Is there evidence of the size and age composition of U.S. South Atlantic Red Snapper expanding under an ongoing fishing moratorium?

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Fish and Wildlife Research Institute

Florida Fish and Wildlife Conservation Commission

100 8th Ave SE

St. Petersburg, FL 33701

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ABSTRACT

In this project, we partially replicated a survey conducted in 2012 to assess whether the size- and age-composition of Red Snapper in the U.S. South Atlantic has expanded following several years of a near-complete prohibition of harvest. A standardized, repetitive timed-drop hooked-gear survey was conducted using a combination of 8/0, 11/0, and 15/0 hooks from April – July 2018. In total, 364 sites were sampled in 2018; sampling effort was allocated proportionally to available reef habitat within three spatial strata (NMFS statistical zones 722, 728, and 732 extending from 28° 00' N to 30° 45' N) and two depth strata (< 30 m and 30 – 150 m). A total of 2,656 Red Snapper were captured during the present study, of which 1,962 were retained for subsequent age and sex determination. In contrast, 1,132 Red Snapper were captured in 364 samples collected during the 2012 study. Initial comparisons of size- and age-comparison of Red Snapper indicated that individuals captured were both smaller ($Mean_{FL}$ = 463.4 mm; SE_{FL} = 2.60 mm) and younger ($Mean_{AGE}$ = 3.51 years; SE_{AGE} = 0.05 years) during the present study than they were in 2012 ($Mean_{FL}$ = 532.9 mm; SE_{FL} = 4.10 mm; $Mean_{AGE}$ = 4.35 years; SE_{AGE} = 0.06 years). However, after adjusting size- and age-composition by size- and age-specific catch per unit effort (CPUE; individuals per hook deployed), both an increase in the number of large, old Red Snapper (age 8+) and small, young Red Snapper (ages 2 – 4) was detected. No marked changes in the spatial distribution of Red Snapper between 2012 and 2018 were evident. Small, young Red Snapper dominated the catch in all NMFS statistical zones and depth strata in 2018, and there was a general increase in CPUE for older fish (aged 11+), especially within nearshore waters. Results of this study indicate that Red Snapper in the U.S. South Atlantic are exhibiting continued recovery, as evidenced by both an increase in the overall abundance of older fish in the population as well as a dramatic increase in juvenile recruitment. Nevertheless, we recommend a periodic (~ every five years) reexamination of the size- and age-composition of Red Snapper to continue to monitor the health and recovery of Red Snapper, especially as fishing pressure inevitably resumes on this stock.

EXECUTIVE SUMMARY

Reef fish resources have historically supported multi-million dollar commercial and recreational fisheries along the U.S. South Atlantic coast, with species such as Red Snapper, Vermilion Snapper, Gag, Red Porgy, Scamp, and Black Sea Bass among the most heavily targeted reef fishes over the past 50 years. In recent years, stock assessments for these and other species in the U.S. South Atlantic have shown varied degrees of overfishing, resulting in the implementation of various fishing regulations (e.g., size limits, bag limits, trip limits, seasonal closures, annual quotas) to alleviate overfishing. Traditional management practices such as restrictive size and bag limits, quotas, and prohibition of harvest have impacted the utility of fisheries-dependent data to assess populations through time, resulting in an increased need for fishery-independent surveys. State (FWC) and federal (SERFS) fishery-independent monitoring programs in the South Atlantic are evaluating different gear-types to provide data on a variety of reef fishes. Actively-fished hooked-gear surveys developed and conducted by the FWC since 2012 have shown great utility in capturing a wide size and age range of Red Snapper and augmenting data provided by the SERFS camera/trap survey. In addition, results of a 2016 study completed by the FWC that examined the selectivity of three capture gears (SERFS Chevron traps, FWC hooked-gear, and industry-defined hooked-gear) to that of stereo-camera observations, indicated that hooked-gear methods caught generally larger fish than the Chevron traps. These results suggest hooked-gear methodology may be a useful complementary sampling approach to provide relative abundance data and associated life history data for a broader size- and age-range of fish (including potentially older fish). Accordingly, in this study we conducted a standardized hooked-gear survey to assess whether the size- and age-composition of Red Snapper in the U.S. South Atlantic has expanded following several years of a near-complete prohibition of harvest.

A total of 364 stations, proportionally allocated between NMFS statistical zones 722, 728, and 732, were sampled between April – July 2018. At each sampling station hooked-gear sampling was conducted using methods developed and employed by the FWC since 2012 [repetitive timed-drop (RTD)]. A total of 4,090 individuals representing 42 taxa were collected during 2018 surveys. Catches were dominated by Red Snapper (n=2,656) which accounted for 64.9% of the overall catch. Red Snapper was the most abundant species collected in all three NMFS statistical zones [722 (n=500), 728 (n=1,286) and 732 (n=870)] and comprised 53.9%, 60.5%, and 83.7% of the total catch, respectively. A total of 36 taxa were collected from the nearshore depth strata and 30 collected from the offshore depth strata. A total of 1,515 individuals were collected from the nearshore depth strata and 2,575 individuals collected from the offshore depth strata. In both depth strata, 8/0 hooks captured the most fish (all species combined) and total catch decreased with increased hook size. Demographic data (i.e., sex, age, growth, mercury analysis) was summarized for Red Snapper and a sub-sample of other federally-managed fishes collected during the survey.

Age, length, and CPUE data collected from the current study was compared to that of a similar survey conducted in 2012. We hypothesized that during the recent period of harvest prohibition, overall survival rates of Red Snapper would increase, resulting in an expanded size and age structure where several strong age classes (2-, 3-, and 5-year-old Red Snapper) detected in 2012 would have persisted into 2018 (as 8-, 9-, and 11-year-old Red Snapper, respectively) resulting in detectible increases in mean size and age composition of the stock. In the present study, Red Snapper collected were, on average smaller and younger than those collected in 2012. This trend was reflected in both relative frequency plots comparing size- and age-composition as well

as kernel density estimates comparing length frequency distributions between 2012 and 2018. Both analytical approaches indicated that Red Snapper collected were comprised of a much higher proportion of younger (age 2 – 4) and smaller (250 – 550 mm FL) fish in 2018 than was evident in 2012.

Results of these initial comparisons of size and age composition between 2012 and 2018 indicated that, contrary to our expectations, Red Snapper collected in 2018 were generally smaller and younger than those collected in 2012. These results were surprising, especially given recent evidence from both the SERFS chevron trap and trap-mounted camera survey as well as the FWC RTD hooked-gear survey that indicate the relative abundance of Red Snapper has increased exponentially in the U.S. South Atlantic. Upon closer examination of our data, it appears as if observed patterns are being driven largely by dramatic increases in the recruitment of smaller and younger Red Snapper into the population that were subsequently impeding our ability to detect any differences in the composition of larger and older Red Snapper between the two time periods. To address this concern, subsequent analyses were conducted to compare size- and age-specific catch per unit effort (CPUE, Individuals per hook) between the two time periods rather than relative frequency.

CPUE-adjusted length-frequency histograms indicated that the size- and age-composition of Red Snapper shifted from a distinct bimodal pattern in 2012 to a unimodal pattern in 2018, although the overall size range was similar between the two surveys. Overall, size-specific CPUE was higher in 2018 for all size classes, although increases in size-specific CPUE were notably higher for smaller Red Snapper (< 550 mm FL). The 2012 survey was dominated by age-3 and age-5 Red Snapper with few fish collected greater than 10-years-old. In contrast, the 2018 survey was dominated by young fish (primarily age-2), with a notable increase in older Red Snapper (age 11+). The increase in CPUE of younger Red Snapper was most pronounced for the 8/0 and 11/0 hooks, whereas the increase in CPUE of older Red Snapper was limited largely to those collected using 15/0 hooks. Further analyses comparing ratios of percentage composition between 2018 and 2012 indicate that, for all three hook sizes, young Red Snapper (primarily age 2 – 4) comprised a higher proportion of the total catch in 2018 (ratio > 1) than they did in 2012 and, for 15/0 hooks, so did older Red Snapper (age 8 +).

Abundances for Red Snapper increased within each NMFS statistical zone from 2012 to 2018 with notably higher size-specific CPUE's for smaller Red Snapper (< 500 mm FL). CPUE-adjusted age-frequency plots showed a similar pattern; abundances were markedly higher for younger Red Snapper (2-5-years-old) in 2018 in all zones, but unlike 2012, there was also an increase in CPUE for older fish (aged 11+) in all zones and depth strata.

Results of this study indicate that Red Snapper in the U.S. South Atlantic are exhibiting continued recovery, as evidenced by both an increase in the overall abundance of older fish in the population as well as a dramatic increase in juvenile recruitment. Nevertheless, we recommend a periodic (~ every five years) reexamination of the size- and age-composition of Red Snapper to continue to monitor the health and recovery of Red Snapper, especially as fishing pressure inevitably resumes on this stock.

PURPOSE

A. PROBLEM DESCRIPTION

Reef fish resources (specifically the grouper-snapper complex; Ault et al. 2006) along the U.S. South Atlantic coast have historically supported multi-million dollar commercial and recreational fisheries, with species such as Red Snapper, Vermilion Snapper, Gag, Red Porgy, Scamp, and Black Sea Bass among the most heavily targeted reef fishes over the past 50 years. In recent years, stock assessments for these and other species in the U.S. South Atlantic have shown varied degrees of overfishing, and as a result, numerous recreational and commercial fishing regulations (e.g., size limits, bag limits, trip limits, seasonal closures, annual quotas) have been implemented as mandated by the Magnuson-Stevens Act to alleviate overfishing and rebuild overfished stocks. Among current regulations, none have been more restrictive, or more controversial, than those implemented for Red Snapper. Results from a 2008 stock assessment indicated that U.S. South Atlantic Red Snapper were experiencing overfishing and were overfished (SEDAR 15 2008). In response to the assessment, in 2010 the South Atlantic Fisheries Management Council (SAFMC) implemented an emergency closure of the commercial and recreational fishery throughout federal waters (3 to 200 miles offshore). The SAFMC also approved Amendment 17A to the South Atlantic Snapper Grouper Fishery Management Plan to reduce overfishing and rebuild Red Snapper stocks (SAFMC 2010). Amendment 17A involved several provisions, including the continuation of the closure of the Red Snapper fishery (Gitschlag and Renaud 1994; Rummer and Bennett 2005; SAFMC 2010). Before Amendment 17A was enacted an updated assessment (SEDAR 24 2010) was completed that confirmed that Red Snapper were overfished and undergoing overfishing (SEDAR 24 2010). Subsequently, aside from very limited recreational and commercial seasons in 2012 – 2014 and 2017 – 2019, Red Snapper remain closed to all recreational and commercial harvest.

A new benchmark assessment was released in April 2016 (SEDAR 41 2016) that indicated the Red Snapper stock in the U.S. South Atlantic continues to be overfished and that overfishing is occurring. The report also concluded that, despite both the estimated abundance at age and the total estimated abundance increasing in recent years, each indicated a truncation of older age classes (SEDAR 41 2016). In particular, the overall abundance estimates for 2014 were similar to those observed in the 1960s, but the stock was found to be comprised primarily of fish ages 1-4 years old (96% by number). As such, the stock was considered overfished due to the paucity of older fish in the population. For Red Snapper populations, older, larger females generally have markedly higher batch fecundities, and produce more batches in a given year, than do smaller females (Collins et al. 1996; Lowerre-Barbieri et al. 2015). As age truncation may have profound impacts on overall stock productivity and the potential for stock recovery, it is critical to effectively monitor the potential recovery of older, larger Red Snapper through time.

Recognized limitations of fishery-dependent data sources have resulted in significant effort during recent years to improve the availability of fishery-independent data in the U.S. South Atlantic. In 2010, the long-running Marine Resources Monitoring, Assessment, and Prediction program (MARMAP) and the South Atlantic Southeast Area Monitoring and Assessment Program (SA-SEAMAP) were augmented by the initiation of the NMFS Southeast Fishery-Independent Survey (SEFIS). Collectively referred to as the Southeast Reef Fish Survey (SERFS), these new and expanded survey efforts have involved (1) a range extension south to St. Lucie Inlet, Florida and north to Cape Hatteras, North Carolina, (2) an increase in annual sampling effort throughout the survey area, and (3) the addition of video cameras to the chevron traps long used by the MARMAP program (Bacheler et al. 2013). In the SEDAR 41 Data Workshop, the SERFS chevron trap and video datasets were each recommended as separate fisheries-independent indices of abundance in the assessment. At the SEDAR 41 Assessment Workshop, it was concluded that these two indices should be combined since the data collected for each came from the same sampling platform and were thus not independent of each other (SEDAR 41 2016). The result was that only one fisheries-independent index, covering 2010-2014, was used in the latest assessment model. Research recommendations at the SEDAR 41 Data, Assessment, and Review workshops all highlighted the increased need for additional fisheries-independent surveys to provide reliable indices of abundance and estimates of size and age composition for future stock assessments (SEDAR 41 2016).

To complement ongoing SERFS trap and camera surveys and provide another source of fishery-independent data that could be used in future stock assessments, the Florida Fish and Wildlife Conservation Commission (FWC) has been developing a hooked-gear survey of hard bottom habitats in the U.S. South Atlantic since 2012. The actively-fished hooked-gear survey has utilized a series of "team drops" to standardize the bottom soak time and effort for each individual fisher at each site (repetitive timed-drop [RTD hooked-gear]). FWC has completed several hooked-gear surveys that have applied the RTD methodology; the first was a study completed in 2012 that employed a combination of bottom longlines, vertical longlines, and the RTD hooked-gear (Guenther et al. 2013). All three gears were able to capture a wide size range of Red Snapper, though the RTD hooked-gear collected significantly more fish during the study and proved to be the most effective hooked-gear to collect Red Snapper. Subsequent FWC RTD hooked-gear surveys have been completed in 2014 (Brodie and Switzer 2015), 2016 (Paperno et al. 2018), and 2017, each consistently collecting a broad size range of Red Snapper. The 2012 study showed strong year classes of age-3 and age-5 fish with all sampling gears and these age-classes are clearly captured in the later FWC studies which demonstrates the utility of the RTD hooked-gear approach at tracking strong year classes over time. It should be noted that the 2014 study focused on spawning aggregations of Red Snapper, Scamp, and Gag and the site selection protocols were different from the other FWC studies, focusing primarily on deeper sites with a high likelihood of spawning-capable Red Snapper, so any direct comparison of the results for that study should be done with caution.

The FWC study completed in 2016 (Paperno et al. 2018) was designed to address questions regarding the selectivity of Red Snapper and other reef fishes to gear types currently used during ongoing fisheries-independent monitoring surveys in the U.S. South Atlantic off the east coast of Florida. The study examined the selectivity of three capture gears (SERFS Chevron traps, FWC RTD hooked-gear, and industry-defined hooked-gear) to that of stereo-camera observations. Results of that study indicated that while the stereo-cameras observed the largest fish and showed the least amount of selectivity, both hooked-gear methods caught larger fish than the Chevron traps, indicating that the RTD hooked-gear methodology designed by FWC may be a useful complementary sampling approach to provide relative abundance data and associated life history data for a broader size/age range of fish (including potentially older fish). In addition, this study also showed that RTD hooked-gear methods captured a statistically similar number, size, and age range of Red Snapper as fishing methods commonly used during commercial and charter fishing trips, which may be a better predicter of actual industry catches than that of the Chevron traps.

Assessing the recovery of fish stocks is best accomplished using long-term data from annual surveys. In the absence of long-term data, an alternative approach for long-lived species is to re-construct historical studies to document how a stock has changed through time. In the eastern GOM, Winner et al. (2014) conducted a study to assess the recovery of adult Red Drum, for which there is no current fishery nor any ongoing fishery-independent surveys, by comparing the size and age composition of their purse-seine survey to one conducted a decade earlier. The earlier study on Red Drum, much like U.S. South Atlantic Red Snapper, found a population with a compressed age structure that contained few fish at older ages (Murphy and Crabtree 2001). Winner et al. (2014) hypothesized that if the Red Drum stocks were recovering, they would expect to see (1) a persistence of strong juvenile year-classes into the nearshore adult population which would be evidence of adequate escapement from estuarine nurseries, and (2) an expanded size and age structure in the offshore population which would provide evidence of improved survival of adult fish. Results validated their hypotheses; the proportion of old Red Drum in the eastern Gulf of Mexico has increased, and their ability to track the persistence of strong age classes into the adult population provided additional support to the notion that stocks are recovering (Winner et al. 2014). Similar efforts would be valuable for Red Snapper in the U.S. South Atlantic.

To assess if the relative abundance, size and age composition of Red Snapper in the U.S. South Atlantic has expanded during a six-year fishing moratorium, we conducted a one-year study in the U.S. South Atlantic off the east coast of Florida that partially replicated the 2012 FWC hooked-gear study. The project only re-evaluated the 2012 RTD hooked-gear survey, which was found to be the most efficient and effective approach to capturing Red Snapper. This study was conducted monthly from April to July within NMFS statistical zones 722, 728, and 732 in water depths <150 m, which represents the core distribution of Red Snapper along the east coast of Florida and includes the full depth range within which Red Snapper have been collected in prior surveys (Guenther et al. 2014; Mitchell et al. 2014). As in the previous study, sampling occurred at randomly-selected sites known to contain hard-bottom reef and artificial reef habitat. Overall monthly sampling effort was stratified by NMFS statistical zone (722, 728, and 732) and depth (< 30 m and 30 – 150 m) and allocated proportionally based on the total number of potential hard-bottom and artificial reef sites within each area (Guenther et al. 2013). We worked cooperatively with various sectors of the fishery, including for-hire recreational charters and commercial operators, to conduct all field sampling. These cooperative partners provided regional knowledge and experience as well as provided platforms from which the surveys were conducted. The knowledge and experience combined with their familiarity with the fishery greatly contributed to the effectiveness of the overall survey design and allowed for the accurate targeting of selected habitat.

B. OBJECTIVES

The primary goal of the proposed project was to assess whether the size and age composition of Red Snapper in the U.S. South Atlantic had expanded during a six-year fishing moratorium. The actively-fished hooked-gear study was conducted in the portion of the South Atlantic Bight from roughly 28° 00’ N (Melbourne, FL) to 30° 45’ N latitude (Florida-Georgia border). To accomplish this goal, we addressed the following specific objectives:

1. Provide demographic data (i.e., age and sex) for Red Snapper and other reef fish species for use in future stock assessments in the U.S. South Atlantic.

2. Evaluate whether the size and age composition of Red Snapper in the U.S. South Atlantic had expanded during an ongoing fishing moratorium.
3. Evaluate if and how the relative abundance of Red Snapper in the U.S. South Atlantic had changed during an ongoing fishing moratorium.
4. Assess, to what degree, the spatial dynamics of Red Snapper in the U.S. South Atlantic had changed during an ongoing fishing moratorium.

APPROACH

A. WORK PERFORMED

A standardized fisheries-independent survey of reef fishes was designed based on prior FWC surveys conducted in the U.S. South Atlantic between 2012 – 2017 but was focused on re-evaluating the RTD hooked-gear survey completed in 2012 to assess whether the relative abundance, size and age composition of Red Snapper in the U.S. South Atlantic has expanded during a six-year fishing moratorium. Several project-development meetings were held in conjunction with commercial, charter, and recreational fishers at the outset of the study to solicit their input regarding project design and all field sampling activities were conducted cooperatively with industry partners.

Sampling Period – All sampling was conducted during the months of April – July 2018 which corresponds to peak spawning and months of highest relative abundance of Red Snapper within the U.S. South Atlantic (White and Palmer 2004; Brown-Peterson et al. 2009; Guenther et al. 2013; Brodie and Switzer 2015; Lowerre-Barbieri et al. 2015). This sampling period also corresponds to that of prior hooked-gear studies conducted by the FWC in the U.S. South Atlantic, specifically the 2012 study that serves as the primary time period of comparison.

Geographic Coverage and Survey Design – Red Snapper and other federally-managed reef fishes were quantified during a fisheries-independent survey using a stratified-random sampling design. For this project, sampling effort was stratified based on latitude and depth. 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). Each statistical zone (zone) was subdivided into two depth strata – nearshore (< 30 m) and offshore (30 - 150 m). Sampling targeted hard-bottom sites, which included both natural and artificial reef habitats.

Sample sites were proportionally allocated between zones and depth strata based on the total available sampling sites within the FWC sampling universe for each area. Sampling was limited to depths less than 150 m as that encompasses the full depth range from which Red Snapper have been collected in prior surveys (Guenther et al. 2014; Mitchell et al. 2014). A total of 364 RTD hooked-gear sites were randomly selected for this project. This corresponds to the total number of RTD hooked-gear sites completed during the 2012 study and will help to facilitate comparisons to that survey. A subset of randomly chosen alternate sampling sites were also selected to be sampled; these were only used if a primary sampling site was unable to be sampled (i.e. unable to locate appropriate habitat, strong currents, active fishing occurring on-site, etc.).

Gear Description – Repetitive Timed-Drop (RTD) Hooked-Gear – Powered (12V DC) Electramate© rigs (model 940XP) were used during this survey (**Figure 2**). The Electramate© 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 Electramate© rigs was standardized. A barrel swivel was attached to the mainline from the reel. Starting from the swivel a 1.8 m section of 45 kg (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 and the other near the bottom. A specific hook size (either 8/0, 11/0, and 15/0 Mustad circle hooks (Ref 39960D)) was assigned to both the top and bottom leads for each rig. A lead egg sinker or bank sinker (size depending on prevailing 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**).

Fishery-independent sampling employed a standardized system of active fishing that used a series of "team drops" with a set bottom soak time for each individual fisher at each site [referred to as repetitive timed-drop (RTD)] aimed to reduce individual fisher bias. A "team drop" consisted of all fishers simultaneously dropping their rigs to the bottom and allowing their rig to soak for no more than two minutes. 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 remaining rigs were retrieved and rebaited. All fishers who retrieved their rig within the two-minute time period (i.e. caught fish, checked bait, lost fish, etc.) were not permitted to re-drop 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. An 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.

At each RTD hooked-gear sampling site, three anglers were assigned to a particular rig with a specific hook combination. All hooks were baited with Atlantic mackerel (*Scomber scombrus*) cut proportional to hook size. A total of ten "team drops" were completed at each site. The rig fished by anglers was alternated at each sampling site throughout the day to remove any biases of angler experience with respect to hook size or fishing position on the boat.

Collection and Processing of Field Data – Geographic coordinates and water depths were recorded at each sampling site along with various other metrics (i.e., soak/fishing time, weather, time of day, etc.). A HOBO U22 temperature logger was deployed to record representative bottom temperatures at all sites sampled.

Deployment and catch data were recorded at each sampling site. 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 (lb. test and type), reel type, start and end time, bait type, number of team drops completed per angler, and detailed hook information (i.e. style and size). Catch specific parameters were recorded that included fisher/crew initials (i.e. who caught the fish), specific rig number, drop number (number of team drop the fish was captured), species (identified to the lowest possible taxa), length measurements, sex, fish health code, bait type, 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), unique specimen number, and any biological samples taken. All individuals collected were identified to the lowest taxonomic level possible and measured to the nearest mm (SL, FL, and TL) prior to either being released or culled for biological processing. Fish that exhibited barotrauma were vented prior to release if not being culled. On occasion, measurements were not recorded due to uncontrollable situations (i.e. fish partially preyed upon prior to landing). In these situations, plus counts towards overall catches (individual species) were recorded.

Objective 1: Provide demographic data (i.e., age and sex) for Red Snapper and other reef fish species for use in future stock assessments in the U.S. South Atlantic.

The first 2,000 Red Snapper were sacrificed to provide valuable fisheries-independent demographic data (i.e. sex, age, mercury concentration) as allowed by a formal NMFS Letter of Acknowledgement (LOA) to FWC. In addition, a random subsample of other federally managed species was culled at each sampling site. Biological material was provided to the Fish and Wildlife Research Institute (FWC-FWRI) for processing.

Sex – Sex of each culled fish collected during the survey was determined through macroscopic inspection of gonads by FWC staff either in the field or upon return to the laboratory. If the sex of a fish was unable to be determined through macroscopic determination (i.e. gonads were undeveloped), it was categorized as "unsexed".

Annual Age – Otoliths were extracted from each culled fish collected and were further processed by the FWC-FWRI's Age-and-Growth Lab for age determination. Although several species were aged, only Red Snapper ages are summarized in this report. Thin (~0.5 mm) transverse sections were cut at or adjacent to the core of the left sagitta with a Buhler Isomet low-speed saw equipped with a diamond blade; the right sagitta was sectioned when the left sagitta was missing or had been damaged. Otolith sections were mounted on microscope slides by using Histomount solution (Thermo Fisher Scientific, Waltham, MA). With a dissecting microscope (8 – 25× magnification), 2 or 3 readers independently counted the opaque rings on each otolith twice under reflected light. Readers counted rings without knowledge of sex, length, or capture date of specimens. Disagreements in annulus counts were resolved by at least 2 readers, without knowledge of previous counts. If an annulus count could not be agreed upon after re-examination, the otolith was rejected from the age and growth analysis. Assigned ages were calendar ages and adjusted accordingly based on a January 1 birthdate.

A von Bertalanffy growth model for Red Snapper was estimated based on determined ages. 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 Core Team 2017).

Mercury Analysis – Tissue samples for mercury analysis were collected from all fish culled during the survey. For each fish, a clean stainless-steel knife was used to remove white axial muscle tissue samples from the left dorsal area in the region anterior to the origin of the dorsal fin and above the lateral line. White muscle tissue taken near this region is representative of the portion of the fish that is consumed by humans, and mercury results from this specific target area are directly comparable to long-term monitoring results and historical fish mercury datasets in the southeastern United States (Adams et al. 2003; Tremain and Adams 2012; Adams et al. 2018). Care was taken to assure that the sample made no contact with the external surface of the specimen, scales, blood, or any surrounding surfaces during the extraction process. All tissue samples were immediately placed in sterile polyethylene scintillation vials, sealed, and frozen at -20° C until analyzed.

Total mercury (THg) concentration, measured as milligrams per kilogram (mg/kg) wet weight, of each muscle sample was determined at FWC-FWRI by thermal decomposition, amalgamation, and atomic absorption spectrometry [EPA Method 7473] (EPA 2007). Total mercury serves as a reasonable proxy for methylmercury in Red Snapper as the majority of mercury in muscle tissue (> 97%) is in the monomethyl form (CH3Hg; Bank et al. 2007). Briefly, wet muscle subsamples of 0.05 to 0.10 g were cut from filet tissues, and the analysis was completed with a calibrated DMA-80 Direct Mercury Analyzer (Milestone Inc., Shelton, Connecticut). Quality control procedures included analysis of laboratory method blanks, duplicate or triplicate tissue samples, and certified reference material (CRM; TORT-3 or DORM-4 obtained from the National Research Council of Canada) for each group of 10 samples analyzed. In addition, we performed duplicate matrix spikes with the CRM BCR-463 for each group of 40 samples analyzed. All quality assurance measurements were within recommended EPA limits for the analytical method (EPA 2007). Linear regression was used to describe the relationship of fish length to total mercury concentration.

Data Entry and Management – Data collection and management followed standard FWC methods which included the use of currently utilized data sheets and data entry programs. Data were entered into an existing relational SQL database that can capture physical, hydrological, habitat, abundance, length frequency, age and growth, reproductive, fish health, and contaminant data. Once entered, all data passed through an established system of QA/QC procedures developed by FWC to ensure the accuracy and reliability of the data captured by this database.

Objective 2: Evaluate whether the size and age composition of Red Snapper in the U.S. South Atlantic has expanded during an ongoing fishing moratorium.

Objective 3: Evaluate if and how the relative abundance of Red Snapper in the U.S. South Atlantic has changed during an ongoing fishing moratorium.

Objective 4: Assess, to what degree, the spatial dynamics of Red Snapper in the U.S. South Atlantic has changed during an ongoing fishing moratorium.

Statistical Analysis – Overall summaries of 2018 sampling effort (# sites) and catch were compiled by region (NMFS statistical zones 722, 728, and 732), depth strata (nearshore [< 30 m] and offshore [30 - 150 m]), and hook size (8/0, 11/0, and 15/0). Length and age frequency histograms were constructed for Red Snapper collectively and by NMFS statistical zone, hook size, and sex.

Size- and age-specific relative abundances of Red Snapper were compared between the two study periods (2012 and 2018) by calculating CPUE as the number of collected individuals per total number of hooks dropped collectively by survey year, by hook size (8/0, 11/0, and 15/0), by NMFS statistical zone (722, 728, and 732), and depth strata (nearshore [< 30 m] and offshore [30 - 150 m]). For comparisons of size composition, mean CPUE was calculated for 50 mm FL intervals, while for age comparisons, mean CPUE was calculated for each age class. Not all Red Snapper were retained for ageing during the 2012 and 2018 surveys. To allow for an age comparison of all Red Snapper collected by each survey, all unaged Red Snapper (2012, n=32; 2018, n=688) were assigned ages based on an age-length key developed from individuals aged during each given survey year. Age- and length-specific CPUE were then compared between time periods for all Red Snapper collectively, by hook size, NMFS statistical zone, and by depth.

Length-frequency distributions were compared using kernel density estimates (KDE). This method is sensitive to differences both in the shape and the location of length-frequency distributions. To examine differences due to shape, data were standardized by median and variance (y = x - median/standard deviation; Bowman and Azzalini 1997). Following Langlois et al. (2012), statistical differences were tested by comparing the area between KDEs for each method to that of random pairs resulting from permutations of the data (10,000 permutations) using the R package 'sm' (Bowman and Azzalini 2010; R Core Team 2017). If the data from both methods have the same distribution, the KDEs should only differ in minor ways due to within-population variance and sampling effects (Langlois et al. 2012). The 'sm.density.compare' function in the 'sm' package was used to plot the length-frequency distributions with a grey band centered on the mean KDE and extending one standard error above and below, therefore showing the null model of no difference between the pair of KDEs (Bowman and Azzalini 1997).

To examine the relative contribution of each age class of Red Snapper between the 2012 and 2018 studies, we developed an approach similar to suitability analysis where, for each hook size, we first calculated the percentage of the total catch of Red Snapper within each age class for each year. We then calculated a ratio of percentages (2018 : 2012) to determine whether composition has changed. Ratio values ~ 1 would indicate that percent composition has not changed, ratio values > 1 would indicate that percent composition for that age class was higher in 2018, and ratio values < 1 would indicate that percent composition was higher in 2012. To remove patchy and zero catches, age 0-1-year old fish were excluded from these analyses. In addition, the upper age classes of Red Snapper were combined into a single age class to reduce the influence of sparse data within specific age classes: for 8/0 hooks all fish 7 years and older were combined, for 11/0 hooks all fish 8 years and older were combined, and for 15/0 hooks all fish 12 years and older were combined.

To further examine the changes in relative abundances of Red Snapper between 2012 and 2018, indices of abundance (IOAs) were calculated as the overall average abundance of Red Snapper per sample site. We calculated IOAs for Red Snapper collectively, for each hook size, and for each NMFS statistical zone. Each IOA was computed using a generalized linear model with a negative binomial distribution to adjust for the effects of spatial and temporal variability between samples. Depth strata (nearshore and offshore), month, NMFS statistical zone, and year were treated as classification variables. Covariates included total number of each hook size dropped (8/0, 11/0, 15/0). The GLIMMIX procedure (SAS Institute Inc 2013), which fits generalized linear models and allows for non-normal data, was used to complete all analyses. For the overall IOA (all hook sizes and NMFS statistical zones combined) all variables that were not significant ($\alpha > 0.05$) were dropped and the analysis repeated with the exception of year and total number of drops for each hook size. For the remaining IOAs year was retained regardless of significance, otherwise all other variables that were not significant ($\alpha > 0.05$) were dropped and the analysis repeated. Least-squares adjusted means and standard errors were calculated for each year.

B. PROJECT MANAGEMENT

Dr. Theodore Switzer (Research Scientist, Florida Fish and Wildlife Conservation Commission/ Fish and Wildlife Research Institute/Fisheries-Independent Monitoring) was responsible for overall project management, overseeing field operations, as well as the preparation of interim and final reports. He also aided in overall survey design and final data analysis.

Mr. Russell Brodie (Research Administrator, Florida Fish and Wildlife Conservation Commission/Fish and Wildlife Research Institute/Fisheries-Independent Monitoring), was responsible for organizing and coordinating field operations, budgetary tracking, and preparation of interim and final progress reports.

Mr. Justin Solomon (Research Associate, Florida Fish and Wildlife Conservation Commission/Fish and Wildlife Research Institute/Fisheries-Independent Monitoring), was responsible for overseeing field operations, data processing with the assistance of the hired research technicians and current FWRI staff, and preparation of interim and final progress reports.

Dr. Richard Paperno (Research Administrator, Florida Fish and Wildlife Conservation Commission/Fish and Wildlife Research Institute/Fisheries-Independent Monitoring) helped develop the study design and conduct statistical analyses.

Dr. Todd Kellison (NMFS – Beaufort, NC) served as the NMFS collaborative partner and provided insight into management needs and implications.

FINDINGS

A. ACTUAL ACCOMPLISHMENTS AND FINDINGS

Overall Project Accomplishments:

Individual project-development meetings were held prior to the start of the survey that served as a forum for discussing appropriate sampling sites, methods for comparative surveys of hooked-gears, implementation of gear sampling techniques onboard commercial and charter vessels, and the overall goals and expected benefits of the proposed research. By adopting a cooperative approach for this project, we were able to address questions or concerns from our industry partners as well as combine the strengths of each representative group (i.e. commercial and charter industries) to improve the overall effectiveness of the study. The knowledge and experience of our participating industry partners ensured that the selected sample sites corresponded to the desired targeted strata.

Geographic Coverage and Survey Design – The selected sampling area (NMFS statistical zones 722, 728, and 732) covered an area along the east coast of Florida from roughly 28° 00' N (Melbourne, FL) to 30° 45' N latitude (Florida-Georgia border; **Figure 1**). Each zone was subdivided into two depth strata – nearshore (< 30 m) and offshore (30 - 150 m) – with the offshore depth strata truncated at 150 m. The selected sampling area corresponds to that of the 2012 FWC survey and will facilitate a more direct comparison of the two surveys.

The full spatial extent of the sampling universe was gridded into a series of 0.1 nm W x 0.3 nm L sampling units. All 0.1 nm x 0.3 nm sampling units that intersected with areas of known or potential hard-bottom sites (natural and artificial) were included in the sampling universe. Sample sites were randomly selected from an established FWC universe that includes sites obtained from the SERFS sampling universe, prior FWC work conducted in the region, data from USGS, and sites provided from participating commercial and recreational fishers (**Figure 1**).

The FWC RTD survey in the U.S. South Atlantic has been modified since its initiation in 2012 in an effort to improve its utility. One of these modifications pertains to the survey design and stratification of sample sites. To acknowledge that natural hard-bottom and artificial reef habitats utilized by Red Snapper and other reef fish may serve to function in different capacities, as well as provide a pathway to investigate potential differences in habitat use, the RTD hooked-gear survey has incorporated habitat type (natural hard-bottom vs. artificial reef) as a specific stratum in the nearshore depth stratum (< 30 m). This habitat stratification was not included in the 2012 RTD hooked-gear study, although both habitats were sampled. The survey design modification was implemented in the current study to maintain continuity of RTD hooked-gear surveys in recent years. All sites sampled during the current study were designated as hard-bottom habitat when analytically comparing results to the 2012 RTD hooked-gear survey.

Other modifications to the survey design include the number and combination of hooks fished at each sample site. During the 2012 RTD hooked-gear survey, four anglers fished at each site versus three anglers at each site during the current study. In addition, the two hooks fished by each angler in the 2012 study were of different size with more smaller hooks fished in the nearshore depth strata and more larger hooks fished in the offshore depth strata. Modification to the RTD hooked-gear survey design has since dictated that the two hooks be the same size and the same number of each hook be fished regardless of depth strata. To account for the differing amount of hook-effort per site between the two surveys, catch-per-unit-effort (CPUE) for each survey was calculated based on the overall number of hooks dropped per site as well as the total number of each hook size dropped per site. Previous analysis of hook position (top vs. bottom; **Figure 3**) has shown that catch is similar between the top and bottom hook positions (Guenther et al. 2013); therefore, data from the upper and lower hook positions were pooled for all subsequent analyses for both surveys.

Site Selection – RTD hooked-gear sample sites were randomly selected using ArcGIS software and the Geospatial Modeling Environment Software. Sample sites were proportionally allocated between zones, habitat, and depth strata based on the total number of available sampling sites within the FWC sampling universe for each area. A total of 364 potential sampling sites were randomly selected for this survey and proportionally allocated between zones based on available sampling habitat in each: zone 722 (n=80), zone 728 (n=188), and zone 732 (n=96) (**Table 1**). The total number of sample sites selected for this study directly corresponds to the total number of sites completed during the 2012 survey.

Repetitive Timed-Drop (RTD) Hooked-Gear Sampling Overview – All proposed sampling sites (n=364) were sampled as planned between April – July 2018 (**Table 1, Figure 4**). A total of 144 sites were completed in the nearshore (< 30 m) depth strata and 220 sites were completed in the offshore (30 – 150 m) depth strata. Site-specific abundances of Red Snapper ranged from 1 to 20 individuals per site (**Figure 4**).

A total of 4,090 individuals representing 42 taxa were collected during 2018 RTD surveys (**Table 2**). Catches were dominated by Red Snapper (n=2,656) which accounted for 64.9% of the overall catch. Red Snapper was the most abundant species collected in all three NMFS statistical zones [722 (n=500), 728 (n=1,286) and 732 (n=870)] and comprised 53.9%, 60.5%, and 83.7% of the total catch, respectively (**Table 2**).

A total of 36 taxa were collected from the nearshore depth strata and 30 collected from the offshore depth strata (**Table 3**). A total of 1,515 individuals were collected from the nearshore depth strata and 2,575 individuals collected from the offshore depth strata. In both depth strata, 8/0 hooks captured the most fish (all species combined) and total catch decreased with increased hook size.

Objective 1: Provide demographic data (i.e., age and sex) for Red Snapper and other reef fish species for use in future stock assessments in the U.S. South Atlantic.

The first 2,000 Red Snapper and a random subset of other federally-managed species collected during this study were culled to provide valuable fisheries-independent demographic data (i.e., sex, age, growth, mercury analysis; **Table 4**). As the focus of this project was on Red Snapper, only information for that species will be summarized for all sections of this objective, data for other species are available upon request from project Principal Investigators.

Lengths – Measurements were recorded for 2,648 Red Snapper during this study. Eight Red Snapper were partially preyed upon while being retrieved; therefore, lengths for those fish were not recorded. The mean size of Red Snapper collected was 463.4 mm FL (SE = 2.6) with a range of 225 – 907 mm FL (**Figure 5**). The mean size of Red Snapper did not differ markedly between the nearshore (n=921; mean = 463.23 mm FL; SE = 4.57) and offshore (n=1,727; mean = 463.42 mm FL; SE = 3.14) depth strata. Red Snapper (n=499) collected in the northernmost zone (zone 722) had a smaller mean length [443.34 mm FL (SE = 5.31)] than those collected in zones 728 [n=1,281; mean = 469.28 mm FL (SE 3.96)] and 732 [n=868; mean = 466.12 mm FL (SE = 4.34)] (**Figure 6**).

Mean size of collected Red Snapper increased with increasing hook size (8/0, 11/0, and 15/0; **Figure 7**). The mean size of Red Snapper collected with 8/0 hooks was 389.83 mm FL (SE = 3.03), compared to 463.59 mm FL (SE = 3.91) for the 11/0 hooks and 567.64 mm FL (SE = 4.82) for the 15/0 hooks. The overall size range of Red Snapper collected was similar for each hook size, although the smallest Red Snapper was collected with an 8/0 hook and the largest collected with a 15/0 hook.

Sex – Sex was determined for 1,961 Red Snapper collected during this study (**Figure 8**). There was a nearly equal proportion of males to females collected, with 954 classified as male and 1,007 classified as female. Sizes of collected male Red Snapper ranged from 225 – 835 mm FL with a mean size of 464.1 mm FL (SE = 4.4). Female Red Snapper ranged in size from 263 – 907 mm FL and had a slightly larger mean size of 474.1 mm FL (SE = 4.2).

Annual Age – A total of 1,962 Red Snapper were aged during this study (**Figure 9**). The mean age for collected Red Snapper was 3.51 years (SE = 0.05). The youngest Red Snapper collected was age-1 (n=4) while the oldest was age-22 (n=1). The median age of Red Snapper collected was 3 years and the most frequent age-class collected was age-2 (n=841).

The overall age structure of Red Snapper collected within each of the three zones (722, 728, and 732) was similar (**Figure 10**). Age-2 was the most abundant age-class collected in each zone. The mean age of Red Snapper collected in zone 722 was 3.11 years (SE = 0.11), which was slightly younger than those collected in zones 728 and 732 where the mean ages were 3.60 years (SE = 0.07) and 3.60 years (SE = 0.08), respectively.

The mean age of Red Snapper collected during this study increased with increasing hook size (**Figure 11**). The mean age of Red Snapper collected with 8/0 hooks was 2.60 years (SE = 0.05), compared to 3.40 years (SE = 0.07) for the 11/0 hooks and 4.94 years (SE = 0.13) for the 15/0 hooks. The age range of Red Snapper collected was similar for each hook size.

The age frequency between male and female Red Snapper collected during this study (all hooks combined) was similar (**Figure 12**). The mean age of male Red Snapper was 3.48 years (SE = 0.08) while the mean age of females was 3.52 years (SE = 0.07). For both sexes, the relative frequency of age classes decreased markedly beyond 5 years of age.

The von Bertalanffy growth curve confirms that Red Snapper grow rapidly during the younger ages and growth slows after age-5 (**Figure 13**). The estimated parameters from the von Bertalanffy growth model are: L_∞ = 848.95 mm, k = 0.212, and t_0 = -0.708.

Mercury Analysis – Total mercury (THg) concentrations were determined for 176 Red Snapper ranging in size from 229 – 907 mm FL (**Table 5**). At these sizes, THg concentrations ranged from 0.019 – 1.506 mg/kg with a mean THg concentration of 0.205 mg/kg. Approximately 72% of all Red Snapper samples collected had THg concentrations less than 0.200 mg/kg (**Figure 14**). Several individuals above 700 mm SL contained THg concentrations that were noticeably higher than the majority analyzed. Mercury concentrations in Red Snapper collected during this project (up to approximately 800 mm FL) increased directly with fish length, as described by the Equation: THg = –0.231 + (0.000893 * FL).

Objective 2: Evaluate whether the size and age composition of Red Snapper in the U.S. South Atlantic has expanded during an ongoing fishing moratorium.

Objective 3: Evaluate if and how the relative abundance of Red Snapper in the U.S. South Atlantic has changed during an ongoing fishing moratorium.

To begin to assess the potential recovery of Red Snapper in the U.S. South Atlantic, we compared the size and age composition of Red Snapper between 2012 and the present study (2018). We hypothesized that during the recent period of harvest prohibition, overall survival rates of Red Snapper would increase, resulting in an expanded size and age structure where several strong age classes (2-, 3-, and 5-year-old Red Snapper) detected in 2012 would have persisted into 2018 (as 8-, 9-, and 11-year-old Red Snapper, respectively) resulting in detectible increases in mean size and age composition of the stock. In the present study, the mean size of Red Snapper collected was 463.4 mm FL (SE = 2.60) and the mean age of Red Snapper was 3.51 years (SE = 0.05), whereas in 2012, Red Snapper had a mean size of 532.9 mm FL (SE = 4.10) and a mean age of 4.35 years (SE = 0.06), indicating that on average, Red Snapper were smaller and younger during the present study. This trend is also reflected in relative frequency plots comparing size-composition (**Figure 15**) and age-composition (**Figure 16**) between 2012 and 2018, which indicate that Red Snapper collected were comprised of a much higher proportion of younger (age 2 – 4) and smaller (250 – 550 mm FL) in 2018 than was evident in 2012. Kernel density estimates (KDEs) comparing length frequency distributions between 2012 and 2018 confirm that generally smaller fish were collected in 2018 among all hook sizes (**Figure 17**). Spatially, the difference in size composition between the two surveys appears to be most pronounced in NMFS statistical zones 722 and 728 which show the greatest disparity between survey years (**Figure 18**); trends were generally similar in both nearshore and offshore depth strata (**Figure 19**).

Results of these initial comparisons of size and age composition between 2012 and 2018 indicated that, contrary to our expectations, Red Snapper collected in 2018 were generally smaller and younger than those collected in 2012. These results were surprising, especially given recent evidence from both the SERFS chevron trap and trap-mounted camera survey as well as the FWC RTD hooked-gear survey that indicate the relative abundance of Red Snapper has increased exponentially in the U.S. South Atlantic (SAFMC 2018). Upon closer examination of our data, it appears as if observed patterns are being driven largely by dramatic increases in the recruitment of smaller and younger Red Snapper into the population that are subsequently impeding our ability to detect any differences in the composition of larger and older Red Snapper between the two time periods. To address this concern, subsequent analyses were conducted to compare size- and age-specific catch per unit effort (CPUE, Individuals per hook) between the two time periods rather than relative frequency.

CPUE-adjusted length-frequency histograms indicated that the size-composition of Red Snapper shifted from a distinct bimodal pattern in 2012 to a unimodal pattern in 2018, although the overall size range was similar between the two surveys (**Figure 20**). Overall, size-specific CPUE was higher in 2018 for all size classes, although increases in size-specific CPUE were notably higher for smaller Red Snapper (< 550 mm FL). This trend was evident across all three hook sizes, although increases in the CPUE of smaller Red Snapper was greater for 8/0 and 11/0 hooks, whereas 15/0 hooks detected a greater increase in the CPUE of larger Red Snapper (**Figure 21**).

Examination of CPUE-adjusted age-frequency histograms indicated similar trends to those observed in the size-frequency plots. Overall age-composition of Red Snapper shifted from a distinct bimodal pattern in 2012 to a primarily unimodal pattern in 2018 **(Figure 22)**. The 2012 survey was dominated by age-3 and age-5 Red Snapper with few fish collected greater than 10-years-old. In contrast, the 2018 survey was dominated by young fish (primarily age-2), with a notable increase in older Red Snapper (age 11+). Overall, the increase in CPUE of younger Red Snapper was most pronounced for the 8/0 and 11/0 hooks, whereas the increase in CPUE of older Red Snapper was limited largely to those collected using 15/0 hooks (**Figure 23**).

Analyses comparing ratios of percentage composition between 2018 and 2012 indicate that, for all three hook sizes, young Red Snapper (primarily age 2 – 4) comprised a higher proportion of the total catch in 2018 (ratio > 1) than they did in 2012 and, for 15/0 hooks, so did older Red Snapper (age 8 +; **Figure 24**). In contrast, Red Snapper aged 5 – 7 comprised a higher proportion of the total catch in 2012 for all three hook sizes.

Indices of abundance (IOAs) were calculated (collectively, by hook size, and by NMFS statistical zone) to further examine the changes in relative abundances of Red Snapper between 2012 and 2018. Overall, the average abundance increased notably from 2012 to 2018 (**Figure 25**). The final model for the overall data included the year, NMFS statistical zone, month, number of 8/0 hooks, number of 11/0 hooks, and number of 15/0 hooks. Average abundance of Red Snapper showed an increase for all hook sizes from 2012 to 2018 with the greatest increase observed for the 11/0 hook size. The final models for both the 8/0 and 11/0 hook sizes included year, month, depth strata, NMFS statistical zone, and the number of respective hooks dropped. The final model for the 15/0 hook size included the year and the number of 15/0 hooks dropped.

All IOAs showed a large increase (i.e. several orders of magnitude) in abundance from 2012 to 2018 when examined by NMFS statistical zone (**Figure 26)**. Zone 732 showed the largest increase, although all three NMFS statistical zones were similar. The final model for each individual zone included year, month, number of 8/0 hooks, number of 11/0 hooks, and number of 15/0 hooks.

Objective 4: Assess, to what degree, the spatial dynamics of Red Snapper in the U.S. South Atlantic has changed during an ongoing fishing moratorium.

CPUE-adjusted size- and age-frequency histograms were used to examine if the spatial dynamics of Red Snapper in the U.S. South Atlantic had changed between the 2012 and 2018 surveys. Abundances for Red Snapper increased within each NMFS statistical zone from 2012 to 2018 (**Figure 27**). As noted previously, there was a general shift in length frequencies from a bimodal to unimodal distribution within each NMFS statistical zone, although the overall size range of fish collected within each NMFS statistical zone was similar between survey years. Size-specific CPUE's were notably higher for smaller Red Snapper (< 500 mm FL) in all zones in 2018. While there was an overall increase in CPUE between survey years for larger fish (> 550 mm FL) in all zones, these differences were more pronounced for zone 732. When abundances within NMFS statistical zones were examined by depth strata [nearshore (< 30 m) and offshore (30 – 150 m)], the 300 – 400 mm FL size range of fish collected in 2018 dominated all zones and depth strata

(**Figure 28**). Patterns of CPUE-adjusted size distributions were similar between surveys in the offshore depth strata for all zones. The most notable change in size-specific abundances occurred in the nearshore depth strata. In nearshore zone 722, very few small Red Snapper were collected in 2012, whereas small Red Snapper dominated the catch in 2018.

CPUE-adjusted age-frequency plots showed a similar pattern seen in the length frequency analysis; abundances were markedly higher for younger Red Snapper (2-5-years-old) in 2018 in all zones, but unlike 2012, there was also an increase in CPUE for older fish (aged 11+; **Figure 29**). Among zone and depth strata, one notable difference between 2012 and 2018 was that older fish (aged 11+) were captured in all three zones and both depth strata (**Figure 30**); in 2012, no old Red Snapper were captured within nearshore waters of zones 728 and 732.

B. IF SIGNIFICANT PROBLEMS DEVELOPED WHICH RESULTED IN LESS THAN SATISFACTORY OR NEGATIVE RESULTS, THEY SHOULD BE DISCUSSSED

No significant problems were encountered that impacted the current project and we were able to sample the full number of proposed sampling sites. However, due to persistent strong Gulf Stream currents encountered during the sampling period, several of the originally selected sites, in the deepest portions of the offshore depth strata, had to be rotated to alternately selected sites further inshore in order to deploy gear following standardized protocols. Despite the need to sample alternate sites, sampling was completed within the originally-selected depth strata, and we do not expect that this impacted project results in any way.

Similar to the 2012 survey, we originally planned on culling all Red Snapper captured during this project for age comparison. Based on the number of fish collected/culled in 2012 (1,099) we conservatively requested authorization to sacrifice 2,000 Red Snapper on the federal letter of acknowledgement for scientific research. Due to higher than expected catches of Red Snapper in 2018, we realized we would exceed the number we were authorized to sacrifice. Accordingly, our culling protocols were altered midway through the study to ensure that a representative subset of Red Snapper were sacrificed for aging within each spatial strata. Despite this limitation, we were still able to retain most Red Snapper for age determination, and by applying age-length keys, were able to make valid comparisons of age composition between 2012 and 2018 for all sampled strata.

C. DESCRIPTION OF NEED, IF ANY, FOR ADDITIONAL WORK

Although the standardized repetitive timed-drop hooked-gear survey has shown great promise as an alternative approach to characterizing the relative abundance and size composition of Red Snapper and other managed reef fishes, questions still remain as to whether this survey can further be improved upon. Notably, recent reviews of survey results question whether standardizing drop duration to a set time period (e.g., two minutes), regardless of whether or not an angler detects a potential bite, may further remove any angler bias from survey methods. One concern with this approach is that failure to reel in immediately upon hooking may result in an increased number of fishes pulling the gear into reef habitat causing lines to break, thus dramatically reducing catch rates. Nevertheless, implications of increased standardization to FWC RTD hooked-gear methods should be further explored.

The hooked-gear surveys developed and conducted in the U.S. South Atlantic by the FWC show continued value to providing data on abundances as well as life-history information for Red Snapper and other managed reef-fish. The FWC's recently completed CRP grant (Grant# NA15NMF4540104, "*First direct assessment of the size-selectivity of hook and line gear, Chevron traps, and underwater cameras for Red Snapper and other reef fishes in the U.S. South Atlantic.*") showed that the overall average length of Red-Snapper collected was larger than that of both chevron trap captured fish and measurements of Red Snapper collected from deployed stereo-cameras. Given the maximum age of Red Snapper in the U.S. South Atlantic and the current rebuilding plan of the stock, it will be important to continue to monitor the recovery of older fish. Continued FWC RTD hooked-gear surveys, conducted annually or at a minimum periodically, would be beneficial in order to provide life history information for Red Snapper to monitor continued recovery of older fish. In addition, these surveys would provide an additional index of abundance for Red Snapper in the U.S. South Atlantic on which management decisions can be in part based on.

EVALUATION

A. EXTENT TO WHICH THE PROJECT GOALS AND OBJECTIVES WERE ATTAINED

Overall, the project successfully met the proposed objectives. The primary objective was to assess changes in the size and age composition, relative abundance, and spatial dynamics of Red Snapper in the U.S. South Atlantic under an ongoing fishing moratorium. To accomplish this goal, we replicated a fishery-independent repetitive timed-drop hooked-gear survey conducted in 2012 and compared Red Snapper population dynamics. Overall relative abundances of Red Snapper exhibited an increase from 2012 to 2018. Increased CPUE of Red Snapper was observed for all hook sizes deployed and showed in increase in abundance for all sizes and ages of fish collected. This trend was documented within all three NMFS statistical zones sampled as well as in both nearshore and offshore strata. Increased relative abundances of Red Snapper were observed throughout all size and age classes collected, however, this was particularly evident in 2-year-old fish which accounted for nearly 43% of the total of all Red Snapper aged during the survey. Although the high number of 2-year-old fish indicates a potentially good recruitment year, these high abundances also impede our ability to document the recovery of older, larger fish using traditional comparisons of overall size and age composition. To account for this, we employed comparisons of size- and age-composition between 2012 and 2018 that accounted for time-varying abundances. These CPUE-adjusted comparisons allowed us to document an increase in the abundance of larger/older Red Snapper, in addition to small/young Red Snapper, in 2018.

In addition to addressing questions regarding Red Snapper population dynamics in the U.S. South Atlantic, we were also able to obtain valuable life history data for twenty-three managed fish species, although most data pertain to Red Snapper. Overall, life history data were obtained from 1,987 Red Snapper and 713 other managed reef-fishes collected throughout the survey area. Life history data collected on Red-Snapper was instrumental in the analysis conducted during this survey and will be available, along with life history data collected from other species, for use in future stock assessments in the U.S. South Atlantic.

B. DISSEMINATION OF PROJECT RESULTS

We anticipate presenting project results at various regional meetings over the coming years and investigating the potential of manuscript development for a peer-reviewed scientific journal. Results from this study, as well as previous FWC studies, will be available and provided by participating FWC staff to upcoming stock assessments for Red Snapper and other reef-fishes for which data were collected. Data from this study, as well as prior hooked-gear surveys conducted by the FWC, will be used as part of an upcoming MARFIN grant (#NA19NMF4330235, "*Developing indices of relative abundance and size/age composition for the assessment of Red Snapper and other reef fishes in the U.S. South Atlantic using data from a fishery-independent hooked-gear survey*.") as a component of developing indices of Red Snapper and other reef fish abundances in the U.S. South Atlantic. Data collected during this study will also be available to the general public and other researchers, in a variety of formats, upon request.

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We gratefully acknowledge our industry partners whose knowledge and expertise were invaluable in developing and implementing our survey. A very special thanks to Captains Robert Johnson, Jimmy Hull, Steve Park, and Tony Grillo and each of their crews. These captains provided their vessels and years of knowledge and experience that allowed us to not only complete all our objectives, but to make this a safe and successful study. We acknowledge our colleague at NMFS - Beaufort (Dr. Todd Kellison) for his insight and partnership during the development of this study. Thanks to Dax Ruiz for NOAA-Fisheries grants administration. Many thanks to FWC chief scientists that led research trips on industry vessels (Amy Hulsey, Carissa Wood, Jacob Schneider, and Dwayne Edwards) and to all other staff that traveled from various parts of the state to help with data collection. Special thanks to FWRI Grants Office staff for their assistance in administering this grant. A special thanks to the many other FWRI staff and groups that put in countless hours processing samples, entering and proofing data, filling in for staff that were conducting field sampling, and assuring that all components of this project were completed as scheduled. A very special thanks to Amy Hulsey and Heather Christiansen for their analytical efforts in preparing this report.

Lastly, we would like to give special recognition and thanks to the late Captain Steve Park for the assistance he has provided to FWC reef fish research efforts during this study as well as all previous FWC studies in the south Atlantic since 2012. Captain Steve was instrumental in the development of these studies by not only providing his vessel as a platform for our research, but also by unselfishly sharing his many years of knowledge and experiences that greatly enhanced the design and utility of each study he participated in. He will be missed.

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Table 1. The number of sites sampled within each NMFS Statistical Zone and depth strata during FWC RTD hooked-gear surveys along the Atlantic coast of Florida (2018).

NMFS Statistical Zone	Nearshore (< 30 m) Sites Sampled	Offshore (30 - 150 m) Sites Sampled	Total Sites Sampled
722	22	58	80
728	72	116	188
732	50	46	96
TOTALS	144	220	364

Table 2. Summary of catch by NMFS statistical zone during FWC RTD hooked-gear surveys (n=364) along the Atlantic coast of Florida (2018). Percent (%) Total Catch is the percentage composition of each taxon out of all fish collected. Percent (%) Catch per Zone is the percentage each taxon represents out of all fish collected within each NMFS statistical zone. Taxa are arranged alphabetically.

Taxon	**Number Collected**			**Total**	**% Total Catch**	**% Catch per Zone**		
	722	**728**	**732**			**722**	**728**	**732**
Balistes capriscus	5	13	7	25	0.6	0.5	0.6	0.7
Calamus leucosteus	1	-	-	1	<0.1	0.1	-	-
Caranx crysos	-	6	1	7	0.2	-	0.3	0.1
Carcharhinus falciformis	3	32	-	35	0.9	0.3	1.5	-
Carcharhinus plumbeus	1	4	1	6	0.1	0.1	0.2	0.1
Carcharhinus sp.	-	-	1	1	<0.1	-	-	0.1
Centropristis ocyurus	2	12	-	14	0.3	0.2	0.6	-
Centropristis striata	43	162	56	261	6.4	4.6	7.6	5.4
Cephalopholis cruentata	4	1	1	6	0.1	0.4	<0.1	0.1
Cynoscion nothus	-	-	1	1	<0.1	-	-	0.1
Cynoscion regalis	1	-	-	1	<0.1	0.1	-	-
Diplectrum formosum	-	5	-	5	0.1	-	0.2	-
Diplodus holbrookii	4	-	-	4	0.1	0.4	-	-
Echeneis naucrates	-	-	1	1	<0.1	-	-	0.1
Echeneis spp.	5	3	4	12	0.3	0.5	0.1	0.4
Epinephelus morio	-	8	3	11	0.3	-	0.4	0.3
Ginglymostoma cirratum	-	3	-	3	0.1	-	0.1	-
Haemulon aurolineatum	74	230	54	358	8.8	8.0	10.8	5.2
Holocentrus adscensionis	4	1	-	5	0.1	0.4	<0.1	-
Lagodon rhomboides	2	1	-	3	0.1	0.2	<0.1	-
Lutjanus analis	5	3	-	8	0.2	0.5	0.1	-
Lutjanus campechanus	500	1,286	870	2,656	64.9	53.9	60.5	83.7
Lutjanus griseus	11	12	3	26	0.6	1.2	0.6	0.3
Lutjanus synagris	-	11	5	16	0.4	-	0.5	0.5
Micropogonias undulatus	6	-	-	6	0.1	0.6	-	-
Mycteroperca microlepis	4	11	-	15	0.4	0.4	0.5	-
Ocyurus chrysurus	2	-	-	2	<0.1	0.2	-	-
Opsanus tau	-	1	1	2	<0.1	-	<0.1	0.1
Orthopristis chrysoptera	1	-	-	1	<0.1	0.1	-	-
Pagrus pagrus	36	12	3	51	1.2	3.9	0.6	0.3
Pomatomus saltatrix	2	10	1	13	0.3	0.2	0.5	0.1
Rachycentron canadum	-	1	1	2	<0.1	-	<0.1	0.1
Rhizoprionodon terraenovae	12	40	3	55	1.3	1.3	1.9	0.3

Taxon	Number Collected			Total	% Total Catch	% Catch per Zone		
	722	728	732			722	728	732
Rhomboplites aurorubens	162	215	16	393	9.6	17.5	10.1	1.5
Sciaenops ocellatus	3	-	-	3	0.1	0.3	-	-
Scomber colias	1	4	1	6	0.1	0.1	0.2	0.1
Scomberomorus maculatus	-	1	-	1	<0.1	-	<0.1	-
Scorpaena plumieri	-	1	-	1	<0.1	-	<0.1	-
Seriola dumerili	2	6	-	8	0.2	0.2	0.3	-
Seriola rivoliana	13	8	3	24	0.6	1.4	0.4	0.3
Seriola zonata	17	20	1	38	0.9	1.8	0.9	0.1
Sphyraena barracuda	-	1	-	1	<0.1	-	<0.1	-
Sphyraena borealis	-	-	1	1	<0.1	-	-	0.1
Trachinocephalus myops	1	-	-	1	<0.1	0.1	-	-
Totals	**927**	**2,124**	**1,039**	**4,090**				

Table 3. Summary of taxa collected by hook size in the nearshore (< 30 m) and offshore depth strata (30-150 m) during FWC RTD hooked-gear surveys along the Atlantic coast of Florida (2018). Taxa are arranged alphabetically.

Taxon	**Nearshore (< 30 m)**			**Offshore (30-150 m)**			**Totals**
	Hook Size			**Hook Size**			
	8/0	**11/0**	**15/0**	**8/0**	**11/0**	**15/0**	
Balistes capriscus	12	-	1	8	4	-	**25**
Calamus leucosteus	-	-	-	1	-	-	**1**
Caranx crysos	4	2	-	1	-	-	**7**
Carcharhinus falciformis	-	-	-	5	21	9	**35**
Carcharhinus plumbeus	-	-	2	-	1	3	**6**
Carcharhinus sp.	-	-	-	-	-	1	**1**
Centropristis ocyurus	1	-	-	12	-	1	**14**
Centropristis striata	91	37	8	60	50	15	**261**
Cephalopholis cruentata	1	-	1	3	-	1	**6**
Cynoscion nothus	1	-	-	-	-	-	**1**
Cynoscion regalis	1	-	-	-	-	-	**1**
Diplectrum formosum	-	-	-	4	1	-	**5**
Diplodus holbrookii	2	-	2	-	-	-	**4**
Echeneis naucrates	1	-	-	-	-	-	**1**
Echeneis spp.	3	2	2	3	2	-	**12**
Epinephelus morio	1	1	-	-	2	7	**11**
Ginglymostoma cirratum	-	3	-	-	-	-	**3**
Haemulon aurolineatum	176	63	17	56	39	7	**358**
Holocentrus adscensionis	-	1	-	3	-	1	**5**
Lagodon rhomboides	1	2	-	-	-	-	**3**
Lutjanus analis	1	-	-	3	2	2	**8**
Lutjanus campechanus	315	365	243	632	675	426	**2,656**
Lutjanus griseus	1	6	-	5	10	4	**26**
Lutjanus synagris	5	3	-	4	4	-	**16**
Micropogonias undulatus	5	1	-	-	-	-	**6**
Mycteroperca microlepis	1	3	2	2	2	5	**15**
Ocyurus chrysurus	-	-	-	1	1	-	**2**
Opsanus tau	-	-	1	-	-	1	**2**
Orthopristis chrysoptera	1	-	-	-	-	-	**1**

Taxon	Nearshore (< 30 m)			Offshore (30-150 m)			Totals
	Hook Size			Hook Size			
	8/0	**11/0**	**15/0**	**8/0**	**11/0**	**15/0**	
Pagrus pagrus	-	-	-	29	20	2	**51**
Pomatomus saltatrix	4	6	2	-	-	1	**13**
Rachycentron canadum	2	-	-	-	-	-	**2**
Rhizoprionodon terraenovae	3	10	4	15	16	7	**55**
Rhomboplites aurorubens	48	18	-	219	97	11	**393**
Sciaenops ocellatus	1	-	2	-	-	-	**3**
Scomber colias	1	-	-	1	4	-	**6**
Scomberomorus maculatus	1	-	-	-	-	-	**1**
Scorpaena plumieri	-	1	-	-	-	-	**1**
Seriola dumerili	2	1	1	1	2	1	**8**
Seriola rivoliana	5	-	-	9	9	1	**24**
Seriola zonata	6	3	1	7	12	9	**38**
Sphyraena barracuda	-	-	-	-	-	1	**1**
Sphyraena borealis	-	1	-	-	-	-	**1**
Trachinocephalus myops	-	-	-	1	-	-	**1**
Totals	**697**	**529**	**289**	**1,085**	**974**	**516**	**4,090**

Table 4. Summary of biological specimens retained for demographic analysis during FWC RTD hooked-gear surveys along the Atlantic coast of Florida (2018). Taxa are arranged alphabetically.

Taxon	**Number Culled**
Balistes capriscus	25
Calamus leucosteus	1
Centropristis striata	125
Cephalopholis cruentata	6
Cynoscion regalis	1
Epinephelus morio	11
Haemulon aurolineatum	217
Lutjanus analis	8
Lutjanus campechanus	1,987
Lutjanus griseus	26
Lutjanus synagris	15
Mycteroperca microlepis	15
Ocyurus chrysurus	2
Pagrus pagrus	31
Pomatomus saltatrix	8
Rachycentron canadum	1
Rhomboplites aurorubens	202
Sciaenops ocellatus	2
Scomberomorus maculatus	1
Seriola dumerili	7
Seriola rivoliana	3
Seriola zonata	5
Sphyraena barracuda	1
Total	**2,700**

Table 5. Summary of fish length (mm) and total mercury concentrations (mg/kg) for Red Snapper (n=176) collected during FWC RTD hooked-gear surveys along the Atlantic coast of Florida (2018).

Length Statistic	**Fork Length (mm)**	**Total Mercury (mg/kg)**
Mean	488	0.205
Median	455	0.148
Std. Dev.	147	0.195
Minimum	229	0.019
Maximum	907	1.487

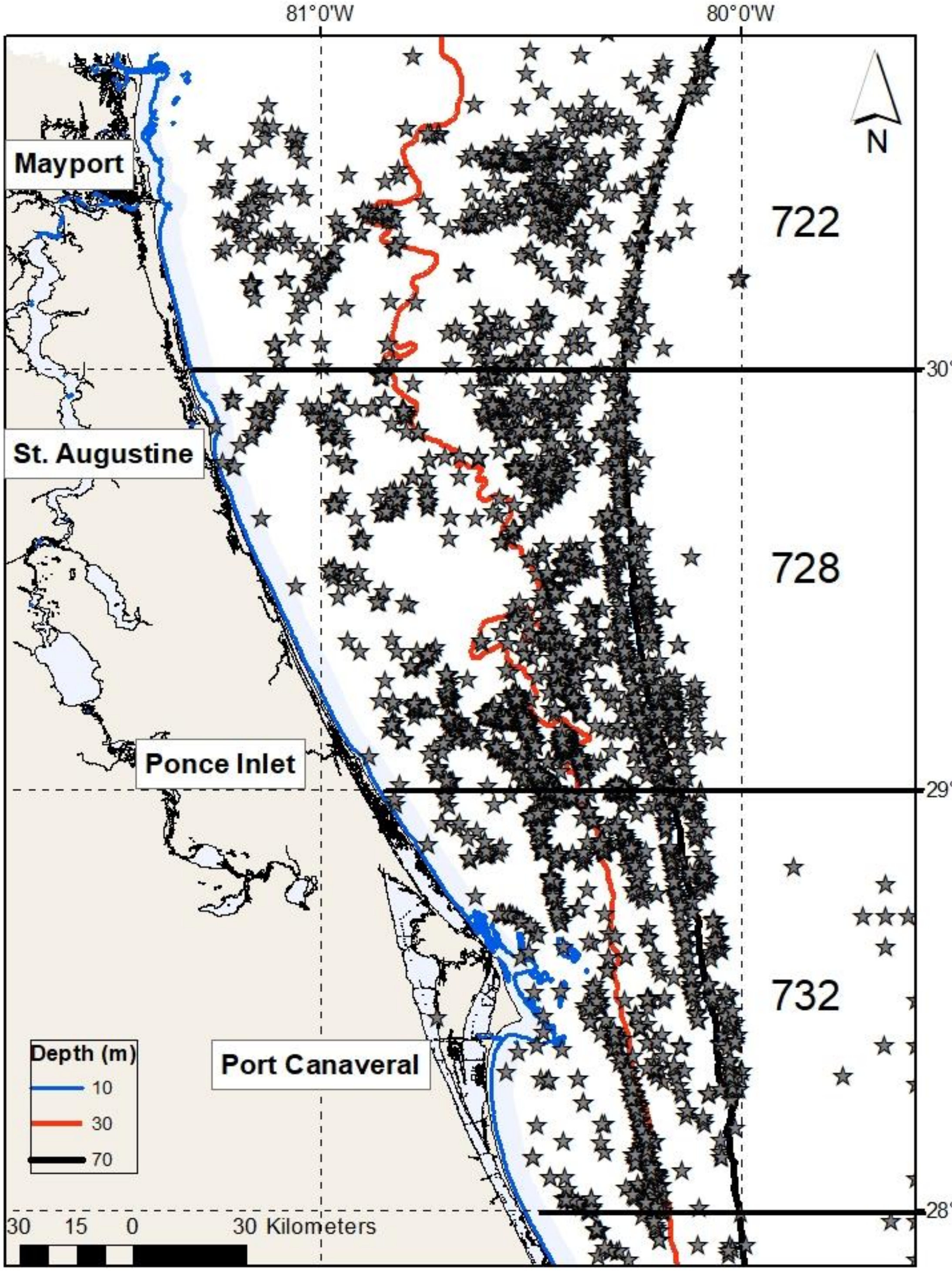

Figure 1. Study area (sampling bounded by 28° 00'N and 30° 45'N) for FWC RTD hooked-gear surveys along the Atlantic coast of Florida (2018), including NMFS statistical zones 722, 728 and 732. The blue, red, and black lines represent the 10-m, 30-m, and 70-m isobaths, respectively. Stars represent all potential hardbottom sites in the FWC sampling universe.

Figure 2. Electric reel (Electramate© model 920-XP) equipped with a Penn 9/0 Senator reel used during FWC RTD hooked-gear surveys along the Atlantic coast of Florida (2018).

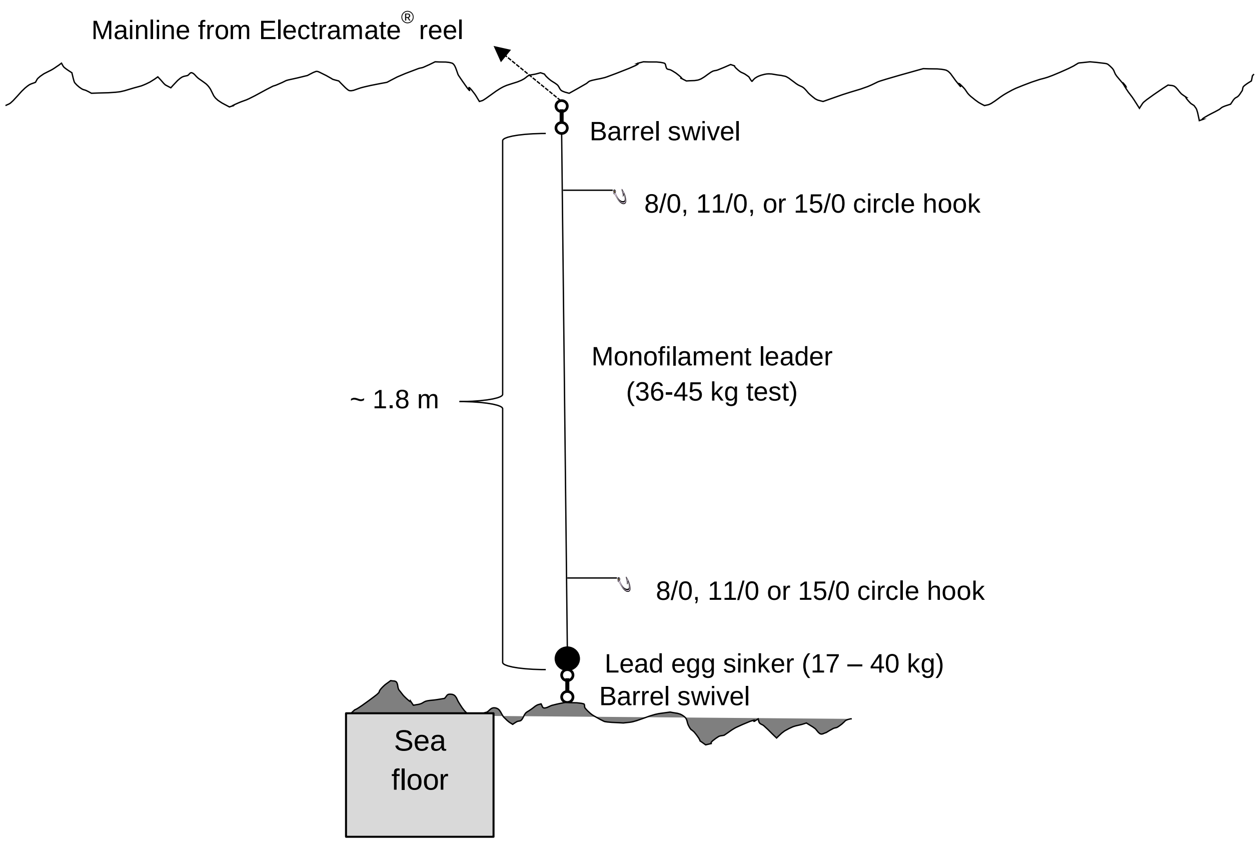

Figure 3. Diagram of terminal tackle, double-hook “chicken rig”, used during FWC RTD hooked-gear surveys along the Atlantic coast of Florida (2018).

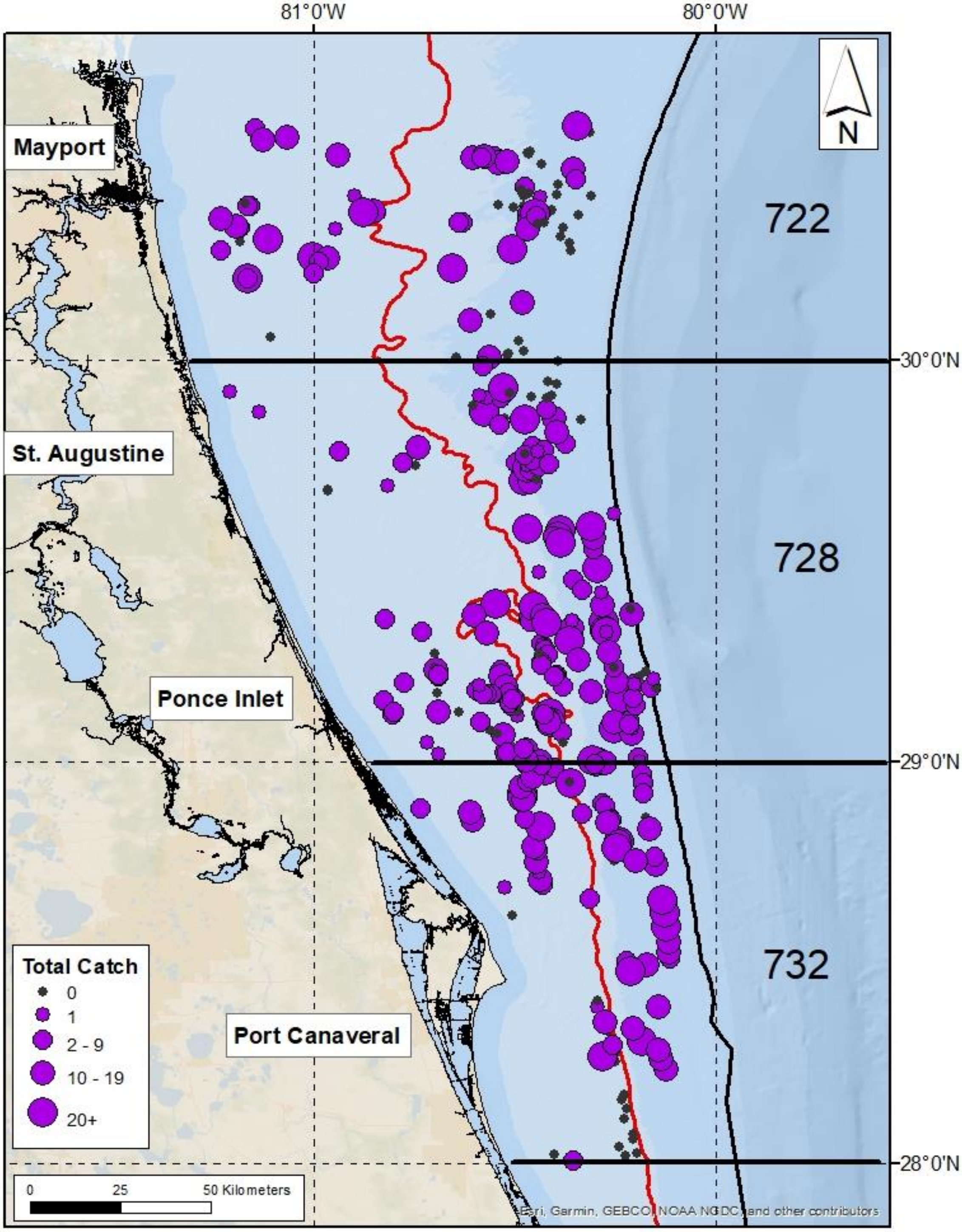

Figure 4. Bubble plot showing locations of Red Snapper collected during FWC RTD hooked-gear surveys along the Atlantic coast of Florida (2018). Number of Red Snapper collected at each site corresponds to the size of the circle as given in the legend. Small black circles represent sampled sites where no Red Snapper were collected. The red and black lines represent the 30-m and 70-m isobaths, respectively.

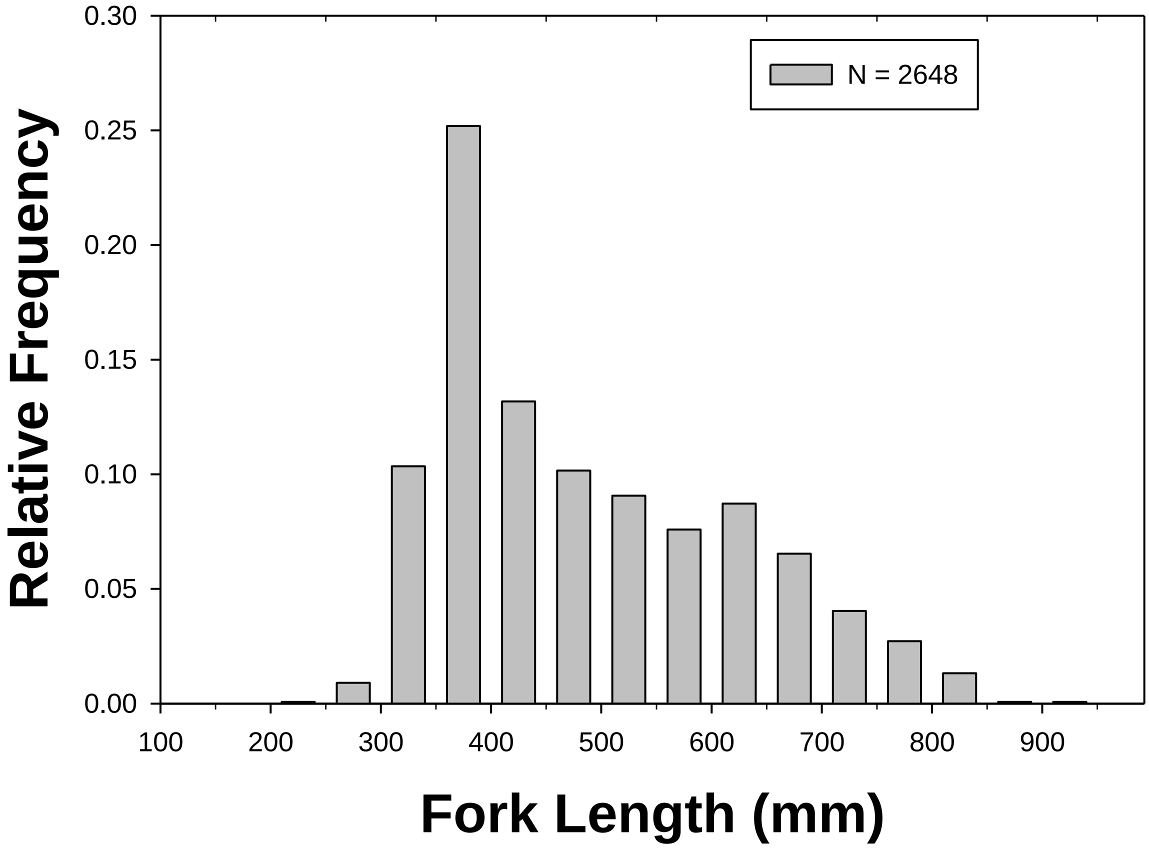

Figure 5. Overall length frequency (mm FL) of all Red Snapper collected during FWC RTD hooked-gear surveys along the Atlantic coast of Florida (2018).

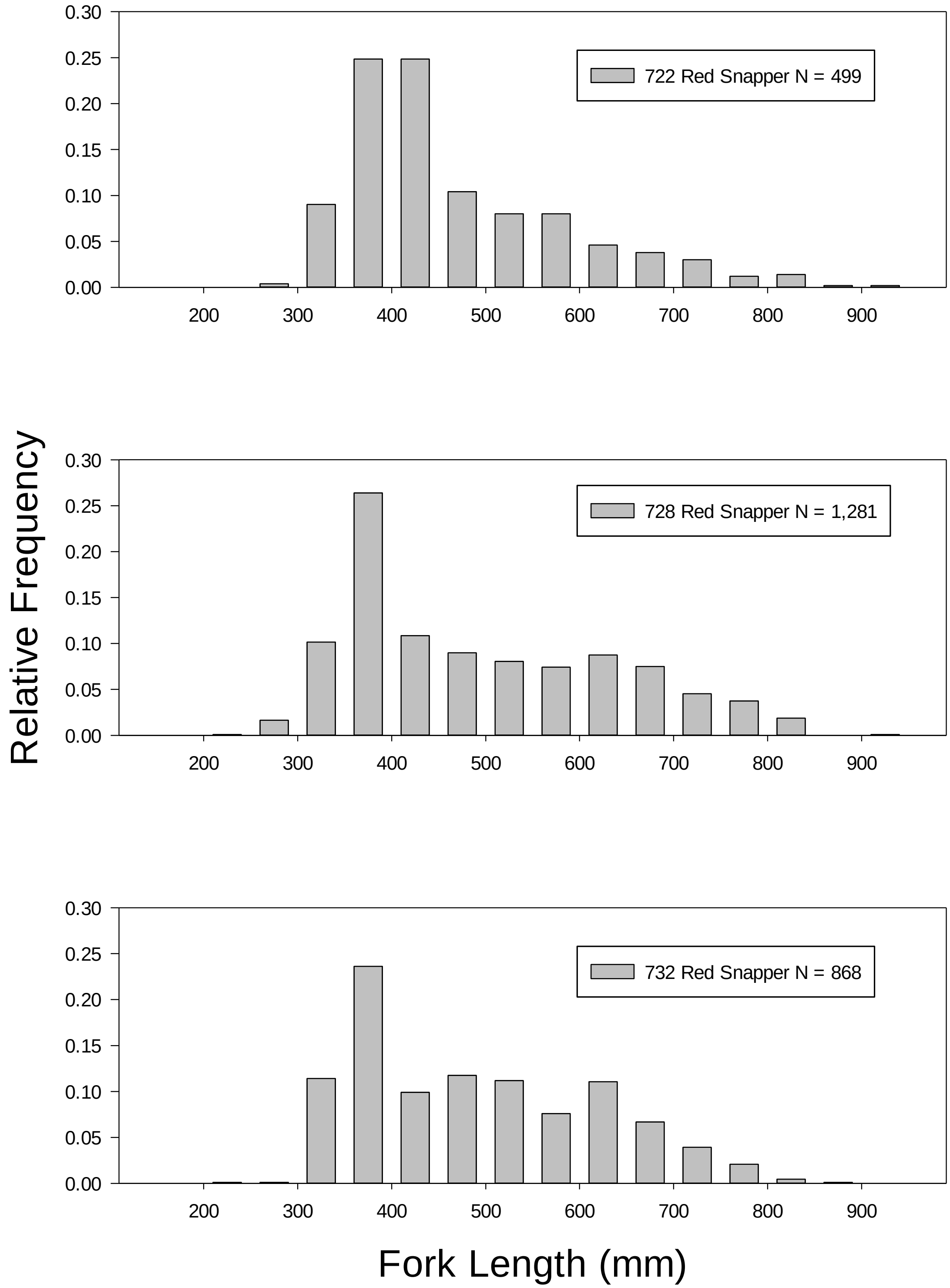

Figure 6. Length frequency (mm FL) of Red Snapper collected during FWC RTD hooked-gear surveys along the Atlantic coast of Florida (2018) for each of the three NMFS Zones (722, 728, 732) sampled.

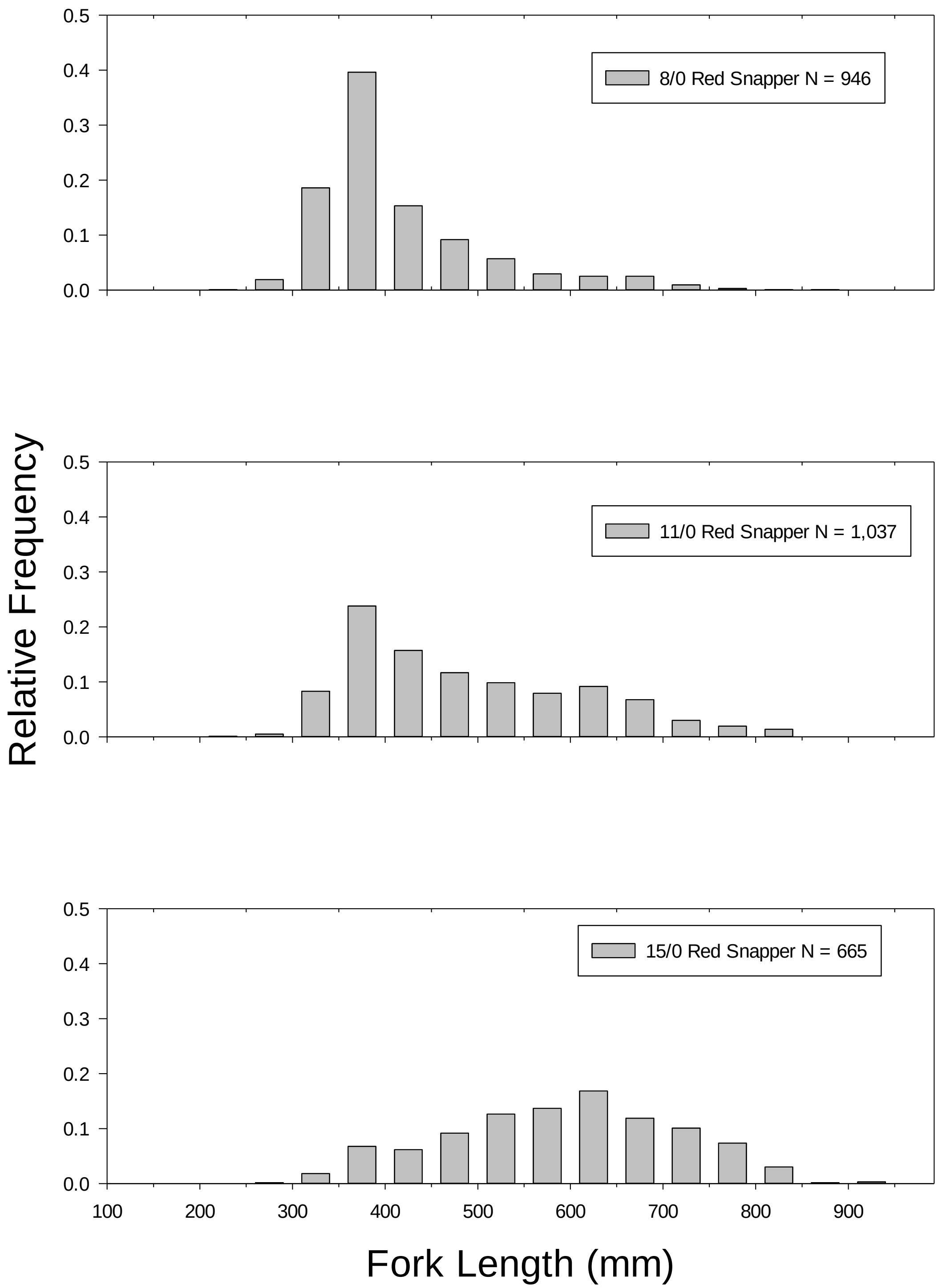

Figure 7. Length frequency (mm FL) of Red Snapper collected during FWC RTD hooked-gear surveys along the Atlantic coast of Florida (2018) by hook size (8/0, 11/0, 15/0).

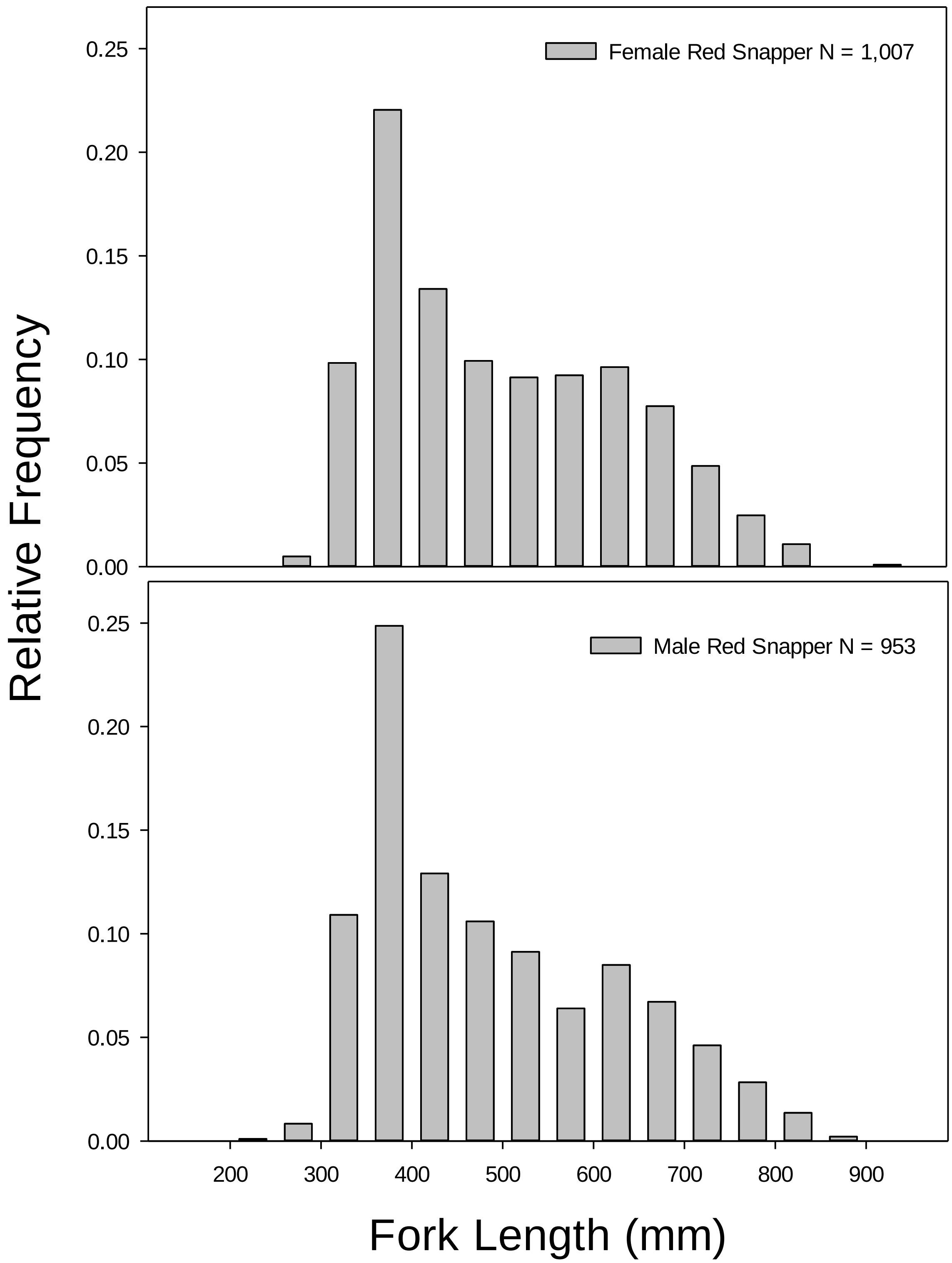

Figure 8. Length frequency (mm FL) of Red Snapper collected during FWC RTD hooked-gear surveys along the Atlantic coast of Florida (2018) by sex.

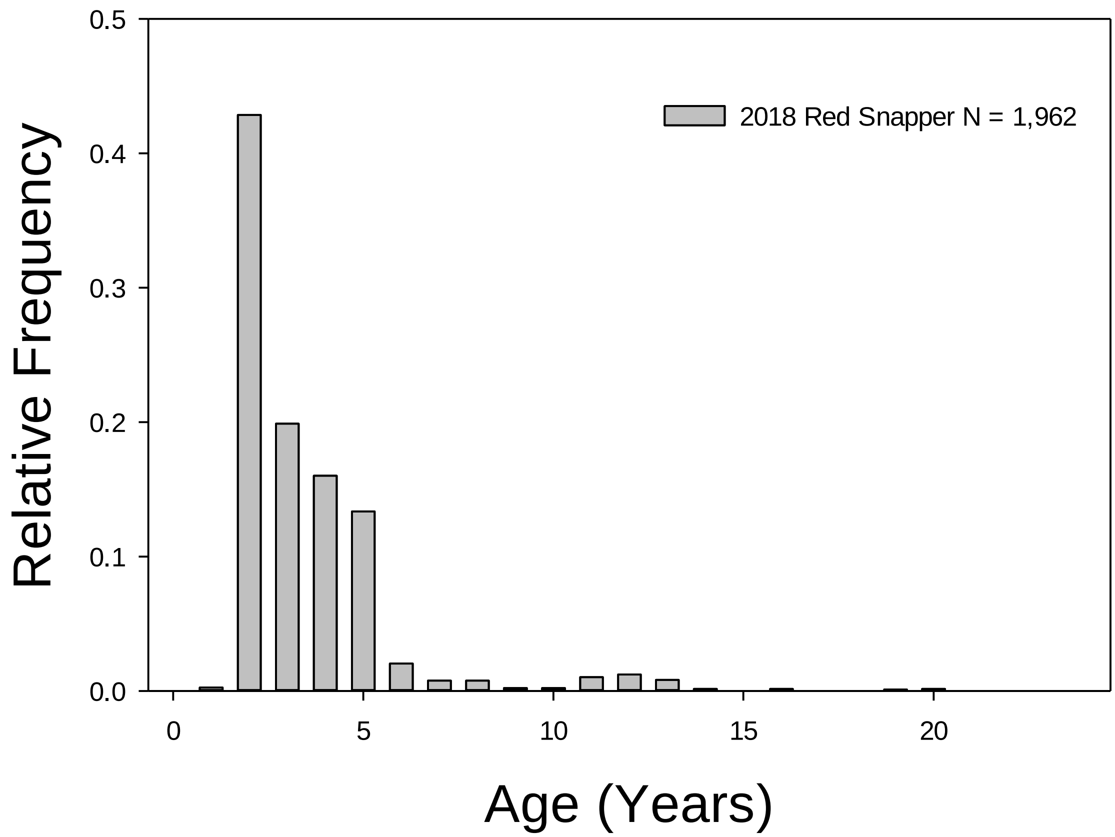

Figure 9. Age frequency of Red Snapper collected during FWC RTD hooked-gear surveys along the Atlantic coast of Florida (2018).

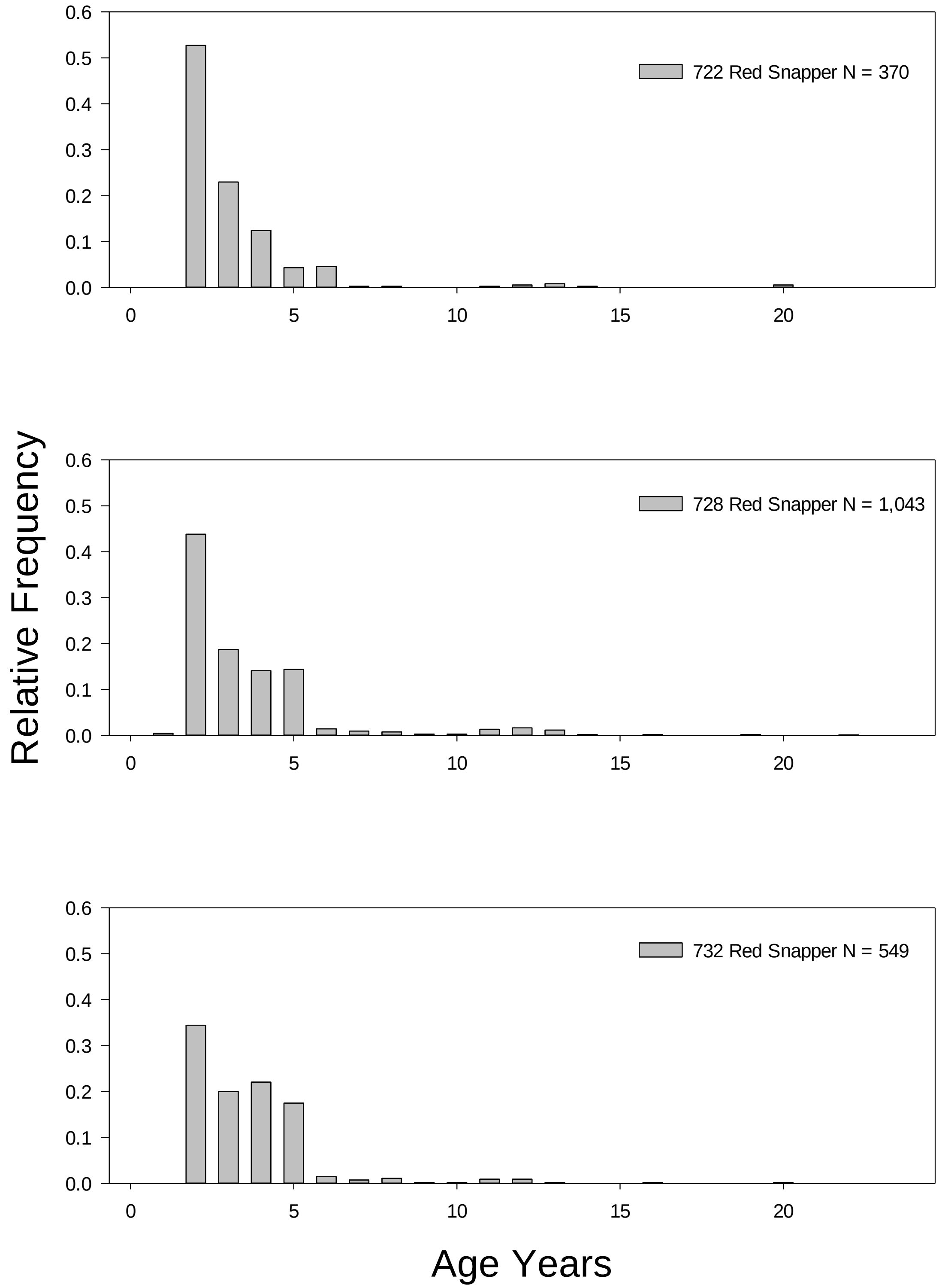

Figure 10. Age frequency of Red Snapper collected during FWC RTD hooked-gear surveys along the Atlantic coast of Florida (2018) by NMFS statistical zone (all hook sizes combined).

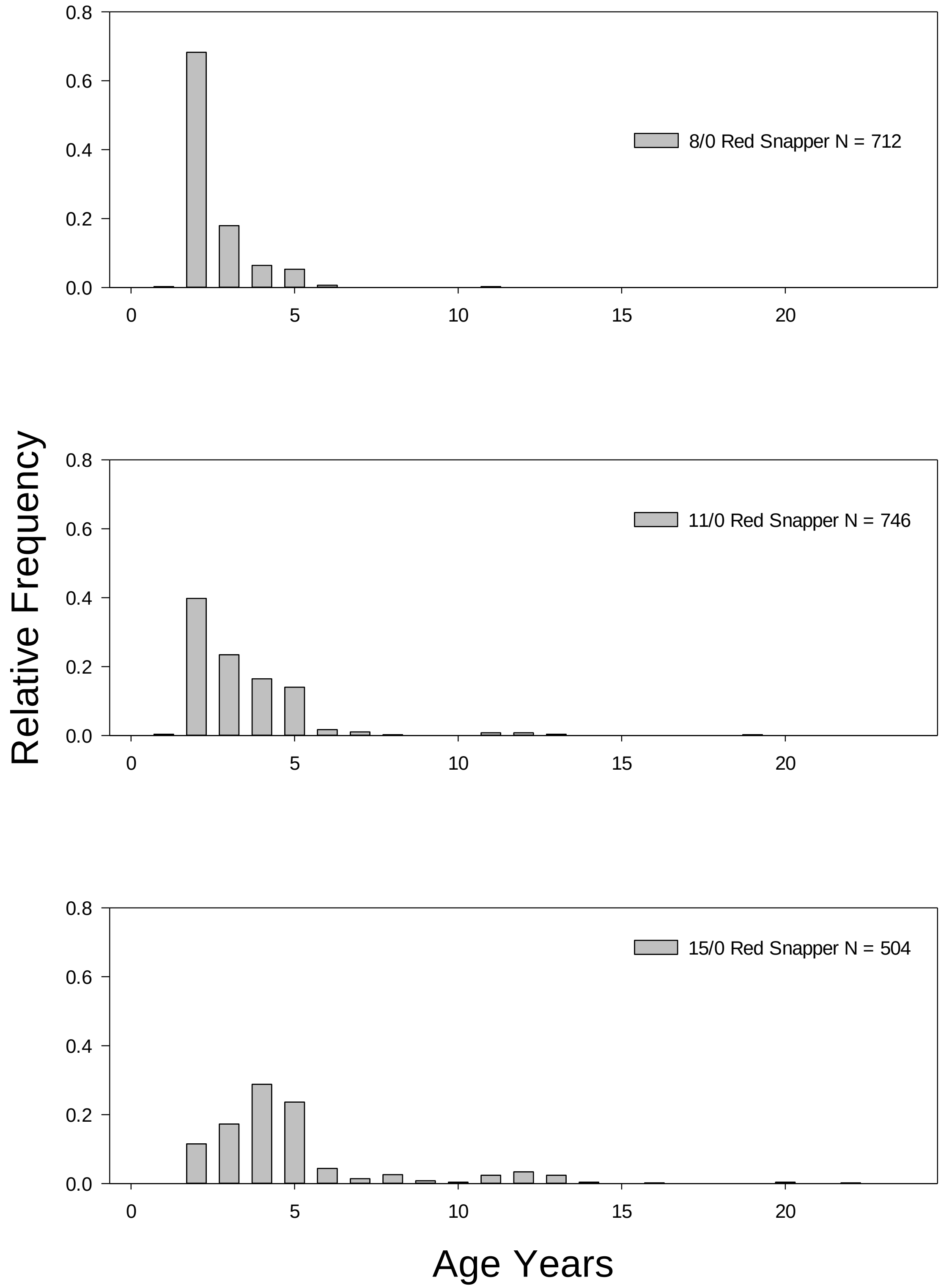

Figure 11. Age frequency of Red Snapper collected during FWC RTD hooked-gear surveys along the Atlantic coast of Florida (2018) by hook size (8/0, 11/0, 15/0).

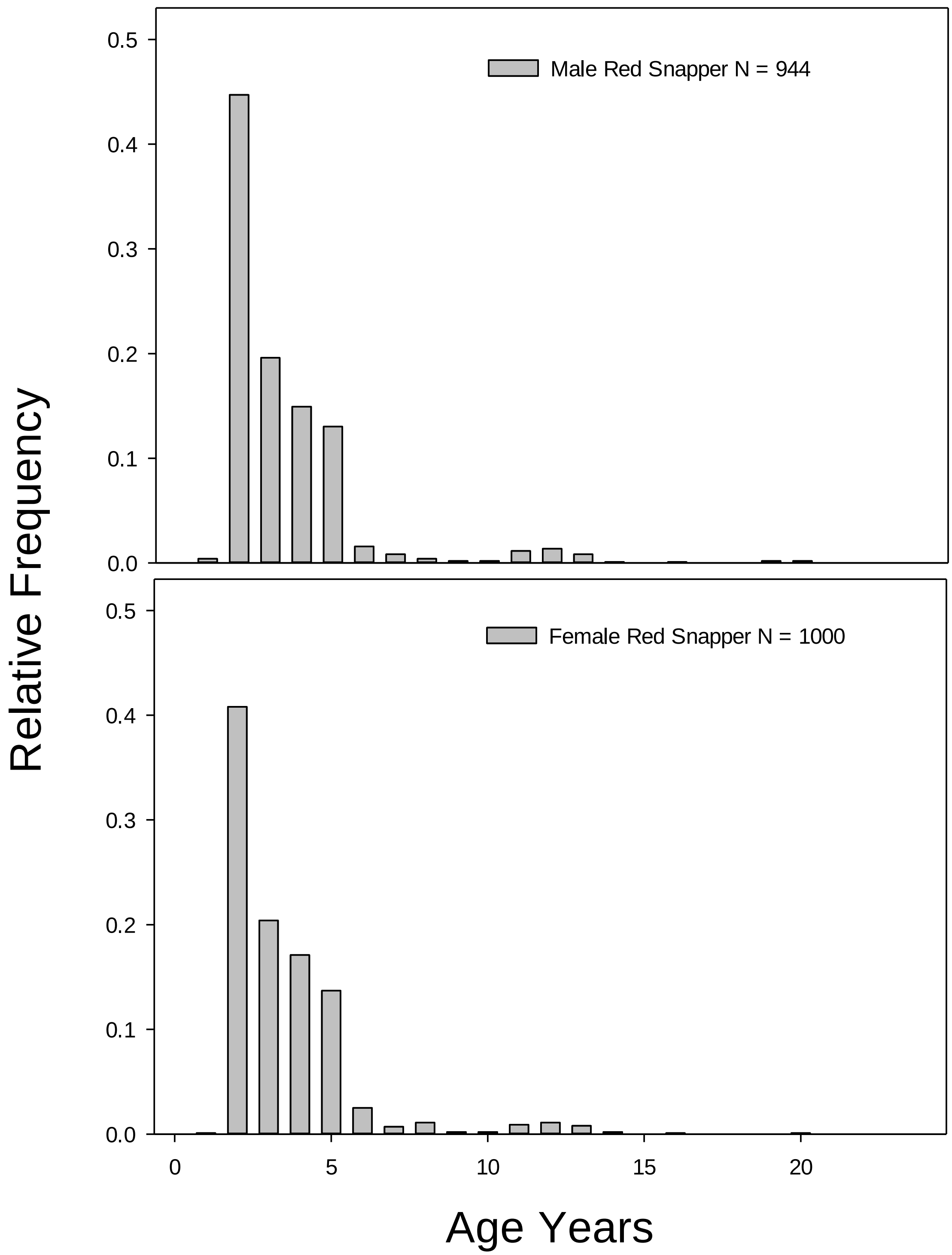

Figure 12. Age frequency of Red Snapper collected during FWC RTD hooked-gear surveys along the Atlantic coast of Florida (2018) by sex (all hook sizes combined).

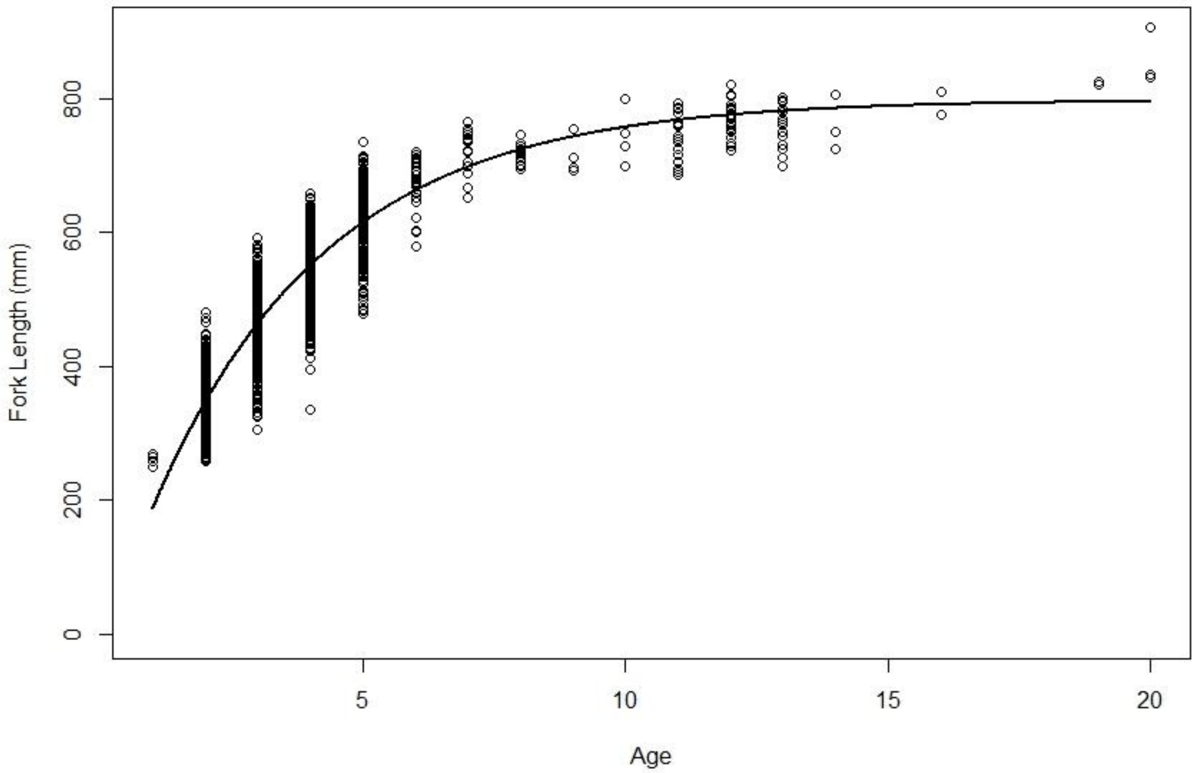

Figure 13. Observed length-at-age (mm FL) of Red Snapper (n = 1,962) collected during FWC RTD hooked-gear surveys along the Atlantic coast of Florida (2018). The continuous line is the estimated von Bertalanffy function where L_∞ = 848.95 mm, k = 0.212 and t_0 = -0.708.

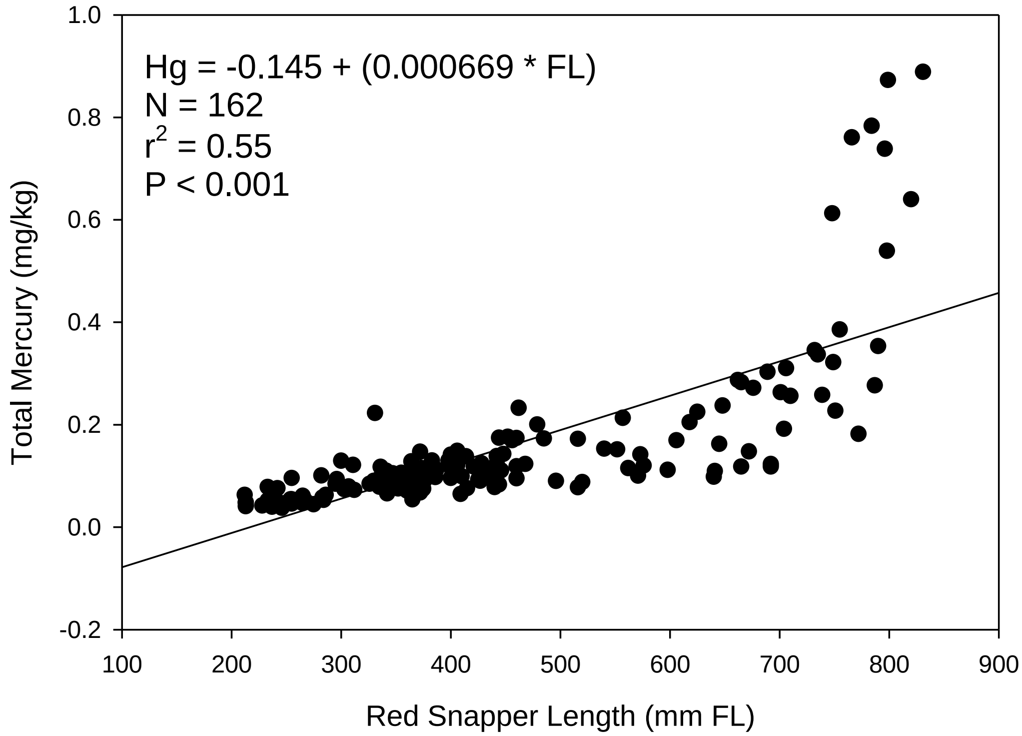

Figure 14. Total mercury concentrations (mg/kg) in Red Snapper (n=176) collected during FWC RTD hooked-gear surveys along the Atlantic coast of Florida (2018) by length (mm FL).

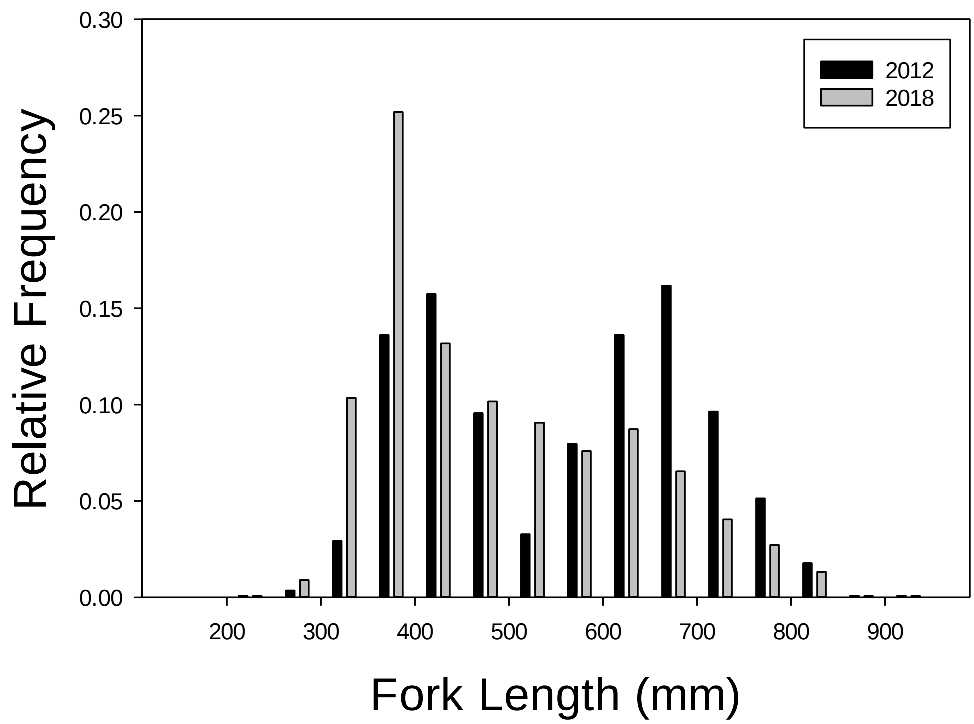

Figure 15. Length frequency (mm FL) of Red Snapper collected during FWC RTD hooked-gear surveys along the Atlantic coast of Florida in 2012 (black bars) and 2018 (gray bars).

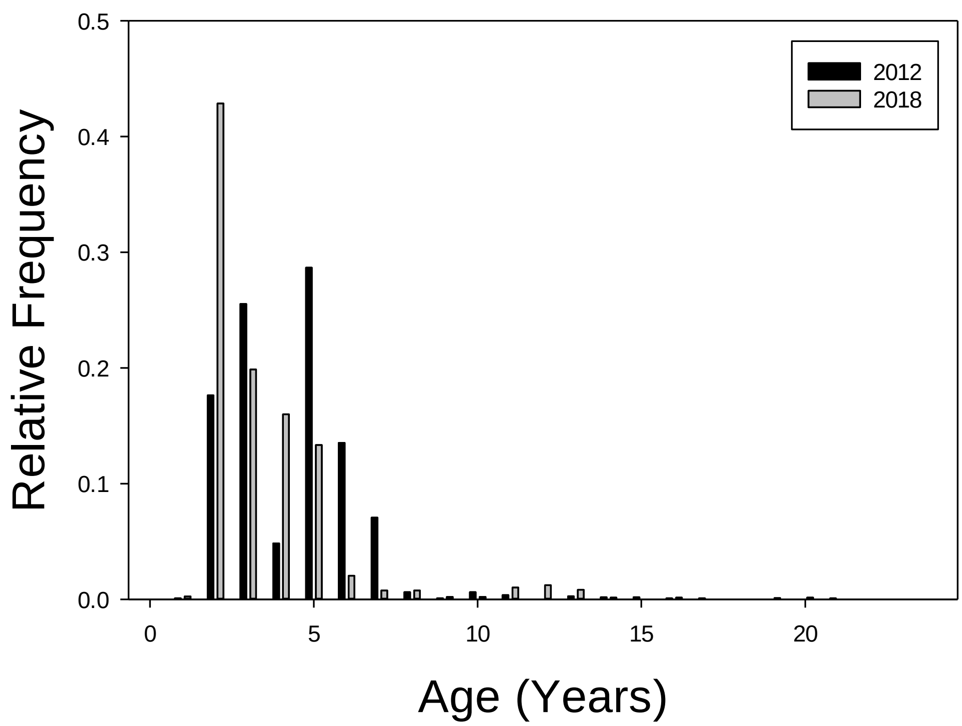

Figure 16. Age frequency (Years) of Red Snapper collected during FWC RTD hooked-gear surveys along the Atlantic coast of Florida in 2012 (black bars) and 2018 (gray bars).

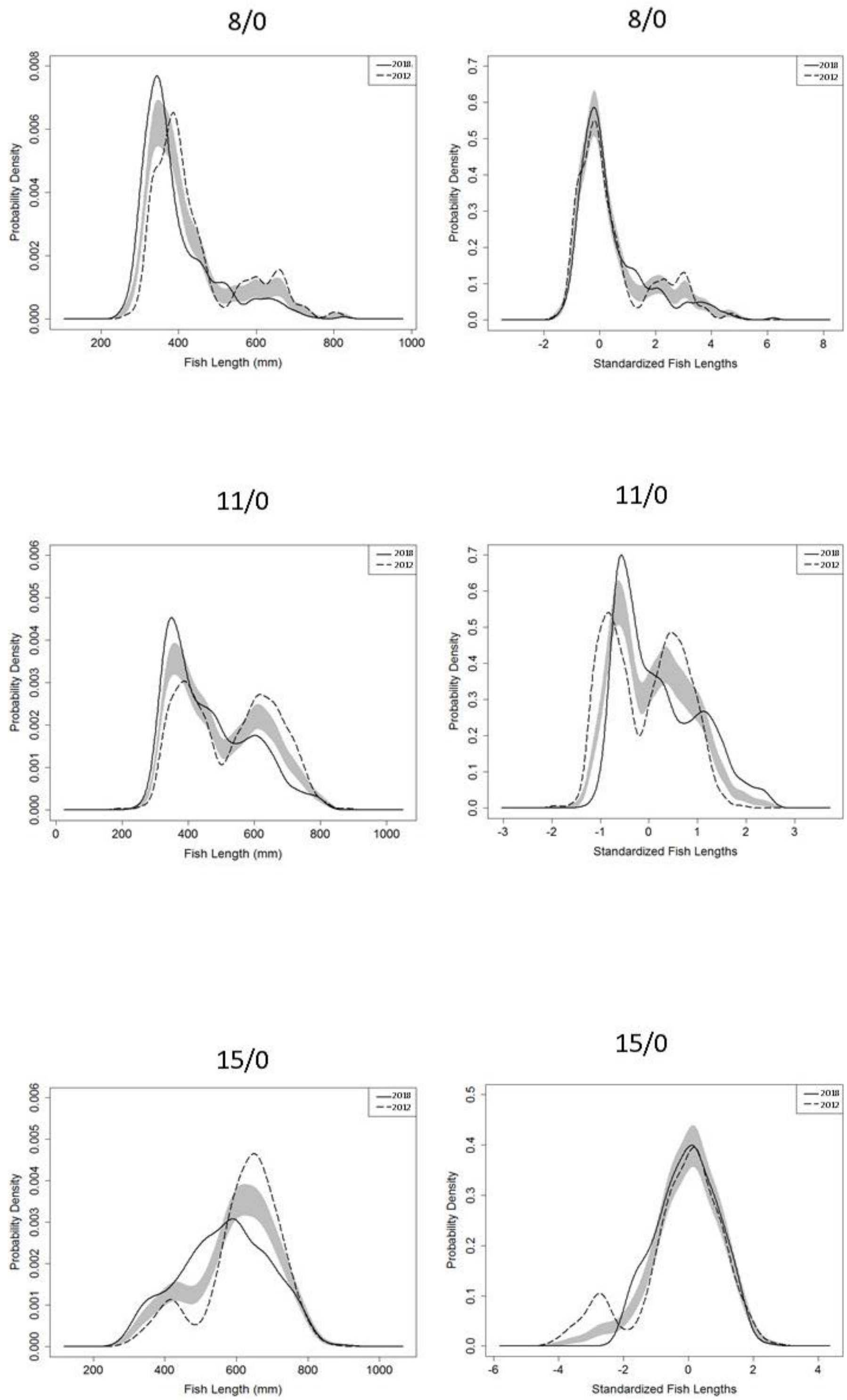

Figure 17. Kernel density estimates of length frequency distributions of Red Snapper collected during FWC RTD hooked-gear surveys along the Atlantic coast of Florida in 2012 (dashed line) and 2018 (solid line) between years by hook size. Left column is test for differences in shape and location. Standardized data in right column tests for differences in shape only.

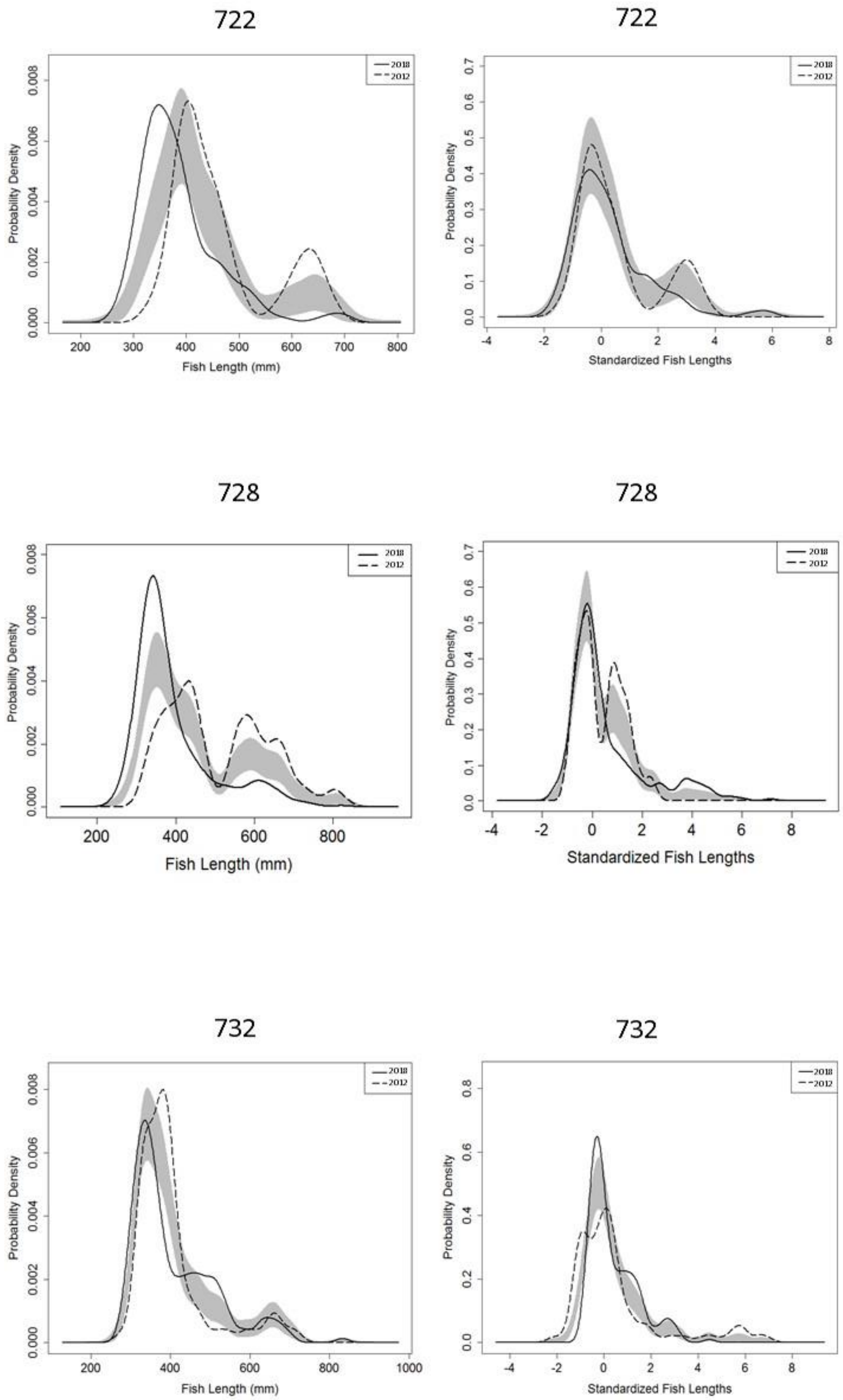

Figure 18. Kernel density estimates of length frequency distributions of Red Snapper collected during FWC RTD hooked-gear surveys along the Atlantic coast of Florida in 2012 (dashed line) and 2018 (solid line) between years by NMFS statistical zone. Left column is test for differences in shape and location. Standardized data in right column tests for differences in shape only.

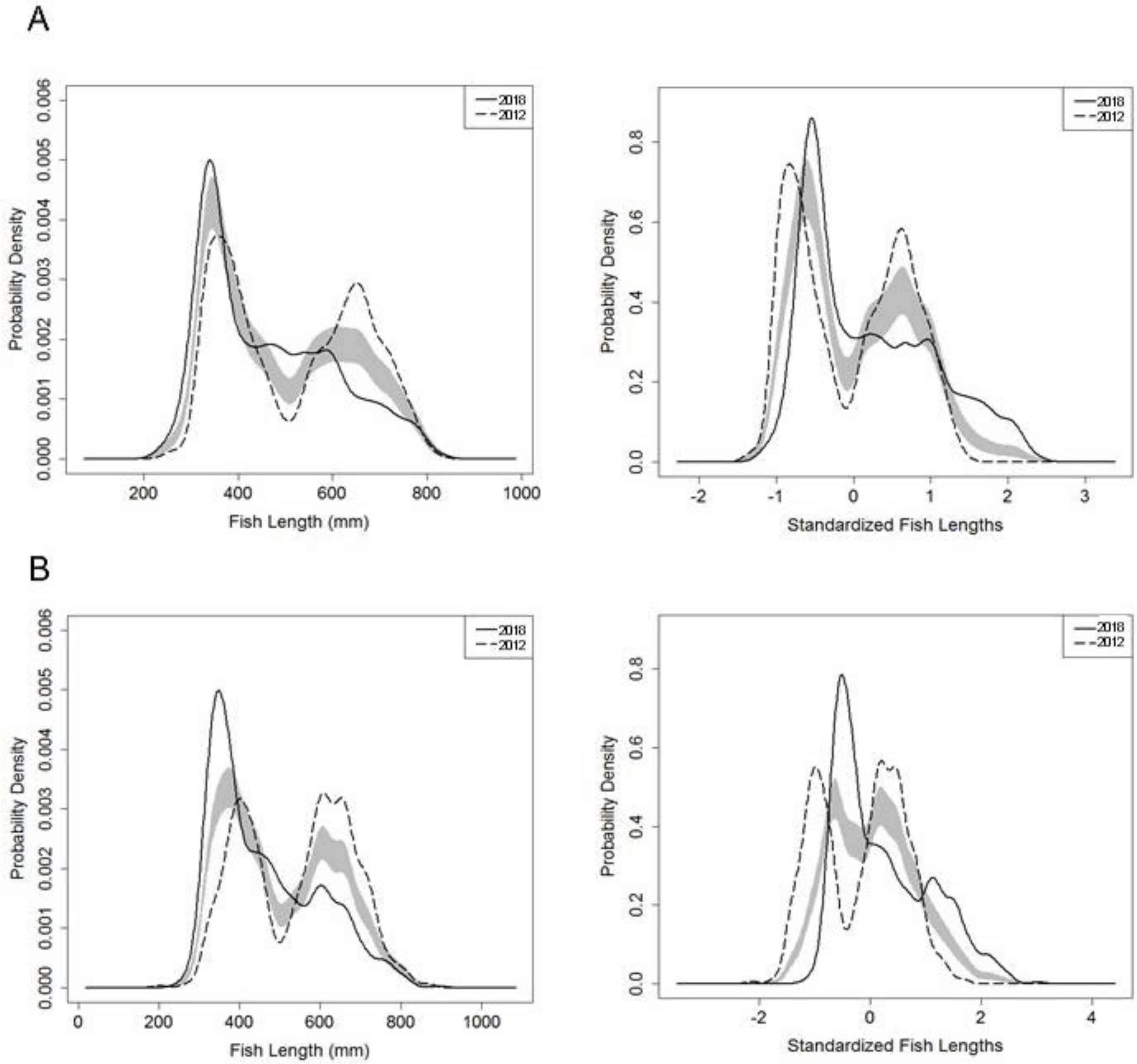

Figure 19. Kernel density estimates of length frequency distributions of Red Snapper collected during FWC RTD hooked-gear surveys along the Atlantic coast of Florida in 2012 (dashed line) and 2018 (solid line) by depth strata: A) nearshore (< 30 m), B) offshore (30 – 150 m). Left column is test for differences in shape and location. Standardized data in right column tests for differences in shape only.

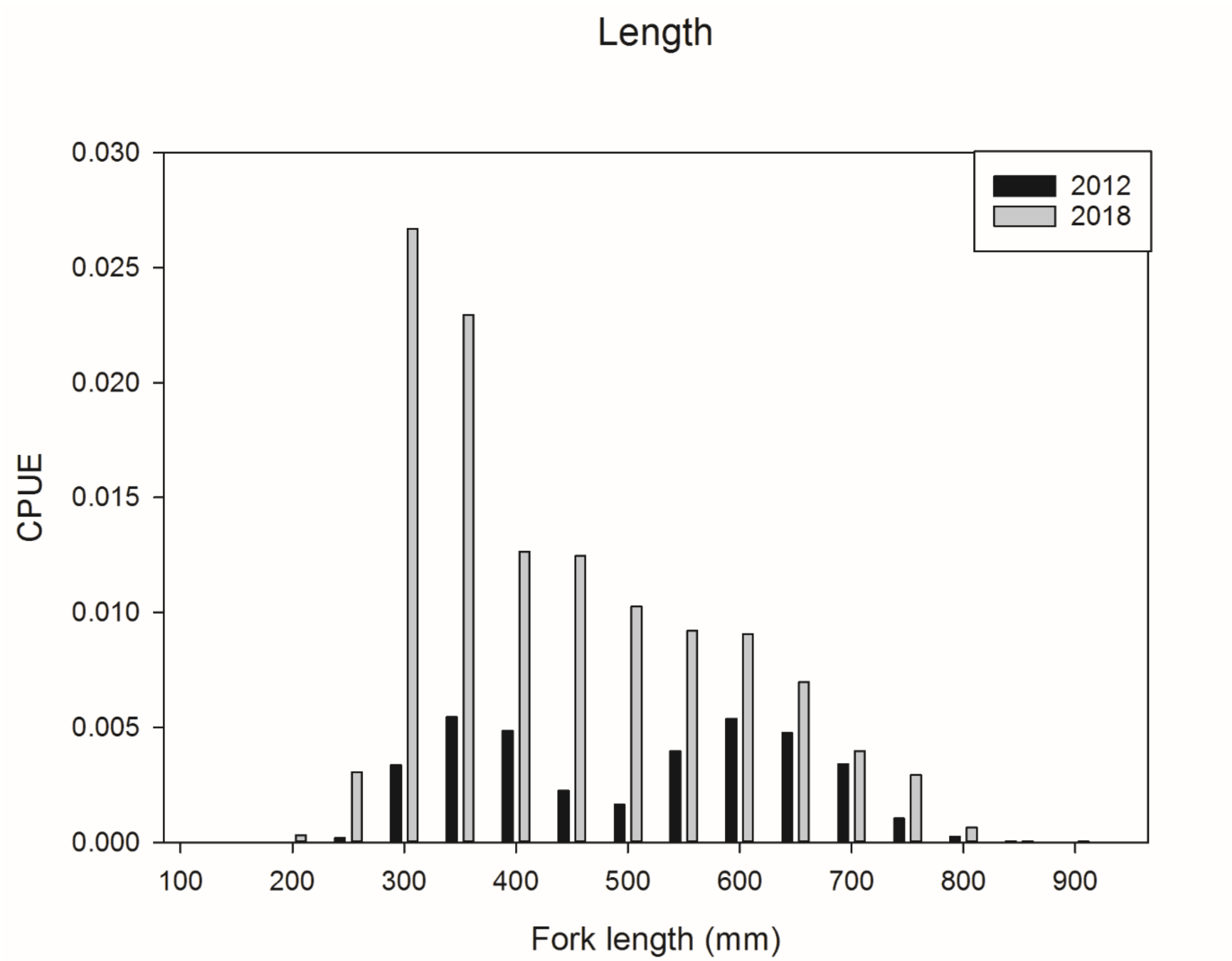

Figure 20. Catch-per-unit-effort (CPUE) for Red Snapper collected during FWC RTD hooked-gear surveys along the Atlantic coast of Florida in 2012 (black bars) and 2018 (gray bars). CPUE was calculated as the number of Red Snapper collected for each 50-mm size class per total number of hooks dropped per survey year (all hook sizes, NMFS statistical zones, and depth strata combined).

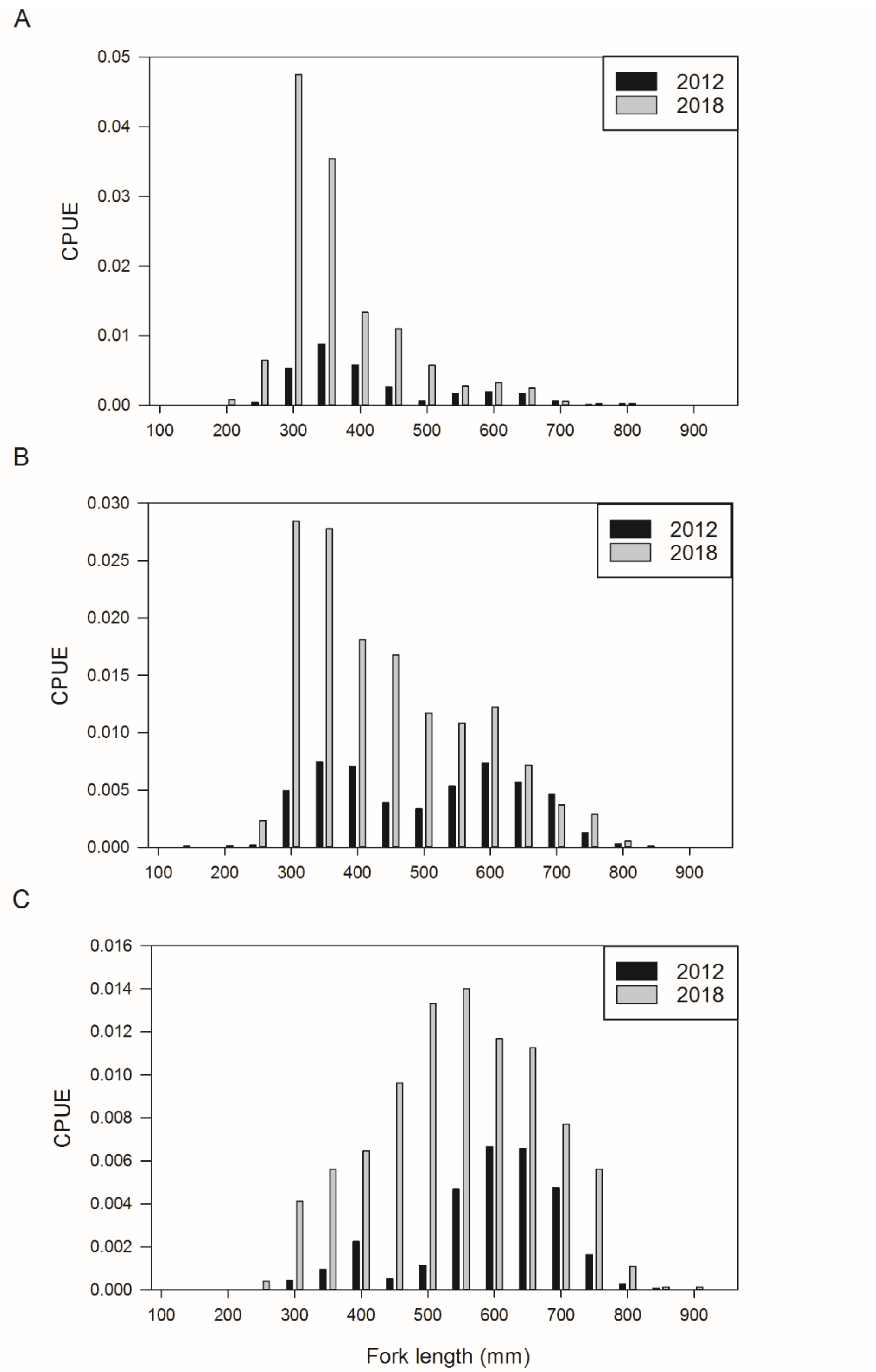

Figure 21. Catch-per-unit-effort (CPUE) for Red Snapper collected during FWC RTD hooked-gear surveys along the Atlantic coast of Florida in 2012 (black bars) and 2018 (gray bars). CPUE was calculated as the number of Red Snapper collected for each 50-mm size class per total number of hooks dropped per survey year by hook size: A) 8/0, B) 11/0, C) 15/0.

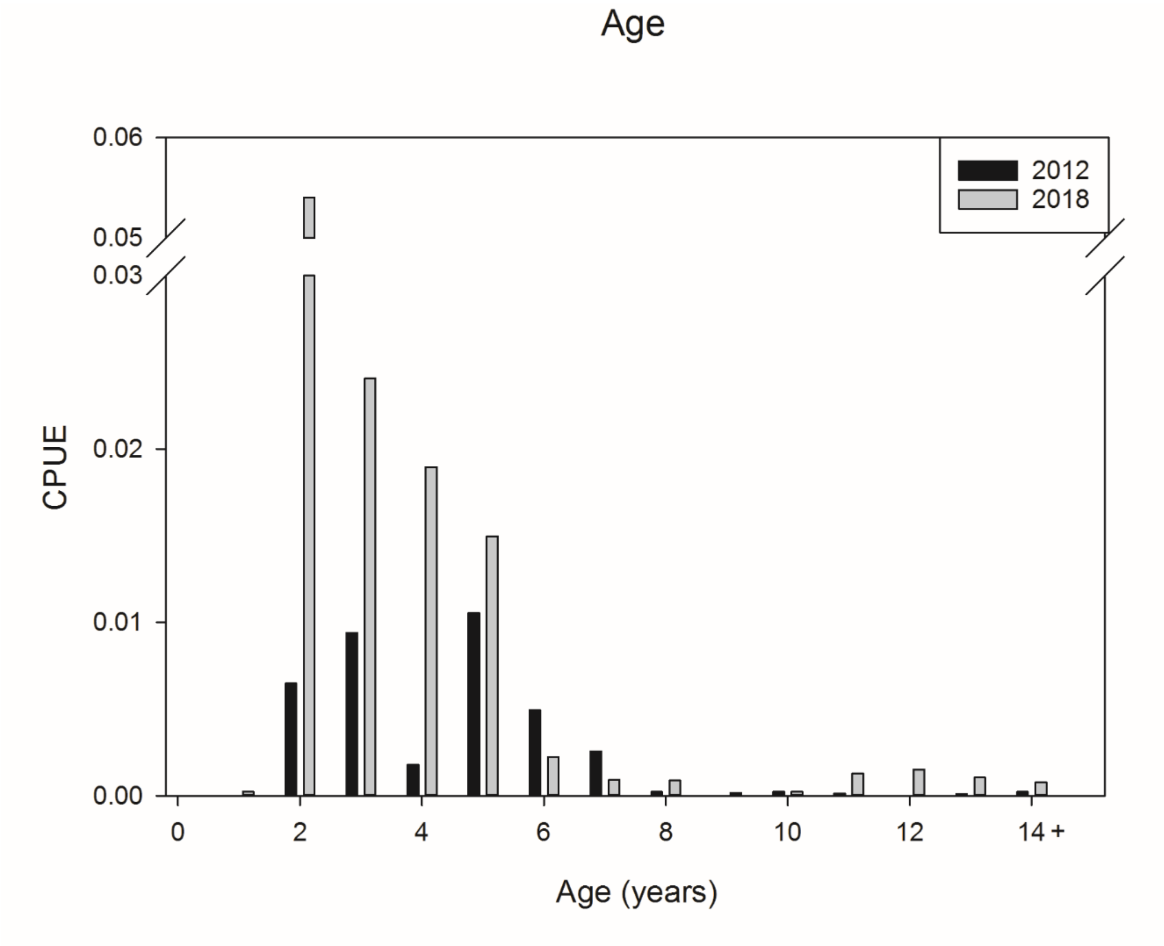

Figure 22. Catch-per-unit-effort (CPUE) for Red Snapper collected during FWC RTD hooked-gear surveys along the Atlantic coast of Florida in 2012 (black bars) and 2018 (gray bars). CPUE was calculated as the number of Red Snapper collected for each age class per total number of hooks dropped per survey year (all hook sizes, NMFS statistical zones, and depth strata combined). Unaged Red Snapper from each survey year (2012, n=32; 2018, n=688) were assigned ages for this comparison based on an age-length key developed from all individuals aged during the given survey year.

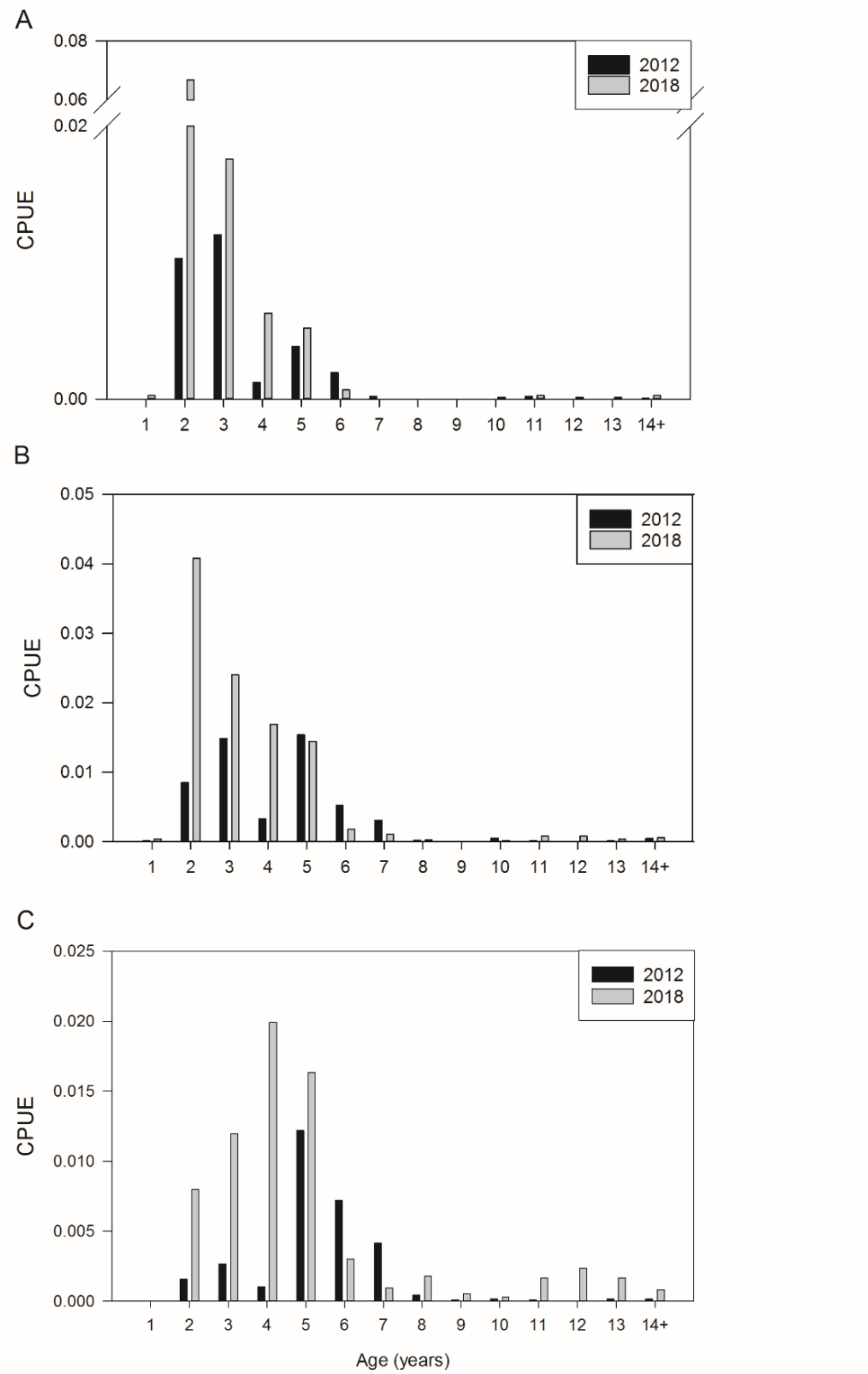

Figure 23. Catch-per-unit-effort (CPUE) for Red Snapper collected during FWC RTD hooked-gear surveys along the Atlantic coast of Florida in 2012 (black bars) and 2018 (gray bars). CPUE was calculated as the number of Red Snapper collected for each age class per total number of hooks dropped per survey year by hook size: A) 8/0, B) 11/0, C) 15/0. Unaged Red Snapper from each survey year (2012, n=32; 2018, n=688) were assigned ages for this comparison based on an age-length key developed from all individuals aged during the given survey year.

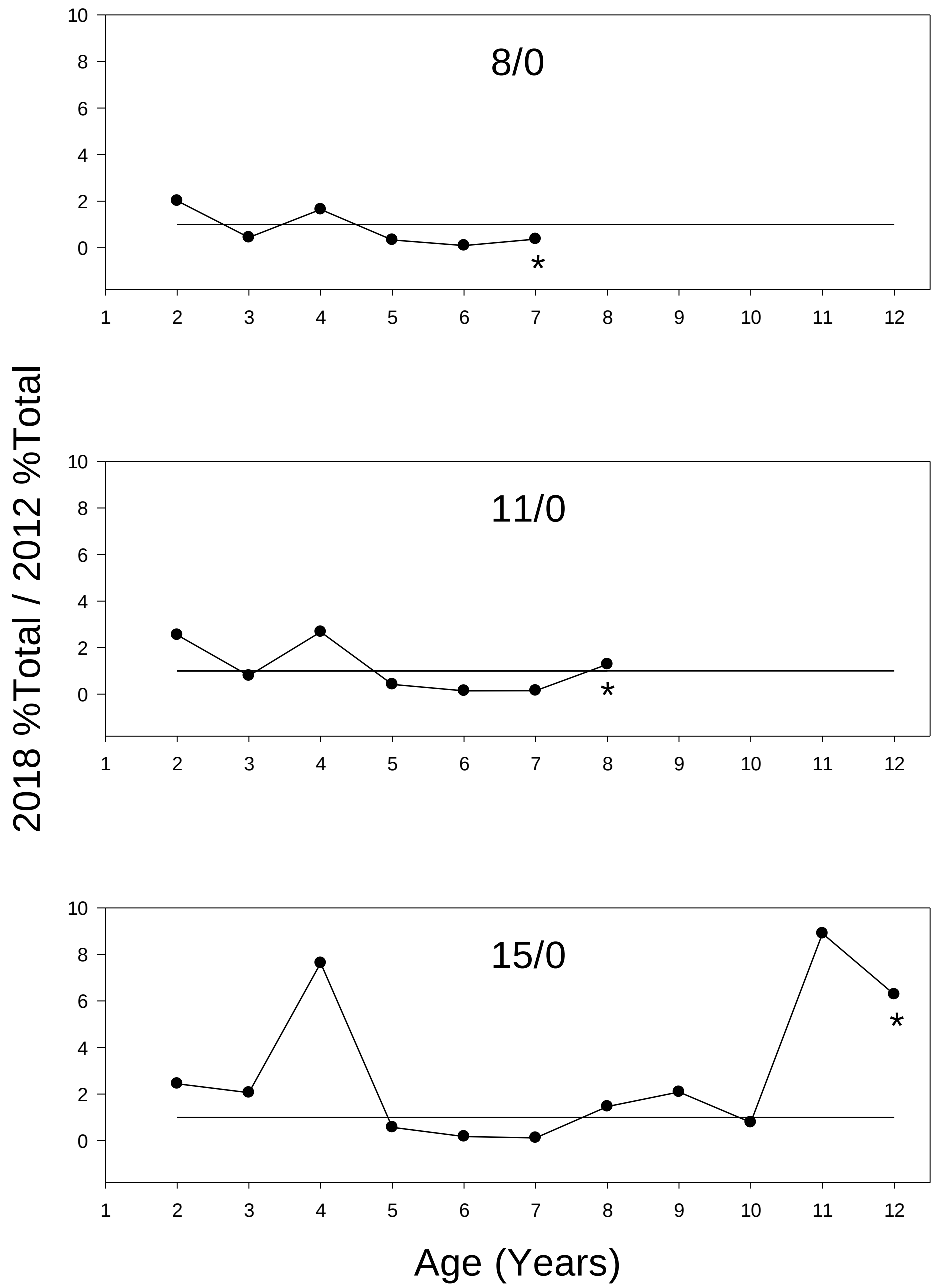

Figure 24. Index of the percent total (% Total) of Red Snapper collected during FWC RTD hooked-gear surveys along the Atlantic coast of Florida in 2018 to the percent total of Red Snapper collected in 2012 surveys by age class for each hook size – 8/0 (Top), 11/0 (Middle), and 15/0 (Bottom). The horizontal line represents a hypothetical 1:1 relationship where equal proportions of each age class were collected between the 2012 and 2018 surveys (i.e. no difference). Values above the line indicate a greater proportion of that age class was captured in 2018, while values below the line indicate a greater proportion of that age class was captured in 2012. ★ Upper age classes for each hook size (7+ for 8/0, 8+ for 11/0, and 12+ for 15/0) were pooled due to low sample sizes in older age classes.

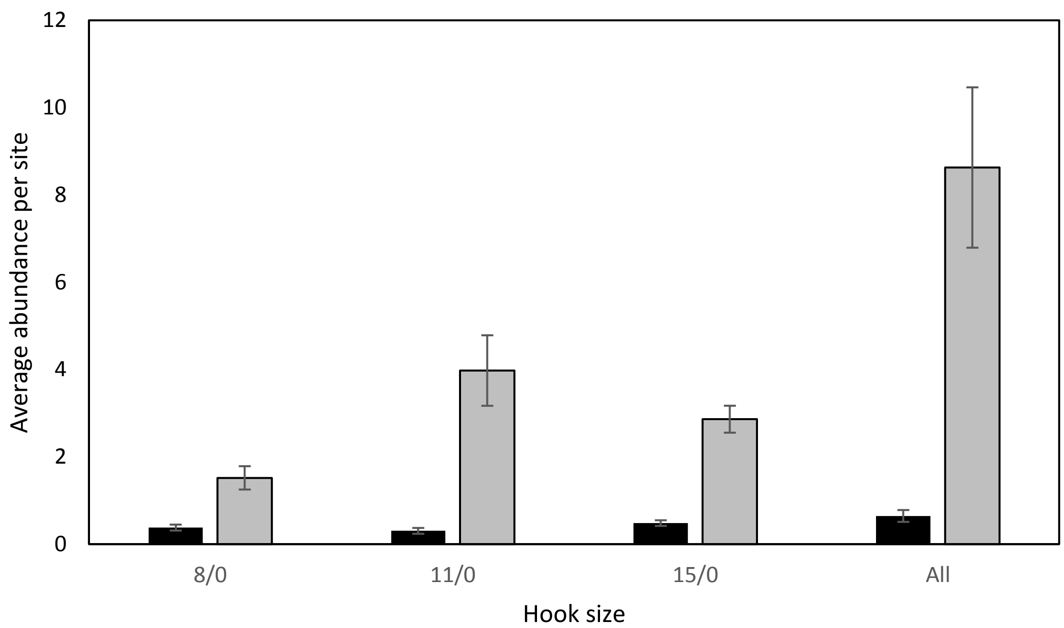

Figure 25. Index of Abundance (± SE) for Red Snapper collected during FWC RTD hooked-gear surveys along the Atlantic coast of Florida in 2012 (black bars) and 2018 (gray bars) by hook size (8/0, 11/0, and 15/0) and all hooks combined (All).

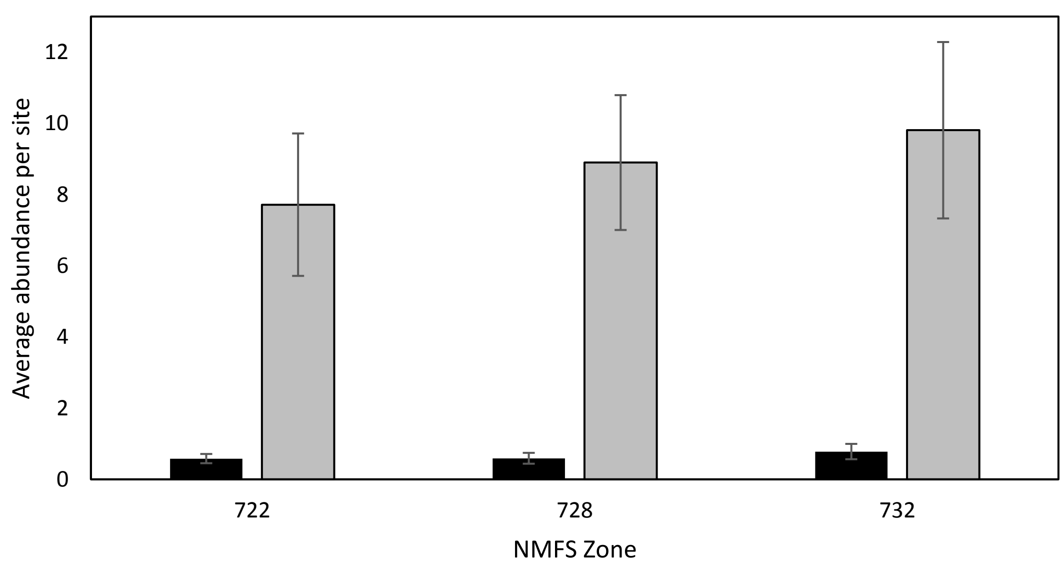

Figure 26. Index of Abundance (± SE) for Red Snapper collected during FWC RTD hooked-gear surveys along the Atlantic coast of Florida in 2012 (black bars) and 2018 (gray bars) by NMFS statistical zone (722, 728, and 732).

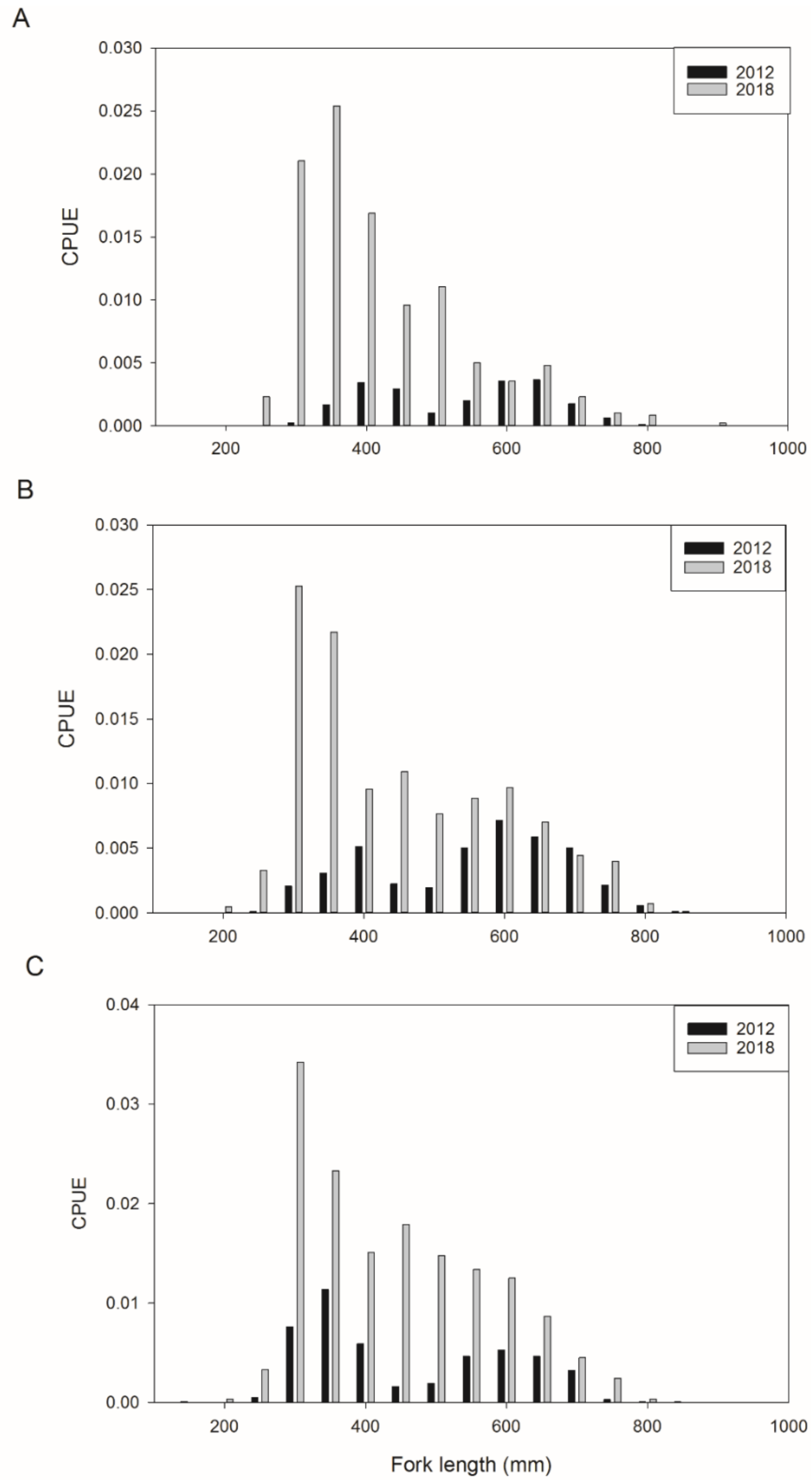

Figure 27. Catch-per-unit-effort (CPUE) for Red Snapper collected during FWC RTD hooked-gear surveys along the Atlantic coast of Florida in 2012 (black bars) and 2018 (gray bars). CPUE was calculated as the number of Red Snapper collected for each 50-mm size class per total number of hooks dropped per survey year by NMFS statistical zone: A) 722, B) 728, C) 732.

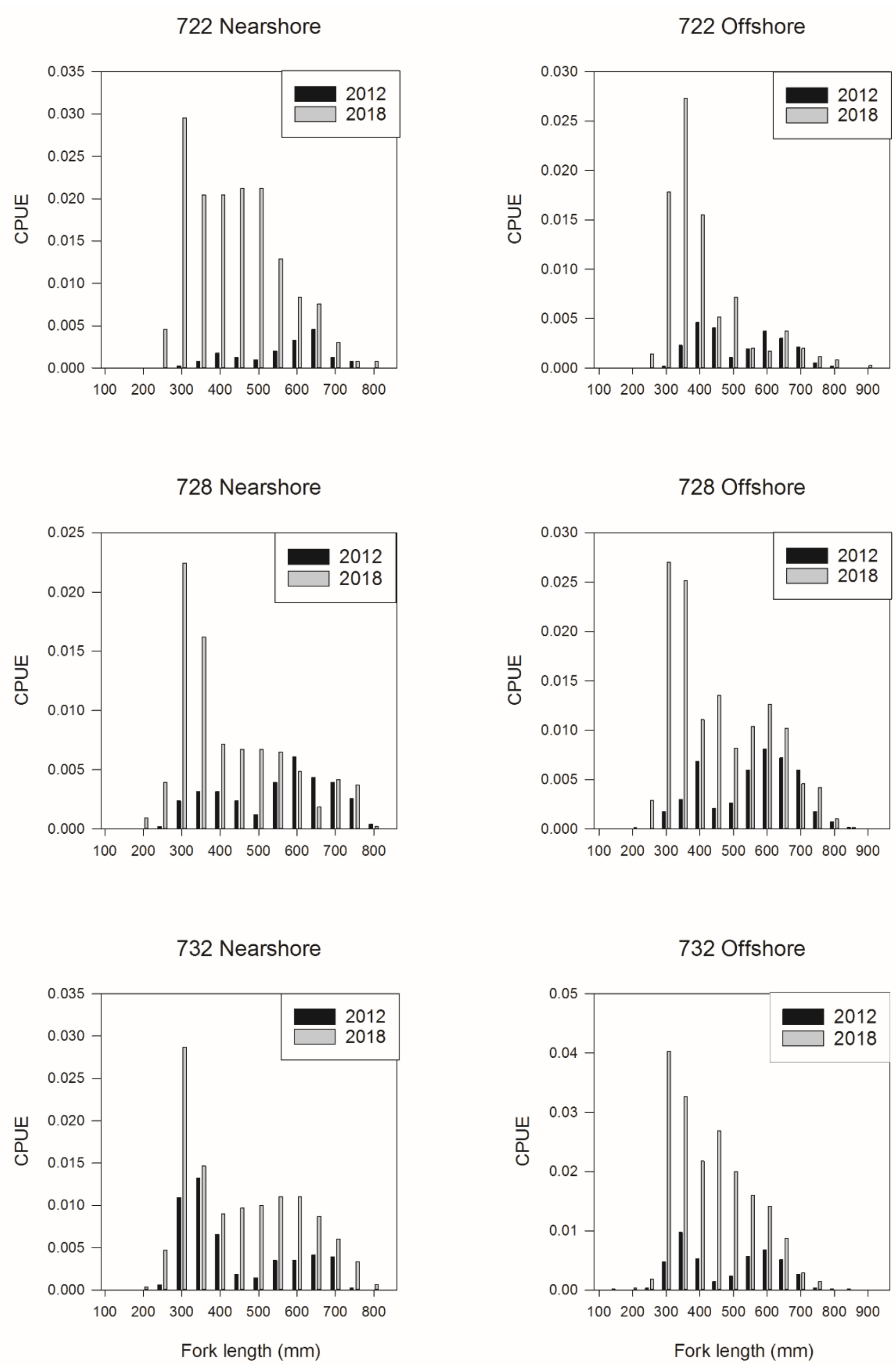

Figure 28. Catch-per-unit-effort (CPUE) for Red Snapper collected during FWC RTD hooked-gear surveys along the Atlantic coast of Florida in 2012 (black bars) and 2018 (gray bars). CPUE was calculated as the number of Red Snapper collected for each 50-mm size class per total number of hooks dropped per survey year by NMFS statistical zone (722, 728, and 732) and depth strata (nearshore [< 30 m] and offshore [30 – 150 m]).

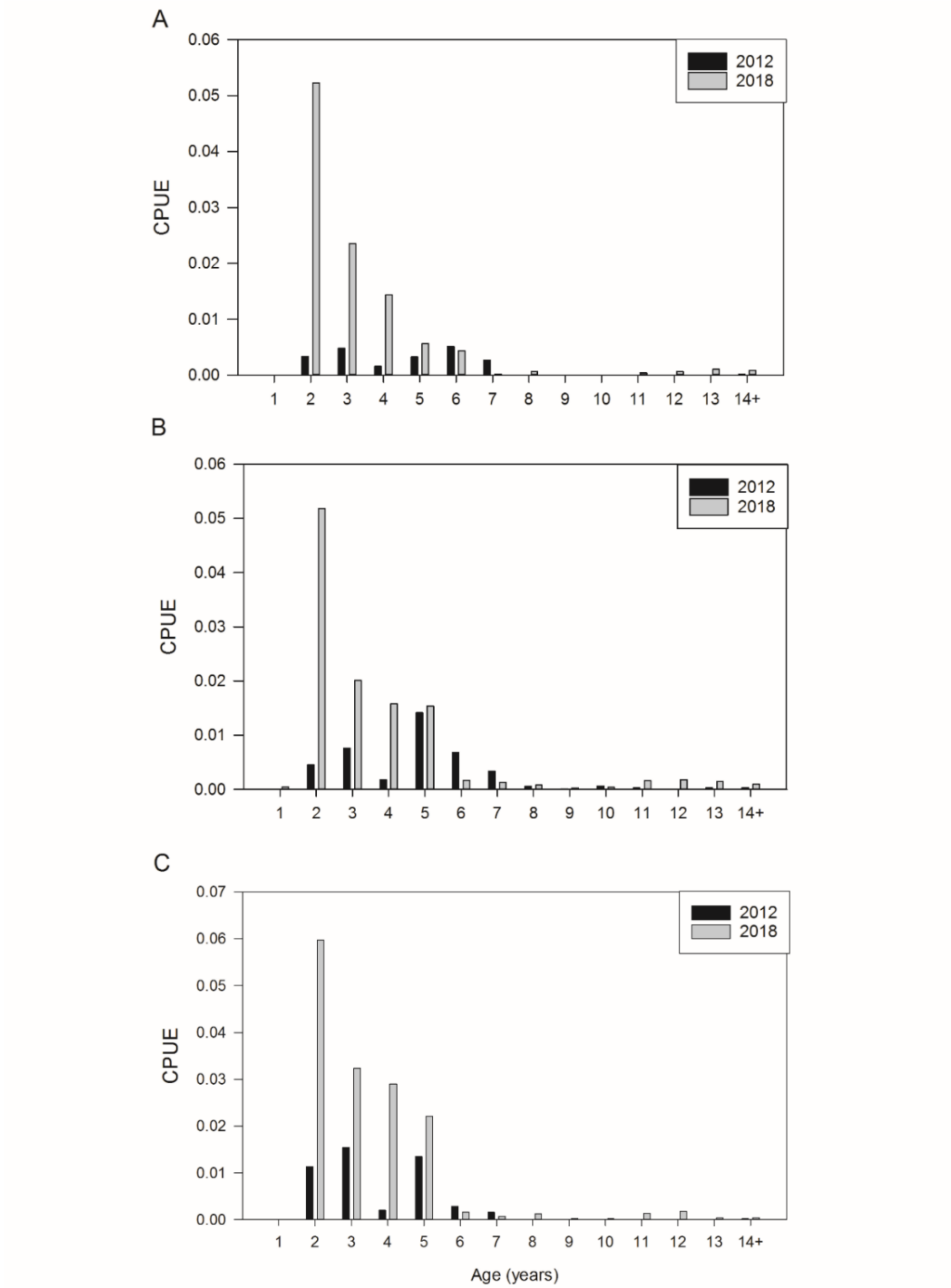

Figure 29. Catch-per-unit-effort (CPUE) for Red Snapper collected during FWC RTD hooked-gear surveys along the Atlantic coast of Florida in 2012 (black bars) and 2018 (gray bars). CPUE was calculated as the number of Red Snapper collected for each age class per total number of hooks dropped per survey year by NMFS statistical zone: A) 722, B) 728, C) 732. Unaged Red Snapper from each survey year (2012, n=32; 2018, n=688) were assigned ages for this comparison based on an age-length key developed from all individuals aged during the given survey year.

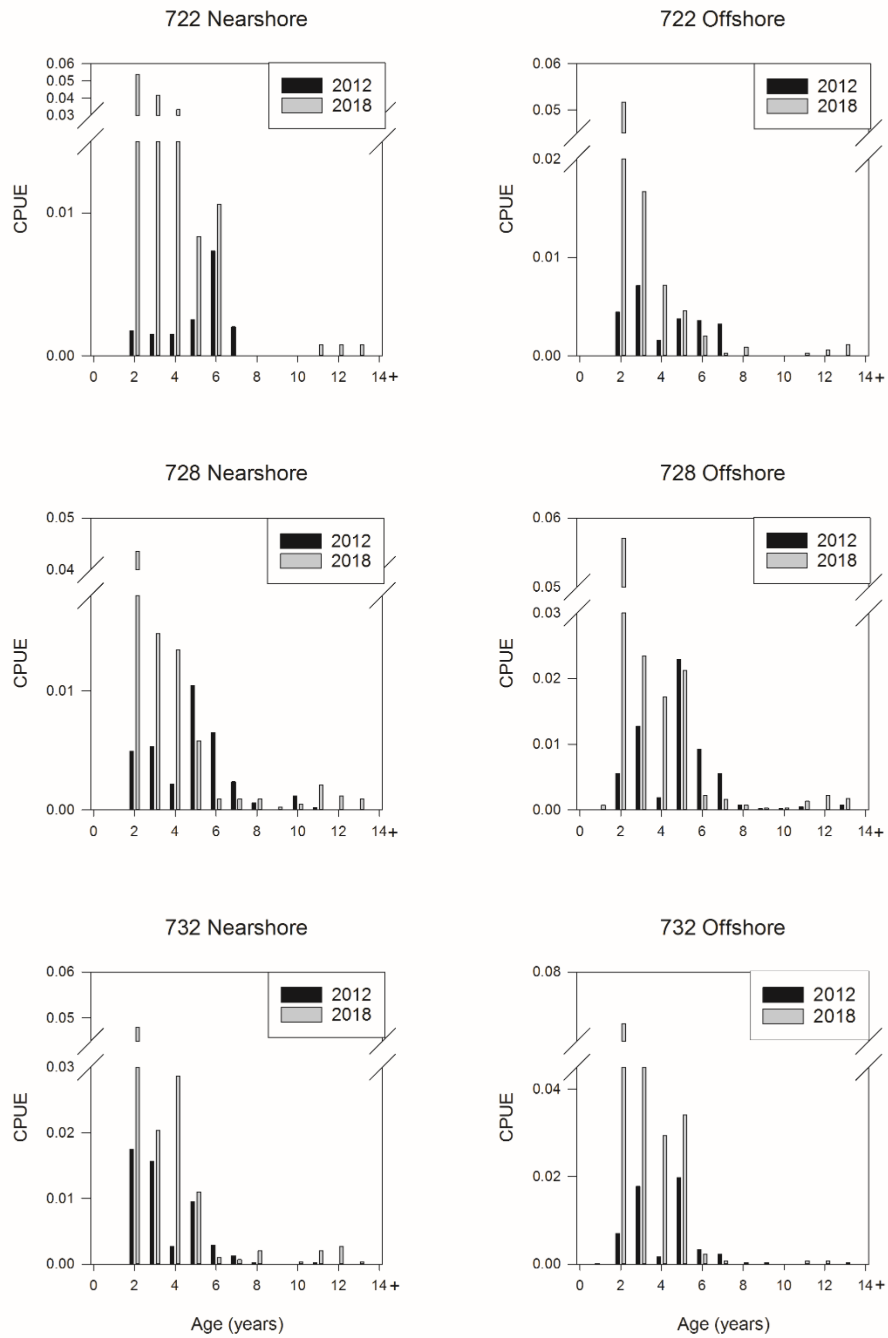

Figure 30. Catch-per-unit-effort (CPUE) for Red Snapper collected during FWC RTD hooked-gear surveys along the Atlantic coast of Florida in 2012 (black bars) and 2018 (gray bars). CPUE was calculated as the number of Red Snapper collected for each age class per total number of hooks dropped per survey year by NMFS statistical zone (722, 728, and 732) and depth strata (nearshore [< 30 m] and offshore [30 – 150 m]). Unaged Red Snapper from each survey year (2012, n=32; 2018, n=688) were assigned ages for this comparison based on an age-length key developed from all individuals aged during the given survey year.