Fisheries Research 188 (2017) 166–172

Contents lists available at ScienceDirect

Fisheries Research

journal homepage: www.elsevier.com/locate/fishres

Full length article

Sink or swim? Factors affecting immediate discard mortality for the gulf of Mexico commercial reef fish fishery

J.R. Pulver

National Marine Fisheries Service, Southeast Fisheries Science Center, Galveston Laboratory, 4700 Avenue U, Galveston, TX 77551, United States

ARTICLE INFO

Article history:
Received 3 October 2016
Received in revised form 5 December 2016
Accepted 24 December 2016
Handled by George A. Rose

Keywords:
Discard mortality
Reef fish
Grouper
Snapper
Barotrauma
Logistic regression

ABSTRACT

Fishery observer data collected from June 2006 through December 2015 in the Gulf of Mexico commercial reef fish fishery were examined to determine if any covariates available affected immediate discard mortality for six species: red grouper *Epinephelus morio*, red snapper *Lutjanus campechanus*, vermilion snapper *Rhomboplites aurorubens*, gag grouper *Mycteroperca microlepis*, scamp grouper *Mycteroperca phenax*, and speckled hind *Epinephelus drummondhayi*. Using logistic regression models, this study predicted immediate discard mortality was positively correlated with increased depths, seasons associated with warmer water temperatures, and external evidence of barotrauma. Additionally, bottom longline gear increased the predicted probability of immediate mortality compared to vertical line gear for all species except vermilion snapper. Air bladder venting significantly decreased the predicted probability of immediate mortality for all species except speckled hind. Future research incorporating tag-recapture data into the current observer program for the commercial reef fish fishery is vital to assess if condition assessment at release can be relied on as an accurate proxy for long-term survival. This research provides information that managers could potentially use to make more informed decisions when implementing measures such as changes to existing size limits, venting requirements, and seasonal, area, or gear restrictions intended to reduce unwanted discard mortality.

Published by Elsevier B.V.

1. Introduction

The Gulf of Mexico (Gulf) commercial reef fish fishery is a multi-species fishery primarily targeting groupers (*Epinephelus* sp. and *Mycteroperca* sp.) and snappers (*Lutjanus* sp. and *Rhomboplites* sp.) using two primary gear types, bottom longline and vertical line (handline or bandit). Some of the management options, such as size limits, area closures, and species-specific quota systems, result in fish discarded at-sea in depths correlated with immediate mortality (Bartholomew and Bohnsack, 2005; Gitschlag and Renaud, 1994; Render and Wilson, 1994; Rudershausen et al., 2007; Wilson and Burns, 1996). Grouper and snapper species are physoclistous, meaning they lack a duct leading from the swim bladder to the alimentary canal, making it difficult to quantify discard mortality due to internal injuries potentially not visible at release, e.g. ruptured swim bladder. Additionally, discard mortality rates can be affected by a number of different stressors, such as hooking trauma, barotrauma, handling time, and temperature (Campbell et al., 2014; Curtis et al., 2015; Jarvis and Lowe, 2008). The reduction of catch-and-release mortality rates are an important consideration for fishery managers due to the overexploitation of many stocks. In 2008, Gulf reef fish fishery managers enacted a rule requiring fishermen targeting reef fish to use circle hooks to reduce potentially fatal hook injuries sustained during capture (GMFMC, 2007). At the beginning of 2008, fishermen were required to use a venting tool on swim bladders for released reef fish captures to reduce the effects of barotrauma; however, the venting requirement was rescinded in 2013 due to questions regarding its effectiveness (GMFMC, 2013).

Multiple studies have attempted to quantify long-term survival rates using tag-recapture or other methods such as acoustic telemetry (Curtis et al., 2015; Patterson et al., 2002; Rudershausen et al., 2014; Sauls, 2014). Long-term or delayed discard mortality studies typically include covariates of interest when fitting logistic, proportional hazards regression, or relative risk models to determine their effect on mortality. Using acoustic telemetry (Curtis et al., 2015) and a meta-analysis (Campbell et al., 2014), research has reported reduced mortality rates for red snapper *Lutjanus campechanus* when captured at shallower depths and in seasons associated with cooler water temperatures. Campbell et al. (2014) evaluated the effects of venting the swim bladder of red snapper, and predicted that venting decreased immediate mortality compared to not venting, but increased delayed mortality. Sauls

E-mail address: jeff.pulver@noaa.gov

http://dx.doi.org/10.1016/j.fishres.2016.12.018
0165-7836/Published by Elsevier B.V.

(2014), using tag-recapture to estimate long-term mortality for gag grouper *Mycteroperca microlepis*, determined venting was associated with increased mortality, but noted the increased mortality may have been affected by other confounding factors besides venting. For example, Sauls (2014) reported vented gag groupers were typically both larger and caught at greater depths than non-vented fish. In both studies, it was stressed that other factors besides venting, e.g. increased handling time, may affect mortality.

Similar to other studies, the National Marine Fisheries Service (NMFS) Southeast Fisheries Science Center (SEFSC) fishery observer program currently determines immediate discard mortality through surface observations of individual fish after discard (Patterson et al., 2002; Stephen and Harris, 2010). Short-term survival is assumed if the fish rapidly or slowly is able to descend and immediate mortality is classified when the fish floated on the surface or floated on the surface then slowly descended (not swimming). Although submergence ability as a proxy for mortality is problematic since it does not account for any long-term effects, similar studies have shown that when other factors, such as hook trauma or barotrauma, are included it can be used as a reasonably accurate method for inferring mortality rates (Patterson et al., 2002; Rudershausen et al., 2014). Since the data available from the observer program span a relatively long time series and cover a large geographic area, inferences derived should be more robust than studies with a more limited scope and would be reflective of the actual fishery. Also, given that release conditions are highly variable and fish are subject to a multitude of stressors, the large number of observations available for most of the species of interest allows for an accurate evaluation of the different factors potentially affecting mortality. The purpose of this study was to determine if factors collected by the fishery observer program could be used to predict post-release survival for six commonly captured commercial reef fish species in the Gulf: red grouper *Epinephelus morio*, red snapper, vermilion snapper *Rhomboplites aurorubens*, gag grouper, scamp grouper *Mycteroperca phenax*, and speckled hind *Epinephelus drummondhayi*.

2. Methods

2.1. Reef fish observer program data

In July 2006, the NMFS SEFSC began a mandatory observer program with partial coverage to characterize the commercial reef fish fishery in the Gulf (Scott-Denton et al., 2011). Prior to 2006, the only observer coverage of the commercial reef fishery was a voluntary NMFS observer program conducted from 1993 through 1995. For the Gulf reef fish fishery mandatory program, vessels were randomly selected quarterly each year to carry an observer. Sampling effort was stratified by season and gear in the eastern and western Gulf based on annually updated vessel logbook data (Scott-Denton et al., 2011). Beginning in February 2009, increased observer coverage levels were directed at the bottom longline fishery in the eastern Gulf due to concerns regarding sea turtle interactions. Additionally, in 2011, increased funding allowed enhanced coverage of both the vertical line and bottom longline fisheries through 2014. As a result of these actions, observer coverage levels did not remain consistent throughout the years, but varied depending on funding levels. Fishery observer data collected using standardized sampling protocols from July 2006 through December 2015 were used for all fisheries management analyses (NMFS, 2016). Only data from bottom longline and vertical line were included as >99% of the number of captures for the fishery occurred with these gear types.

Fishery observers on reef fish vessels assigned one of the following dispositions to each fish captured by the vessel: kept, used for bait, discarded alive, discarded dead, discarded unknown if dead or alive, and unknown if kept or discarded. For the discarded fish, the alive or dead determination was based on surface observation of individual fish. If the fish rapidly or slowly descended, even with barotraumatic stress indicators, it was recorded as alive. It was considered dead if it floated on the surface or floated on the surface then slowly descended (not swimming). Some fish were recorded with an unknown discarded disposition due to the difficulty in observing discards attributed to poor lighting, high seas, or other factors. In this study, only individual fish that were discarded as either alive or dead were used to examine immediate mortality. Individual fish recorded as dead upon arrival were excluded from the analyses since the study's goal was to examine factors affecting survival of fish post-release.

Onboard reef fish vessels, observers assign a condition of capture for each individual fish based on external indicators of barotrauma. Research has shown that external indicators of barotraumatic stress will likely have an implication for the survival of the discarded fish (Rudershausen et al., 2007; Rudershausen et al., 2014). The condition categories were assigned as follows: normal appearance, everted stomach (protrusion from the buccal cavity), exopthalmia (eyes bulging out of the socket), both everted stomach and exopthalmia, dead on arrival, damaged by predators, and unknown. These condition categories attempt to quantify the level of barotraumatic stress on the fish based on expansion of the swim bladder. The expansion of the swim bladder can force the stomach and/or eyes out of the body cavity. Observers also recorded if the fish was vented (air bladder punctured) prior to release by the vessel; however, no distinction on the quality of the observed technique was recorded. Fishery observers measured fork length to the nearest mm for all species except for scamp grouper which were measured as stretched total length. Bottom depths were recorded in feet using fishing vessel equipment, i.e. typically depth sounders, and for vertical line vessels a fishing depth was estimated by monitoring gear deployment at each fishing site. All depths were converted to meters for the analyses.

2.2. Statistical analyses

For each of the six species, logistic regression models were fit using stepwise backwards selection to determine which covariates affected the proportion of immediate mortality observed. Non-significant ($P > 0.05$) covariates were removed using the likelihood ratio χ^2 *P*-Value to determine significance at each step. The initial model fit to the binary response of immediate mortality (alive or dead) was modeled as;

$$\begin{aligned} Logit\,(Y_i) &= \alpha + \beta Depth_i + \beta Season_i + \beta GearType_i + \\ &\beta Length_i + \beta ConditionCategory_i + \beta Vented_i \end{aligned} \quad (1)$$

where α is the intercept and β are the estimated model coefficients, depth of capture, astronomical season (e.g. winter is from 21 December through 21 March), gear type (bottom longline or vertical line), length, condition category at capture, and whether vented occurred. For the significant variables remaining in the models, the predicted odd ratios with profile likelihood 95% confidence intervals calculated using the 'confint' function in R were reported. For each final model, the overall χ^2 significance compared to an intercept only model, percent of deviance explained, and area under the receiver operating characteristic curve (AUC) were also reported. The AUC is a measure of overall model predictive accuracy, with 0.5 considered random and 1.0 a perfect fit (Agresti, 2013).

Hosmer-Lemeshow test statistics were used to assess the goodness of fit for each logistic regression model (Agresti, 2013). The Hosmer-Lemshow test sorts the observations (n) in the data set by the estimated probability of success and divides the sorted set into groups (g). The difference in the expected and observed counts