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Research Paper

Minimizing bycatch and improving efficiency in the commercial bottom longline fishery in the Eastern Gulf of Mexico

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ABSTRACT

We investigated the effects of hook soak time on targeted reef species and shark bycatch in the reef fish bottom longline fishery in the Gulf of Mexico. Beginning in 2010, capture time and catch per unit effort (CPUE) for the primary target species red grouper (*Epinephelus morio*) in the fishery were evaluated using hook timers. Findings indicated that typical duration of hook soak times is longer than necessary to efficiently harvest red grouper and a reduction in gear soak times to less than one hour would result in minimal or no reduction in red grouper CPUE. The mean capture time of sharks and red grouper differed significantly, suggesting that a reduction in soak time would likely reduce the bycatch of sharks in the fishery. The study also revealed barometric pressure, lunar phase, and fish size were significant covariates with red grouper capture times and that different bait types significantly affected CPUE. Implementing shorter hook soak times would likely improve fishery profitability and potentially reduce discards of unwanted species in the fishery.

1. Introduction

Bottom longlines have been the primary method of harvesting grouper in the Gulf of Mexico (GoM) since the early 1980's with a peak in total grouper landings of 5670 t in 1982 (Goodyear and Schirripa, 1993). The primary species targeted inshore of the 91 m (50 fathom) contour is red grouper (*Epinephelus morio*) but the incidental capture of other important reef fish species also occurs. Currently, there are approximately 62 permit holders with a reef fish bottom longline endorsement operating in the eastern Gulf of Mexico (SERO, 2016). In 2014, the GoM bottom longline fishery landed 1785 t of red grouper valued at 12.6 million dollars. The eastern GoM is not only an important fishing ground, but also critical habitat and foraging area for sea turtles (Schmid and Barichivich, 2005; Foley et al., 2014).

The management of the reef fish fishery has been regulated by area closures, quota systems, and size limits to enhance fish stock strength and reduce bycatch. The effectiveness of these measures has long been debated (Coleman et al., 2000; Nieland et al., 2007; Stephen and Harris, 2010). The management system for many of the species currently targeted in the fishery has shifted from a "derby" fleet-wide quota to an individual fishing quota within the past ten years. The individual fishing quota system annually distributes a transferrable allocation of the quota for each species category to shareholders in the fishery. The shareholders can then assign a portion or all of the allocated allowable catch to a fishing vessel in their fleet. Once a vessel's quota for a particular species is reached, another finfish species may become the target. The current management system does allow some flexibility between species categories to reduce discards if a vessel lacks the necessary allocation.

In 2006, the National Marine Fisheries Service (NMFS) Southeast Fisheries Science Center (SEFSC) implemented a mandatory observer program to gain a greater understanding of catch rates, bycatch composition, and discard mortality associated with the U.S. Gulf of Mexico commercial reef fish fishery (Scott-Denton et al., 2011). Before the mandatory observer program, industry self-reporting through logbook and discard supplementary data submission was used to estimate landings and bycatch (inclusive of protected species).

The bycatch of both unwanted and undersized species, notably red grouper is of particular concern. The minimum size limit for red grouper was 50.8 cm in total length (TL); in 2009, the limit was reduced to 46 cm TL. Based on surface observations of discarded species in the bottom longline fishery (Scott-Denton et al., 2011), the majority of discards were released alive; however, 42% of the individuals displayed visual signs of barotrauma stress (air bladder expansion and/or eyes protruding). Of the individuals released alive, undersized red grouper, Atlantic sharpnose shark (*Rhizoprionodon terraenovae*), smooth dogfish shark (*Mustelus canis*), and red snapper (*Lutjanus campechanus*), accounted for 83%.

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Based on the documented takes of loggerhead sea turtles (*Caretta caretta*) during the first two years of the observer program, the estimated take in the fishery exceeded the authorized take level promulgated in the 2005 biological opinion and led to regulatory action. In May 2009, an emergency rule to protect sea turtles went into effect prohibiting the use of bottom longline gear east of Cape San Blas, Fla., shoreward of the 91 m (50 fathom) contour (US Department of Commerce, 2009a). These time and area closures were intended to reduce the spatial and temporal overlap of fishing effort and sea turtles when turtles were on the summer foraging grounds.

Subsequent regulations in 2010 restricted bottom longline gear east of Cape San Blas, Fla., shoreward of the 64 m (35 fathom) contour from June through August, limited the number of hooks onboard to 1000, of which only 750 could be rigged for fishing, and reduced the number of vessels through an endorsement system based on documentation of an average annual landing of at least 18.14 t during 1999 through 2007 (US Department of Commerce, 2010). The hook number restriction was intended to minimize the amount of time needed to set and haul the gear, thus limiting the mean hook soak time and decreasing the likelihood that sea turtles will drown if captured. However, little is known about the capture process of the targeted reef fish or bycatch species and what potential affect the reduced soak times may have had.

As with many reef fish species, groupers are sedentary, opportunistic feeders that lie in wait and ambush their prey (Thompson and Munro, 1978). In contrast, sharks are roving foragers with large home ranges. While exhibiting varying degrees of philopatry, foraging ranges commonly include areas of hundreds of square kilometers (Hueter et al., 2005). In addition, the fishing power or catch efficiency of bottom longline gear changes over time due to several factors including bait loss and target or bycatch species occupying hooks (Shomura, 1955; Shepard et al., 1975; Skud and Hamley, 1978; Løkkeborg, 1994; He, 1996). These studies indicate that the rate of bait loss over time is influenced by bait type and baiting technique, with firm bait such as squid (*Loliginidae*) being less likely to be torn or fall from hooks compared to soft fish baits such as mackerel (*Scomber spp*.). Bait is often removed by scavengers such as smaller fish that occasionally become hooked and in turn, become bait themselves.

The objective of this study was to use hook timers to characterize the time it takes for target and bycatch species to become hooked after the gear reaches the bottom. In this study, capture times were compared for animals with differing foraging strategies to assess the potential effects of reducing hook soak times on CPUE. The effects of environmental parameters and bait type on red grouper catch rates and capture times were also evaluated.

2. Materials and methods

2.1. Data collected in the study

Beginning in September 2010, experimental data were collected by fishery observers on contracted commercial bottom longline vessels equipped with hook timers (Table 1). Data were collected in two fishing periods from September to December 2010 and January to May 2013 to distribute effort across the calendar year. Summer months (June to August) were excluded due to seasonal restrictions in place to limit sea turtle interaction in the fishery. Fishery observers collected data consistent with the mandatory reef fish observer program in addition to specific supplementary hook timer experimental information (NMFS, 2015). Scott-Denton et al. (2011) and Scott-Denton and Williams (2013) provide detailed descriptions of the protocol on data collection for the reef fish observer program. Prior to the initiation of the experiment, the variables of interest that may affect capture times were determined with input from industry and collaboration with other researchers. Table 2 provides a summary and brief description of the covariates examined for their influence on capture times for both phases of the study.

Table 1
Summary information including the number of unique vessels, fishing trips, fishing sets, total number of hooks, and total number of hook timers deployed for each fishing period of the study.

Fishing Period	September–December 2010	January–May 2013
Number of Vessels	3	1
Fishing Trips	9	5
Fishing Sets Observed	216	147
Total Number of Hooks Set	145,674	96,016
Total Number of Hook Timers Deployed	28,608	19,106

Sets were deployed between dawn and dusk. Prior to each set, the barometric pressure and pressure trend were recorded from a Cole-Palmer, model WU-90080-02 barometer (accuracy ± 12 mbar). The barometer displayed pressure readings from the previous 12 h as a histogram. The pressure trend was interpreted by the observer as Falling, Rising, or Stable. During set deployment, hook timers (HT 600, Lindgrin Pittman Inc.) were distributed evenly across the set on every fifth or sixth hook (Fig. 1). Section markers were placed on the mainline every tenth hook timer to demarcate the gear into sections. Up to four Temperature/Depth Recorders (TDR) (LAT 1400, Lotek Wireless Inc.) were randomly placed along the line to record temperature and depth at one-minute intervals and provide an estimate of the average time needed for the gear to reach the bottom (sink time). Deployment times (time of day) were recorded for each section marker. Due to the rapid deployment rate of hooks, all hook timers within a section were assigned the mean deployment time for that section, i.e. the mean deployment time of the two adjacent section markers. Section deployments took up to four minutes; therefore using the mean section deployment time as an estimate for individual hook deployment times was accurate to +/− two minutes.

When fish were boarded on gangions with hook timers, the observer recorded the boarding time (time of day) and elapsed time from the hook timer. The capture time was calculated as follows;

$$\text{Capture Time} = \text{Boarding Time} - \text{Elapsed Time} - \text{Sink Time} - \text{Mean Section Deployment Time} \quad (1)$$

Because of using the mean section deployment time (instead of individual hook deployment times) in the capture time calculation, results were on occasion slightly negative when fish activated the timer immediately upon reaching the bottom. When the negative capture times occurred, the times were rounded up to zero min. Approximately 7% of the fish were either too small to activate hook timers or activated timers during haulback (i.e. elapsed times < 5 min) and therefore were not included in the capture time analyses. The fork length of red grouper was measured and converted to total length using the regression: TL = 1.05 * FL – 5.95, where TL is total length and FL is fork length, both in cm (SEDAR, 2009).

2.2. Statistical analyses

Analyses concentrated on drawing inferences for the two different metrics of capture times as a quantile or mean and catch per unit effort (CPUE) for evaluating efficiency in the fishery. For each major species group and the common individual species, 95% confidence intervals of the quantiles (0.5, 0.9, and 0.95) for capture times were generated by bootstrapping with 10,000 iterations. Bootstrapping was used because the capture times were not distributed normally and many subsets of the data had a limited amount of observations available. Different potential management scenarios for reducing soak time could then be compared by evaluating these results. Next, the available covariates were examined for their influence on mean capture times for red grouper and sharks. The final set of analyses examined the CPUE of red