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Red Snapper Discard Mortality in Florida's Recreational Fisheries

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Background

The assessment for the South Atlantic Red Snapper stock conducted in 2009 (SEDAR 15) used a predictive model for depth-dependent mortality developed from three limited studies available at the time, including one from a commercial fishery in the Gulf of Mexico (Nieland et al. 2007), an experimental cage study that combined observations from a surrogate species (Burns et al. 2002), and an unpublished study that borrowed data from the cage study and other unspecified studies (SEDAR 2010). Since no information on the depth distribution of recreational discards was available, limited data on the distribution of fishing effort was used to apply a depth-dependent mortality rate to estimated discards. This method estimated approximately 40% mortality, which was applied to recreational discards. A more recent assessment applied a reduced discard mortality percentage of 28.5% after circle hook use was required in 2011 (SEDAR 2017).

The most recent assessment for the Gulf of Mexico stock conducted in 2013 relied on a meta-analysis that combined data from eleven separate studies conducted over three decades and employed a variety of experimental and observational methods (Campbell et al. 2014). The analysis revealed a strong positive relationship between depth of capture and point estimates for mortality, and the model estimated a range for discard mortality of 7.4% at 0 meters up to 39.1% at 100 meters. The depth distribution of recreational discards was estimated from data provided by anglers who voluntarily reported fishing trips through a smart phone app, which indicated that a majority of discarding takes place in shallow depths. A mortality rate of 21% to 22% was assumed for discards prior to 2008, before anglers in the Gulf were required to vent the swim bladder of discarded Red Snapper to alleviate barotrauma (SEDAR 2013). In later years, a lower rate of 10% to 11% was applied based on an assumption that venting reduced mortality.

There is a need to confirm whether differential mortality rates applied to Red Snapper discards in the Gulf and Atlantic are representative of conditions in the recreational fisheries. Multiple factors may potentially explain variable mortality across the two regions. A positive relationship between capture depth and severity of barotrauma exposure has been well documented (Campbell et al. 2014, Rummer and Bennett 2005), and differences in nearshore to offshore depth gradients may explain region specific mortality rates. Different selectivity functions are used to characterize the size and age composition of fish vulnerable to each fishery (Cowan 2011, Mitchell et al. 2014), which could also explain regional differences if larger sized fish are more or less susceptible discard mortality. Water temperatures vary seasonally and across regions, and high surface temperatures coupled with a strong thermocline during summer months has been linked to increased discard mortality in the western Gulf of Mexico (Campbell et al. 2010, Gale et al. 2013). In addition, fishing practices that contribute to discard mortality may vary among recreational fisheries in each region. Examples include injuries related to the size, type and configuration of hooks and methods used to remove embedded hooks; various choices anglers make before returning fish to the water, including whether to vent the swim bladder when fish are released at the surface; and fight time, which may be related to a variety of factors such as line strength, fish size and capture depth (Cooke and Suski 2004, Cooke and Schramm 2007, Rummer 2007, Drumhiller et al. 2014). Regulatory differences are also a likely factor, given that Gulf and Atlantic Red Snapper stocks are managed with recreational harvest seasons that vary in duration and timing, and size limits and daily bag limits also differ. Gear requirements intended to increase survival of discards following catch-and-release also vary in each region. Federal regulations require circle hook use throughout the Gulf and north of 28 degrees latitude in the Atlantic. The state of Florida only requires circle hook use in the Gulf, and circle hooks must have 0 degrees of offset (flat hook with no offset). Both flat and offset circle hooks may be used in federal waters. Regulations for circle hook use and release methods are difficult to enforce, and compliance rates are likely less than 100% and potentially vary by region (Sauls and Ayala 2012). Venting was required in the Gulf in 2008; however, available research on the conservation benefits was inconclusive (Wilde 2009, Scyphers et al. 2013) and the rule was rescinded in 2013 to allow for more flexibility for anglers to choose how to best release fish. Although venting was never required on the Atlantic coast, anglers may still choose to vent fish prior to release. In recent years, outreach efforts have focused an alternative release method that employs a weighted device to rapidly descend and recompress fish at depth. However, estimates for how widespread the practice of venting or recompression are in each region do not exist.

In an effort to better understand factors that influence the condition of regulatory discards in the recreational hook-and-line fishery, the state of Florida has worked cooperatively with the for-hire industry to develop fishery observer programs on both the Gulf and Atlantic coasts (Sauls and Ayala 2016, Sauls et al. 2014). For-hire fisheries include headboats that may carry groups of eleven or more anglers who each pay an individual fare to board the vessel, and charter boats that cater to smaller parties who pay a single trip fare for a private fishing trip. A large portion of for-hire trips in Florida target federally managed reef fish species, and during sampled trips, fisheries observers ride along with anglers to collect information from fish caught and released at-sea. Regulatory discards are also marked with a conventional tag prior to release. From this work, mark-recapture data have been used successfully to develop a predictive model of survival for Gag grouper *Mycteroperca microlepis* in the Gulf, which may be applied directly to observations of discarded fish to quantify mortality attributed to catch-and-release across the wide range of exposures within the recreational fishery (Sauls 2014). For this analyses, we combine mark-recapture data from fishery observer coverage and other tagging studies from the Gulf of Mexico and Atlantic coasts of Florida for a comprehensive look at survival of Red Snapper discards. We also compare and contrast for-hire recreational effort and condition of discarded fish from charter boat and headboat fleets in each region and quantify release mortality for the two separate management units.

Methods

Fishery dependent at-sea observers first began accompanying anglers fishing from headboats in Florida in 2005. Methods were modified in 2009 to collect more detailed data on regulatory discards, and coverage was also expanded to include the charter fishery (Sauls et al. 2014). Spatial and temporal coverage over the time series has fluctuated with available funding (Table 1). Vessels were randomly selected throughout the year for observer coverage in each region of the state, which includes the northwestern panhandle and western peninsula on the Gulf coast, the Florida Keys, and the eastern peninsula on the Atlantic coast.

During a sampled trip, the captain was asked to provide the bottom depth and locational coordinates to the observer each time their vessel moved to a new fishing location. Biologists either observed fishing activity for all anglers on the vessel, or monitored a sub-set of anglers if the party was too large to observe 100% of fishing activity. As anglers fished with recreational hook-and-line gear, observers recorded for each fish caught the species, length (in mm), and whether the fish was harvested or discarded. In 2009, fishery observers on the west coast of Florida began collecting additional data from managed species, including Red Snapper, and these methods were expanded in later years to include the east coast (Table 1). For each Red Snapper caught, observers recorded hook location (lip, mouth, gill, throat, gut, eye, or external snag) and barotrauma symptoms (none, bulging eyes, everted stomach, extruded intestines). If a Red Snapper was discarded, the release method (unvented, swim bladder vented, stomach punctured, other) and condition at the surface (submerged immediately; submerged slowly or initially disoriented; floating at surface; unresponsive; consumed by a predator) was also recorded. Prior to release, each discard was marked with a Hallprint plastic-tipped dart tag with an external monofilament streamer that was labeled with a unique tag number, a toll-free phone number for a central tag return hotline, and the word “REWARD”. Anglers who captured and reported tagged fish received a t-shirt with an artist’s image of a Red Snapper (art courtesy of the artist Diane Rome Peebles).

Additional Red Snapper were also tagged during directed research and citizen science initiatives. In the northern Gulf, charter vessels were hired by FWC during the months of March through May in 2010–2013 as part of an effort to disburse hurricane disaster relief funds. During these trips, Red Snapper were targeted using recreational hook-and-line gear supplied by the vessel, and fishery observers accompanied each trip to tag Red Snapper and collect data using the same procedures described above for randomly sampled for-hire recreational fishing trips. Additional red snapper were also tagged on the Atlantic coast of Florida through a cooperative research project (Brodie et al. 2014).

Data Analysis

To assess the relative impacts of different hook regulations in the study region, the prevalence of observed Red Snapper caught with flat or offset circle hooks and J hooks was described for each fishery. The influence of various hooks on condition of released fish was also assessed. Fish with hooks that embedded in a gill, eye, the throat or the gut were classified as bad hook sets; and fish observed with hooks embedded inside the mouth cavity, the lip or jaw were classified as good hook sets. Logistic regression was used to assess the odds of a potentially lethal hook across hook types.

To assess latent mortality for live discards, fish were assigned to one of three release condition categories (Table 2) and a proportional hazards regression model was developed to assess the relative survival of fish released in different condition categories. This approach is similar to methods used previously to evaluate relative survival of discards in a recreational fishery for gag (*Mycteroperca microlepis*) in the Gulf of Mexico (Sauls 2014). For the proportional hazards model, the response variable 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) at the end of the study. The treatment tested was release condition category, which was included as an independent class variable in the proportional hazards model, and fish released in good condition were assigned as the reference group.

To remove the variable effects of fishing pressure and subsequent tag-recapture rates across the large temporal spatial scales encompassed by the study, separate models were constructed for the Gulf and Atlantic. In the Gulf, the recreational harvest season for Red Snapper opens as early as May in state waters of Florida and remains open for variable lengths of time each year throughout summer and fall months. Harvest in state waters occurs frequently in the northwestern panhandle; however, Red Snapper are not frequently encountered in state waters along the eastern or western peninsula of Florida and harvest is primarily from federal waters. The recreational Red Snapper season in federal waters of the Gulf opens on June 1 each year and was 75 days long during the first year that FWC began tagging discards for this study (2009). However, in more recent years the federal season has been reduced to between 9 and 11 days. Since FWC began tagging Red Snapper discards on the Atlantic coast of Florida in 2011, the federal recreational fishing season in the South Atlantic has been narrowly restricted to a range of 0 to 8 days annually. Thus, targeted fishing effort in federal jurisdictions is highly concentrated over short periods of time. Annual effort is also influenced by episodic events, most notably the Deepwater Horizon oil spill in the Gulf of Mexico which occurred during 2010 and resulted in large fishing area closures during peak months for recreational fishing.

Fishing effort was also expected to vary within each region (Gulf and Atlantic) with human population and proximity to offshore fishing grounds, seasonally (for example, fishing effort decreases during winter months and varies with latitude), and annually in response to changes in fishing regulations; thus, each model was stratified by year and quarter (three month periods). Stratification generates separate partial likelihood functions for fish that entered into the study during each distinct time period, and multiplies results to produce one overall parameter estimate that maximizes the function (Allison 2010). Control variables were also tested for inclusion in the proportional hazards model. To control for variable tag return rates within the Gulf and Atlantic regions, a class variable for zone was included as a covariate. In Florida, zones were defined at intervals of one degree of latitude for the eastern and western peninsula regions, or one degree of longitude for the northwestern panhandle. Other effects tested for influence on recapture rates included total length (TL) and potential interaction between TL and zone.

To estimate depth-dependent discard mortality, the number of live discards observed in good, vented (and otherwise unimpaired), or impaired conditions (N_1, N_2, and N_3, respectively) at each 10-meter depth interval (e.g., where d = 1–10 meters, 11–20 meters) were summed and 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:

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

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 derived from the proportional hazards model for fish that were vented or impaired (respectively), relative to fish released in good condition. To estimate overall discard mortality across all depths fished in a given fishery, the numbers of fish observed in each release condition category were summed and multiplied by the point estimate for discard mortality, as well as the upper and lower confidence limits.

Because fish had to be captured in order to be tagged and released, there was no true control to reference the good condition category treatment group to; therefore, a range of values was assigned for S_1. The majority (>95%) of Red Snapper released in good condition were captured from depths 40 meters or less, and a meta-analysis of 11 separate discard studies for Red Snapper estimated 15.5% mortality for discards in the recreational fishery captured at 40 m (Campbell et al. 2014). Since fish with visible injuries or swimming impairments were excluded from the good release condition group and a large portion were caught from depths less than 40m, their survival is expected to be somewhat higher. Therefore, for this analysis, overall depth-dependent discard mortality was calculated separately under three assumptions for S_1: 1) a maximum of 100% released in good condition survive ($S_1 = 1.000$); 2) a minimum of 85% survive ($S_1 = 0.850$); and 3) a median of 92.5% survive ($S_1 = 0.925$). To calculate overall discard mortality estimates for each depth interval, the median value for S_1 was used as the point estimate in equation 1, and uncertainty was calculated by substituting the minimum and maximum assumed values of 0.85 and 1.0 for S_1, and substituting point estimates for H_2 and H_3 with lower and upper 95% confidence limits for H_2 and H_3.

To explore the relationship between release condition, fish size, and capture depth, and differences among regions, the numbers of fish observed in each release condition were summarized in 3x3 contingency tables with rows composed of three ordinal size classes (large ≥20", medium 16" to <20", and small <16") and columns composed of the response variable for release condition (Table 1). Separate tables were constructed to test the overall association (observations from all depths and regions), two depth strata (capture depths up to 30 meters and >30 meters), and three regions (Atlantic, north Gulf, central Gulf). The Chi Square Mantel-Haenszel (CSMH) statistic was used to test significance of the linear association between degree of impairment and increased size.

Results

Between the years 2009 and 2016, a total of 27,070 Red Snapper in the northern Gulf of Mexico, 2,838 in the central Gulf, and 6,733 on the Atlantic coast were captured with recreational hook-and-line gear, tagged, and released alive off the coast of Florida (Table 2). Discards were observed from a total of 1,383 randomly sampled for-hire recreational fishing trips from headboats and charter boats off the Atlantic and Gulf coasts of Florida (Table 2). More than 85% of discards observed from both charter boats and headboats in the northwestern panhandle were caught from depths less than 40 meters (Figure 1). In contrast, for-hire vessels operating off the west coast of the peninsula discarded Red Snapper farther from shore and a greater proportion were caught from depths of at least 40 meters (Figure 1). However, during some years Red Snapper were more accessible to the nearshore recreational fishery off the west peninsula coast and discarding was observed from shallower depths. On the Atlantic coast, the majority of Red Snapper discarding occurred in shallower depths <40 meters (Figure 1).

The size composition of released fish varied across years, which has potential implications for overall discard mortality. The annual proportions of Red Snapper observed in the for-hire fishery that were less than 404 mm total length (the legal size limit for recreational harvest in the Gulf of Mexico) ranged from 24–72% off the Gulf coast of Florida, and 34–69% off the Atlantic coast (Figure 2). Controlling for the variable effects of depth and region, there was a significant linear correlation between increased size and the severity of condition for released fish (Table 4). Medium (404–507 mm TL) and large (>507 mm TL) sized fish were increasingly more likely to be vented or released in an impaired condition compared to smaller (<404 mm) fish (Figure 3). Within each region, a higher percentage of Red Snapper discards retrieved from depths >29 meters were vented or impaired, compared to discards caught from shallower depths, and across all size classes discards were vented more frequently in the Atlantic (Figure 3).

Across all regions fish that were released unvented in good condition exhibited the highest recapture percentages, followed by fish that were vented and otherwise unimpaired (Table 3). Overall, 7.2% of unvented Red Snapper exhibited swimming impairments that placed them in the poor release condition group, compared to 5.9% of that that were vented. However, since the poor condition group pooled all vented and unvented fish that demonstrated swimming impairments or other injuries, it was not possible to evaluate whether relative survival showed a measurable response to venting. Due to low numbers of tagged fish and/or recapture events in each sub-group, the poor condition group could not be sub-divided into vented and unvented fish with and without swimming impairments, versus other injuries.

The response variable for the proportional hazards model was the number of days each tagged fish was at large before it was either reported as recaptured or censored at the end of the study, and it was necessary to control for variables that influenced mark-recapture reporting rates in each region but were unrelated to relative survival of discards. On the Atlantic coast, tag-recapture percentages increased from north to south and is likely due in part to the decreasing distance that must be travelled offshore to reach areas where Red Snapper were observed in the recreational fishery. Likewise, in the Gulf of Mexico, Red Snapper were more accessible to the nearshore recreational fishery off the coast of the northwestern panhandle compared to the western peninsula. Thus, tag return rates may be influenced by the relative accessibility of Red Snapper to recreational fishing effort, and the zone (defined as one degree change in latitude or longitude along the Florida coastline) where each fish was tagged and released was a significant control variable included in proportional hazards models for the Gulf and Atlantic regions.

Total length (TL) at time of initial capture had varied effects on the Gulf and Atlantic proportional hazards models. In the Gulf, TL had a positive influence on recapture rate ($p < 0.0001$), and the overall hazard for recapture increased 39.6% for every 100mm increase in TL. This was unexpected given the previously discussed correlation between increased fish size and level of impairment, but is likely due to the fact that fish above the minimum size limit of 404 mm TL are more likely to be reported during recreational seasons in the Gulf. When fish are not released, tags have a higher chance of being detected by anglers and reported, and this is evidenced by the proportion of recaptured fish that were reported during months when the harvest season was open. Each year, the highest numbers of tags reported to FWC from the Gulf of Mexico were received during the month of June, when recreational harvest was open continuously in state waters (with the exception of closed areas during 2010 following the Gulf oil spill) and the federal season was also open. Tag returns reported to FWC off the east coast of Florida were more evenly distributed throughout the year. The effect of TL was also significant ($p=0.0026$) in the proportional hazards model for the Atlantic coast; however, the hazard for recapture decreased 16.4% with each 100mm increase in TL. Recreational harvest in the Atlantic was prohibited three out of six years during this study, and was restricted by a very short season ranging from 3 to 8 days annually in the remaining three years. Furthermore, whenever the recreational harvest season was open, no minimum size limit was in effect to reduce wasteful discarding. Since there was no reason to suspect a bias in recapture reporting rates for larger sized fish in the Atlantic, TL was not included in the proportional hazards model for this region. However, TL was included in the Gulf model to account for the apparent tag reporting bias for legal sized fish.

After controlling for covariates on recapture reporting rates, the effect of release condition was significant in both regions. In the Atlantic and Gulf, Red Snapper that were able to submerge immediately without the assistance of venting survived at higher rates compared to those that were vented or impaired (Figure 4). Red Snapper that were vented and otherwise unimpaired were 75.2% and 70.5% as likely to be reported as recaptured compared to unvented fish in the Gulf and Atlantic, respectively. Discards with an impairment were 45.6% and 46.6% as likely to be recaptured in the Gulf and Atlantic, respectively. Confidence intervals (95%) around hazard ratios for vented and impaired fish did not overlap with 1.0, indicating a significantly reduced recapture rate relative to unvented fish (Figure 4). Relative survivals were also significantly reduced for impaired fish compared to fish that were vented, suggesting that venting may help mitigate some impairments (Figure 4).

When relative survival rates were applied to fish observed in each release condition at 10 meter depth intervals, point estimates for the percentage that suffered discard mortality increased with depth (Figure 5). When the numbers of fish observed in each release condition category were summed for each fishery, the overall estimated percentage of discard mortalities across all depths ranged from 21.06% to 29.85% off the Gulf coast and 28.75% to 31.07% off the Atlantic coast (Figure 6).

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Table 1. Temporal and spatial coverage of fishery observer trips and targeted Red Snapper tagging trips by region and trip type. Trips were conducted year-round, except where noted. Upper case Xs indicate years when Red Snapper, if observed, were marked with conventional tags prior to release.

	2005	2006	2007	2008	2009[1]	2010	2011	2012	2013	2014[2]	2015	2016
NW panhandle												
Charter boat					X	X	X	X	X		X	X
Headboat	x	x	x		X	X	X	X	X	X	X	X
Targeted[3]						X	X	X	X			
W peninsula												
Charter boat					X	X	X	X	X		X	X
Headboat	x	x	x		X	X	X	X	X	X	X	X
Multi-day					X	X	X	X	X		X	X
FL Keys												
Charter boat						X	X	X	X	X	X	X
Headboat	x	x	x			X	X	X	X		X	X
Multi-day	x	x	x									
E peninsula												
Charter boat									X	X	X	
Headboat	x	x	x	x	x	x	X	X	X	X	X	X
Targeted							X	X	X			

[1] June through December

[2] Coverage in northern and central Gulf limited to a small sub-set of vessels

[3] March through May

Table 2. Description of live release condition categories for reef fishes observed during recreational hook-and-line fishing (modified from Sauls 2014).

Condition category	Description
Good (not impaired and not vented)	Fish immediately submerged without the assistance of venting, and did not exhibit any impairments
Vented (not impaired and vented)	Fish immediately submerged after the swim bladder was vented, and did not exhibit any impairments
Impaired	Any fish that exhibited one or more of the following impairments: 1) chased by a predator near the surface 2) disoriented or unresponsive at the surface before submerging 3) buoyant at the surface and unable to submerge 4) improperly vented by puncturing the stomach or anus 5) hook embedded in gill, eye, esophagus, or gut 6) released with hook still embedded 7) bleeding from the gills 8) exopthalmia, indicative of severe barotrauma

Table 3. By region: numbers of Red Snapper tagged in each release condition category, the percentage (and numbers) reported as recaptured at least once; mean size and capture depth of tagged fish; and numbers of trips that fish were tagged from.

	A) Northwest Florida Panhandle	B) West Florida Peninsula	C) East Florida Peninsula
Numbers of fish tagged:			
Condition 1	9,743	732	849
Condition 2	14,131	1,522	4,913
Condition 3	3,196	584	971
Percent of fish recaptured:			
Condition 1 (number)	13.5 (1,316)	9.0 (66)	8.6 (73)
Condition 2 (number)	11.1 (1,571)	6.4 (97)	6.0 (294)
Condition 3 (number)	6.9 (219)	4.3 (26)	4.6 (45)
Mean length (mm TL)	459.23 ± 102.72	479.62 ± 116.86	486.99 ± 155.95
Mean capture depth (m)	32 ± 7	39 ± 12	27 ± 7
Number of trips:			
Single-day charter	486	60	113
Single-day headboat	387	44	239
Multi-day headboat	-	54	-
Directed research	135	28	

Table 4. Mean size and capture depth and t test comparisons among vented and unvented Red Snapper tagged and released from the Gulf (WFL) and Atlantic (EFL) coasts of Florida.

Region	Release method	Number of observations	Mean TL (mm) ±SE	t	p	Mean depth (m) ±SE	t	p
WFL	Vented	11,984	437 ±0.7883	-34.21	<0.0001	31 ±0.0563	-35.10	<0.0001
	Unvented	17,706	478 ±0.8409			34 ±0.0654		
EFL	Vented	1,015	404 ±3.5477	-19.56	<0.0001	24 ±0.1482	-14.41	<0.0001
	Unvented	5,731	501 ±1.9974			27 ±0.0926		

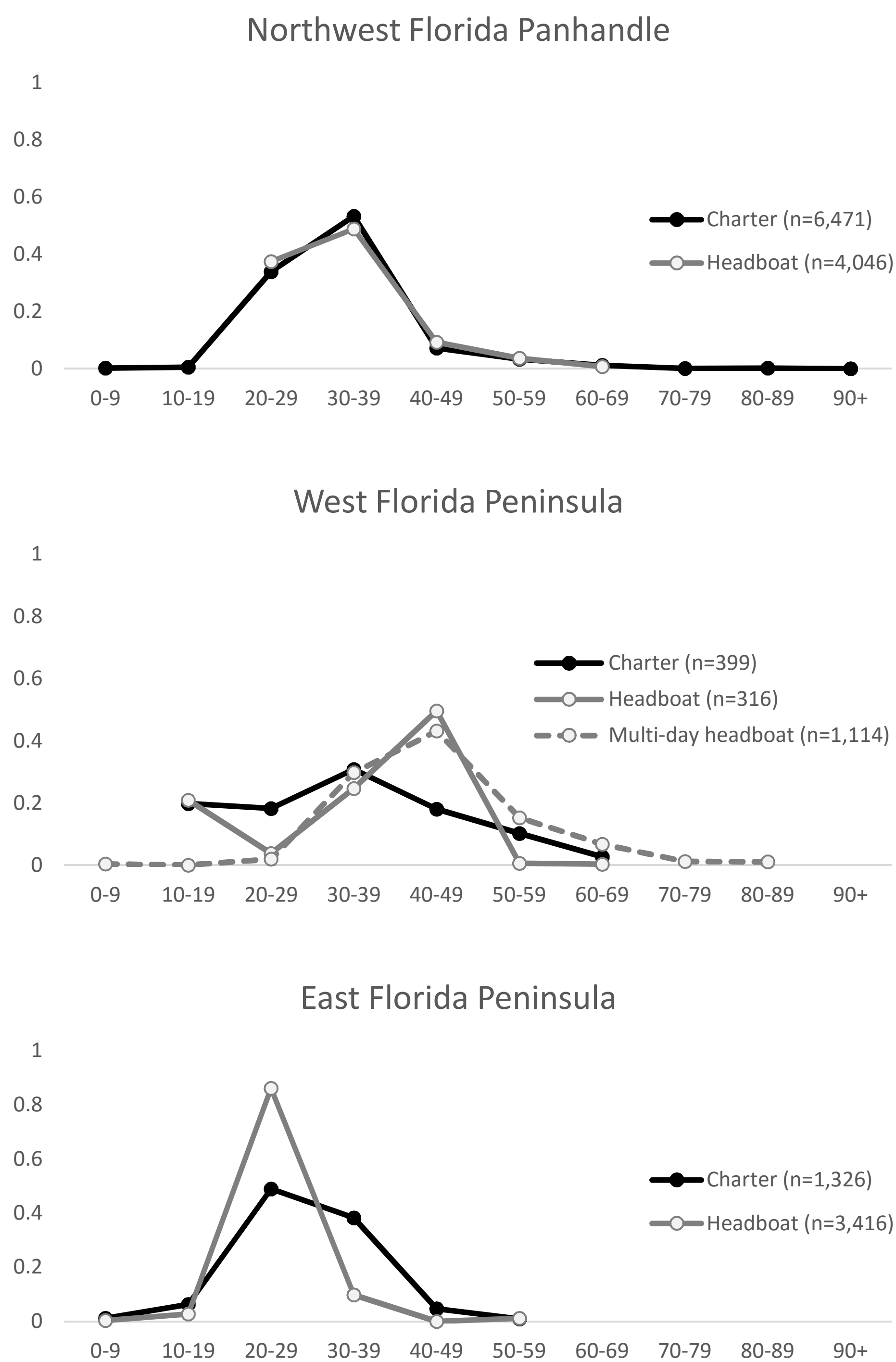

Figure 1. Distribution of capture depths for discards observed during for-hire recreational fishing trips in the northern Gulf (top), central Gulf (middle) and Atlantic (bottom) coasts of Florida.

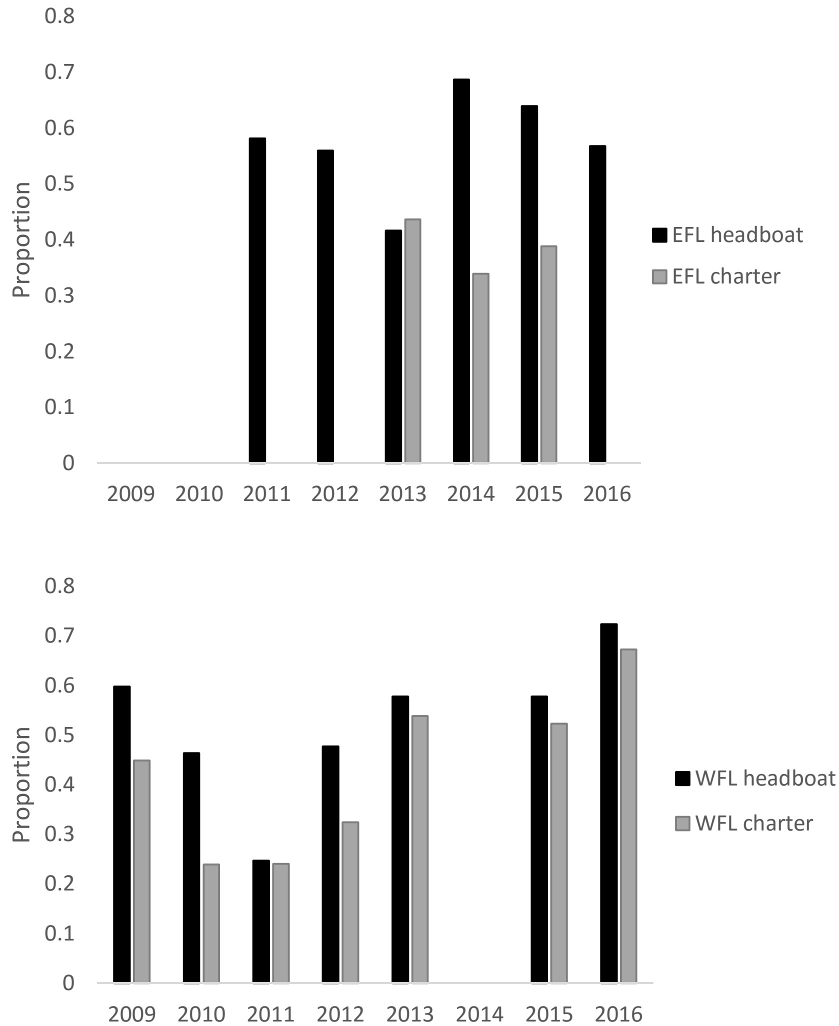

Figure 2. Annual proportions of Red Snapper discards observed in recreational fisheries off the Atlantic (top) and Gulf of Mexico (bottom) coasts of Florida that were less than 406 mm total length by trip-type and year.

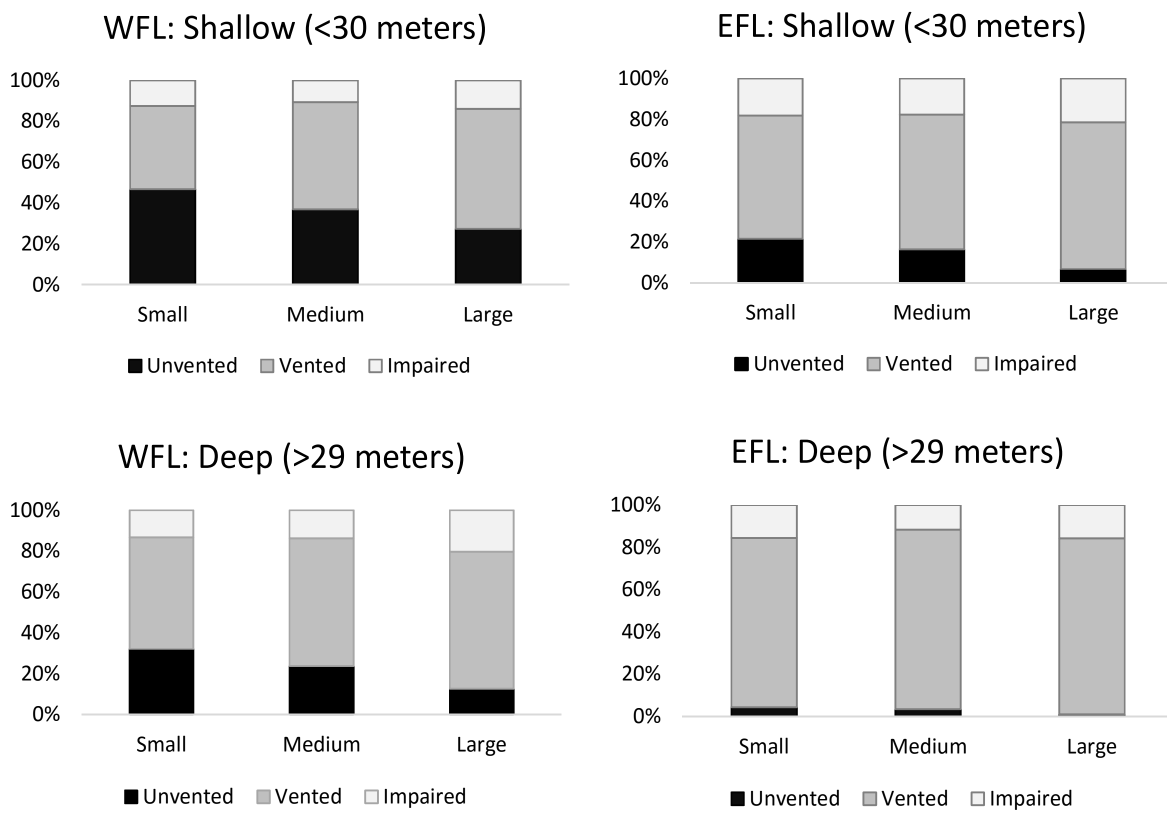

Figure 3. Percentages of large (>507mm TL), medium (404-507mm TL), and small (<404) Red Snapper discards observed from shallow (<30 meters) and deep (>29 meters) fishing depths during recreational fishing trips on for-hire charter boats and headboats taken in the Gulf of Mexico (WFL) and Atlantic (EFL) by release condition category. Controlling for the effects of region and depth, there was a positive linear association between increased length and severity of impairment (Cochran-Mantel-Haenszel Statistic = 448.9, $p < 0.0001$).

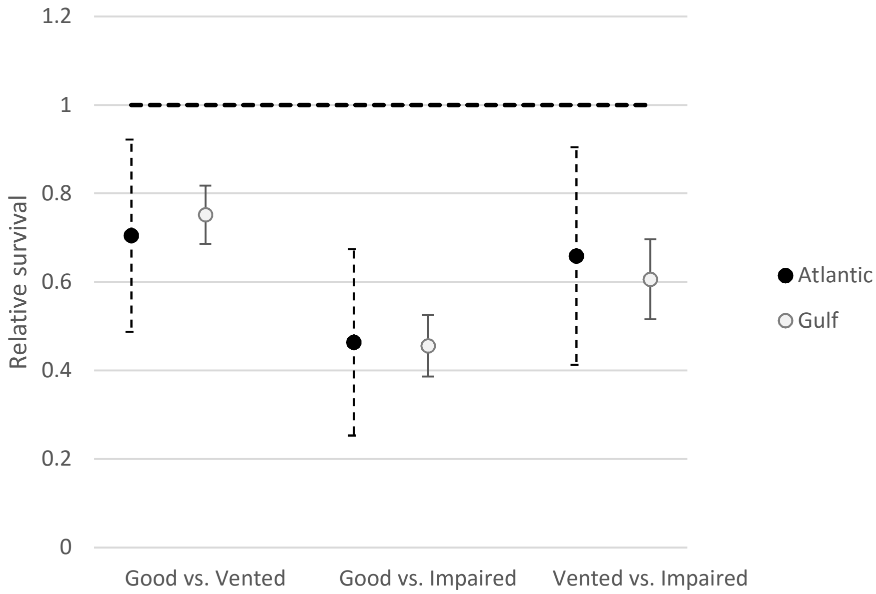

Figure 4. Relative survival of discarded red snapper released in different condition categories compared to a reference group using observations from the Atlantic and Gulf of Mexico. Point estimates below 1.0 indicate decreased survival for vented or impaired fish relative to a reference group. For example, the point estimate of 0.752±0.043 from the Gulf model for good versus vented fish indicates that vented fish are 69–82% as likely to survive a catch and release event compared to fish released in good condition. Wider confidence intervals for point estimates in the Atlantic model are due to lower numbers of tagged and recaptured fish.

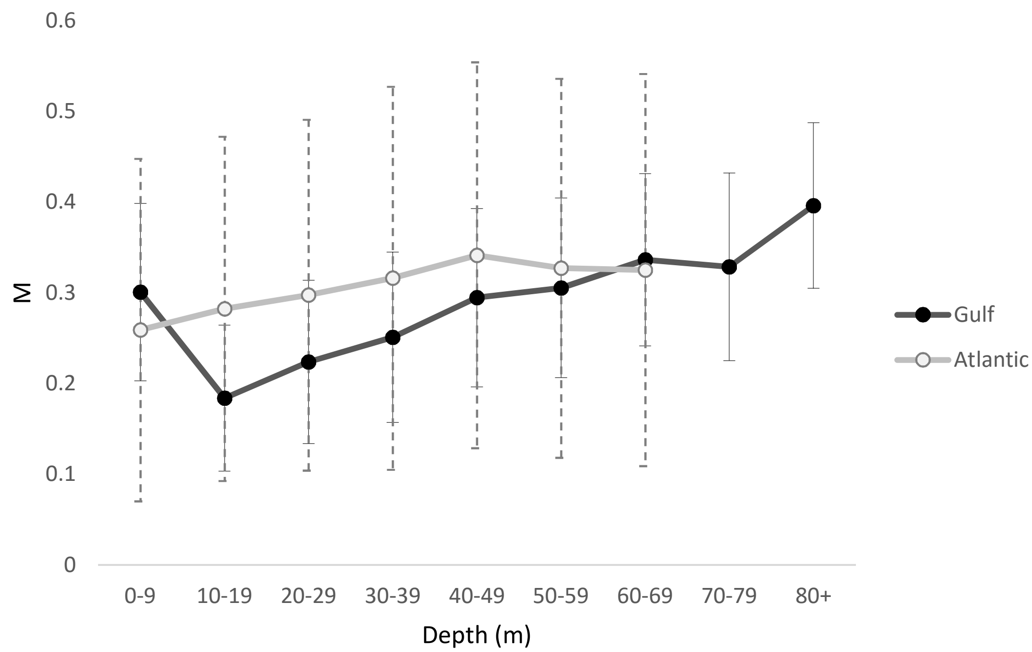

Figure 5. Estimated proportions of live discards from each depth interval that suffered mortality based on observed release conditions. Error bars represent 95% confidence intervals for the Gulf (solid line) and Atlantic (dashed line).

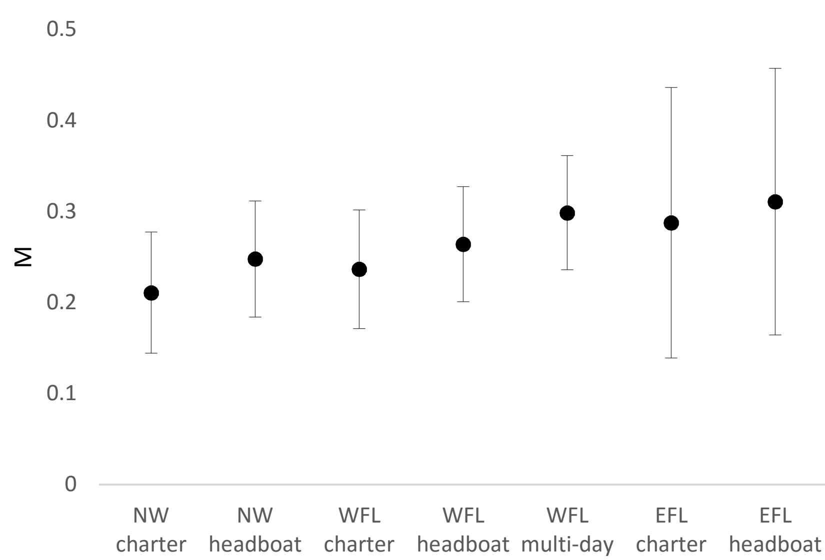

Figure 6. Overall estimated discard mortality by fishery.