A meta-analysis of immediate and delayed discard mortality of red snapper (*Lutjanus campechanus*) in the Gulf of America (formerly the Gulf of Mexico)

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A meta-analysis of immediate and delayed discard mortality of red snapper (*Lutjanus campechanus*) in the Gulf of America (formerly the Gulf of Mexico)

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Abstract

Red snapper (*Lutjanus campechanus)* is an economically important fishery in the Gulf of America (formerly the Gulf of Mexico). This species is subject to discard mortality from barotrauma. Novel discard mortality research on this species has estimated delayed mortality in addition to immediate mortality at the surface (*i.e.,* swim or float). To determine how this combined mortality measurement changes red snapper discard mortality we conducted a meta-analysis, combining 11 studies, with 84 distinct estimates from 34 years of research. We assessed if depth, season, release method, or region predict discard mortality. We found a significant positive relationship between depth and discard mortality and that, in the western Gulf, fishing in the summer significantly increases discard mortality compared to fishing in other seasons and regions. Analyzing studies with well-defined release method treatments, we found that venting and descending generates a 14.6% decrease in estimated release mortality compared to no barotrauma mitigation. We estimate a 31% discard mortality at 33m, the median fishing depth of the private recreational fleet. This more than doubles the estimate of discard mortality generated by a previous meta-analysis. Given that we generated estimates from both immediate mortality and delayed mortality, we propose that these updated, higher estimates of discard mortality likely more representative of the mortality experienced by this recreational fishery.

Introduction

Catch and release fishing has long been accepted as an effective and intuitive conservation tactic (Policansky 2022). In theory, fish that do not meet a minimum size limit or are not the target species can be released alive, having no negative impact on the fish population (Cooke and Schramm 2007; Raby *et al.* 2014). However, in practice, fishing can lead to mortality, and estimating how many untargeted or undersized fish experience mortality from fishing is an important part of effectively managing fisheries. Due to size limits and season closures, 70% of Red Snapper caught in the Gulf of America (formerly the Gulf of Mexico) by the private recreational and for-hire fisheries are discarded (NMFS Fisheries Statistical Division 2023). Therefore, as new data on discard mortality rates for this species become available, updated estimates should be used to better predict potential impacts to the fishery as it continues to be successfully rebuilt (SEDAR 52 2018).

Early research on discard mortality largely focused on immediate mortality from fishing (*i.e.,* fish dead on release or unable to swim away; Campbell et al., 2014; S. L. Diamond & Campbell, 2009; Patterson et al. 2002). Immediate mortality is often caused by barotrauma or hooking injures (Muoneke and Childress 1994; Bartholomew and Bohnsack 2005; Rummer and Bennett 2005; Burns and Froeschke 2012). Hooking injuries such as lacerations to gill, internal viscera, or esophagus can lead to immediate mortality at the surface and are easily identifiable prior to release (Render and Wilson 1994; Bartholomew and Bohnsack 2005; Burns and Froeschke 2012). Barotrauma occurs due to pressure changes fish experience as they are brought to the surface. Common symptoms of barotrauma are bulging eyes, a distended abdominal region, flared opercula, and stomach eversion or prolapse (Rummer and Bennett 2005). These effects can be particularly problematic for fish that are physoclistous (*i.e.,* do not have a pneumatic duct connecting the swim bladder to the digestive tract, which allows fish to fill or empty their swim bladder rapidly), such as Red Snapper, and therefore cannot acclimate as quickly to changes in depth. Distended swim bladders can cause fish to be positively buoyant and unable to easily descend upon release, making them vulnerable to predation from both the sea and air as well as increased stress due to exposure to higher temperatures and sunlight (Rummer and Bennett 2005; Wilde 2009; Scyphers *et al.* 2013). Recent research has focused on the use of descender devices to reduce discard mortality from barotrauma (Diamond *et al.* 2011; Drumhiller *et al.* 2014; Curtis *et al.* 2015; Stunz, Curtis and Tompkins 2017; Ayala 2020; Bohaboy *et al.* 2020; Runde *et al.* 2021). Descender devices force the fish back down to their capture depth, allowing them to be released at the depth, temperature and pressure to which they were acclimated.

While hooking injures and barotrauma can be easy for anglers to identify, fish that are caught often undergo more subtle physical damage and physiological stress which can lead to delayed mortality (Raby *et al.* 2014). For example, barotrauma, handling, and air exposure can cause changes in heart and ventilation rates, blood pressure, reductions in muscle energy stores, and other physiological stress responses. These responses, which may take hours to return to baseline levels, can result in cellular and tissue damage, reduced immunity, and behavioral changes which can lead to delayed mortality (Wood, Turner and Graham 1983; Davis 2002; Rummer 2007; Mohan *et al.* 2020). These physiological changes can leave fish too disoriented to avoid predation (Parsons and Eggleston 2005; Campbell 2008) and can even cause fish to release chemical cues that attract predators (Jenkins, Mullen and Brand 2004; Dallas *et al.* 2010). Due to these effects, researchers have been increasingly studying both immediate and delayed mortality when assessing discard mortality. For example, much of the recent research on Red Snapper discard mortality has used either acoustic or passive tags to assess any additional mortality that occurs in fish that appear healthy upon release (Curtis et al. 2015; Stunz, Curtis and Tompkins 2017; Tompkins 2017; Bohaboy et al. 2020; Sauls et al. 2017; Runde et al. 2021).

In 2014, Campbell *et al.* performed a meta-analysis to assess Red Snapper discard mortality rates in the Gulf of America and whether they differed based on common fishing factors such as differences between commercial and recreational fisheries, fishing depth, etc. (Campbell *et al.* 2014). This model included studies that estimated immediate mortality, which was a majority of the published literature at the time but are likely underestimates as they do not capture mortality that is occurring over hours-days (i.e. delayed). However, the authors emphasized the need for more research on delayed mortality and cautioned that using only immediate mortality for estimations provides an incomplete measure of total discard morality and should only be done as a minimum data collection (Campbell *et al.* 2014). Due to the novel research focusing on delayed mortality and descender devices that has occurred since this meta-analysis was conducted, we have updated this model. We reassessed factors that affect discard mortality and estimated mortality rates in the recreational Red Snapper fishery in the Gulf of America using new research and with a focus on studies that include delayed mortality.

Methods

We updated the Campbell *et al.* 2014 meta-analysis by adding data from studies that assessed the discard mortality of Red Snapper in the Gulf of America after 2014. As a result, 8 new studies with 101 new point estimates were added to the dataset for a total of 18 studies and 156 individual estimates of discard mortality. This dataset will hereafter be referred to as the 'mixed mortality' dataset. Due to concerns that the inclusion of studies that only estimated immediate impacts of release mortality would underestimate Red Snapper mortality, as negative physiological and behavioral effects from being fished can persist (Campbell 2008; Drumhiller *et al.* 2014; Raby *et al.* 2014), we ran an initial analysis on the mixed morality dataset to explicitly assess how the addition of delayed morality increases discard mortality estimates. After this analysis we removed estimates and studies that only measured immediate mortality upon release (Table S1; removed studies). This generated a database of 11 studies with 94 distinct estimates of discard mortality throughout the Gulf of America used to assess factors that can be used to predict discard mortality and will hereafter be referred to as the "full mortality" dataset (Table 1). Finally, we subset the data to specifically assess the effects of venting and descending devices on discard mortality. Studies where venting was not completed on all fish in the venting treatment and an additional laboratory study focused on the effects of venting and descending on Red Snapper mortality was added (Drumhiller *et al.* 2014). This study was excluded from the initial datasets as release mortality estimates from laboratory settings may not reflect natural morality due to the exclusion of predators and other such release morality drivers. This dataset had 50 estimates from 8 studies and will hereafter be referred to as the "release method" dataset (Table S2). Mortality estimates in all databases were classified by depth of catch (m), region (west, east, and central Gulf), season (summer and not summer), and release method (no venting, some venting, total venting, and descending device used) when possible. If a point estimate was not separatable by one of those factors, it was not included in the analysis of that factor.

There were 8 studies with some measures of immediate mortality (Table S1). Two studies measured discard mortality in the commercial fleet (Nieland *et al.* 2007; Pulver 2017), and the remaining studies focused on the recreational fleet (see supplemental methods for more details). Of the 11 studies in the full mortality database (Table 1), most used acoustic tags to track fish, with only one study where fish were marked with passive tags (conventional plastic-tipped dart tags; Vecchio et al. 2022) and three cage studies (Parker 1985; Render and Wilson 1996; Diamond and Campbell 2009). Six studies were in the western region (defined as Texas and Louisiana to MRIP statistical zone 13), three studies were conducted at least partially in the central region (defined as the rest of Louisiana, Mississippi, Alabama, and the panhandle of Florida through MRIP statistical zone 7 and Levy County), and only one study assessed discard mortality in the eastern region (defined as peninsular Florida starting at statistical zone 6 and Citrus County and continuing south). Regions defined here are stock assessment regions for SEDAR 74 (Image 1; SEDAR 74, 2022). Of the 94 estimates, 46 occurred during the summer. Only 5 studies reported surface water temperature and only 4 studies reported temperature by depth. The average summer temperature was 28.6 °C and the average non-summer temperature was 22.6 °C. However, temperature could not be used in the model since temperature values were only available in the western region. Therefore, the metric of season was used instead of temperature in our models. Depths ranged from 10-85m, with a mean of 45m. A total of 19 estimates were classified as no venting (surface release without barotrauma mitigation), 22 estimates were from descended fish (not always to the sea floor), and the remaining estimates came from fish where venting procedures were performed prior to surface release. Fish were classified as 'total venting' if all the fish in the treatment group were vented. Fish were classified as 'some venting' if some of the fish from the estimate were vented either through angler discretion (Vecchio *et al.* 2022) or because mortality estimates were not broken down by venting treatment (Render and Wilson 1996). These studies that had estimates of discard mortality that included both immediate and delayed mortality all came from the recreational fleet. Circle hooks or a combination of circle and J hooks were used in all studies.

Of the 8 studies and 50 estimates in the release methods database (Table S2), depths ranged from 27.5 to 60m. Estimates were evenly spread across summer and not summer although season was not defined for two studies (Drumhiller *et al.* 2014; Runde *et al.* 2021). Acoustic tagging was used to assess delayed mortality in all studies except one, which was conducted in a laboratory setting (Drumhiller *et al.* 2014). 16 of the mortality estimates came from fish released at the surface with no barotrauma mitigation, 10 of the estimates were from vented fish, and 24 of the estimates were from descended fish. Across all datasets, the sample sizes of fish tested to generate our estimates varied widely from three to 34,465. Differences in sample sizes were addressed by giving estimates with smaller sample sizes higher variances around their effect sizes (and vice versa) and including this variance in our models, as described below.

Analyses were conducted in R using the *metafor* package (R Core Team, 2020; Viechtbauer, 2010). Effect sizes were calculated using the *escalc* function using the frequency of dead fish out of the total number of fish tested. This function also calculates a variance for each effect size from the sample size of the estimate. Mixed effect models were run with the *rma.mv* function. The calculated effect sizes were used as the response variable. To assess which factors predict discard mortality using the full mortality database (Table 1), season, region, the interaction between season and region, depth, and release method were used as predictor variables. Study and study type (cage, passive tag, acoustic tag) were included as random effects. Depth was a continuous variable, and the rest of the variables were categorical. Post-hoc tests were run by separating the analyses into the western and not western (eastern and central regions combined) regions to allow us to generate separate, more accurate predictions across regions, seasons, and depths as the effect of season was only present in the western region.

To explicitly assess the contribution of delayed mortality on discard mortality, the mixed mortality database (Tables S1 & 1) and additional predictor variables of whether the study estimated mortality as immediate only or included delayed mortality (0 or 1), whether the study was on the recreational fleet or not (0 or 1), and whether fish were caught with circle hooks (0 or 1). These predictors were added to explicitly test the contribution of delayed mortality on discard mortality estimates as well as control for other variables present in this larger database. Study and study type were used as random effects. The best fit model included the binary variables of delayed mortality, recreational fleet, and circle hooks as well as the depth, release method, and season by region interaction variables included in the full mortality model. To further assess the effects of venting and descending on discard mortality a separate analysis was run using the release method database (Table S2). The best fit model included release method, depth, season, depth by season interaction, and uses study as a random effect.

Variances from the calculated effect sizes were included in all models. A backward stepwise regression model selection procedure was performed using AICs and BICs. Predicted values and their associated 95% confidence limits were calculated using the *predict* function in *metafor* (Viechtbauer 2010) and converted back to proportions by taking the inverse of the logit-transformed data (see Campbell et al., 2014 for more details). Heterogeneity in all models were tested using Cochran's Q-test. This is a commonly used heterogeneity test, which allows us to determine if the variability in the meta-analysis indicates 'true' variability or is due to sampling error (Cochran, 1954). Graphs were generated using the *ggplot2* package (Wickham et al., 2022).

Results

In the full mortality model, summer significantly increased the estimated mortality when compared to non-summer (estimate=0.76, $z_{9,76}$=3.27. p<0.01; Fig. 1A; Table S3). There was also a significant interaction between region and season with the western region showing significantly higher mortality rate in the summer than in the non-summer. However, this pattern was not true for the other regions, suggesting that these significant effects of seasonality were driven by the estimates from the western region (summer*central: estimate=-0.80, $z_{9,76}$=-3.40, p<0.001; summer*eastern: estimate=-0.74, $z_{9,76}$=-3.04, p<0.01; Fig. 1B). There was a significant positive association between depth and mortality rate (estimate=0.012, $z_{9,76}$=7.70, p<0.001; Fig. 2A). We calculated the slope of this positive association for comparison with the estimates generated by Campbell et al. 2014. Our results estimated a 4% increase in mortality for every 10m increase in depth, while the Campbell et al. 2014 paper predicted a 3% increase (Fig. 2). Region did not significantly alter estimated mortality rates as a main effect (Region Central: estimate=0.85, $z_{9,76}$=0.87, p=0.38; Region East: estimate=1.12, $z_{9,76}$=1.15, p=0.25). Release method also did not significantly affect Red Snapper mortality rate (descending: estimate=-0.39, $z_{9,76}$=-1.58, p=0.11; total venting: estimate=-0.38, $z_{9,76}$=-1.06, p=0.27; some venting: estimate=-1.20, $z_{9,76}$=-0.92, p=0.38).

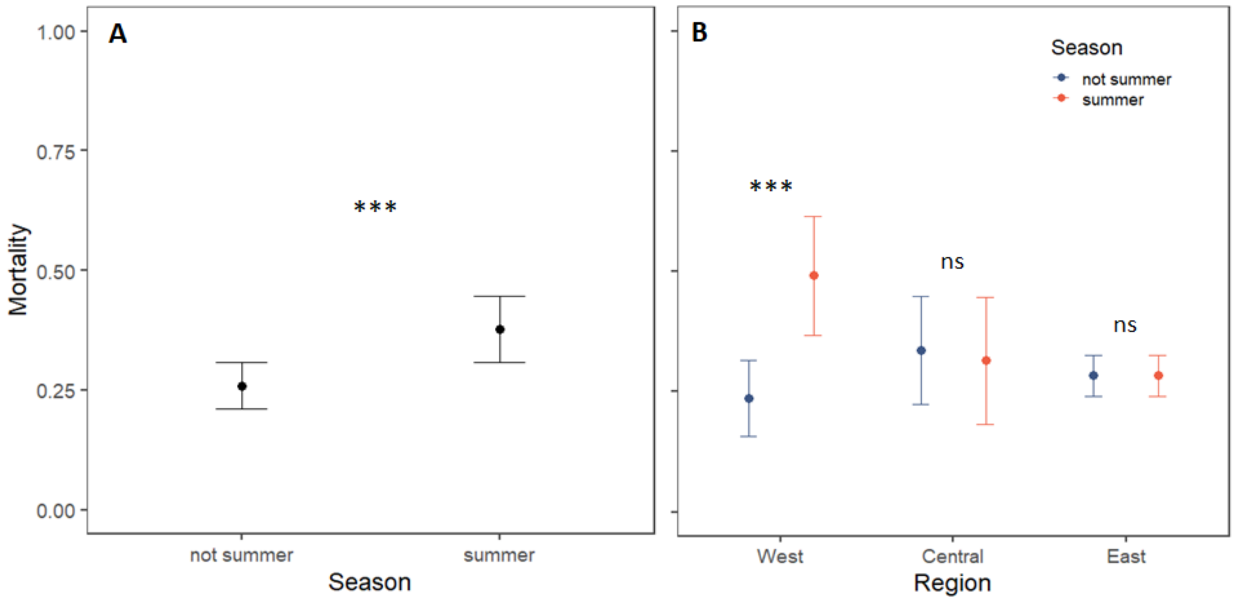

Figure 1: **A)** The proportional discard mortality of Red Snapper (*Lutjanus campechanus)* in the Gulf of America (formerly known and the Gulf of Mexico) was significantly higher in summer than the non-summer seasonal group (estimate=0.76, $z_{9,76}$=3.27, p<0.01). **B)** The western region had a significantly higher proportional mortality rate in the summer than in non-summer, but this pattern was not true for the other regions (summer*central: estimate=-0.80, $z_{9,76}$=-3.40, p<0.001; summer*eastern: estimate=-0.74, $z_{9,76}$=-3.04, p<0.01). Points represent average proportional mortalities and error bars represent 95% confidence intervals. Asterisks indicate significance level and 'ns' indicate comparisons that were not significant.

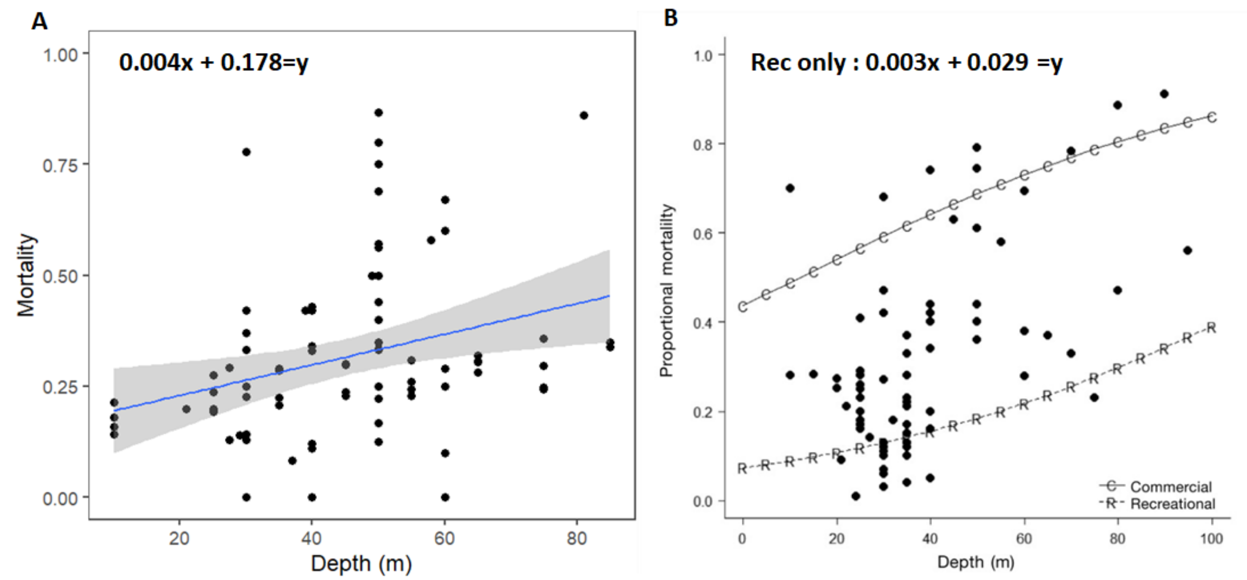

Figure 2: A) The proportional discard mortality of Red Snapper (*Lutjanus campechanus)* in the Gulf of America (formerly known as the Gulf of Mexico) had a significant positive association with depth (estimate=0.012, $z_{9,76}$=7.70, p<0.001). Shown is the slope of the line, indicating a 3.6% increase in mortality with every 10m. Points are raw mortality estimates from the data, the blue line indicates the predicted mortality by depth from the data and the gray band represents at 95% confidence interval around this prediction. **B)** There was also a significant positive association between depth and proportional mortality in the Campbell et al. 2014 paper. Shown is the slope of the line for the recreational data only (the slope which most closely aligns with our data), indicating a 3% increase in mortality with every 10m. The points are raw mortality estimates, and the line indicates the predicted relationship between mortality and depth.

Post-hoc tests addressing the western region separately from the eastern and central regions found similar results. In the western region, summer mortality was significantly higher than non-summer (estimate = 0.64, $z_{2,34}$=2.75, p<0.01), there was a positive association between depth and mortality (estimate=0.04, $z_{2,34}$=4.01, p<0.001; Fig. 3A). In the eastern and central regions, season did not significantly predict mortality (estimate=-0.03, $z_{2,35}$=-0.65, p=0.52), but depth was positively associated with mortality (estimate=0.02, $z_{2,35}$=9.4, p<0.001, Fig.3B). These models predicted that mortality at the average fishing depth (45m) from the tested studies in the western region in the winter is 37.3% and that this increases to 53.1% in the summer. Whereas the estimated mortality in the eastern and central regions is 35.2% regardless of season.

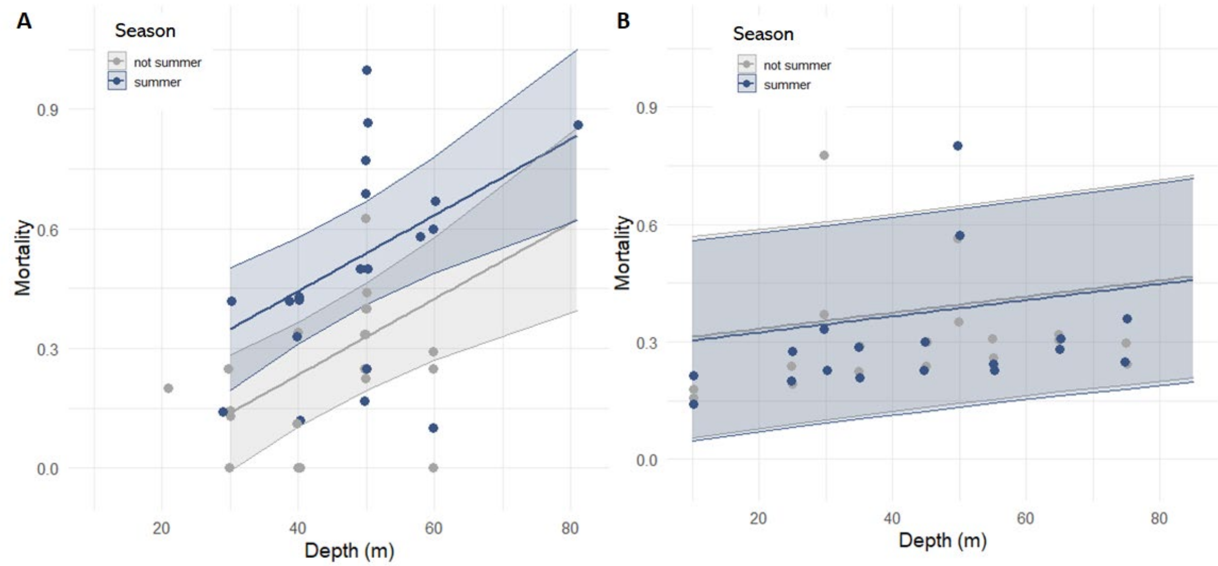

Figure 3: A) In the western region (Texas and Louisiana) of the Gulf of America (formerly known as the Gulf of Mexico) **t**he proportional discard mortality of Red Snapper (*Lutjanus campechanus)* was significantly positively associated with depth (estimate=0.04, $z_{2,34}$=4.02, p<0.001) and summer led to significantly higher discard mortality than non-summer (estimate = 0.64, $z_{2,34}$=2.75, p<0.01). **B)** In the eastern and central regions (Mississippi, Alabama, and parts of Louisiana and Florida) there was also a significant positive association between depth and mortality (estimate=0.01, $z_{2,35}$=9.4, p<0.001), but season did not affect discard mortality (estimate=-0.03, $z_{2,35}$=-0.65, p=0.52). Points are raw mortality estimates from the data, the lines indicate the predicted mortality by depth from the data and the bands represent the 95% confidence interval around this prediction. Blue and gray lines and bands represent summer and not summer data, respectively.

Mortality estimates ranged from 0-100% with a mean of 32% and a median of 28% in the full mortality dataset. The highest mortality estimates occurred during the summer, in the western region in unvented fish, at 40 and 50m (Diamond & Campbell, 2009). Four studies had average mortality estimates between 45-65% (Bohaboy et al., 2020; Diamond et al., 2011; Diamond & Campbell, 2009; Tompkins, 2017) and three studies had average mortality estimates of less than 20% (Parker, 1985; Render and Wilson 1996; Runde et al., 2021). The full mortality model predicted that the discard mortality at the average fishing depth from the tested studies (45m) would be 34%, which more than doubles the 16.4% mortality estimate from Campbell

2014 at the same depth. Additionally, the mixed methods analysis found that mortality estimates from the recreational fishery that included delayed mortality increased by 8.6%, from 26% (immediate mortality only) to 35% (including both immediate and delayed mortality) at 45m (estimate=0.63, $z_{15,129}$=2.74, p<0.01; Fig. S1). This further supports that including estimates of delayed mortality are important to accurately assess discard mortality. See supplement for more detailed results from the mixed mortality model (Table S4).

The release method analysis found that both venting (estimate -0.64, $z_{7,41}$=-2.00, p<0.05) and descending (estimate = -0.62, $z_{7,41}$=-2.64, p<0.001) decreased discard mortality relative to surface release with no barotrauma mitigation. At the mean depth of the studies used in the analysis (45m), the model predicts Red Snapper will experience 43.6% mortality if no barotrauma mitigation is used, 28.8% mortality with venting, and 29.3% mortality with descending (Fig. 4). We also found a significant interaction between season and depth (estimate = -0.06, $z_{7,41}$=-2.96, p<0.01), where there is a significantly steeper depth by mortality slope in the summer than not in the summer. In summer the model predicts a 15% increase in mortality for every 10m deeper depth fished, compared with 3% in the non-summer seasons (Fig. 5).

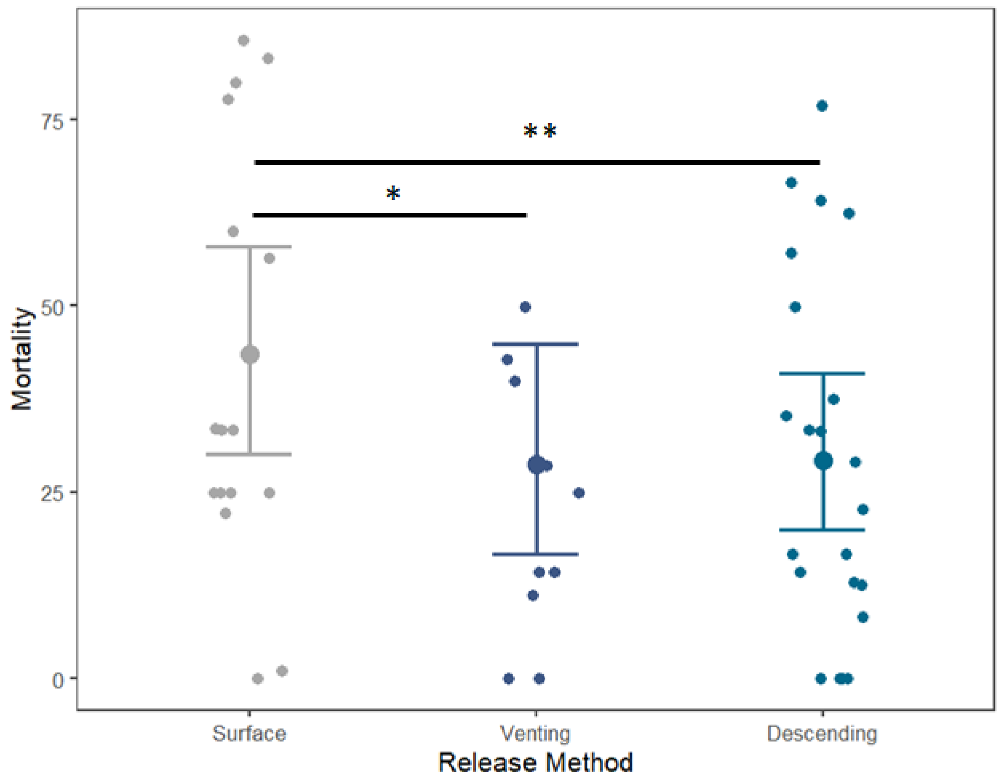

Figure 4. In the analysis that only includes studies explicitly testing release method, venting (estimate -0.65, $z_{7,41}$=-2.00, p<0.05) and descending (estimate = -0.62, $z_{7,41}$=-2.64, p<0.01) both significantly reduce discard mortality, generating a 14.6% decrease in release mortality. Smaller points are raw mortality estimates from the data, larger points indicate the predicted mortality by release method, and the error bars represent the 95% confidence intervals around this prediction. Asterisks indicate significant differences.

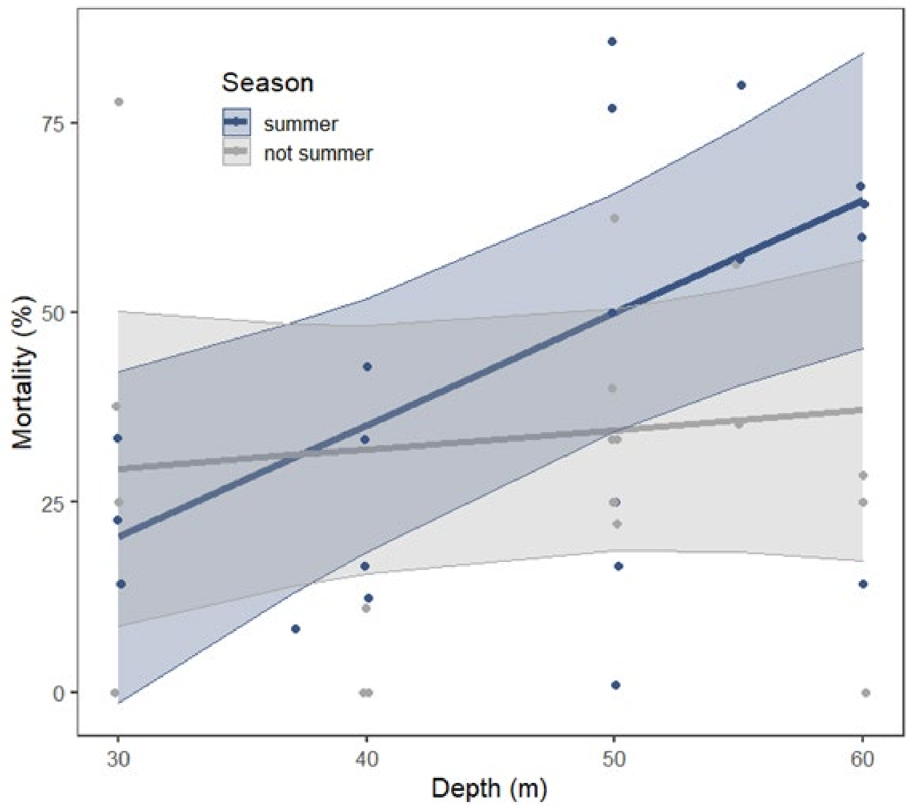

Figure 5. Analyzing studies with well-defined release method treatments, the slope of the positive association between depth and mortality is predicted by the season that fish were caught in (estimate = -0.06, $z_{7,41}$=-2.96, p<0.01). In summer the model predicts a 15% increase in mortality every 10m deeper depth fished, compared with 3% in the non-summer seasons. Most of the estimates (>60%) in this analysis are from the western region and none are from the eastern region, meaning that these results do not pertain to the eastern Gulf of America (formerly known as the Gulf of Mexico). Points are raw mortality estimates from the data, the lines indicate the predicted mortality by depth from the data and the bands represent the 95% confidence band around this prediction. Blue and gray lines and bands represent summer and not summer data, respectively.

When testing for heterogeneity the Cochran's Q-test showed that there was significant variability among the predictors (mixed mortality: QM_{15}=417.42, p<0.001; full mortality: QM_{9}=164.96, p<0.001; release method model: QM_{7}=36.50, p<0.001) and a significant amount of residual heterogeneity in the mixed mortality and full mortality models (mixed mortality: QE_{129}=653.23, p<0.001; full mortality: QE_{76}=121.84, p<0.001), but not in the release method model (QE_{41}=56.29, p=0.056). These heterogeneity tests suggest that all models predict the variation in the data well, although remaining residual heterogeneity suggests that the tested predictors do not encompass all the variation in the data. This is likely because these models had a wider breadth of data which allows for more unidentified variables driving variation in mortality estimates.

Discussion

Red Snapper is an economically important fishery in the Gulf of America. Seasonal closures and size limits cause 70% of Red Snapper that are caught to be discarded (NMFS Fisheries Statistical Division, 2023). While significant research has been directed to understand this vital component of mortality that impacts the population, previous estimates relied largely on methods that were insufficient in estimating delayed mortality. Thus, updating the discard mortality estimates used in stock assessments with newly available research will help support the successful rebuilding of the Gulf of America Red Snapper fishery (SEDAR 52, 2018). When synthesizing new data on release mortality in the recreational Red Snapper fishery, including only studies which measured both immediate and delayed mortality, we found that estimated discard mortality was higher in the summer than in other seasons in the western gulf, and consistent with all studies on the topic, depth of capture was positively associated with discard mortality. We also found that venting and descending use equally reduce discard mortality compared to surface release with no barotrauma mitigation. Finally, we found that the updated model more than doubled the estimated percent discard mortality compared to a previous meta-analysis that included studies with only immediate discard mortality estimates (Campbell et al., 2014).

We found that depth of capture was significantly positively associated with discard mortality in the Gulf of America (Fig. 2). Studies in this meta-analysis that examined this question also found that discard mortality increased with increased depth of capture (Curtis et al., 2015; Diamond & Campbell, 2009; Stunz et al., 2017; Tompkins, 2017). Additionally, a positive association between capture depth and fishing mortality has been seen in other fisheries (Alós J., 2008; Bartholomew & Bohnsack, 2005; Campbell et al., 2010; Drumhiller et al., 2014; Hannah et al., 2008; Sauls, 2014). The previous meta-analysis by Campbell et al. 2014 found that a 10m increase in depth led to a 3% increase in mortality. Our model found a similar result of 3.6%. In keeping with a majority of studies we showed a positive relationship between depth of capture and increased barotrauma (Brown et al., 2010; Ferter et al., 2015; Rummer & Bennett, 2005). Barotrauma can cause extensive physical and behavioral damage to fish that experience it (Raby et al., 2014; Rummer & Bennett, 2005). Recent regulations have required venting and descending devices onboard fishing vessels with a goal of reducing the negative effects from barotrauma. Managers have been working to mitigate these effects through the use of venting and descending devices. Only 19 of the estimates in this study did not include either a venting or a descending device treatment when releasing fish (Table 1), and yet a positive association between depth and mortality still occurred. This suggests that even if venting or descending can reduce discard mortality, catching fish at shallower depths is still the most effective way to lower discard mortality, as the physiological effects of barotrauma are reduced. Additionally, there is evidence that mortality may reach 100% after a certain depth, due to catastrophic barotrauma seen at depths of 50m and above (Stunz et al., 2017; Tompkins, 2017). Catastrophic barotrauma occurs when the swim bladder ruptures and this often leads to mortality (Rummer & Bennett, 2005; Stunz et al., 2017). However, we did not see a steep increase in mortality at depths below 50m in this analysis.

We also found that discard mortality in the western region was higher in summer than in non-summer seasons (Fig. 1). The effect of warmer water increasing discard mortality has been found previously (Bartholomew & Bohnsack, 2005; Diamond & Campbell, 2009; Render & Wilson, 1994), and it is likely due to a steep thermocline that generates during the warmer months (Curtis et al., 2015; Stunz et al., 2017). The change in temperature a fish experiences as it is brought to the surface increases the negative physiological and behavioral affects a fish would experience normally during capture (Boyd et al., 2010; Campbell, 2008; Muoneke & Childress, 1994). Additionally, oxygen stress can lead to discard mortality and higher temperature waters do not hold as much oxygen as cooler waters (Bartholomew & Bohnsack, 2005; Rummer, 2007). We did not see this pattern in the more eastern gulf, potentially due to the eastern and central data coming predominately from passive tagging, whereas the western gulf data was predominately collected using acoustic tagging. In the release method dataset, which consisted primarily of western region estimates (>60%) and had no eastern estimates, we also found that the positive association between depth and mortality is much stronger in the summer than not in the summer. In the summer we estimated a 15% increase in mortality for every 10m deeper depth fished compared to 3% for other seasons combined (Fig. 5). However, we suggest that future research explicitly assess if the effects of seasonality that we saw in the western region are comparable to the changes in discard mortality across fishing seasons and to reassess if the more eastern regions also have a seasonality effect. This could be done using similar tagging methodologies throughout the Gulf to obtain estimates across open/closed seasons. Thereby researchers would collect relevant estimates for all types of regulatory discards generated in the fishery (i.e. length and season).

In the release method model, we found that venting and descending both reduce discard mortality by about 14.6% (Fig. 4). Studies that compare vented or recompressed fish directly with a control group (fish released untreated at the surface) have found that barotrauma mitigation can effectively reduce discard mortality for Red Snapper (Ayala, 2020; Drumhiller et al., 2014; Pulver, 2017), including many of the studies used in this analysis (Bohaboy et al., 2020; Curtis et al., 2015; Runde et al., 2021; Stunz et al., 2017; Tompkins, 2017). However, sometimes conflicting results across studies generated higher variability in our datasets, especially for descended treatments. For example, one study found that the positive effects from venting and descending fish were much greater in the summer (Curtis et al., 2015) whereas another study found that descending fish was more effective in the winter (Stunz et al., 2017). This is likely due to the smaller sample sizes within some of the acoustic tagging studies in the western region, the region where we found seasonal effects on discard morality. A better understanding of which fishing factors are driving the effectiveness of venting or descending could help account for this variability and better inform management decisions. We did not find a significant effect of release methods on discard mortality in the full mortality analysis. This was likely due to the above-described variability and confounding effects from only some fish being vented or in other studies (Render & Wilson, 1996; Vecchio et al., 2022).

Focusing on studies that included estimates of both immediate and delayed mortality led to more than a doubling of estimates of discard mortality of Red Snapper in the Gulf of America (Campbell et al., 2014). At 33m, the median fishing depth of the Gulf recreational fleet (SEDAR 74 2022), we found that release mortality was 31%, compared to 12.8% as predicted by the

Campbell model. As the slope of the positive relationship between depth and mortality remained similar to what was previously reported (Campbell et al., 2014), this over twofold increase in release mortality occurs across all depths of capture (Fig. 2). Studies that have analyzed immediate and delayed mortality have also found that immediate mortality estimates approximately doubled (Curtis et al., 2015) or more than doubled (Diamond & Campbell, 2009) with the addition of delayed mortality. Our analysis on this topic found that including delayed mortality generated an increase from 26% mortality to 34% release mortality at the mean depth from the tested studies (45m; Fig. S1). We conclude that discard mortality estimates used in assessments should include delayed mortality. In addition to mounting evidence in support of the inclusion of delayed mortality (Curtis et al., 2015; Davis, 2002; Diamond & Campbell, 2009), we show that it can significantly increase the expected discard mortality in a fishery.

Season and size limits are still in effect as the Red Snapper fishery in the Gulf of America continues to rebuild (SEDAR 52, 2018). Therefore, assessments of the mortality of discarded fish are necessary to continue effectively managing this fishery. Here we provide a model that can be used to estimate mortality in the recreational fishery by fishing depth throughout the Gulf and by season in the western Gulf. More studies are required to understand why seasonal effects were not conserved across regional domains. Additionally, this model predicts a more than twofold increase in discard mortality estimates than was seen in previous work (Campbell et al., 2014) through inclusion of new research and by excluding studies that only measure immediate discard mortality. A simulation study using Gulf of America Red Snapper stock assessment models showed that reducing discard mortality, especially if discard mortality is larger than previously estimated, could lead to significant increases in fishing season length as well as benefits to an array of fisheries performance metrics (Bohaboy et al., 2022). Therefore, although the estimates generated here suggest that discard mortality of Red Snapper was previously underestimated in the Gulf of America, continued efforts to reduce discard mortality are likely to lead to significant benefits to the fishery.

Mortality from predation was included in the delayed mortality estimates from tagging studies and therefore was a part of the overall estimates of mortality predicted by our model. However, as only of few of the studies in this meta-analysis explicitly separated out discard mortality from predation from discard mortality from other causes, we were not able to explicitly quantify the effect of predation alone on mortality. Some studies in this analysis reported major effects of predation on discard mortality, including the presence of sharks or dolphins in 32% of all Red Snapper releases, 83% of discard mortality resulting from predation (Bohaboy et al., 2020), and predation being described as 'inevitable' when descended Red Snapper were spotted by a predator (Tompkins, 2017). As shark populations continue to rebound (Froeschke et al., 2012; Peterson et al., 2017; SEDAR 54, 2017), quantifying the proportion of discard mortality that comes from predation compared to other factors such as barotrauma may be the next step to increasing scientific understanding of discard mortality.

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Table 1: List of studies used in a meta-analysis of release mortality of red snapper (*Lutjanus campechanus)* in the Gulf of America for which estimates of mortality are categorized by depth (m); season grouped as not summer (NS) and summer (S); region grouped as east (E), central (C), and west (W); study type (Type) grouped as caged (C), acoustic tag (AT), and passive tag (PT); and release method (RM) grouped as not vented (NV), some fish vented (SV), all (total) fish vented (TV), and descended (D). The number of fish included in each estimate (n) and the number of “dead” and “alive” fish used to calculate the mortality are also shown.

Mortality	n	Dead	Alive	Depth	Season	Region	Type	RM	Study
0.37	8	3	5	30	NS	C	AT	D	Bohaboy et al. 2020
0.78	9	7	2	30	NS	C	AT	NV	Bohaboy et al. 2020
0.23	22	5	17	30	S	C	AT	D	Bohaboy et al. 2020
0.33	18	6	12	30	S	C	AT	NV	Bohaboy et al. 2020
0.35	17	6	11	50	NS	C	AT	D	Bohaboy et al. 2020
0.56	16	9	7	50	NS	C	AT	NV	Bohaboy et al. 2020
0.57	14	8	6	50	S	C	AT	D	Bohaboy et al. 2020
0.80	10	8	2	50	S	C	AT	NV	Bohaboy et al. 2020
0.00	7	0	7	30	NS	W	AT	D	Curtis et al. 2015
0.25	8	2	6	30	NS	W	AT	NV	Curtis et al. 2015
0.14	7	1	6	30	NS	W	AT	TV	Curtis et al. 2015
0.33	6	2	4	50	NS	W	AT	D	Curtis et al. 2015
0.33	6	2	4	50	NS	W	AT	D	Curtis et al. 2015
0.40	10	4	6	50	NS	W	AT	NV	Curtis et al. 2015
0.22	9	2	7	50	NS	W	AT	NV	Curtis et al. 2015
0.40	5	2	3	50	NS	W	AT	TV	Curtis et al. 2015
0.17	6	1	5	50	S	W	AT	D	Curtis et al. 2015
0.87	7	6	1	50	S	W	AT	NV	Curtis et al. 2015
0.25	4	1	3	50	S	W	AT	TV	Curtis et al. 2015
0.13	30	4	26	30	NS	W	C	TV	Diamond & Campbell 2009
0.42	47	20	27	30	S	W	C	TV	Diamond & Campbell 2009
0.34	32	11	21	40	NS	W	C	TV	Diamond & Campbell 2009
0.42	56	24	32	40	S	W	C	TV	Diamond & Campbell 2009
0.44	36	16	20	50	NS	W	C	SV	Diamond & Campbell 2009
0.69	24	17	7	50	S	W	C	SV	Diamond & Campbell 2009
0.13	8	1	7	50	NS	W		NV	Diamond et al. 2011
0.50	8	4	4	50	NS	W			Diamond et al. 2011
0.75	8	6	2	50	S	W		SV	Diamond et al. 2011
0.33	9	3	6	50	S	W			Diamond et al. 2011
0.21	14	3	11	22	NS		C		Parker et al. 1987
0.11	30	3	27	30	S		C		Parker et al. 1987
0.20	282	56	226	21	NS	E	C	SV	Render & Wilson 1996
0.05	42	2	40	27.5	NS	W	C	NV	Render & Wilson 1996
0.08	39	3	36	27.5	NS	W	C	TV	Render & Wilson 1996

0.06	50	3	47	35	NS	W	C	NV	Render & Wilson 1996
0.04	49	2	47	35	NS	W	C	TV	Render & Wilson 1996
0.12	26	3	23	43.5	NS	W	C	NV	Render & Wilson 1996
0.00	20	0	20	43.5	NS	W	C	TV	Render & Wilson 1996
0.09	35	3	32	51.5	NS	W	C	NV	Render & Wilson 1996
0.07	30	2	28	51.5	NS	W	C	TV	Render & Wilson 1996
0.20	10	2	8	55	NS	W	C	NV	Render & Wilson 1996
0.00	7	0	7	55	NS	W	C	TV	Render & Wilson 1996
0.08	36	3	33	37	S		AT	D	Runde et al. 2021
0.00	7	0	7	40	NS	W	AT	D	Stunz et al. 2017
0.00	10	0	10	40	NS	W	AT	NV	Stunz et al. 2017
0.11	9	1	8	40	NS	W	AT	TV	Stunz et al. 2017
0.12	8	1	7	40	S	W	AT	D	Stunz et al. 2017
0.33	6	2	4	40	S	W	AT	NV	Stunz et al. 2017
0.43	7	3	4	40	S	W	AT	TV	Stunz et al. 2017
0.00	8	0	8	60	NS	W	AT	D	Stunz et al. 2017
0.25	8	2	6	60	NS	W	AT	NV	Stunz et al. 2017
0.29	7	2	5	60	NS	W	AT	TV	Stunz et al. 2017
0.67	9	6	3	60	S	W	AT	D	Stunz et al. 2017
0.60	5	3	2	60	S	W	AT	NV	Stunz et al. 2017
0.10	7	1	6	60	S	W	AT	TV	Stunz et al. 2017
0.14	14	2	12	29	S	W	AT	D	Tompkins 2017
0.42	12	5	7	39	S	W	AT	D	Tompkins 2017
0.50	14	7	7	49	S	W	AT	D	Tompkins 2017
0.58	14	8	6	58	S	W	AT	D	Tompkins 2017
0.86	15	13	2	81	S	W	AT	D	Tompkins 2017
0.16	49	8	41	10	NS	C	PT	SV	Vecchio et al. 2022
0.18	237	43	194	10	NS	E	PT	SV	Vecchio et al. 2022
0.14	31	4	27	10	S	C	PT	SV	Vecchio et al. 2022
0.21	30	6	24	10	S	E	PT	SV	Vecchio et al. 2022
0.19	3997	769	3228	25	NS	C	PT	SV	Vecchio et al. 2022
0.24	352	84	268	25	NS	E	PT	SV	Vecchio et al. 2022
0.20	1259	251	1008	25	S	C	PT	SV	Vecchio et al. 2022
0.28	161	44	117	25	S	E	PT	SV	Vecchio et al. 2022
0.22	6150	1377	4773	35	NS	C	PT	SV	Vecchio et al. 2022
0.29	962	279	683	35	NS	E	PT	SV	Vecchio et al. 2022
0.21	1766	367	1399	35	S	C	PT	SV	Vecchio et al. 2022
0.29	295	84	211	35	S	E	PT	SV	Vecchio et al. 2022
0.24	1147	273	874	45	NS	C	PT	SV	Vecchio et al. 2022
0.30	885	264	621	45	NS	E	PT	SV	Vecchio et al. 2022
0.23	333	76	257	45	S	C	PT	SV	Vecchio et al. 2022
0.30	288	86	202	45	S	E	PT	SV	Vecchio et al. 2022
0.26	382	100	282	55	NS	C	PT	SV	Vecchio et al. 2022
0.31	586	181	405	55	NS	E	PT	SV	Vecchio et al. 2022
0.23	128	29	99	55	S	C	PT	SV	Vecchio et al. 2022
0.24	139	34	105	55	S	E	PT	SV	Vecchio et al. 2022
0.31	125	38	87	65	NS	C	PT	SV	Vecchio et al. 2022
0.32	151	48	103	65	NS	E	PT	SV	Vecchio et al. 2022
0.28	18	5	13	65	S	C	PT	SV	Vecchio et al. 2022
0.31	21	6	15	65	S	E	PT	SV	Vecchio et al. 2022
0.24	60	15	45	75	NS	C	PT	SV	Vecchio et al. 2022

0.30	12	4	8	75	NS	E	PT	SV	Vecchio et al. 2022
0.25	3	1	2	75	S	C	PT	SV	Vecchio et al. 2022
0.36	21	8	13	75	S	E	PT	SV	Vecchio et al. 2022
0.35	33	12	21	85	NS	C	PT	SV	Vecchio et al. 2022
0.34	36	12	24	85	NS	E	PT	SV	Vecchio et al. 2022
0.13	71	9	62	27.5		W	AT	D	Williams-Grove 2015
0.29	86	25	61	27.5		W	AT	D	Williams-Grove 2015

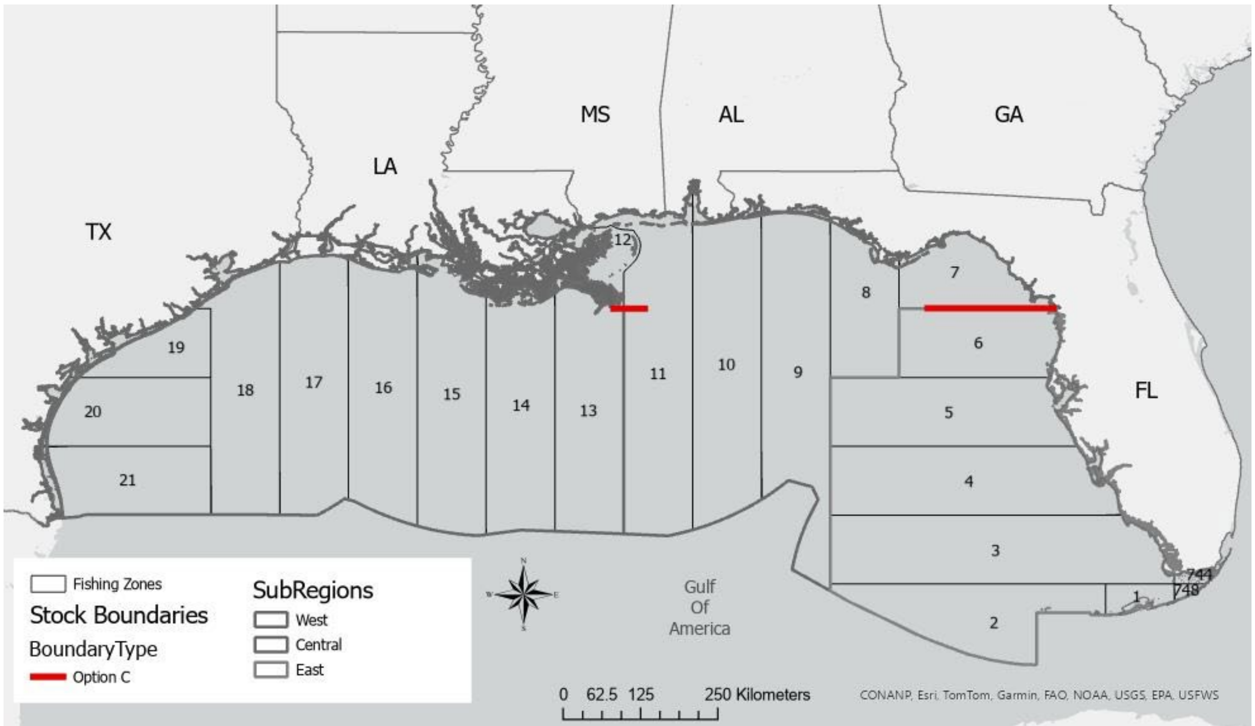

Image 1. Map of the Gulf of America (formerly known as the Gulf of Mexico) used for the SEDAR 74 and in the process of being used for SEDAR 98. Three subregions were chosen (east, central, and west), separated by the red lines. Image from SEDAR74 Stock ID process final report. The fishing zones shown here are National Marine Fisheries Service (NMFS) fishing areas, divided into 21 statistical fishing zones in the Gulf of America. https://sedarweb.org/documents/sedar-74-gulf-of-mexico-red-snapper-stock-id-process-final-report/

Supplementary Materials

Methods

Data from studies where only immediate mortality was measured (Table 1) had depths ranging from 0-90m. Half of the studies were from the western region (defined as Texas and Louisiana to MRIP statistical zone 13), one was from the central region (defined as the rest of Louisiana, Mississippi, Alabama, and the panhandle of Florida through MRIP statistical zone 7 and Levy County), and three did not specify region. Regions defined here are stock assessment regions for SEDAR 74(Image 1; SEDAR 74, 2022). Estimates that reported season were split almost evenly between summer and not summer and only two studies did not include season. Summer was defined as fish captured from June – September. Only 4 estimates descended fish, 23 vented fish, and 27 did not vent. Five studies used J hooks to catch fish, whereas the rest used circle hooks or a combination of hook types.

Table S1. A list of studies with estimates of immediate release mortality of red snapper (*Lutjanus campechanus)* in the Gulf of Mexico. Estimates of mortality are categorized into depth (m); fleet type grouped as recreational (Rec) and commercial (Com); season grouped as not summer (NS) and summer (S); region grouped as east (E), central (C), and west (W); hook type grouped as circle (C) or J hook (J); and release method (RM) grouped as not vented (NV), some fish vented (SV), all (total) fish vented (TV), and descended (D). The number of fish included in each estimate (n) and the number of "dead" and "alive" fish used to calculate the mortality are also shown.

Mortality	n	Dead	Alive	Depth	Fleet	Season	Region	Hook	RM	Study
0.00	7	0	7	30	Rec	NS	W	C	D	Curtis 2015
0.20	10	2	8	30	Rec	NS	W	C	NV	Curtis 2015
0.11	9	1	8	30	Rec	NS	W	C	TV	Curtis 2015
0.00	8	0	8	50	Rec	NS	W	C	D	Curtis 2015
0.30	10	3	7	50	Rec	NS	W	C	NV	Curtis 2015
0.00	8	0	8	50	Rec	NS	W	C	TV	Curtis 2015
0.00	6	0	6	50	Rec	S	W	C	D	Curtis 2015
0.57	7	4	3	50	Rec	S	W	C	NV	Curtis 2015
0.25	4	1	3	50	Rec	S	W	C	TV	Curtis 2015
0.00	6	0	6	50	Rec	NS	W	C	D	Curtis 2015
0.22	9	2	7	50	Rec	NS	W	C	NV	Curtis 2015
0.21	137	29	108	30	Rec	NS	W	C	TV	Campbell et al. 2010
0.23	137	31	106	30	Rec	S	W	C	TV	Campbell et al. 2010
0.21	282	60	222	60	Rec	NS	W	C	TV	Campbell et al. 2010
0.26	282	73	209	60	Rec	S	W	C	TV	Campbell et al. 2010
0.28	25	7	18	10	Rec	S	W	J	NV	Dorf 2003
0.28	425	120	305	15	Rec	S	W	J	NV	Dorf 2003
0.27	825	225	600	20	Rec	S	W	J	NV	Dorf 2003
0.41	525	215	310	25	Rec	S	W	J	NV	Dorf 2003
0.47	225	106	119	30	Rec	S	W	J	NV	Dorf 2003
0.15	100	15	85	35	Rec	S	W	J	NV	Dorf 2003
0.40	155	62	93	40	Rec	S	W	J	NV	Dorf 2003
0.63	280	176	104	45	Rec	S	W	J	NV	Dorf 2003
0.61	105	64	41	50	Rec	S	W	J	NV	Dorf 2003
0.58	240	139	101	55	Rec	S	W	J	NV	Dorf 2003
0.38	125	48	78	60	Rec	S	W	J	NV	Dorf 2003
0.37	50	19	32	65	Rec	S	W	J	NV	Dorf 2003
0.33	10	3	7	70	Rec	S	W	J	NV	Dorf 2003
0.23	75	17	58	75	Rec	S	W	J	NV	Dorf 2003
0.47	100	47	53	80	Rec	S	W	J	NV	Dorf 2003
0.56	30	17	13	95	Rec	S	W	J	NV	Dorf 2003
0.01	140	1	139	24	Rec	NS		J	TV	Gitschlag and Renaud 1994
0.10	31	3	28	30	Rec	NS		J	TV	Gitschlag and Renaud 1994
0.44	61	27	34	40	Rec	NS		J	TV	Gitschlag and Renaud 1994
0.70	40	28	12	10	Com	NS	W	C	NV	Nieland et al. 2007
0.25	465	117	348	20	Com	NS	W	C	NV	Nieland *et al.* 2007
0.68	789	537	252	30	Com	NS	W	C	NV	Nieland *et al.* 2007
0.74	814	602	212	40	Com	NS	W	C	NV	Nieland *et al.* 2007
0.74	1638	1219	419	50	Com	NS	W	C	NV	Nieland *et al.* 2007
0.69	464	322	142	60	Com	NS	W	C	NV	Nieland *et al.* 2007
0.78	404	316	88	70	Com	NS	W	C	NV	Nieland *et al.* 2007
0.89	88	78	10	80	Com	NS	W	C	NV	Nieland *et al.* 2007

0.91	68	62	6	90	Com	NS	W	C	NV	Nieland *et al*. 2007
0.09	1064	96	968	21	Rec		C	J	TV	Patterson *et al.* 2001
0.14	856	120	736	27	Rec		C	J	TV	Patterson et al. 2001
0.18	1012	182	830	32	Rec		C	J	TV	Patterson et al. 2001
0.03	138	4	134	30	Rec	NS		J	TV	Patterson et al. 2001
0.06	31	2	29	30	Rec	NS		J	TV	Patterson et al. 2001
0.07	52	4	48	30	Rec	S		J	TV	Patterson et al. 2001
0.12	221	27	194	30	Rec	NS		J	TV	Patterson et al. 2001
0.04	375	15	360	35	Rec	NS		J	TV	Patterson et al. 2001
0.10	196	20	176	35	Rec	NS		J	TV	Patterson et al. 2001
0.13	264	34	230	35	Rec	S		J	TV	Patterson et al. 2001
0.17	563	96	467	35	Rec	NS		J	TV	Patterson et al. 2001
0.05	65	3	62	40	Rec	NS		J	TV	Patterson et al. 2001
0.16	107	17	90	40	Rec	NS		J	TV	Patterson et al. 2001
0.16	44	7	37	40	Rec	S		J	TV	Patterson et al. 2001
0.20	60	12	48	40	Rec	NS		J	TV	Patterson et al. 2001
0.24	34465	8272	26193		Com					Pulver 2017

Table S2. A reduced list of studies used in a meta-analysis to assess how release method effects discard mortality of red snapper (*Lutjanus campechanus)* in the Gulf of Mexico. This subsetted dataset includes only studies where release method was explicitly tested in the study and release method (RM) is clearly defined as no barotrauma mitigation (S – surface release), vented (V), or descended (D). An additional laboratory study addressing this question was included (Drumhiller *et al.* 2014). Estimates of mortality are categorized into depth in meters, season grouped as not summer (NS) and summer (S), region grouped as east (E), central (C), and west (W), and study type (ST) grouped as caged (C), acoustic tag (AT), and passive tag (PT). The number of fish included in each estimate (n) and the number of “dead” and “alive” fish used to calculate the mortality are also shown.

Mortality	n	dead	alive	Depth	Season	ST	Region	RM	Study
0.778	9	7	2	30	NS	AT	C	S	Bohaboy et al. 2020
0.376	8	3	5	30	NS	AT	C	D	Bohaboy et al. 2020
0.335	18	6	12	30	S	AT	C	S	Bohaboy et al. 2020
0.227	22	5	17	30	S	AT	C	D	Bohaboy et al. 2020
0.563	16	9	7	55	NS	AT	C	S	Bohaboy et al. 2020
0.353	17	6	11	55	NS	AT	C	D	Bohaboy et al. 2020
0.8	10	8	2	55	S	AT	C	S	Bohaboy et al. 2020
0.571	14	8	6	55	S	AT	C	D	Bohaboy et al. 2020
0	7	0	7	30	NS	AT	W	D	Curtis et al. 2015
0.333	6	2	4	50	NS	AT	W	D	Curtis et al. 2015
0.167	6	1	5	50	S	AT	W	D	Curtis et al. 2015
0.333	6	2	4	50	NS	AT	W	D	Curtis et al. 2015
0.14286	7	1	6	30	NS	AT	W	V	Curtis et al. 2015
0.25	4	1	3	50	S	AT	W	V	Curtis et al. 2015
0.4	5	2	3	50	NS	AT	W	V	Curtis et al. 2015
0.25	8	2	6	30	NS	AT	W	S	Curtis et al. 2015
0.222	9	2	7	50	NS	AT	W	S	Curtis et al. 2015
0.875	7	6	1	50	S	AT	W	S	Curtis et al. 2015
0.25	8	2	6	50	NS	AT	W	S	Curtis et al. 2015
0	6	0	6	30		C		D	Drumhiller et al. 2014
0.1667	6	1	5	60		C		D	Drumhiller et al. 2014
0	6	0	6	30		C		V	Drumhiller et al. 2014
0	6	0	6	60		C		V	Drumhiller et al. 2014
0.333	6	2	4	30		C		S	Drumhiller et al. 2014
0.833	6	5	1	60		C		S	Drumhiller et al. 2014
0.125	8	1	7	40	S	AT	W	D	Stunz et al. 2017
0.3333	6	2	4	40	S	AT	W	S	Stunz et al. 2017
0.42857	7	3	4	40	S	AT	W	V	Stunz et al. 2017
0.6667	9	6	3	60	S	AT	W	D	Stunz et al. 2017
0.6	5	3	2	60	S	AT	W	S	Stunz et al. 2017
0.14286	7	1	6	60	S	AT	W	V	Stunz et al. 2017
0	7	0	7	40	NS	AT	W	D	Stunz et al. 2017
0	10	0	10	40	NS	AT	W	S	Stunz et al. 2017
0.1111	9	1	8	40	NS	AT	W	V	Stunz et al. 2017
0	8	0	8	60	NS	AT	W	D	Stunz et al. 2017
0.25	8	2	6	60	NS	AT	W	S	Stunz et al. 2017
0.2857	7	2	5	60	NS	AT	W	V	Stunz et al. 2017
0.5	14	7	7	50	S	AT	W	D	Tompkins 2017
0.14286	14	2	12	30	S	AT	W	D	Tompkins 2017
0.16667	12	2	10	40	S	AT	W	D	Tompkins 2017
0.64286	14	9	5	60	S	AT	W	D	Tompkins 2017
0.77	9	7	2	50	S	AT	W	D	Diamond et al. 2011
0.5	4	2	2	50	S	AT	W	V	Diamond et al. 2011

1	12	12	0	50	S	AT	W	S	Diamond et al. 2011
0.625	8	5	3	50	NS	AT	W	D	Diamond et al. 2011
0.25	8	2	6	50	NS	AT	W	S	Diamond et al. 2011
0.13	71	9	62	27.5		AT	C	D	Williams-Grove 2015
0.291	86	25	61	27.5		AT	C	D	Williams-Grove 2015
0.083	36	3	33	37	NS	AT		D	Runde et al. 2021

Results

Table S3. Shown are the results of the analysis focused on generating discard mortality estimates of Red Snapper (*Lutjanus campechanus)* using only mortality estimates that have combined immediate and delayed morality. The best fit model included depth of capture (m), release method (descended, vented, or surface release), regions of the Gulf of Mexico (western, central, or eastern), season (summer or not summer) and an interaction between region and season. Study and study type (cage, passive tag, acoustic tag) were included as random effects.

	estimate	se	z value	p value	lower CI	upper CI
Intercept	-1.3519	0.4426	-3.0542	0.0023	-2.2194	-0.4844
Depth	0.0123	0.0016	7.7005	<.0001	0.0092	0.0154
Descending	-0.3878	0.2456	-1.5789	0.1144	-0.8692	0.0936
Some Venting	-1.1951	1.2988	-0.9202	0.3575	-3.7408	1.3505
Total Venting	-0.3812	0.3447	-1.1059	0.2688	-1.0568	0.2944
Central Region	0.8477	0.4438	0.8700	0.3843	-1.0620	2.7575
Eastern Region	1.1237	0.4451	1.1524	0.2492	-0.7875	3.0349
Summer	0.7557	0.1286	3.2746	0.0011	0.3034	1.2080
Central Region * Summer	-0.8014	0.1367	-3.4045	0.0007	-1.2628	-0.3400
Eastern Region * Summer	-0.7426	0.1521	-3.0353	0.0024	-1.2222	-0.2631

Table S4. Shown are the results of an analysis focused on estimating how discard mortality estimates of Red Snapper (*Lutjanus campechanus)* differ when mortality estimates include only immediate estimates of discard mortality or have a combination of immediate and delayed discard mortality (Delayed). The best fit model also included depth of capture (m), fleet type (recreational or commercial), release method (descended, vented, or surface release), hook type (circle or J hook), regions of the Gulf of Mexico (western, central, or eastern), season (summer or not summer), and an interaction between region and season. Study and study type (cage, passive tag, acoustic tag) were included as random effects.

	estimate	se	z value	p value	lower CI	upper CI
Intercept	-0.1965	0.9003	-0.2182	0.8272	-1.9610	1.5680
Delayed	0.5061	0.2460	2.0571	0.0397	0.0239	0.9882
Depth	0.0176	0.0011	16.7422	<.0001	0.0155	0.0197
Recreational Fleet	-1.9406	0.8654	-2.2424	0.0249	-3.6367	-0.2444
Descending	-0.5366	0.2115	-2.5374	0.0112	-0.9511	-0.1221
Venting	-0.2784	0.2215	-1.2569	0.2088	-0.7126	0.1558
Circle Hook	-0.0634	0.4411	-0.1438	0.8856	-0.9279	0.8010
Central Region	0.3162	0.6577	0.4808	0.6307	-0.9729	1.6054
Eastern Region	0.5534	0.6586	0.8402	0.4008	-0.7375	1.8442
Summer	0.4037	0.1287	3.1373	0.0017	0.1515	0.6559
Central Region * Summer	-0.4432	0.1368	-3.2390	0.0012	-0.7114	-0.1750
Eastern Region * Summer	-0.3828	0.1522	-2.5151	0.0119	-0.6811	-0.0845

Table S5. Shown are the results of the analysis focused on estimating how barotrauma mitigation affects discard mortality estimates of Red Snapper (*Lutjanus campechanus)*. The best fit model included depth of capture (m), release method (descended, vented, or surface release), season (summer or not summer), and an interaction between depth and season. Study was included as a random effect.

	estimate	se	z value	p value	lower CI	upper CI
Intercept	-2.8921	0.6669	-4.3366	<.0001	-4.1992	-1.5850
Depth	0.0658	0.0134	4.9213	<.0001	0.0396	0.0920
Descending	-0.6196	0.2344	-2.6431	0.0082	-1.0791	-0.1601
Venting	-0.6437	0.3232	-1.9914	0.0464	-1.2771	-0.0102
Not Summer	2.3009	0.9783	2.3521	0.0187	0.3836	4.2183
Depth * Not Summer	-0.0602	0.0203	-2.9636	0.0030	-0.1001	-0.0204

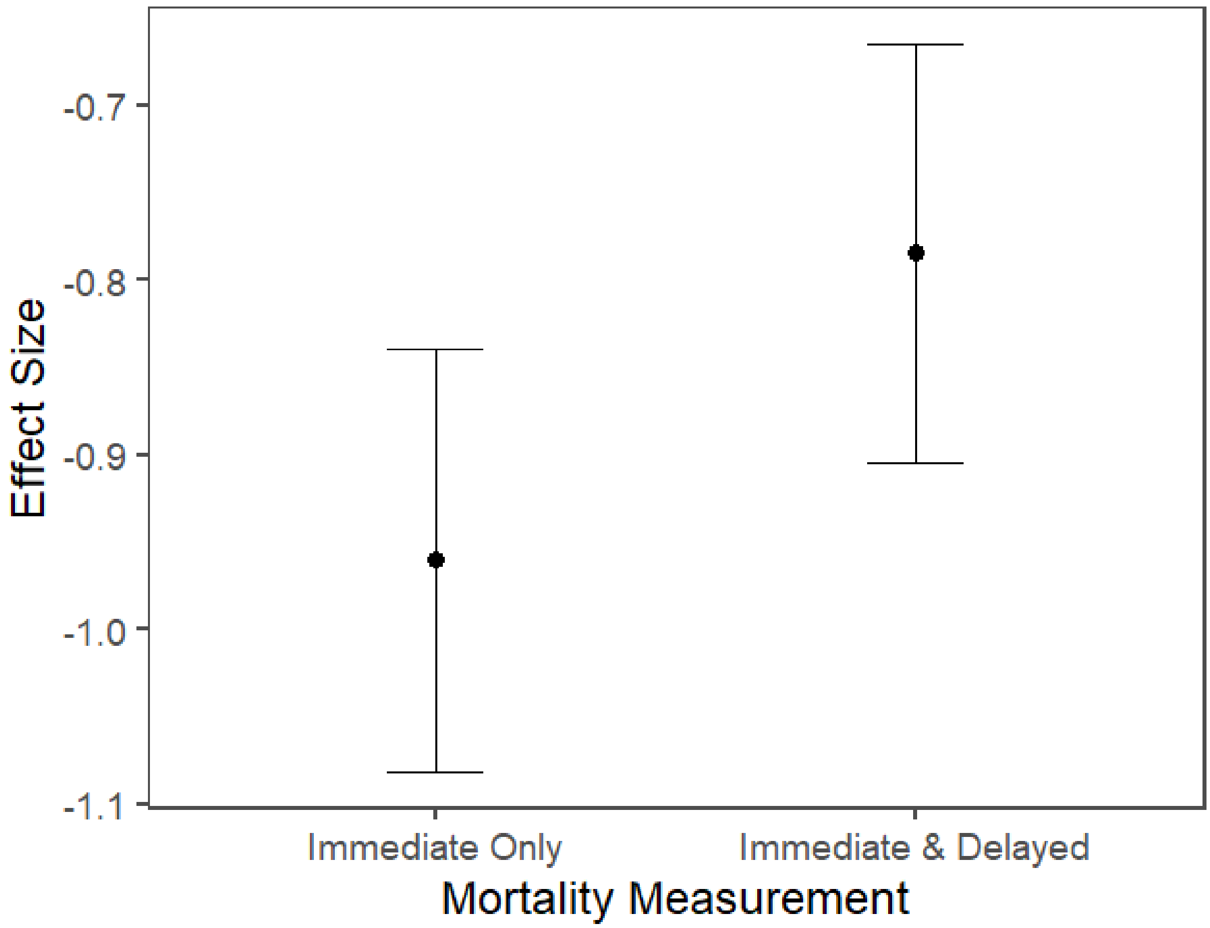

Figure S1: A) When assessing the effects of the inclusion of delayed mortality when estimating discard mortality of Red Snapper (*Lutjanus campechanus*), delayed mortality significantly increased the predicted discard mortality in the Gulf of Mexico (estimate=0.51, $z_{15,139}$=2.06, p<0.05). At the average fishing depth of the tested studies (45m) the estimated mortality is 35% for studies include delayed mortality (immediate & delayed) compared to 26% for studies that do not (immediate only). Points are the calculated mean effect sizes and error bars represent the 95% confidence interval.