Release mortality in the red snapper fishery: a synopsis of three decades of research

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Abstract

Catch-and-release fishing has been successfully applied in many fisheries as a regulation to promote sustainable fisheries and is widely accepted by most anglers as a wise conservation strategy. Despite the intent of CAR regulations if released fish do not survive following release then the regulations are not appropriate for the fishery. Analysis of thirty years of release mortality experiments shows that mortality increased with increasing capture depth, increasing water temperature, or from the compounding effects of those two variables. Designing experiments that incorporate a full range of conditions is difficult, if not unlikely, but future surveys, at minimum, should be structured around quarterly sampling, collect water temperature profile data, reflect the range of depths associated with the fishery, and strive to calculate season and depth specific estimates. Studies that evaluate the effects of thermal stress, that test bottom release devices and those that develop tag-and-recapture models are of particular interest in the future.

Introduction

The use of catch and release (CAR) fishing as a conservation measure began in Great Britain during the 19th century, and was eventually introduced in the United States in the 1950's within salmonid fisheries. Since that time the practice has been successfully applied in many fisheries as a regulation to promote sustainable fisheries and is widely accepted by most anglers as a wise conservation strategy. The intent behind CAR regulations is to reduce fishing mortality for immature age groups of fish, allow those age groups to grow and mature to reproductive ages, and help preserve age structure in a population. Despite the intent of CAR fishing regulations, for many species stress of capture leads to increased frequency of barotraumas and reduced reflex responses, the synergistic effects of which often results in increased release mortality and renders those regulations ineffective (Davis 2007, Campbell et al. 2010a). Stressors experienced by fishes during CAR fishing can include hook trauma, physical overexertion, barotraumas, rapid thermal change, air exposure, and physical handling (Davis et al. 2001, Rummer and Bennett 2005, Nieland 2007, Jarvis and Lowe 2008). These CAR fishing stressors can also translate into long-term, sub-lethal, negative consequences for individuals and potentially for populations, such as reduced growth and fecundity (Woodley and Peterson 2003, Ryer et al. 2004, Davis 2007). The effects of CAR fishing can be particularly problematic for marine species such as red snapper (*Lutjanus campechanus*) that inhabit relatively deep water and possess a physoclistus gas bladder.

Red snapper have been utilized as a fishery resource in the Gulf of Mexico (GOM) for over a century and are considered to be one of the most economically important fisheries in the region (Strelcheck and Hood 2007). The first regulations managing the fishery were put in place in 1984 in response to the overfished status of the stock (see Hood et al. (2007) for a comprehensive management history). In general, both commercial and recreational regulations have focused on reducing total catch by implementing annual time closures, which in turn generates regulatory discards in the off season. Additionally, resource managers implemented minimum size regulations that increased the number regulatory discards. As discussed earlier, size limits ideally reduce fishing mortality for immature age groups thus allowing them to reach maturity. In both cases the fact that regulatory discards are a byproduct, necessitates tracking the rate at which fish are discarded, as well as eventual fate following release.

Reported percent discard mortality in the red snapper fishery ranges from 0 to 100% (SEDAR 7, 2005) depending on fishery sector (e.g. recreational and commercial), gear types deployed, capture depth, water temperature, exposure to thermoclines, handling time, and air exposure (Table 1, Figure 1). Due to the wide range in reported mortality rates and the convoluted nature of interacting factors, a comprehensive evaluation of pertinent research is needed. The central thesis of this paper focuses on the status of our knowledge regarding discard mortality in the red snapper fishery with the intent of identifying critical unresolved issues.

Measuring the response

Derivation of the percent release mortality estimate is a point of contention among investigators and has been identified in calls for proposals as an issue requiring resolution. Methods used to derive mortality estimates (Table 1) each have their benefits, biases and shortcomings that require exploration; however, in general, the problems are associated with the timing of observation, exclusion of predators, insufficient tag returns, and sample size issues. Methods used to derive estimates include surface observation, cage studies, hyperbaric chamber simulations, and tag-recapture (Table 1). Mortality estimates from these studies are broadly categorized as either immediate (seconds to minutes), or delayed (hours to days).

Table 1. List of studies conducted in the Gulf of Mexico reporting release mortality estimates by 5 meter depth groups.

Depth range (m)	Season	Release Mortality	*N*	Method	Study	Region
< 20	None*	0.00	None	Hyperbaric	Burns et al. (2004) MARFIN	Panama City, FL
21-25	None	21.00	14	Cage+SCUBA	Parker (1985, unpublished)	Daytona, FL
	Quarterly †	20.00	282	Cage	Render and Wilson (1994)	Louisiana
	Fall	1.00	140	Surf obs	Gitschlag and Renaud (1994)	Galveston, TX
	Quarterly †	9.00	2932	Surf obs	Patterson et al. (2001)	AL coast
	None*	0.00	None	Hyperbaric	Burns et al. (2004) MARFIN	Panama City, FL
	Summer	41.00	3851	Surf obs	Dorf (2003)	Texas ports
26-30	none	11.00	44	Cage+SCUBA	Parker (1985, unpublished)	Galveston, TX
	Fall	10.00	31	Surf obs	Gitschlag and Renaud (1994)	Galveston, TX
	Quarterly †	14.00	2932	Surf obs	Patterson et al. (2001)	AL coast
	None*	0.00	None	Hyperbaric	Burns et al. (2004) MARFIN	Panama City, FL
	Summer and fall †	53.00	115	Cage	Diamond and Campbell (2009)	Port Aransas, TX
	Summer	47.00	3851	Surf obs	Dorf (2003)	Texas ports
	Summer and fall †	27.00	137	Surf obs	Campbell et al. 2010	Corpus Christi, TX
	Winter	3.00	138	Surf obs	Patterson & Addis (2008)	Pensacola, FL
	Spring	6.40	31	Surf obs	Patterson & Addis (2008)	Pensacola, FL
	Summer	7.00	52	Surf obs	Patterson & Addis (2008)	Pensacola, FL
	Fall	12.00	221	Surf obs	Patterson & Addis (2008)	Pensacola, FL
31-35	Quarterly †	18.00	2932	Surf obs	Patterson et al. (2001)	AL Coast
	Summer	15.00	3851	Surf obs	Dorf (2003)	Texas ports
	Winter	4.00	375	Surf obs	Patterson & Addis (2008)	Pensacola, FL
	Spring	10.00	196	Surf obs	Patterson & Addis (2008)	Pensacola, FL
	Summer	13.00	264	Surf obs	Patterson & Addis (2008)	Pensacola, FL
	Fall	17.00	563	Surf obs	Patterson & Addis (2008)	Pensacola, FL
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36-40	Fall	44.00	61	Surf obs	Gitschlag and Renaud (1994)	Galveston, TX
	Summer	40.00	3851	Surf obs	Dorf (2003)	Texas ports
	Winter	5.00	65	Surf obs	Patterson & Addis (2008)	Pensacola, FL
	Spring	16.00	107	Surf obs	Patterson & Addis (2008)	Pensacola, FL
	Summer	16.00	44	Surf obs	Patterson & Addis (2008)	Pensacola, FL
	Fall	20.00	60	Surf obs	Patterson & Addis (2008)	Pensacola, FL
41-45	None*	40.00	None	Hyperbaric	Burns et al. (2004) MARFIN	Panama City, FL
	Summer and fall †	71.00	97	Cage	Diamond and Campbell (2009)	Port Aransas, TX
	Summer	63.00	3851	Surf obs	Dorf (2003)	Texas ports
46-50	Fall	36.00	55	Cage	Gitschlag and Renaud (1994)	Galveston, TX
	Summer and fall †	69.00	110	Cage	Diamond and Campbell (2009)	Port Aransas, TX
	Summer	61.00	3851	Surf obs	Dorf (2003)	Texas ports
	Summer	79.00	24	Acoustic tags	Diamond et al. (2011) Marfin	Corpus Christi, TX
	Winter	40.00	20	Acoustic tags	Diamond et al. (2011) Marfin	Corpus Christi, TX
51-55	Summer	58.00	3851	Surf obs	Dorf (2003)	Texas ports
56-60	None*	45.00	None	Hyperbaric	Burns et al. (2004) MARFIN	Panama City, FL
	Summer	38.00	3851	Surf obs	Dorf (2003)	Texas ports
	Summer and fall †	27.00	282	Surf obs	Campbell et al. (2010)	Corpus Christi, TX
61-65	Summer	37.00	3851	Surf obs	Dorf (2003)	Texas ports
66-70	Summer	33.00	3851	Surf obs	Dorf (2003)	Texas ports
71-75	Summer	23.00	3851	Surf obs	Dorf (2003)	Texas ports
76-80	Summer	47.00	3851	Surf obs	Dorf (2003)	Texas ports
>81	Summer	56.00	3851	Surf obs	Dorf (2003)	Texas ports

* No temperatures reported for experiment, however fish could only be collected during cold months

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† indicates an experiment that sampled in more than one season but only produces a single estimate

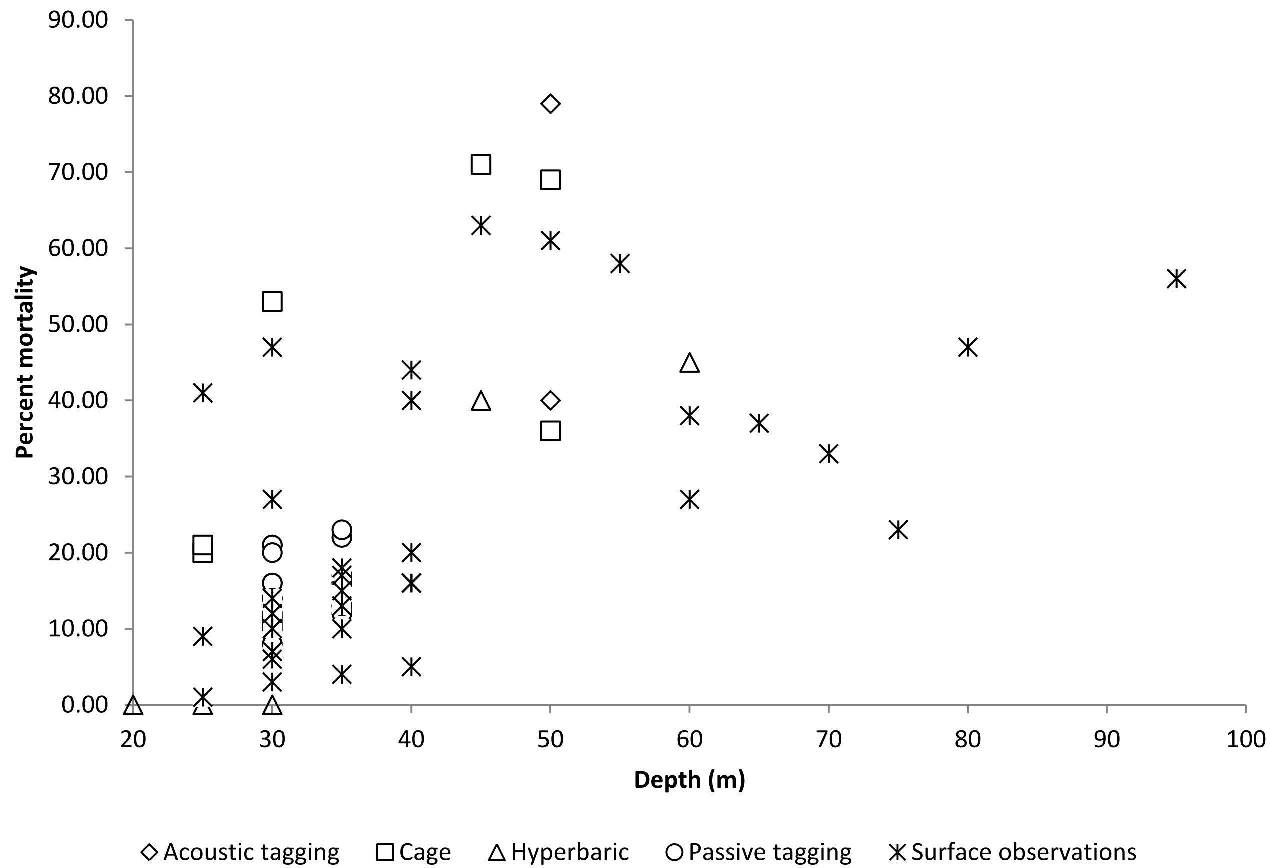

Fig 1. Plot of the relationship between study depth and estimated percent release mortality with individual study types identified (acoustic tagging = diamond, cage studies = square, hyperbaric chamber simulation = triangle, passive tag-recapture = circle, and surface observation = asterisk).

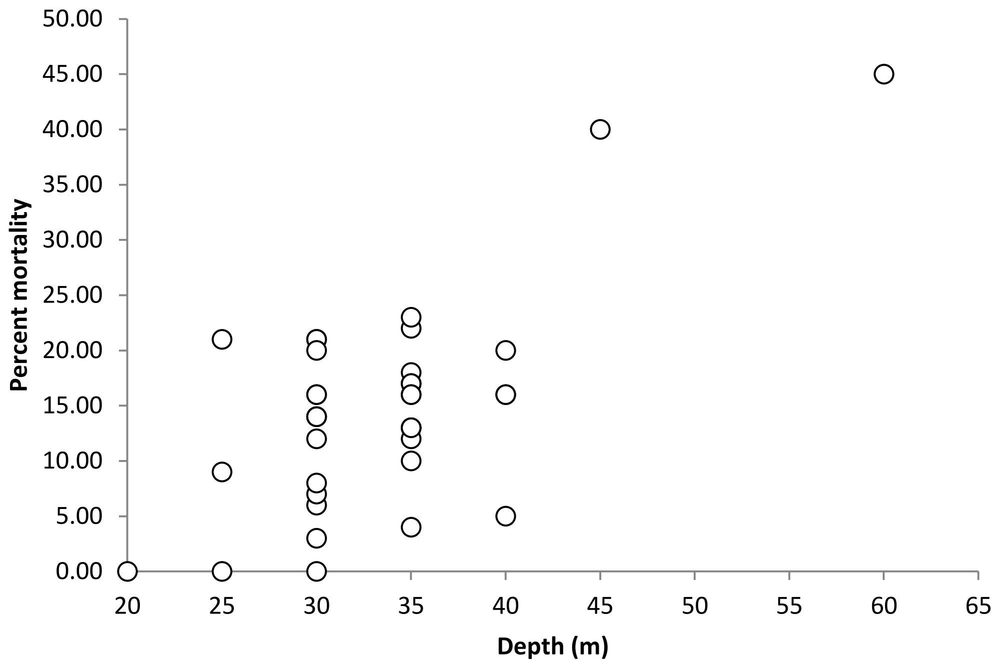

Fig 2. Eastern GOM release mortality estimates all methods, all seasons.

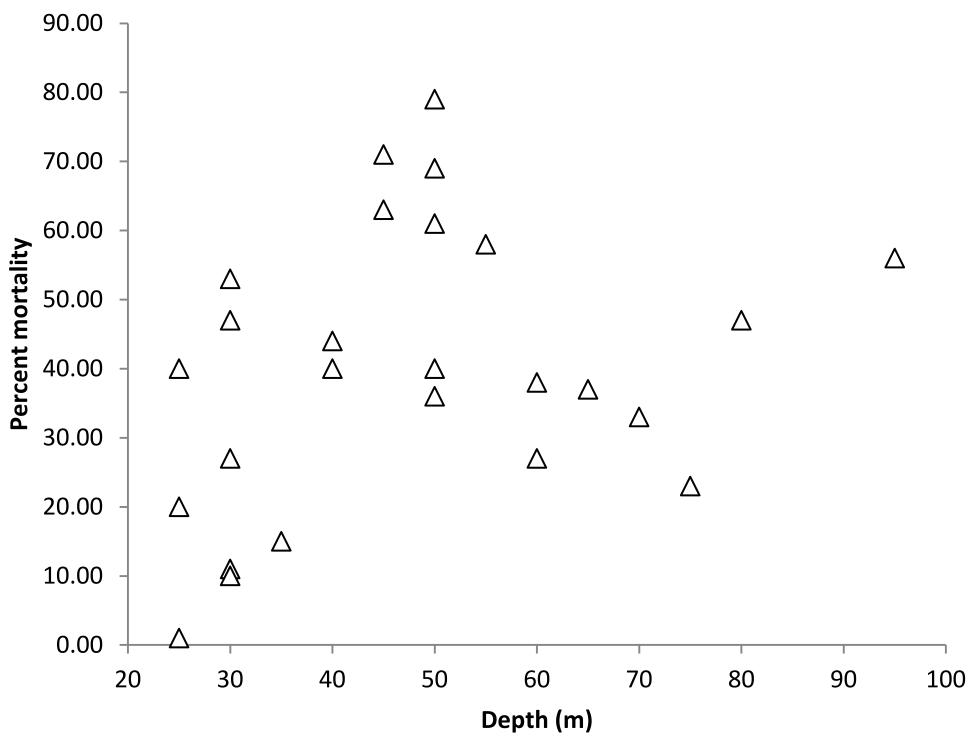

Fig 3. Western GOM release mortality estimates all methods, all seasons.

Surface observations

The most common mortality estimation method is surface observation of release activity. Estimates derived using this method are among the most conservative, show high variation among surveys, and report considerable regional differences (Table 1, Figures 1, 2 and 3). Surface observation experiments have used two categorization systems. Type-1 surface observation methods classify release activity into four categories: (1) swam down, (2) erratic swimming at the surface with eventual submersion, (3) erratic swimming at the surface without submersion, and (4) floating (Patterson 2001, Campbell 2010a). Type-2 surface release observation methods use slightly different categories: (1) swam down, (2) erratic swimming, (3) floating, and (4) dead (Dorf 2003). The main difference between these two systems is that type-1 considers an erratic swimming fish that eventually submerged as a survivor while type-2 considers all of the erratic swimmers as mortalities regardless of submergence.

High variation reported among surveys could be attributable to season, depth, categorization system or region (Table 1, Figures 1, 2 and 3). For instance, Dorf (2003) reported the highest release mortality estimates among surface observation studies, however, the data were collected exclusively during the summer on fishery dependent surveys, from relatively deep stations, and erratic swimmers were all considered mortalities regardless of submergence. Patterson et al. (2001) reported lower estimates from data collected quarterly on scientific research cruises, at shallower stations, and only considered erratic swimmers failing to submerge as mortalities. If the erratic swimmers from the Dorf estimates are split equally into the submergence categories from type-1 methods, those high estimates would then reflect mortality from studies that used that system. Furthermore the regional pattern of higher estimates from western GOM data would reduce to within a range reported from the east, and therefore the apparent regional differences should more correctly be attributed to methodology (Figures 1 and 2).

Surface observations are useful due to low operational costs, minimal equipment requirements, and the ease with which large sample sizes can be generated. Limitations of the method center on its observational nature. For instance, unsuccessful submergence is only a proxy of mortality, release behavior is subjective, observations are immediate (<1 minute), and subsurface observations are rare. Surface observations also ignore issues associated with CAR fishing such as hooking injuries, thermal stress, and barotrauma that could result in mortality over hours to days (Campbell et al. 2010a). In spite of the stated limitations, surface release activity data should always be collected during surveys. If the method is used to formulate release mortality estimates then clarification is needed in regards to classifying erratic swimming fish, and tag-and-recapture methods should be utilized to evaluate misclassification rates from each unique release activity group.

Cage studies

Cage studies were the first to address delayed mortality, and where comparisons are possible, generally result in higher release mortality estimates within a given depth group (Table 1). Like surface observations this group of studies tends to show a lot of variability about the associated mortality estimates most of appears to be related to study specific issues. It should be noted that all of the aforementioned cage studies were performed in Texas and/or Louisiana with cages suspended from oil production platforms, therefore regional differences (east versus west) cannot be discerned and effects of day to day activities on oil platforms may be of concern (e.g. release of drilling muds or petro-chemicals near captive fish).

The first cage study was performed by Parker (1985), unfortunately this frequently cited paper was an internal report that the authors have been unable to obtain, and the two estimates were derived from a sample of 14 and 44 fish (Table 1). Render and Wilson (1994) reported 20% release mortality from their cage which is the second highest mortality reported from the < 20 m depth group, and from which the only higher estimate was Dorf (2003) who used the least conservative surface release methodology (type-2). Diamond and Campbell (2009) generated mortality estimates from a cage study that in their associated depth groups, and among all studies combined, are among the highest reported (Table 1, Figure 1). The Diamond and Campbell (2009) study was confounded by three important factors including very warm surface water summer during summer sampling (~ 32.2 - 33.3°C), fish were placed in cages at the surface for extended periods before descent (waiting for scuba diving intervals to expire), and fish included in the experiment had blood drawn from them which could have influenced mortality rates. While cage studies show high mortality estimates sample size and methodology appear to cloud the overall picture coming from these sources.

The primary advantage of a cage study is the ability to track survival over extended periods which gives insight into the long term effects of CAR trauma that the immediate observational estimates cannot produce. Cage studies are biased because they exclude predatory interactions, prevent foraging, can cause additional injury (e.g. abrasions), and disrupt normal behaviors, all of which interact in unknown ways relative to the fate of the released fish. Cage studies are useful in shedding light on the delayed mortality question but they do not replicate post-release conditions occurring in the fishery about which mortality estimates need to be most reflective.

Hyperbaric Chamber Simulations

Hyberbaric chambers have been used to simulate the effect of depth and temperature, to and evaluate CAR fishing stress and infrequently generate mortality estimates (Rummer and Bennett 2005, Burns et al. 2004, Campbell et al. 2010b). Rummer and Bennett (2005) euthanized all fish following barotrauma simulation so that necropsies could be performed and therefore report no mortality estimate. Campbell et al. (2010b) reported no mortality but had two issues that likely influenced this result including short acclimation periods in chambers and simulation water temperatures reflected winter/spring conditions. Burns et al. (2004) report mortality estimates, but do not report sample sizes, nor do they report simulation water temperatures. Both Burns et al. (2004) and Campbell et al. (2010b) treated fish for ectoparasites, culled sick fish from the experiments, frequently report no mortalities, and fish collected during summer months experienced high mortalities and so summer collections were discontinued. Unnatural conditions experienced by fish during chamber experiments, culling of unhealthy fish, and extremely low reported mortalities likely preclude the use of resultant estimates in elucidating mortality rates of red snapper in a field setting.

Tag-and-recapture

The primary advantage of both acoustic and passive tag-and-recapture studies is that they can produce both immediate and delayed mortality estimates. Recaptured fish can also be used to evaluate the accuracy of surface activity proxies of mortality used in surface observation studies. Passive tags contain contact information and a unique number, are dependent upon angler participation (i.e. recapture reporting), and are sensitive to the timing of tagging relative to effort in a fishery. Acoustic tags come in a variety of types, can be attached either internally or externally to the fish, and all of them require passive or active data collection using hydrophones which must be in close proximity to a tagged fish. Data collected from acoustic tags can be as simple as a unique number or as complicated as geo-position and environmental data, and the expense increases with increasing complexity.

Three passive tagging studies were available for examination only 1 of which is currently published (Patterson et al. 2001) while the other two are unpublished data made available by associated authors (Patterson & Addis unpublished data, Sauls unpublished data). Both Patterson et al. (2001) and Patterson & Addis (unpublished data) derived mortality estimates from surface release observations which were covered in an earlier section. Analysis from Sauls was not available at the time of submission for the SEDAR process however the data is being used to develop tag-and-recapture models to estimate mortality rather than relying on surface release activities. In the future it might be useful to reassess older tagging information if an acceptable model is developed. Diamond et al. (2011) utilized acoustic tagging methodology and estimated some of the highest release mortality estimates reported (winter - 40%, and summer - 79%). Furthermore, their data showed that increased water temperature negatively impacted survival. However, this study derived mortality estimates from a low sample size (~ 40 total fish), and required surgery to implant tags which could have biased the results.

While passive tagging surveys typically tag large numbers fish, they frequently suffer from low recapture rates. Acoustic tagging programs are costly, time consuming, surgery is often required, selection of subjects can be biased towards healthy and/or large individuals, and sample sizes tend to be low. The primary advantage of both acoustic and passive tag-and-recapture studies is that they can produce both immediate and delayed mortality estimates. Recaptured fish can also be used to evaluate the accuracy of activity proxies of mortality used in surface observation studies. Finally there is promise that efficient recapture models can be developed.

Depth effect

Regardless of study methodology or region, a consistent trend among mortality data is a positive correlation between depth and mortality (Table 1, Figure 1). The eastern GOM estimates showed a linear response from 20 to 40 m (Figure 2), and the western GOM estimates showed a steeper linear increase and estimate higher mortality through 40 m after which the response plateaus (Figure 3). The linear relationship that is evident in both the eastern and western GOM from 20 to 40 m indicates the effect of capture depth on released fish appears to function similarly regardless of region. Furthermore the deep water (> 40 m) estimates from the western GOM data are strongly influenced by the less conservative type-2 surface observation methodology, as well as several studies that used problematic methodologies that must be considered.

Extreme estimates in the western GOM come from a cage study and an acoustic tagging study (Diamond and Campbell 2009, Diamond et al. 2011). Diamond and Campbell (2009) report a significant depth effect but had compounding issues associated with the effects of high surface water temperatures and extreme handling situations as discussed earlier. The Diamond et al. (2011) acoustic tagging study showed high mortality rates from deep water but reported difficulty in having enough fish survive in the summer to conduct the experiment and derived mortality estimates from a small sample size (n ~ 40). If these two experiments are treated as outliers then the linear functional form plateauing after 40 m appears to strengthen because there less noise about estimates from those particular depths (i.e. the relationship tightens). Splitting the Dorf (2003) surface observation estimates associated with the erratic swimming categories by submergence ability would reduce those extreme estimates to within a range reported from the eastern GOM, the relationship would closely resemble that of the eastern GOM, and would plateau at value close to the highest values reported from the eastern GOM. Extreme estimates in the eastern GOM at 45 and 65 m are associated with the Burns et al. (2004) hyperbaric study, of which there is no published information about the simulated water temperatures during the experiment or sample sizes used to calculate the estimates. It should be noted that these are the only two mortality estimates for fish captured in relatively deep water (>40 m) from the eastern GOM.

The relationship between depth and mortality is most likely associated with injuries sustained during decompression, including gas bladder overexpansion/rupture, esophageal eversion, cloacal prolapse, exophthalmia, and gas infusion into vital organs (Rummer and Bennett 2005, Hannah 2008). Barotrauma injuries do not necessarily result in death, particularly as measured by surface release observation (immediate), however data from studies estimating delayed mortality would suggest the opposite (Diamond and Campbell 2009, Diamond et al. 2011). In lieu of finding ways to reduce release frequency in the fishery several techniques have been explored to potentially reduce the negative impacts of capture so that release survival improves including venting and bottom release devices.

Venting has been advocated as a conservation approach that would alleviate some of the negative consequences associated with barotrauma (Burns et al. 2004) however a metadata analysis on the efficacy of venting in promoting survival suggests the effect is negligible (Wilde 2009). For red snapper studies specifically analyzed in Wilde (2009), there are mixed results one having showed positive effects of venting on survival (Gitschlag and Renaud 1994), two are neutral (Render and Wilson 1994, Render and Wilson 1996), and one negative (Burns 2004). As of 2008 venting is required in the red snapper fishery in spite of mixed results. More research on the topic is needed, with emphasis on the effects of capture depth, water temperature during the survey, and the interaction between those variables.

Recent efforts have focused less on venting and more on bottom-release devices, two of which have been experimentally tested. The concept of using bottom release devices is similar to venting in that you are trying to reverse the effects of swim bladder expansion, but instead of deflating the bladder by puncture it is deflated by recompression at depth. Diamond et al. (2011) tested a Shelton Fish Descender™ (SFD) which operates off of a standard reel, and is composed of a reverse barbless hook attached in line with a weight below the hook (details of the device can be found online). Tag returns in the experiment showed nearly identical frequency of recapture between surface-released fished (vented) and those released at depth using the SFD, suggesting that bottom release does not improve survival. Stunz and Curtis (2012) have been testing a Boga-Grip™ device that releases fish at a preset depth via a pressure sensitive clamp (details of the device can be found online). Results are showing that fish released using the Boga-Grip device are more likely to survive than those which were vented and released at the surface. At this point it is difficult to discern if the differences between these two experiments are due to the bottom release gear used or if the effects of barotrauma cannot be reversed, thus more experimentation is needed.

Thermal stress

Mortality shows a strong relationship to season with lowest estimates from winter, intermediate in fall and spring, and highest in summer (Table 1, Figure 4 &5). There appears to be a strong regional effect with western GOM estimates approximately double the estimates from the east in an equivalent season, however these regional components are in part due to the differences type-1 and type-2 surface release observation methodology. Western data is composed mostly of estimates from Dorf (2003) who used the least conservative methodology. If season is a proxy for water temperature, the data then suggest a positive linear relationship between water temperature and mortality, particularly from eastern GOM estimates. Western GOM estimates show a similar decrease in mortality from summer to fall, but unfortunately there is a paucity of data collected during the spring and winter, there may be a linear relationship but there are really on data from two seasons to evaluate.

Sub-lethal types of responses show similar relationships with water temperature. Impairment in red snapper, as measured by an index score of barotrauma and reflex responses, increased with increasing water temperature (Diamond and Campbell 2009, Campbell et al. 2010a, Campbell et al. 2010b). Furthermore, impairment in at least two of those studies was linked to increased immediate release mortality as measured by release activity proxies of mortality (type-1 surface observation methods). Additionally, tagging data has shown lowest returns from fish tagged during summer and highest from fish tagged during the winter (Sauls 2012, Diamond 2011). Finally, two separate hyperbaric chamber experiments reported inability to keep fish alive that were collected during the summer and had to postpone trips later in the year for cooler weather (Burns 2004, Campbell 2010a). Most investigations have well defined depth treatments but have vaguely defined seasonal classifications, while some report months, and only one reported specific water temperatures and thermocline strength. The amount of attention paid to thermal stress is disappointing given that season appears to be a strong indicator of eventual fate, temperature is easily measured in the field, and temperature is easily controlled in a laboratory.

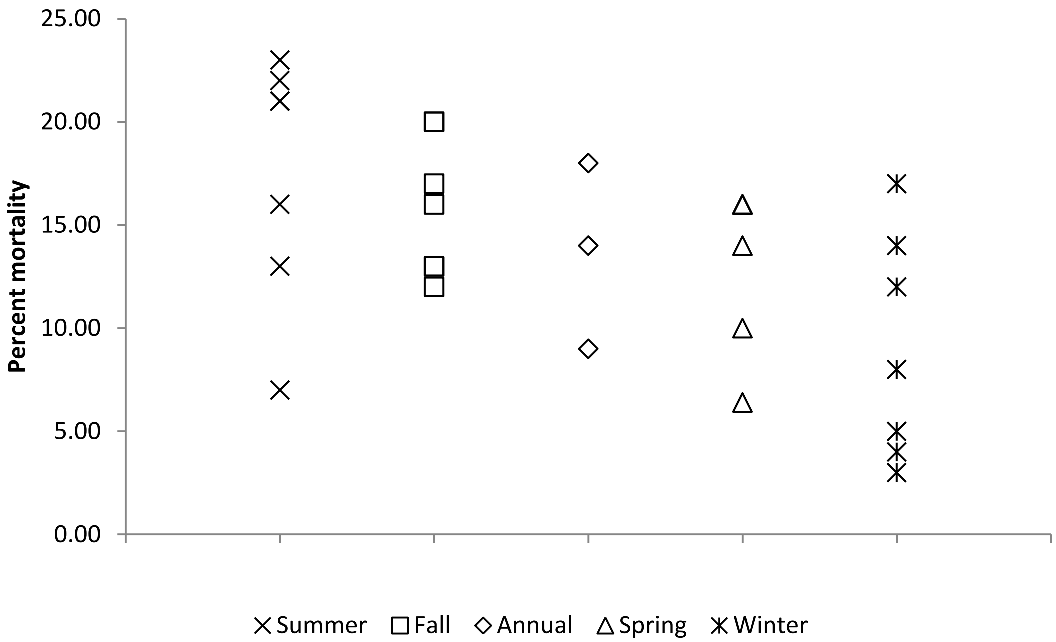

Figure 4. Eastern GOM percent release mortality by sampling season.

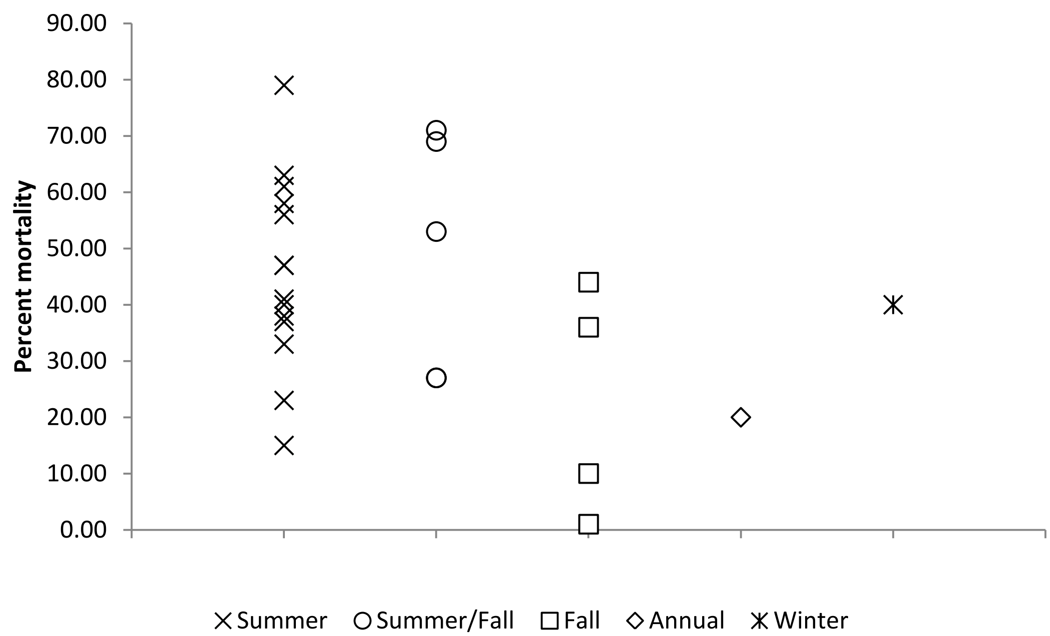

Figure 5. Western GOM percent release mortality by sampling season.

Moving forward

A common thread among release mortality experiments is that mortality increased with increasing capture depth, increasing water temperature, or from the compounding effects of those two variables. Whether due to time, money, personnel, or vessel constraints, few experiments incorporated the full range of depths and temperatures in which the northern Gulf of Mexico red snapper fishery operates. Expecting experiments to incorporate a full range of conditions is futile but future surveys, at minimum, should be structured around quarterly sampling, collect water temperature profile data, reflect the range of depths associated with the fishery, and strive to calculate season and depth specific estimates. Due to the limited number of experiments evaluating the relationship between thermal stress and release mortality it is strongly encouraged that investigators measure and report water temperatures and thermocline profiles associated with capture. More studies evaluating the use of bottom release devices are also needed as there are only two current studies whose results are conflicting.

Recent development of methods that relate impairment to mortality have proven to be an effective method of estimating release mortality for many species including walleye pollock (*Theragrachalcogramma*, Gadidae), coho salmon (*Oncorhynchus kisutch*,Salmonidae), sablefish (*Anoplopoma fimbria*, Anoplopomatidae), northern rock sole (*Lepidopsetta polyxystra*,Pleuronectidae), lingcod (*Ophiodon elongates*, Hexagrammidae), Pacific halibut (*Hippoglossus stenolepis*,Pleuronectidae), and red snapper (Davis et al. 2001, Davis and Ottmar 2006, Davis 2007, Campbell 2010a, Campbell 2010b). Specifics on impairment scaling methodology can be found in those cited works. The principle of impairment scaling is that individual responses rarely correlate with mortality, but scaling the synergistic effect of all of the associated capture traumas resulted in a logistic type of relationship to mortality. The method is useful because the underlying symptoms causing mortality are evaluated and provides insight into ways of alleviating those stressors. In the red snapper fishery the barotrauma-reflex (BtR) impairment scaling procedure showed positive correlation between impairment level and immediate mortality, but still falls short because the estimate was influenced by biases associated with the surface observation methodology (Campbell 2010a). Minimally, future discard observation surveys should collect frequency data regarding specific barotraumas incurred and loss of reflex response because similar relationships could be developed as better techniques are developed to measure the delayed mortality component.

While there has been increasing attention paid to the release mortality, published experiments tend to have similar limitations. Surface observations and cage studies in particular have reached their limits resulting from their associated biases. Passive tagging and acoustic tagging appear to offer the best solutions because they can measure both immediate and delayed mortality components and fish handling biases can be minimized, particularly as technology improves. Acoustic or satellite tags give the ideal level of information (i.e. movement data), but the expense of tags and required monitoring systems results in small sample sizes and poor power to estimate mortality. Until better and more cost effective technology is developed, derivation of mortality estimates from experiments using these types of tags will likely be limited. Recent developments have shown promise in using recapture data (i.e. passive tagging) and impairment scaling to calculate relative survival from risk ratio models and are presented in another SEDAR 31 document (Hueter 2006, Sauls 2012). Experiments estimating impairment scaling, and both immediate and delayed mortality, would be particularly useful so that a relationship among components could be developed and historical immediate release mortality estimates could potentially be adjusted.

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