A directed study of the recreational red snapper fisheries in the Gulf of Mexico along the West Florida shelf

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Final Report
Covering the period: September 2009 to December 2013
To
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A Directed Study of the Recreational Red Snapper Fisheries in the Gulf of Mexico Along the West Florida Shelf
NA09NMF4720265

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Section 1: Introduction

1.1 Background

The Gulf of Mexico supports large and dispersed recreational fisheries for reef fishes. Recreational fishing accounts for more than half of the estimated total poundage of red snapper and gag grouper harvested from the region (SEDAR 2012, 2013; Coleman et al., 2004). In addition, for every red snapper, gag, and red grouper harvested by recreational anglers during 2012 (the last year that final estimates are available for) another 2.4, 7.5, and 6.0 fish, respectively, were estimated to be caught and released alive (personal communication, National Marine Fisheries Service, Fisheries Statistics Division, 3/23/14). The largest portion of recreational harvest for reef fishes takes place on the west Florida shelf, and it is estimated that recreational anglers fishing from private boats made 2.1 million angler trips in state territorial seas and more than 755,000 angler trips in federal waters from the west coast of Florida during 2012 (personal communication, National Marine Fisheries Service, Fisheries Statistics Division, 3/23/14). More than 1 million private recreational anglers are licensed annually to fish for marine and estuarine finfish in the state of Florida; though it is unknown how many licensed anglers participate in the reef fish fisheries on the west Florida shelf. Several hundred for-hire vessels that operate in western Florida, including charter boats and large party headboats, hold federal permits to target managed reef fish species. An undetermined number of for-hire vessels also fish for reef fishes in state territorial seas where no federal permit is required. For-hire vessels account for less than 5% of estimated recreational fishing effort in the Gulf of Mexico; however, due to the much higher catch rates from for-hire trips, this segment of the fishery contributes significantly to the total recreational harvest for reef fish species (Figueira et al., 2010). Approximately 38% of red snapper landed by recreational anglers in the eastern Gulf of Mexico in 2011 were from for-hire trips (SEDAR 2012).

In response to stock declines in the Gulf of Mexico, fisheries managers have taken regulatory steps to reduce harvest of reef fishes. For the recreational sector, size limits have been increased, bag limits have been reduced, and the length of recreational fishing seasons have been adjusted in an effort to keep harvest levels within management targets. This has translated into a growing portion of fish released by recreational anglers that are unavailable for direct observation during fishery dependent surveys. Numbers of discarded fish are more difficult to quantify with precision than harvested catch, due largely to the fact that dockside intercept methods rely on angler recall sometime after the trip has occurred. Compounding the uncertainty, the proportion of discarded fish that suffer latent mortality is largely unknown, and stock assessments have relied on studies that have limited applicability to fisheries as a whole to estimate total removals attributed to fishing mortality.

In recent years, fisheries management has shifted focus to minimizing waste due to discards. Circle hooks are widely viewed as beneficial for reducing mortality attributed to internal hook injuries for a variety of species (Cooke and Suski, 2004). Relatively few studies had been conducted on the effectiveness of circle hooks specifically for reef fishes prior to 2008, when the gear was required for recreational anglers fishing for or catching regulated reef fishes (including snappers, groupers, triggerfishes and amberjacks) with natural bait in the Gulf of Mexico. When fishing in state territorial seas off the west coast of Florida, circle hooks must also be non-offset (0 degrees offset). However, circle hooks are not required when using jigs or artificial lures without natural bait or when reef fishes are not vulnerable to the gear, such as surface trolling for mackerels, tunas and other pelagic species. A second regulation intended to minimize discard mortality also implemented in 2008 was the requirement to possess and use a venting tool when releasing reef fishes in the Gulf of Mexico. However, this requirement has been met with more controversy, largely due to the inflexibility of the regulation to allow alternative methods for release that may also increase survival. The venting requirement was repealed in 2013. There has been a desire by fishery participants to receive credit for the conservation benefits of circle hook and venting requirements in harvest quotas, which take into account removals attributed to discard mortalities. However, stock assessment analysts have struggled to account for changes in total removals due to a lack of research that quantifies the conservation benefits within the context of the diverse and large-scale recreational fisheries that interact with reef fish stocks, or adequate data that document their historic or current usage within these fisheries.

1.2 Objectives and Approach

This study addressed the need for new methods to collect catch data from recreational fisheries that address the fundamental shift from harvest to largely catch-and-release fishing. A directed survey approach was necessary to collect higher resolution data to monitor recreational fisheries. For fisheries managers to better evaluate the impacts of fishing regulations, detailed information on directed effort and angler response to regulatory measures was needed. The approach was to develop new survey methods to better characterize recreational fisheries for important managed species, particularly for discards, develop methods to better quantify total removals, and actively engage fishery participants in the collection of this data.

The objectives of this study were to:

1. Provide direct measures of both harvested and discarded red snapper and associated reef fishes in the for-hire sector of the recreational fishery operating from the west coast of Florida, and collect high resolution data for the most important recreational target species, including size and age composition, detailed information on area fished and release condition, and *in situ* (within fishery) measures for relative survival of discarded fish.

2. Develop a predictive model for survival to apply to fisheries-dependent estimates of numbers of discards.

3. Develop cost-effective methods that integrate conventional fisheries-dependent estimates of recreational discards (from private and for-hire segments) with direct measurements taken during for-hire trips.

4. Integrate fisheries-dependent and fisheries-independent monitoring for reef fish and provide information that will allow for analysis of relationships between stock size, fisheries removals, and fishing behavior.

Section 2 of this report provides detailed methods and results that address Objectives 1 and 2. Results presented in this section include:

- a detailed characterization of the charter and headboat fishery that operates within the study region,
- an evaluation of the conservation benefits resulting from requirements to use circle hooks when catching reef fishes in the Gulf of Mexico and to vent reef fishes prior to release,
- a detailed characterization of the condition of discarded reef fishes measured directly within the hook-and-line recreational fishery,
- an evaluation of the relationship between capture depth and latent mortality of discards, and
- overall estimates of discard mortality that may be applied proportionally to other hook-and-line fisheries based on the amount of effort at various fishing depths.

Section 3 is focused on the larger segment of the recreational hook-and-line fishery that targets red snapper from private recreational boats, and is more difficult to survey and monitor. This section addresses Objective 3 by demonstrating how detailed information utilizing fishery observers in the for-hire fishery may be combined with supplemental information collected from the larger private boat recreational fishery to better inform managers and analysts about both segments.

Objective 4 was addressed by working collaboratively with FWC's Fisheries Independent Monitoring Group, who also work directly with NMFS Southeast Fisheries Science Center to develop fishery independent data collection programs that are standardized throughout the Gulf. During the initial design and implementation of methods described in Section 2, we developed field procedures for collecting detailed trip level, station level, fishing rig level, and individual fish level information with a complementary database structure so that future analyses may combine data from both sources. Complementary tag-recapture data from both data sources may also be used in future stock assessments, for example, to evaluate size and age selectivity for reef fishes caught within the recreational fishery (Bachelor et al, 2010; Myers and Hoenig, 1997).

1.3 Products

Data collected as a result of this work was shared at data workshops for red snapper, greater amberjack, gag, and king mackerel as part of the Southeast Data Assessment and Review (SEDAR). Working papers generated for SEDAR data workshops are publically available on the SEDAR website http://www.sefsc.noaa.gov/sedar/, and papers generated as a direct result of data collected during this study include:

SEDAR31-DW09 Index of Abundance for Pre-Fishery Recruit Red Snapper from Florida Headboat Observer Data

SEDAR31-DW11 A Summary of Data on the Size Distribution and Release Condition of Red Snapper Discards from Recreational Fishery Surveys in the Gulf of Mexico

SEDAR31-DW23 Release Mortality Estimates for Recreational Hook-and-Line Caught Red Snapper Derived from a Large-Scale Tag-Recapture Study in the Eastern Gulf of Mexico

SEDAR33-DW04 Characterization of Greater Amberjack Discards in Recreational For-Hire Fisheries

SEDAR33-DW05 Characterization of Gag Discards in Recreational For-Hire Fisheries

SEDAR33-DW06 Relative Survival of Gags Released Within a Recreational Hook-and-Line Fishery: Application of the Cox Regression Model to Control for Heterogeneity in a Large-Scale Mark-Recapture Study

Custom data sets for gag and greater amberjack, including length measurements, depth of capture and area fished for discards were provided to assessment analysts from the Southeast Fisheries Science Center upon request following the data workshop for SEDAR 33 held in 2013. Discard mortality estimates for gag provided in SEDAR33-DW06 were recommended by data workshop participants during SEDAR 33 for use in the assessment, and discard mortality estimates for red snapper were included in a metadata analysis for SEDAR 31 held in 2012 (Campbell et al., 2012). Hook location data for king mackerel were also shared at the data workshop for SEDAR 38 and summarized in the final data workshop report, and this information was subsequently used in decision making for discard mortality estimates during the data workshop. Data and results from this project will continue to be shared in upcoming stock assessments for relevant species scheduled in 2014, including SEDAR 40 (Gulf of Mexico red grouper), SEDAR 41 (South Atlantic red snapper and red porgy), and updates for Gulf of Mexico red snapper, Gulf of Mexico black grouper, and South Atlantic gag.

Two peer-reviewed publications to date resulted from this project and are provided in Appendices A and B. The first publication was presented at the International Symposium on Circle Hooks in Research, Management and Conservation held May, 2011, in Coral Gables, Florida, and was included in the official proceedings following peer-review (Appendix A; Sauls and Ayala, 2012). Data for gag collected as a result of this project contributed to a Master's Thesis through the University of South Florida, Department of Marine Science, and was made available with open online access (Sauls, 2013), and was also published in one peer-reviewed journal (Appendix B; Sauls, 2014). Results for red snapper and red grouper will be prepared for peer-review and potential publication during 2014, and an abstract has been submitted to present these results at a special symposium planned for the 2014 meeting of the American Fisheries Society in Quebec, Canada titled, "Out of Sight, Not Out of Mind: Estimating and Reducing Release Mortality in Commercial and Recreational Fisheries".

Information about this project and the final data sets has been provided to the Metadata Coordinator for the Fish and Wildlife Research Institute. The Coordinator will document the research conducted and formally archive a list of available data with detailed descriptions of data attributes in a final metadata report. The metadata report along with this final report will be available for discovery from the library housed at the Fish and Wildlife Research Institute in Saint Petersburg, Florida. In the future, we will work with interested data users both internally and externally to provide custom data queries upon request.

Section 2:

Fisheries-Dependent Discard Mortality Study, Including a Characterization of Fishing Effort and the Size, Age, and Condition of Discards in the For-Hire Recreational Fishery

2.1 Methods

2.1.1 Study Design and Field Procedures

From June 2009 through December 2013, fishery observers accompanied passengers on fishing vessels in Florida that offer for-hire recreational fishing trips to target reef fishes in the eastern Gulf of Mexico. For-hire vessels include large capacity vessels, termed headboats, that carry upwards of 100 individual passengers and charter boats that cater to smaller private fishing parties. Work summarized here includes headboat trips that were sampled by fishery observers for 18 months between June 2009 and December 2010 as part of a separate Cooperative Research Program grant (NA09NMF4540140, final report submitted to SERO October 2011). With the additional funding provided by this grant, fishery observer coverage was expanded to include charter boats and coverage for both charter boats and headboats was continued through 2013. Operators of more than 160 vessels voluntarily participated in this study. Vessels were randomly selected year-round each month for observer coverage from each of three regions: A) the northwestern Panhandle, B) nearshore areas adjacent to Tampa Bay, and C) areas approximately 80–100 miles offshore adjacent to Tampa Bay (Figure 2.1). Monthly sample quotas were assigned to two trip types in areas A and B: 1) single day charter trips and 2) single day headboat (large party boat) trips. Monthly sample quotas for a third trip type, multi-day (>24 hour) headboat trips, were assigned in area C. Area D, the Big Bend region, was not routinely sampled due to the small number of boats that target reef fishes offshore and the infrequent nature of trips; however, observers were able to conduct a small number of trips in this region.

Each week, vessels in each region were randomly selected and observers contacted operators of vessels in the order selected to arrange a trip during the selected week. If the first vessel was not operating or was fully booked to vessel capacity, the next selected vessel was contacted until a trip was successfully scheduled. Biologists paid full passenger fare to reserve a space on headboats, and $100 for a space on charter vessels. Before a trip disembarked, cooperating captains and mates announced to the fishing party that FWC biologists were on board the vessel to conduct a scientific study. During at-sea trips, one or two FWC biologists observed all fishing activity during the duration of the trip. For headboats carrying a large number of passengers with high volumes of fish being caught and released, biologists selected a sub-sample of up to 16 anglers fishing from both sides of the vessel to observe. During each trip, FWC biologists recorded the length of the trip, the number of hours spent fishing, and the total number of anglers on board. With assistance from the vessel mates and participating anglers, the biologist inspected fishing rods and collected measurements on the hooks being used during fishing. Hook type was recorded as circle hook (as defined by state and federal regulations), J hook (O'Shaughnessy), or other hook type (Kahle, treble, etc.). To ensure consistency in hook sizing for circle hooks and J hooks, hook size was determined by matching a hook to a printed chart of standard hook sizes (Figure 2.2). Hooks of various brands and sizes were grouped into three standard size categories: small, medium, and large. Whether a hook was offset was also recorded. Biologists had no influence on the gear used by recreational anglers. As paying customers fished with recreational hook-and-line gear, information was recorded for each fish caught, including species, length (midline), and anatomical location where the fish was hooked (lip, mouth, gill, throat, gut, or external).

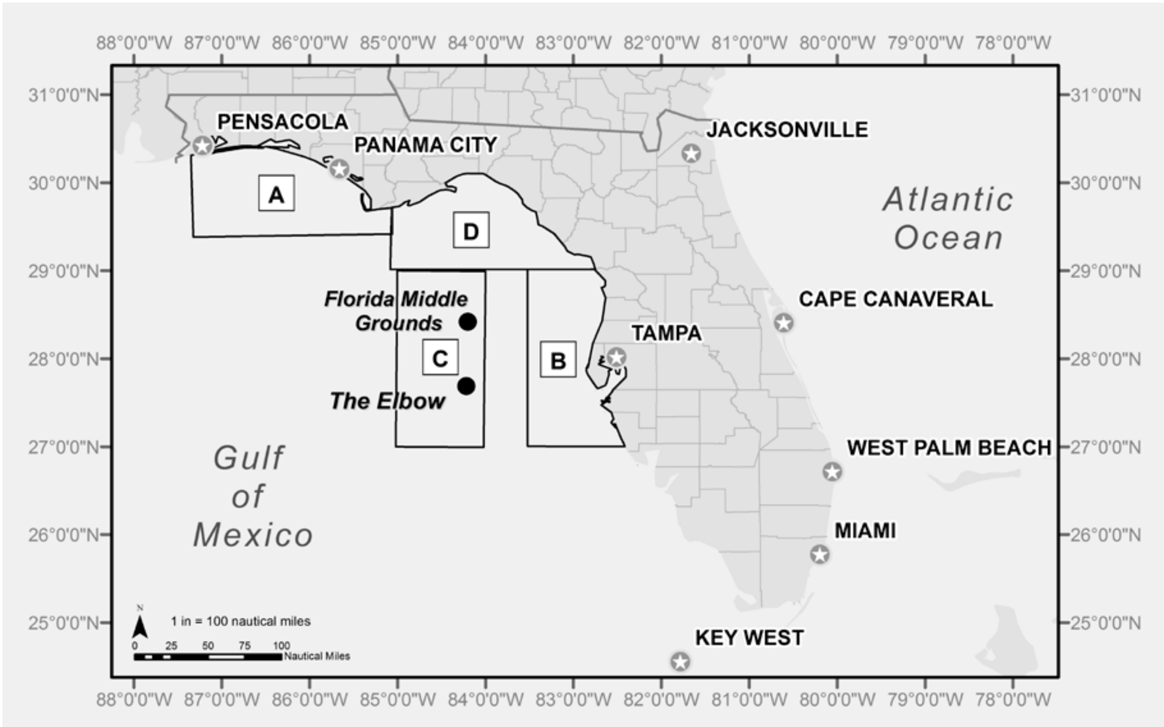

Figure 2.1. Study areas in the Gulf of Mexico. Box A represents the area where half-day and full-day trips originating from the northwest panhandle region (NW) took place, Box B represents the area where half-day and full-day trips originating from the Tampa Bay region (TB) took place, Box C represents the area where multi-day trips originating from the Tampa Bay region (TB) took place. Box D is the Big Bend region (BB) where only a small number of trips took place.

Figure 2.2. Example of a small, medium, and large circle hook on a sizing chart used to record a standardized measurement for the range of circle hooks in the observed fishery. Complete hook sizing chart provided in Appendix C.

Each time a vessel moved to a new fishing location during a sampled trip, the biologist recorded the number of the fishing stop (sequentially, starting with 1 for the first stop) at the top of a catch data sheet. A new catch data sheet was started at each new fishing location. For each fishing location during a sampled trip, the captain of the vessel recorded bottom depth and fishing location data in the order of arrival and provided these data to the biologist at the end of the fishing trip. Fishing location was recorded either as a latitude/longitude coordinate in degrees and minutes, or as a coordinate from a grid chart provided to the captain by the biologist.

The biologist(s) recorded the number of anglers he or she directly observed fishing at each fishing location, and for those observed anglers, the biologist kept track of start times and stop times when anglers were actively fishing and kept a running tally of the number of each fish species harvested and the number of each fish species released. For managed species, the biologist also recorded the species and length (mid-line or fork length in mm) for as many discarded fish as possible. When a species in the Gulf of Mexico reef fish management group was caught, the biologist also recorded the following data elements:

- Hook type
- Bait type (live, cut, whole dead, artificial)
- Hook location (lip, mouth, gill, throat, gut, eye, or external snag)
- Difficulty unhooking (easy, difficult, hook left in)
- Method used by mate for unhooking (hand, pliers, dehooking tool, other)
- Barotrauma symptoms (none, bulging eyes, everted stomach, everted intestines, external hemorrhaging)
- Venting method used by mate (not vented, swim bladder punctured with venting tool, stomach punctured, other)
- Release condition at surface (good, fish swam away immediately; fair, fish disoriented and slowly swam away; poor, fish alive and floating at surface; dead; eaten by predator).

In addition to recording the minimum data elements from fish captured by observed anglers, biologists attempted to tag as many discards as possible for six priority species, including red snapper, red grouper, gag, scamp, vermilion snapper, and gray triggerfish. Recording the minimum data elements and tagging the primary species was given first priority over all other data recording, except for keeping the running tally of all harvested and discarded fish by species. Vessel mates assisted with this study by making sure the biologist was able to collect data from each fish caught by an observed angler prior to releasing it over the side. Biologists provided no input into the mate or angler’s decisions whether to release or harvest fish.

Figure 2.3. Prior to release, fishery observers recorded injuries and barotrauma symptoms (top left), measured (top right) and tagged (bottom left) each reef fish discarded by observed anglers, and recorded the final disposition at the surface upon release (bottom left).

2.1.2 Mark-Recapture Methods

Care was taken to minimize fish processing time so that handling did not influence survival of tagged fish. Since it was normal fishing practice for anglers to hold fish at the surface or bring fish to the deck while waiting for assistance from the mate, we considered fish processing time to begin immediately upon removal from an angler's hook. Some biologists processed fish faster than others; therefore, processing time varied among biologists. Regardless of which biologist handled fish, individual fish were typically processed within 30 seconds during moderate-paced fishing. Biologists and vessel mates were instructed to release fish without tags any time there were more fish on the deck than could be processed in less than one minute. Due to space limitations on multi-passenger fishing vessels, it was not possible to set up a live well to hold fish before processing.

Fish were tagged in the upper dorsal shoulder region with Hallprint plastic-tipped dart tags that were anchored between anterior pterygiophores (Figure 2.4). Each tag had an external monofilament streamer labeled with a unique tag number, a toll-free phone number, and the word "REWARD". FWC operates a toll-free tag return hotline for anglers to report recaptures for multiple fish tagging studies around the state, and this number was provided on fish tags used in this study so that commercial and recreational fishers that captured tagged reef fish could report tag returns 24 hours a day and seven days a week. Callers were asked to provide the tag number, species, length, location of capture, and disposition of the tagged fish (harvested or re-released with or without tag) for each tagged fish they reported. A t-shirt with the phrase, "I caught a tagged reef fish" and an artist's image of a red snapper (courtesy of Diane Rome Peebles) was mailed to respondents for each tagged fish reported. To increase public awareness about the fish tagging study and how to report tagged fish, posters were placed in prominent locations throughout the study area, including marinas, bait and tackle shops, and other fishing access points. Posters include a description of the tag and tag location, pertinent information to record when a tagged fish was captured, and how to report information. We also worked with FWC's Communications Team to prepare press releases that were provided to media outlets prior to the opening of the red snapper recreational fishing season. Information about the study and how to report tag returns was also posted on FWC's official web-site.

Figure 2.4. A gag that was tagged during this study and subsequently recaptured by a recreational angler and reported to FWC. Discards were marked prior to release with a Hallprint plastic tip dart tag (www.hallprint.com) inserted in the front dorsal area and securely anchored between the first and second leading dorsal fin rays prior to release. Each tag had an external monofilament streamer labeled with a unique tag number, the phone number for FWC's toll-free tag-return hotline, and the word REWARD. Photo courtesy of Bob Harbison.

When a recaptured fish was encountered during a sampled trip, the biologist recorded all the previously described minimum data elements, and if the fish was not harvested by the angler it was re-released with the tag in place. Since charter and headboat vessels are likely to return frequently to the same sites where fish were tagged during sampled trips, we devised an incentive for vessel operators to record tag-recapture information when biologists were not present to record information. Vessel operators were provided with a supply of postage-paid cards to record tag return information for all recaptured fish encountered during fishing, and anglers provided their mailing address on the cards for the t-shirt reward. Involving vessel operators in reporting tag returns serves a dual purpose. Vessel mates handle most fish caught by their customers and are more likely to notice tags; however, mates are also busy assisting multiple customers and work for tips. Experiencing the novelty of catching a tagged fish for research and then giving customers credit for receiving the t-shirt reward improves the fishing experience for the customer and is good incentive for mates to take time to record tag numbers and report the information to FWC.

In addition to tagging discards during randomly sampled recreational fishing trips, red snapper were tagged during charter vessel trips hired by FWC with funds provided as part of the federal Emergency Disaster Relief Program, or EDRP, for dispersal to industry following 2005 hurricanes impacting regions of western Florida. The hired charter trips took place in areas A and D (Figure 3) during the months of March through May in 2010–2013. The purpose of the hired charter trips was to tag and release red snapper caught using recreational fishing methods. Gag, red grouper, scamp, gray triggerfish and vermilion snapper caught during these trips were also tagged and released. During hired charter trips, volunteer anglers fished using recreational hook-and-line gear supplied by the vessel. Captains were asked to target red snapper but were given no instructions from scientific crew on where to fish or how to target fishing. Data collected during these trips was identical to data collected during randomly sampled recreational fishing trips on charter boats and headboats funded by this study. Tag-recapture data from this study and the EDRP funded trips were combined to improve sample sizes for reported tag returns, particularly for red snapper, for analyses of relative survival and discard mortality.

2.1.3 Data Management

Prior to developing a database for this project, we met with staff from FWC's Fishery-Independent Monitoring group to review data elements collected as part of offshore monitoring programs developed collaboratively between FWC and NMFS. Data elements for this work were designed to provide records for each sampled trip at the trip level (e.g. date, area fished, trip duration), station level (latitude, longitude, depth, fishing time), individual angler and fishing rig level (angler number, rig number, gear configuration, catch per unit effort), and individual fish level (species, size, handling, condition, disposition and tag number), with each level of data linked by a unique identifier for the trip, and separate nested unique identifiers for the individual station, fisher, rig, and fish sampled within the trip. All data elements collected during the field methods described above were designed to match data elements collected during trips conducted by FWC's Fishery Independent Monitoring group utilizing hook-and-line sampling gear, so that combined analyses may be conducted in the future.

A SQL Server database with a Visual Basic data entry form was developed for electronic data entry and storage. Electronic data were updated and backed-up routinely throughout the duration of this project. Data were recorded in the field on paper data sheets (Appendix D), and data sheets were reviewed by the project manager before data were approved for electronic data entry. Data were entered by FWC biologists into a SQL Server database. The data entry form has features to prevent common data entry errors. All electronic data were proofed by two readers that compared field data sheets with a print-out of electronic data for each entered trip. Once data were proofed and all data entry errors were corrected, data were certified as final.

Data summaries were prepared in advance of SEDAR Data Workshops, and workshops were attended by project staff. Custom data queries were provided to NMFS Assessment Analysts upon request.

2.1.4 Characterization of Trips:

Sampled trips were categorized into the following trip-types based on the duration of the sampled trip:

- Single-Day Trips (<24 hours)
  - Half-Day: < 6 hours
  - Three-Quarter-Day: 6 hours to <9 hours
  - Full-day: 9 hours to <24 hours
- Multi-Day Trips (≥24 hours)

To generate weighting factors for different trip-types, fishing effort data for the years 2009 through 2013 were used to calculate proportional effort by trip-type. Headboat vessels report fishing effort in logbook trip reports, and effort data from the two study regions in the Gulf of Mexico were provided by the NMFS Southeast Fisheries Science Center in Beaufort, NC. Effort data for charter vessels is collected through the For-Hire Survey component of the Marine Recreational Information Program, which a weekly vessel directory telephone survey of charter boat operators (Van Voorhees et al. 2002). Proportional fishing effort was calculated as the total numbers of trips in the Gulf of Mexico reported for a given trip-type in a given region (TB or NW) divided by the total number of Gulf trips reported in the same region. To obtain the sample weight (W_t), proportional effort was then divided by the proportion of a given trip type in the sample population:

$$W_t = (N_t/N) / (n_t/n) \qquad \text{Equation 1}$$

Where N_t/N is the number of trips of type t divided by total trips reported, and n_t/n is the number of trips of type t in the sample population divided by the total number of sampled trips. Trip-types with $W_t < 1$ are down weighted to account for oversampling and trip-types with $W_t > 1$ are inflated to account for undersampling.

2.1.5 Characterization of Hook-and-Line Gear

Descriptive data collected during at-sea observer trips was synthesized to characterize the execution of gear requirements for the use of circle hooks. For each sampled trip, the total number of hook-and-line fishing rigs observed with circle hooks was divided by the total number of rigs observed to get the proportion of rigs with circle hooks. A fishing rig refers to terminal tackle for a single fishing rod that is outfitted with one or more hooks of similar type and size. If a rod was outfitted with two or more hooks of different types or sizes, each hook was recorded as a separate rig; however, this was rarely observed. Rigs were recorded each time the vessel moved to a new fishing station due to the fact that rig-switching may occur when a vessel moves to different locations and targets different types of fish. The proportion of rigs with circle hooks (P_c) versus other hook-types was calculated by sample region and trip-type:

$$P_c = \frac{\sum(\text{rigs with circle hooks at all fishing stations for all trips})}{\sum(\text{rigs observed at all stations for all trips})} \qquad \text{Equation 2}$$

Methods to evaluate the effectiveness of circle hooks for reducing potentially lethal internal injuries or for increasing the size selectivity of hook-and-line gear are described in detail in Sauls and Ayala (2012, attached as Appendix A). For each of the five target species for this study, we constructed a 2x2 contingency table to compare relative proportions of fish hooked in the lip (column 1) versus non-lip hooking (column 2) between fish caught on circle hooks (row 1) and all other non-circle hooks (row 2). To determine whether fish caught with circle hooks were more or less likely to be hooked in the lip than fish caught with other types of hooks, SAS software was used to calculate relative risks (RR) and 95% confidence intervals for each species (Cody and Smith 2006). Relative risk is typically used to measure the strength of the relationship between specific exposures (in this study, fish caught with circle hooks and non-circle hooks) and their outcomes (Zhang and Yu 1998). In this study, the potential outcomes are lip-hooking, which is considered to be a non-lethal injury, and non-lip hooking, which is more often associated with injuries to internal organs, gills, and eyes (Cooke and Suski, 2004).

Relative risk (RR) is calculated as:

$$RR = [L_c /(L_c+N_c)] / [L_n /(L_n+N_n)] \qquad \text{Equation 3}$$

Where L_c is the number of fish caught with circle hooks that were lip-hooked, N_c is the number of fish caught with circle hooks that were not lip hooked, L_n is the number of fish caught with non-circle hooks that were lip hooked, and N_n is the number of fish caught with non-circle hooks that were not lip hooked. The relative number of observations of fish caught with circle hooks was inflated compared to other hook types due to regulations requiring circle hook use when fishing for the species of interest; however, relative risk is based on incidence rates of outcomes in each exposed population and is not influenced by unequal numbers of observations.

2.1.6 Characterization of Discards

Fish mid-line lengths were placed in one cm length bin categories. Fish in each length bin category were summed by region, trip-type, and disposition. Disposition categories included harvested and discarded.

For each trip-type (t) in each region, counts of fish in each length bin were multiplied times the respective weighting factor (W_t). The weighted proportion of fish in a single length bin (p_x) was calculated as follows:

$$p_x = \frac{(\sum L_H)W_H + (\sum L_Q)W_Q + (\sum L_F)W_F + (\sum L_M)W_M}{\sum_{bin\ (i=1\ldots n)} [(\sum L_H)W_H + (\sum L_Q)W_Q + (\sum L_F)W_F + (\sum L_M)W_M]} \qquad \text{Equation 4}$$

Where L_H equals the number of fish in length bin x for a given disposition in a given region observed during half-day trips (H); and W_H is the weighting factor for half-day trips in the same region. Q = ¾-day trips, F = full-day trips, and M = multi-day trips. The denominator is the sum of all numerators for length bin 1 to length bin n.

Discard ratios by year were calculated by summing the numbers of observed fish harvested and discarded (n_d and n_h) for each trip and calculating the mean ratio ($r_{dt} = n_d/n_h$) in each region and trip type separately for charter boat and headboat trips. The mean ratios were then multiplied times the proportions of charter and headboat effort for each region and trip type (p_t). The overall discard ratio was calculated as:

$$r_d = \sum_{\text{trip type t to x}} r_{dt} * p_t \qquad \text{Equation 5}$$

The 95% confidence interval was calculated as:

$$CI\ r_d = \sum_{\text{trip type t to x}} LCL\ r_{dt} * p_t\ ,\ \sum_{\text{trip type t to x}} UCL\ r_{dt} * p_t \qquad \text{Equation 6}$$

2.1.7 Characterization of Immediate and Latent Discard Mortalities

Immediate mortality for discards was calculated as the percentage of all fish that were caught (and not harvested) that died prior to or immediately following release. This percentage included fishes that were released without a tag because they were dead on retrieval (usually attacked by a predator during ascent) and fishes that were tagged and were either unresponsive and presumed dead or visibly preyed upon at the surface. Tagged fish that suffered immediate mortality were not included in latent mortality calculated from mark-recapture rates.

Live discards for each species from each region were assigned to one of three release condition categories described in Table 2.1. Fish discarded by release condition were summed by trip type and region and multiplied by the respective weighting factor. The weighted sum of discarded fish in each release condition category was divided by the weighted sum for all discards to get proportions of discards in each release condition category. Logistic regression was used to compare the presence of barotrauma symptoms among fishes observed in the three release condition categories. Generalized linear models and Tukey post hoc tests were used to compare mean capture depth and mean size of fishes among release condition categories and regions.

Table 2.1. Description of live release condition categories for reef fishes observed during recreational hook-and-line fishing.

Condition category	Description
1. Not impaired, not vented	Fish immediately submerged without the assistance of venting and did not suffer internal hook injuries or visible injury to the gills.
2. Not impaired, vented	Fish was vented first and submerged immediately, and did not suffer internal hook injuries or visible injury to the gills.
3. Impaired	Fish was either initially disoriented before it submerged or remained floating at the surface (regardless of whether it was vented), suffered internal hook injuries, suffered visible injury to the gills, or any combination of the three impairments.

To evaluate the timing and occurrence of recapture events among fish released in condition categories 2 and 3 relative to condition category 1, the PHREG procedure in SAS was used to construct a proportional hazards model (described in Sauls, 2014 included as Appendix B and Sauls 2013). To estimate depth-dependent discard mortality, the number of live discards observed in conditions 1, 2 and 3 (N_1, N_2, and N_3, respectively) at each 10-meter depth interval (e.g., where d = 1–10 meters, 11–20 meters) was first multiplied by the proportion of fish in each condition category estimated to survive. Discard mortality at each depth interval (M_d) was expressed as a percentage using the equation:

$$M_d = [1 - (N_1 * S_1 + N_2 * \widehat{H}_2 + N_3 * \widehat{H}_3) / (N_1 + N_2 + N_3)] * 100 \qquad \text{Equation 7}$$

where S_1 is the absolute survival following catch-and-release for fish released in good condition (which is not truly known), and H_2 and H_3 are the estimated survival proportions for fish released in condition categories 2 and 3 (respectively), relative to fish released in condition category 1, derived from the proportional hazards model.

Ideally, absolute survival for fish in condition category 1 (S_1) should be measured; however, because all fish had to be captured in order to be tagged and released, there was no true control to reference this treatment group to. Because the majority of fish released in category 1 were caught from shallow depths, and individuals with hook injuries, visible gill injuries, potential internal injuries related to venting, or swimming impairments at the surface were excluded from this group, it is reasonable to assume that discard mortality in this treatment was minimal. For this analysis, overall depth-dependent discard mortality was calculated separately under three assumptions for S_1: 1) that 100% released in good condition survive ($S_1 = 1.000$); 2) that as few as 85% survive ($S_1 = 0.850$); and 3) that a median of 92.5% survive ($S_1 = 0.925$). For the median assumption, uncertainty around overall discard mortality estimates for each depth interval was calculated by substituting S_1 in equation 7 with lower and upper assumed values of 0.85 and 1.0, and substituting point estimates for H_2 and H_3 in equation 7 with lower and upper 95% confidence limit values.

To estimate overall discard mortality across all depths, numbers of fish observed at each 10 meter depth interval were weighted proportional to effort by trip type (half, three-quarter, full and multi-day trips). Weighted sums were multiplied by the point estimate for discard mortality at each depth interval (M_d), and the upper and lower confidence limits, to derive the total weighted number of discards caught from each depth that suffered mortality. The number of discards that died was then summed across all depths and divided by the total number of weighted discards to get the overall proportion within the fishery that is estimated to suffer mortality.

2.2 Results

2.2.1 Characterization of For-Hire Trips

In both regions, the majority of effort reported by headboats and charter boats (on logbook trip reports and in the telephone effort survey, respectively) were less than 9 hours in duration (half day and ¾ day trips), though charter boats offered a higher percentage of trips 9 hours or longer (full day trips) when compared to headboats (Figure 2.5). However, in 2013 paper-based logbook trip reports for headboats were replaced with a new electronic reporting system, which now includes 8-9 hour trips in the full day trip category (trips <9 hours previously were included in the ¾ day trip category). This change in 2013 resulted in a higher percentage of overall headboat effort in the full-day trip category (Figure 2.5). In the NW region, the percentage of half day trips varied seasonally, whereas these shorter trips were more distributed throughout the year in the TB region (Figure 2.5). Overall from 2009 through 2013, half day trips made up 36.2%, ¾ day trips made up 46.1% and full day trips made up 17.7% of reported fishing effort from charter boats in the NW region (Figure 2.5). In the TB region, half day charter trips made up 48.6%, ¾ day trips made up an additional 38.4%, and full day trips made up 12.9% of reported effort (Figure 2.5). Multi-day trips made up less than 1% of charter trips in both regions. Headboat effort in the NW region was made up of 25.8% half day trips, 63.9% ¾ day trips, 9.5% full day trips, and less than 1% multi-day trips (Figure 2.5). Half day trips made up a higher proportion (50.9%) of headboat effort in the TB region, an additional 44.2% of trips were ¾ day length, 3.7% were full day, and 1.2% were multi-day trips (Figure 2.5).

Numbers of half day (<6 hours), ¾ day (6-8 hours), full day (9-15 hours), and multi-day trips (>24 hours) sampled in each region are provided in Table 2.2. Figure 2.6 shows the distribution of sampled trips, which may be compared to proportional effort reported in the charter and headboat fisheries in Figure 2.5. Sampled trips were distributed among all available trip types throughout the year (Figure 2.6), and were weighted proportional to effort to ensure that data were representative of the fishery. Sample weights are provided in Table 2.3 and will be made available to data users for all future applications. Sample weights for 2013 may need to be recalculated in light of changes to how headboat trips were reported during this year, and values provided in Table 2.3 are preliminary and subject to change.

In both regions, mean depths fished increased with the duration of the sampled trip (Figures 2.7 and 2.8). Depths fished were deeper in the NW region compared to the TB region during half day and three quarter day charter boat and headboat trips and full day charter boat trips (Figure 2.9 and Table 2.4). Full day headboat trips fished in similar depths in both regions (33.1 m in TB versus 36.6 m in NW), and multi-day trips in the TB region fished at the deepest mean depth (44.1 meters).

Table 2.2. Numbers of headboat (H) and charter (C) trips sampled by month and region. *Indicates trips funded by a complementary CRP project (NA09NMF4540140) that overlapped with this study. Maps showing geographic distribution of sampled trips are provided in Appendix E.

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2009	NW	H						*7	*6	*4	*4	*3	*2	*2	*28
		C						7	8	5	10	4	3	0	37
	TB	H						*8	*8	*7	*5	*5	*7	*4	*44
		C						0	3	1	4	3	5	3	19
		Total						22	25	17	23	15	17	9	128
2010	NW	H	*1	*2	*3	*3	*0	*6	*6	*4	*3	*3	*1	*1	*33
		C	1	1	3	1	7	9	3	5	4	15	13	0	62
	TB	H	*5	*5	*3	*6	*6	*7	*8	*4	*7	*4	*3	*3	*61
		C	3	4	3	3	3	7	4	1	2	4	3	3	40
		Total	10	12	12	13	16	29	21	14	16	26	20	7	196
2011	NW	H	2	3	4	5	5	8	6	6	5	4	4	2	54
		C	1	4	6	7	8	11	9	10	8	8	2	3	77
	TB	H	2	5	4	6	4	10	5	3	3	6	7	14	69
		C	4	4	4	1	4	6	1	1	5	5	3	9	47
		Total	9	16	18	19	21	35	21	20	21	23	16	28	247
2012	NW	H	8	4	2	6	4	6	5	6	3	3	4	2	53
		C	3	5	5	7	7	9	10	9	4	10	6	4	79
	TB	H	2	5	4	4	4	7	5	4	4	4	3	7	53
		C	3	4	4	2	3	1	8	3	5	6	8	4	51
		Total	16	18	15	19	18	23	28	22	16	23	21	17	236
2013	NW	H	3	4	5	1	2	8	5	3	3	5	2	3	44
		C	4	2	9	7	3	14	11	5	5	6	5	5	76
	TB	H	6	4	5	6	4	9	5	7	4	4	2	4	60
		C	4	5	6	6	5	4	6	5	4	3	2	0	50
		Total	17	15	25	20	14	35	27	20	16	18	11	12	230

Table 2.3. Sample weights by region, year and trip type. Note, 2013 weights are preliminary and subject to change.

Region	Year	Half day	3/4 day	Full day	Multi-day
NW charter	2009	4.880992	0.759578	0.512414	
	2010	2.721536	0.601878	0.962257	
	2011	3.522423	0.562034	1.267357	
	2012	2.253355	0.620278	0.977800	
	2013	1.332341	0.754993	1.262676	
TB charter	2009	9.409514	0.843459	0.203723	
	2010	2.199546	0.916811	0.378559	0.037793
	2011	1.336384	1.071163	0.287683	
	2012	2.864030	0.679953	0.271719	
	2013	1.435865	0.655321	1.02407	
NW headboat	2009	3.195040	0.809157	0.485660	
	2010	1.411872	1.071423	0.517099	
	2011	1.751629	0.827638	1.087451	
	2012	0.967779	1.009353	0.903839	
	2013	0.819255	0.662255	12.68847	
TB headboat	2009	5.567868	1.115631	0.144392	0.107750
	2010	2.866887	0.974461	0.200011	0.110359
	2011	1.473135	1.232547	0.134893	0.109264
	2012	1.800704	1.011923	0.144242	0.174416
	2013	1.095362	0.700267	2.924499	0.039150

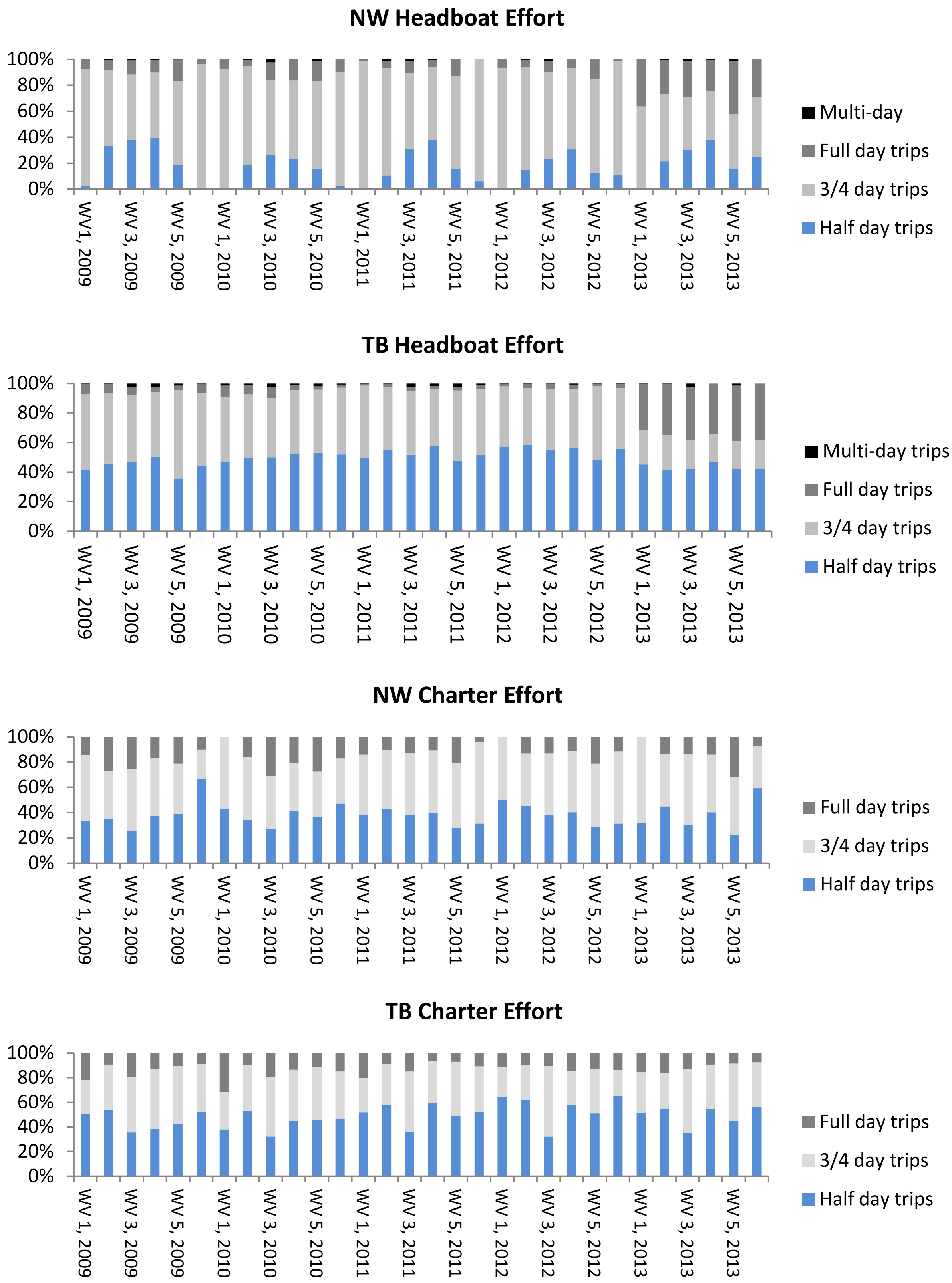

Figure 2.5. Distribution of reported fishing effort by trip duration by two month wave. The increased percentage of full-day headboat trips in 2013 is due to a change in how trips were classified in 2013.

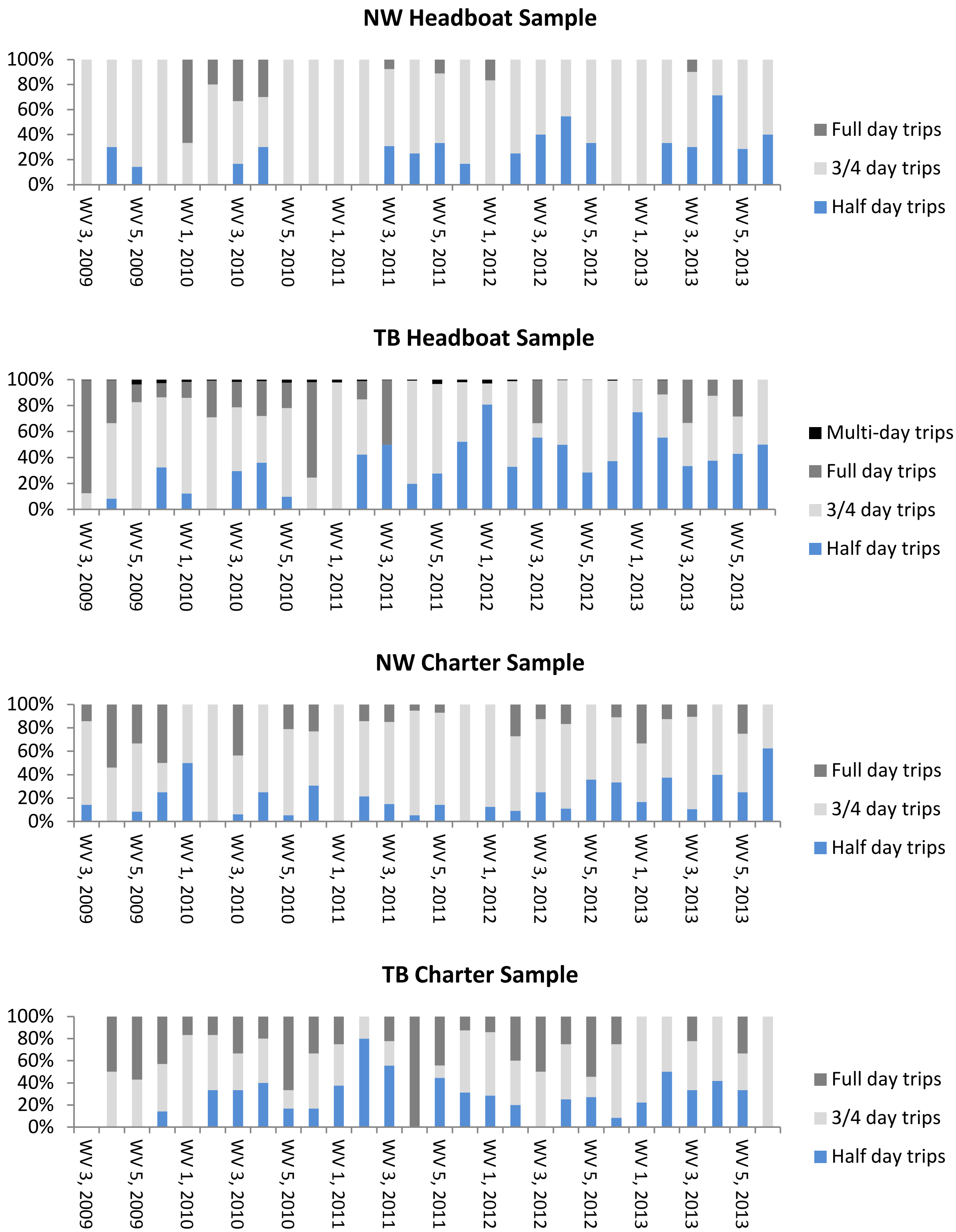

Figure 2.6. Distribution of sampled trips by trip duration by two month wave.

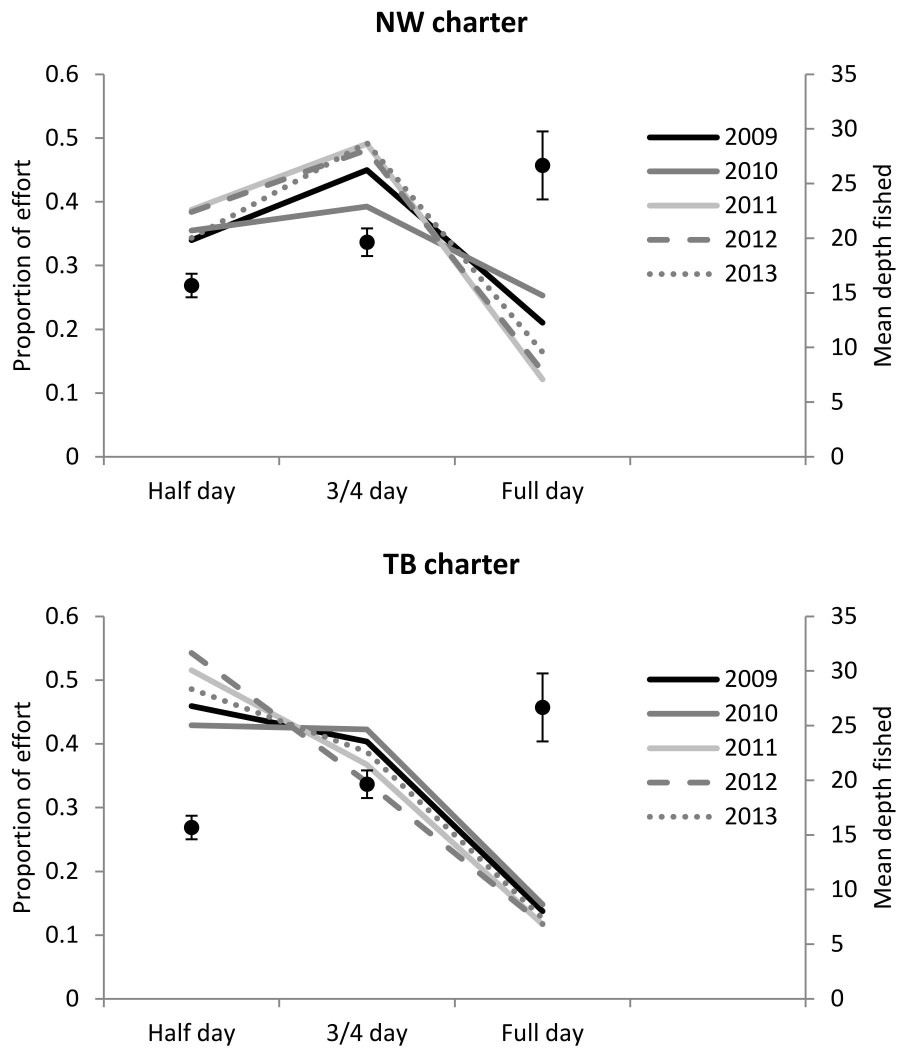

Figure 2.7. Annual proportion of reported fishing effort for charter vessels by trip duration in the NW region (top) and TB region (bottom). Mean depths fished during sampled trips are also plotted on the right y axis (black circles).

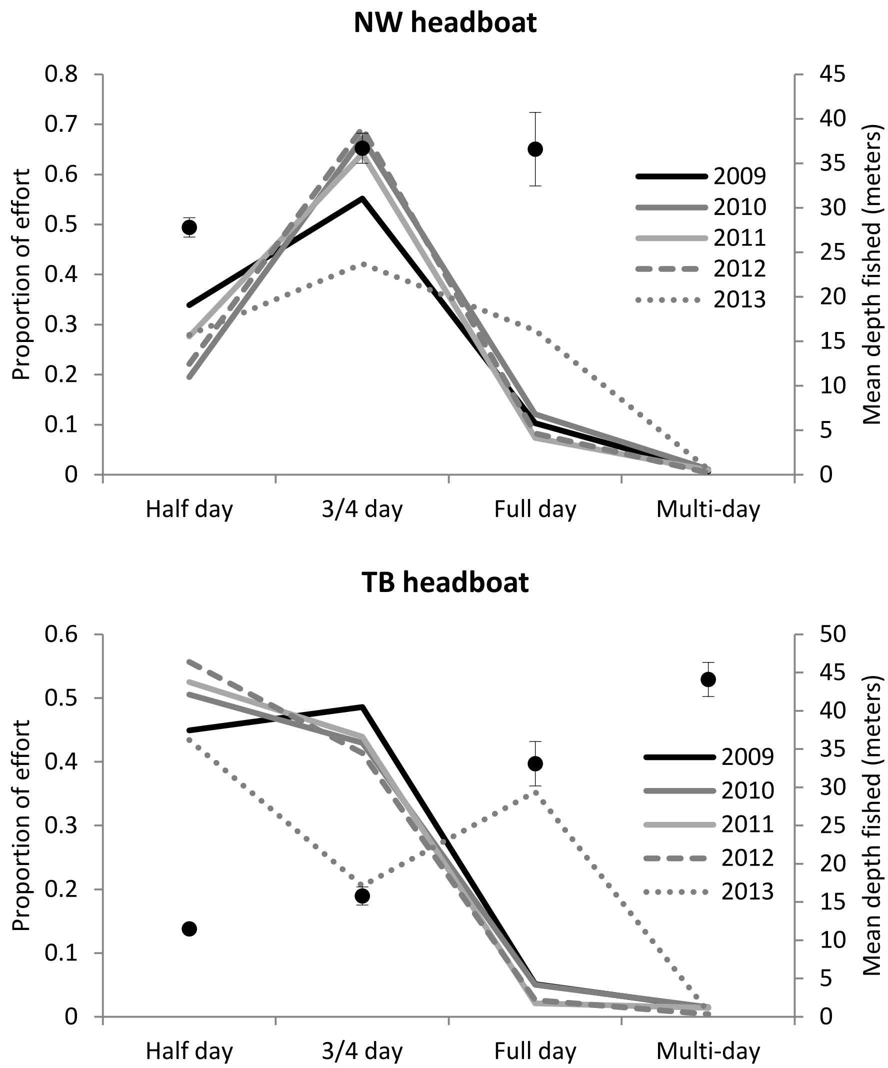

Figure 2.8. Annual proportion of reported fishing effort for headboat vessels by trip duration in the NW region (top) and TB region (bottom). Mean depths fished during sampled trips are plotted on the right y axis (black circles). Note in 2013 effort reporting for single-day trips changed to include trips 8 hours and longer in the full-day category (in previous years, trips 8 to 8.9 hours were included in ¾ day category).

Table 2.4. Mean depth (in meters) and 95% confidence intervals (CI) for sampled trips by region and trip duration.

Region	**Vessel type**	**Half day trips**	**¾ day trips**	**Full day trips**	**Multi-day trips**
Northwest (NW)	Headboat (H)	27.8 (26.7, 30.1)	36.7 (35.0, 41.6)	36.6 (32.5, 43.3)	
	Charter (C)	26.9 (25.5, 29.4)	33.9 (32.5, 37.7)	40.6 (37.1, 48.5)	
Tampa Bay (TB)	Headboat (H)	11.5 (11.1, 12.1)	15.8 (14.6, 17.7)	33.1 (30.2, 37.9)	44.1 (41.9, 54.1)
	Charter (C)	15.7 (14.6, 18.0)	19.6 (18.4, 22.7)	26.7 (23.5, 32.8)	

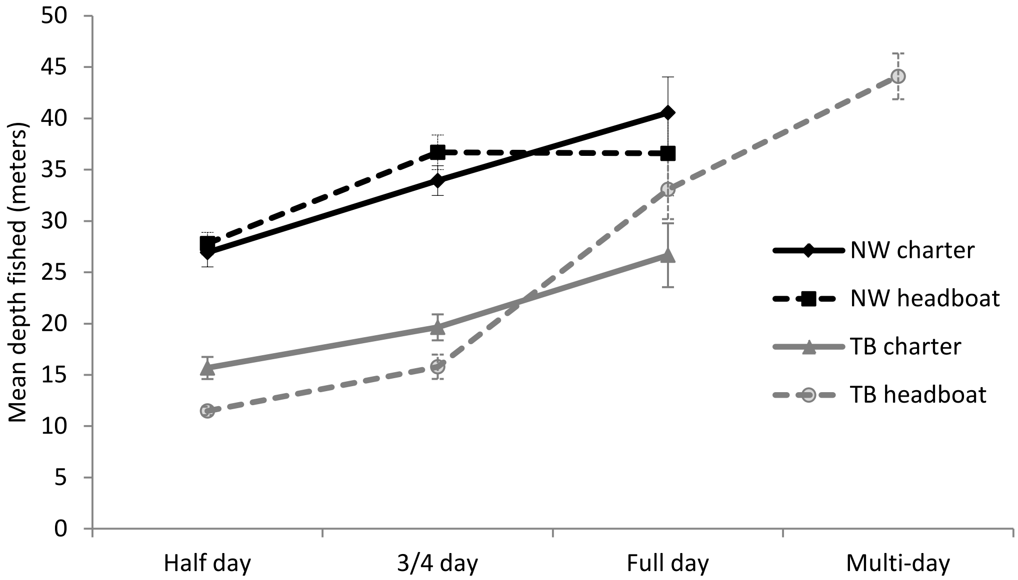

Figure 2.9. Mean depths fished by region and vessel type with 95% confidence intervals. Values provided in Table 2.4.

2.2.2 Species Targeted and Characterization of Hook-and-Line Gear

In the NW region, snappers were among the top two targeted species groups for all trip types (Table 2.5). Trips in the TB region were more likely to target groupers, except half and three-quarter day headboat trips were more likely to target white grunt (Table 2.5). Grunts are not included in the managed reef fish complex; however, groupers are often caught along with these species.

Circle hook usage was high (>80% non-offset and offset circle hooks combined) in the NW region among both headboats and charter boats, and was also high among charter boats in the TB region (Figure 2.10). Circle hook usage was lower on headboats in the TB region (68% on single-day trips, 49% on multi-day trips), and it is common for walk-on customers on headboats to bring their own tackle. On charter boats, customers more often use gear that is provided as part of the trip. The lower percentage of circle hook usage on headboats may be more indicative of overall compliance in the recreational fishery.

Results of early analyses comparing circle hooks and all other hook types combined were presented at an international conference on circle hooks that was hosted by NMFS in 2011 and published in the meeting proceedings (Sauls and Ayala, 2012). The analyses included observations for all harvested and discarded fish for ten species through November 2010. Results reported here are updated for the increased sample sizes collected since that publication. For nine out of ten species evaluated, there were significant reductions in potentially lethal injuries for fish caught with circle hooks compared to all other hook types (Table 2.6). Reductions ranged from 43% to 94% overall (Figure 2.11). Initially the difference between circle hooks and other hook types was not significant for gag, scamp, or red porgy (Sauls and Ayala, 2012). For scamp, potentially lethal injuries remained <5.0% for both circle hooks and other hook types and reductions were still not significant, but the larger number of potentially lethal observations for non-circle hooks for gag and red porgy now allow for detection of significant differences. However, potentially lethal hook injuries remained low for both circle hooks and other hook types (3.09% versus 7.31%, respectively for gag), and a small but significant decrease may not translate into numbers that are meaningful for fisheries management, especially when compared to other species. Some species that were more susceptible to hook injuries with other hook types benefitted the most from circle hooks. For example, potentially lethal hook injuries with other hook types were the highest for red snapper (19.6%) and were reduced to 5.5% with circle hooks, which was a 72% reduction. Greater amberjack also demonstrated a large reduction from 13.6% to 2.7% with circle hooks. For gray snapper, potentially lethal hook injuries were significantly reduced (from 16%), but 9.2% potentially lethal hook injuries with circle hooks was still relatively high compared to other species. Given that there was no negative effect for any species listed in Table 2.6 (i.e. no significant increases in potentially lethal hooking injuries with circle hooks) and these species are frequently caught together within recreational fisheries, the requirement to use circle hooks whenever regulated reef fishes are caught should have a positive net benefit for the multi-species complex.

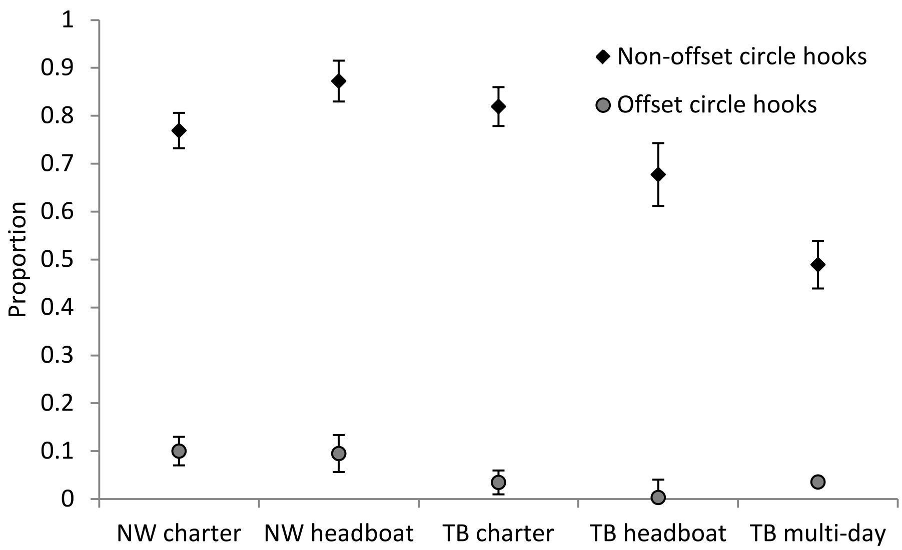

Figure 2.10. Proportion of observed fishing rigs per sampled trip that were outfitted with circle hooks. Non-offset circle hooks are required when fishing in state waters.

Table 2.5. Species groups targeted and proportions of sampled trips where the group was targeted during all or a portion of the fishing time.

	Half day trips		3/4 day trips		Full day trips		Multiday trips	
Region	Sp. group	Prop.	Sp. group	Prop.	Sp. group	Prop.	Sp. group	Prop.
NW charter	Snappers	0.366	Snappers	0.322	Snappers	0.297		
	Porgies	0.199	Porgies	0.162	Groupers	0.218		
	Groupers	0.174	Jacks	0.143	Jacks	0.158		
	Triggerfishes	0.130	Triggerfishes	0.141	Porgies	0.109		
	Mackerels	0.056	Groupers	0.130	Triggerfishes	0.109		
	Jacks	0.050	Mackerels	0.073	Mackerels	0.064		
	Flounder	0.012	Grunts	0.012	Cobia	0.010		
	Dolphinfishes	0.006	Wahoo	0.007	Dolphinfishes	0.010		
	Grunts	0.006	Sharks	0.005	Wahoo	0.010		
			Baitfish	0.003	Flounder	0.005		
					Tripletail	0.005		
NW headboat	Snappers	0.445	Snappers	0.389	Groupers	0.418		
	Porgies	0.318	Porgies	0.297	Snappers	0.248		
	Groupers	0.100	Triggerfishes	0.140	Grunts	0.177		
	Triggerfishes	0.082	Groupers	0.103	Jacks	0.050		
	Grunts	0.055	Jacks	0.034	Mackerels	0.050		
			Grunts	0.032	Barracudas	0.035		
			Hogfish	0.002	Dolphinfishes	0.007		
			Mackerels	0.002	Triggerfish	0.007		
					Wahoo	0.007		
TB charter	Groupers	0.439	Groupers	0.458	Groupers	0.418		
	Grunts	0.371	Grunts	0.281	Snappers	0.248		
	Mackerels	0.098	Mackerels	0.123	Grunts	0.177		
	Snappers	0.083	Snappers	0.108	Jacks	0.050		
	Baitfish	0.008	Jacks	0.015	Mackerels	0.050		
			Barracudas	0.010	Barracudas	0.035		
			Porgies	0.005	Dolphinfishes	0.007		
					Triggerfish	0.007		
					Wahoo	0.007		
TB headboat	Grunts	0.740	Grunts	0.474	Snappers	0.423	Snappers	0.450
	Groupers	0.231	Groupers	0.418	Groupers	0.381	Groupers	0.351
	Snappers	0.029	Snappers	0.064	Grunts	0.144	Jacks	0.144
			Porgies	0.040	Jacks	0.052	Porgies	0.015
			Jacks	0.004			Sharks	0.015
							Grunts	0.010
							Bigeyes	0.005
							Mackerels	0.005
							Tripletail	0.005

Table 2.6. Numbers of fish observed (N) and percentage hooked in an anatomical location other than the lip or jaw area (lip-hooked) for circle hooks and other hook types. Values for relative risk (RR) and 95% confidence intervals (CI) about RR is the ratio of lip-hooked fish caught with circle hooks divided by lip-hooked fish caught with other hook types. RR values >1.00 indicate circle hooks have a positive effect. The effect of circle hooks is not significant when the 95% CI includes 1.00 (values in parenthesis). Numbers of fish are not weighted with respect to fishing effort and should not be interpreted as a measure of compliance with circle hook requirements. Updated table from Sauls and Ayala (2012).

	Circle Hooks		Other Hooks		Relative Risk	
	N	Not lip-hooked	N	Not lip-hooked	RR	95% CI
Red Grouper	13,632	4.94%	3,803	10.78%	1.07	1.05, 1.08
Gag	4,500	3.09%	1,423	7.31%	1.05	1.03, 1.06
Scamp	777	2.06%	224	4.91%	1.03	(0.99, 1.06)
Gray Snapper	1,769	9.16%	2,892	16.01%	1.08	1.06, 1.11
Red Snapper	27,480	5.49%	1,267	19.57%	1.18	1.14, 1.21
Vermilion Snapper	9,348	1.20%	1,468	6.54%	1.06	1.04, 1.07
Greater Amberjack	1,750	2.74%	567	13.58%	1.13	1.09, 1.16
Gray Triggerfish	3,565	0.39%	493	5.88%	1.06	1.04, 1.08
Red Porgy	7,496	0.21%	1,128	3.46%	1.03	1.02, 1.05
White Grunt	6,790	1.03%	4,386	8.82%	1.09	1.08, 1.10

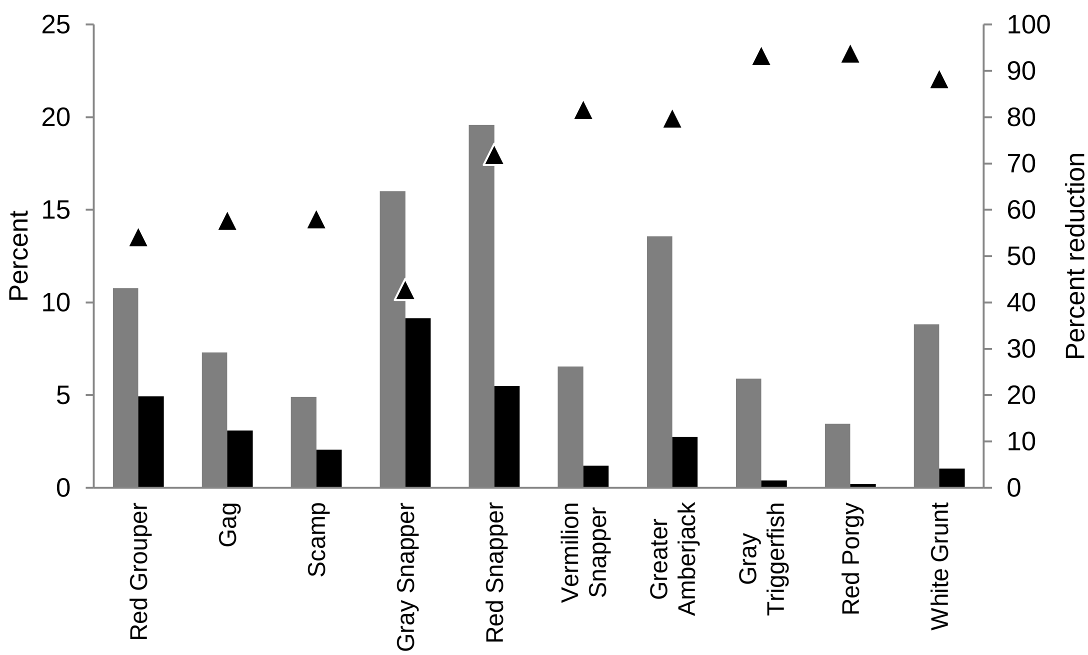

Figure 2.11. Percentage of fish, by species, that were hooked in the eyes, mouth, esophagus, gills, gut, or externally for circle hooks (black bars) and all other hook types (gray bars). Black triangles denote the percent reductions in potentially lethal hooking injuries for fish caught with circle hooks compared to other hook types. Note that differences between hook types for scamp are not significant. Updated figure from Sauls and Ayala (2012).

2.2.3 Characteristics of Observed Catch

A complete list of species in each region that were observed during sampled trips in order by frequency (unweighted) is provided in Table 2.7. Red snapper, vermilion snapper and red porgy were among the top five most frequently observed species among all trip types in the NW region (Table 2.8). In the TB region, red grouper, white grunt and gag were the three most prevalent species observed during single-day trips (Table 2.9), and gray snapper, vermilion snapper and red grouper were the top three species observed during multi-day trips (Table 2.10). Samples for aging were collected from harvested fish at the end of sampled trips, and numbers of samples are provided in Table 2.11. Age structures were either processed at FWRI or delivered to the Southeast Fisheries Science Center and data were shared during regional stock assessments. Length frequencies for harvested and discarded red snapper, gag and red grouper are shown in Figures 2.12 to 2.14.

Discard ratios were highest for red grouper and gag in the TB region, where they are most abundant (Table 2.12). Harvest for red grouper is permitted almost year-round, with the exception of a short closed season during February-March throughout the years of this study. The majority of red grouper observed were less than the minimum size limit (Figure 2.12), and the high numbers discarded for this species is largely due to by-catch of undersized fish in shallow depths where the majority of fishing effort takes place. Single-day headboat trips in TB often target white grunt (Table 2.5), which occurs in depths where sub-legal sized groupers are abundant. Discard ratios for gag were much lower compared to red grouper (Table 2.12) and were also likely impacted by changes in fishing regulations across years. In 2009, the recreational bag limit for gag within the 5 fish per person per day shallow water grouper aggregate limit was reduced to 2 gags per person per day; and in 2011, 2012, and 2013 harvest was closed during 10, 8 and 7 months, respectively. Discard ratios for red snapper and gray triggerfish were highest in the NW region where the species are more abundant (Table 2.12). Vermilion snapper are also more abundant in the NW region, but harvest is permitted year-round and discard ratios were low for this species (Table 2.12).

Table 2.7. Unweighted frequency of species observed from all sampled trips, by region.

NW Region		TB Region	
Species	N	Species	N
Red snapper	9,306	Red grouper	13,459
Vermilion snapper	8,205	White grunt	9,707
Red porgy	7,091	Gray snapper	3,767
Gray triggerfish	3,191	Gag	3,641
Tomtate	2,370	Vermilion snapper	1,710
Greater amberjack	1,219	Red snapper	1,514
Banded rudderfish	724	Red porgy	902
Bank sea bass	582	Greater amberjack	860
Red grouper	533	Scamp	451
Gag	481	Black sea bass	281
Sand perch	420	Littlehead porgy	264
Spanish mackerel	311	Knobbed porgy	263
Scamp	275	Spanish mackerel	225
King mackerel	259	Banded rudderfish	212
Whitebone porgy	246	Almaco jack	133
Lane snapper	123	King mackerel	131
Little tunny	121	Southern puffer	127
Littlehead porgy	100	Gray triggerfish	126
Sharksucker	99	Tomtate	103
Gray snapper	95	Sand perch	100
Pinfish	92	Grass porgy	90
Almaco jack	73	Graysby	90
Bluefish	70	Atlantic sharpnose shark	70
Atlantic sharpnose shark	67	Hogfish	56
Blue runner	58	Morays	55
Dolphin	57	Lane snapper	53
Red drum	44	Little tunny	52
Short bigeye	41	Pinfish	51
Grass porgy	37	Sharksucker	47
Gulf flounder	34	Requiem sharks	43
Cobia	26	Spottail pinfish	41
Unidentified species	22	Toadfishes	39
Inshore lizardfish	19	Yellowtail snapper	39
Tattler	19	Blue runner	38
Knobbed porgy	17	Pigfish	37
Jolthead porgy	17	Rock hind	34
Bigeye	17	Leopard toadfish	33
Whitefin sharksucker	17	Lizardfishes	30
Whitespotted soapfish	13	Porgy genus	30
Remora	11	Inshore lizardfish	29
Sandbar shark	11	Squirrelfishes	25
Dusky flounder	10	Gulf flounder	22
Pigfish	9	Blacknose shark	22
Sharksuckers	9	Bluefish	19
White grunt	8	Sharksuckers	19
Morays	8	Jolthead porgy	17
Southern flounder	8	Great barracuda	17

Table 2.7 Continued.

NW Region		TB Region	
Species	N	Species	N
Black sea bass	7	Creole-fish	15
Great barracuda	7	Dusky flounder	14
Searobin	7	Amberjacks	13
Requiem sharks	6	Cobia	12
Hardhead catfish	6	Blackfin tuna	11
Ladyfish	6	Mutton snapper	10
Lefteye flounders	6	Mackerel scads	8
Rock sea bass	6	Porgy family	8
Rock hind	5	Sand tilefish	8
Blackfin tuna	5	Whitespotted soapfish	7
Dolphinfishes	5	Remora	7
Cubbyu	5	Dolphinfishes	7
Rough scad	5	Crevalle jack	7
Wahoo	5	Dolphin	5
Squirrelfishes	4	Short bigeye	5
Spinner shark	4	Cubbyu	5
Rainbow runner	4	Sharpnose lizardfishes	5
Dusky shark	4	Spotted scorpionfish	5
Lizardfishes	3	Yellowmouth grouper	5
Porgy genus	3	Bigeye	4
Filefish	3	Barracudas	4
Bull shark	3	Goliath grouper	4
Speckled hind	3	Nurse shark	4
Reticulate moray	3	Scorpionfishes	4
Unicorn filefish	3	Bank sea bass	3
Southern puffer	2	Oyster toadfish	3
Graysby	2	African Pompano	3
Hogfish	2	Mackerel scad	3
Toadfishes	2	Slippery dick	3
Blacknose shark	2	Spinner shark	2
Creole-fish	2	Filefish	2
Oyster toadfish	2	Black grouper	2
Black grouper	2	Gulf toadfish	2
Gulf toadfish	2	Sailfish	2
Sailfish	2	Common puffers	2
Saucereye porgy	2	Gray angelfish	2
Tripletail	2	Soapfishes	2
Crevalle jack	1	Bonnethead	2
Sharpnose lizardfishes	1	Longspine squirrelfish	2
Spotted scorpionfish	1	Sheepshead	2
Barracudas	1	Tattler	1
Goliath grouper	1	Southern flounder	1
Common puffers	1	Searobin	1
Gray angelfish	1	Hardhead catfish	1
Soapfishes	1	Rainbow runner	1
Spotted moray	1	Bull shark	1
Atlantic bonito	1	Speckled hind	1

Table 2.7 Continued.

NW Region		TB Region	
Species	N	Species	N
Atlantic croaker	1	Spotted moray	1
Bandtail puffer	1	Banded jawfish	1
Bank butterflyfish	1	Bank cusk-eel	1
Bigeye scad	1	Bigeyes	1
Blackbar drum	1	Blacktip shark	1
Blackfin searobin	1	Blue parrotfish	1
Common moray	1	Chub mackerel	1
Doctorfish	1	Conger eel	1
Green moray	1	Conger eels	1
Guaguanche	1	Cubera snapper	1
Lesser amberjack	1	Finetooth shark	1
North American searobins	1	Gafftopsail catfish	1
Queen triggerfish	1	High-hat	1
Red hind	1	Leatherjacket	1
Sanddabs	1	Octopus	1
Sheepshead porgy	1	Sand diver	1
Smooth dogfish	1	Southern flounders	1
Snakefish	1	Stingrays	1
Snowy grouper	1	Striped burrfish	1
Spiny dogfish	1		
TOTAL	36,737		39,314

Table 2.8. Frequency of observations among the ten most prevalent species (both harvested and discarded fish) in the NW region during single-day trips.

	Half day		3/4 day		Full day	
	Species	N	Species	N	Species	N
NW charter	Bnd. rudderfish	30	Bnd. rudderfish	374	Bnd. rudderfish	170
	Bank sea bass	102	Bank sea bass	255	Bank sea bass	14
	Gag	80	Gag	246	Gag	111
	Gray triggerfish	347	Gray triggerfish	1,475	Gray triggerfish	405
	Gr. amberjack	53	Gr. amberjack	740	Gr. amberjack	225
	Red grouper	14	Red grouper	140	Red grouper	266
	Red porgy	652	Red porgy	2,507	Red porgy	784
	Red snapper	939	Red snapper	4,031	Red snapper	1,454
	Tomtate	283	Tomtate	647	Tomtate	66
	Vermilion sn.	290	Vermilion sn.	2,548	Vermilion sn.	887
NW headboat	Bnd. rudderfish	24	Bnd. rudderfish	120	Bnd. rudderfish	6
	Bank sea bass	35	Bank sea bass	168	Bank sea bass	8
	Gag	9	Gag	33	Gag	2
	Gray triggerfish	92	Gray triggerfish	783	Gray triggerfish	89
	Gr. amberjack	5	Gr. Amberjack	160	Gr. amberjack	36
	Red grouper	14	Red grouper	85	Red grouper	14
	Red porgy	383	Red porgy	2,425	Red porgy	340
	Red snapper	411	Red snapper	2,147	Red snapper	324
	Tomtate	263	Tomtate	1,086	Tomtate	25
	Vermilion sn.	469	Vermilion sn.	3,522	Vermilion sn.	489

Table 2.9. Frequency of observations among the ten most prevalent species (both harvested and discarded fish) in the TB region during single-day trips.

	Half day		3/4 day		Full day	
Trip type	Species	N	Species	N	Species	N
TB charter	Black sea bass	6	Black sea bass	30	Black sea bass	4
	Gag	254	Gag	964	Gag	532
	Gray snapper	2	Gray snapper	22	Gray snapper	81
	Gr. amberjack	4	Gr. amberjack	38	Gr. amberjack	59
	Red grouper	1,639	Red grouper	3,699	Red grouper	2,222
	Red porgy	0	Red porgy	0	Red porgy	7
	Red snapper	0	Red snapper	20	Red snapper	174
	Scamp	9	Scamp	45	Scamp	64
	Vermilion sn.	0	Vermilion sn.	4	Vermilion sn.	51
	White grunt	664	White grunt	1,575	White grunt	698
TB headboat	Black sea bass	82	Black sea bass	152	Black sea bass	7
	Gag	65	Gag	1,165	Gag	202
	Gray snapper	0	Gray snapper	37	Gray snapper	46
	Gr. Amberjack	0	Gr. amberjack	20	Gr. amberjack	42
	Red grouper	505	Red grouper	3,404	Red grouper	724
	Red porgy	0	Red porgy	1	Red porgy	1
	Red snapper	0	Red snapper	8	Red snapper	257
	Scamp	2	Scamp	48	Scamp	35
	Vermilion sn.	0	Vermilion sn.	45	Vermilion sn.	79
	White grunt	1,821	White grunt	4,490	White grunt	322

Table 2.10. Frequency of observations among the ten most prevalent species (both harvested and discarded fish) in the TB region during multi-day trips.

	Multi-day	
Trip type	Species	N
TB	Black sea bass	0
	Gag	479
	Gray snapper	3,579
	Gr. amberjack	697
	Red grouper	1,266
	Red porgy	893
	Red snapper	1,055
	Scamp	248
	Vermilion sn.	1,531
	White grunt	137

Table 2.11. Numbers of otoliths or spines collected for ageing.

TSN	COMMON	N
168853	Red Snapper	2,521
168909	Vermilion Snapper	600
167759	Gag	597
167702	Red Grouper	528
168848	Gray Snapper	442
168689	Greater Amberjack	287
167763	Scamp	42
172435	King Mackerel	30
168860	Lane Snapper	24
173138	Gray Triggerfish	18
167696	Rock Hind	15
168907	Yellowtail Snapper	10
167687	Black Sea Bass	7
167741	Graysby	6
172436	Spanish Mackerel	5
168849	Mutton Snapper	3
172736	Gulf Flounder	3
167760	Black Grouper	2
167762	Yellowmouth Grouper	1
168566	Cobia	1
168847	Cubera Snapper	1
170566	Hogfish	1
172738	Southern Flounder	1
Total		5,145

Table 2.12. Ratio of discarded to harvested fish (by species) by vessel type, region and year; weighted by trip type (half day, ¾ day, full day and multi-day).

		Red grouper			Gag			Red snapper		
Region	Year	Ratio	LCL	UCL	Ratio	LCL	UCL	Ratio	LCL	UCL
NW charter	2009	0.488	-3.310	4.286	0.425	-3.773	4.623	2.231	0.263	1.997
	2010	4.353	-36.626	45.332	3.691	-1.768	9.150	2.276	0.877	3.675
	2011	1.115	0.511	1.720	0.408	-0.283	0.651	1.357	-0.675	3.388
	2012	0.487	-0.054	0.185	0.754	0.066	0.929	2.904	-4.105	9.912
	2013	0.086			0.215			4.727	-17.127	26.580
TB charter	2009	11.307	-0.392	23.007	1.183	0.298	2.069	0.293		
	2010	32.495	2.530	62.455	3.322	0.806	5.836	0.073	-0.018	0.162
	2011	27.538	-15.562	70.638	2.695	-6.106	11.495			
	2012	13.327	-7.066	33.720	1.751	-0.837	4.340	0.066	-0.137	0.270
	2013	12.116	0.939	23.292	0.548	0.294	0.803	0.038	0.011	0.064
NW headboat	2009	1.379						2.162	-0.300	4.624
	2010	0.794			0.672			0.935	-0.031	1.413
	2011	0.788						1.984	-1.226	5.077
	2012	1.384						0.902	-0.140	1.944
	2013							1.244	-0.110	2.598
TB headboat	2009	8.575	2.267	14.884	7.475	0.806	6.960	0.762	-1.075	2.599
	2010	15.335	-1.474	32.143	4.376	1.159	7.593	0.318	-3.645	4.281
	2011	11.896	2.360	21.433	1.430	-0.366	2.119	0.038	-0.038	0.114
	2012	10.176	1.100	19.201	0.896	-0.239	2.032	0.026		
	2013	8.198	0.988	15.408	3.478	0.400	0.908	0.420	-0.184	1.023
		Vermilion snapper			Gray triggerfish					
		Ratio	LCL	UCL	Ratio	UCL	LCL			
NW charter	2009	0.114	-0.028	0.257	3.810	-0.517	6.925			
	2010	0.067	-0.295	0.429	2.064	0.491	2.847			
	2011	0.122	0.011	0.170	6.182	-0.447	12.811			
	2012	0.657	-0.102	0.493	2.086	0.470	2.778			
	2013	0.306	-0.259	0.697	6.653	0.739	12.568			
TB charter	2009				0.255					
	2010	0.077	-0.387	0.541	0.213					
	2011									
	2012									
	2013									
NW headboat	2009	0.170	-0.037	0.316	1.673	0.406	2.941			
	2010	0.116	0.024	0.208	2.075	-0.679	4.438			
	2011	0.129	-0.025	0.284	3.423	1.238	5.535			
	2012	0.956	-0.314	2.226	3.651	-0.198	7.500			
	2013	0.289	0.012	0.493	3.190	0.547	5.833			
TB headboat	2009	0.113	-0.245	0.442						
	2010	0.034	-0.179	0.247	0.015					
	2011	0.044	-0.227	0.315	0.019	-0.001	0.039			
	2012	0.014	-0.001	0.002						
	2013	0.294	-0.455	1.044	0.007					

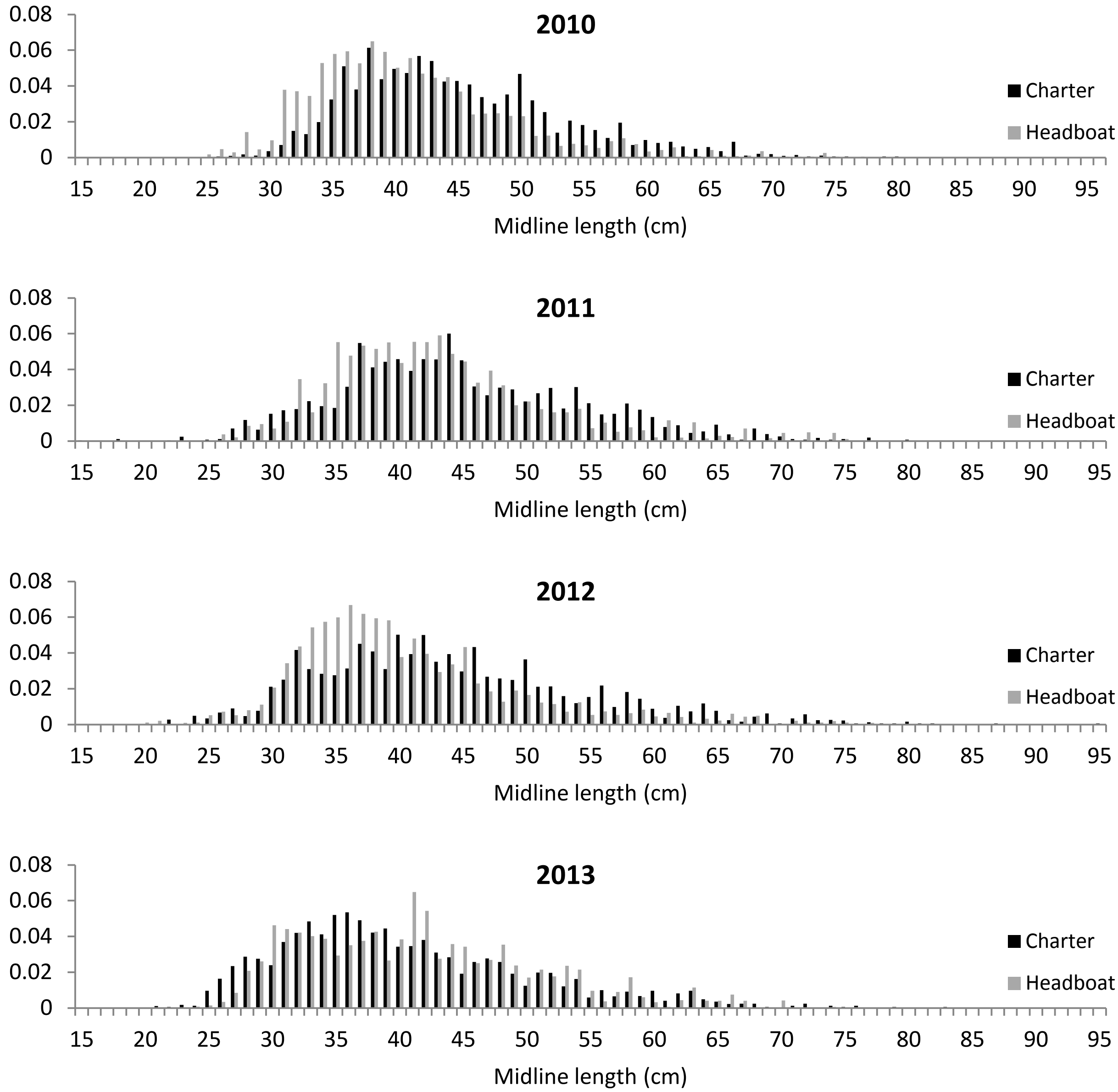

Figure 2.12. Weighted length frequencies (expressed as proportions) for red snapper (harvest and discards for TB and NW regions combined). The minimum size limit for harvest is 16” total length (40.6 cm TL).

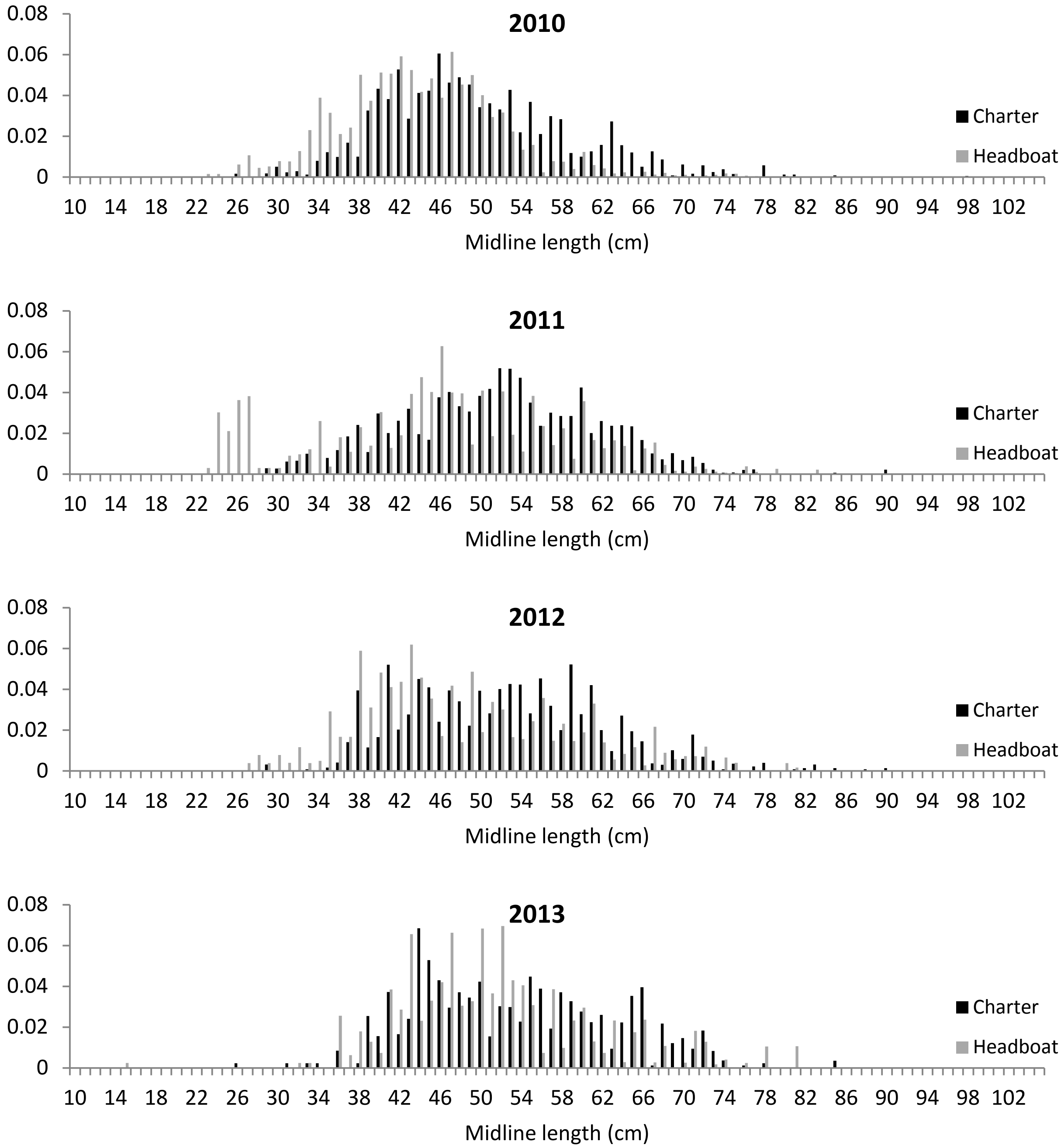

Figure 2.13. Weighted length frequencies (expressed as proportions) for gag (harvest and discards for TB and NW regions combined). The minimum size limit for harvest is 22” total length (55.9 cm TL).

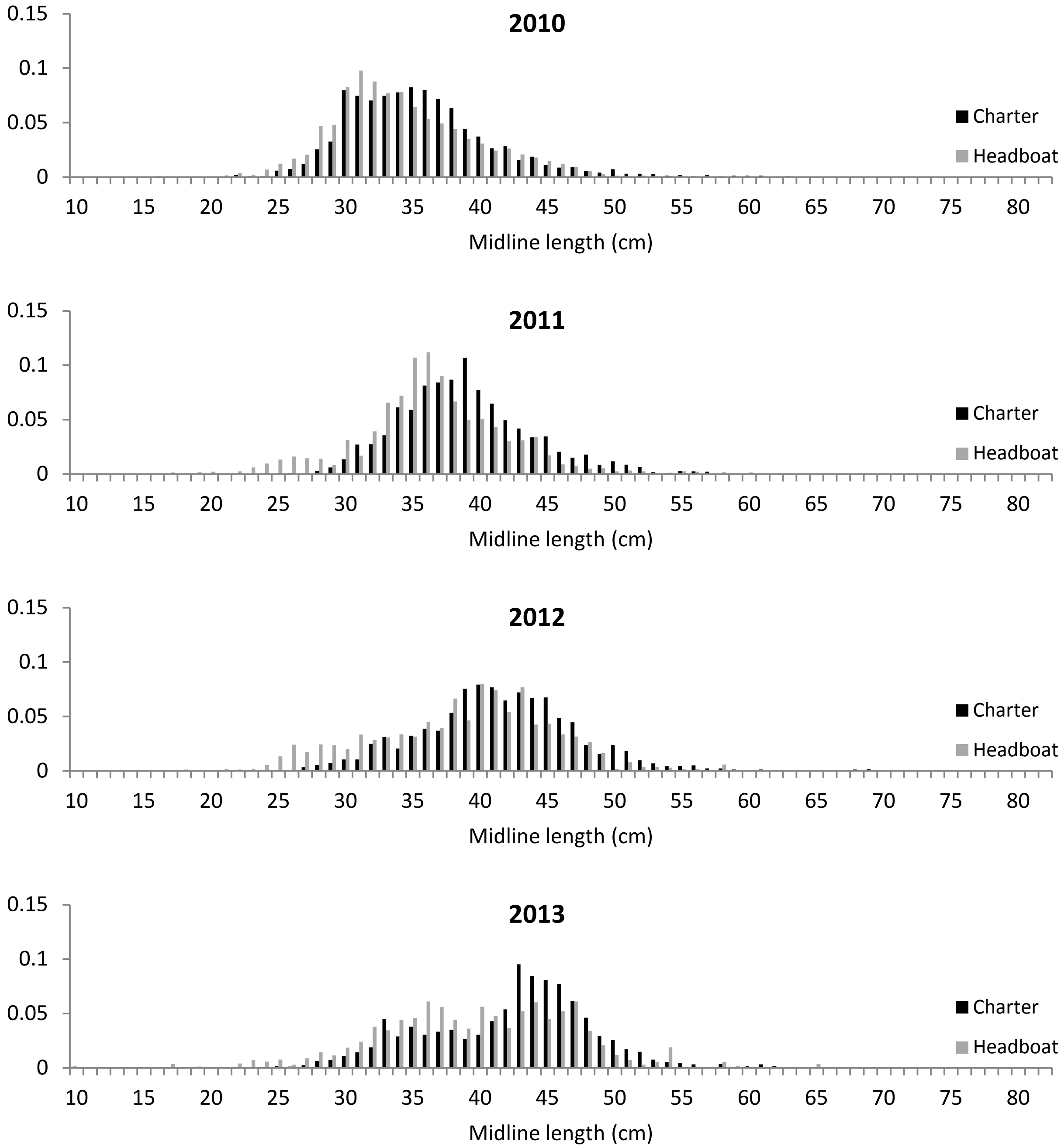

Figure 2.14. Weighted length frequencies (expressed as proportions) of red grouper (harvest and discards for TB and NW regions combined). The minimum size limit for harvest is 20” total length (50.8 cm TL).

2.2.4 Condition of Discarded Fish

Immediate mortalities

Immediate mortalities include any fish that was attacked by a predator during retrieval, was unresponsive and presumably died on the deck, or was visibly preyed upon at the surface at the time of release. Fish that were floating on the surface following release were not presumed to be an immediate mortality. Immediate mortalities represented less than 1% of observed discards (Table 2.13). Fish that were tagged prior to release and suffered immediate mortality were not included in any further analysis for survival of discards. Therefore, the percentages for immediate mortalities reported in Table x are in addition to live discard mortality estimates reported later in this report and the two percentages are additive.

Table 2.13. Frequency of immediate mortalities, and expressed as a proportion of total observed discards.

Species	Total observed discards	Immediate mortalities	Percent immediate mortality
Gag	5,097	14	0.275
Red grouper	16,081	33	0.205
Scamp	767	6	0.782
Red snapper	25,767	213	0.827
Vermilion snapper	1,399	12	0.858
Gray triggerfish	3,268	5	0.153

Prevalence of barotraumas

The proportions of fish in each live release condition category that exhibited external symptoms of barotrauma, including intestinal extrusion, stomach eversion, and exopthalmia are shown if Figure 2.15. Gag and red grouper were more prone to stomach eversion. In addition, a higher percentage of gag and red grouper that were vented and submerged immediately when released exhibited this symptom, which indicates that the decision to vent was related to the presence of this symptom. Variable degrees of severity for stomach eversion were observed (ranging from mild eversion at the esophagus to severe protrusion through the buccal cavity); however, this symptom was only recorded as present or absent. It is possible that gag and red grouper that were not vented and also exhibited this symptom were judged to be less in need of swim bladder deflation due to less severe extrusion. Future studies that record this symptom in the field should include a measure for the degree of severity. All three grouper species exhibited a low prevalence of intestinal extrusion. The percentage of fish that exhibited exopthalmia was low among all six species evaluated; however, red grouper had the highest percentage.

Red snapper were prone to both stomach eversion and intestinal extrusion, and there were no obvious trends among fish that were vented or not vented. Among all species, gray triggerfish were most prone to exhibit intestinal extrusion, whereas, stomach eversion was rare observed in this species. This may be explained by the morphology of this species, including a stiff and compressed body form that may restrict internal swim bladder expansion, and a small buccal cavity that may inhibit stomach eversion. The effects of barotrauma exposure for this species are poorly studied and should be a focus of future research.

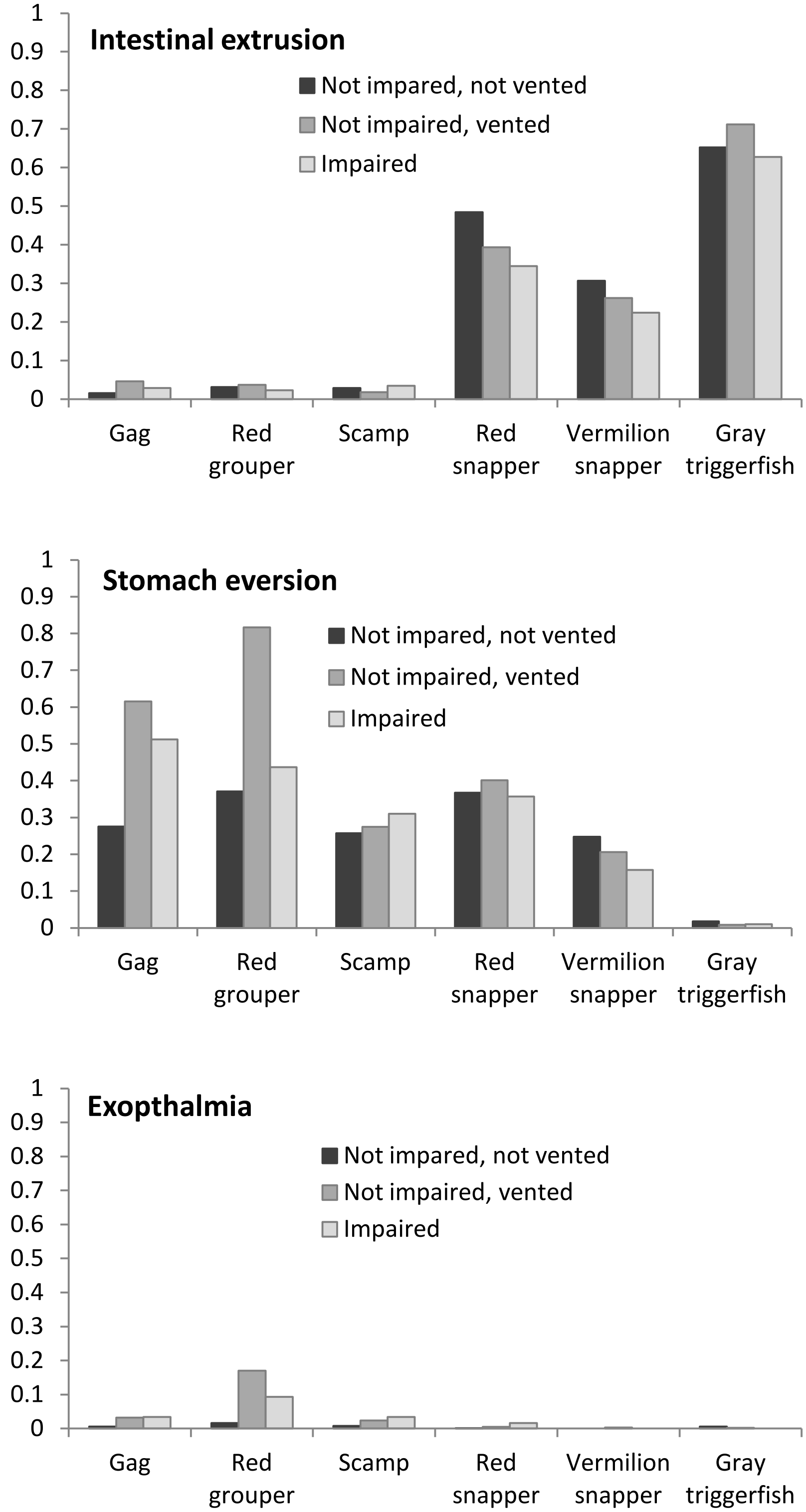

Figure 2.15. Proportion of discards observed within each condition category that exhibited external symptoms of barotrauma exposure, including intestinal eversion (top), stomach eversion (middle), and exopthalmia (lower).

2.2.5 Relative Survival and Discard Mortality Estimation

A total of 26,992 reef fishes caught by recreational anglers fishing from headboats and charter boats were tagged and released as a direct result of this study, and an additional 24,933 reef fishes were tagged in other funded studies that were complimentary to this work (Table 2.14). Complementary tagging studies include 18 months (June 2009–December 2010) of observer coverage on headboats from a grant funded through the Cooperative Research Program (CRP, grant number NA09NMF4540140), and charter trips that were hired prior to the recreational season opening (March, April and May, 2010 through 2013) specifically to target red snapper for tag-and-release funded through the Emergency Disaster Relief Program (EDRP). Tag-recapture percentages for conventional tag studies typically are low (~10%), and data from these three studies were combined for mark-recapture analyses to maximize the number of records for recaptured fish and improve precision around estimates of relative survival and discard mortality.

Table 2.14. Numbers of discards tagged directly as a result of this study and total numbers of tagged fish, including fish tagged from headboats during a complementary CRP project and directed red snapper tagging trips funded by EDRP.

	Tagged in this study	Total tagged
Red snapper	8,008	25,629
Gag	3,462	5,091
Red grouper	12,186	15,969
Scamp	476	652
Vermilion snapper	344	1,343
Gray triggerfish	2,516	3,241

The total numbers of fish tagged (all studies combined) by region and release condition and the numbers and percentage that were recaptured are provided in Table 2.15. The majority of red snapper were tagged in the NW region, where the species is more abundant. Red snapper were also encountered during multi-day trips In the TB region, and a small number were tagged during full-day trips in this region. The majority of red grouper and gag were tagged in the TB region where they were frequently observed during all trip-types. Vermilion snapper and gray triggerfish were less abundant in the TB region, and low numbers of gray triggerfish and vermilion snapper were tagged in both regions due to less restrictive harvest limits for these species. Scamp was added to the tag-recapture portion approximately halfway through the study due to the numbers of discards observed in both the TB and NW regions.

The majority of red snapper discards were observed from fishing depths between 21 meters and 40 meters and re-submerged immediately with no visible impairments, though a large portion were vented prior to release (Figure 2.16). A large proportion of gag and red grouper were caught from depths less than 21 meters, which is attributed to the fact that the majority were observed in the shallower TB region where both species are more abundant. Most gag and red grouper that re-submerged without impairments were not vented; however, the portion that was vented increased with increased capture depths. Almost all red snapper discards were observed either in the NW region or during multi-day trips in the TB region, which explains the deeper depths from which these discards were observed, and may also explain the higher incidence of venting for this species. Gray triggerfish, scamp, and vermilion snapper all were similar to red snapper in that the majority were captured from depths deeper than 21 meters and a large portion of fish without impairments were vented prior to release (Figure 2.17).

Recapture percentages varied among species and region, but within each the overall trend was for diminishing recapture percentages with deteriorating release condition, at least where good numbers of fish were tagged in each category (i.e. highest recapture percentage from condition category 1, and decreasing percentages from categories 2 and 3, respectively; Table 2.15). Three species had sufficient numbers of tag and recapture records across regions and years to evaluate relative survival among release condition groups, and include red snapper, gag and red grouper. Results of proportional hazards models are provided in Table 2.16, and the effect of release condition was significant for all three species after controlling for covariates on recapture reporting rates. The results for these three species clearly indicate fish that are able to submerge immediately without the assistance of venting survive at higher rates compared to vented fish that submerge and fish that are released in an impaired condition (Figure 2.18, condition 1 versus conditions 2 and 3). Note the smaller confidence intervals around red snapper, which results from the high numbers of fish tagged in each of the three condition categories. Gag had the widest confidence interval due to fact that >90% of tagged fish were from a single condition category and served as the reference group (condition 1). Sample sizes for red snapper and red grouper were sufficient to detect relative survivals that were significantly higher for vented fish that re-submerged when compared to those that were released in an impaired condition (Figure 2.18, condition 2 versus condition 3), suggesting that venting may at least be helpful for fish that do not have internal hook or gill injuries if it is necessary to assist with re-submergence. Larger sample sizes for tag returns from fish released in condition categories 2 and 3 are needed before relative survivals can be evaluated for gray triggerfish, vermilion snapper and scamp (Table 2.15). Tag-return sample sizes for impaired fish were also too low to discern whether reduced survival was related to hook injury, gill injury, difficulty re-submerging, or a combination of factors for any species. Reported tag-returns from fish tagged during this project will continue to be collected through the FWC tag-return hotline and during FWC's other field sampling efforts so that these analyses may be updated in future years as sample sizes increase.

Estimated discard mortality increased with depth of capture for red snapper, gag and red grouper (Figure 2.19). When point estimates were regressed against median values for 10 meter depth intervals (x = 5m, 15m… n), there was a significant positive linear relationship (alpha 0.05) that explained 80% or more of variation (Figure 2.19). This functional relationship between depth of capture and survival may be applied broadly to any recreational hook-and-line fishery within the region for which proportions of discards captured from various depths is known. Overall discard mortality for the charter and headboat fisheries was estimated across all depths by calculating the proportions of fish discarded at various depths, after samples were weighted proportional to fishing effort among single-day and multi-day trip types (Figure 2.20). Overall mortality was highest for red snapper and point estimates ranged from 23.7% to 27.4% (Figure 2.20).

Table 2.15. Raw numbers of observed discards tagged and released in each release condition category (and percent of total number tagged within each region), and numbers (and percent within each region and condition category) recaptured. Includes fish tagged during this study and complementary studies.

		NW	TB, nearshore	TB, offshore	BB
Red Snapper	Numbers of fish tagged:				
	Condition 1 (%)	6,049 (35.2)	35 (31.0)	150 (17.0)	65 (45.5)
	Condition 2 (%)	9,108 (53.1)	56 (49.5)	510 (57.9)	54 (37.8)
	Condition 3 (%)	2,004 (11.7)	22 (19.5)	221 (25.1)	24 (16.8)
	Numbers of fish recaptured:				
	Condition 1 (% tagged)	791 (13.1)	1 (2.9)	13 (8.7)	13 (20.0)
	Condition 2 (% tagged)	893 (9.8)	2 (3.6)	40 (7.8)	3 (5.6)
	Condition 3 (% tagged)	131 (6.5)	0	12 (5.4)	2 (8.3)
Gag	Numbers of fish tagged:				
	Condition 1 (%)	300 (44.0)	2,499 (93.8)	180 (33.6)	146 (93.0)
	Condition 2 (%)	336 (49.3)	82 (3.1)	286 (53.5)	3 (1.9)
	Condition 3 (%)	46 (6.7)	84 (3.2)	69 (12.9)	8 (5.1)
	Numbers of fish recaptured:				
	Condition 1 (% tagged)	50 (16.7)	250 (10.0)	24 (13.3)	10 (6.8)
	Condition 2 (% tagged)	48 (14.3)	5 (6.1)	28 (9.8)	0
	Condition 3 (% tagged)	8 (17.4)	3 (3.6)	3 (4.3)	0
Red Grouper	Numbers of fish tagged:				
	Condition 1 (%)	146 (31.8)	8,731 (87.8)	459 (29.1)	255 (93.8)
	Condition 2 (%)	261 (56.9)	577 (5.8)	881 (55.9)	1 (0.4)
	Condition 3 (%)	52 (11.3)	634 (6.4)	237 (15.0)	16 (5.9)
	Numbers of fish recaptured:				
	Condition 1 (% tagged)	11 (7.5)	1,147 (13.1)	90 (19.6)	36 (14.1)
	Condition 2 (% tagged)	33 (12.6)	44 (7.6)	154 (17.5)	0
	Condition 3 (% tagged)	1 (1.9)	54 (8.5)	28 (11.8)	1 (6.3)
Scamp	Numbers of fish tagged:				
	Condition 1 (%)	62 (30.1)	100 (86.2)	81 (49.4)	2 (66.7)
	Condition 2 (%)	131 (63.6)	13 (11.2)	71 (43.3)	0
	Condition 3 (%)	13 (6.3)	3 (2.6)	12 (7.3)	1 (33.3)
	Numbers of fish recaptured:				
	Condition 1 (% tagged)	8 (12.9)	4 (4.0)	7 (8.6)	1 (50.0)
	Condition 2 (% tagged)	12 (9.2)	0	4 (5.6)	
	Condition 3 (% tagged)	0	1 (33.3)	1 (8.3)	0
Gray Triggerfish	Numbers of fish tagged:				
	Condition 1 (%)	892 (41.6)	46 (82.1)	29 (76.3)	23 (76.3)
	Condition 2 (%)	1,162 (54.2)	7 (12.5)	9 (23.7)	1 (41.7)
	Condition 3 (%)	91 (4.2)	3 (5.4)	0	0
	Numbers of fish recaptured:				
	Condition 1 (% tagged)	71 (8.0)	1 (2.2)	0	2 (8.7)
	Condition 2 (% tagged)	129 (11.1)	0	0	0
	Condition 3 (% tagged)	4 (4.4)	0		
Vermilion Snapper	Numbers of fish tagged:				
	Condition 1 (%)	589 (59.3)	16 (64.0)	8 (72.7)	0
	Condition 2 (%)	329 (33.1)	8 (32.0)	3 (27.3)	0
	Condition 3 (%)	75 (7.6)	1 (4.0)	0	0
	Numbers of fish recaptured:				
	Condition 1 (% tagged)	26 (4.4)	0	0	
	Condition 2 (% tagged)	9 (2.7)	0	1 (33.3)	
	Condition 3 (% tagged)	3 (4.0)	0		

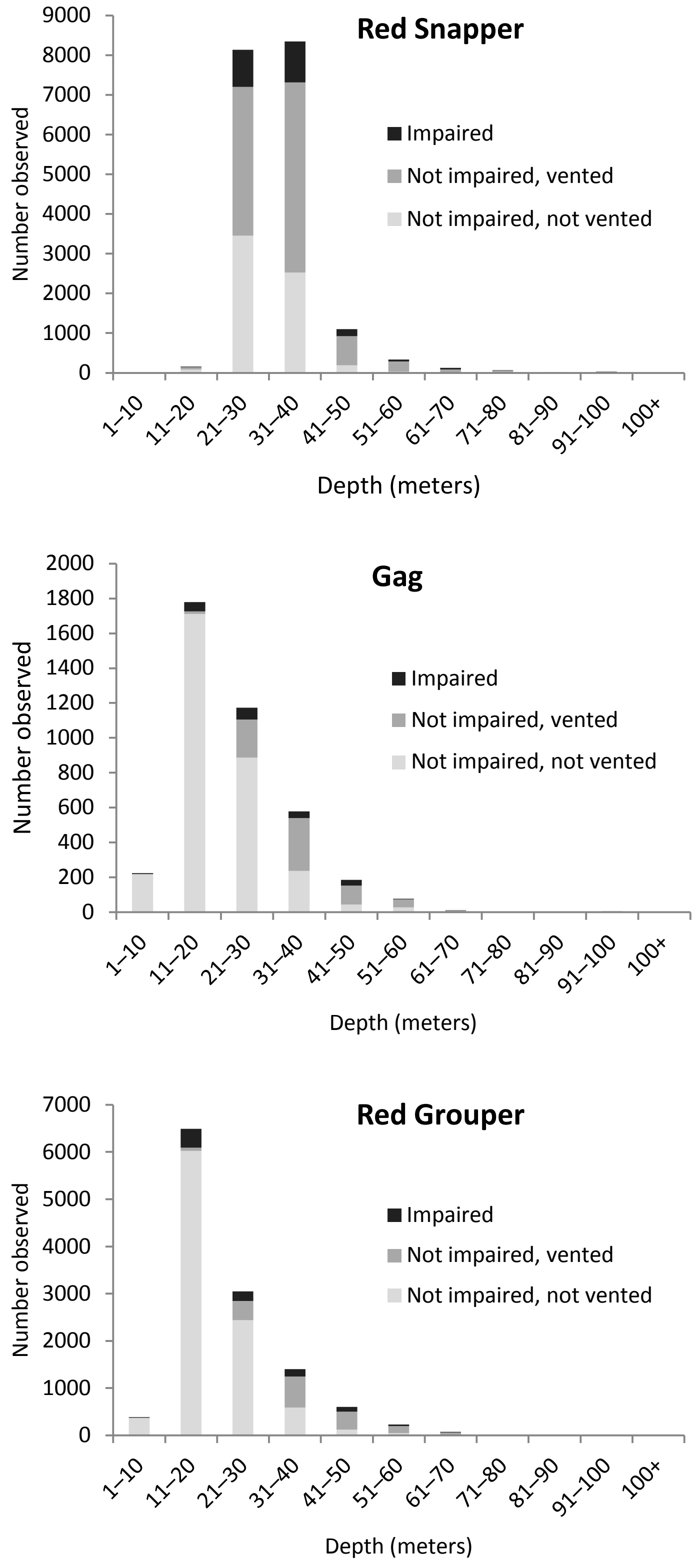

Figure 2.16. Numbers of red snapper, gag and red grouper discards observed by depth interval that submerged immediately without the need for venting, submerged immediately and were vented, or that suffered one or more impairments (vented or unvented fish that were disoriented or remained floating on the surface, internal hook injuries, or visible injury to the gills).

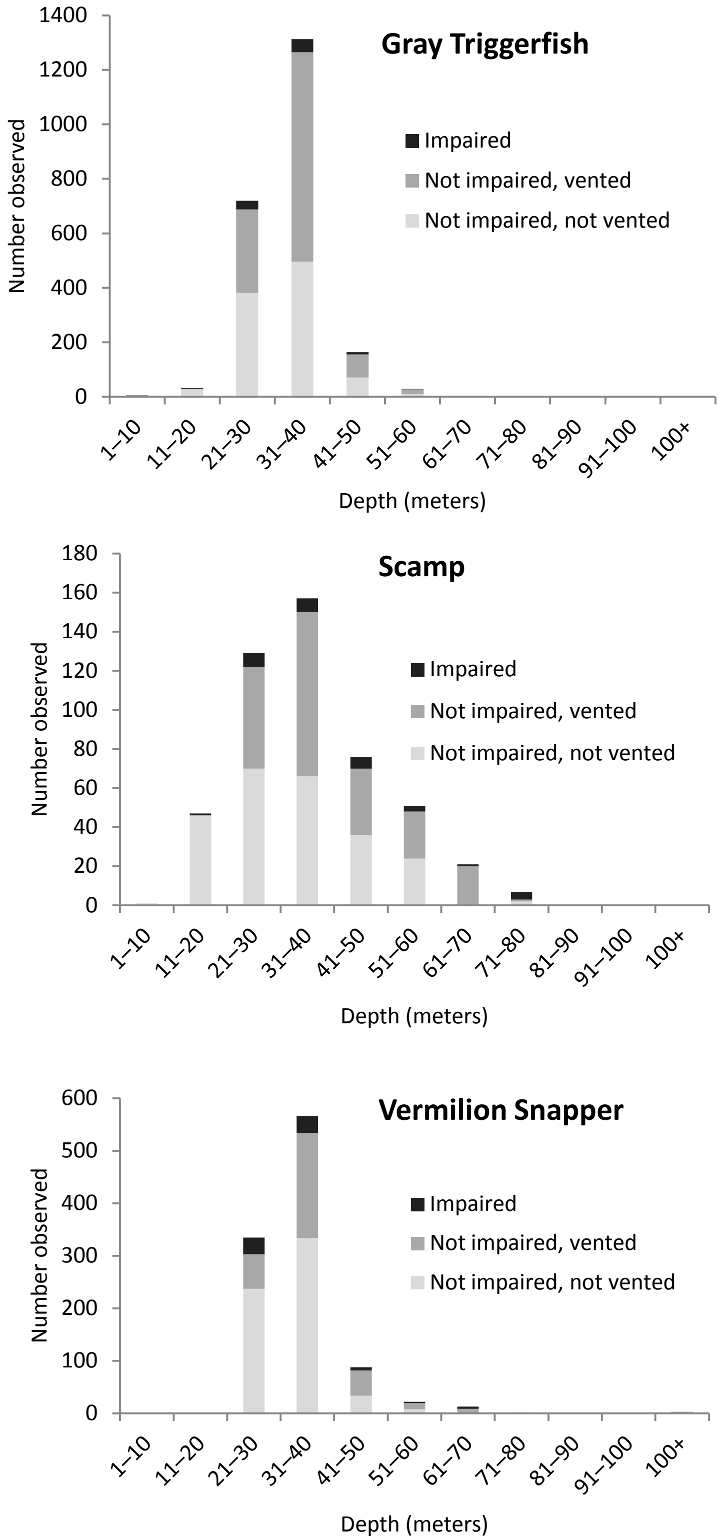

Figure 2.17. Numbers of gray triggerfish, scamp, and vermilion snapper discards observed by depth interval that submerged immediately without the need for venting, submerged immediately and were vented, or that suffered one or more impairments (vented or unvented fish that were disoriented or remained floating on the surface, internal hook injuries, or visible injury to the gills).

Table 2.16. Summary of the proportional-hazard model forward selection of independent variables on the number of days fish were at large before they were either reported as recaptured or censored at the end of the study without having been recaptured. Models for each species were stratified by year of entry. Variables tested during the forward-selection procedure include region of capture, length at time of capture, capture month, depth of capture, and all possible interactions.

	Effect entered	df	χ^2	*p*
Gag	Region	2	22.406	<0.0001
	Condition category	2	6.482	0.039
	Length	1	5.350	0.021
	Month	11	18.376	0.073
	Length*month	11	21.221	0.031
	Length*region	1	5.172	0.075
Red grouper	Month	11	89.720	<0.0001
	Length	1	47.590	<0.0001
	Condition category	2	27.007	<0.0001
	Region	2	19.709	<0.0001
	Length*month	11	26.741	0.005
Red snapper (Tampa Bay nearshore region excluded due to low sample size)	Length	1	197.902	<0.0001
	Condition category	2	96.222	<0.0001
	Month	11	53.386	<0.0001
	Depth	1	13.428	0.0002
	Depth*month	11	21.769	0.0262
	Length*month	11	14.515	0.2058

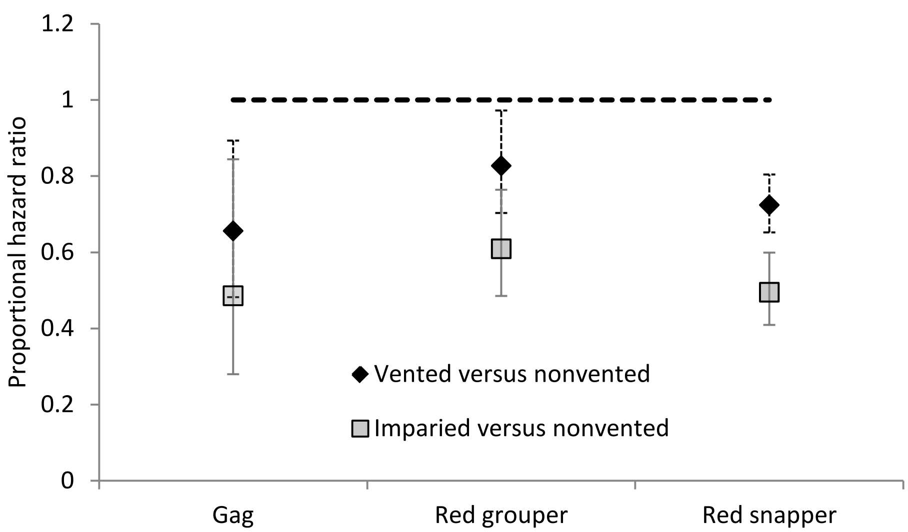

Figure 2.18. Proportional hazard ratios and 95% confidence intervals for fish that were vented (and not impaired) prior to release and that were impaired (regardless of venting), both referenced against fish that were released in the best condition category (neither vented or impaired). Hazard ratios <1.0 indicate survival was reduced relative to the reference group, and the difference is significant if confidence intervals do not overlap 1.0 (dashed line). For example, a point estimate of 0.60 indicates fish in the treatment group are 60% as likely to survive compared to the reference group.

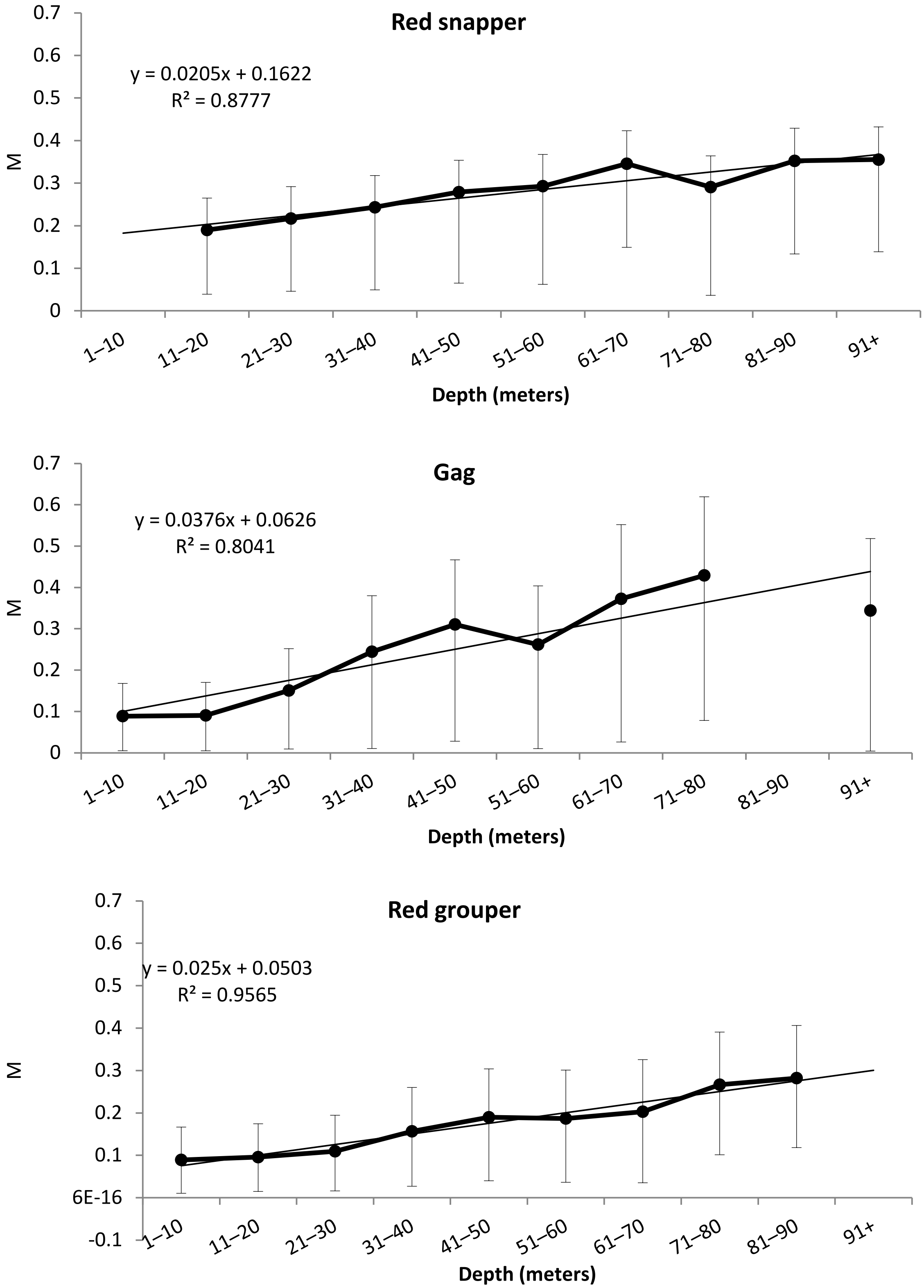

Figure 2.19. Estimated proportions of live discards that suffer mortality based on release conditions for discards observed from each depth interval. Assumes 0% to 15% (median 7.5%) mortality for fish that were not impaired and submerged without venting.

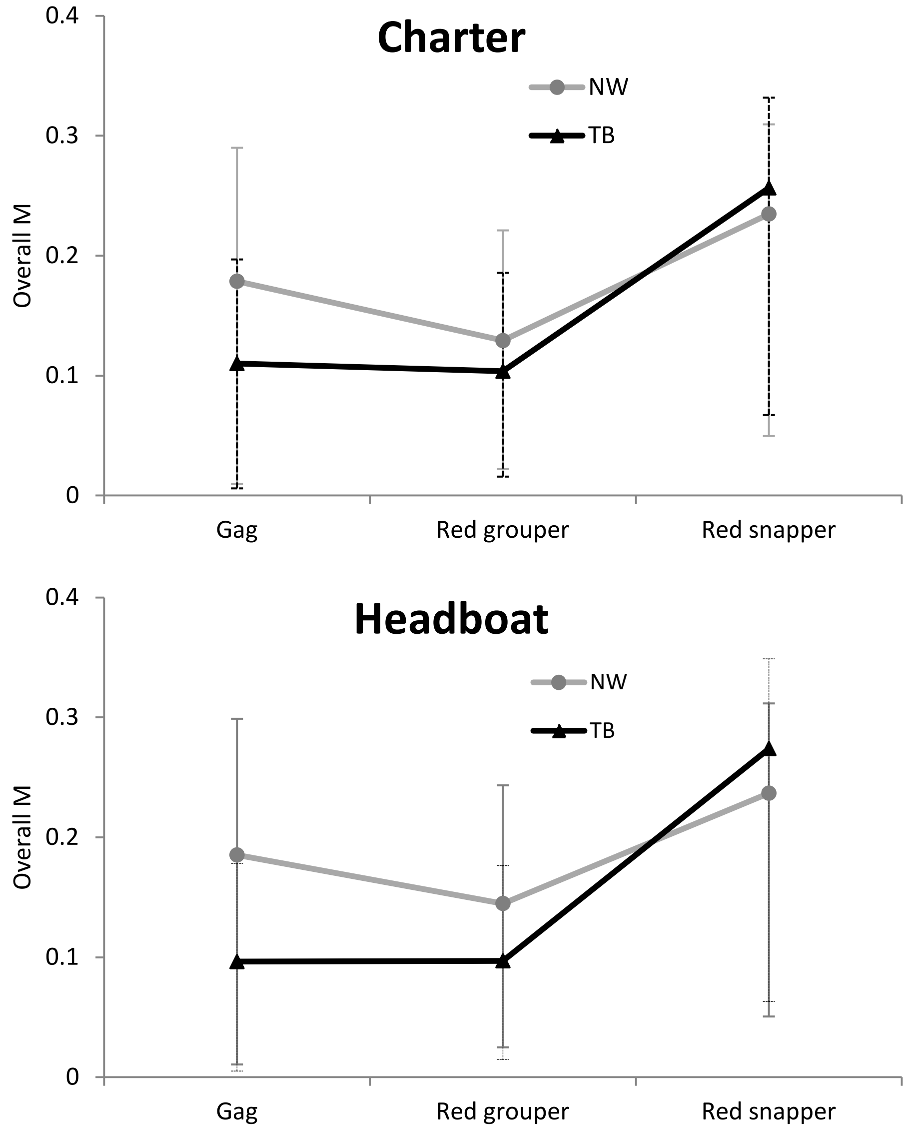

Figure 2.20. Estimated discard mortality over all depths, weighted proportional to fishing effort.

2.3 Conclusions

The results from this study indicate there are several key differences between regions and among trip types that should be accounted for when applying discard mortality rates to the reef fish fishery as a whole. First, regional differences in accessibility to deep water and the relative proportion of trips that take place at varied depths within each region should be considered when applying depth-dependent discard mortality rates. Exposure studies indicate that depth-dependent mortality for various reef fishes is low at shallow depths (<20m), increases to between 20% - 40% (depending on the species) at capture depths below a threshold between 30 or 40 meters, and mortality exponentially increases beyond the threshold at deeper depths (Wilson and Burns, 1996; Rummer, 2007; Rummer and Bennet, 2005; Rudershausen et al., 2014). Results reported herein also support this conclusion. In the TB region, the majority of trips take place in mean depths <20m and In the NW region, most fishing effort takes place in mean depths of 40 meters or less. Multi-day trips take place in deeper depths above the threshold for high mortality rates; however, these trips account for less than 3% of total fishing effort. Consequently, understanding where and how recreational fisheries operate is critical when assessing catch-and-release mortality. If this information is known, depth-dependent discard mortality relationships described by studies such as this one may be applied to other recreational hook-and-line fisheries for which it is less feasible to measure discard mortality directly, such as the private boat fishery.

Variable effects of circle hooks and release methods (venting versus releasing without venting) also demonstrate the importance of monitoring within a fishery, both for quantifying discard mortalities and changes in fishing behaviors in response to regulations. For species with high discard rates, even low percentage reductions for discards that suffer mortality can have a significant impact on total fishery removals. Red grouper discard ratios in the TB region ranged between 8 and 32 fish released for every fish harvested during any given year (Table 2.12). Except for a brief closure February-March during the years of this study, red grouper was open to recreational harvest year-round and it is clear from the size distribution of discards that the majority of grouper that are vulnerable to capture are under the legal harvest size. Even small percentage reductions in mortality attributed to the use of circle hooks for species with high rates of discarding, such as red grouper, can equate to substantial reductions in total removals attributed to the fishery. Red snapper are discarded at lower rates compared to red grouper, but discards are still a substantial portion of total removals and this species appears to be more vulnerable to hook injuries; therefore, this species may particularly benefit from larger reductions in discard mortality through the use of circle hooks. Results from this study also indicate that fish that can re-submerge on their own have a higher rate of survival if they are not vented, but may benefit from venting when it helps them re-submerge. Recent rule changes in the Gulf that removed the requirement to vent reef fishes give anglers more discretion for how to release fish. In light of these results, outreach that provides anglers with best practice guidelines to help maximize survival of released fish could be most beneficial.

Section 3:

Comparison of Discards Observed in the For-Hire Fishery with Voluntary Angler Reported Discards Collected from the Private Boat Recreational Fishery; and Feasibility of a Random Survey of State Licensed Anglers to Estimate Participation, Effort, and Harvest

3.1 Methods

3.1.1 Private Boat Red Snapper Catch Cards

Pre-printed postage-paid catch logs were freely distributed to red snapper private boat recreational anglers in Florida (Appendix C). Catch logs were given to anglers and placed on windshields at fishing access points, supplied to participating bait and tackle shops and organized fishing clubs, handed out during public fishing shows and other outreach venues, and made available on FWC's public website (http://www.myfwc.com/media/202837/OnlineCatchCard.pdf). An email address was also available on the FWC website for the public to request a personal supply of postage-paid catch logs mailed to their address. The catch log was designed for anglers to take with them during a recreational fishing trip and included a matrix to keep a running tally of red snapper by size category and hook location as they were caught and released during a single fishing trip (Table 3.1). Size categories (in inches) were: up to 10"; >10" to 12"; >12" to 14"; >14" to 16"; and >16" total length. Other data fields on the catch log included:

- date and time of departure and return
- city or county the trip originated from
- type of access point (public boat ramp, private marina, dry storage, private dock)
- type of trip (private recreational, for-hire, commercial, tournament)
- number of people that fished on the boat
- distance from shore and depths fished (including minimum, maximum, and majority of fishing time)
- type of gear used (non-offset circle hook, offset circle hook, J hook, or other including spear gun)
- number of red snapper harvested, released dead, and eaten by predators
- whether the respondent had participated in the catch card survey before

Participants who filled out and returned a catch log were sent a free adhesive fish measurement ruler that could be placed on their boat or cooler and a supply of postage paid catch cards for use during future trips.

Trips reported on catch cards were categorized into three single-day trip categories that matched those used for for-hire trips discussed in Section 2:

- Half-Day: < 6 hours
- Three-Quarter-Day: 6 hours to <9 hours
- Full-day: 9 hours to <24 hours

Analyses were focused on the NW region where the majority of private boat fishing interactions with red snapper takes place. Since red snapper are more abundant in the NW region, distribution efforts were more successful at getting catch cards into the hands of participants in the fishery and the cards were widely distributed. Since effort by trip duration is not quantified for private boats, no attempt was made to weight catch card data by trip-type. Instead, data from each trip type was compared directly with data of the same trip type from charter boats and headboats. A generalized linear model (glm) was used to compare least square means for average depths fished during private boat trips versus charter and headboat trips within trip types (half day, ¾ day, and full day trips). P values were adjusted for multiple comparisons using the Tukey-Kramer option in SAS. To compare the relative proportions of red snapper released in different size categories, the proportions of red snapper released in each size category were calculated for each catch card trip report. Red snapper that were measured during sampled trips on charter boats and headboats were also grouped into the same size categories, and proportions for each category were calculated for each sampled trip. The slope for the linear trend in the proportions of discarded fish with increasing size class, controlling for the effect of trip duration (to the nearest hour), was compared among each fleet in a general linear model to test for significant differences.

Table 3.1: Matrix on catch logs where recreational anglers were asked to keep a running tally of red snapper discards by size category and hook location.

HOOK LOCATION	LIP/MOUTH	THROAT	GILL	GUT	EYE	EXTERNAL
10” or less						
More than 10” up to 12”	l					
More than 12” up to 14”						
More than 14” up to 16”						
More than 16”						

3.1.2 Saltwater Angler License Survey

A mail survey of licensed saltwater anglers designed to estimate the portion of licensed saltwater anglers that participate in the Gulf of Mexico red snapper fishery, where trips originate from, and the relative proportions of trips take place in various regions of the west coast of Florida was developed and implemented in November, 2009. A state-issued saltwater fishing license is required to fish for red snapper from a private boat in Florida. Exceptions to the license requirement include minors under 16 years of age and resident seniors 65 years of age and older. No special endorsement is required to fish for red snapper or other reef fishes in the Gulf of Mexico; therefore, the sample universe is defined as all licensed saltwater anglers. A random sample of 3% of licensed saltwater anglers was selected each month, which equated to between 3,500 and 3,800 licenses per month. Samples of resident and non-resident licenses were selected proportionally, with 36% of the sample representing non-resident license holders and 64% representing resident license holders. Within the 64% sample of Florida resident license holders, 60% were selected from residents that lived in counties adjacent to the Gulf of Mexico from the Florida panhandle to Sarasota County, where red snapper fishing is most prevalent. The remaining 40% of the resident sample was drawn from license holders that lived in other parts of the state, including southwest Florida, inland counties, and the Atlantic coast.

A pre-notification postcard was mailed to selected license-holders two weeks prior to the survey period. The postcard notified the survey participant that they were selected for a survey of reef fish fishing in the Gulf of Mexico and would be receiving a survey in the mail in the next two weeks. The postcard also included a web address for participants who preferred to fill out the survey on-line. For the portion of selected licenses that also had an e-mail address listed in the contact information, license holders also received an e-mail with reminders asking them to participate in the survey. Up to two follow-up mail surveys were sent to late respondents to evaluate non-response bias. To account for under-coverage for anglers 16 years of age and younger, the mail and web surveys collected information on party size and number of youth anglers for reported trips. Under-coverage for anglers 65 years of age and older was partially addressed by this method; however, it did not account for seniors who do not fish in parties that include licensed anglers.

3.1.3 Analyses

Data collected from catch cards may be combined with proportional effort from the license survey to estimate the proportions of discarded red snapper by depth. The magnitude (in numbers) of red snapper discarded by private boats is estimated by the Marine Recreational Information Program (MRIP), and proportions of red snapper trips and fish discarded by depth may be applied to total MRIP discard estimates to calculate the estimated numbers of red snapper released at 10 meter depth intervals. Total mortalities may then be estimated by applying depth-dependent discard mortality percentages derived from the tag-recapture model described in Section 2. For reasons discussed in section 3.2, these combined analyses could not be completed.

3.2 Results

3.2.1 Private Boat Red Snapper Catch Cards

From June 2009 through December 2013, a total of 503 individual catch cards were returned from private boat trips that took place within in the study area (Table 3.2). Results presented here focus on the NW region, where the majority of cards were returned throughout the year during each year of the study. This is also where the majority of private boat fishing interactions with red snapper takes place.

Average fishing depths for half day, ¾ day and full day trips reported on catch cards were compared to depths recorded during for-hire trips sampled by fishery observers (Table 3.3 and Figure 3.1). Average depths fished from private boats during half day and ¾ day trips were shallower than charter boat and headboat trips of the same duration ($p<0.001$); however, for full day trips there was no significant difference in average depths fished ($p=1.0$). More than 90% of red snapper released were not deep hooked or foul-hooked, and more than half of fish released were greater than the minimum size limit of 16” total length (Table 3.4). The mean proportions of red snapper discards from private boat trips that were reported for various size categories on catch cards are plotted in Figure 3.2. For comparison, red snapper discards observed during sampled charter boat and headboat trips were grouped to the same size categories and the mean proportions per sampled trip are also plotted in Figure 3.2. There is an apparent departure between the sizes of red snapper discarded on full day headboat trips compared to charter boats and private boats (bottom panel, Figure 3.2). However, within each trip type the confidence intervals around mean proportions between private boat trips and charter boat trips overlap in nearly every size category. A generalized linear model was used to compare the increase in proportion of catch with increasing size category of red snapper among vessel types, controlling for any potential effects of trip duration, and there were no significant differences between private boats and charter boats or headboats. Therefore, detailed size distribution of discarded fish measured in the for-hire fishery with observers may be useful for making inferences about the size distribution of discards from private boat trips.

Table 3.2. Number of volunteer angler red snapper catch logs received by month and year. NW=northwest Florida, BB=big bend, TB=greater Tampa Bay area.

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2009	NW						14	29	48	9	7	6	1	114
	BB													
	TB						2		1					3
2010	NW	2	1	6	20	13	27	6	1	3	21	3	1	104
	BB				1		5			2	7		2	17
	TB						6							6
2011	NW	1		1	7	3	26	22	9	4	3		2	78
	BB			2	2	1	5	2						12
	TB						6	1						7
2012	NW	6	3	15	4	12	26	27	5	8	3	2		111
	BB						4	1						5
	TB						1			1	1			3
2013	NW	1	1	2	3	4	11	4		2	10	1		39
	BB				1	3								4
	TB													

Table 3.3. Least square means for average depth fished (in meters) from the generalized linear model comparing depths fished by vessel type and trip type in the NW region. * Indicates means for private boats that are significantly different from other vessel types within the same trip type.

Vessel type	Half day	¾ day	Full day
Private boats	23.95*	27.11*	36.47
Charter boats	26.92	32.60	35.96
Headboats	27.83	34.16	36.67

Table 3.4. Numbers of red snapper reported on catch cards in the NW region in each size category and hook location category by trip type.

Trip type	Size category	Lip	Throat	Gill	Gut	Eye	External	Totals	Proportion
Half day trips n=149	Up to 10"	64	1	0	1	1	0	67	0.036
	>10" up to 12"	117	20	1	1	0	0	139	0.075
	>12" up to 14"	195	30	0	2	0	0	227	0.123
	>14" up to 16"	377	26	0	3	0	0	406	0.220
	>16"	927	46	4	23	0	8	1,008	0.546
	Totals	1,680	123	5	30	1	8	1,847	
	Proportion	0.910	0.067	0.003	0.016	0.001	0.004		
3/4 day trips n=196	Up to 10"	120	6	0	2	1	0	129	0.035
	>10" up to 12"	310	21	1	10	0	0	342	0.091
	>12" up to 14"	425	26	0	6	1	2	460	0.123
	>14" up to 16"	736	52	10	18	1	3	820	0.219
	>16"	1,845	84	11	42	1	4	1,987	0.532
	Totals	3,436	189	22	78	4	9	3,738	
	Proportion	0.919	0.051	0.006	0.021	0.001	0.002		
Full day trips n=90	Up to 10"	85	7	0	1	0	0	93	0.060
	>10" up to 12"	138	5	2	5	0	1	151	0.097
	>12" up to 14"	143	13	3	3	0	0	162	0.104
	>14" up to 16"	208	19	0	9	0	0	236	0.152
	>16"	868	24	0	19	0	2	913	0.587
	Totals	1,442	68	5	37	0	3	1,555	
	Proportion	0.927	0.044	0.003	0.024	0.000	0.002		

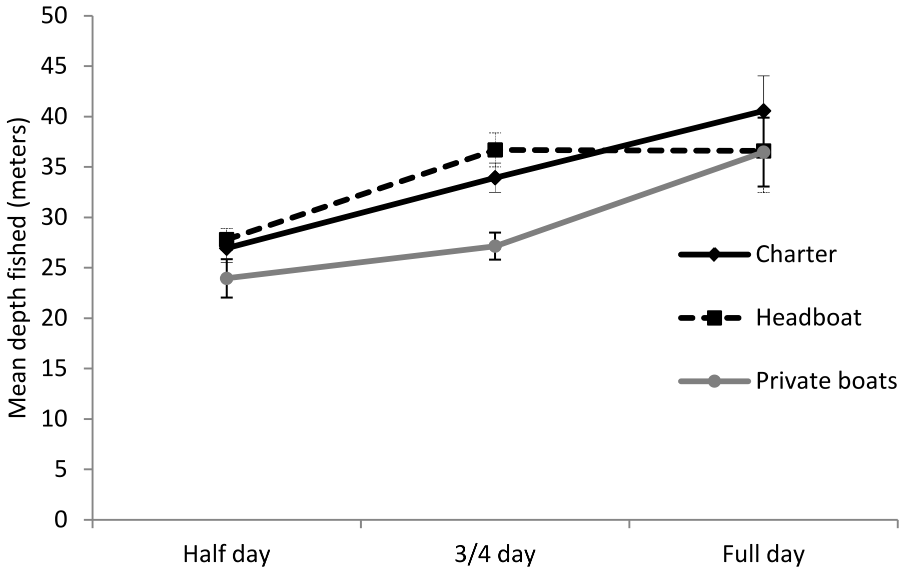

Figure 3.1. Average depth fished in the NW region during half day, ¾ day and full day trips reported on catch cards for private boats, versus sampled charter boat and headboat trips.

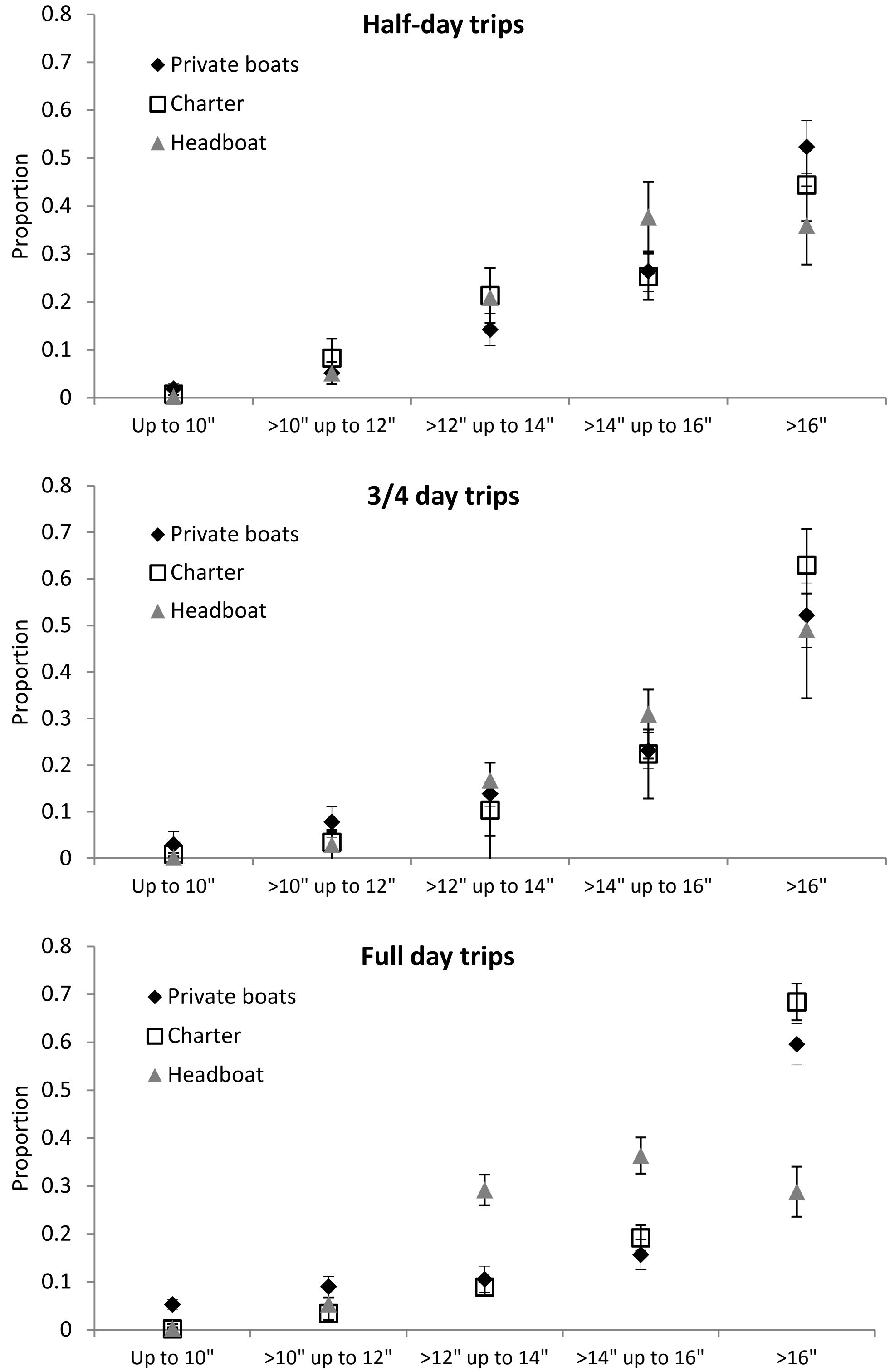

Figure 3.2. Proportions of red snapper discarded by size class reported on catch cards from private boat trips in the NW region versus observed during sampled trips on charter boats and headboats.

3.2.2 Saltwater License Angler Survey

The Saltwater License Angler Survey was initiated in November 2009. The percentage of selected license holders that returned surveys either by mail or electronically was low during every month that the survey was conducted, and averaged less than 10% (Table 3.5). Response rates less than 40% are not accepted as a credible survey that is representative of the population sampled, and the survey was discontinued after August, 2010. No further results are presented because there was no way to account for potential biases in the responses received due to the very high percentage of surveys that were not returned.

Table 3.5. Total numbers of state saltwater licenses selected each month, numbers of mail surveys that were returned undeliverable (U= unknown, records not retained), numbers of responses received by mail and internet, and overall response (expressed as percentage of number selected).

	Selected	Undeliverable by mail	Responses	Overall response (%)
Nov-09	3,567	130	161	4.51
Dec-09	3,567	U	668	18.73
Jan-10	3,567	U	437	12.25
Feb-10	3,567	U	216	6.06
Mar-10	3,567	100	270	7.57
Apr-10	3,567	11	250	7.01
May-10	3,795	150	165	4.35
Jun-10	3,795	122	292	7.69
Jul-10	3,795	245	533	14.04
Aug-10	3,795	132	363	9.57
Totals	**36,582**	**890**	**3,355**	**9.17**

3.3 Conclusions

Within the context of depth-dependent discard mortality, the significance of the shallower mean depths fished by private boats during half-day and ¾ day trip types does not equate to a large percent reduction in discard mortalities. Point estimates for red snapper discard mortality presented in Section 2 of this report are 0.217 between depths of 21–30 meters and 0.243 between depths of 31–40 meters, which means mortality is 2.6% higher for headboat and charter boats fishing in slightly deeper depths during ¾ day trips. However, the magnitude of discards for red snapper is much greater in the private boat fishery, and a savings of 2.6% could potentially equate to a large number of fish if a major portion of private boat effort is made up of ¾ day trips. Therefore, it is important to collect trip level information from the private boat fishery to discern differences in depths fished and the amounts of effort expended at different depths. However, the size of red snapper discarded in the private boat fishery appears to be similar to what can be readily observed on charter boats, and this information may not be necessary to collect directly from private boat trips. Detailed data on the size of discarded fish is much more difficult to collect from private recreational boats, since this information cannot be recalled accurately in dockside surveys, at-sea observer programs are not practical, and video monitoring may be considered too intrusive. Electronic reporting tools, such as smart phone apps, could be promising for collecting this type of data on a voluntary basis from private recreational anglers. However, data collected through self-selected reporting systems such as phone apps or the catch card utilized in this study, should be coupled with a statistically valid data source such as the fishery observer data collected in this study. This coupling of data sources allows for analyses to be based on common factors, such as trip duration or depths fished, and potential biases which may not be accounted for can at least be partitioned out. Inferences about the overall fishery can then be made using unbiased estimates of total catch or effort. However, the Marine Recreational Information Program currently partitions private boat effort into broad areas (greater than or less than 10 miles from shore for the Gulf coast of Florida), and does not collect more detailed information that would allow for the partitioning of effort into finer spatial scales. Methods tested in this study to achieve this goal were unsuccessful, and alternative methods should be pursued in the future to collect this critical data from the private boat-based recreational fishery.

Since the proportion of recreational fishing effort by depth in each region could not be estimated from the Saltwater License Survey, the total estimated number of red snapper discards by depth and associated discard mortality also could not be estimated in this study. This will continue to be a critical data need for stock assessments into the foreseeable future. However, direct comparisons between private boat trips and for-hire trips resulting from this study demonstrate significant parallels between the two fisheries that may better inform stock assessments in the near-term. This study also demonstrates the utility of combining high resolution fishery observer data obtained from the for-hire fishery with supplemental data from the private boat fishery to achieve dual goals. Data collected from the for-hire fishery was informative for characterizing this particular segment of the fishery and for evaluating the relative impacts of hook-and-line fishing on the discarded portion of fish, as well as making inferences about the overall impacts of recreational hook-and-line fisheries, including the private boat segment.

The general population of non-resident and statewide resident license holders was not a viable sample universe for surveys directed specifically to red snapper fishing in the Gulf of Mexico. Sample strata included visitors that purchased a temporary non-resident fishing license that could be used to fish in any part of the state, and resident anglers throughout the state who could potentially use their fishing license to fish in any estuarine or marine water body anywhere in the state. Given the short distance between the Atlantic and Gulf coasts of the state, it is feasible for resident license holders in central areas, such as the densely populated area around Orlando, to travel to either side of the Florida peninsula to saltwater fish. State fishing licenses are also required to fish for a variety of invertebrate species throughout the state. A special endorsement must be purchased in addition to the general fishing license to harvest spiny lobster, and this endorsement is used by FWC to conduct annual surveys that are used successfully to estimate participation, effort and harvest during harvest seasons (Sharpe et al, 2005). Response rates for the spiny lobster survey have ranged between 40% and 63%, though there has been a steady decline over time (Sharpe et al., 2005). Nonetheless, when compared to response rates for this survey that focused on the red snapper fishery but sampled the entire population of license holders, the use of an endorsement or other method to identify a sub-population of license holders is an effective tool to improve response rates and better direct surveys for specialized fisheries.

During 2013, FWC convened a series of working group meetings and conference calls with a small group of stakeholders to develop a plan for implementing a special permit or registration requirement for reef fish anglers in the Gulf of Mexico. In early 2014, the concept was presented during a series of open public meetings from Naples through Pensacola. The Division of Marine Fisheries Management is currently in the process of evaluating responses from those meetings and will report findings to the Commission for their consideration in decision making. PI’s from this project are also participating in workshops hosted by Gulf States Marine Fisheries Commission in collaboration with the Marine Recreational Information

Program (MRIP) to develop pilot studies throughout the Gulf region that are designed to produce improved catch and effort estimates for red snapper. Knowledge and information gained as a result of this study will help guide the design and future implementation of directed red snapper surveys in Florida.

References

Bachelor, N.M., J.E.Hightower, S.M. Burdick, L.M. Paramore, J.A. Buckel and K.H. Pollock. 2010. Using generalized linear models to estimate selectivity from short-term recoveries of tagged red drum *Sciaenops ocellatus*: Effects of gear, fate, and regulation period. Fisheries Research 102: 266-275.

Campbell, M.D., W.B. Driggers and B. Sauls. 2012. Release mortality in the red snapper fishery: a synopsis of three decades of research. SEDAR31-DW22.

Cody, R. P., and J.K. Smith. 2006. Applied statistics and the SAS programming language (5th ed.). Upper Saddle River, NJ: Pearson Prentice Hall.

Clarke, K.R., and R.N. Gorley. 2006. PRIMER v6: User Manual/Tutorial, Primer-E, Ltd. Plymouth, U.K. 190pp.

Cooke, S.J. and C.D. Suski. 2004. Are circle hooks an effective tool for conserving marine and freshwater recreational catch-and-release fisheries? Aquatic Conservation: Mar. Freshw. Ecosyst. 14: 299-326.

Coleman, F., Figueira, W., Ueland, J., Crowder, L., 2004. The impact of United States recreational fisheries on marine populations. Science 305, 1958–1960.

Figueira, W.F. and F.C. Coleman. 2010. Comparing landings of United States fishery sectors. Bulletin of Marine Science 86: 499-514.

Fleiss, J.L., B. Levin and M.C. Paik. 2003. *Statistical Methods for Rates and Proportions*, 3rd edition. Wiley series in probability and statistics. John Wiley & Sons, Inc. Hoboken, NJ. 760 pp.

McGovern, J.C., G.R. Sedberry, H. Meister, T.M. Westendorff, D. Wyanski and P.J. Harris. 2005. A tag and recapture study of gag, Mycteroperca microlepis, off the southeastern U.S. Bull. Mar. Sci. 76:47-59.

Monson, R.R. 1980. *Essential Epidemiology, Principles and Applications*. CRC Press, Boca Raton, FL. 368 pp.

Myers, R.A. and J.M. Hoenig. 1997. Direct estimates of gear selectivity from multiple tagging experiments. Canadian J. Fisheries and Aquatic Science. 54: 1-9.

Quinn, G.P, and M.J. Keough. 2002. *Experimental Design and Data Analysis for Biologists*. Cambridge University Press. 537 pp.

Rudershausen, P.J., J.A. Buckel and J.E. Hightower. 2014. Estimating reef fish discard mortality using surface and bottom tagging: effects of hook injury and barotraumas. Canadian Journal of Fisheries and Aquatic Sciences 0(0): 1-7, e-first article 10.1139/cjfas-2013-0337.

Rummer, J.L. 2007. Factors affecting catch and release (CAR) mortality in fish: insight into CAR mortality in red snapper and the influence of catastrophic decompression. Amer. Fish. Soc. Symp. 60: 123-144.

Rummer, J.L. and W.A. Bennett. 2005. Physiological effects of swim bladder overexpansion and catastrophic decompression on red snapper. Trans. Amer. Fish. Soc. 134: 1457-1470.

Sauls, B. 2013. Relative survival of gags *Mycteroperca microlepis* released within a recreational hook-and-line fishery: application of the Cox regression model to control for heterogeneity in a large-scale mark-recapture study. Master's Thesis presented to University of South Florida, Department of Marine Science, Marine Resource Assessment Program.
Accessed 3/17/14 at: http://pqdtopen.proquest.com/pqdtopen/doc/1474904021.html?FMT=ABS

Sauls, B. 2014. Relative survival of gags *Mycteroperca microlepis* released within a recreational hook-and-line fishery: application of the Cox regression model to control for heterogeneity in a large-scale mark-recapture study. Fisheries Research 150: 18-27.

Sauls, B. and O. Ayala. 2012. Circle hook requirements in the Gulf of Mexico: application in recreational fisheries and effectiveness for conservation of reef fishes. Bull. Mar. Sci. 88: 667–979.

SEDAR (Southeast Data, Assessment, and Review), 2012. SEDAR 31 Section II: Data Workshop Report, Gulf of Mexico Red Snapper. SEDAR, North Charleston, SC. Accessed 3/23/2014 www.sefsc.noaa.gov/sedar

SEDAR (Southeast Data, Assessment, and Review), 2013. SEDAR 33 Section II: Data Workshop Report, Gulf of Mexico Gag. SEDAR, North Charleston, SC. Accessed 3/23/2014 www.sefsc.noaa.gov/sedar

Sharpe, W.C., R.D. Bertelsen, and V.R. Leeworthy. 2005. Long-term trends in the recreational lobster fishery of Florida, United States: landings, effort and implications for management. New Zealand Journal of Marine and Freshwater Research. 39: 733-747.

Stokes, M.E., C.S. Davis, G.G.Koch. 2000. Categorical Data Analysis Using the SAS System, Second Edition. SAS Institute and Wiley Interscience.

Van Voorhees, D., T. Sminkey, J. Schlechte, D. Donaldson, K. Anson, J. O'Hop, M. Norris, J. Shepherd, T. Van Devender, and B. Zales. 2002. The new Marine Recreational Fisheries Statistics Survey method for estimating charter boat fishing effort. Gulf and Caribbean Fisheries Institute. 53: 332-343. http://research.myfwc.com/publications/publication_info.asp?id=41919

Wilson, R., Burns, K.M., 1996. Potential survival of released groupers caught deeper than 40m based on shipboard and in-situ observations, and mark-recapture data. Bull. Mar. Sci. 58, 234–247.

Zhang, J. and K.F. Yu. 1998. What's the relative risk? A method of correcting the odds ratio in cohort studies of common outcomes. J. Amer. Med. Assoc., 280 (19): 1690-1691.

BULLETIN OF MARINE SCIENCE. 88(3):667–679. 2012
http://dx.doi.org/10.5343/bms.2011.1055

CIRCLE HOOK REQUIREMENTS IN THE GULF OF MEXICO: APPLICATION IN RECREATIONAL FISHERIES AND EFFECTIVENESS FOR CONSERVATION OF REEF FISHES

Beverly Sauls and Oscar Ayala

ABSTRACT

In 2008, recreational anglers in the US Gulf of Mexico were required to use circle hooks when catching federally managed reef fishes (50 C.F.R. 622.41). From June 2009 through November 2010, we observed recreational hook-and-line fishing during for-hire trips off the west coast of Florida. Anglers used circle hooks and other hook types in a wide range of sizes from a variety of manufacturers. The present study evaluated the effectiveness of circle hooks toward reducing potentially lethal hooking injuries and the number of undersized reef fishes caught in the Florida recreational fishery. For seven out of 10 species evaluated, there were significant reductions in potentially lethal injuries for fish caught with circle hooks compared to all other hook types. Overall, reductions ranged from 30% to 93%. Potentially lethal injuries for red snapper [*Lutjanus campechanus* (Poey, 1860)] were reduced to 6.3% with circle hooks (from 17.1% with other hook types), which was a 63.5% reduction. For gag [*Mycteroperca microlepis* (Goode and Bean, 1879)] and scamp (*Mycteroperca phenax* Jordan and Swain, 1884) potentially lethal injuries were <5.5% for both circle hooks and other hook types and differences were not significant. There was no clear evidence that circle hooks reduced bycatch of undersized fishes when compared to J-hooks. There was an increase in mean fish length with increasing circle hook size for multiple species; however, r^2 values were low and much of the explained variance was unrelated to circle hook size.

The US Gulf of Mexico supports substantial, year-round recreational fisheries that are vital to local economies. In 2009, more than 23 million recreational fishing trips were made by residents and visitors to the region (NMFS 2010). For many fish stocks in the Gulf, recreational harvest constitutes a significant portion of total removals and can surpass commercial landings (Coleman et al. 2004). A primary target group for offshore recreational anglers in the Gulf of Mexico is the reef fish complex, which includes an assemblage of snappers (family Lutjanidae), groupers (Serranidae, subfamily Epinephilinae), triggerfishes (Balistidae), amberjacks (Carangidae), and other associated finfish species. Recreational fisheries for reef fishes historically have been regulated through harvest-control measures that include a suite of size limits, bag limits, and seasonal closures. In recent years, annual catch limits for federally managed stocks have required substantial adjustments in harvest controls to keep recreational landings within mandated limits. Harvest control measures, combined with sustained high levels of recreational fishing effort in the Gulf of Mexico, have resulted in increasing numbers of regulatory releases (Bartholomew and Bohnsack 2005, Hanson and Sauls 2011). In recent years, the released portion of the recreational catch of red snapper [*Lutjanus campechanus* (Poey, 1860)], gag [*Mycteroperca microlepis* (Goode and Bean, 1879)], and red grouper [*Epinephelus morio* (Valenciennes, 1828)] has exceeded 80% of total recreational catch from state and federal jurisdictions in the region (NMFS 2010). Recent research suggests that release mortality rates for reef fishes may be high due to a combination of factors, including hooking injuries and barotrauma (Burns et al. 2002, Burns and Wilson 2004, McGovern et al. 2005, St. John and Syers 2005, Rudershausen et al. 2007, Rummer 2007). When the released portion of total catch is high, post-release mortality has the potential to lead to recruitment overfishing (Coggins et al. 2007).

Amendment 27 to the Gulf of Mexico Reef Fish Fishery Management Plan (GMFMC 2007) explored several management options for minimizing catch-and-release mortality. In 2008, the Gulf of Mexico Fishery Management Council adopted the preferred management alternative requiring recreational anglers fishing in federal waters to use non–stainless steel circle hooks when catching reef fishes with natural bait (50 C.F.R. 622.41). A circle hook was defined by this regulation as "a fishing hook designed and manufactured so that the point is turned perpendicularly back to the shank to form a generally circular, or oval, shape." A minimum hook size to potentially reduce bycatch of undersized red snapper was also considered as an alternative management option but was not adopted. The State of Florida matched federal regulations for state territorial seas in the Gulf of Mexico in 2008, with the added specification that a circle hook must have 0° of offset (Florida Administrative Code § 68B-14.005).

The preferred management alternative in Amendment 27 was supported by a comprehensive meta-analysis, which reviewed 43 studies for 25 species and concluded that mortality rates were reduced by approximately 50% overall when circle hooks are used compared with J-hooks (Cooke and Suski 2004). Circle hooks had a greater tendency to set in the lip or jaw, resulting in fewer internal injuries for the majority of species studied. Amendment 27 cited additional studies suggesting circle hooks may be more size-selective than J-hooks, which could provide the added benefit of reducing regulatory discards of undersized fish. Cooke and Suski (2004) cautioned that management strategies should not incorporate circle hooks unless studies confirmed that their use had benefits for the particular species of concern. At the time when regulations were being considered in the Gulf of Mexico, studies to evaluate the potential benefits of circle hook use for reef fishes were limited and most available studies compared only select numbers of hook brands and sizes.

In the present study, we directly observed reef fishes caught in for-hire recreational fisheries that operate off the west coast of Florida. We compared hooking injury rates for fish caught with circle hooks and other types of hooks used in the recreational fishery. We evaluated size-selectivity of reef fishes captured with circle hooks and J-hooks in similar size categories to determine if circle hooks reduce bycatch of undersized fish. Additionally, we explored the potential for increasing size selectivity of reef fishes through the use of larger circle hooks in the recreational fishery. Analyses were conducted for eight species in the Gulf of Mexico reef fish complex that were most frequently encountered: red grouper, gag, scamp (*Mycteroperca phenax* Jordan and Swain, 1884), gray snapper [*Lutjanus griseus* (Linnaeus, 1758)], red snapper, vermilion snapper [*Romboplites aurorubens* (Cuvier, 1829)], greater amberjack [*Seriola dumerili* (Risso, 1810)], and gray triggerfish (*Balistes capriscus* Gmelin, 1789). Two unregulated species that are frequently targeted in the recreational fishery were also evaluated: white grunt [*Haemulon plumieri* (Lacépède, 1801)] and red porgy [*Pagrus pagrus* (Linnaeus, 1758)].

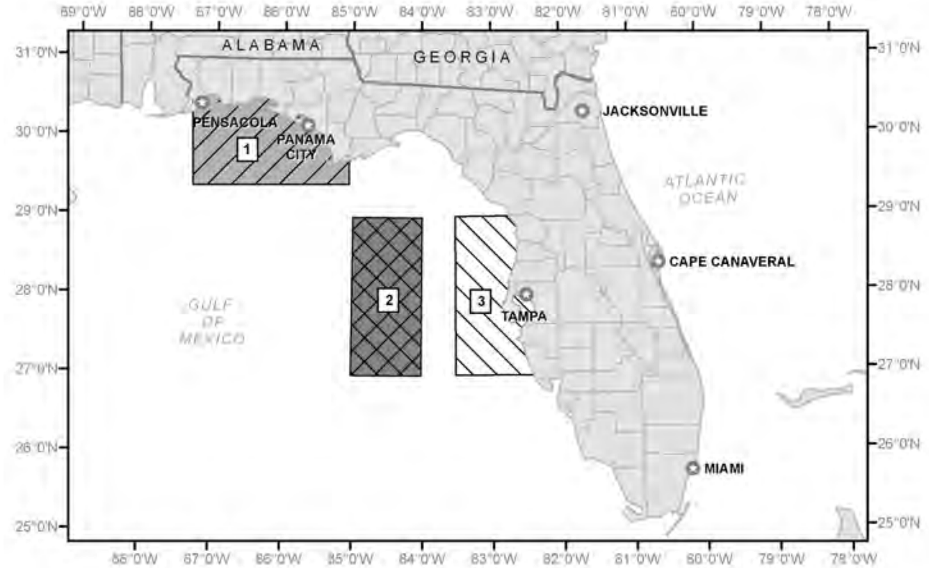

Figure 1. Study area in the Gulf of Mexico. 1 = area where single-day headboat, charter, and research trips from the Panhandle region took place; 2 = area where multi-day trips from Tampa Bay region took place; 3 = area where single-day charter and headboat trips from Tampa Bay region took place.

Methods

In June 2009, the State of Florida implemented a cooperative research project with operators of for-hire fishing vessels that offer recreational fishing trips in the Gulf of Mexico. A total of 166 private charter, large-party (headboat), and multi-day vessels from two regions were recruited into the voluntary study (Fig. 1). In each region, biologists were assigned to randomly selected vessels each week to observe recreational anglers during hook-and-line fishing. Biologists had no influence on recreational fishing during this fishery-dependent study. Between June 2009 and November 2010, 127 single-day trips (4–12 hrs) from headboat and charter vessels and 17 multiday trips (>24 hrs) were sampled in the Tampa Bay region, and 153 single-day trips from headboat and charter vessels were sampled in the Panhandle region. Included in this analysis are an additional 21 single-day research trips that targeted red snapper from charter vessels in the Panhandle region. During each research trip, four volunteer anglers fished with tackle chosen by the charter vessel operators and two volunteer anglers fished with circle hooks provided by the research team. Vessel operators provided bait and chose fishing locations without guidance from the research team.

During both research and randomly sampled trips, biologists visually inspected hooked fish prior to release or harvest and recorded the species, length at the fork or midline (mm), type of terminal tackle used for capture, and location where the hook was embedded (lip, mouth, gills, esophagus, stomach, or externally). Hook type was recorded as circle, J-type, or other (e.g., kahle, treble). Circle hooks and J-hooks from various manufacturers were sized by matching hooks to a printed chart of standard hook sizes (Fig. 2). Width of the bend, which is the curved section of the hook between the point and the shank, was used to group circle hooks and J-hooks into three similar-sized categories (small, medium, and large; Fig. 3).

We tested the hypothesis that circle hooks embedded in the lip or jaw (lip-hooking) more frequently than other hook types. Lip-hooking injuries were classified as non-lethal, whereas hook injuries in all other locations, including the eyes, gills, esophagus, stomach, or external

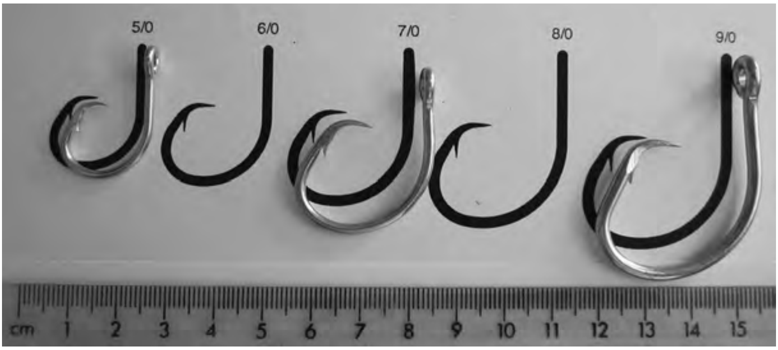

Figure 2. Example of a small, medium, and large circle hook matched to a chart used to record a standard size for different brands of hooks. For multiple comparison analyses, hook size categories included small (5/0 or smaller), medium (6/0, 7/0, and 8/0), and large (9/0 or larger).

areas of the body, were categorized as potentially lethal hooking injuries. For each species evaluated, we constructed a two-by-two contingency table to compare lip-hooking rates for circle hooks compared to the full range of other hook types observed in the recreational fishery. SAS software was used to calculate relative risks (RR) and 95% confidence intervals around RR values (Cody and Smith 2006). Relative risk for each species was calculated as the probability that circle hooks embed in the lip or jaw divided by the probability that other hook types embed in the lip or jaw. A RR value >1.0 indicated a positive effect for circle hooks and <1.0 indicated a negative effect for circle hooks. A RR value = 1.0 and/or a confidence interval that contained 1.0 indicated no effect for circle hooks.

The second hypothesis tested was that circle hooks caught larger fish than similar-sized J-hooks for each species evaluated. Only circle hooks and J-hooks were compared since other hook types could not be grouped into similar size categories. Differences in how hooks were baited to target different species could not be controlled in this study. Comparisons of mean fish length among hook type and hook size categories were made within similar trip types. Since the majority of J-hook observations were from the Tampa Bay region, we ran simple *t*-tests to determine whether mean fish length was significantly different between the two regions. For species that differed significantly in length between regions, observations from the Panhandle region were not included. Research trips were excluded because there were no J-hook observations. Multiday trips were also excluded, because two or more J-hooks were sometimes used together (with a single bait) during these trips and such observations could not be distinguished in our data. Due to low numbers of cell-level observations for large J-hooks, the large hook size category could not be included in multiple comparisons. To test for significant differences in mean fish lengths for each species, we used a general linear model (GLM) and adjusted for multiple comparisons using the Tukey-Kramer method (Cody and Smith 2006). Model parameters included hook type and size (medium circle, medium J, small circle, and small J), trip type (single-day headboat or single-day charter), and an interaction term.

The third hypothesis tested was that larger circle hooks were more selective and caught larger fish than smaller circle hooks. Separate GLMs using all circle hook observations from the Tampa Bay and Panhandle regions were used to compare mean lengths for fish caught with large, medium, and small circle hooks within four different trip types (single-day headboat, single-day charter, multiday, and red snapper research trips). Research trips were only evaluated for red snapper and gag, since numbers of observations for other species during those trips were low.

Hypotheses were developed to test the potential benefits of hook type and hook size for individual species within a multi-species fishery. A conservative, a priori alpha level (0.01) was selected that was sufficient to detect significant effects for a single species and minimize the probability of falsely concluding (by random chance) that the effects extend across multiple species.

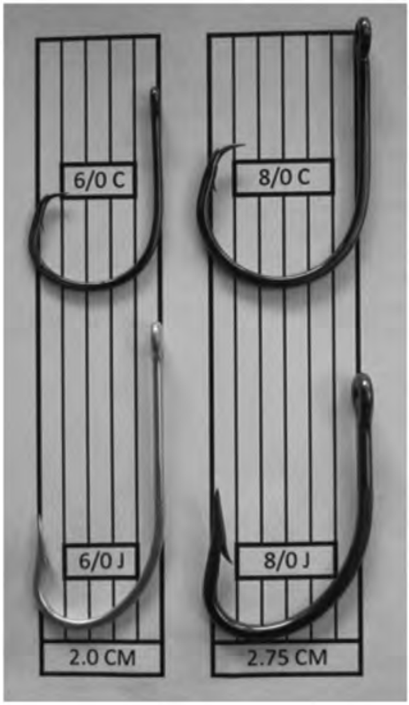

Figure 3. Examples of 6/0 and 8/0 circle hooks (top) and J-hooks (bottom) observed in the fishery. Width of the curved section between the point and the shank of the hook was used to group circle hooks and J-hooks into similar size categories.

Results

For seven out of 10 species evaluated, evidence was consistent with the hypothesis that circle hooks embed in the lip more often and result in fewer potentially lethal injuries than other hooks. The majority of observations for other hook types were made up of J-hooks (96%). For gag, scamp, and red porgy, potentially lethal hooking injuries were low (<5.5%) for both circle hooks and other hooks, and there was no appreciable difference in hooking injuries between hook types (Table 1). Results for the remainder of the 10 species evaluated were significant and RR indicated that fish were 1.04–1.13 times more likely to be exposed to a non-lethal injury (lip-hooked) when caught with circle hooks (Table 1). Across all species, there was a 30%–93% reduction in potentially lethal injuries for fishes caught with circle hooks compared to other hook types (Fig. 4). Potentially lethal injuries for red snapper decreased from 17.1% with other hook types to 6.3% with circle hooks (63.5% reduction), gray snapper decreased from 15.2% to 11.2% (29.7% reduction), and greater amberjack decreased from 13.9% to 3.5% (57.8% reduction). The percentage of potentially lethal injures with circle hooks was still relatively high for gray snapper and red snapper (11.2% and 6.3%, respectively) when compared with other species (5.4% for red grouper and from 0.3% to 3.8% for all other species).

There was no evidence to support the hypothesis that circle hooks are more selective and catch larger fish than J-hooks. For five species, mean fish lengths were

Table 1. Number of fishes observed (n) and percentage hooked in the lip or jaw area (lip-hooked) for circle hooks and other hook types. Values for relative risk (RR) and 95% confidence intervals (CI) around RR is the ratio of lip-hooked fish caught with circle hooks divided by lip-hooked fish caught with other hook types. RR values >1.00 indicate circle hooks have a positive effect. The effect of circle hooks is not significant when the 95% CI includes 1.00 (values in parentheses). Numbers of fish are not weighted with respect to fishing effort and should not be interpreted as a measure of compliance with circle hook requirements.

	Circle hooks		Other hooks		Relative risk	
	n	Lip-hooked	n	Lip-hooked	RR	95% CI
Red grouper	5,675	94.52%	1,969	90.66%	1.04	1.03, 1.06
Gag	1,433	96.23%	772	94.56%	1.02	(1.00, 1.04)
Scamp	363	97.80%	115	94.78%	1.03	(0.99, 1.08)
Gray snapper	770	88.83%	1,114	84.11%	1.06	1.02, 1.10
Red snapper	7,449	93.74%	589	82.85%	1.13	1.09, 1.17
Vermillion snapper	2,510	97.69%	795	94.21%	1.04	1.02, 1.06
Greater amberjack	693	96.54%	309	86.08%	1.12	1.07, 1.18
Gray triggerfish	593	99.66%	352	95.45%	1.04	1.02, 1.07
Red porgy	1,379	99.35%	465	97.85%	1.02	(1.00, 1.03)
White grunt	2,282	98.90%	1,346	89.75%	1.10	1.08, 1.12

significantly different between the Panhandle and Tampa Bay regions (Fig. 5). For those species, observations from the Panhandle region were not included in GLMs due to the low number of J-hook observations from that region. Among multiple comparisons for all species, only one significant difference in mean fish length between circle hooks and J-hooks was detected for gag caught with small hooks from headboats (Table 2). Model r^2 values were low for all species, and P values were not significant (alpha = 0.01) for gray snapper, vermilion snapper, and white grunt (Table 2). Hook type and size was not a significant factor for red snapper or gray triggerfish. Red porgy could not be evaluated due to a low number of J-hook observations.

There was a detectable increase in mean fish length with increasing circle hook size for multiple species (Fig. 6). However, r^2 values were low for all species and for all but three species (gray snapper, greater amberjack, and white grunt), trip type accounted for the largest proportion of explained variance (high F, Table 3). Circle hook size was a significant factor ($P < 0.01$) influencing fish length for red grouper, scamp, red snapper, vermilion snapper, white grunt, greater amberjack, and red porgy. However, the interaction term was significant for six species ($P \leq 0.01$), which may be attributed to differences in species targeted on headboat, charter, and multiday trips. For headboat trips, there were no significant differences among circle hook size categories for any species (Table 3). Headboat trips tended to target smaller fishes that are unregulated in the Gulf, including white grunt and red porgy, and squid was the primary bait type observed (57.2% of baits vs 40% on charter). For charter trips, mean size of fish increased significantly with increasing circle hook size for red grouper, scamp, red snapper, vermilion snapper, greater amberjack, and red porgy. Live baits and whole dead fish baits were more prevalent on charter trips (22.2% of baits vs 9.4% on headboats). Research trips were conducted similarly to charter trips and results of hook comparisons were consistent with those from charter trips. Multiday trip comparisons yielded conflicting results (smaller hooks caught significantly larger fish for some species). There was a smaller size range of circle hooks used on multiday trips compared to other trip types (Fig. 6), and >70% of baits were cut fish (vs <40% on charter and headboat), 13.8% were squid, and 11.8% were live.

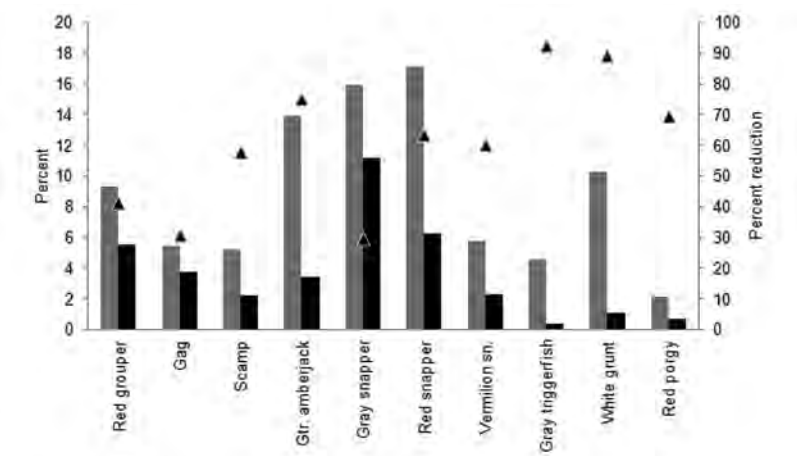

Figure 4. Percentage of fish, by species, that were hooked in the eyes, mouth, esophagus, gills, gut, or externally for circle hooks (black bars) and all other hook types (gray bars). Black triangles denote the percent reductions in potentially lethal hooking injuries for fish caught with circle hooks compared to other hook types. Note that differences between hook types for gag, scamp, and red porgy were not significant.

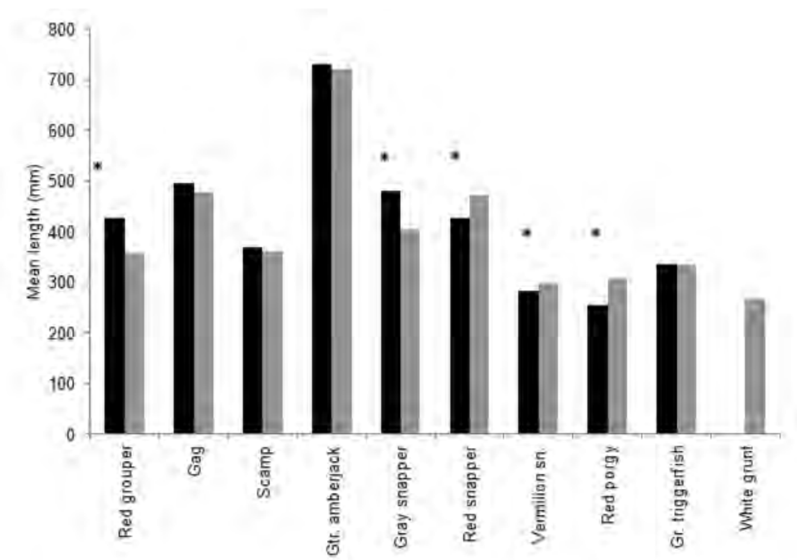

Figure 5. Mean length (mm at fork or midline) for the 10 most frequently encountered reef fish species in the Panhandle region (black bars) and Tampa Bay region (gray bars). Asterisks indicate *t*-test comparisons that were significant (alpha = 0.01).

Table 2. Results of general linear model analyses (r^2 = explained variance, P = significance) of fish length (mm fork or midline). Variables included in the model were hook type (small circle, small J, medium circle, medium J), trip type (charter, headboat) and interaction of hook type and trip type (H × T). Values for P in parentheses are not significant (alpha = 0.01). Multiple comparisons for each trip type among medium and small hooks indicate whether mean length of fish caught with circle hooks (C) was greater (>), less (<), or not significantly different (=) than mean length of fish caught with similar sized J-hooks (J). Comparisons were not made for hook types with fewer than 10 observations.

							Headboat		Charter	
Species	n	r^2	P	Hook type	Trip type	H × T	Med.	Small	Med.	Small
Red grouper	4,932	0.03	<0.0001	<0.0001	(0.94)	<0.0001	C = J	C = J	C = J	C = J
Gag	1,297	0.08	<0.0001	<0.01	<0.0001	(0.83)	C = J	C > J	C = J	C = J
Scamp	210	0.16	<0.0001	0.01	(0.04)	<0.01	C = J	C = J	C = J	C = J
Gray snapper	114	0.13	(0.04)	(0.02)	(0.19)	(0.18)	C = J	C = J	C = J	C = J
Red snapper	163	0.19	<0.0001	(0.29)	(0.05)	(0.16)	C = J	C = J		
Vermillion snapper	92	0.12	(0.09)	(0.12)	(0.93)	(0.54)	C = J			
Greater amberjack	136	0.15	<0.001	<0.01	(0.23)	(0.10)			C = J	C = J
White grunt	812	0.01	(0.13)	(0.08)	(0.74)	(0.30)		C = J	C = J	C = J
Gray triggerfish	701	0.02	<0.01	(0.92)	(0.27)	(0.41)				C = J

Discussion

For species that are susceptible to high levels of fishing effort and strict harvest restrictions, reductions in release mortality rates may equate to meaningful conservation benefits (Coggins et al. 2007). The present study indicates that multiple species within the managed reef fish complex potentially benefit from circle hook use in the Gulf of Mexico, including red grouper, greater amberjack, and red snapper. Should measures become necessary for species with fewer harvest restrictions, such as gray snapper, gray triggerfish, vermilion snapper, white grunt, and red porgy, results from our study may serve to guide future management. Before we can definitively conclude that circle hooks increase survival rates for released reef fishes, further studies are needed to evaluate internal injuries before hooks are set. A study by Aalbers et al. (2004) found for a sciaenid [*Atractoscion nobilis* (Ayres, 1860)] that 32% of all mortalities (circle and J-hooks combined) were from internal damage to the esophagus caused before the hook ultimately embedded in the lip or mouth. The study also found that fewer fish were hooked in the viscera with circle hooks, but a higher proportion of those fish incurred latent mortality (circle hooks, 69%; J-hooks, 42%). Internal injuries in the present study were evaluated based on visual observations of embedded hooks prior to fish being released alive, and other potential internal injuries could not be examined.

For two managed grouper species in our study, gag and scamp, potentially lethal hook injuries were low (<5.5%) for both circle hooks and other hook types, and there were no significant differences in hook injuries between hook types. However, vessel operators that participated in our study expressed concern for the increased difficulty of removing circle hooks that are embedded deeply, particularly in the gills, esophagus, and stomach. A review of hooking studies found that circle hooks in general are more difficult to remove than J-hooks (Cooke and Suski 2004). Cooke et al. (2003) also noted anecdotally that removing circle hooks caused more tissue damage to fish, even when hooks were easy to remove, and warned that deep-set circle hooks may cause more internal damage. If circle hooks do cause more internal

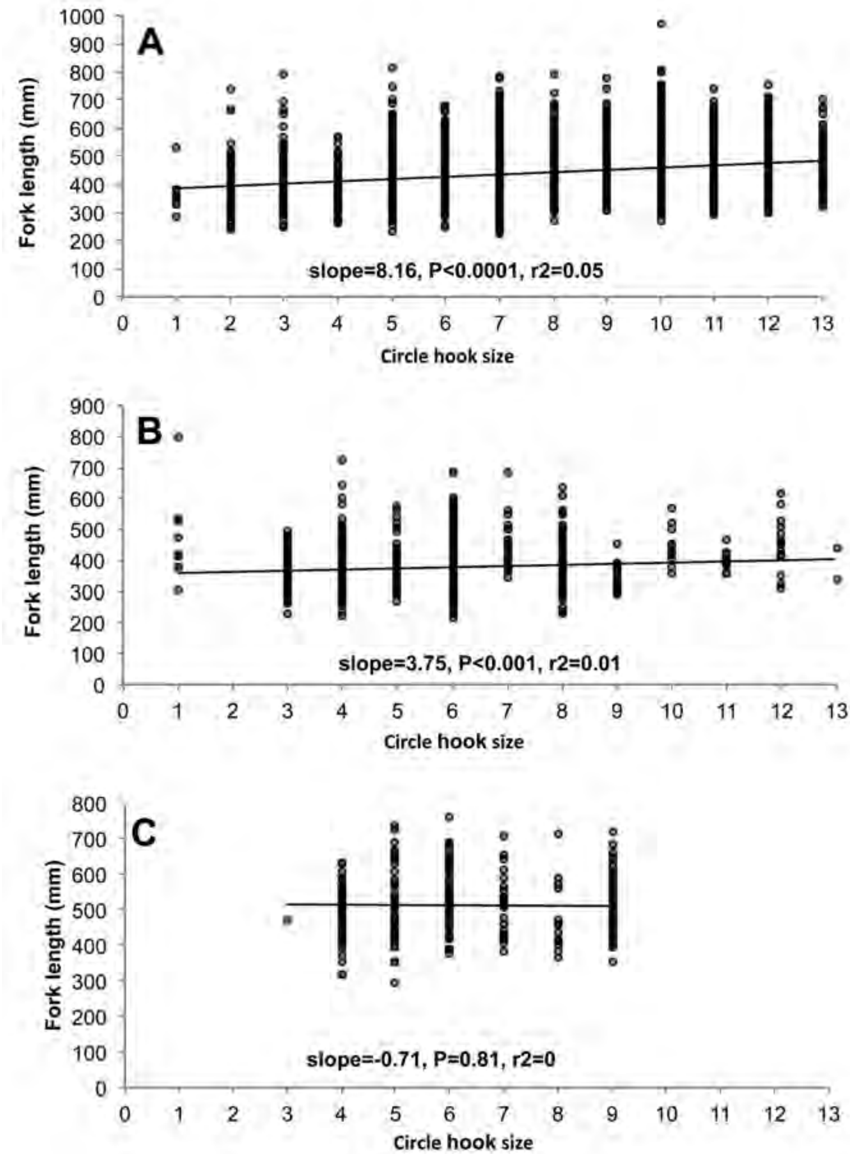

Figure 6. Fork length (FL) for red snapper (*Lutjanus campechanus*) caught using small (1–5), medium (6–8), and large (≥9) circle hooks during (A) charter, (B) headboat, and (C) multiday trips (see Fig. 2). Red snapper caught during research trips on charter vessels are included in (A). The minimum size limit for red snapper is equivalent to approximately 378 mm FL.

damage during removal, then gag and scamp may incur greater release mortality as a cost of protecting other species. The potential for greater injury during removal of circle hooks is also a concern for other species evaluated in our study. For gray snapper and red snapper, hooks that embedded in the eyes, mouth, gills, esophagus, gut, and externally were significantly reduced with circle hooks. However, compared to the other species evaluated, proportions of potentially lethal injuries for these two species remained high with circle hooks. Rummer (2007) cited several references

Table 3. Results of general linear model analyses (r^2 = explained variance, P = significance) of fish length (mm fork or midline). Variables included in the model were circle hook size (L = large, M = medium, and S = small), trip type (headboat, charter, multiday, red snapper research), and interaction of circle hook size and trip type, with F and P values for each. Values for P in parentheses are not significant (alpha = 0.01). Multiple comparisons for each trip type among different sized circle hooks indicate whether mean fish length in the larger hook size was greater (>), less (<), or not significantly different (=) than fish compared to the next smaller hook size. Comparisons were not made for hook sizes with fewer than 10 observations.

			Hook size		Trip type		Interaction		Multiple comparisons			
Species	r^2	P	F	P	F	P	F	P	Headboat	Charter	Multiday	Research
Red grouper	0.08	<0.0001	29.6	<0.0001	94.1	<0.0001	11.2	<0.0001	L = M = S	L > M > S	L < M > S	
Gag	0.13	<0.0001	0.1	(0.88)	40.1	<0.0001	5.0	<0.0001	M = S	L = M = S	L = M = S	L = M
Scamp	0.21	<0.0001	4.7	0.01	15.8	<0.0001	6.7	<0.0001	L = M = S	L = M > S	L = M = S	
Gray snapper	0.06	<0.001	3.6	(0.03)	1.5	(0.22)	1.1	(0.38)	M = S	L = M = S	L = M = S	
Red snapper	0.14	<0.0001	36.5	<0.0001	130.0	<0.0001	5.7	<0.0001	L = M = S	L > M > S	L = M = S	L > M > S
Vermillion snapper	0.11	<0.0001	24.6	<0.0001	48.5	<0.0001	7.8	<0.0001	L = M = S	L = M > S	L > M = S	
Greater amberjack	0.23	<0.0001	4.6	0.01	2.2	(0.11)	4.4	<0.01	L = M = S	L > M = S	L = M < S	
White grunt	0.02	0.01	5.1	0.01	1.3	(0.25)	1.4	(0.26)	L = M = S	L = M = S		
Red porgy	0.39	0.0001	4.6	0.01	51.4	<0.0001	2.7	(0.03)	M = S	L > M = S	L = M = S	
Gray triggerfish	0.06	<0.0001	0.9	(0.41)	16.1	<0.0001	1.2	(0.29)	M = S	L = M = S		

for aggressive feeding behavior in red snapper, which could explain higher deep-hooking rates for this species. An action that could mitigate internal injury resulting from circle hook removal is to release deep-hooked fish with the hook left in place. Aalbers et al. (2004) found higher survival rates when deep-set hooks were cut from the leader and left in the fish (41% mortality) compared with fish for which hooks were removed (65%), regardless of hook type. For fish in our study that were not lip-hooked and were caught with circle hooks, we observed that 7% of red snapper and approximately 4% of red grouper, gag, and gray snapper were released with hooks left in place.

There was no clear evidence that circle hooks result in reduced bycatch of undersized fish than J-hooks under the conditions observed in the present study. These results are consistent with Cooke and Suski (2004), who reviewed 14 published studies and found no evidence to support differential size selectivity between circle hooks and J-hooks. An alternative management option that was not implemented in the Gulf of Mexico was to regulate hook size to reduce bycatch of undersized red snapper. Circle hook size was a significant factor related to mean fish length for a majority of species in our study, including red snapper. However, r^2 values for all models in this analysis were low and much of the explained variance was unrelated to circle hook size. We did not measure morphological characteristics beyond length; however, relationships between fish length and hook size are less evident for species with large mouth gapes (Cooke et al. 2005). In a study that compared four hook sizes from a single hook manufacturer, Patterson et al. (2012) found declining catch rates with increasing circle hook size for multiple reef fish species in the Gulf of Mexico. While our results were less equivocal, an important point to be made from this and other observational studies is that conditions are highly variable in real-world fisheries and maximum conservation benefits may not be attained.

The prevalence of circle hook use across all segments of the recreational fishery for reef fishes must also be determined to assess their true conservation benefits. Prior to the circle hook requirement in 2008, Burns et al. (2002) and Burns and Wilson (2004) attempted to recruit volunteer anglers from headboats in the Tampa Bay region to use circle hooks for a comparison study with J-hooks. Initially, the researchers experienced difficulties convincing anglers to switch to circle hooks, even when hooks were provided free. Based on conversations with vessel operators whom we have come to know over the course of our study, the use of circle hooks has gained acceptance since the requirements for reef fishes were implemented. However, it was not uncommon for individual anglers to bring their own gear on large-capacity vessels and target unregulated species without circle hooks. Rules specify that circle hooks must be used when catching reef fishes; however, identifying an unintentional act of noncompliance is not practical and generally not the best use of enforcement resources. A better approach for reducing unintended reef fish interactions with J-hooks and other hook types is to increase anglers' awareness of the problems and regulations through outreach.

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Literature Cited

Aalbers SA, Stutzer GM, Drawbridge MA. 2004. The effects of catch-and-release angling on the growth and survival of juvenile white seabass captured on offset circle and J-type hooks. N Am J Fish Mgt. 24:793–800.

Bartholomew A, Bohnsack JA. 2005. A review of catch-and-release angling mortality with implications for no-take reserves. Rev Fish Bio Fish. 15:129–154. http://dx.doi.org/10.1007/s11160-2175-1

Burns KM, Koenig C, Coleman F. 2002. Evaluation of multiple factors involved in release mortality of undersized red grouper, gag, red snapper and vermilion snapper. Marine Fisheries Initiative (MARFIN) Grant No. NA87FF0421. Technical Report 790, Mote Marine Laboratory, Sarasota, Florida. 36 p. Available from: https://dspace.mote.org/dspace/ Accessed 30 June, 2011.

Burns KM, Wilson RR. 2004. Partitioning release mortality in the undersized red snapper bycatch: comparison of depth versus hooking effects. Marine Fisheries Initiative (MARFIN) Grant No. NA97FF0349. Technical Report 932, Mote Marine Laboratory, Sarasota, Florida. 43 p.

Cody RP, Smith JK. 2006. Applied statistics and the SAS programming language. 5th ed. Pearson Prentice Hall, Upper Saddle River, New Jersey. 574 p.

Coggins LG, Catalano MJ, Allen MS, Pine WE, Walters CJ. 2007. Effects of cryptic mortality and the hidden costs of using length limits in fishery management. Fish Fish. 8:196–210.

Coleman F, Figueira W, Ueland J, Crowder L. 2004. The impact of United States recreational fisheries on marine fish populations. Science. 305:1958–1960.

Cooke SJ, Suski CD, Siepker MJ, Ostrand KG. 2003. Injury rates, hooking efficiency and mortality potential of largemouth bass (*Micropterus salmoides*) captured on circle hooks and octopus hooks. Fish Res. 61:135–144.

Cooke SJ, Suski CD. 2004. Are circle hooks an effective tool for conserving marine and freshwater recreational catch-and-release fisheries? Aquat Conserv: Mar Freshwat Ecosyst. 14:299–326. http://dx.doi.org/10.1002/aqc.614

Cooke SJ, Barthel BL, Suski CD, Siepker MJ, Philipp DP. 2005. Influence of circle hook size on hooking efficiency, injury, and size selectivity of blue gill with comments on circle hook conservation benefits in recreational fisheries. N Amer J Fish Mgt. 25:211–119. http://dx.doi.org/10.1577/M04-056.1

Gulf of Mexico Fishery Management Council (GMFMC). 2007 Amendment 27 to the reef fish fishery management plan and amendment 14 to the shrimp management plan. GMFMC, Tampa, Florida. 480 p. Available from: http://www.gulfcouncil.org Accessed 30 June, 2011.

Hanson C, Sauls B. 2011 Status of recreational saltwater fishing in Florida: characterization of license sales, participation and fishing effort. Amer Fish Soc Symp. 75:355–365.

McGovern JC, Sedberry GR, Meister HS, Westendorff TM, Wyanski DM, Harris PJ. 2005. A tag and recapture study of gag, *Mycteroperca microlepis*, off the southeastern US. Bull Mar Sci. 76:47–59.

NMFS (National Marine Fisheries Serivce). 2010. Fisheries of the United States 2009. Current Fishery Statistics No. 2009. National Marine Fisheries Service, Silver Spring, Maryland. 103

p. Available from: http://www.st.nmfs.noaa.gov/st1/fus/fus09/index.html via the Internet. Accessed 30 June, 2011.

Patterson WF, Strelcheck AJ, Porch CE. 2012. Effect of circle hook size on reef fish catch rate, species composition, and selectivity in the northern Gulf of Mexico. Bull Mar Sci. 88:647–665. http://dx.doi.org/10.5343/bms.2011.1086

Rudershausen PJ, Buckel JA, Williams EH. 2007. Discard composition and release fate in the snapper and grouper commercial hook-and-line fishery in North Carolina, USA. Fish Mgt Ecol. 14:103–113.

Rummer JL. 2007. Factors affecting catch and release (CAR) mortality in fish: insight into CAR mortality in red snapper and the influence of catastrophic decompression. Amer Fish Soc Symp. 60:123–144.

St. John J, Syers CJ. 2005. Mortality of the demersal West Australian dhufish, *Glaucosoma hebraicum*, following catch and release: the influence of capture depth, venting and hook type. Fish Res. 76:106–116. http://dx.doi.org/10.1016/j.fishres.2005.05.014

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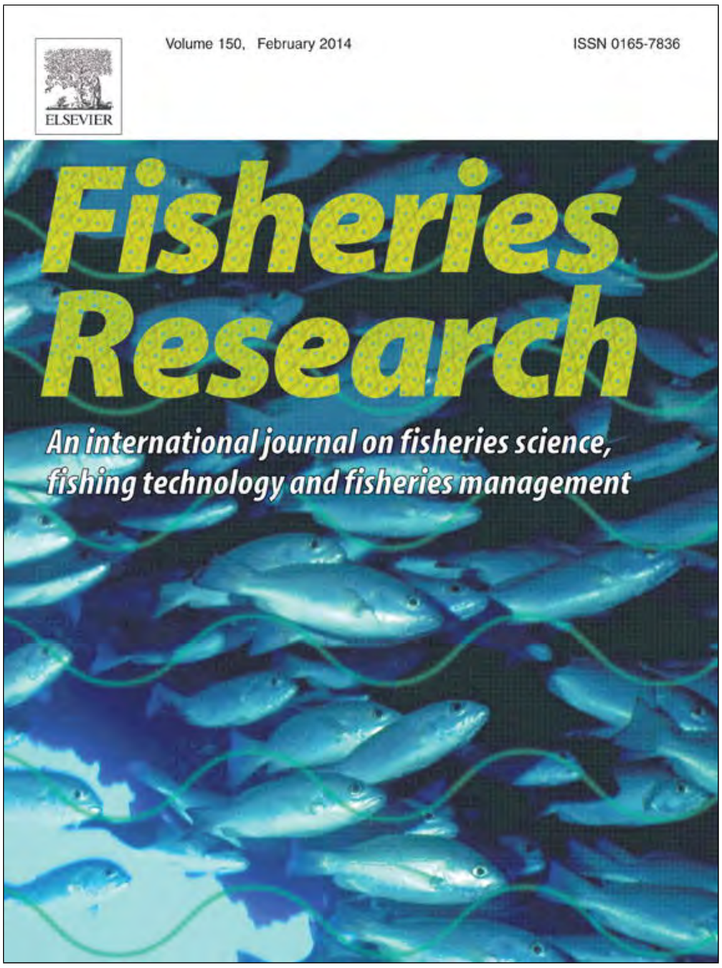
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Relative survival of gags *Mycteroperca microlepis* released within a recreational hook-and-line fishery: Application of the Cox Regression Model to control for heterogeneity in a large-scale mark-recapture study

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ABSTRACT

From June 2009 through December 2012 fishery observers were placed on charter and headboat vessels operating in the Gulf of Mexico to directly observe reef fishes as they were caught by recreational anglers fishing with hook-and-line gear. The objective of this study was to relate injuries and impairments measured directly from gags *Mycteroperca microlepis* caught and released within the recreational fishery to subsequent mark-recapture rates. Due to the large spatial and temporal scales of the study design, it could not be assumed that encounter probabilities were equal for all individual tagged fish in the population. Also, changes in fishing effort following the Deepwater Horizon oil spill during 2010 in the Gulf of Mexico and drastically reduced recreational harvest seasons for gag during 2011 and 2012 were unanticipated during the design of this study. Therefore, it was necessary to control for potential covariates on encounter and recapture rates for gags tagged in different regions, different years, and different times of year. This analysis demonstrates the utility of the Cox regression proportional hazards model in comparing relative survival among gags released in various conditions while controlling for potential covariates on both the occurrence and timing of recapture events. A total of 3954 gags were observed in this study, and the majority (77.26%) were released in good condition (condition category 1), defined as fish that immediately submerged without assistance from venting and had not suffered internal injuries from embedded hooks or visible damage to the gills. However, compared to gags caught in shallower depths, a greater proportion of gags caught and released from depths deeper than 30 m were in fair or poor condition. Relative survival was significantly reduced (alpha <0.05) for gags released in fair and poor condition after controlling for variable mark-recapture rates among regions and across months and years when tagged fish were initially captured and released. Gags released within the recreational fishery in fair and poor condition were only 66.4% (95% C.I. 46.9–94.0%) and 50.6% (26.2–97.8%) as likely to be recaptured, respectively, as gags released in good condition. Overall discard mortality was calculated for gags released in all condition categories at 10 m depth intervals. There was a significant linear increase in estimated mortality from less than 15% (range of uncertainty, 0.1–25.2%) in shallow depths to 30 m, to 35.6% (5.6–55.7%) at depths greater than 70 m ($p < 0.001$, $R^2 = 0.917$)

1. Introduction

In the Gulf of Mexico, gag *Mycteroperca microlepis* are highly sought for their recreational value, particularly in nearshore areas along the shallow west Florida continental shelf, where the species is abundant. The Gulf region supports some of the largest recreational fisheries in the United States, with the greatest concentration of effort along the west coast of Florida (Hanson and Sauls, 2011). For some highly targeted species in the region, total removals from recreational fisheries can exceed those from commercial fisheries (Coleman et al., 2004). Quantifying fishery removals attributed to mortality of regulatory discards has become an important data need for regional stock assessment models. Recreational fisheries are currently managed with an allocation of 61% of the total allowed catch for gag (GMFMC, 2008), which includes estimated removals attributed to mortality of discarded fish. In 2011–2012, recreational anglers fishing from the west coast of Florida caught an estimated 1 million gags annually (including

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harvested and released fish), down from 2.2 to 4.5 million gags in previous years (personal communication, National Marine Fisheries Service, Fisheries Statistics Division). Recreational harvest is regulated through a combination of minimum size limits, daily bag limits, and harvest seasons that have become increasingly restrictive in recent years. Prior to 2011, recreational harvest was closed during February and March to protect gag spawning aggregations. However, in 2009 the gag stock in the Gulf of Mexico was classified as overfished and undergoing overfishing, and since 2011 recreational harvest has been closed for a majority of months to allow the stock to recover. Consequently, approximately 90% of gags caught by recreational anglers in recent years were released as discards.

A field of study has emerged in recent decades to elucidate factors that influence survival of regulatory discards, including exposures to barotrauma, hook injuries, and variable handling and release techniques (reviews in: Bartholomew and Bohnsack, 2005; Cooke and Suski, 2004; Cooke and Schramm, 2007; Rummer, 2007; Wilde, 2009). Shortcomings of available studies are that many have focused on isolating the effects of a single factor, such as hook injury or barotrauma, often under experimental conditions, and results vary. In addition, many studies have not measured latent mortality and have provided only a partial measure of discard mortality. Some experimental studies have evaluated effects of exposure to multiple factors by retaining fish in cages to quantify immediate and short-term mortalities (Diamond and Campbell, 2009; St. John and Syers, 2005), and models for discard mortality that attempt to account for multiple factors have also begun to emerge (Rummer, 2007). Recent studies indicate that seasonal differences in water temperature at the surface and beneath the thermocline may also have an important influence on the condition of fish retrieved from depth (Diamond and Campbell, 2009), and more year-round studies are needed to fully assess seasonal effects of fishing on survival.

There is a growing need for methods that relate capture and handling practices measured in situ (i.e. within fisheries) to subsequent survival of released fish. Such methods are necessary to assess the true benefits of harvest control measures that may also result in increased regulatory discards and to quantify actual reductions in discard mortalities attributed to conservation measures, such as the use of circle hooks (Coggins et al., 2007; Cooke and Schramm, 2007; Sauls and Ayala, 2012). Conventional tagging studies have been used extensively to estimate survival in open populations (Pine et al., 2003). The advantages of mark-recapture studies to evaluate catch-and-release survival are that they measure survival under natural conditions, potential interactions between multiple stressors are measured intrinsically, latent mortality is included in survival estimates, and any potential increased mortality due to predation of impaired fish is not excluded, as it is in cage and laboratory studies. Models developed for tag-recapture data that were designed to estimate population parameters, however, are not useful for evaluating relationships between survival and explanatory variables (Burnham et al., 1987). Furthermore, many tag-recapture models require that individuals be tagged and recovered during discrete sampling events, which is not always possible, particularly in in situ studies. Estimates of survival derived from tag-recapture models were once thought to be robust to the assumption that all tagged fish within a study shared equal probabilities for recapture, but it has now been shown that variable encounter probabilities can introduce substantial bias in parameter estimates in tag-recapture models (Pledger et al., 2003).

Hueter et al. (2006) described a tag-recapture model that assumed equal encounter probabilities and equal survival rates following a recovery period for sharks tagged and released from gill nets. Each tagged fish was assigned to one of several treatment groups based on a measured risk for reduced survival, which for that study was based on the amount of time required to revive sharks caught during release from the gear. The ratios of fish tagged and recaptured among treatment groups was used to calculate relative survival (S), as

$$S = \frac{R_e}{R_u}, \quad (1)$$

where R_e is the ratio of recaptured fish to tagged fish within an exposed (e) treatment group (sharks that required variable lengths of revival time) and R_u is the ratio of recaptured fish to tagged fish within a relatively unexposed (u) treatment group (sharks that required no revival time). The authors demonstrated that this ratio is derived from a logistic model that predicts the proportions of recaptured fish from the exposed and unexposed groups. Eq. (1) assumes that all tagged fish have approximately the same catchability and are subject to the same amount of fishing effort; therefore, the ratio of recapture rates among the two groups is determined solely by the abundance of tagged fish in each group that survived following catch-and-release. The logistic model may also be generalized to include covariates that influence the encounter probability for individual tagged fish.

Survival analysis, also called time-to-event analysis, is more sophisticated, in that it evaluates both the occurrence and timing of recapture events for individual tagged fish. Survival in this type of analysis refers to the length of time an individual is observed in a study before a discrete event occurs. The method has been applied widely in biomedical research to measure, for example, the influence of variable exposure levels on time until death or the onset of disease. Pollock et al. (1989) described the use of survival analysis for testing hypotheses regarding the influence of condition measures on survival of individual animals. Hoffman and Skalski (1995) also demonstrate the utility of survival analysis for handling complex study designs that include multiple tagging groups defined, for example, by different tagging locations, genders, and treatments. Survival analysis accommodates staggered entry times, so long as entry times vary randomly across individuals in the study, and instantaneous recovery times for marked individuals (Hoffman and Skalski, 1995; Pollock et al., 1989). Survival analysis also does not require that the fate of every individual be known. Provided that, for any individual in the study, time until first recapture and time at large without recapture are independent, then individuals that are not reported as recaptured may be included in the analysis as right-censored observations, where the observation time is measured from the point at which a subject entered into the study to the point at which it was known to be lost to the study or the study was terminated. This assumption is potentially violated when the censoring time is arbitrarily short (Leung et al., 1997). For example, survival analysis showed that using only first-year capture histories for PIT-tagged chinook salmon passing through dams potentially underestimated survival of smolts during years when a large portion of tagged individuals overwintered above dams (Lowther and Skalski, 1997). If it can be assumed that loss to a study over time affects all individuals in approximately the same way, regardless of which group they belong to, then arbitrary censoring time should be avoided, and if groups of individuals are disproportionately lost to the study over time, then covariates may need to be considered. For example, if tags on fish that are below a minimum size limit for harvest are less likely to be noticed by anglers, then fish size may be a necessary covariate.

For this analysis, tag-recapture data from a large-scale observational field study were evaluated. The Florida Fish and Wildlife Conservation Commission (FWC) placed fishery observers on for-hire recreational vessels in the eastern Gulf of Mexico to collect vital statistics on reef fishes caught and released during recreational hook-and-line fishing. The objective of this analysis was to develop a model for gags, which were tagged prior to release, that could control for potential covariates on both the occurrence and timing of recapture events so that injuries and impairments could be related to subsequent mark-recapture rates. Because gags were tagged year-round, over multiple years, and over a large geographic area, it was necessary to control for potential covariates on recapture rates for fish tagged in different regions, years, and times of year. Fishing effort is variable among regions within the geographic area of this study. Effort in the Panhandle region is highest during the summer months due to increased tourism and a significant pulse in offshore fishing effort during the short time period when red snapper *Lutjanus campechanus* is open to recreational harvest. The Big Bend region is located within a sparsely populated area of the state, and fishing effort is comparably low there year-round. Tampa Bay is a population center, and fishing effort in the adjacent Gulf of Mexico waters is highly dispersed across a longer fishing season and among low-relief natural-bottom habitats distributed across the broad, shallow West Florida continental shelf. Fishing effort also potentially varied across time due to changes in the length of the recreational harvest season within and among years in this study. Fish that were tagged in earlier years were vulnerable to targeted fishing effort distributed across more months of the year and for more years, whereas fish tagged later in the study were subject to concentrated effort over a variable number of months each year across fewer years. Another unexpected factor that potentially influenced fishing effort during the second year of this study was the Deepwater Horizon oil spill in the Gulf of Mexico. Fishing effort following the episodic event in 2010 was potentially influenced by months-long closures to all fishing in contaminated areas and by more persistent public perceptions believed to influence tourism and seafood consumption throughout the region. It was hypothesized that the timing of recapture events for individual fish in this study was correlated with multiple extraneous factors unrelated to the initial exposure to catch-and-release. Survival analysis was used because the duration of time at large before first recapture could provide a more precise measure of recapture rate in response to covariates than a binomial (recaptured = yes or no) variable.

2. Methods

2.1. Study design

Since June 2009, fishery observers have accompanied passengers on fishing vessels in Florida that offer for-hire recreational fishing trips and target reef fishes in the eastern Gulf of Mexico. Operators of more than 160 vessels participated in the year-round study, and vessels were randomly selected each month for observer coverage from each of three regions: (A) the northwestern Panhandle, (B) nearshore areas adjacent to Tampa Bay, and (C) areas adjacent to Tampa Bay approximately 80–100 miles offshore (Fig. 1). Monthly sample quotas were assigned to two trip types in areas A and B: (1) single day charter trips and (2) single day headboat (large party boat) trips. Monthly sample quotas for a third trip type, multi-day (>24 h) headboat trips, were assigned in area C. Fishery observers boarded vessels along with paying passengers and directly observed recreational fishing during each sampled trip.

In addition to randomly sampled recreational fishing trips, charter vessels were hired as part of an ongoing study of red snapper in area A and in a fourth region commonly referred to as Florida's Big Bend (area D in Fig. 1). The purpose of the hired charter trips was to tag and release red snapper caught using recreational fishing methods. Gags caught during these trips were also tagged and released. During hired charter trips, volunteer anglers fished using recreational hook-and-line gear supplied by the vessel. Captains were asked to target red snapper but were given no instructions from scientific crew on where to fish or how to target fishing. All hired charter trips were conducted from March through May in 2010–2012.

Table 1
Description of release condition categories for gag observed during recreational hook-and-line fishing.

Condition category	Description
Good	Fish immediately submerged without the assistance of venting and did not suffer internal hook injuries or visible injury to the gills.
Fair	Fish did not immediately submerge, or submerged with the assistance of venting, and did not suffer internal hook injuries or visible injury to the gills.
Poor	Fish remained floating at the surface, suffered internal hook injuries, suffered visible injury to the gills, or any combination of the three impairments.

During each randomly sampled recreational trip or hired charter trip, one or two fishery observers monitored recreational anglers during hook-and-line fishing. Depth and latitude/longitude (degrees and minutes) were recorded at each fishing station. For each gag caught and released, observers recorded information that included (1) size (mm midline length), (2) location where the hook was embedded (lip or jaw, inside mouth, esophagus, gill, gut, eye, or external), (3) whether the fish was bleeding (indicating gill injuries), (4) the presence or absence of barotrauma symptoms (swollen bladder, everted stomach, extruded intestines, or exopthalmia), (5) whether the swim bladder was vented to reduce buoyancy from barotrauma prior to release (observers assisted with venting fish when asked to do so by the vessel mate or captain; whether the swim bladder was deflated or the everted stomach was punctured was also recorded), and (6) the observed condition of the fish at the surface following release (good = swam below surface immediately; fair = did not submerge immediately, then swam below surface; poor = floating on surface and unable to submerge; dead = unresponsive and presumed dead upon release; preyed = visually preyed upon at or near the surface).

Prior to release of live discards, each fish was marked with a Hallprint dart tag inserted in the front dorsal area and securely anchored between the first and second leading dorsal fin rays. Each dart tag had an external monofilament streamer labeled with a unique tag number, the phone number for FWC's toll-free tag-return hotline, and the word REWARD. The tagging program was widely publicized throughout the study region and a free t-shirt was offered to any angler who called in tag-return data. Participating charter and headboat vessel operators were also provided a supply of postage-paid cards that were filled out and returned to FWC when tagged fish were encountered. Information collected for each tag return included the tag number, date of recapture, fish size, and approximate location. Recaptured fish were also encountered directly by fishery observers during sampled charter trips.

2.2. Immediate mortalities and live release conditions

Immediate mortality was calculated as the percentage of all gags that were caught (and not harvested) with a release condition of either dead or preyed. This percentage included gags that were released without a tag because they were dead on retrieval (usually attacked by a predator during ascent) and gags that were tagged and were either unresponsive and presumed dead or visibly preyed upon at the surface. Tagged fish that suffered immediate mortality were not included in latent mortality calculated from tag-recapture rates.

Live gag discards from each region were assigned to one of three release condition categories described in Table 1. Logistic regression was used to compare the presence of barotrauma symptoms among gags observed in the three release condition categories. Generalized linear models and Tukey post hoc tests were used to compare mean capture depth and mean size of gags among release condition categories and regions.

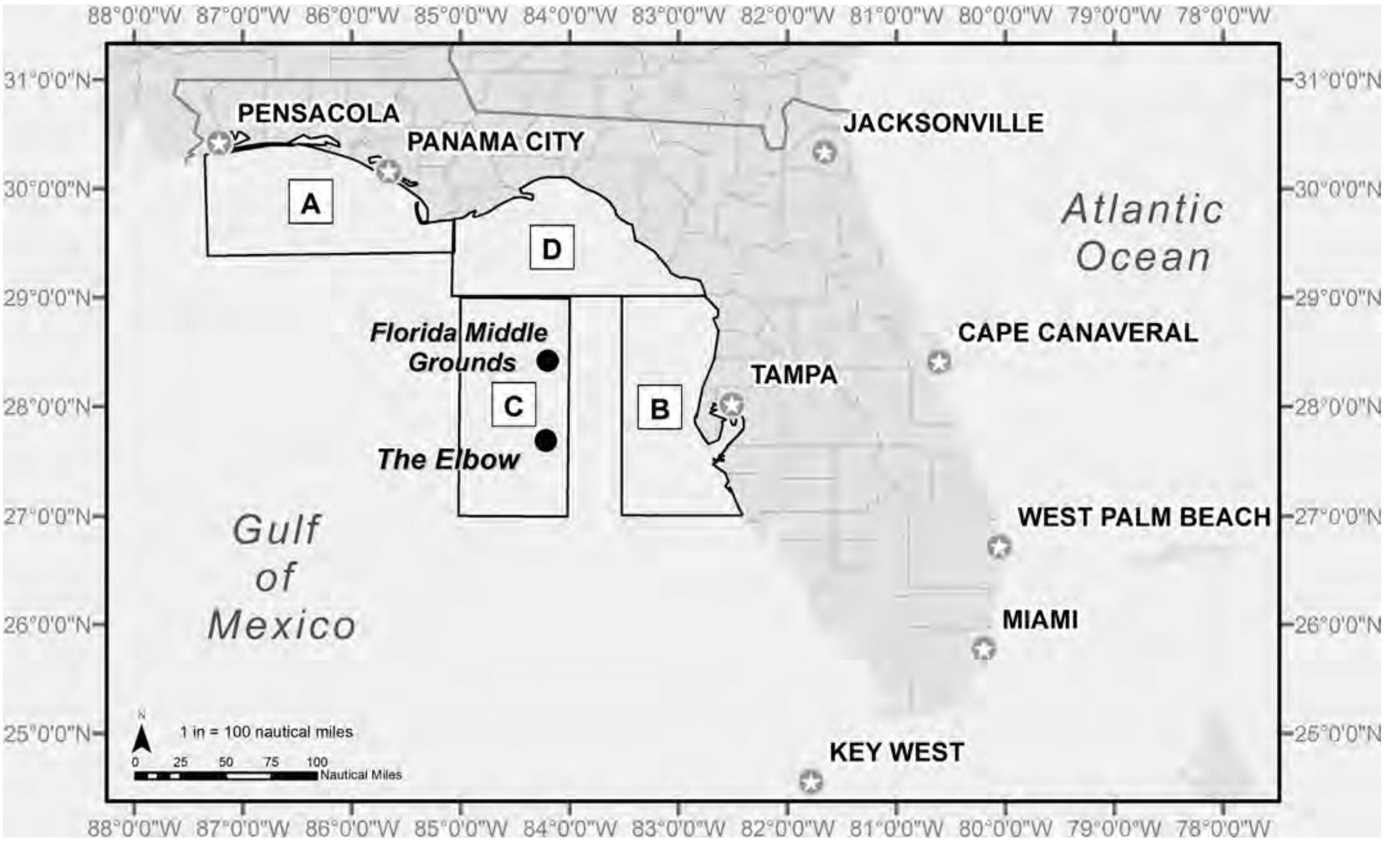

Fig. 1. Regions within the study area include the Panhandle region (A), Tampa Bay nearshore region (B), Tampa Bay offshore region (C), and Big Bend region (D).

2.3. Relative survival of live discards

The objective of this portion of the data analysis was to test hypotheses about the relative survival for fish released in different treatment groups (live release condition categories) specifically in response to catch-and-release events. To evaluate the timing and occurrence of recapture events among gags in condition categories 2 and 3 relative to condition category 1, the PHREG procedure in SAS was used to construct a proportional hazards regression model. The proportional hazards model is a form of survival analysis first described by Cox (1972). The model is used to estimate the hazard (h) for an individual (i) in a population of tagged fish to experience a reported recapture event at time t, and the time-specific recapture reporting rate is described by the hazard function:

$$h_i(\mathrm{t}) = \lim_{\Delta \mathrm{t}} \rightarrow 0\frac{pr(\mathrm{t} \le \mathrm{T} < \mathrm{t} + \Delta\mathrm{t} \,\middle|\, \mathrm{T} \ge \mathrm{t}}{\Delta \mathrm{t}} \quad (2)$$

The numerator is the conditional probability that an individual tagged fish is reported as a recapture, where T is the occurrence of the event between times t and t+Δt, given the event did not already occur before time t. Dividing this probability by the width of the interval (Δt) yields the recapture reporting rate per unit of time, and taking the limit as the interval approaches zero gives an instantaneous rate. The instantaneous rate allows for variability in recapture reporting rates to be explained with a high degree of precision so that significant differences between groups of tagged fish may be detected.

When each tagged fish has a set of measurements (x1 to xk) associated with it, the hazard function is explained by the proportional hazards regression model:

$$h_i(\mathrm{t}\,\middle|\, x_{il} \ldots x_{ik}) = h_0(\mathrm{t}) * \exp(\beta_l x_{il} + \ldots \beta_k x_{ik}) \quad (3)$$

where $h_0(t)$ is the baseline hazard function that describes the hazard for a recapture reporting event for a reference group within the population and the second term is the linear function for a set of k covariates. To demonstrate how the baseline hazard function works, consider a simple model with one variable x, where x=0 if a fish is released at the surface and re-submerges on its own and x=1 if the fish is unable to re-submerge. When x=0, equation 3 reduces to $h_0(t)$, which is the risk for individuals within the reference group to be reported as a recapture at time t. Equation 3 reduces to $h_0(t)$*exp(β) when x=1, where the second term is the proportionate increase or decrease in that risk for individuals in the impaired group. Adding other covariates to this model controls for potential confounding effects on both the reference group and the impaired group. When the instantaneous rates of $h_i(t)$ for two individuals are compared as a ratio (referred to as the hazard ratio, notated here as H), $h_0(t)$ cancels out to yield:

$$\hat{H} = \frac{\exp(\beta_1 X_{i1} + \cdots + \beta_k X_{ik})}{\exp(\beta_1 X_{j1} + \cdots + \beta_k X_{jk})} \quad (4)$$

and the two rates vary proportionally with respect to each other over time (Allison, 2010). Thus, the hazard ratio for two treatment groups is an instantaneous rate that is interpreted much like the rate ratio described in Eq. (1), with the added feature of controlling for covariates on not just the occurrence of recapture events, but also on the more precise measure of the timing of recapture events within and among treatment groups. The confidence interval for the hazard ratio point estimate is calculated as:

$$\mathrm{CI} = \hat{H} \times \exp(\pm Z_{1-\alpha/2} \times \mathrm{s.e.}\hat{H}) \quad (5)$$

The response variable used for this analysis was the number of days a fish was at large before it was either reported as a recapture (coded as 1) or censored (coded as 0). Timing of each recapture event was defined as the number of days from the time that a fish was tagged and released until its first reported recapture. Once a fish was reported as recaptured the first time, survival was confirmed and observation times for subsequent recapture events were not included in the analysis. Fish that were not reported as recaptured were treated as censored observations, and time in the study was defined as the number of days from when individual fish were tagged until December 31, 2012. The treatment to be tested was release condition category, which was included as an independent class variable in the proportional hazards model. Control variables that were also tested for entry into the model included class variables for region, time of year (month), and year that fish were initially tagged and released; continuous variables for capture depth (meters) and size at original capture (mm midline length); and possible interaction terms. Proportionality is an important assumption of the proportional hazards model, and the form of the underlying hazard function was expected to vary across years of entry into the study due to variable fishing effort and species targeting in response to increased harvest restrictions, among other potential factors previously discussed. Annual differences in tag-recapture rates were not of direct interest for this analysis, and to adjust for this confounding effect the proportional hazards model was stratified using the STRATA statement in the PHREG procedure. This procedure constructs separate partial likelihood functions for each stratum (fish tagged in the same year), which are multiplied so that single parameter estimates for β_1 to β_k that maximize the function can be selected (Allison, 2010). Akaike's information criterion (AIC) values based on partial likelihood of the second term in Eq. (3) reported in SAS output were used along with the forward selection procedure to select among potential covariates for the timing of recapture events.

A key assumption for this application of the proportional hazards model, as well as the relative survival model applied by Hueter et al. (2006), is that the probability of encountering a tagged fish that survived catch-and-release is not influenced by the treatment group that the fish belongs to. It is possible that fish in different treatment groups were more or less likely to be recaptured during an initial recovery period immediately following catch-and-release due to differential behavior responses. However, over the range of observation times for which individual fish in each treatment group remained in this study until they were either recaptured or censored (as much as 3.5 years), it was assumed that the effect of short-term differences in catchability among treatment groups was negligible. Other assumptions by Hueter et al. (2006) that also apply to this model are that natural mortality and artifacts of tagging (tag shedding, tag fouling, non-reporting, etc.) affect all fish in the same way, regardless of their condition upon release. Two other assumptions specifically related to staggered entry times and censoring times for individuals in this study are (1) that captured fish were encountered randomly in the fishery, and the probability that an individual did not recover from the catch-and-release event was not influenced by time of entry into the study; and (2) that for an individual censored at the end of the study after *t* days at large, the probability of being reported as a recapture was the same as for all other individuals released in the same treatment group.

2.4. Overall discard mortality estimation

The objective of this portion of the analysis was to estimate overall discard mortality for gags in all condition categories caught and released from various depths in the recreational hook-and-line fishery. To estimate depth-dependent discard mortality, the number of observed gags released in good (N_1), fair (N_2) and poor (N_3) condition categories at each 10-m depth interval (where d = 1–10 m, 11–20 m, etc.) was first multiplied by the proportion of gags in each condition category estimated to survive. Discard mortality at each depth interval (M_d) was expressed as a percentage using the following equation:

$$\hat{M}_d = \left[1 - \frac{(N_1 \times S_1) + (N_2 \times \hat{H}_2) + (N_3 \times \hat{H}_3)}{N_1 + N_2 + N_3}\right] \times 100 \quad (6)$$

where S_1 is absolute survival following catch-and-release for gags released in good condition (which is not truly known), and $\hat{H}_2$ and $\hat{H}_3$ are estimated survival proportions for gags released in fair and poor condition (respectively), relative to gags released in good condition, as derived from the proportional hazards model.

Ideally, absolute survival for gags in condition category 1 (S_1) should be measured; however, because all fish had to be captured in order to be tagged and released, there was no true control to reference this treatment group to. Because the majority of fish released in good condition were caught from shallow depths, where barotrauma should be minimal, and because individuals with hook injuries, visible gill injuries, potential internal injuries related to venting, or swimming impairments at the surface were excluded from this treatment group, it is reasonable to assume that discard mortality in this treatment was low. Discard mortality was also not expected to be greater than overall values reported from shallow depths in other studies, which included fish in more severely impaired conditions than the reference group in this study. A literature review produced during the data workshop for SEDAR (Southeast Data Assessment and Review) number 33 in support of the 2013 Gulf of Mexico gag stock assessment (under way) reported low overall discard mortality estimates in nearshore fisheries, including one unpublished study for gags caught with hook-and-line gear (mean depth 5.7 m, 7.2% discard mortality) and several published studies for other fisheries that operate near shore (10 studies for 6 species, range 2.13–14.4% discard mortality; SEDAR, 2013). Therefore, mortality of gags released in good condition without the need for venting and with no visible injuries or impairments is expected to be less than 15%. For this analysis, overall depth-dependent discard mortality was calculated separately under three assumptions for S_1: (1) that 100% of gags in good condition survive catch-and-release (S_1 = 1.000); (2) that as few as 85% of gags in good condition survive (S_1 = 0.850); and (3) that a median of 92.5% survive (S_1 = 0.925). For the median assumption, uncertainty around overall discard mortality estimates for each depth interval was calculated by substituting S_1 in Eq. (6) with lower and upper assumed values of 0.85 and 1.0, and substituting $\hat{H}_2$ and $\hat{H}_3$ in Eq. (6) with lower and upper 95% confidence limit values (calculated from Eq. (5).

3. Results

3.1. Immediate mortalities and live release conditions

Only 11 gags that were not retained by anglers suffered immediate mortality, which was a small percentage (<1.0%) of the total discards observed. Of the 3954 live gag discards observed, the majority (77.8%) were released in good condition (condition category 1), and this was largely driven by the abundance of gags encountered during trips in the Tampa Bay nearshore region (Table 2). While fewer gags were observed in the Panhandle and Tampa Bay offshore regions, less than half were in good condition, compared to more than 90% in the relatively shallow Tampa Bay nearshore region (Table 2). Similarly, in the shallow Big Bend region, 92% of gags observed were in good condition. Gag discards from the Tampa Bay nearshore region were significantly smaller, and gag discards in the Panhandle and Tampa Bay offshore regions were captured in significantly deeper depths (29.76 and 41.10 m respectively) compared to other regions and were also significantly different from each other (α = 0.05, Table 2). More than half of gag

Table 2
Characteristics of observed gag discards tagged and released by region. Mean ± SD notated with different lowercase letters represent significant differences ($p < 0.05$) from GLM and Tukey post hoc tests.

	(A) Panhandle	(B) Tampa Bay nearshore	(C) Tampa Bay offshore	(D) Big Bend
Numbers of fish tagged:				
Condition 1 (%)	294 (43.43)	2435 (94.02)	180 (33.96)	146 (93.00)
Condition 2 (%)	355 (52.44)	83 (3.20)	287 (54.15)	3 (1.91)
Condition 3 (%)	28 (4.14)	72 (2.78)	63 (11.89)	8 (5.10)
Numbers of fish recaptured:				
Condition 1 (% tagged)	46 (15.65)	217 (8.91)	19 (10.56)	10 (6.85)
Condition 2 (% tagged)	42 (11.83)	4 (4.82)	26 (9.06)	0
Condition 3 (% tagged)	4 (14.29)	3 (4.17)	3 (4.76)	0
Mean length (mm midline)	522.65 ± 117.14 (a)	462.77 ± 87.49 (b)	584.98 ± 105.20 (c)	532.24 ± 82.99 (a)
Mean capture depth (m)	29.76 ± 7.44 (a)	18.18 ± 7.45 (b)	41.10 ± 10.97 (c)	20.60 ± 3.44 (b)
Number of trips:				
Single-day charter	99	127	–	–
Directed red snapper charter	72	–	–	7
Single-day headboat	47	129	–	–
Multi-day headboat	–	–	37	–

Table 3
Odds ratios (95% CI) from logistic regressions of release condition category on the presence of barotrauma symptoms. Confidence intervals that overlap 1.00 indicate that the odds were not significantly increased or decreased among condition categories.

	Swollen bladder	Everted stomach	Extruded intestines	Exopthalmia
Condition 2 vs. 1	29.30 (15.11, 56.81)	3.81 (3.21, 4.53)	3.73 (2.34, 5.97)	6.00 (3.24, 11.11)
Condition 3 vs. 1	2.35 (1.51, 3.65)	2.98 (2.18, 4.08)	0.89 (0.21, 3.70)	6.10 (2.39, 15.57)
Condition 2 vs. 3	12.47 (5.68, 27.38)	1.28 (0.91, 1.80)	4.21 (1.00, 17.74)	0.98 (0.40, 2.45)

discards in the two regions with deeper depths were vented before release (53% in the Panhandle and 61% in Tampa Bay offshore), which is in contrast to the two shallower regions, where more than 90% of fish were released in good condition without the need for venting (Fig. 2). The greatest percentage (11.98%) of gags released in poor condition (condition category 3) was also in the Tampa Bay offshore region (compared to <5.5% for other regions). The total number of gags observed in the Big Bend was small because fewer trips were conducted there, and very small numbers of fish were released in fair or poor condition (Table 2).

Overall, across all regions, gags released in good condition were significantly smaller and were caught from significantly shallower depths than those released in fair condition (Fig. 3). Gags released in fair and poor condition also have significantly greater odds of exhibiting symptoms of barotrauma compared with those released in good condition (Table 3). A majority of gags in all release-condition categories exhibited a swollen bladder (range = 71.9% to 98.7%), which indicates at least mild barotrauma (Fig. 4); however, those in fair and poor conditions were significantly more likely to exhibit this symptom (Table 3). The presence of an everted stomach was less prevalent (Fig. 4), and gags released in fair or poor condition were 3.81 and 2.98 times more likely, respectively, to exhibit this symptom than those

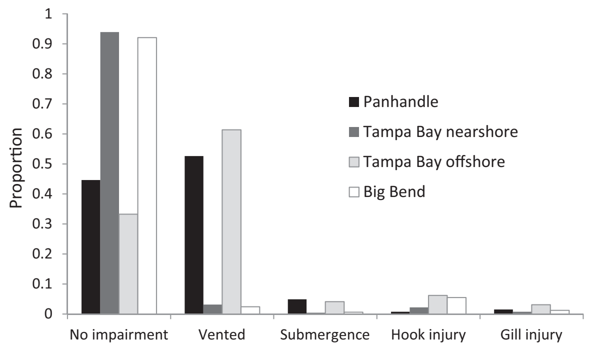

Fig. 2. Proportion of gag discards by region that exhibited no impairment or that exhibited one or more impairments at the time of release (individuals with more than one impairment symptom are included in multiple categories). No impairment means fish submerged immediately upon release without assistance from venting and did not suffer hook or gill injuries. Venting refers to deflation of the swim bladder or puncture of the stomach before a fish was released. Submergence means a fish did not submerge immediately or floated when released. Hook injury means hooks were embedded in the esophagus, gut, gill, or through the eye. Gill injury means the fish was visibly bleeding from the gills.

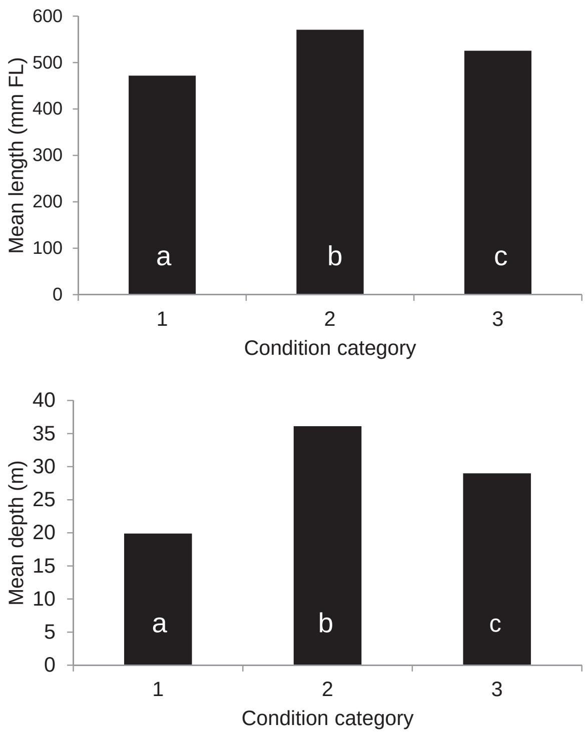

Fig. 3. Mean length of gag discards (top) and mean depth of capture for gag discards by release condition category (Table 1). Different lowercase letters represent significant differences ($p < 0.05$) from GLM and Tukey post hoc tests.

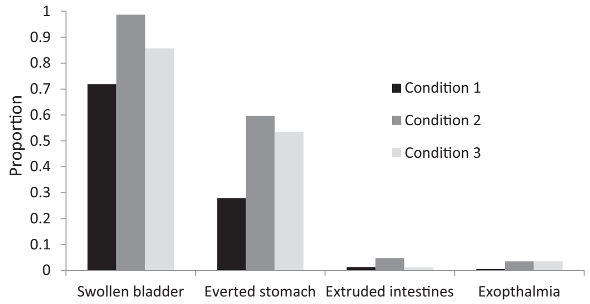

Fig. 4. Proportion of gags observed with visible barotrauma by release condition category. The odds for observing each symptom among fish in each condition category are summarized in Table 3.

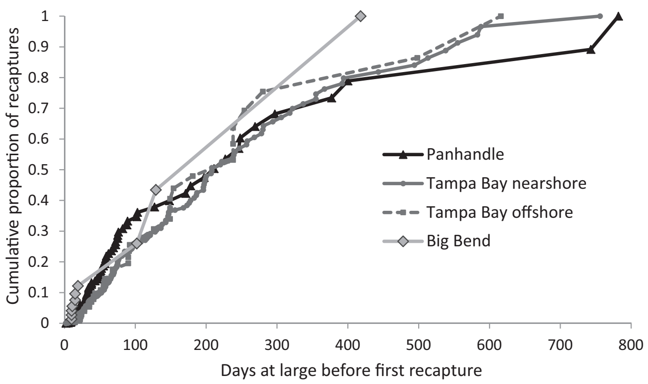

Fig. 5. Days at large before first recapture expressed as the cumulative proportion of total at-large times for all recaptured fish, by region. The median time at large before first recapture was 34 days in the Panhandle region, 55 days in the Tampa Bay nearshore region, 68 days in the Tampa Bay offshore region, and 15 days in the Big Bend region. Sample sizes for recaptured fish in each region are provided in Table 2; note the low sample size for the Big Bend region ($n = 10$).

released in good condition (Table 3). Symptoms of more severe barotrauma, including extruded intestines and exopthalmia, were rare (<5.0%) for gags observed in all release conditions (Fig. 4). When severe symptoms were present, fish were more likely to be in fair or poor condition (Table 3).

3.2. Reported tag recaptures

A total of 374 gags were reported to be recaptured, for an overall tag-return percentage of 9.46%. The tag-return percentage varied regionally, with the greatest percentage in the Panhandle region (Table 2). The region in which fish were tagged was highly correlated with time at large before the first reported recapture ($p < 0.0001$), and recaptured fish were at large for a minimum of 2 days and a maximum of 782 days before the first reported recapture (Fig. 5). Recaptured fish were at large for longer periods in the Tampa Bay nearshore and offshore regions (medians of 55 days and 68 days, respectively) compared to the Panhandle region (median = 34 days), and fish in the Big Bend region were at large for the shortest period (median = 15 days). In every region, the largest tag return percentage was from gags released in good condition (Table 2). Due to the small number of gags tagged in the Big Bend region, particularly in fair and poor condition categories, only 10 recaptures were reported, and none were from fish released in fair or poor condition; therefore, this region was excluded from the analysis for relative survival among treatment groups.

Table 4
Summary of the proportional-hazard model forward selection of independent variables on the number of days gag were at large before they were either reported as recaptured or censored at the end of the study without having been recaptured. The model was stratified by year of entry (Fig. 1). Variables tested that were not included during the forward-selection procedure were depth of capture, two-way interactions between depth with length and month, and a three-way interaction between month × region × length.

Effect entered	df	χ^2	p	AIC after inclusion
Region	2	20.995	<0.0001	4784.190
Month	11	20.895	0.035	4784.483
Length	1	4.098	0.043	4782.397
Length × month	11	24.301	0.012	4780.189
Condition category	2	7.896	0.019	4775.841

Table 5
Estimated hazard ratios ($\hat{H}$) and 95% CIs (in parentheses) for gags in Tampa Bay nearshore (TBn), Tampa Bay offshore (TBo) and Panhandle (PH) regions, after controlling for the effect of covariates on reported recapture rates (Table4 Hazard ratios are significant when the 95% CI does not overlap 1.0.

Region	$\hat{H}$	s.e.	χ^2	p
TBn vs. PH	0.574 (0.420, 0.784)	0.1589	12.221	0.001
TBo vs. PH	0.569 (0.381, 0.849)	0.2040	7.651	0.006
TBn vs. TBo	1.009 (0.689, 1.478)	0.1948	0.002	0.963

Table 6
Estimated hazard ratios ($\hat{H}$) and 95% CIs (in parentheses) for gags in condition categories 2 and 3 versus a reference group, after controlling for the effect of covariates on reported recapture rates (Table4).

Condition category	$\hat{H}$	s.e.	χ^2	p
2 vs. 1	0.664 (0.469, 0.940)	0.1772	5.324	0.021
3 vs. 1	0.506 (0.262, 0.978)	0.3365	4.105	0.043
2 vs. 3	1.314 (0.667, 2.588)	0.3460	0.6221	0.430

3.3. Relative survival of live discards

The proportional hazards model was stratified by year, and potential control variables entered into the model were region, capture depth, fish size at time of original capture, and associated interaction terms. Significant covariates selected during the forward selection procedure are summarized in Table 4 and include region, month in which fish were tagged and entered into the study, fish length at the time they entered the study, and an interaction term between month and fish length. When referenced against the Panhandle region, the hazard for recapture was significantly reduced for gags tagged and released in other regions ($\chi^2 = 20.995$ and $p < 0.0001$), which confirmed the necessity to control for variable tag-recapture rates among regions. Gags were only 57.4% as likely to be recaptured when tagged in the Tampa Bay nearshore region and 56.9% as likely when tagged in the Tampa Bay offshore

Table 7
Number of gags observed in condition categories 1, 2 and 3 (N_1–N_3) by depth interval, and estimated overall discard mortality ($\hat{M}_d$) expressed as percentage under varying assumptions of survival for gags in condition category 1 (S_1). Uncertainty around point estimates for $\hat{M}_d$ when S_1 equals the median value 0.925 is provided in parentheses and was calculated by substituting lower and upper 95% confidence limits for $\hat{H}_2$ and $\hat{H}_3$ from Table 6 and lower and upper assumed values of 0.850 and 1.000 for S_1 into Eq. (6). See also Fig. 6.

Depth (m)	N_1	N_2	N_3	Percentage discard mortality ($\hat{M}_d$)		
				$S_1 = 1.000$	$S_1 = 0.925$	$S_1 = 0.850$
1–10	216	1	6	1.48	8.74 (0.09, 16.75)	16.01
11–20	1687	17	50	1.73	8.95 (0.12, 17.05)	16.16
21–30	850	226	49	8.90	14.57 (1.30, 25.21)	20.23
31–40	231	308	31	20.84	23.88 (3.36, 38.79)	26.92
41–50	44	111	29	28.06	29.85 (3.97, 47.25)	31.64
51–60	27	46	5	22.98	25.58 (3.68, 41.24)	28.17
61–70	0	12	0	33.60	33.60 (6.00, 53.10)	33.60
>70	0	7	1	35.58	35.58 (5.53, 55.69)	35.58

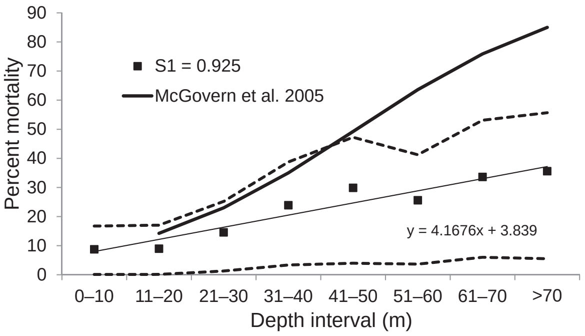

Fig. 6. Overall estimated percentage mortality for gags observed, by 10-meter depth interval. Point estimates (squares) assume 92.5% survival of gags released in condition category 1 (S_1 = 0.925), and the linear relationship (light line) between point estimates and the median for each depth interval is significant (p < 0.001, R^2 = 0.917). Uncertainty around point estimates is shown by the dashed lines (see Table 7 for values). A low number of sampled trips took place in depths >60 m, and gags captured in depths >70 m are combined into a plus group (see Table 7 for sample sizes). Percentage mortalities from McGovern et al., 2005 (dark line) are plotted for comparison.

region (Table 5). Depth of original capture and interactions between depth and other covariates were not significant. The release condition category was significant (χ^2 = 7.896 and p = 0.0193) and, after covariates were controlled for, the hazard (or probability) for recapture was significantly reduced for fish in condition categories 2 and 3 when referenced against fish in good condition, category 1 (Table 6). Fish in condition category 2 were only 66.4% as likely to be recaptured as fish in condition category 1. Fish in poor condition, category 3, were only 50.6% as likely to be recaptured as fish released in good condition. There was no significant difference in relative survival between fish in condition categories 2 and 3 (Table 6).

3.4. Overall discard mortality estimates

Discard mortality over all gags observed within the recreational hook-and-line fishery was calculated at 10-m depth intervals (Table 7). For the median survival value, at which 92.5% of gags observed in good condition are assumed to survive catch-and-release (S_1 = 0.925), the overall discard mortality percentage for gags was estimated to be less than 15.0% (range of uncertainty, 0.1–25.2%) in shallow depths to 30 m. There was a significant positive linear increase in discard mortality point estimates with depth (p < 0.001, R^2 = 0.917). Discard mortality estimates gradually increased from 23.9% (3.4–38.8%) at depths between 31 and 40 m to 35.6% (5.6–55.7%) at depths greater than 70 m (Fig. 6).

4. Conclusions and discussion

The results of this analysis provide some important conclusions that are informative regarding the survival of gag discards in the recreational hook-and-line fishery. Perhaps most important, in the region where the majority of gags were encountered, gags were captured in relatively shallow depths and released in good condition, meaning they did not require venting in order to immediately submerge and they did not sustain internal injuries from embedded hooks or visible injury to the gills during handling. Immediate mortality was low (<1%) and was similar to another published study that reported predation mortality of 1.3% observed for hooked fish released at the surface (Overton et al., 2008). However, in regions where fishing took place in significantly deeper depths, gags were released in poorer condition and relative survival was significantly reduced for fish released in fair or poor condition compared to those released in good condition. A large percentage of fish in the fair condition category were vented prior to release; however, the result that these fish suffered greater mortality compared to unvented fish in good condition should not be interpreted as a negative effect from venting. The act of venting does require additional handling time and introduces the possibility of internal injury resulting from improper venting techniques. However, fish in fair condition were significantly larger and were caught from significantly deeper depths than fish that did not require venting to re-submerge, and it is possible that additional stress unrelated to the act of venting itself contributed to their reduced survival. It is also possible that vented fish would have suffered greater mortality if they had not been vented and thus unable to re-submerge.

This was an observational study that measured true conditions experienced by fish captured and released in an actual fishery. By collecting data on a variety of impairments and condition factors in the field, fish in the best condition could be distinguished, which allowed for meaningful comparisons with fish released in poorer condition. Given the highly variable conditions of capture, handling and release that fish are potentially exposed to in recreational fisheries, the detection of significant differences in relative survival between release condition categories is an unequivocal result. The utility of the proportional hazards model to effectively control for variable fishing effort across regions and across years is also demonstrated. However, confidence intervals around hazard ratios for gags in fair and poor condition were wide, and this analysis could not compare fish released in good condition to a true control, because they had to be captured and handled in order to be tagged. A potential source of mortality that was not measured in this study is predation of fish released in good condition as they swim through the water column and return to bottom habitats. To account for the unknown sources of mortality for the control group, an acceptable range of survival percentages was selected and incorporated into uncertainty around estimates of overall discard mortality. Overall estimated discard mortality in shallow water, where nearly 80% of fish in the control group were observed, was approximately 9% (range of uncertainty 0.09– 17.05%) at depths up to 20 m and approximately 15% (1.30–25.21%) between 21 and 30 m. This range is comparable to the two other studies for gag. One published tag-recapture study estimated overall mortality to be 14.3% and 23% for gags released in depth intervals of 11–20 m and 21–30 m, respectively (McGovern et al., 2005; Fig. 6). At shallower depths (mean 5.7 m), another unpublished study reported 7.2% of gags (n = 111) caught with hook-and-line gear suffered mortality when held in cages for 48 h (Flaherty et al., 2011). Both estimates included mortalities from hooking injuries, gill injuries and barotrauma (to the extent that it was present in shallow depths). The cage study excluded potential mortality from predation during release, whereas the tagging study included any mortality (including that unrelated to catch-and-release).

Two published mark-recapture studies for gag and other grouper species cite diminished tag returns as evidence of greater mortality with increased depth. Wilson and Burns (1996) reported reduced recapture percentages with depth for gag, scamp (*Mycteroperca phenax*) and red grouper (*Epinephelus morio*) tagged in the Gulf of Mexico (between 26 and 30 degrees latitude adjacent to the west coast of Florida) during 1990–1994. Likewise, McGovern et al. (2005) reported reduced percentages of recaptures and greater estimated mortality with increased depth for gags tagged in the Atlantic Ocean between North Carolina and the Florida Keys during 1995–1998. While there were few changes in fishing regulations during the 1990s that would have affected fishing pressure across years, neither of these studies controlled for the potential effect of variable fishing effort among regions in the respective geographic areas. In the McGovern et al. (2005) study, 81% of gag were tagged in South Carolina; however, the authors noted that recapture percentages were greater off Florida and attributed this observation to the fact that gag spawning aggregations at depths of 49–91 m along the narrow continental shelf are more accessible to fishermen in that area. This then raises the question of whether reduced recapture rates in greater depths may be explained, at least in part, by comparatively less fishing effort offshore in the region where the majority of fish were tagged.

Unlike the two other mark-recapture studies for gag, reported recapture percentages in this study did not decline with increased depth. Overall recapture percentages for gags tagged in the two regions adjacent to Tampa Bay were similar in the offshore and nearshore areas (9.06% and 8.65%, respectively), even though fishing effort offshore is low due to inaccessibility, takes place at much greater depths (mean = 41.1 m offshore versus 18.2 m nearshore), and only 33% of gags were released in good condition (compared with 94% nearshore). This may be attributed to exceptional cooperation by the small number of headboat operators who exclusively offer multiday fishing trips in this region and that also allowed fishery observers from FWC to tag and release fish during their trips. In the Panhandle region, fewer than half (45%) of gags observed were released in the best condition, and fishing also took place in relatively greater depths (mean = 29.8 m) than in the Tampa Bay nearshore region, yet the highest overall tag-recapture percentage (13.6%) was from this region. Once the effect of regional fishing effort was controlled for, the proportion of gags that were released in fair and poor condition at greater depths in this study translated into a significant increase in overall estimates of discard mortality with increased depth. However, the band of uncertainty for estimates in this study was wide at depths >30 m due to higher proportions of gags in fair or poor condition and the large confidence intervals around estimates of S_2 and S_3. Even given the wide band of uncertainty around estimates in this study, the increase in mortality with depth was much more gradual compared to estimates from the previous study in the Atlantic, where variable recapture and reporting rates were not controlled for (Fig. 6).

The greatest concentration of recreational fishing effort in the Gulf of Mexico is off the west coast of Florida (Hanson and Sauls, 2011), and interpreting low recapture percentages in the Tampa Bay nearshore region as evidence that gags suffered greater discard mortality in shallow depths would have profound implications for fisheries management and stock assessments. The shallow west Florida continental shelf is an important staging area for sub-adult gags before migrating offshore (Koenig and Coleman, 1998; Switzer et al., 2012), and sub-adult gags are highly abundant and vulnerable to the nearshore recreational fishery (as evidenced by this study). For investigators interested in comparing the relative recapture rates of released fish in other large-scale tag-recapture studies, this analysis demonstrates the importance of understanding and accounting for covariates on tag-recapture rates before interpreting results. It was expected during the design of this study that variable fishing pressures among regions would influence encounter rates for tagged fish. Changes in fishing regulations over the course of this study, however, were not anticipated. Prior to 2011, recreational harvest was open during most months of the year, whereas recreational harvest of legal-size gag from federal waters was restricted to September 16–November 15 in 2011 and July 1–October 31 in 2012. Fish tagged and released just prior to the opening of a recreational season may be encountered after a shorter time at large, compared with fish tagged at other times of the year, simply due to increases in targeted fishing effort during the season. Therefore, it was important to control for the month and year in which fish were tagged and released. Examining interactions of covariates also helped interpret the combined effects of variable closed seasons with a minimum size limit (559 mm), which remained unchanged during this study. The hazard ratio for length in this model was 1.148, which means that for each 100 mm increase in the size of fish at the time they were tagged, the hazard of recapture increased 14.8%. This result was counterintuitive, given that fish in good condition were significantly smaller than those in fair or poor condition. When the interaction between fish size and month was revealed, it was clear that something other than release condition alone was influencing reporting rates for larger fish. This interaction may be explained by increased targeting of legal-size fish during months when recreational harvest is permitted. Also, if anglers are less likely to notice tags on fish that must be released, then tags on legal-size gags may be noticed less often during months when harvest is closed. Since sublegal-size gags must be released year-round, tags may not be noticed or may be reported even less often. By including length and the interaction between length and month as covariates, the potential effects of the minimum size limit and the harvest season on the timing of first reported recapture were controlled for in this analysis. In conclusion, it is important that researchers be aware of potential confounding effects when designing and interpreting results for tag-recapture studies, particularly those that depend on commercial and recreational fishers for tag-return observations, and that they can adequately account for those effects in tag-recapture models.

Acknowledgments

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References

Allison, P.D., 2010. Survival Analysis Using SAS: A Practical Guide, second ed. SAS Press, Cary, NC.
Bartholomew, A., Bohnsack, J., 2005. A review of catch-and-release angling mortality with implications for no-take reserves. Rev. Fish Bio. Fish. 15, 129–154.
Burnham, K.P., Anderson, D.R., White, G.C., Brownie, C., Pollock, K.H., 1987. Design and Analysis Methods for Fish Survival Experiments Based on Release-Recapture. Am. Fish. Soc. Monograph 5, Bethesda, MD.
Coggins, L.G., Catalano, M.J., Allen, M.S., Pine, W.E., Walters, C.J., 2007. Effects of cryptic mortality and the hidden costs of using length limits in fishery management. Fish Fish. 8, 196–210.
Coleman, F., Figueira, W., Ueland, J., Crowder, L., 2004. The impact of United States recreational fisheries on marine populations. Science 305, 1958–1960.
Cooke, S.J., Schramm, H.L., 2007. Catch and release science and its applications to conservation and management of recreational fisheries. Fish. Manag. Ecol. 14, 73–79.
Cooke, S.J., Suski, C.D., 2004. Are circle hooks an effective tool for conserving marine and freshwater recreational catch-and-release fisheries? Aquat. Conserv. 14, 299–326.
Cox, D.R., 1972. Regression models and life tables. J. R. Stat. Soc. Ser. B: Stat. Methodol. 34, 187–220.
Diamond, S.L., Campbell, M.D., 2009. Linking "sink or swim" indicators to delayed mortality in red snapper using a condition index. Mar. Coast. Fish. 1, 107–120.
Flaherty, K.E., Winner, B.L., Barbieri, L., 2011. Characterization of recreational-discard composition and mortality rates for gray snapper and other estuarine-dependent reef fishes within a Gulf Coast Estuary and Nearshore Florida Waters. In: NOAA/NMFS Cooperative Research Program Final Report. Award #NA09NMF4540136, submitted October 28, 2011.
GMFMC, 2008. Reef Fish Amendment 30b: Gag-end Overfishing and Set Management Thresholds and Targets, Red Grouper-set Optimum Yield TAC and Management Measures, Time/Area Closures, and Federal Regulatory Compliance. Gulf of Mexico Fishery Management Council, Tampa, FL.

Hanson, C., Sauls, B., 2011. Status of recreational saltwater fishing in Florida: characterization of license sales, participation, and fishing effort. Am. Fish. Soc. Symp. 75, 355–365.

Hoffman, A., Skalski, J., 1995. Inferential properties of an individual-based survival model using release-recapture data: sample size, validity and power. J. Appl. Stat. 22, 579–595.

Hueter, R.E., Manire, C.A., Tyminski, J.P., Hoenig, J.M., Hepworth, D.A., 2006. Assessing mortality of released or discarded fish using a logistic model of relative survival derived from tagging data. Trans. Am. Fish. Soc. 135, 500–508.

Koenig, C., Coleman, F., 1998. Absolute abundance of juvenile gags in sea grass beds of the northeastern Gulf of Mexico. Trans. Am. Fish. Soc. 127, 44–45.

Leung, K., Elashoff, R.M., Afifi, A.A., 1997. Censoring issues in survival analysis. Annu. Rev. Public Health 18, 83–104.

Lowther, A.B., Skalski, J., 1997. The design and analysis of salmonid tagging studies in the Columbia Basin. A New Model for Estimating Survival Probabilities and Residualization from a Release–Recapture Study of Fall Chinook Salmon (*Oncorhynchus tshawytscha*) Smolts in the Snake River, vol. VII. U.S. Department of Energy, Bonneville Power Administration, Portland, OR http://www.cbr.washington.edu/papers (accessed May 2013).

McGovern, J.C., Sedberry, G.R., Meister, H., Westendorff, T.M., Wyanski, D., Harris, P.J., 2005. A tag and recapture study of gag *Mycteroperca microlepis*, off the southeastern U.S. Bull. Mar. Sci. 76, 47–59.

Overton, A.S., Zabawski, J., Riley, K.L., 2008. Release mortality of undersized fish from the snapper-grouper complex off the North Carolina coast. N. Am. J. Fish. Manage. 28, 733–739.

Pine, W.E., Pollock, K.H., Hightower, J.E., Kwak, T.J., Rice, J.A., 2003. A review of tagging methods for estimating fish population size and components of mortality. Fisheries 28, 10–22.

Pledger, S., Pollock, K.H., Norris, J.L., 2003. Open capture–recapture models with heterogeneity. I. Cormack-Jolly-Seber model. Biometrics 59, 786–794.

Pollock, K.H., Winterstein, S.R., Conroy, M.J., 1989. Estimation and analysis of survival distributions for radio-tagged animals. Biometrics 45, 99–109.

Rummer, J.L., 2007. Factors affecting catch and release (CAR) mortality in fish: insight into CAR mortality in red snapper and the influence of catastrophic decompression. Am. Fish. Soc. Symp. 60, 3–144.

Sauls, B., Ayala, O., 2012. Circle hook requirements in the Gulf of Mexico: application in recreational fisheries and effectiveness for conservation of reef fishes. Bull. Mar. Sci. 88, 667–979.

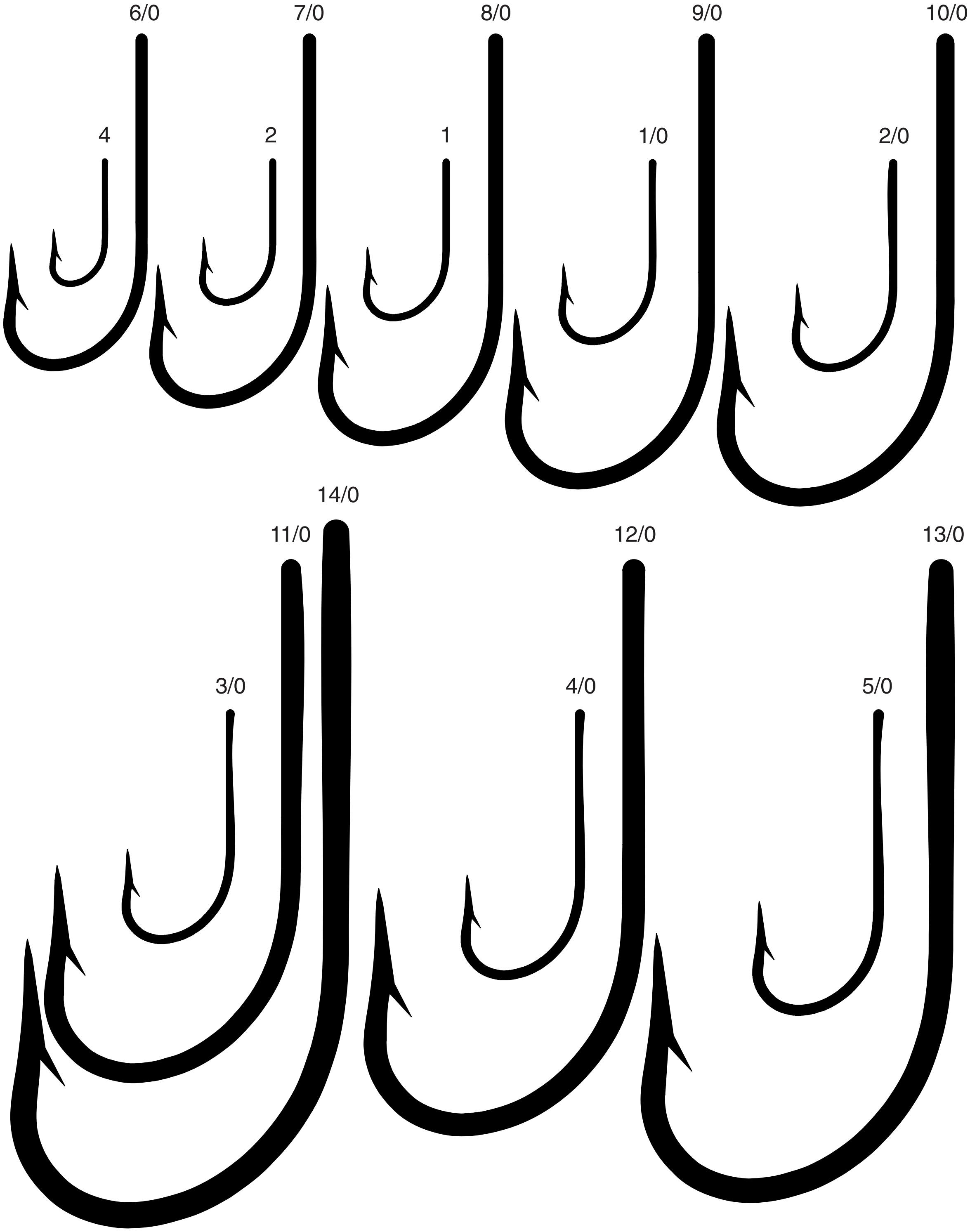
SEDAR (Southeast Data, Assessment, and Review), 2013. Section II: Data Workshop Report, Gulf of Mexico Gag. In: SEDAR 33. SEDAR, North Charleston, SC http://www.sefsc.noaa.gov/sedar, www.sefsc.noaa.gov/sedar (accessed October, 2013).

St. John, J., Syers, C.J., 2005. Mortality of the demersal West Australian dhufish *Glaucosoma hebraicum* following catch and release: the influence of capture depth, venting and hook type. Fish. Res. 76, 106–116.

Switzer, T., MacDonald, T., McMichael, R., Keenan, S., 2012. Recruitment of juvenile gags in the eastern Gulf of Mexico and factors contributing to observed spatial and temporal patterns of estuarine occupancy. Trans. Am. Fish. Soc. 141, 707–719.

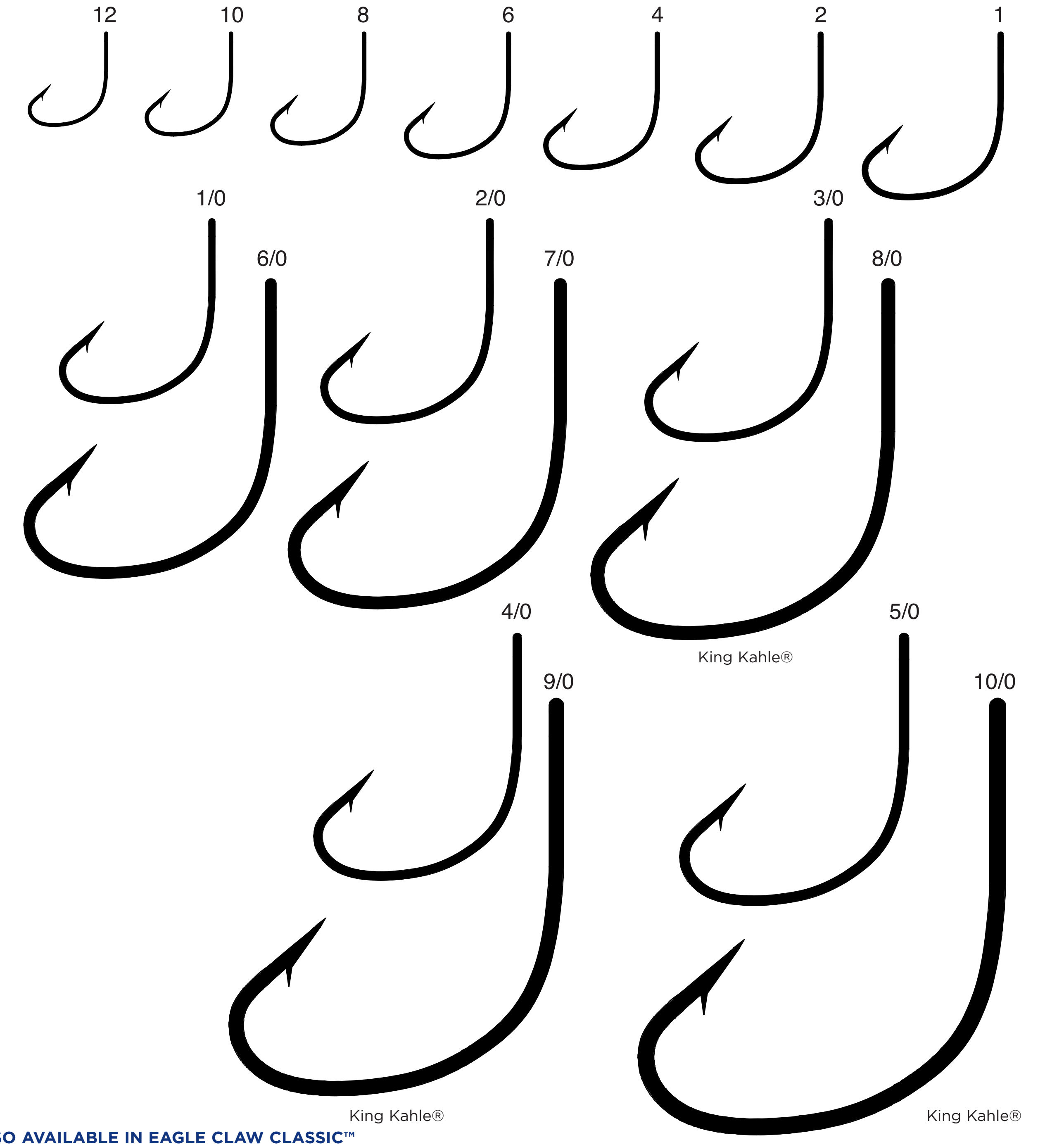
Wilde, G., 2009. Does venting promote survival of released fish? Fisheries 34, 20–28.

Wilson, R., Burns, K.M., 1996. Potential survival of released groupers caught deeper than 40 m based on shipboard and in-situ observations, and tag-recapture data. Bull. Mar. Sci. 58, 234–247.



ALSO AVAILABLE IN EAGLE CLAW CLASSIC™

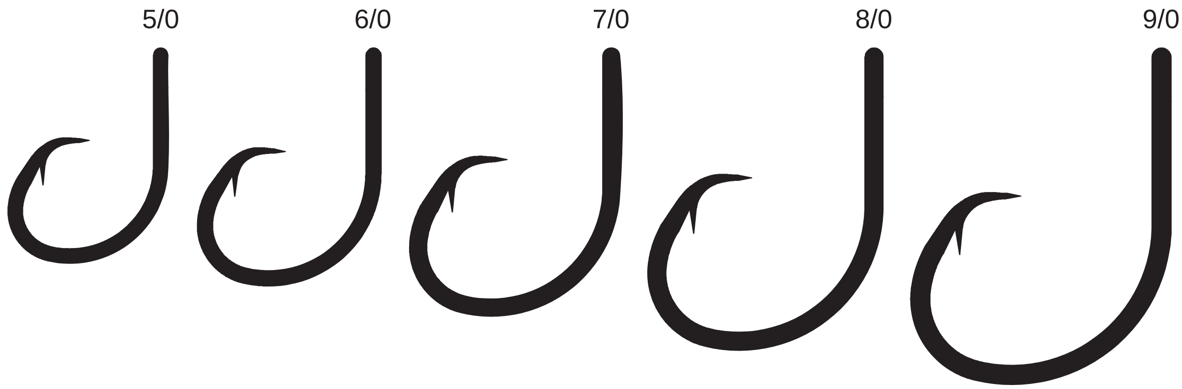
Part #	Finish	Description	Size	Package
254	Sea Guard™	O'Shaughnessy, Non-Offset, Ringed Eye, Forged	4, 2, 1, 1/0, 2/0, 3/0, 4/0, 5/0, 6/0, 7/0, 8/0, 9/0, 10/0, 11/0, 12/0, 13/0, 14/0	100, A, F, Bulk



ALSO AVAILABLE IN EAGLE CLAW CLASSIC™

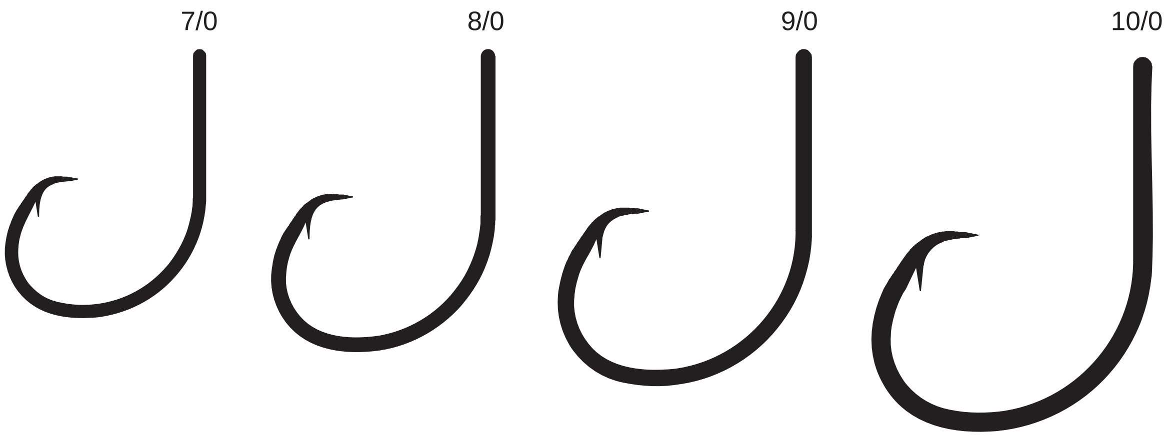
Part #	Finish	Description	Size	Package
L141	Bronze	Kahle®, Offset, Ringed Eye, Non-Forged, Plain Shank	12, 10, 8, 6, 4, 2, 1, 1/0, 2/0, 3/0, 4/0, 5/0, 6/0, 7/0	F, G, Bulk
L141BP	Platinum Black™	Kahle®, Offset, Ringed Eye, Non-Forged, Plain Shank	1/0, 3/0, 5/0, 7/0, 8/0, 9/0, 10/0	F
L141C	Chartreuse	Kahle®, Offset, Ringed Eye, Non-Forged, Plain Shank	1/0, 2/0, 3/0, 4/0, 5/0,	G
L141K	Krawfish™	Kahle®, Offset, Ringed Eye, Non-Forged, Plain Shank	1/0, 2/0, 3/0, 4/0, 5/0	G
L141R	Red	Kahle®, Offset, Ringed Eye, Non-Forged, Plain Shank	6, 4, 2, 1, 1/0, 2/0, 3/0, 4/0, 5/0, 6/0	G
L142	Nickel	Kahle®, Offset, Ringed Eye, Non-Forged, Plain Shank	4, 2, 1, 1/0, 2/0, 3/0, 4/0, 5/0, 6/0, 7/0	F, G, Bulk
L143	Gold	Kahle®, Offset, Ringed Eye, Non-Forged, Plain Shank	12, 10, 8, 6, 4, 2, 1, 1/0, 2/0	G

L2004



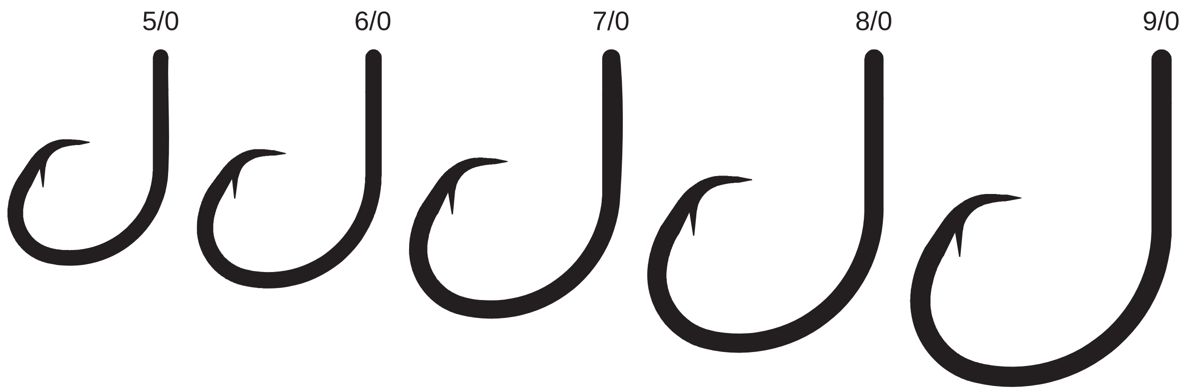
Part #	Finish	Description	Size	Package
L2004	Platinum Black™	Circle Sea™, Medium Wire, Offset, Ringed Eye	5/0, 6/0, 7/0, 8/0, 9/0	F, G, Bulk

L2004EL - L2004ER



Part #	Finish	Description	Size	Package
L2004EL	Sea Guard™ Red	Endorsed by the Billfish Foundation, Sailfish, Circle Sea™, Wide Gap, Non-Offset, Ringed Eye, Light Wire	7/0, 8/0, 9/0, 10/0	F, G, Bulk
L2004ER	Sea Guard™ Black	Endorsed by the Billfish Foundation, Sailfish, Circle Sea™, Wide Gap, Non-Offset, Ringed Eye, Light Wire	7/0, 8/0, 9/0	F

L2005



Part #	Finish	Description	Size	Package
L2005	Bronze	Circle Sea™, Medium Wire, Offset, Ringed Eye	5/0, 6/0, 7/0, 8/0, 9/0	F

Offshore Data Sheet

Sample Identification

G	M	D													F	D			X	X

Type — Year — Month — Office Use — Station Number — Day — Project — Region

H (Gear) — Mode — Chum — **C**harter/**H**eadboat — 1 2 0 (Vessel ID) — Sampler ID Number

	Target Species Groups (see list)	Est. % fished
1		
2		
3		

Location Information

		Degrees	Minutes	Degrees	Minutes
Instr.	Lat.		X X		X X
	Long.		X X		X X
		Beginning		*Ending*	

Statistical Zone — Subzone — Depth (m) — Bottom Type (other:)

Weather

Wind Direction — Wind Speed MPH — % Cloud Cover

Precipitation — Period — Sea State

Sea State:

0 - Calm (0m)
1 - Calm (0-0.1m)
2 - Smooth(0.1-0.5m)
3 - Slight (0.5-1.25m)
4 - Mod. (1.25-2.5m)
5 - Rough (2.5-4.0 m)

Fishers

	Fisher/Crew Initials	Rig #	*Bait 1* Type	% fished	*Bait 2* Type	% fished	*Bait 3* Type	% fished	*Hook* No	Size	Type	Offset	*Leader Line* Test (lb)	Type	Reel Type	*Start Time* Hours	Min	*End Time* Hours	Min	Breaks (minutes)	*Notes*
1																					1
2																					2
3																					3
4																					4
5																					5
6																					6
7																					7
8																					8
9																					9
10																					10
11																					11
12																					12
13																					13
14																					14
15																					15
16																					16
17																					17
18																					18
19																					19
20																					20

Region: **NW** - northwest; **BB** - big bend; **TB** - greater Tampa Bay; **KY** - Keys

Instr.: **C**hart; **D**ifferential GPS; **G**PS (non-differential); **L**ORAN; **W**AAS GPS

Bottom Type: **A**rtificial reef; **N**atural reef; **F**lat bottom; **U**nknown

Line Type: **M**onofilament; **B**raided; **W**ire, **F**luorocarbon

Reel Type: **S**pinning; **B**aitcasting; **F**ly; **O**ther

Hook: **C**ircle; **J**-hook; **T**reble, **K**hale

Bait: **A** - Artificial (single hook); **M** - Artific. (multi-hook); **C** - Dead (cut bait); **D** - Dead (whole); **F** - Fish (live); **S** - Shrimp (live); **Q** - Squid; **K** - Cocktail

Notes:

Offset: **N**O; **Y**ES (or write degrees if measured)

Chum: **B**ottom chum bag; **S**urface chum bag; chum b**A**lls; **L**ive bait

Mode: **A**nchored; **D**rifting; **T**rolling; **H**olding

Period: **1** - 1 hr before/after sunrise; **2** - Daytime; **3** - 1 hr before/after sunset; **4** - Night

Precip: **F**og; **N**o precipitation, **R**ain

Wind Direction: ***N***, ***E***, ***S***, ***W***, ***NE***, ***NW***, ***SE***, ***SW***

0 = No wind

2010 Offshore data sheet, 03/09/2010

Recorded — Reviewed — Entered — Proofed — Corrected — Complete

Catch Data

G | M | D — Type | Year | Month | Office Use | Station Number | Day | Sheet: ___ of ___ | Vessel ID: 1 2 0 | Sampler ID | ___ of ___ Page

	Fisher/Crew		Species	*Measurements (mm)*			Disp	Bait	Rod Attnd	*Hook*			*Fishing Depth*	Health		*Release*			Use	Tag	*Tag Information*		*Weight*	Spec No	Sex	*Wet Lab*							
	Initials	Rig #		SL	FL	TL				Posit.	Rmvd.	H Tool		Barotrauma	FHC	Cond	Vent	V Tool			Type	Tag #	Wet (g)			O	F	G	H	M	D	S	X
1																																	
	Notes:																						*HG Vial:*										
2																																	
	Notes:																						*HG Vial:*										
3																																	
	Notes:																						*HG Vial:*										
4																																	
	Notes:																						*HG Vial:*										
5																																	
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20																																	
	Notes:																						*HG Vial:*										

Sample Identification

Station Number
Each time the vessel moves to a new fishing location, begin a new data sheet and record a sequential station number.

Region
NW - Northwest (Escambia to Gulf counties)
BB - Franklin to Levy Co.
TB - Citrus to Sarasota
KY - Monroe County

Fishing Mode
A - Boat Anchored
D - Boat Drifting
T - Boat Trolling
H - Holding (No anchor)

Chum
B - Bottom chum bag
S - Surface chum bag
A - Chum balls
L - Live bait chum

Vessel ID
7 digit vessel ID code from FDM vessel register

Estimated % Fished
Percentage of the total time fishing for each target group. Written as an integer from **1** to **X**, with **X** representing 100% and all other numbers representing 10% increments.

Target Species Groups
Serranidae (Seabass: GG, RG, BG, BSB, etc.)
Lutjanidae (Snappers: RS, VS, GS, LS, MS, SS)
Haemulidae (Grunts: WG, TT, etc.)
Balistidae (GT)
Sparidae (Porgies: RP, LHP, JHP, etc.)
Scombridae (Mackerels: KM, SM, WA, LT, BT, YT...)
Coryphaenidae (Dolphins: DO)
Carangidae (Jacks: GAJ, LAJ, BR, ALM, etc.)
Miscellaneous (Other fish: CO)

Ch/Head
C - Charter Boat
H - Headboat
M-multi **D**-Directed

Location Information

Location Instr.
C - Chart
D - Differential GPS
G - Non-Differential GPS
L - LORAN
W - WAAS GPS

Lat./Long.
Ask captain for permission in advance to record beginning latitude and longitude in degrees and minutes (to the nearest tenth of a minute) when fishing begins at each station. If vessel is not anchored, record ending lat/long when fishing stops.

Bottom Type
A - artificial reef
N - natural reef
F - flat bottom
U - unknown relief

Depth
Bottom depth (in meters) at fishing station.

Statistical Zone/Subzone
Refer to Marine Fisheries Trip Ticket Fishing Area Code Map

Fishers

Fisher/Crew
Combination of initials along with sequential number representing each different rig fished. First fisher listed is the PI.

Bait Type
A - Artificial - single hook
C - Dead bait-Cut
D - Dead bait-whole
F - Fish-Live
K - Cocktail (combo)
M - Artificial - Multi-hook
S - Shrimp-Live
Q - Squid - dead/live

Hook Type
C - Circle
J - J-hook
T - Treble
K - Kahle

Leader Test
Integer for test of leader material (pounds)

Bait % Fished
Estimated % time fished per bait per fisher, **1-X**

Leader Type
B - Braided
F - Fluro
W - Wire
M - Mono

Rig
Integer for number of fishing setups the angler is using for that station (using multiple poles or changing the leader and hook type)

Hook Number
Integer for number of hooks on rig fished

Hook Size
Either one digit or **X/0**

Offset
N - No
Y - Yes (Not measured) Degrees offset if measured

Reel Type
B - Baitcasting
E - Electromate
F - Fly
S -Spinning
T - Bandit
O - Other (describe in notes)

Start and End Time
Times should be in whole minutes and in military time

Catch Data

Fisher/Crew
Should match information recorded for each fisher in ***Fisher*** section.

FHC (Health code)
T - Tumor
B - Bloody areas
E - Erosion
P - Parasite
F - Fin rot
S - Skeletal deformity
O - Other
U - Ulcer
. - Null (not checked)

Rod Attend
Y - attended
N - not attended

Species
Species being measured, three letter genus and full species name. Record ***No Fish*** if no fish caught.

Hook Removed
D - Yes, difficult
E - Yes, easy
N - No

BTC (Barotrauma Code) Record up to 4 codes
B - Bladder inflated
P - Pop-eyes
I - Intestines visible
S - Stomach everted
N - No visible signs
X - External bleeding
O - Other
. - Not checked

Hook Position
E - Eye
L - Lip
F - Foul hooked
T - Throat
G - Gill
U - Gut
I - Inside mouth

Measurements
Measurements of the fish's Fork Length (**FL**), Standard (SL), and Total Length (**TL**) to nearest mm.

Release Condition
G - Good, fish swam toward bottom immediately upon release
F - Fair, fish disoriented, slowly swam towards bottom
B - Bad, fish disoriented, remained at surface
D - Dead, fish dead/unresponsive after release
P - Preyed upon by fish/bird
M - Preyed upon by marine mammal
N-Net/recompression tool
U-Unobserved/unknown
. - Null, fish culled/harvested

Disposition
1 - Released alive, legal
2 - Released alive, not legal
3 - Kept to eat
4 - Used for bait
5 - Plan to sell
6 - Released dead
7 - EFP Sampled
8-Fish Preyed upon

Use
C - Culled-Random
F - Freed-w/other data
N - Culled-Non-random
R-Removed/replaced tag
. - no other data

Tag
R - Recaptured fish
T - Tag and release

Vented
A-Anus
B - Yes, bladder
N - No
S - Yes, stomach

Vent Tool
H-Hook/Poker
T - Venting Tool
K - Knife
S - Syringe
O - Other

H Tool
Dehooking tool used
D - Dehooker
O - Other
H - Hands
. - N/A
P - Pliers

Fishing Depth
Depth fish caught
S - Surface
M - Middle
B - Bottom

Tag Type
D - Dart tag
X - PDX tag

Sex
F - Female
B - Sym. hermaphrodite
M - Male
U - Sex indeterminate
N - Not checked but should have been

Tag Number
Number on the tag

Weight
Total weight of fish (g)

Specimen Number
Number assigned to each specimen of a species from which wetlab information is taken.

Tag
R - Recaptured fish
T - Tag and release

Wetlab
O - Sagittal otoliths extracted, (**Y**/**N**)
F - Fish health sample taken, (**Y**/**N**)
G - Genetic sample taken (fin clip or cheek swab), (**Y**/**N**)
S - Spine taken for aging, (**Y**/**N**)
X - Other sample taken, (**Y**/**N**)

Species Abbreviations (for common species in target species groups)

Lutjanidae: snappers	Serranidae: seabass	Carangidae: jacks	Haemulidae: grunts
RS - red snapper	GG - gag grouper	GAJ - greater amberjack	WG - white grunt
VS - vermillion	RG - red grouper	LAJ - lesser amberjack	TT - tomtate
MS - mutton snapper	BG - black grouper	BRF - banded rudderfish	**Sciaenidae: drums**
YT - yellowtail snapper	BSB - black seabass	ALM - almaco jack	RD - red drum
LS - lane snapper	**Scombridae: mackerels**	BR - blue runner	**Coryphaenidae:**
GS - gray snapper	KM - king mackerel	**Miscellaneous:**	DO - Dolphin
SS - silk snapper	SM - spanish mackerel	CO - cobia	**Balistidae: triggerfish**
Sparidae: porgies	WA - wahoo		GT - gray triggerfish
LHP - littlehead porgy	BFT - blackfin tuna		
RP - red porgy	YFT - yellowfin tuna		
JHP - jolthead porgy	LT - little tunny		