" from the western Gulf (broadly defined as the Texas area) with an average CPUE of 1.14. Red snapper were less abundant (10% of catch, second most abundant food fish) from the north-central Gulf (denoted the Panama City Florida area) and rare (0.6% of catch, seventh most abundant food fish) in the eastern Gulf (denoted the St. Petersburg Florida area) (Prytherch, 1983). Anecdotal information indicates that current fishing practices also reflect this geographic pattern (D. Fable, pers. comm.). For example, commercial longliners departing northwest Florida ports reportedly seek red snapper as a principal target species when they travel west (e.g., off Louisiana), whereas commercial longliners fishing the west Florida shelf view red snapper as infrequent bycatch in the grouper-directed longline fishery. Together, these results indicate a likelihood of a difference in the distribution of red snapper from the western compared with northern and eastern areas of the Gulf, and this difference may have persisted since the early 1980s. Results from the 2001 and 2002 longline surveys support this observation.

Catch rates for red snapper also varied with depth, with highest abundance of snapper caught at depths of 55–92 m. A Texas scientific longline study (1977–1979) reported low catches of red snapper (average CPUE = 0.23 red snapper/100 hook hr) at depths less than 92 m, but this study contained many stations outside the optimal depth range of the large snapper observed in our surveys (Cody and Avent, 1980); thus, inclusion of shallower stations (<55 m) would reduce CPUE estimates proportionately. Historically in the hook-and-line fishery, fishing depth ranged from about 31–156 m (mean 82 m) (Jarvis, 1935).

Commercial longliners at the beginning of the fishery in the late 1970s early 1980s deployed gear at depths between 73–183 m, with deepest sets made to 311 m (Prytherch, 1983). Since 1990, however, bottom longlining has been prohibited at depths less than 92 m along most of the U.S. Gulf coast and prohibited at depths less than 37 m along the west Florida shelf east of Cape San Blas (Reef Fish Fishery Management Plan, 1990). Patterns in commercial catch at depth are likely related to habitat features and U.S. depth regulations. Historical catches were associated with coral and hard bottom, particularly in the eastern Gulf, and "mud lump" features offshore of Texas (Jarvis, 1935; Prytherch, 1983). These habitat features are principally thought to have formed as Pleistocene reefs during periods of lower sea level and were the focus of much commercial fishing at the 73- to 110-m depth range (Moe, 1963; Darnell, 1990; Sager et al., 1992).

The 1999–2002 longline surveys yielded a notably older age structure of red snapper than has been captured with other gears. The

red snapper sampled during the Texas 2000 survey ranged in age to 53 yr, median 11 years, and ages reached 17 yr before the proportion by age dropped to less than 1%. The 2001 and 2002 longline surveys collected red snapper to 37 yr with median 12 yr and to 44 yr with median 13 yr, respectively. This pattern is similar to the age distribution observed in longline samples taken from the commercial fishery of the western Gulf (Allman et al., 2002). In contrast, commercial and recreational hook-and-line fisheries, which account for greater than 99% of the entire harvest, have been recently dominated by age 2–6 (>90% of ages) red snapper. The annual median age of red snapper taken in these fisheries is 3–4 yr, with age proportions dropping to less than 1% beyond age 8 or 9 (Allman et al., 2002; Wilson et al., 1998; Wilson and Nieland, 2000). This apparent age difference suggests disparity in the ages of fish subject to capture by the various gears because of the areas and depths fished or features of the gear such as hook size and fish behavior.

Age composition of red snapper also varied from west to east in the survey area as did distribution. Although red snapper were rarely caught east of the Mississippi River, they were younger than their western counterparts. There is some evidence that this trend may have been evident at least as far back as the early 1980s based on sizes of red snapper. When the Gulf commercial longline fishery was just beginning, Prytherch (1983) noted that longlined red snapper from Texas were generally larger than their eastern counterparts with 95% of red snapper (n = 315) from the west exceeding 6.4 kg but only 50% of red snapper (n = 6) from the east exceeding 6.4 kg. This geographic pattern is not as clear among the red snapper sampled from the commercial and recreational hook-and-line fisheries. However, there is a slight trend toward increased age (higher proportion of fish older than age 4) for western- as compared with eastern-Gulf red snapper caught by hook-and-line (Allman et al., 2002).

There are several issues that remain to be addressed for improving survey estimates of red snapper abundance and stock structure. One issue is the determination of gear selectivity that is attributed to area fished vs gear effects. Current catch patterns may not be as closely associated with natural habitat as was historically evident. Fishing practices, regulations, creation of artificial habitats (oil and gas platforms, artificial reefs, etc.), and ephemeral environmental phenomena such as hurricanes may affect stock distribution patterns (Patterson, 1999). Therefore, we initiated a survey design of random longline sets stratified only by depth and longitude rather than by habitat. Much seafloor mapping and analysis remains to be done in U.S. southeastern continental waters before adequate sampling designs based on habitat can be undertaken (Coral Reef Research Plan, 2000), but habitat-based stratification would be a desired goal in future surveys. Once the relative effect of locality and depth on age–size structure is better known, gear effects can be resolved into their component effects such as hook size, hook saturation, and fish behavior–attraction. The question of assessing population distribution as a function of habitat may be difficult to address with longlines alone because of the problems of gear loss and hangs near reefs and artificial structure (Jarvis, 1935). Because of the selectivity of various gear types, incorporating other gear such as traps into the survey design would be useful for comparison and may help address size and age selection across habitat gradients. The use of longline gear for assessments offers many advantages, particularly for a species such as red snapper that may be much less reef-obligate than other lutjanids. Longline gear proved to be an effective sampling tool for red snapper, but the next step will be to determine whether or not it is reasonably nonselective among ages at individual sites. This issue of selectivity will be a primary objective in future studies.

Conclusions

The results of the pilot studies and 2 yr of Gulf-wide surveys provide some important insights into the status of red snapper populations in the Gulf of Mexico. The Texas–Louisiana snapper population seems to be relatively stable exhibiting a distribution of age classes out to 50+ yr and abundance levels (based on CPUE estimates) similar to those observed in the 1970s and 1980s. The eastern Gulf, on the other hand, contains fish in the 3–6 yr age range comparable in numbers with the western Gulf but with minimal recruitment to what might best be termed a remnant population of adult brood stocks. We speculate that a healthy red snapper population in the eastern Gulf would look similar in terms of abundance and age structure to what we currently see off Texas.

From a management perspective, our findings suggest that recovery of red snapper in the Gulf of Mexico may require different strat-

egies in different areas. Assuming there is a single population of snapper in the Gulf, recovery of eastern Gulf snapper to former levels of abundance would appear to be a formidable task, whereas maintaining "status quo" for western Gulf snapper may require less stringent regulatory actions. It may be necessary to develop separate stock estimates for eastern and western Gulf snapper even if they are not distinct stocks and to develop models to determine what must be done to rebuild stocks in the eastern Gulf and maintain or increase current stock levels in the western Gulf.

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