The utility of a hooked gear survey in developing a fisheries-independent index of abundance for red snapper along Florida's Atlantic coast

Cameron B. Guenther, Theodore S. Switzer, Jessica Carroll, Russell B. Brodie,
Justin J. Solomon, Jeff T. Sauer, and Richard Paperno

SEDAR41-DW08

Submitted: 21 July 2014

Please cite this document as:

Guenther, C.B., T. S. Switzer, J. Carroll, R. B. Brodie, J.J. Solomon, J. T. Sauer, and R. Paperno. 2014. The utility of a hooked gear survey in developing a fisheries-independent index of abundance for red snapper along Florida’s Atlantic coast. SEDAR41-DW08. SEDAR, North Charleston, SC. 53 pp.

The utility of a hooked-gear survey in developing a fisheries-independent index of abundance for red snapper along Florida's Atlantic coast

Cameron B. Guenther[1], Theodore S. Switzer[1], Jessica Carroll[1], Russell B. Brodie[2], Justin J. Solomon[2], Jeff T. Sauer[3], and Richard Paperno[3]

[1] Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute, 100 8th Avenue SE, St. Petersburg, FL 33701

[2] Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute, Jacksonville University Field Laboratory, 2800 University Boulevard N, Jacksonville, FL 32211

[3] Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute, Indian River Field Laboratory, 1220 Prospect Avenue, Suite 285, Melbourne, FL 32901

ABSTRACT

Reef-fish resources along the Florida's Atlantic coast historically supported multi-million dollar commercial and recreational fisheries, with red snapper *Lutjanus campechanus*, among the most heavily-targeted species. Recognizing the need for broad-scale, fisheries-independent data and as an important step in the continued development of an offshore reef fish monitoring program, the Fish and Wildlife Research Institute of the Florida Fish and Wildlife Conservation Commission (FWC) conducted a study to compare and evaluate active and passive hooked gear types in their ability to efficiently and effectively characterize the distribution, abundance, and size-structure of red snapper along Florida's Atlantic coast. Monthly sampling (April – October) was conducted along Florida's Atlantic coast. A fisheries-independent reef fish survey, using actively and passively-fished hooked gears was conducted within three latitudinal and two depth strata. Red snapper comprised one of the most abundant species within the catch across all strata. Larger and older red snapper were captured in the two northern most zones compared to the southern zone. The size-frequency distribution of all red snapper differed significantly between shallow and deep strata. Hook size was a significant factor in determining catch-per-unit effort for red snapper. Length samples collected from fisheries-independent monitoring clearly show a bimodal distribution with the center of the first mode occurring at 350 mm fork length and the center of the second mode at 560 mm fork length. Overall differences in size structure were found with respect to depth and NMFS statistical zone. These hooked gear types compliment data collected from camera and trap surveys currently used by NMFS and MARMAP by providing catch data of larger managed reef fish not collected in traps and demographic data (i.e., age, sex, reproductive condition, mercury concentrations, etc.) not obtained by cameras. All three methods are capable of providing valuable data for red snapper, although the repetitive timed drop approach did appear to characterize the broadest diversity of fishes.

Introduction

Reef fish resources (specifically the grouper-snapper complex; Ault et al. 2006) along the south Atlantic United States coast have historically supported multi-million dollar commercial and recreational fisheries, with species such as red snapper among the most heavily targeted reef fishes over the past 50 years. The red snapper fishery along the southeastern United States has been active since the 1950s, with a substantial proportion of landings recorded along the east coast of Florida. The east coast Florida red snapper fishery experienced the greatest annual landings during the 1970s after which time landings declined markedly (White and Palmer 2004). Declines in landings from commercial, recreational, and head-boat fisheries from 1986 to 1995 were also documented by Manooch et al. (1998) as part of the first formal assessment of the south Atlantic red snapper stock. Results from a 2008 assessment indicated that south Atlantic red snapper are experiencing overfishing and are overfished (SEDAR 15 2008). In response to this assessment, the South Atlantic Fisheries Management Council (SAFMC) implemented an emergency closure of the commercial and recreational red snapper fishery throughout federal waters (3 to 200 miles offshore) in the south Atlantic region. As a continuation of the emergency closure implemented in 2008 the SAFMC approved Amendment 17A to the South Atlantic Snapper Grouper Fishery Management Plan to continue to reduce overfishing and rebuild red snapper stocks as mandated by the Magnuson-Stevens Act (SAFMC 2010). Amendment 17A involved several provisions, including the continuation of the closure of the red snapper fishery as well as a large area closure off of northeastern Florida and southern Georgia where fishing for all snapper/grouper species in depths from 98 to 240 would have been prohibited to reduce red snapper discard mortalities (Gitschlag and Renaud 1994; Rummer and Bennett 2005; SAFMC 2010). Before Amendment 17A was enacted a new benchmark assessment (SEDAR 24) was completed and was available for review by the SAFMC. The new assessment confirmed that red snapper were overfished and undergoing overfishing, however it also revealed that stocks were in better condition than what was initially indicated in SEDAR 15. As a result, the large area closure was not implemented; however, aside from a very limited recreational seasons in the fall of 2012, and summers of 2013 and 2014, red snapper has remained closed to all recreational and commercial harvest.

Federal and state agencies have been involved with the assessment and management of snapper/grouper stocks in the southeastern United States since the early 1980's. The assessment and management of commercial and recreational fisheries has historically relied heavily on fisheries-dependent data, although limitations and biases inherent to these data are admittedly a major source of uncertainty in current stock assessments. These assessments are generally reactive in nature, and management actions are designed to avoid further damage to the fishery rather than ensure future sustainability. In the absence of a fisheries-independent time-series that adequately samples reef fish species in the south Atlantic, assessment scientists must rely upon fisheries-dependent landings data which provide the only continuous time-series from which to evaluate changes in abundance for regional stock assessments. During the first red snapper SEDAR in the south Atlantic (SEDAR 15 2008), landings data collected from commercial harvesters and dealers and from recreational headboats (large party boats), which primarily target reef fishes, served the dual purpose of providing measures of fisheries extractions as well as indices of relative abundance. As a result of current closure of red snapper to all commercial harvest, commercial landings data are not currently available to assess the status of red snapper stocks. Regardless, commercial and headboat landings data have always been limited to harvestable-sized fish, which are highly influenced by regulatory changes (i.e., size limits, recreational bag limit). During SEDAR 24, a fishery-dependent index of abundance was developed based on information collected for pre-harvest red snapper in the headboat fishery. The headboat at-sea observer program has been conducted from North Carolina to the east coast of Florida continuously since 2005 and collects information on the size distribution and catch-per-unit-effort (CPUE) of both harvested fish and regulatory discards. The headboat at-sea observer index is of particular interest since it provides information on the relative strengths of young age classes observed by the fishery, and is an indicator of recruitment strength (SEDAR 24 2010). This time-series will likely not be as useful for future assessments due to the current recreational closure of red snapper which will most likely lead to the alteration of fishing methods and targeted species by vessels such as headboats. Combined, these limitations will render it virtually impossible to assess the response and recovery of south Atlantic red snapper populations to current and proposed management regulations.

The reliance on fisheries-dependent data is particularly problematic for the assessment and management of south Atlantic red snapper, where fisheries-independent data are limited. Accordingly, Amendment 17A also included a provision to develop and establish a fisheries-independent monitoring program to track the rebuilding of south Atlantic red snapper stocks (SAFMC 2010). Fisheries-independent surveys of reef fish resources reflect the status of fish populations as a whole, rather than just the portion of the population taken in the fishery (Williams and Carmichael 2010). When available, data from fisheries-independent surveys can be used to develop indices of abundance that are especially valuable because these data generally 1) are based on a statistically-valid sampling design, 2) incorporate standardized sampling methodologies, and 3) are collected over relatively long time periods. Although fisheries scientists and managers in the south Atlantic have long agreed that a comprehensive survey of reef fishes is needed, obtaining the resources necessary for such an undertaking has proven difficult. At present, several fishery-independent surveys are conducted throughout the SA (Marine Resources Monitoring, Assessment, and Prediction program (MARMAP), the South Atlantic Southeast Area Monitoring and Assessment Program (SA-SEAMAP), and the Southeast Fisheries Independent Survey (SEFIS)), although these surveys have historically had limited success in providing data for red snapper (White and Palmer, 2004). The availability of more robust fisheries-independent data for red snapper and other reef fishes would have great utility in terms of providing a baseline with which trends in reef fish data can be evaluated (Koenig and Coleman, 1998; Coleman et al., 1999).

In comparison to red snapper in the GOM, relatively little is known concerning the habitat preferences, site fidelity, and population demographics of south Atlantic red snapper and other members of the grouper/snapper complex. The GOM fishery has benefited recently from the development of a fisheries-independent monitoring program designed to monitor the grouper/snapper complex. Although fisheries-independent monitoring programs exist in the South Atlantic (i.e., MARMAP, SEAMAP) neither was designed to specifically target red snapper. This is evident from their respective catch statistics for red snapper. Accordingly, we conducted a study on the east coast of Florida designed to 1) test the efficacy of a fisheries-independent hooked-gear survey for providing data for red snapper, *Lutjanus campechanus* along Florida's east coast and to 2) provide vital population demographic data instrumental to assessing recovery of red snapper in the south Atlantic. Surveys were conducted during late spring, summer, and early fall within NMFS statistical zones 722, 728, and 732 which represent areas of elevated landings data for red snapper (White and Palmer 2004). These surveys targeted hard bottom habitats where recreational/commercial fishing for red snapper and other reef fish has historically occurred. We worked cooperatively with various sectors of the for hire fishery, including headboats (i.e., up to 100 paying customers) and six-pack charters (i.e., up to six paying customers), as well as the commercial sector. We relied on experience from both for-hire and commercial vessel operators in the region during survey development as platforms from which the surveys were conducted. The knowledge and experience combined with their familiarity with the fishery contributed greatly to the effectiveness of the overall survey design and allowed accurate targeting of reef fish habitat. We utilized industry knowledge to augment existing databases of suitable hard-bottom habitat throughout the study area from which the sampling universe was constructed. Fishery-independent active and passive fishing methods were standardized throughout the study and followed methods used in similar survey efforts conducted by the FWC in the GOM to assure comparability of collected data. Results from this study were used to provide recommendations as to overall survey design and sampling effort for implementing a regional fisheries-independent monitoring program targeting red snapper and other managed fishes along the United States Atlantic coast.

Objectives:

The primary goal of this project was to test the utility of a hooked-gear survey in developing a fisheries-independent index of abundance for red snapper along Florida's Atlantic coast. To accomplish this, three objectives were addressed:

1. Evaluate the efficacy of various hooked gear methods in providing fisheries-independent data for red snapper in the south Atlantic.

2. Develop, based on results from the proposed project, recommendations as to a fisheries-independent survey to provide data for developing indices of abundance for red snapper in the south Atlantic.

3. Provide demographic data (i.e., age, sex, reproductive condition) for red snapper and other federally-managed reef fishes.

Methods

A fisheries-independent survey of reef fishes, using both actively and passively-fished hooked gears, was designed based on prior hooked gear research studies conducted along the WFS of Florida coupled with input from commercial and recreational fishers from the east coast of Florida. A project-development workshop was held in conjunction with commercial and recreational fishers in northeastern Florida at the outset of study. This workshop served as a forum for discussing appropriate sampling sites, methods for comparative surveys of hooked gears, and the overall goals and expected benefits of the proposed research. By adopting a cooperative approach at the outset of the proposed project, we were able to combine the strengths of each respective group to improve the overall strength of the study. One particular benefit of the workshop was the seasonal start date for sampling was adjusted based on participants recommendations. The project was originally slated to start in June and sample through September; however, based on participants' recommendations we moved our start date and began sampling in April with an anticipated end in July/August. The reason for moving our start date up was due to an expected thermocline that persists during the summer months throughout the offshore waters of our sampling area and often negatively effects fishing effectiveness.

Survey Design:

Monthly hooked-gear surveys were conducted within three regions of the south Atlantic (Figure 1): NMFS statistical zones 722, 728, and 732. These regions occupy the portion of the South Atlantic Bight from roughly 28° 00' N (Melbourne, FL) to 30° 45' N latitude (Florida-Georgia border). Within each of the sampling zones, locations (GPS coordinates) of suitable hard-bottom habitat were obtained from either participating fishers (both commercial and recreational), federal agency partners (i.e., NMFS, USGS), or from existing historical data collected by FWC. All habitat data were incorporated into a sampling universe and subdivided into primary sampling units (0.3 nm latitude by 0.1 nm longitude).

Each month (April –July) 32 sampling units (sites) were randomly selected within each of the three NMFS statistical zones for a total of 96 sampling sites per month throughout the study area. Sampling sites were randomly selected from a universe of presumed hard-bottom locations. Sampling effort was stratified by depth (inshore, inside the 30 m isobath; offshore, between the 30 m and 100 m isobaths) within each sampling zone. Twelve inshore sites were selected for each of the three zones. Due to a larger number of identified hard bottom locations in the offshore areas of our sampling universe more effort was allocated to these areas (N= 20 selected per month per zone) in order to preserve the proportionality of sampling throughout our universe. Weather and other factors precluded us from completing all of our selected sites in any given month. As a result, we extended our sampling timeline by two time-periods (August and September/October). In order to compensate for the sites that were not completed, our sampling design was adjusted to select more stations from the sampling zones and strata that were generally under sampled during the initial four month sampling window (Table 1).

Gear Description

Active fishing survey

Elec-tra-mate© rigs:

Powered (12V DC) Elec-tra-mate© rigs (model 940XP) were used as our active sampling gear (Figure 2). The Elec-tra-mate© rig was outfitted with a Penn 115L 9/0 (Senator model) reel equipped with 45 kg (100 lb) test monofilament. The entire rig was mounted onto a heavy-duty fiberglass fishing pole (~ 2.4 m). Terminal tackle for all Elec-tra-mate© rigs was standardized. A barrel swivel was attached to the mainline from the reel. Starting from the swivel a ~ 1.8 m section of 36-45 kg (80-100 lb) test monofilament leader was attached. Two short leads (~ 0.2 m long) were tied along the length of this leader (i.e., "dropper loops"), one located near the top of the rig ending with either an 8/0 or 11/0 Mustad circle hook (Ref 39960D) and the other near the bottom ending with either an 11/0 or 15/0 Mustad circle hook. A lead egg sinker (size depending on current conditions, ranging from 0.17 kg to 0.40 kg) was inserted at the bottom of the leader followed by a barrel swivel (Figure 3). See the section on 'Experimental design' (below) for details on hook order for terminal tackle.

In an effort to standardize the active fishing gear and reduce individual fisher bias we developed a system of active fishing that utilized a series of "team drops" to standardize the bottom soak time for each individual fisher for each site. A "team drop" consisted of each of the fishers simultaneously dropping their rigs to the bottom and allowing their rig to soak for no more than two minutes. When the first rig reached the bottom the fisher notified the principal investigator and a stopwatch was started to keep track of the soak time. Fishers soaked their rigs in contact with the bottom and reeled in their rig as soon as a fish was hooked. After the two minute time period elapsed for each "team drop" all fishers retrieved their rig and rebaited their hooks as necessary. All fishers who retrieved there rig within the two minute time period (caught fish, check bait, lost fish, etc.) were not permitted to redrop their rig during that "team drop". After all fishers had retrieved their rig, unhooked and processed any captured fish, and rebaited hooks, a subsequent "team drop" was performed by all anglers. Each individual "team drop", beginning with drop one, was numbered at each site and the number of the "team drop" in which any fish were captured was recorded.

Passive fishing survey

Vertical long line:

The vertical long line gear consisted of a monofilament back-bone (~7.3 m long [26']); 181kg (400 lb.) test equipped with 12 evenly spaced (every 0.61 m [2 ft.]) crimped t-swivels (Figure 4). Attached to each of the t-swivels was a gangion which consisted of a snap swivel crimped onto the end, a length of 100 lb. test monofilament, and a single Mustad circle hook (either 8/0, 11/0, or 15/0; Ref 39960D) attached using a uni knot. All gangions were a standard length of 45.7 cm (18") as measured from the tip of the snap swivel to the tip of the circle hook. A lead weight was attached at the base of the back-bone to anchor the gear (8-15 lbs., amount depending on current and sea conditions). Immediately above the back-bone was a large barrel swivel and a sub-surface buoy, which kept the back-bone near-vertical while fishing the bottom. The gear was tethered to the surface via the monofilament (181 kg [~400 lb. test]) mainline from a commercial bandit reel aboard the vessel. A buoy system was attached at the water's surface and slack played off of the bandit reel spool to allow the gear to remain 'autonomous' from any vessel movements. The gear was allowed to fish for five minutes and then retrieved using the bandit reel.

Horizontal long line:

The horizontal long-line system consisted of a back-bone/mainline with 12 evenly spaced gangion-rigs placed every 1.83 m (6 ft) (Figure 5). The mainline material was 317 kg (700 lb.) test monofilament with a diameter of 3.0 mm. Each gangion-rig consisted of a stainless steel gangion clip (10.2 cm [4"] long, 158 kg [350 lb.] test) crimped to one end of a length of 45 kg (100 lb.) test monofilament. A single Mustad circle hook (8/0, 11/0, or 15/0) was attached to the other end using a uni-knot. Gangion-rigs were constructed at a standard length of 1.52m (5ft), as measured from the end of the gangion clip swivel to the tip of the circle hook. The resulting gear design consisted of four gangion-rigs of each hook size (3 hooks sizes x 4 gangion-rigs = 12 total gangion-rigs per deployment). Lead weights were attached on each ends of the mainline 2.25-6.75 kg (5-15 lbs.) to anchor the gear. The mainline was attached to a surface buoy (using .95cm [3/8"] poly braid line) to mark the location of the gear. The gear was allowed to fish for fifteen minutes and then retrieved using the bandit reel.

Sampling methods:

Fishing methods and effort were standardized at all sampling sites. At each sampling site we conducted one vertical long line, one horizontal long line, and we actively fished each site using the "team drop" fishing method and Elec-tra-mate© gear. The order in which the gear was fished altered between even and odd numbered sampling sites. For odd numbered sites active fishing was followed by the vertical long line and ended with the horizontal long line. Even numbered sites were sampled in the reverse order. At each site both the active fishing using the Elec-tra-mate© gear as well as the vertical long line were fished on anchor directly over the selected hard bottom location when possible. In certain conditions (rough seas, extreme tide, etc.) sites were motor fished in order to properly maintain the boat position directly over the intended site. For each selected station the horizontal long line was fished at least 0.1 nm away from the other gears. If it was determined that there was not suitable habitat within the selected station to sample all gears, priority was given to the active fishing and vertical long line gears.

At each sampling site anglers were assigned to a particular rig with a specific hook combination and bait type. Three hook types were tested: 8/0, 11/0, and 15/0 Mustad circle hooks (Ref 39960D). All hooks were baited with Atlantic mackerel (*Scomber scombrus*) cut proportional to hook size. Four rigs were deployed at each sampling station. Each rig consisted of a two-hook combination. Three rigs were used at all stations (8/0 and 11/0, 8/0 and 15/0, or 11/0 and 15/0 hooks), with the bigger hook size always at the bottom of the rig. The fourth rig fished at a station varied by depth; for the inshore depth strata one additional 8/0 and 11/0 hook combination was deployed, and for the offshore depth strata one additional 11/0 and 15/0 hook combination was used. All hooks were baited with Atlantic mackerel cut proportional to hook size. The rig fished by anglers was alternated at each sampling site to remove any biases of angler experience with respect to hook size or fishing position on the boat. We targeted to complete twelve “team drops” in the inshore depth strata. Because of time constraints due to more difficult fishing conditions in the offshore depth strata we targeted ten “team drops” at each site.

Immediately following or preceding active fishing (depending on series number) the vertical long line was set while on anchor. The order of hooks on the vertical long line was randomly selected for each three-hook triplet (one each of 8/0, 11/0, and 15/0), and this pattern was repeated for the remaining triplets (twelve hooks total). All hooks were baited with Atlantic/Boston mackerel cut proportional to hook size. This gear was not set in extreme current (> 2knots) due to gear drift away from the intended sampling habitat.

The horizontal long line was set while motoring over the intended habitat. Hook order for all horizontal long lines were a standard pattern (8/0, 11/0, 15/0 from the poly-line down, repeated three times). All hooks were baited with Atlantic mackerel cut proportional to hook size. This gear was not set in extreme current (> 2knots) due to gear drift away from the intended sampling habitat.

Deployment and catch data were recorded at each sampling site. For all gear deployments, local time, weather, water depth (m), bottom water temperature, and location information were recorded. Angler specific parameters recorded at each sampling site included fishing mode, drop duration, team drops (total number of drops performed at each site), water depth, fisher/crew initials, rig number, leader (test and type), reel type, start and end time, bait type, number of team drops completed per angler, and detailed hook information.

Catch specific parameters were also recorded, including fisher/crew initials (i.e., who caught the fish), rig number, drop number (number of team drop captured), species (identified to the lowest possible taxa), length measurements, sex, use, fish health code, bait type, rod attended, hooking information (i.e., location of hook in fish and tool used to remove hook), release information (i.e., condition of fish and venting information), tagging information (i.e., type and number), specimen number, and wetlab samples taken. All individuals collected were identified to the lowest taxonomic level possible and measured prior to either being released or culled for biological processing. On occasion measurements were not recorded due to uncontrollable situations (i.e., fish partially preyed upon prior to retrieval). In these situations, plus counts towards overall catches (individual species) were recorded. Lengths (mm) measurements were recorded as standard length (SL), fork length (FL), and maximum total length (TL) for fish or precaudal length for elasmobranchs. Fish that exhibited barotrauma were vented before being released. Biological samples were taken to aid in the assessment of reef fish resources in the South Atlantic. Random subsets of individuals collected were sacrificed to provide valuable fisheries-independent demographic data (i.e., age, sex, reproductive condition, mercury concentration) for managed reef fishes. Biological material was provided to the Fish and Wildlife Research Institute for processing.

All data were entered using an existing relational Access database to capture physical, habitat, abundance, length frequency, age and growth, reproductive, and fish health data. All data passed through an established system of QA/QC procedures to ensure the accuracy and reliability of collected data. Data contained within this database, along with extensive metadata, are available in a variety of formats useable by most individuals and/or organizations.

Statistical Analysis:

Overall sampling effort (# stations completed) was summarized separately by zone (NMFS statistical reporting zones 722,728,732) and gear (active hooked gears, passive vertical longlines, and passive horizontal longlines). Catch summaries were compiled to explore differences among gear types in each region. Catches were also compared among hook sizes (8/0, 11/0, 15/0) independently and collectively. Size-frequency histograms were constructed for red snapper for all three gear types by statistical zone, depth, and hook size; similarly, a histogram was constructed for red snapper to explore size frequency based on position on the vertical longline. Where sample size was sufficient, a Kolmogorov-Smirnov (K-S) test was used to identify differences in size-frequency distribution. Further, size-frequency of red snapper was compared among the three gear types. Analysis of variance (ANOVA) tested the effects of hook size on total length of fish captured between various hook sizes. Catch-per-unit-effort data (CPUE; # fish per hook) for red snapper was standardized using generalized linear models. The most parsimonious model was selected using the information theoretic criterion by comparing the fit statistics of the fully parameterized model to reduced models. The effect of categorical variables (e.g., gear, , zone, month, hook size etc.) on catch rates (CPUE) was examined using ANOVA. LSmeans (adjusted means) were calculated for each significant categorical variable and differences in catch rates were examined using Tukey-Kramer multiple comparisons. All statistics were conducted using the glm and glm.nb packages in R (R development core team 2008).Data collected from April through August only were used for CPUE comparisons due to the reduced effort of the passive gears during the final two months of the extended sampling period. Models utilizing the data from all months were computed and the fit was compared to the models utilizing data from April-August only. Model fit diagnostics confirmed that the sparstity of sampling in September and October reduced the overall fit and resolution of the model and justified excluding these months.

Power Analyses:

A series of power analyses were conducted to 1) identify what level of change in relative abundance would be detectible based on applied sampling effort, and 2) identify what level of sampling effort would be required to detect varying magnitude of change in relative abundance. The POWER procedure in SAS (SAS Institute 1989) was used to conduct power analyses using mean and standard deviation of the number of fish per station across all NMFS statistical zones for select species. Power analyses were used to calculate the number of samples needed in order to detect a 10%, 25%, 50%, 75%, and 100% change in population size, using a power of 0.8 (80% detection rate).

The majority of red snapper and a random subset of other managed reef species collected during the study were sacrificed to provide valuable fisheries-independent demographic data (i.e., age sex, reproductive condition, mercury). Biological material was processed by the Florida Fish and Wildlife Conservation Commission's, Fish and Wildlife Research Institute age-and-growth and histology labs. Ages were determined by sectioning left side otoliths and mounting the sections to slides. All otoliths were aged at least twice. Any differing age measurements are re-read for agreement

Red snapper ages were summarized by sex, depth stratum (shallow: < 30m and deep > 30m) and statistical zone (NMFS statistical reporting zones 722,728,732). Age frequency histograms were constructed for red snapper collectively and by sex, depth and statistical zone. Where sample sizes were sufficient, a Kolmogorov-Smirnov (K-S) test was used to identify differences in age composition. A von Bertalanffy growth model for red snapper was estimated based on ages determined from sectioning and reading saggital otoliths. The model was fitted using the re-parameterized von Bertalanffy growth equation of Francis (1988) using nonlinear least squares estimation. Conventional von Bertalanffy parameters were back calculated from the model output Von Bertalanffy growth models and parameters were estimated using the R statistical package (R development core team 2008).

RESULTS

<u>Hooked-gear survey</u>:

Sampling was conducted on a monthly basis within NMFS statistical zones 722, 728, and 732. Overall, 364 stations were sampled within zone 722 (N=121), zone 728 (N=123), and zone 732 (n=120) using actively (HNL N=362) and passively fished (vertical LL N=328, horizontal LL N=234) hooked-gears (Table 1). Sampling occurred within the inshore (N=152) and offshore strata (N=212) in each zone. A total of 71 species were collected throughout the survey, with 43 species collected from zone 722, 51 species from zone 728, and 37 species collected from zone 732 (Appendices 1-3). In total 5,690 individuals were collected during hooked-gear surveys, with 1,666 individuals collected from zone 722, 2,178 individuals from zone 728, and 1,846 individuals collected from zone 732. Red snapper (N=1,294) was one of the more abundant taxa collected in all three regions. Red snapper accounted for 13.9% of the total catch in zone 722, 23.5% in 728, and 29.8% in zone 732.

Standardization of CPUE was performed using the glm and glm.nb packages in R (R development core team 2008), and a variety of underlying distributional families (Poisson, negative binomial, gamma, quasi-Poisson) were tested for red snapper. The negative binomial model produced the best fit to the observed data. Fully parameterized models included a suite of categorical variables (fixed effects) including: gear, month, hook size, hook position and

NMFS statistical zone. Continuous variables included in the full model included depth, number of hooks per gear, sea surface temperature and time of day. Interaction terms included the combinations of NMFS statistical zone*Depth, NMFS statistical zone*Month, and Month*Depth. For red snapper hook position and time of day were dropped in the final reduced model. The reduced model was the most parsimonious model while still providing the best overall fit to the observed data based on the theoretic information criterion (Table 2). CPUE varied significantly amongst gears with the highest catch rates occurring with the active timed drops, followed by the horizontal long line, and then the vertical long line (Figure 6). Latitudinal differences (NMFS statistical zone) in catch rates were significantly different in the southern zone (732) when compared to the two northern zones (Figure 7). Hook size did significantly influence catch rates with the highest CPUE observed for the 11/0 circle hook regardless of gear type (Figure 8). Temporal differences in CPUE for red snapper were observed during the study with the highest CPUE occurring earlier in April and May and declining through August (Figure 9). Depth significantly improved the overall fit of the model and is negatively related to CPUE (Table 3, Supplemental Figure S1). Likewise sea surface temperature significantly improved the overall fit of the model and is inversely related to CPUE (Table 3, Supplemental Figure S2). The number of hooks per gear was significant and positively correlated with CPUE (Table 3). Interactions between variables are complex and vary across months, zone and depth (Table 3).

<u>Active Repetitive Timed Drop Survey:</u>

The size-frequency distribution of red snapper did not differ between the two northern statistical zones, although both northern statistical zones differed significantly from the southernmost zone (Figure 10; $p_{KS} < 0.05$). The southernmost zone generally contained a higher proportion of small red snapper, although size-frequency distributions from all zones exhibited a multi-modal distribution representing several size/age classes. The size-frequency distribution of red snapper differed significantly between shallow and deep strata (Figures 11; $p_{KS} < 0.05$). Red snapper individuals in the deep stratum were generally larger than those collected in the shallow stratum.

The size-frequency distribution of red snapper differed significantly among hook sizes (Figure 12; $p_{KS} < 0.05$ for all comparisons), with larger hooks generally capturing larger individuals, although minimum and maximum sizes captured were not markedly different. Prior to conducting analyses, we explored whether or not position of the hook significantly influenced red snapper characterized by the 11/0 hooks. Overall it does not appear that catch rates of red snapper differs markedly between the top and bottom position for 11/0 hooks (Figure 13), although some differences in the relative abundance were evident between the upper (position 1) and lower (position 2) position (Figure 14). These differences were not significant, and so data from the upper and lower positions were pooled for 11/0 hooks for subsequent analyses.

<u>Passive Vertical Long line Survey:</u>

The size-frequency distribution of red snapper differed significantly among statistical zones (Figure 15; $p_{KS} < 0.05$ for all comparisons); these differences appear to be due to differences in the range of sizes collected and were most likely attributable to varying sample sizes. The size-frequency distribution of red snapper did not differ significantly between depth strata (Figure 16). The size-frequency distribution of red snapper only differed between 8/0 and 15/0 hooks (Figure 17; $p_{KS} < 0.05$), with significantly larger red snapper caught on 15/0 hooks. No significant differences in size-frequency distribution based on triplet position on the vertical long line were evident for red snapper (Figure 18).

Prior to conducting analyses, we explored whether or not position of the hook significantly influenced catch, in particular of red snapper. Since position and hook size were confounded, position was summarized in terms of position of each hook triplet (combination of 8/0, 11/0, and 15/0). Triplet A represented the three hooks closest to the bottom, triplet B represented the next three hooks and so on through triplet D which represented the top three hooks. In regards to red snapper, catches were not very different among the hook triplets (Figure 19). Data from all four positions were pooled for each hook size for subsequent analyses.

<u>Passive Horizontal Long line Survey:</u>

The size-frequency distribution of red snapper did not differ significantly among statistical zones, with a broad range of size occurring within each zone (Figure 20). There were also no significant differences in size-frequency distribution of red snapper between depth strata (Figure 21) or between 8/0 and 11/0 hooks, although both captured significantly smaller individuals than did the 15/0 hooks (Figure 22; $p_{KS} < 0.05$).

<u>Comparison Among Gears:</u>

No significant differences in size structure were evident among the various gear types for red snapper (Figure 23). All three gears captured a broad size range of red snapper, ranging from approximately 200 – 750 mm SL.

Power analyses indicated that our survey effort and design for both active repetitive timed drops and passive gears was satisfactory Analyses based on a power of 0.8 indicated between 12 and 32 samples would be needed to detect a 100% change in a population for red snapper (Table 4). At the level of sampling used during this study we would be able to detect a 25% change in population size for all red snapper. Overall, our survey design had a better detection rate in population changes using the passive gears than the active repetitive drops. These analyses assumed that coefficient of variation values are representative; multiple years of data are necessary to more accurately assess inter-annual variability in relative abundances.

Our sampling design allowed us to compare catch rates across all gears. Overall, catch rates tended to be higher with the active repetitive timed drops, followed by the passive horizontal longline and lastly the vertical long line. Catch rates were higher with active repetitive timed drops and caught more fish overall and caught more species providing a broader characterization of the reef community. Both the passively fished long lines and the active repetitive drops show great promise for many reef associated species, neither was very good at catching groupers. Discussions with fisherman and captains indicate that the gear and more likely bait were the reason for low capture rates of groupers. In targeting theses species future testing with different gear/bait combinations should be explored.

A summary of the number of biological samples collected by repetitive timed drops, horizontal long lines, vertical long lines and all hooked gears is shown in Appendices 4-7. Overall, 1,307 red snapper captured during fisheries-independent monitoring were aged. The mean age for red snapper was 4.39 years. The youngest red snapper captured was age 1, while the oldest was age 21. The median and most frequent age was five years. Age frequency distributions appear bimodal with peaks at 2-3 years and 5-7 years (Figure 24). Age frequency distributions separated by sex were similar and the K-S test confirms there are no significant differences (p_{KS}=0.171). Seven hundred and fifteen female red snapper (mean age = 4.41) and 589 male snapper were aged (mean age=4.36). In general age frequencies for both sexes exhibit the same bimodal patterns (Figure 25a). Age composition of red snapper by zone was marginally non-significant (p_{KS}=0.068) indicating somewhat older individuals in the deeper stratum (Figure 25b). From the shallow stratum 670 red snapper were aged (mean age = 4.14 years), and 637 from the deep stratum were aged (mean age=4.64). Age frequencies by zone exhibited the same bimodal patterns as seen elsewhere (Figure 25c). Mean age in the northern zone (NMFS stat zone 722; N=233) was 4.7 years. In the central zone (NMFS stat zone 728; N=524) mean age was 4.84 years. In the southern zone (NMFS stat zone 732; N=550) mean age was 3.81 years. The K-S test confirmed that age composition was similar between NMFS zones 722 and 728 (p_{KS}=0.122), but that the distribution was significantly different in NMFS zone 732 (p_{KS}=0.013 and 0.011, respectively). Overall, younger fish were captured in NMFS stat zone 732 relative to zones 722 and 728. The von Bertalanffy growth curve confirms that red snapper grow rapidly during the younger ages and growth slows after age 5 (Fig 26). The estimated parameters from the von Bertalanffy growth mode are: Linf = 770.93 mm, K = 0.216 and t0=-0.081.

Based on project results, it is apparent that the hooked-gear methods tested have great potential in providing valuable fisheries-independent relative abundance and demographic data for red snapper and other reef fishes along the Atlantic coast of Florida. With the continued implementation of stricter management regulations and individual fishing quotas, it is becoming increasingly difficult to develop fisheries-dependent indices of relative abundance for managed species. Accordingly, we recommend that the implementation of a fishery-independent, hooked-gear survey along the southeast US Atlantic coast be given serious consideration. Before implementing a broad-scale survey, it would also be beneficial to conduct a study that directly compares the relative effectiveness of these hooked-gear methods with the camera and trap surveys conducted by MARMAP and SEFIS. Such an effort would assess whether these hooked-gear methods are complementary to the MARMAP/SEFIS survey by providing additional data on species or life-history stages that are underrepresented.

ACKNOWLEDGEMENTS

We gratefully acknowledge our industry partners whose knowledge and expertise were invaluable in developing and implementing our survey. Special thanks to Captains Robert Johnson, Paul Nelson, David Nelson, William Hogue and Brock Anderson. These captains provided their vessels and years of knowledge and experience that allowed us to not only complete all of our objectives, but to make this a safe and successful study. We acknowledge our colleague at NMFS-Panama City (Doug DeVries) for his insight and partnership during the development of this study. Thanks to Cynthia Meyer (NOAA/NMFS) for her assistance in obtaining the proper research permits (LOAs). Thanks to Dax Ruiz for NOAA-Fisheries grants administration. Many thanks to chief scientists that led research trips on industry vessels (Justin Solomon, Russel Brodie, Jeffrey Sauer, Agustin Sebastian) and to all other staff that traveled from various parts of the state, to help with data collection. Special thanks to Linda Torres and Janine Morganstern for their assistance in administering this grant. Lastly we acknowledge the staff of the Fish and Wildlife Research Institute that put in countless hours collecting, entering data, proofing data, filling in for staff that were out sampling, and assuring that all components of this project went smoothly. Lastly, very special thanks to Justin Solomon, Richard Paperno and Bridget Cermak for their efforts in preparing this report.

REFERENCES

Ault, J. S., S. G. Smith, et al. 2006. Building sustainable fisheries in Florida's coral reef ecosystem: positive signs in the Dry Tortugas. Bulletin of Marine Science 78(3): 633-654.

Coleman, F. C., C. C. Koenig, A.M. Eklund, and C. Grimes. 1999. Management and conservation of temperate reef fishes in the grouper-snapper complex of the southeastern United States. Pages 233–242 *in* J. A. Musick, ed. Life in the slow lane: ecology and conservation of long-lived marine animals. Am. Fish. Soc. Symp. 23:233-242.

Francis, R.I.C.C. 1988. Maximum likelihood estimation of growth and growth variability from tagging data. New Zealand Journal of Marine and Freshwater Research 22:42-51.

Gitschlag, G.R. and M.L. Renaud. 1994. Field experiments on survival rates of caged and released red snapper. North American Journal of Fisheries Management 14:131-136.

Koenig, C.C. and F.C. Coleman. 1998. Absolute abundance and survival of juvenile gag, *Myctoperca microlepis*, in seagrass beds of the N.E. Gulf of Mexico. Trans. Am. Fish. Soc. 127(1): 44-55.

Manooch, C.S., III, J.C. Potts, D. S. Vaughan, and M. L. Burton. 1998. Population assessment of the red snapper, *Lutjanus campechanus*, from the southeastern United States. Report prepared for the South Atlantic Fisheries Management Council, Charleston. 84 p.

R Development Core Team. 2008. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Rummer, J.L. and W.A. Bennett. 2005. Physiological effects of swim bladder overexpansion and catastrophic decompression on red snapper. Transactions of the American Fisheries Society 134: 1457-1470.

SAFMC (South Atlantic Fishery Management Council). 2010. Amendment Number 17A, Final Environmental Impact Statement, Initial Regulatory Flexibility Act Analysis, Regulatory Impact Review, and Social Impact Assessment/Fishery Impact Statement for the Fishery Management Plan for the Snapper Grouper Fishery of the South Atlantic Region. South Atlantic Fishery Management Council, 4055 Faber Place, Ste 201, North Charleston, S.C. 29405. 417 pp., http://sero.nmfs.noaa.gov or http://www.safmc.net

SAS Institute. 1994. SAS/STAT guide for personal computers, version 6, fourth edition. SAS Institute, Inc., Cary, North Carolina.

SEDAR 15. 2008. Stock Assessment Report 1 (revised March, 2009). South Atlantic Red Snapper. Available from the SEDAR website: www.sefsc.noaa.gov/sedar/

SEDAR 24. 2010. Standardized discard rates of U.S. Atlantic red snapper (Lutjanus campechanus) from headboat at sea observer data. Available from the SEDAR website: www.sefsc.noaa.gov/sedar/

White, D.B., and S.M. Palmer. 2004. Age, growth and reproduction of the red snapper, *Lutjanus campechanus*, from the Atlantic waters of the southeastern United States. Bull. Mar. Sci. 75: 335-360.

Williams E. H. and J. Carmichael, eds. 2010. South Atlantic Fishery Independent Monitoring Workshop: Final Report. Beaufort, NC. November 17-20, 2009.

Table 1. Summary of sites selected and (sampled) by NMFS statistical zone and depth strata.

Zone	Depth Strata	April	May	June	July	August	Sept./Oct.
722	Shallow (<30m)	12 (10)	12 (11)	12 (11)	12 (8)	6 (3)	10 (6)
	Deep (>30m)	20 (16)	20 (11)	20 (5)	20 (17)	24 (12)	16 (11)
728	Shallow (<30m)	12 (12)	12 (12)	12 (6)	12 (12)	6 (5)	10 (4)
	Deep (>30m)	20 (16)	20 (19)	20 (8)	20 (20)	20 (9)	8 (0)
730	Shallow (<30m)	12 (2)	12 (11)	12 (8)	12 (10)	18 (15)	10 (6)
	Deep (>30m)	20 (20)	20 (12)	20 (4)	20 (14)	25 (9)	16 (9)
	Total	**96 (76)**	**96 (76)**	**96 (42)**	**96 (81)**	**99 (53)**	**70 (36)**

Table 2. Summary output from the fully parameterized and final reduced generalized linear models for red snapper, *L. campechanus*.

	Fully Parameterized Model			Reduced Model Null Deviance =3738		
	DF	Deviance	*P*(F)	DF	Deviance	*P*(F)
No. of hooks	1	1718.71	<0.0001	1	1716.92	<0.0001
Hook Size	2	75.56	<0.0001	2	11.74	0.0028
Hook Position	11	46.53	<0.0001	NA	NA	NA
Gear	2	62.56	<0.0001	2	165.32	<0.0001
Month	4	57.83	<0.0001	4	57.29	<0.0001
Zone	11	33.07	<0.0001	2	33.89	NA
Depth (m)	1	8.08	0.0045	1	8.08	0.0045
Temperature (°C)	1	6.78	0.0092	1	6.80	0.0091
Time of Day	1	0.72	0.3947	NA	NA	NA
Zone*Depth	2	21.98	<0.0001	2	22.75	<0.0001
Month*Zone	8	30.36	0.0002	8	30.53	0.0002
Month*Depth	4	10.10	0.0387	4	10.20	0.0372
		AICC	**4,108**		**AICC**	**4,091**

Table 3. Estimated coefficients for covariate effects on model estimates. Coefficients not shown are baseline, and effects of coefficients on model estimates are calculated using the values shown below.

	Estimate	Std. Error	z	*P*
(Intercept)	0.3174	0.935	0.339	0.7343
No. of Hooks	0.0572	0.009	6.395	<0.0001
Horizontal LL	-1.8321	0.238	-7.69	<0.0001
Vertical LL	-2.6341	0.252	10.446	<0.0001
Hook size (11/0)	0.3649	0.138	2.645	0.0082
Hook size (15/0)	0.0897	0.133	0.674	0.5003
May	-0.3314	0.429	-0.773	0.4395
June	-0.0413	0.641	-0.064	0.9486
July	-0.5578	0.426	-1.308	0.1907
August	-1.6177	0.631	-2.564	0.0104
Zone 728	0.1207	0.488	0.247	0.8048
Zone 732	2.4007	0.552	4.353	0.0000
Depth	-0.0244	0.013	-1.935	0.0530
Surface Temp.	-0.0731	0.032	-2.271	0.0232
Zone728:Depth	0.0228	0.013	1.743	0.0814
Zone732:Depth	-0.0292	0.013	-2.193	0.0283
May:Zone728	-0.4126	0.353	-1.17	0.2420
June:Zone728	0.3454	0.429	0.805	0.4206
July:Zone728	-0.8286	0.382	-2.169	0.0301
August:Zone728	-2.7379	0.740	-3.701	0.0002
May:Zone732	-1.0884	0.399	-2.728	0.0064
June:Zone732	-0.8442	0.476	-1.773	0.0763
July:Zone732	-0.7765	0.417	-1.864	0.0624
August:Zone732	-1.0818	0.598	-1.81	0.0703
May:Depth	0.0232	0.010	2.319	0.0204
June:Depth	-0.0006	0.019	-0.031	0.9755
July:Depth	0.0075	0.010	0.779	0.4358
August:Depth	0.0374	0.011	3.287	0.0010

Table 4. Summary of power analyses for red snapper (*L. campechanus*) captured by active repetitive timed drops (ATD), passive horizontal long lines (PHL) and passive vertical long lines (PVL). Sample sizes (N) needed to detect to a 10%, 25%, 50%, 75%, and 100% change in population, based on a 0.80 power are calculated for each species.

		Fish per station			Sample Size Detection (Power=0.80)				
	Gear	Mean	Std	CV (%)	10%	25%	50%	75%	100%
L. campechanus	ATD	6.96	6.73	96.80	11,758	474	120	56	32
L. campechanus	PHL	1.91	1.04	54.71	3,868	154	40	20	12
L. campechanus	PVL	1.53	0.93	61.20	4,738	192	50	24	14

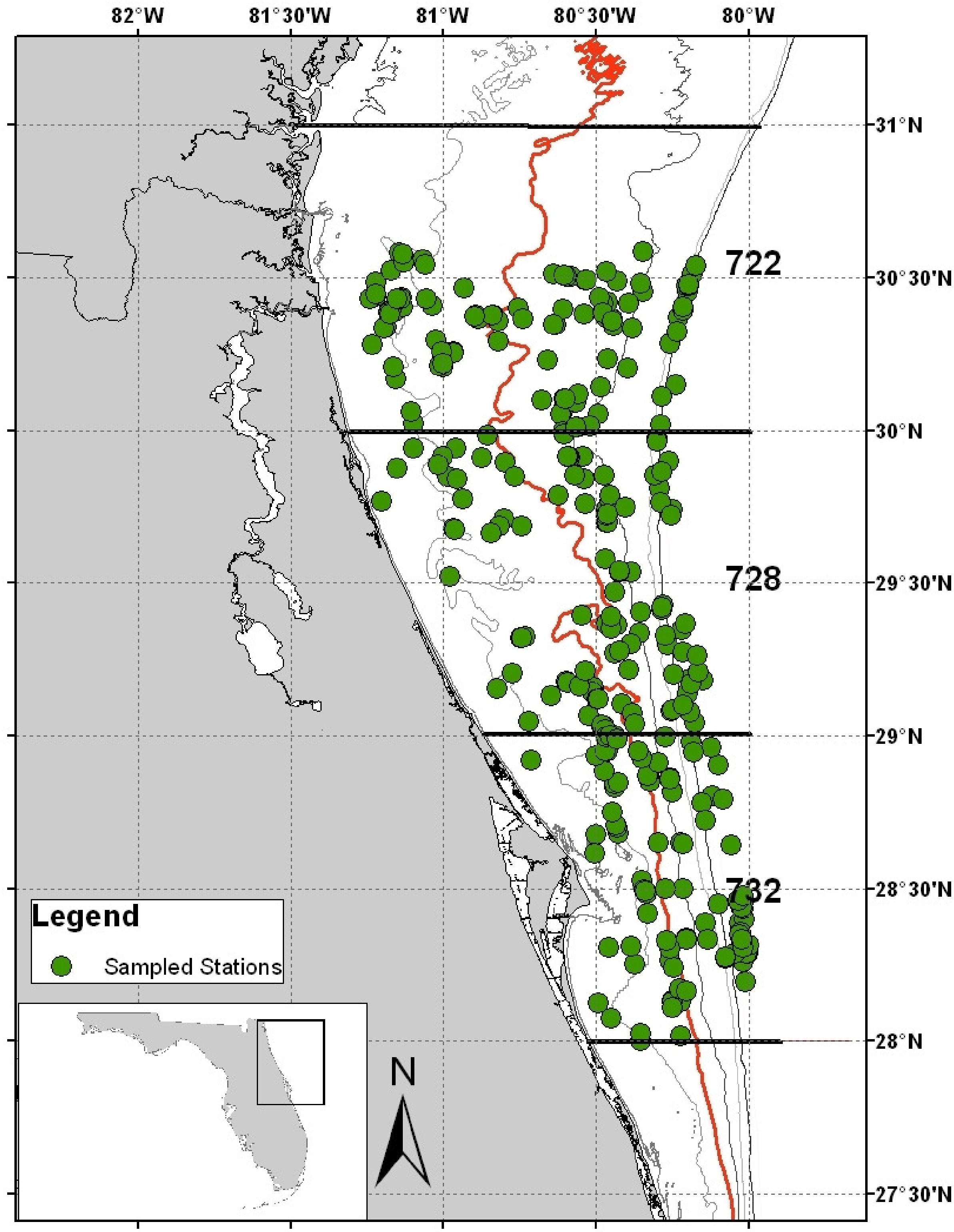

Figure 1. Image of study area (sampling bounded by 28° 00'N and 30° 45'N), including NMFS statistical zones, 30 m isobaths, and location of sampled sites.

Figure 2. Electric reel (Elec-tra-Mate© model 920xp) conventional fishing rig equipped with a Penn 9/0 Senator reel used to monitor reef fishes in South Atlantic waters.

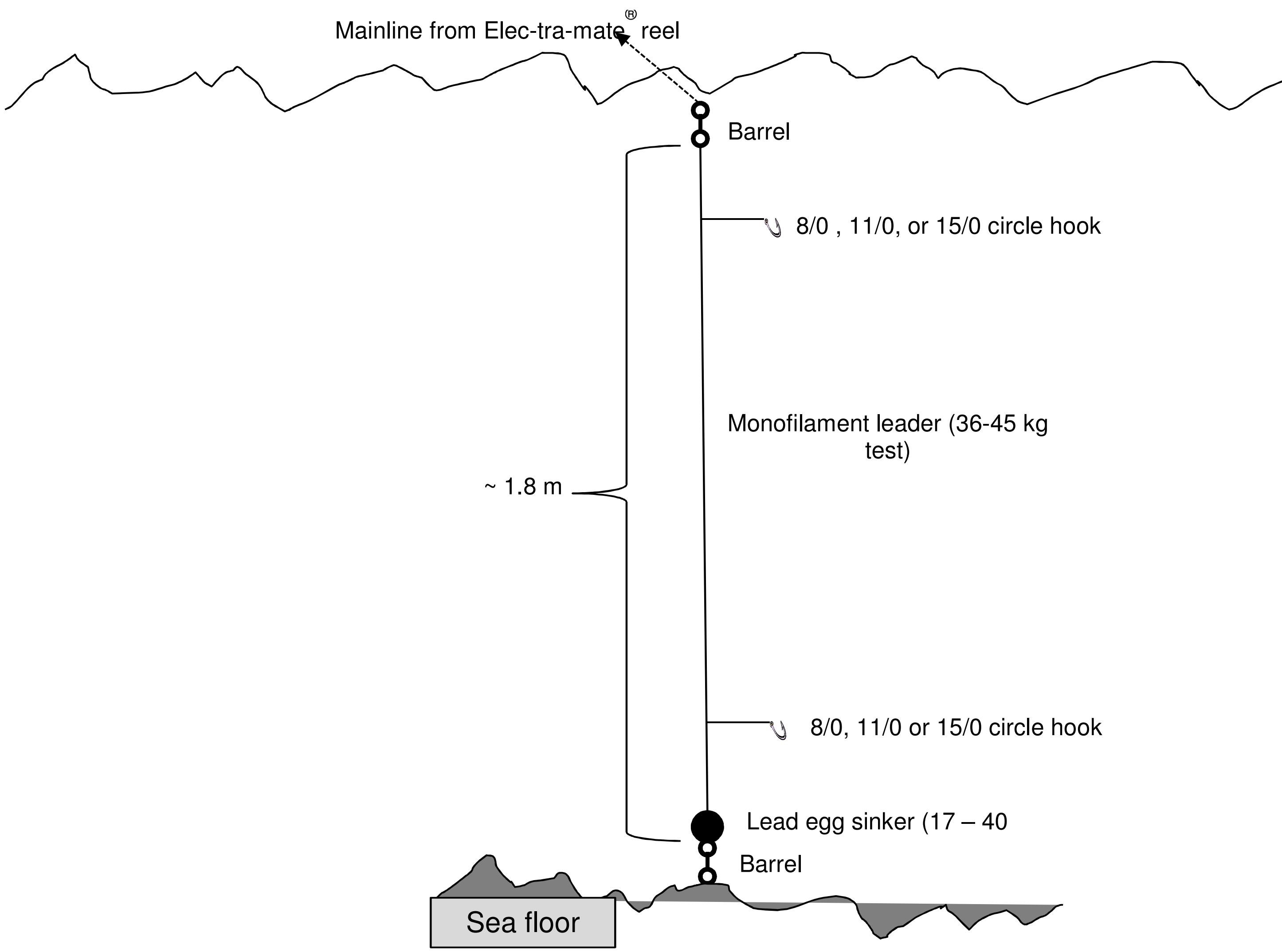

Figure 3. A double-hook “chicken rig”, used with electric reel rigs to conduct actively fished repetitive timed drops.

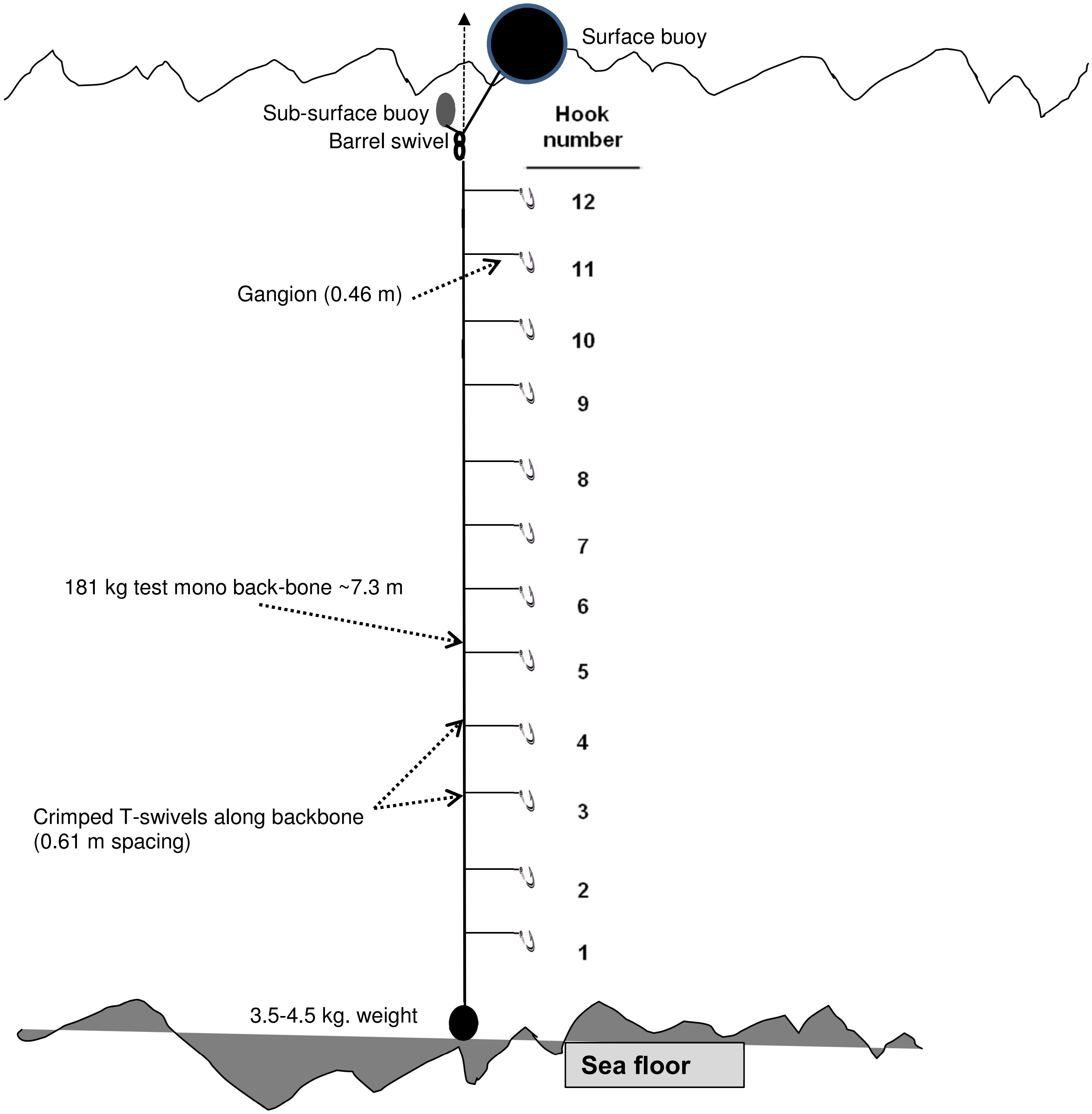

Figure 4. Vertical long line gear and buoy system for sampling reef fish. Large black oval indicates the surface buoy system and the small black oval indicates the subsurface buoy which acts to keep the back-bone vertical on the seafloor. Hook order is randomly selected for the top three hooks from one each of 8/0, 11/0, and 15/0 hooks. The pattern is repeated three times from top to bottom.

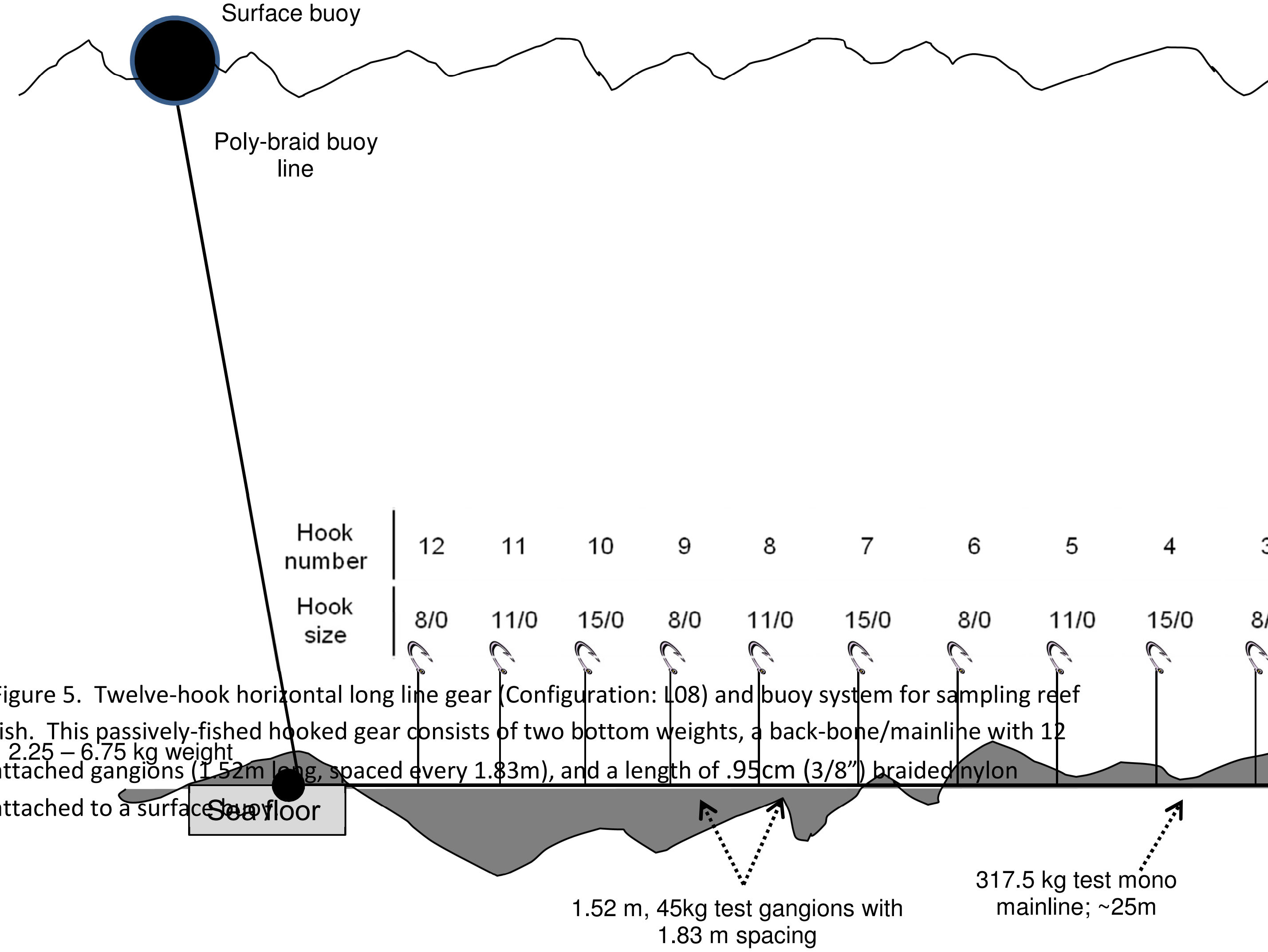

Figure 5. Twelve-hook horizontal long line gear (Configuration: L08) and buoy system for sampling reef fish. This passively-fished hooked gear consists of two bottom weights, a back-bone/mainline with 12 attached gangions (1.52m long, spaced every 1.83m), and a length of .95cm (3/8") braided nylon attached to a surface buoy.

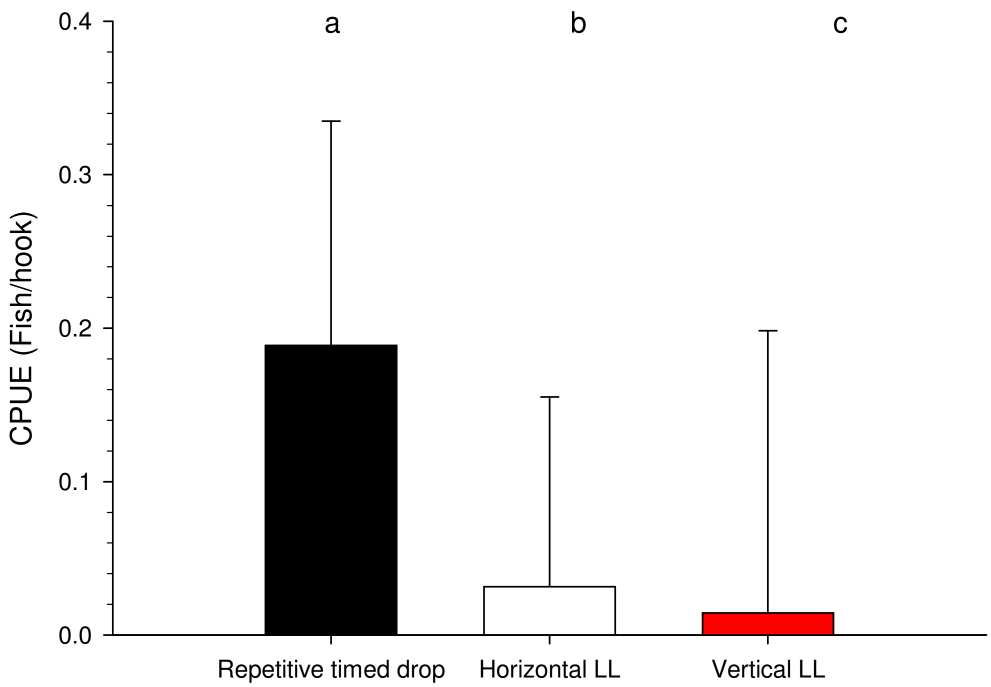

Figure 6. Catch-per-unit-effort (CPUE) for red snapper (*L. campechanus*) with standard error bars. Values are summarized by gear (Active repetitive timed drop, passive horizontal long lines, and passive vertical long lines). Significant differences are indicated by differing letters.

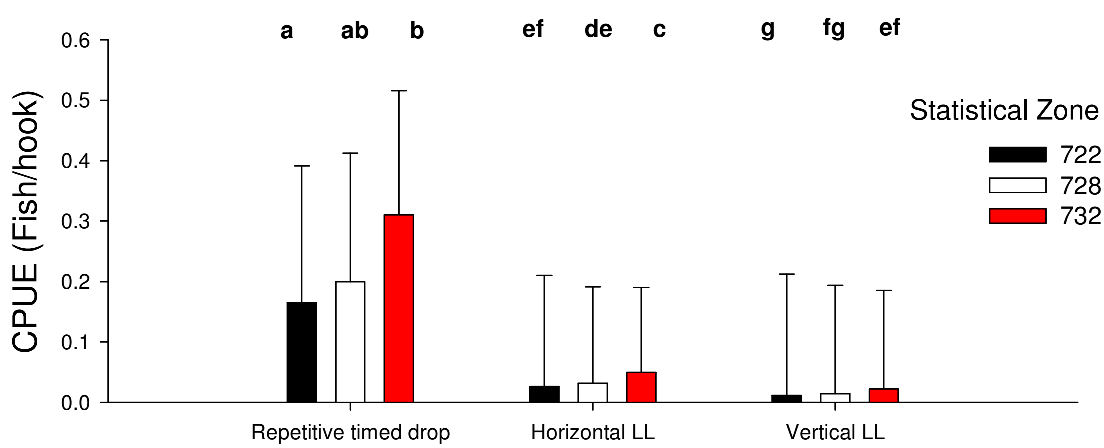

Figure 7. Catch-per-unit-effort (CPUE) for red snapper (*L. campechanus*) with standard error bars. Values are summarized by gear (Active repetitive timed drop, passive horizontal long lines, and passive vertical long lines) by NMFS statistical reporting zone (722 = Jacksonville, 728 = St. Augustine, 732 = Cape Canaveral). Significant differences are indicated by differing letters.

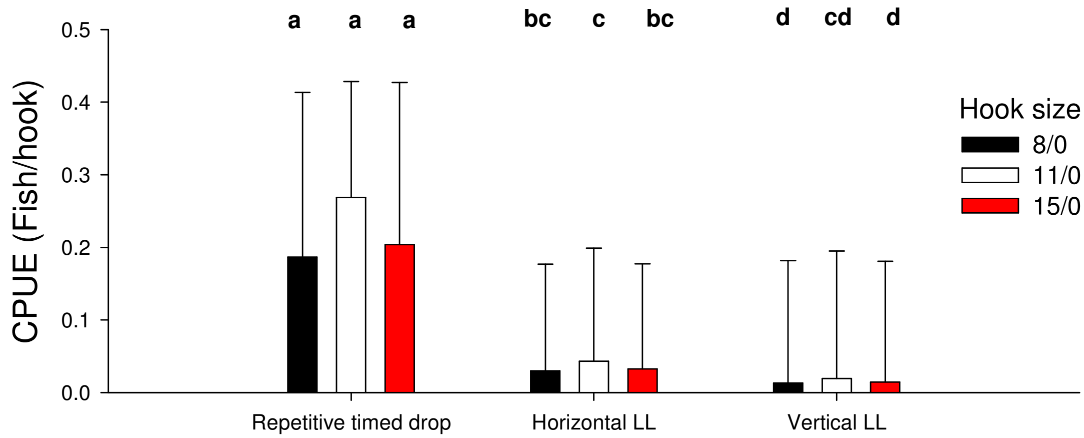

Figure 8. Catch-per-unit-effort (CPUE) for red snapper (*L. campechanus*). Values are summarized by hook size for each gear (Active repetitive timed drop, passive horizontal long lines, and passive vertical long lines). No significant differences were found between hook sizes.

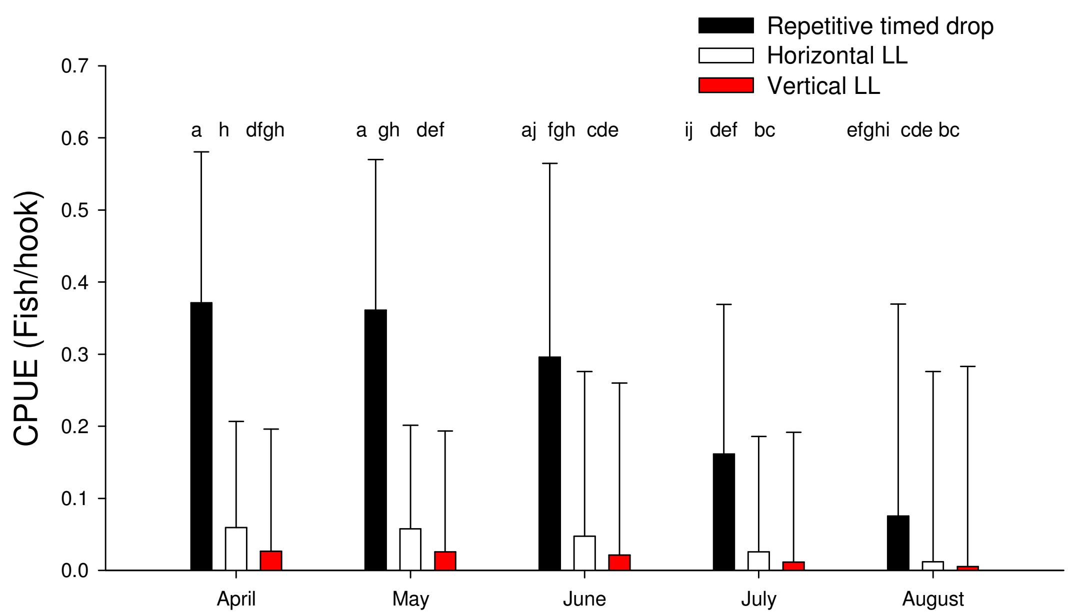

Figure 9. Catch-per-unit-effort (CPUE) for red snapper (*L. campechanus*). Values are summarized by for each gear (Active repetitive timed drop, passive horizontal long lines, and passive vertical long lines) by month.

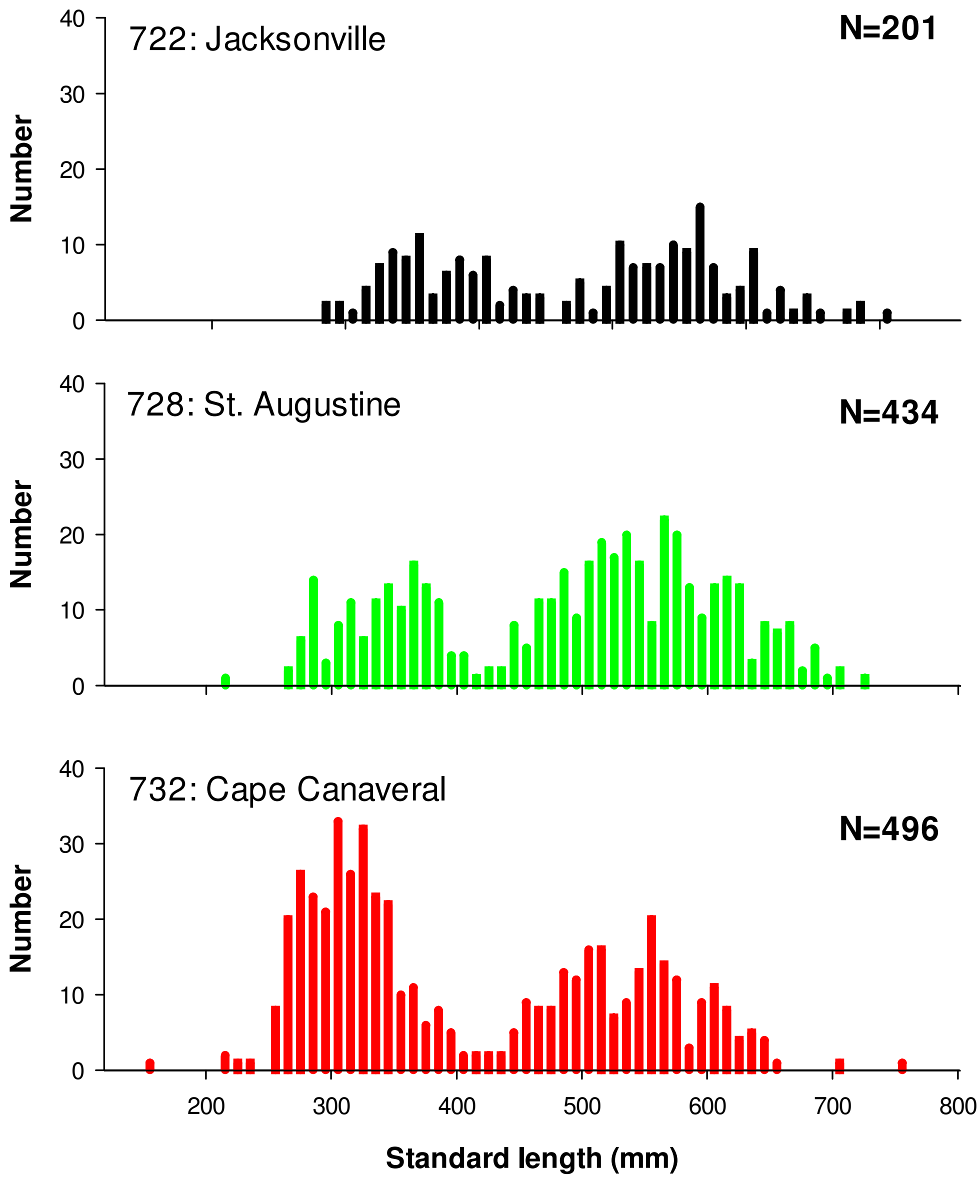

Figure 10. Summary of the length frequency of red snapper among statistical zones (722: Jacksonville; 728: St. Augustine; 732: Cape Canaveral) for the active repetitive timed drop survey.

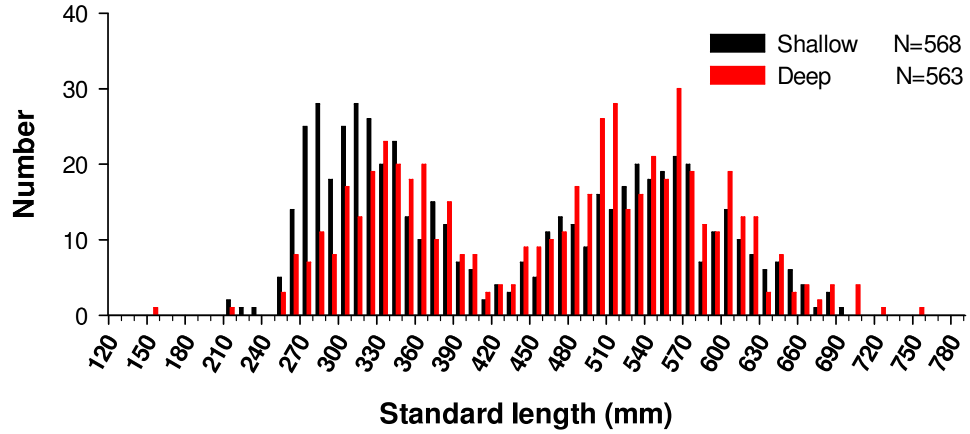

Figure 11. Summary of the length frequency of red snapper between shallow (≤ 30 meters: upper panel) and deep (≥ 30 meters: lower panel) strata for the active repetitive timed drop survey.

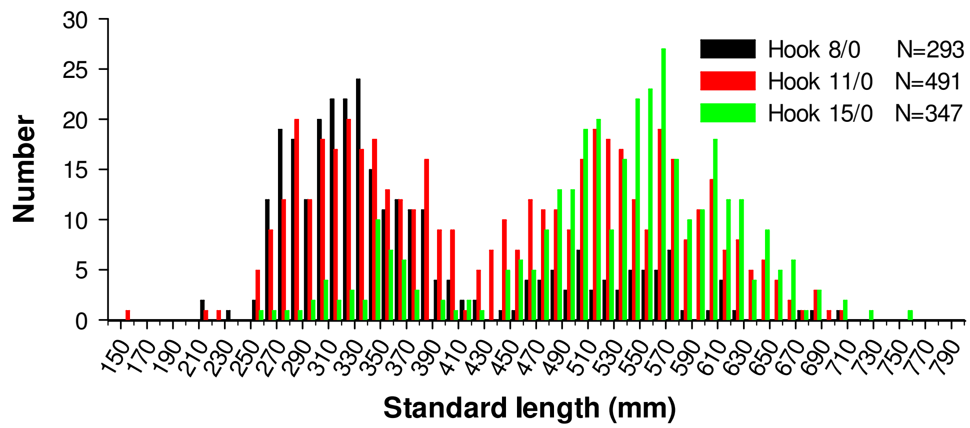

Figure 12. Summary of the length frequency of red snapper among hook sizes for the active repetitive timed drop survey.

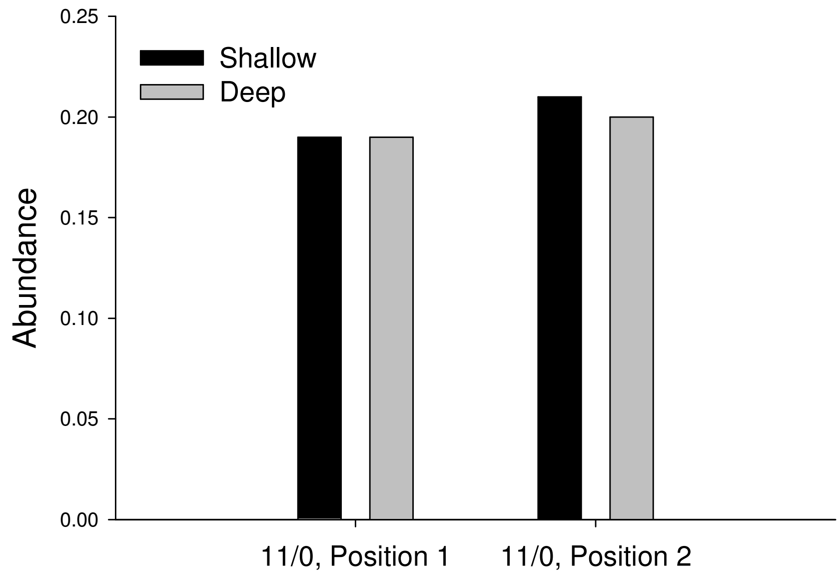

Figure 13. Summary of the relative abundance of red snapper collected on 11/0 hooks in the upper (position 1) and lower (position 2) position of the terminal tackle within the shallow (≤ 30 meters: upper panel) and deep (≥ 30 meters: lower panel) strata for the active repetitive timed drop survey.

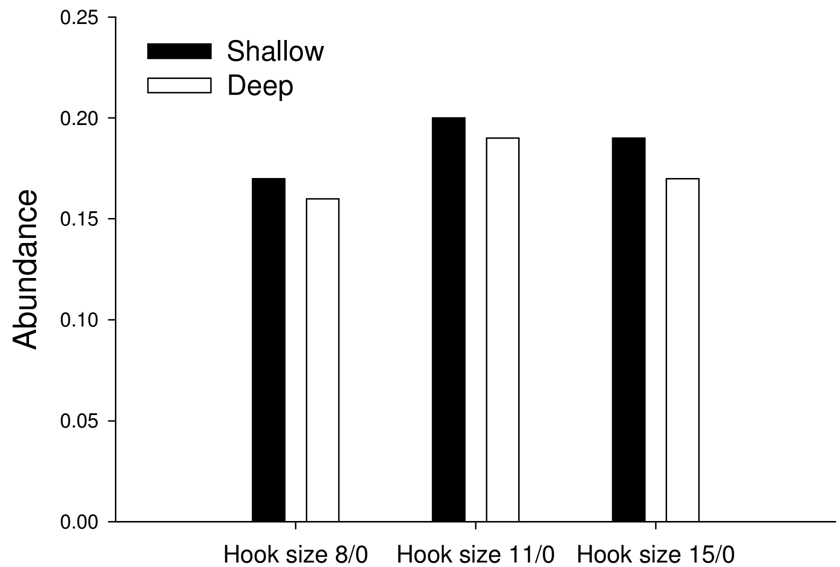

Figure 14. Summary of the relative abundance of red snapper among hook sizes for the shallow (≤ 30 meters: upper panel) and deep (≥ 30 meters: lower panel) strata for the active repetitive timed drop survey.

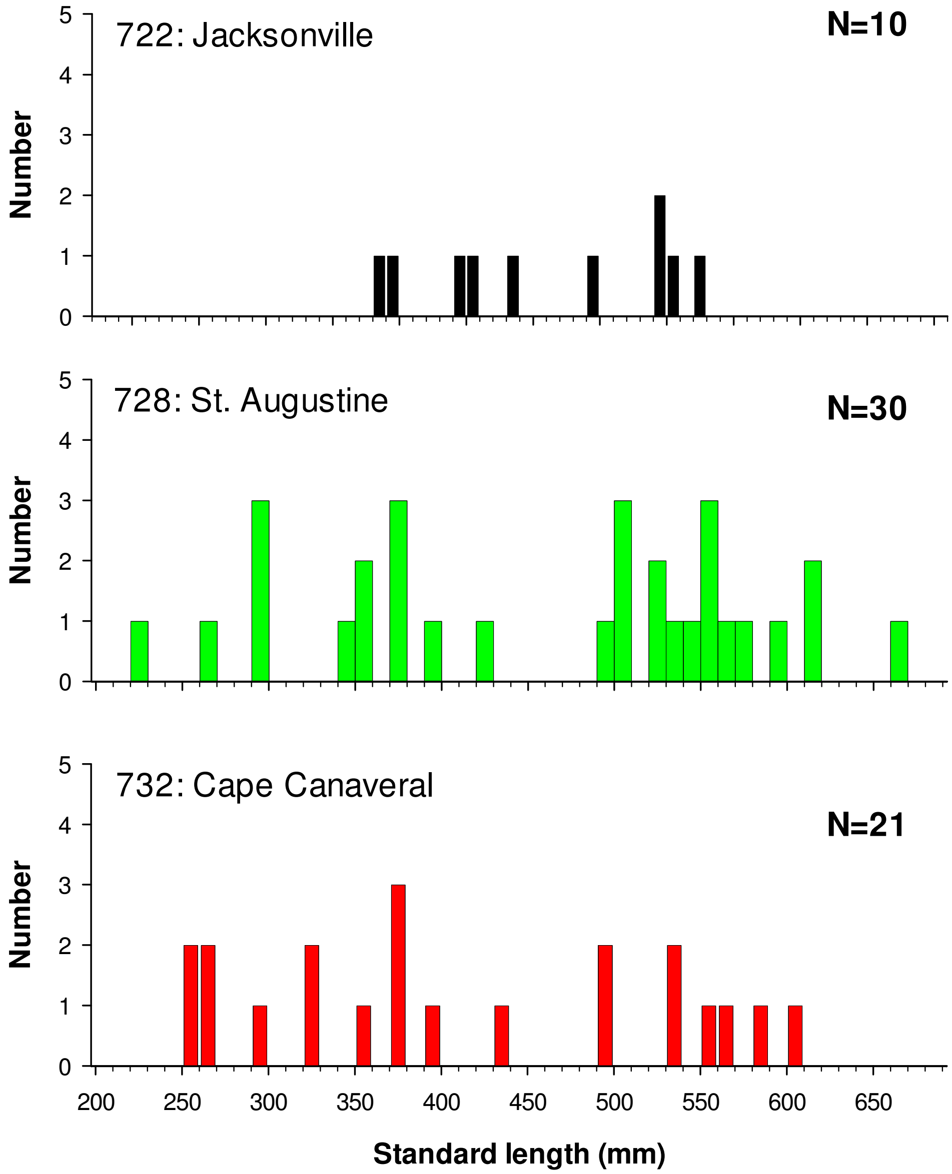

Figure 15. Summary of the length frequency of red snapper among statistical zones (722: Jacksonville; 728: St. Augustine; 732: Cape Canaveral) for the passive vertical long line survey.

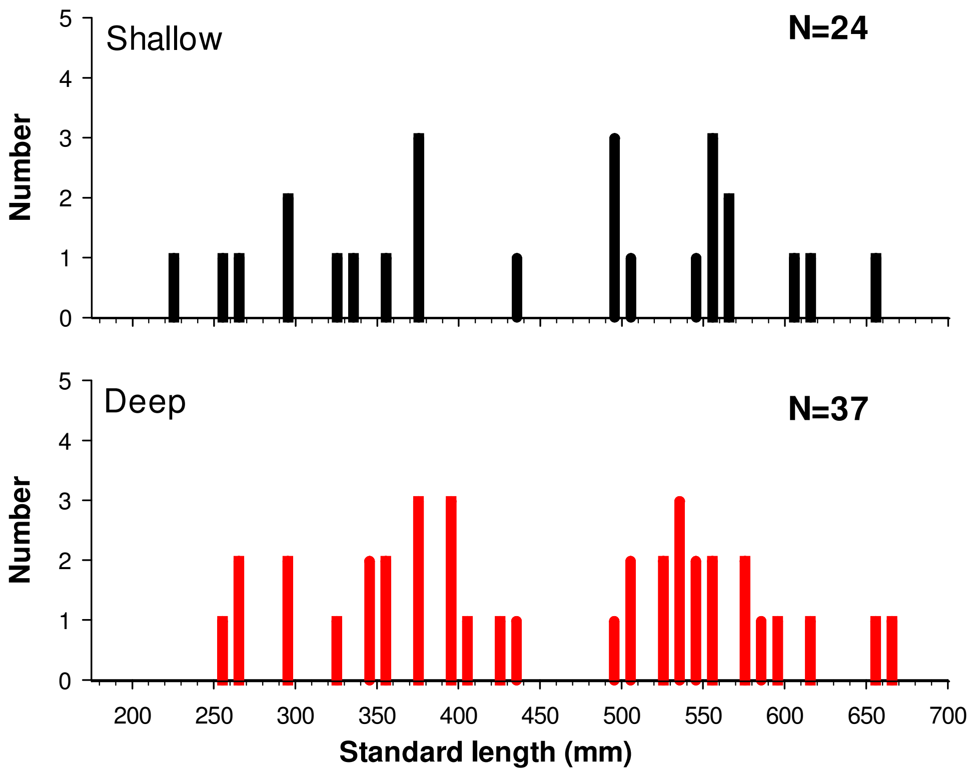

Figure 16. Summary of the length frequency of red snapper between shallow (≤ 30 meters: upper panel) and deep (≥ 30 meters: lower panel) strata for the passive vertical long line survey.

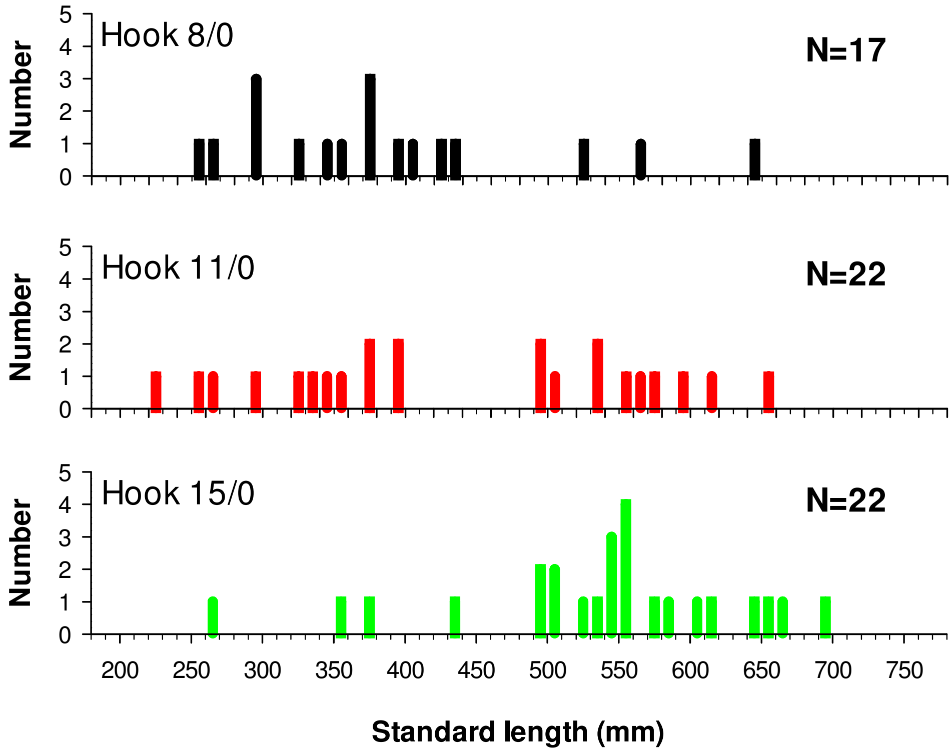

Figure 17. Summary of the length frequency of red snapper among hook sizes for the passive vertical long line survey.

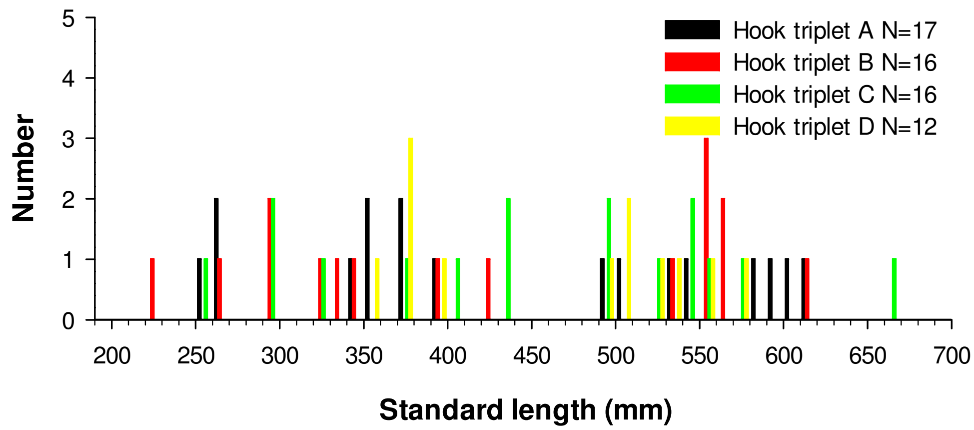

Figure 18. Summary of the length frequency of red snapper among hook triplet position (A: bottom three hooks; B: second three hooks; C: third three hooks; D: top three hooks) for the passive vertical long line survey.

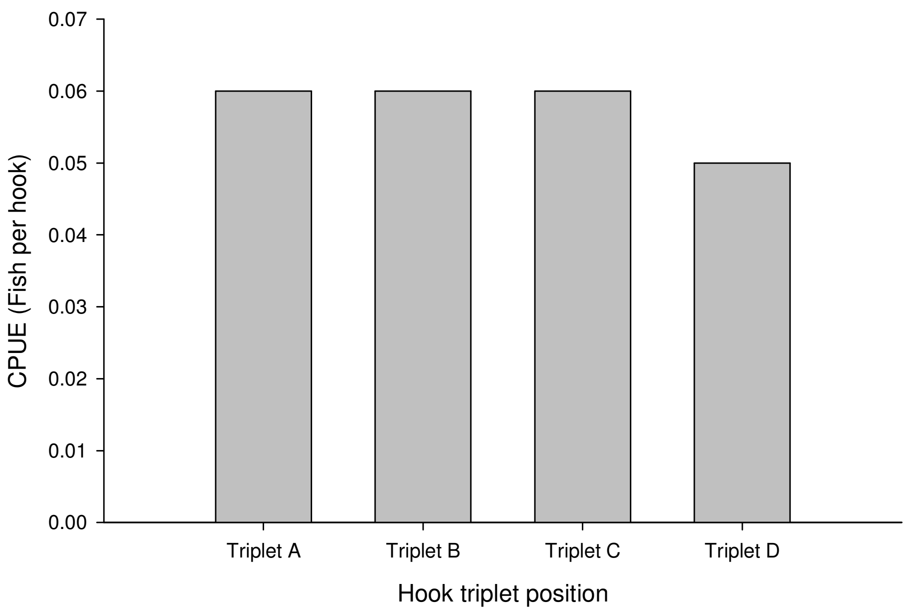

Figure 19. Summary of the relative abundance of red snapper among hook triplet position (A: bottom three hooks; B: second three hooks; C: third three hooks; D: top three hooks) for the passive vertical long line survey.

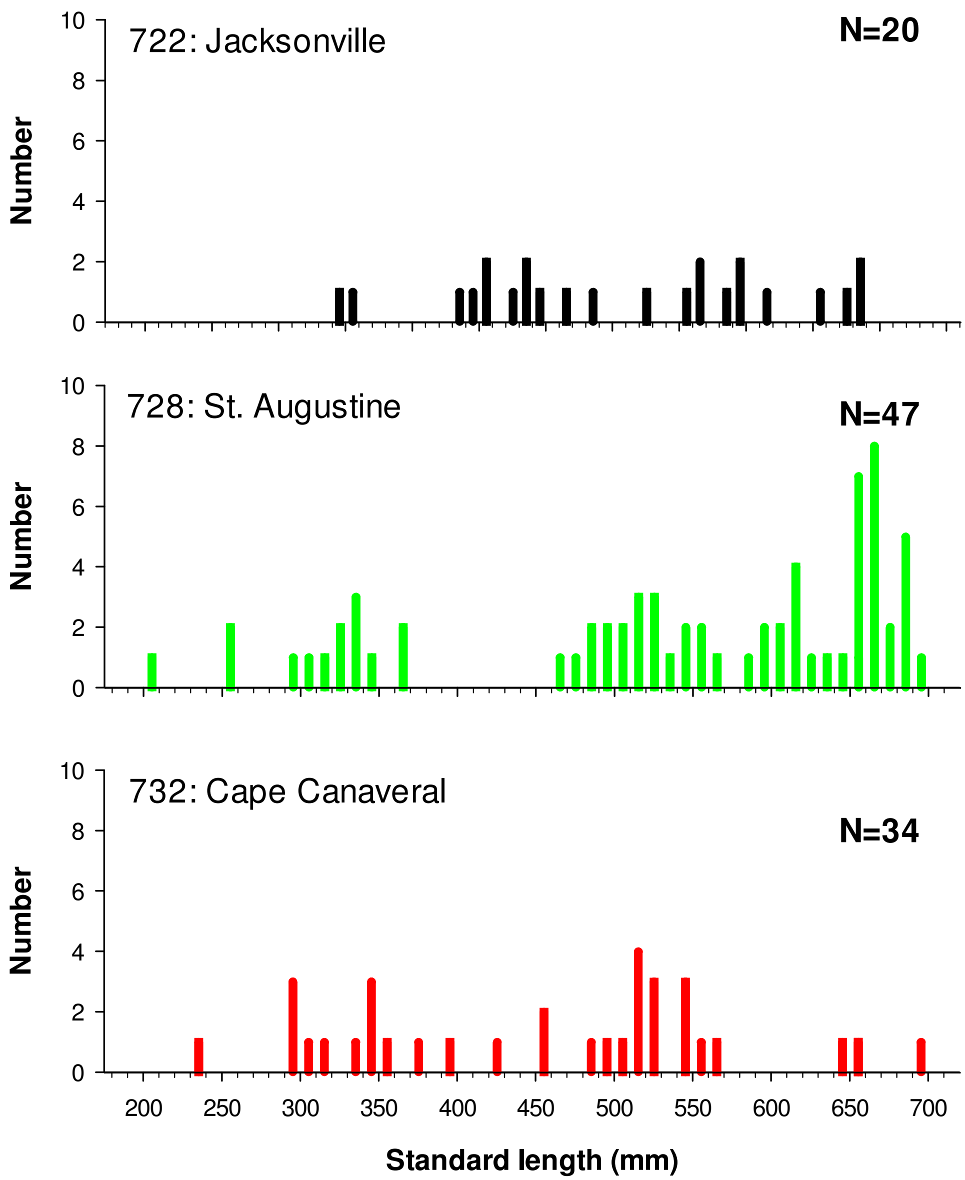

Figure 20. Summary of the length frequency of red snapper among statistical zones (722: Jacksonville; 728: St. Augustine; 732: Cape Canaveral) for the passive horizontal long line survey.

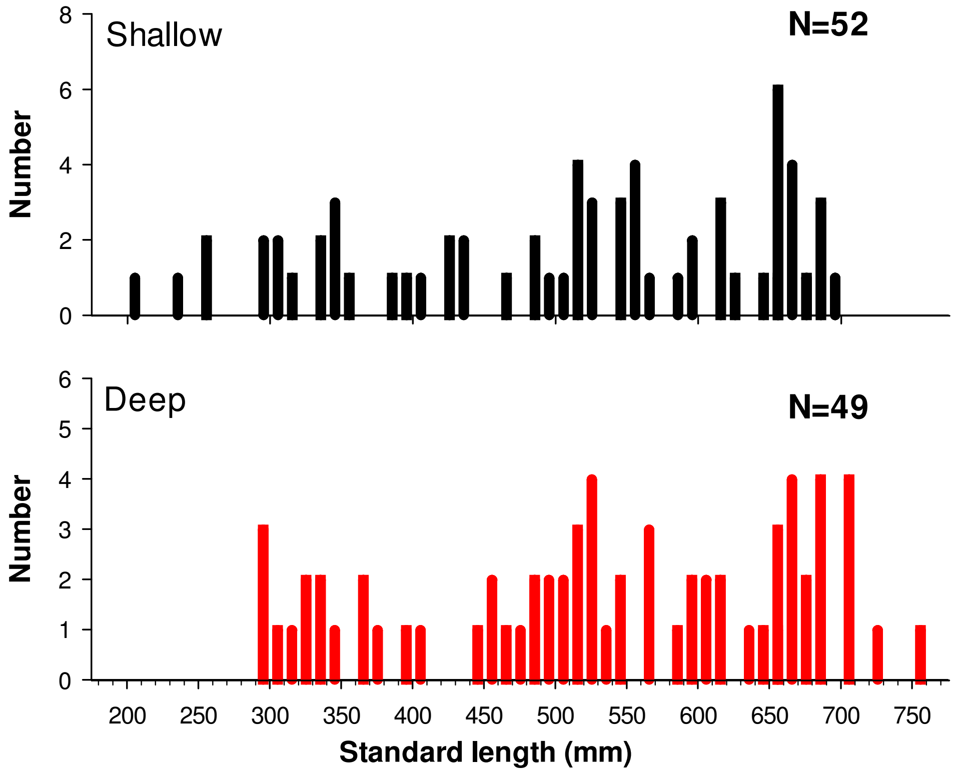

Figure 21. Summary of the length frequency of red snapper between shallow (≤ 30 meters: upper panel) and deep (≥ 30 meters: lower panel) strata for the passive horizontal long line survey.

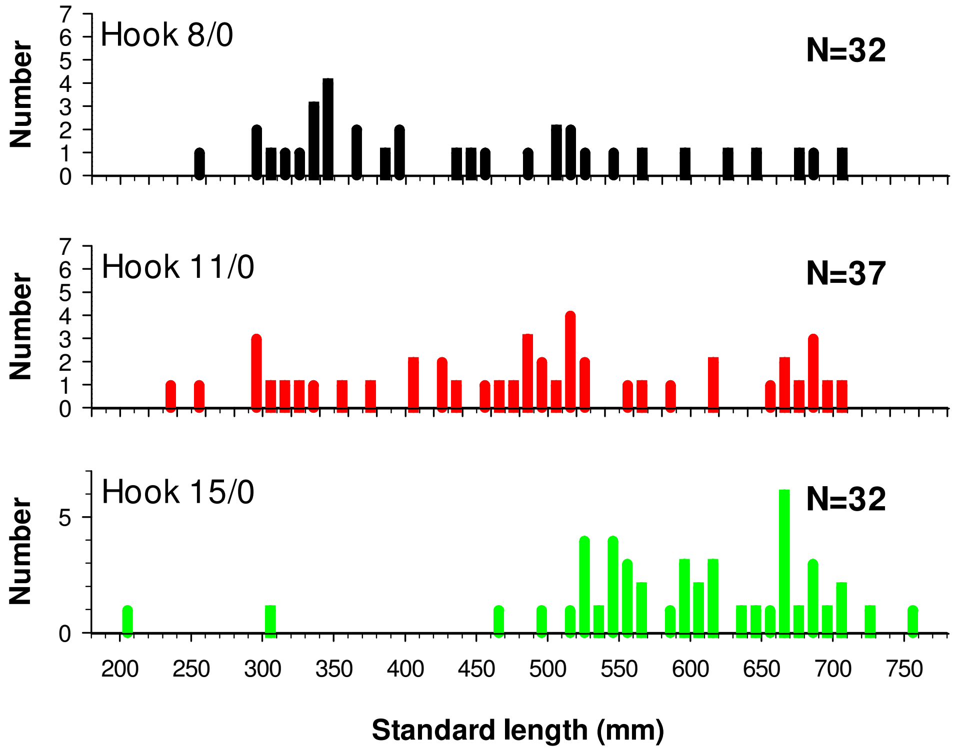

Figure 22. Summary of the length frequency of red snapper among hook sizes for the passive horizontal long line survey.

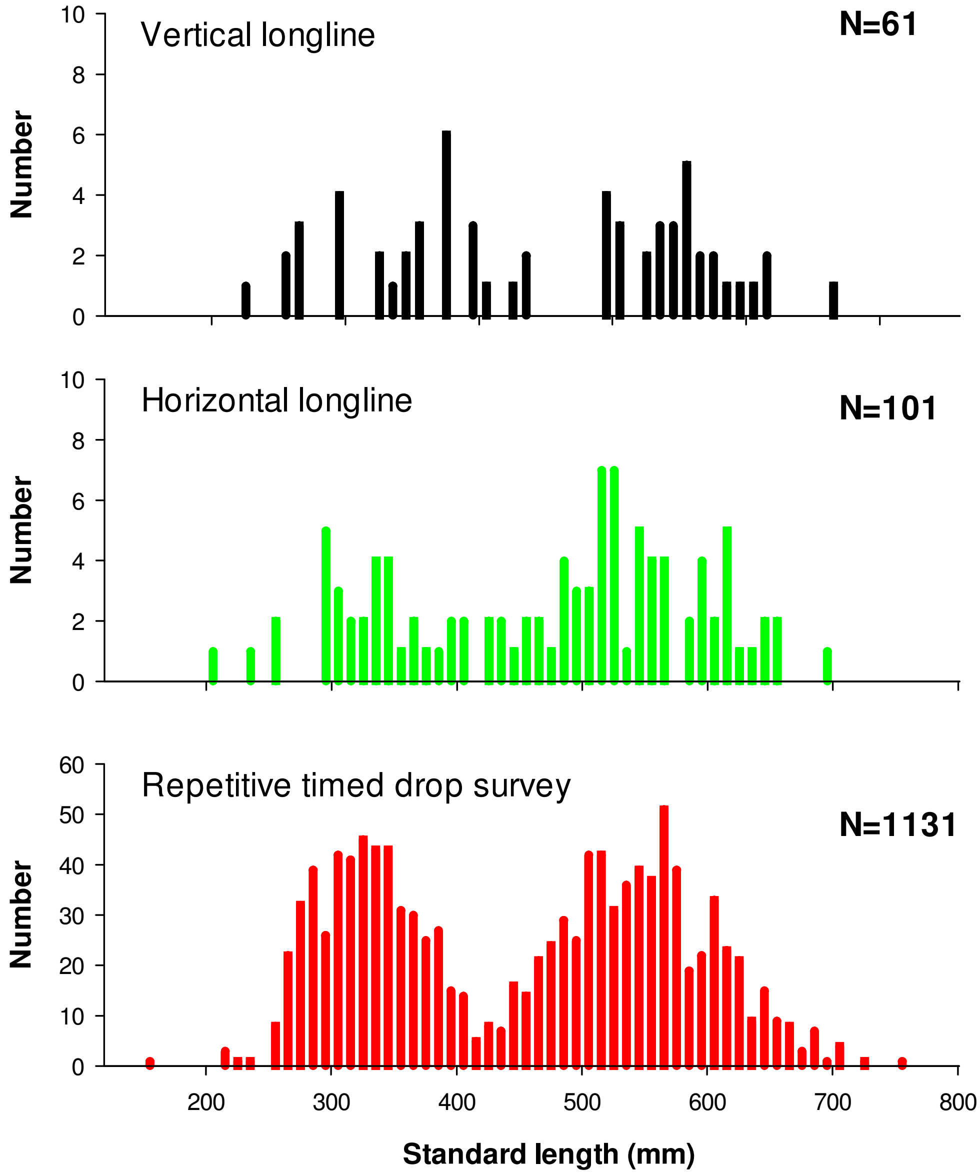

Figure 23. Summary of the length frequency of red snapper among gear types gear (Active repetitive timed drop, passive horizontal long line, and passive vertical long line).

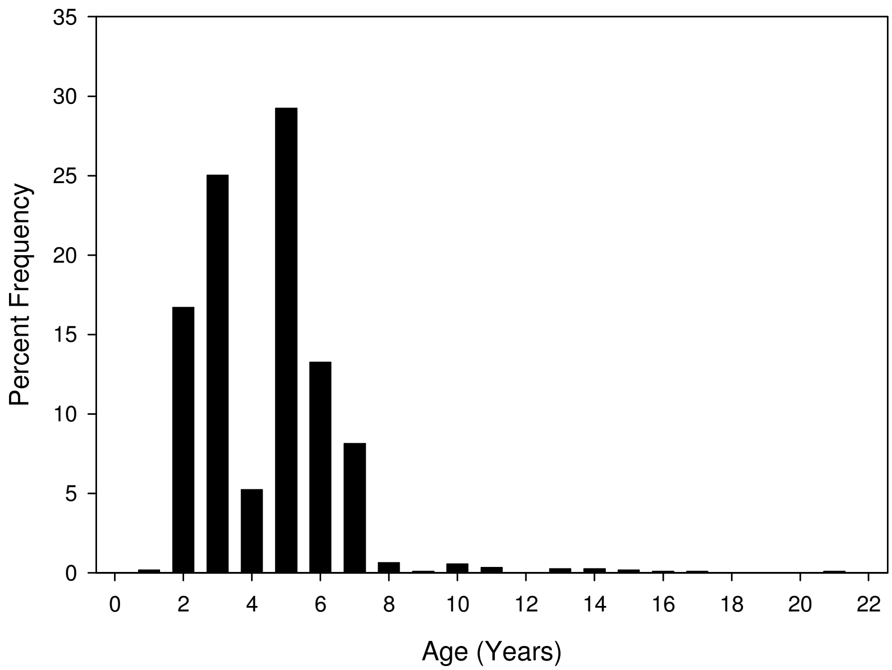

Figure 25. Age composition for all red snapper collected during fisheries-independent, hooked-gear monitoring.

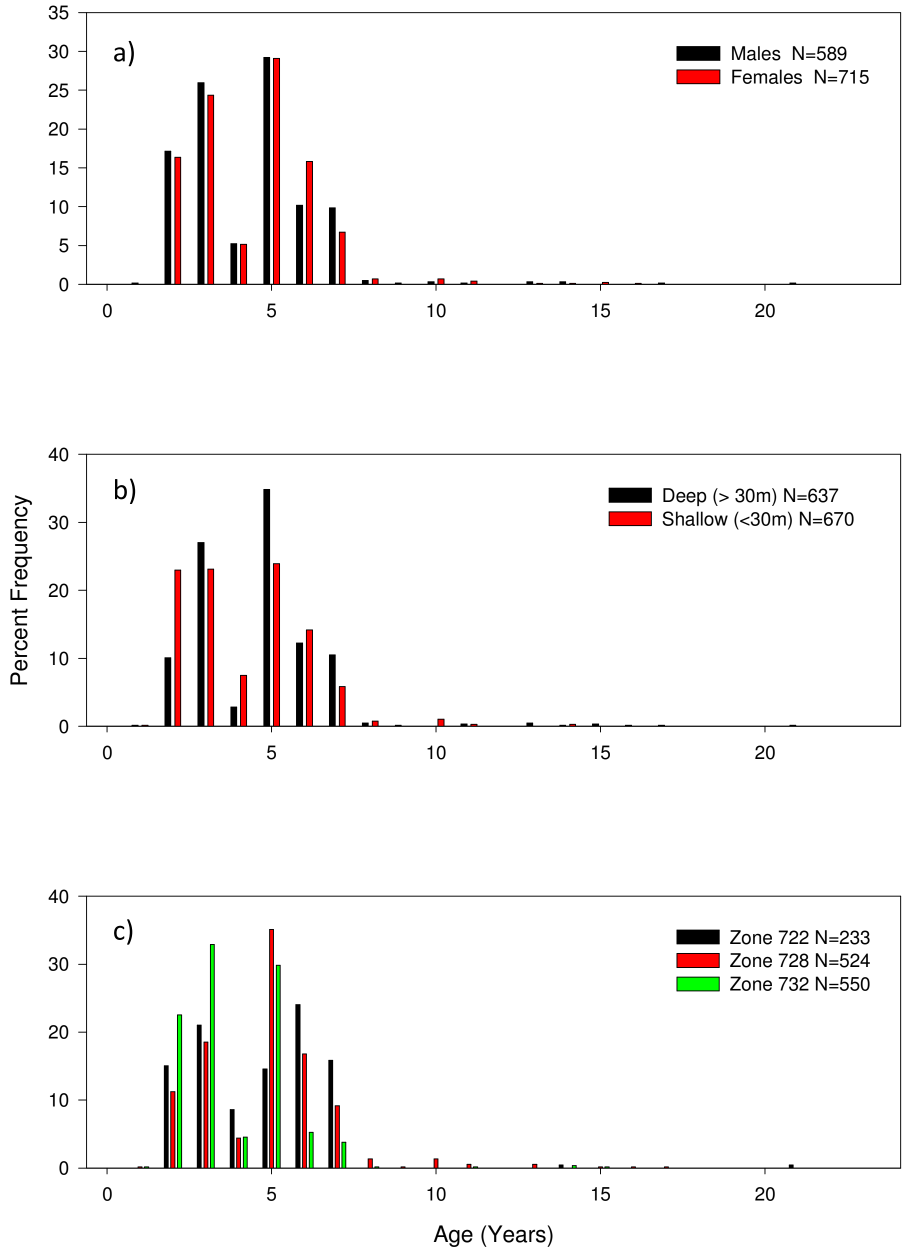

Figure 25. Age composition of red snapper presented by sex (a), depth stratum (b), and NMFS statistical zone (c) as determined via a fisheries-independent, hooked-gear survey. Significant differences were detected for NMFS statistical zones 722 and 732 (p_{ks}=0.013) and for 728 and 732 (p_{ks}=0.011).

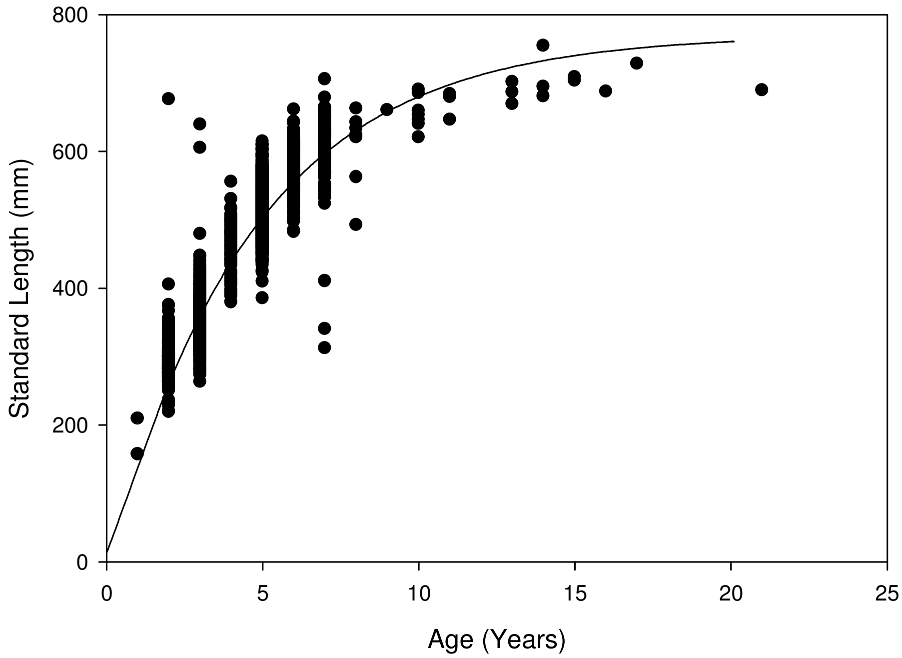

Figure 26. Observed length-at-age of red snapper collected from fisheries-independent, hooked-gear monitoring of red snapper. The continuous line is the estimated von Bertalanffy function where Linf=770.93 mm, K=0.216 and t0=0.081.

Appendix 1. Summary of species collected by hooked gear surveys in Zone 722. Percent (%) fish of total catch is the total number of that species out of total for all species. Percent (%) species per gear is number caught per gear for each species out of total caught for each gear. Active repetitive timed drop=HNL; Passive horizontal long lines=Horizontal LL; Passive vertical long lines=Vertical LL)

Zone 722 Species	Catch per gear HNL	Catch per gear Vertical LL	Catch per gear Horizontal LL	Total	% fish of total catch	% species per gear HNL	% species per gear Vertical LL	% species per gear Horizontal LL
Balistes capriscus	9	2	1	12	0.7	0.6	1.5	0.8
Caranx crysos	1	-	-	1	0.1	0.1	-	-
Carcharhinus falciformis	1	-	1	2	0.1	0.1	-	0.8
Carcharhinus plumbeus	1	-	-	1	0.1	0.1	-	-
Centropristis ocyurus	2	-	-	2	0.1	0.1	-	-
Centropristis philadelphica	-	-	1	1	0.1	-	-	0.8
Centropristis striata	396	35	39	470	28.2	28.1	26.1	32.2
Coryphaena hippurus	-	-	1	1	0.1	-	-	0.8
Decapterus punctatus	1	-	-	1	0.1	0.1	-	-
Diplectrum formosum	-	-	1	1	0.1	-	-	0.8
Diplodus holbrookii	6	-	-	6	0.4	0.4	-	-
Echeneis naucrates	15	13	3	31	1.9	1.1	9.7	2.5
Epinephelus nigritus	-	-	1	1	0.1	-	-	0.8
Epinephelus niveatus	3	-	-	3	0.2	0.2	-	-
Euthynnus alletteratus	-	1	-	1	0.1	-	0.7	-
Galeocerdo cuvier	2	-	-	2	0.1	0.1	-	-
Ginglymostoma cirratum	5	-	-	5	0.3	0.4	-	-
Gymnothorax moringa	1	-	-	1	0.1	0.1	-	-
Haemulon aurolineatum	130	12	4	146	8.8	9.2	9.0	3.3
Holocentrus adscensionis	3	1	-	4	0.2	0.2	0.7	-
Lagodon rhomboides	1	-	-	1	0.1	0.1	-	-
Lutjanus analis	2	-	-	2	0.1	0.1	-	-
Lutjanus campechanus	201	10	20	231	13.9	14.2	7.5	16.5
Lutjanus griseus	2	-	-	2	0.1	0.1	-	-
Muraena retifera	1	-	1	2	0.1	0.1	-	0.8
Mycteroperca microlepis	17	-	1	18	1.1	1.2	-	0.8
Mycteroperca phenax	2	-	-	2	0.1	0.1	-	-
Opsanus tau	1	-	1	2	0.1	0.1	-	0.8
Pagrus pagrus	155	19	11	185	11.1	11.0	14.2	9.1
Paralichthys albigutta	1	-	1	2	0.1	0.1	-	0.8
Pareques umbrosus	1	-	-	1	0.1	0.1	-	-
Pomatomus saltatrix	2	-	-	2	0.1	0.1	-	-
Priacanthus arenatus	-	1	-	1	0.1	-	0.7	-
Rachycentron canadum	2	-	-	2	0.1	0.1	-	-
Raja eglanteria	-	-	1	1	0.1	-	-	0.8
Rhizoprionodon terraenovae	82	4	16	102	6.1	5.8	3.0	13.2
Rhomboplites aurorubens	240	26	10	276	16.6	17.0	19.4	8.3
Rypticus maculatus	-	-	2	2	0.1	-	-	1.7
Seriola dumerili	19	-	-	19	1.1	1.3	-	-
Seriola fasciata	2	2	-	4	0.2	0.1	1.5	-
Seriola rivoliana	44	3	4	51	3.1	3.1	2.2	3.3
Seriola zonata	59	5	1	65	3.9	4.2	3.7	0.8
Sphyraena barracuda	1	-	-	1	0.1	0.1	-	-
Totals	1411	134	121	1666				

Appendix 2. Summary of species collected by hooked gear surveys in Zone 728. Percent (%) fish of total catch is the total number of that species out of total for all species. Percent (%) species per gear is number caught per gear for each species out of total caught for each gear. Active repetitive timed drop=HNL; Passive horizontal long lines=Horizontal LL; Passive vertical long lines=Vertical LL)

Zone 728 Species	Catch per gear			Total	% fish of total catch	% species per gear		
	HNL	Vertical LL	Horizontal LL			HNL	Vertical LL	Horizontal LL
Balistes capriscus	9	1	4	14	0.6	0.5	0.6	1.9
Caranx crysos	2	-	-	2	0.1	0.1	-	-
Carcharhinus falciformis	14	3	6	23	1.1	0.8	1.7	2.9
Carcharhinus obscurus	1	-	-	1	0.0	0.1	-	-
Carcharhinus spp.	1	-	-	1	0.0	0.1	-	-
Caulolatilus microps	4	-	-	4	0.2	0.2	-	-
Centropristis ocyurus	4	-	2	6	0.3	0.2	-	1.0
Centropristis striata	610	73	92	775	35.6	33.9	41.7	44.7
Coryphaena hippurus	-	-	1	1	0.0	-	-	0.5
Cynoscion regalis	1	-	-	1	0.0	0.1	-	-
Echeneis naucrates	20	9	8	37	1.7	1.1	5.1	3.9
Echeneis neucratoides	1	-	-	1	0.0	0.1	-	-
Elagatis bipinnulata	-	2	-	2	0.1	-	1.1	-
Epinephelus morio	4	-	1	5	0.2	0.2	-	0.5
Epinephelus nigritus	2	-	-	2	0.1	0.1	-	-
Epinephelus niveatus	9	-	1	10	0.5	0.5	-	0.5
Euthynnus alletteratus	5	-	-	5	0.2	0.3	-	-
Galeocerdo cuvier	2	-	-	2	0.1	0.1	-	-
Ginglymostoma cirratum	1	-	-	1	0.0	0.1	-	-
Haemulon aurolineatum	182	11	6	199	9.1	10.1	6.3	2.9
Holocentrus adscensionis	-	-	1	1	0.0	-	-	0.5
Lagodon rhomboides	7	-	-	7	0.3	0.4	-	-
Lutjanus analis	3	-	-	3	0.1	0.2	-	-
Lutjanus campechanus	435	30	47	512	23.5	24.2	17.1	22.8
Lutjanus griseus	5	-	-	5	0.2	0.3	-	-
Lutjanus synagris	-	-	1	1	0.0	-	-	0.5
Menticirrhus americanus	-	-	1	1	0.0	-	-	0.5
Micropogonias undulatus	-	-	1	1	0.0	-	-	0.5
Muraena retifera	-	-	1	1	0.0	-	-	0.5
Mycteroperca interstitialis	1	-	-	1	0.0	0.1	-	-
Mycteroperca microlepis	16	1	-	17	0.8	0.9	0.6	-
Mycteroperca phenax	10	-	-	10	0.5	0.6	-	-

Appendix 2. (Cont.)

Zone 728	Catch per gear				% fish	% species per gear		
Species		Vertical	Horizontal		of total		Vertical	Horizontal
	HNL	LL	LL	Total	catch	HNL	LL	LL
Mycteroperca spp.	1	-	-	1	0.0	0.1	-	-
Neomerinthe hemingwayi	1	-	-	1	0.0	0.1	-	-
Ocyurus chrysurus	2	-	-	2	0.1	0.1	-	-
Opsanus tau	1	-	3	4	0.2	0.1	-	1.5
Pagrus pagrus	66	6	6	78	3.6	3.7	3.4	2.9
Pareques iwamotoi	-	-	1	1	0.0	-	-	0.5
Pomatomus saltatrix	4	-	-	4	0.2	0.2	-	-
Pristigenys alta	2	-	-	2	0.1	0.1	-	-
Pristipomoides aquilonaris	1	-	-	1	0.0	0.1	-	-
Rachycentron canadum	6	-	-	6	0.3	0.3	-	-
Rhizoprionodon terraenovae	58	2	10	70	3.2	3.2	1.1	4.9
Rhomboplites aurorubens	160	20	7	187	8.6	8.9	11.4	3.4
Seriola dumerili	11	-	-	11	0.5	0.6	-	-
Seriola rivoliana	36	5	1	42	1.9	2.0	2.9	0.5
Seriola zonata	91	11	2	104	4.8	5.1	6.3	1.0
Stenotomus caprinus	1	-	-	1	0.0	0.1	-	-
Stenotomus chrysops	1	-	-	1	0.0	0.1	-	-
Synodus intermedius	-	-	1	1	0.0	-	-	0.5
Trichiurus lepturus	6	1	2	9	0.4	0.3	0.6	1.0
Totals	1797	175	206	2178				

Appendix 3. Summary of species collected by hooked gear surveys in Zone 732. Percent (%) fish of total catch is the total number of that species out of total for all species. Percent (%) species per gear is number caught per gear for each species out of total caught for each gear. Active repetitive timed drop=HNL; Passive horizontal long lines=Horizontal LL; Passive vertical long lines=Vertical LL)

Zone 732 Species	Catch per gear HNL	Catch per gear Vertical LL	Catch per gear Horizontal LL	Total	% fish of total catch	% species per gear HNL	% species per gear Vertical LL	% species per gear Horizontal LL
Balistes capriscus	6	-	-	6	0.3	0.4	-	-
Calamus penna	1	-	-	1	0.1	0.1	-	-
Caranx crysos	2	-	-	2	0.1	0.1	-	-
Carcharhinus acronotus	1	-	-	1	0.1	0.1	-	-
Carcharhinus falciformis	2	1	3	6	0.3	0.1	0.9	1.9
Caulolatilus microps	1	-	-	1	0.1	0.1	-	-
Centropristis ocyurus	16	1	4	21	1.1	1.0	0.9	2.5
Centropristis philadelphica	1	-	-	1	0.1	0.1	-	-
Centropristis striata	781	63	79	923	50.0	49.6	55.8	50.0
Cynoscion regalis	1	-	-	1	0.1	0.1	-	-
Diplectrum formosum	1	-	1	2	0.1	0.1	-	0.6
Diplodus holbrookii	1	-	-	1	0.1	0.1	-	-
Echeneis naucrates	9	7	2	18	1.0	0.6	6.2	1.3
Epinephelus morio	3	1	1	5	0.3	0.2	0.9	0.6
Epinephelus nigritus	1	-	-	1	0.1	0.1	-	-
Epinephelus niveatus	4	1	5	10	0.5	0.3	0.9	3.2
Galeocerdo cuvier	1	-	-	1	0.1	0.1	-	-
Gymnothorax vicinus	-	-	1	1	0.1	-	-	0.6
Haemulon aurolineatum	72	3	3	78	4.2	4.6	2.7	1.9
Lagocephalus laevigatus	1	-	-	1	0.1	0.1	-	-
Lagodon rhomboides	4	-	-	4	0.2	0.3	-	-
Lutjanus campechanus	496	21	34	551	29.8	31.5	18.6	21.5
Lutjanus griseus	1	-	-	1	0.1	0.1	-	-
Mycteroperca microlepis	10	1	2	13	0.7	0.6	0.9	1.3
Mycteroperca phenax	1	-	-	1	0.1	0.1	-	-
Opsanus tau	-	-	6	6	0.3	-	-	3.8
Orthopristis chrysoptera	2	-	-	2	0.1	0.1	-	-
Pagrus pagrus	13	1	2	16	0.9	0.8	0.9	1.3
Pomatomus saltatrix	4	-	-	4	0.2	0.3	-	-
Rachycentron canadum	1	-	-	1	0.1	0.1	-	-
Rhizoprionodon terraenovae	100	4	13	117	6.3	6.3	3.5	8.2
Rhomboplites aurorubens	20	6	2	28	1.5	1.3	5.3	1.3
Sciaenops ocellatus	1	-	-	1	0.1	0.1	-	-
Seriola dumerili	4	2	-	6	0.3	0.3	1.8	-
Seriola rivoliana	10	-	-	10	0.5	0.6	-	-
Seriola zonata	1	1	-	2	0.1	0.1	0.9	-
Synodus foetens	2	-	-	2	0.1	0.1	-	-
Totals	1575	113	158	1846				

Appendix 4. Summary of biological specimens retained for demographic analysis from the active repetitive timed drop survey. Data have been aggregated over all three sampling regions.

	# of samples				
Species	Otolith	Histology	Mercury	Spine	Batch Fecundity
Balistes capriscus	2	-	25	23	-
Calamus penna	1	-	1	-	-
Carcharhinus acronotus	-	-	1	-	-
Carcharhinus falciformis	-	-	2	-	-
Caulolatilus microps	5	-	6	-	-
Centropristis philadelphica	-	-	1	-	-
Centropristis striata	614	56	614	1	-
Cynoscion regalis	1	-	1	-	-
Epinephelus morio	7	-	7	7	-
Epinephelus nigritus	3	-	3	3	-
Epinephelus niveatus	16	-	16	16	-
Euthynnus alletteratus	1	-	1	-	-
Lagocephalus laevigatus	-	-	1	-	-
Lutjanus analis	5	-	5	5	-
Lutjanus campechanus	1118	641	1116	1112	72
Lutjanus griseus	8	-	8	1	-
Mycteroperca interstitialis	1	-	1	1	-
Mycteroperca microlepis	42	-	42	38	-
Mycteroperca phenax	12	-	11	12	-
Mycteroperca spp.	1	-	1	1	-
Neomerinthe hemingwayi	1	-	1	-	-
Ocyurus chrysurus	2	-	2	1	-
Pagrus pagrus	143	-	143	-	-
Pareques umbrosus	-	-	1	-	-
Pomatomus saltatrix	8	-	8	-	-
Pristipomoides aquilonaris	-	-	1	-	-
Rachycentron canadum	8	-	9	-	-
Rhizoprionodon terraenovae	-	-	1	-	-
Rhomboplites aurorubens	346	97	345	218	27
Sciaenops ocellatus	1	-	1	-	-
Seriola dumerili	29	-	30	-	-
Seriola fasciata	2	-	2	-	-
Seriola rivoliana	17	-	17	-	-
Seriola zonata	9	-	9	-	-
Trichiurus lepturus	5	-	5	-	-
Totals	2408	794	2438	1439	99

Appendix 5. Summary of biological specimens retained for demographic analysis from the passive vertical long line survey. Data have been aggregated over all three sampling regions.

	# of samples				
Species	Otolith	Histology	Mercury	Spine	Batch Fecundity
Balistes capriscus	-	-	3	3	-
Centropristis striata	166	11	166	-	-
Elagatis bipinnulata	2	-	2	-	-
Epinephelus morio	1	-	1	1	-
Epinephelus niveatus	1	-	1	1	-
Lutjanus campechanus	61	39	61	61	7
Mycteroperca microlepis	2	-	2	2	-
Pagrus pagrus	26	-	26	-	-
Rhizoprionodon terraenovae	-	-	1	-	-
Rhomboplites aurorubens	51	16	51	-	-
Seriola dumerili	2	-	2	-	-
Seriola fasciata	2	-	2	-	-
Seriola zonata	2	-	3	-	-
Trichiurus lepturus	1	-	1	-	-
Totals	317	66	322	68	7

Appendix 6. Summary of biological specimens retained for demographic analysis from the passive horizontal long line survey. Data have been aggregated over all three sampling regions.

	# of samples				
Species	Otolith	Histology	Mercury	Spine	Batch Fecundity
Balistes capriscus	-	-	4	5	-
Carcharhinus falciformis	-	-	2	-	-
Centropristis striata	203	9	205	-	-
Coryphaena hippurus	1	-	2	-	-
Epinephelus morio	2	-	2	2	-
Epinephelus nigritus	1	-	1	1	-
Epinephelus niveatus	6	-	6	6	-
Holocentrus adscensionis	1	-	1	-	-
Lutjanus campechanus	101	57	101	99	9
Lutjanus synagris	1	-	1	-	-
Mycteroperca microlepis	3	-	3	3	-
Opsanus tau	4	-	4	-	-
Pagrus pagrus	19	-	19	-	-
Paralichthys albigutta	1	-	1	-	-
Rhomboplites aurorubens	19	7	19	13	-
Seriola rivoliana	1	-	1	-	-
Trichiurus lepturus	1	-	1	-	-
Totals	364	73	373	129	9

Appendix 7. Summary of biological specimens retained for demographic analysis from all hooked gears combined. Data have been aggregated over all three sampling regions.

Species	Otolith	Histology	Mercury	Spine	Batch Fecundity
Balistes capriscus	2	-	32	31	-
Calamus penna	1	-	1	-	-
Carcharhinus acronotus	-	-	1	-	-
Carcharhinus falciformis	-	-	4	-	-
Caulolatilus microps	5	-	6	-	-
Centropristis philadelphica	-	-	1	-	-
Centropristis striata	983	76	985	1	-
Coryphaena hippurus	1	-	2	-	-
Cynoscion regalis	1	-	1	-	-
Elagatis bipinnulata	2	-	2	-	-
Epinephelus morio	10	-	10	10	-
Epinephelus nigritus	4	-	4	4	-
Epinephelus niveatus	23	-	23	23	-
Euthynnus alletteratus	1	-	1	-	-
Holocentrus adscensionis	1	-	1	-	-
Lagocephalus laevigatus	-	-	1	-	-
Lutjanus analis	5	-	5	5	-
Lutjanus campechanus	1280	737	1278	1272	88
Lutjanus griseus	8	-	8	1	-
Lutjanus synagris	1	-	1	-	-
Mycteroperca interstitialis	1	-	1	1	-
Mycteroperca microlepis	47	-	47	43	-
Mycteroperca phenax	12	-	11	12	-
Mycteroperca spp.	1	-	1	1	-
Neomerinthe hemingwayi	1	-	1	-	-
Ocyurus chrysurus	2	-	2	1	-
Opsanus tau	4	-	4	-	-
Pagrus pagrus	188	-	188	-	-
Paralichthys albigutta	1	-	1	-	-
Pareques umbrosus	-	-	1	-	-
Pomatomus saltatrix	8	-	8	-	-
Pristipomoides aquilonaris	-	-	1	-	-
Rachycentron canadum	8	-	9	-	-
Rhizoprionodon terraenovae	-	-	2	-	-
Rhomboplites aurorubens	416	120	415	231	27
Sciaenops ocellatus	1	-	1	-	-
Seriola dumerili	31	-	32	-	-
Seriola fasciata	4	-	4	-	-
Seriola rivoliana	18	-	18	-	-
Seriola zonata	11	-	12	-	-
Trichiurus lepturus	7	-	7	-	-
Totals	3089	933	3133	1636	115

Supplemental Figures:

Figure S1. Observed and Predicted scatter of Red Snapper collected by depth.

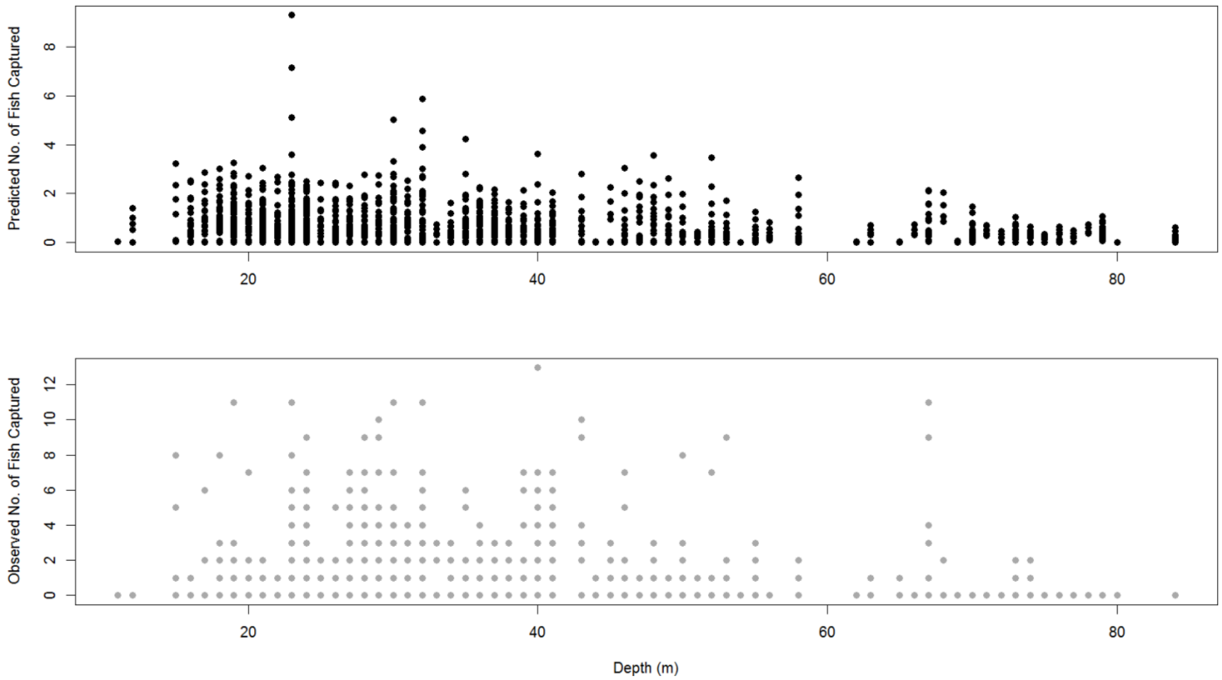

Figure S2. Observed and Predicted scatter of Red Snapper collected by temperature.