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Testing the Efficacy of Recompression Tools to Reduce the Discard Mortality of Reef Fishes in the Gulf of Mexico

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Testing the Efficacy of Recompression Tools to Reduce the Discard Mortality of Reef Fishes in the Gulf of Mexico

by

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DEDICATION

I’d like to dedicate this work to my parents and my family for always believing in me and supporting my dreams of becoming a marine scientist after the first time my parents took me to the water and I caught my first fish. A special thanks to my father who instilled in me a love of the outdoors and taught me how to fish and swim at a young age.

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ABSTRACT

In order to enhance the recovery of overfished stocks, fishery managers have implemented increasingly restrictive harvest regulations. However, discarded fish are susceptible to mortality from barotrauma when retrieved from depth. Venting tools are commonly used to enable fish to return to their depth of capture. An alternative method has been developed that involves the rapid descent of fish to their depth of capture to reduce buoyancy. In the Gulf of Mexico, the released portion of Red Snapper (*Lutjanus campechanus*) and Red Grouper (*Epinephelus morio*) has exceeded 80% of total catch. I tested the survival of these two economically important species after release using venting and recompression methods. Recapture rates for recompressed Red Snapper were higher than those from vented fish, indicating a lower discard mortality. While recompressing Red Snapper to at least 10 meters improved their survival rates over vented fish, recompressing them to 20 meters or deeper improved survival. The recapture rates for Red Grouper did not differ between release methods, possibly due to differences in physiology as well as how the fisheries operate and are managed between the two species. The combined results of this study indicate that there were species specific differences in the benefits of recompression, and this could assist fishery managers in providing guidance to anglers on where, when, and how and to use recompression devices more effectively.

TESTING THE EFFICACY OF RECOMPRESSION TOOLS TO REDUCE THE DISCARD MORTALITY OF REEF FISHES IN THE GULF OF MEXICO

Introduction

Fish discarded from hooked fishing gears can suffer from a variety of complications associated with barotrauma that lead to immediate or latent mortality. Barotrauma afflicted fish may not only experience immediate mortality but also delayed mortality after returning to depth (Curtis et al. 2015). For example, post-released fish that are not able to re-submerge or are sluggish at the surface are vulnerable to predation from other fish, marine mammals, and birds. Those that re-submerge quickly may also suffer from predation during descent. Visible signs of barotrauma include protrusion of the stomach from the fish's mouth, bloated belly, protrusion of the intestines out of the anus and bulging eyes (exophthalmia). Exophthalmia may induce long-term visual impairment and potentially reduce prey capture success, location of micro habitats and predator avoidance (Rogers et al, 2011, Hannah et al. 2008, Jarvis and Lowe 2008, Longbottom, 2000, Parker et al. 2006). Reef fishes are particularly susceptible to mortality following exposure to barotrauma when rapidly retrieved from depth with hook-and-line gear (Wilson and Burns 1996; Rummer and Bennet,2005, Diamond and Campbell 2009). The severity of these effects increases with depth of capture (Burns 2002, Sauls 2014). If a fish is hooked in deep water and brought to the surface, the accompanying decline in ambient pressure can have profound physiological and physical consequences, especially in physoclistous fishes where the swim bladder does not directly connect to the digestive tract. Inflation of the swim bladder can also damage internal organs and increase the probability of mortality (Arlinghaus et al. 2007).

Puncturing the inflated swim bladder in the ventral or abdominal area with a hollow needle (venting tool) is a common technique used to reduce barotrauma and to remove excess gases from the swim bladder and stomach cavity. This technique reduces buoyancy and enables fish to return to their depth of capture. However, studies on venting have found various levels of efficacy (Wilde 2009) and fish may be further exposed to additional internal injuries if vented improperly (Collins et al. 1999, Wilde 2009, Scyphers et al. 2013, Kerr 2001). Additional problems with venting include the possibility of infection due to dirty needles and using other more accessible tools such as hooks, knives, pliers and pokers that are not hollow and may not release enough air. Anglers may also cut or puncture tissues protruding from the mouth or anus, which can damage the internal stomach lining or intestines.

Developing and testing alternative methods for mitigating the effects of barotrauma and predation has been identified as a priority research need for reef fishes (Loftus and Radonski 2012). One alternative method to venting is the use of recompression tools which involves weighting the fish to provide rapid descent back to its depth of capture. Rapid recompression enables fish to overcome excessive buoyancy and increases the solubility of gases in body fluids without venting. Fishes that are rapidly returned to depth with recompression gear do not expend energy swimming down through the water column. Predation while at the surface and during the return to protective bottom habits may also be avoided during rapid descent, although no studies of which I am aware have quantified this. Additional benefits of rapid recompression may arise from the increased flow of water through the mouth and out of the gills while the mouth of the fish is held open by the recompression tool as the fish is lowered to the bottom.

The efficacy of recompression tools has been tested on Pacific Rockfishes (*Sebastes spp*.), which are particularly vulnerable to swim bladder expansion and barotrauma-related injuries (Parker et al. 2006, Hannah et al. 2008). In experimental studies, eight out of nine species of rockfish responded positively to recompression, exhibiting reduced behavioral impairment and a higher potential for survival. One species, Blue Rockfish (*Sebastes mystinus*), continued to exhibit serious behavioral impairment following recompression (Hannah and Matteson 2007).

While recompression has been shown to have positive benefits for rockfishes and the depth related effects on the release condition and survival of discarded reef fish in the Pacific, little work has been done in the Gulf of Mexico (GOM), where recreational fishing takes place in shallower depths (Wilson and Burns 1996, Rummer 2007, Campbell et al. 2014, Sauls et al. 2014, Sauls 2014). A lack of research in the GOM where fishing activity is very high (Coleman et al. 2004) reduces the ability of managers to determine what species might benefit from recompression and prevents them from implementing effective regulations to enhance the recovery of fish stocks that are being depleted. Working cooperatively with the charter boat fishing industry in the GOM, this study was designed to test whether recompression can reduce the mortality rates of regulatory discards in the recreational fishery. Specifically, I asked two questions. First, is survival higher for fish released with a recompression tool compared to those released at the surface? And second, what is the minimum depth to which fish may be released that reduces the need to recompress them all the way to the bottom?

Methods

The focal species for this study were Red Snapper (*Lutjanus campechanus*) and Red Grouper (*Epinephelus morio*). Both species are some of the most commonly caught regulated species on recreational fishing trips in federally managed waters in the GOM. In recent years the released portion of recreational catch of Red Snapper and Red Grouper has exceeded 80% of total recreational catch from both state and federal jurisdictions in the region (NMFS 2010). Fish were caught during chartered fishing trips at depths greater than 32 meters and less than 56 meters, where barotrauma was expected to affect survival of released fish. Fourteen research trips on chartered fishing vessels were completed in two distinct regions of Florida (Figure 1). The two regions were chosen based on the distribution and anticipated catch of the target species: 1) the panhandle and peninsula for Red Snapper and 2) the peninsula for Red Grouper. Seven one-day trips (12 hours each) were conducted in the panhandle region, all during 2014. In the peninsular region, a total of seven two-day trips (40 hours each) were conducted with three in 2014 and four in 2016. The additional trips in 2016 were made to supplement low numbers of Red Grouper sampled and tagged in 2014. Longer trips were necessary in the peninsular region due to the long travel times (12 hours roundtrip) to reach the target depths where barotrauma was expected. All research trips were conducted during peak months of recreational fishing effort for reef fishes (July to October,). This period also coincides with the highest annual water temperatures, that can potentially increase post-release stress on reef fishes. Fishery observer data collected in the GOM for Red Snapper and Red Grouper has shown that immediate discard mortality was positively correlated with increased depths, seasons associated with warmer temperatures, and external evidence of barotrauma (J.R. Pulver 2017).

Four research personnel participated on each trip to capture the fish using standard recreational hook-and-line gear. The terminal tackle used was standard gear required in the GOM (circle hooks) and kept identical for all anglers to control for the potential effects of hook sizes on hooking injuries. All fish were processed immediately upon capture to ensure that they remained out of the water a minimal amount of time (less than 1 minute) that was constant across specimens. Once captured, the species, fork length (in mm), bait used, hook size, and anatomical location where the hook was embedded were recorded. Researchers also recorded the method used to remove the hook, all visible signs of barotrauma, release method (treatment level – see below), and time of release. All fish were tagged prior to release with a conventional 100mm Hallprint™ PDS dart tag. This tag has a ~1.6 mm diameter and is applied with an ~3.3 mm outside diameter applicator needle. This tag is suited to fish across a wide range of sizes, from about 35 cm up to about 55 cm.

The tag was inserted in the dorsal muscle tissue and attached to the pterygiophores, so the act of tagging did not result in inadvertently venting the fish in the experimental treatments. Each tag was printed with the word "REWARD" in bold and a unique alphanumeric tag number. It also had a toll-free telephone number and an email address to report recaptured fish. Catch cards with pre-paid postage were also handed out to the captains of the charter vessels so they could easily record information for recaptured fish and return the information to FWC. A reward incentive in the form of a screen-printed t-shirt was offered to encourage the reporting of recaptured fish. Catch cards were also distributed to other vessel operators in the area and reward posters were posted in regions to encourage tag returns from recreational anglers. Tag return information was collected on recaptured fish following completion of the trips up to the present.

Experimental treatments were designed to compare the current practice in recreational fisheries, where discarded fish are vented at the discretion of the angler and released at the surface, to an alternative method where fish are rapidly recompressed and returned to depth without venting. Upon capture, fish were first assessed for barotrauma and hooking injuries. All visual signs of barotrauma were recorded, including swollen abdomen, stomach eversion into the buccal cavity, anal prolapse, extrusion of intestines through the anal opening, bleeding and exophthalmia. I excluded any fish that had a hooking injury that might have affected its survival rate. Such injuries included fish that were hooked in the gills, inside the mouth, in the throat, or in the gut if the fish had completely swallowed the hook. Despite being excluded from the experiment, these fish were still tagged, vented if necessary, and released at the surface but excluded from the experimental treatments and analysis here. Only fish that were lip hooked were sequentially assigned to be either released at the surface or rapidly recompressed to different depths.

Assignment of the first release treatment of each fishing trip was random, followed by alternating assignment to ensure relatively even sample sizes. Thus, after the first fish was released according to the initial treatment assigned (e.g., surface release), the following fish received the other treatment (e.g., recompression release), then back to the initial release and so on for the remainder of the sampling trip. For the surface release fish, I vented them only if barotrauma was visibly present. If these symptoms were absent, the fish was released at the surface without venting; note that 98% of all fish exhibited visible signs of barotrauma, thus few were surface released without venting. None of the recompressed fish were vented. All recompressed fish were placed inside a cage or a Sea Qualizer recompression tool and lowered to the release depth. Recompressed fish were released to sequential depths of 10 meters (2 atm), 20 meters (3 atm), 30 meters (4 atm), and when water depth was sufficient, to 40 meters (5 atm).

Over the course of this study, a total of 1226 fish were tagged and released in both regions. Of these, 1043 Red Snapper were tagged and released in both the panhandle and peninsular regions. A total of 410 Red Snapper were released at the surface in the two regions combined. Of these, 369 were vented and 41 were not. A total of 633 Red Snapper were recompressed to different depths, with 266 recompressed to 2 atm, 193 to 3 atm, 171 to 4 atm, and 3 to 5 atm. (Table 1). For Red Grouper, a total of 183 Red Grouper were tagged and released in the peninsular region. Among these, 41 Red Grouper were released at the surface with 36 vented and the other 5 not vented. A total of 142 Red Grouper were recompressed to different depths, with 22 were recompressed to 2 atm, 65 to 3 atm, 44 to 4 atm, and 11 to 5 atm (Table 1).

Statistical analyses

To compare the probability of recapture among treatments for each species, I used an exact logistic regression model. These methods have broad applications in determining the conditions or treatment specific survival rates of released fish in research projects in which tag-and-recapture methods are used. In tagging studies, it is of interest to determine the fractions of the released fish that survive the initial stress of capture, handling, tagging, and release, so that the actual number of tagged fish in the post release experiment is known. It can be used to determine the relative survival of two groups of fish that have received different treatments, that have been exposed to different conditions or that have different traits. Relative survival may be studied this way because it is easier to estimate relative rates that absolute rates. (Hueter et al. 2006). Exact methods are also recommended when small counts make maximum likelihood estimation inappropriate. If the exact odds ratio was >1.0, then the comparison group had a higher probability of recapture relative to the reference group, provided that confidence intervals for the estimate did not overlap with 1.0 (and the two-sided p value was <0.05). Exact odds ratios <1.0 indicated the comparison group had a lower probability for recapture. Based on the results from the odds ratio, there were no significant differences found between recapture rates of Red Snapper in the two regions (panhandle vs. peninsula), thus I pooled these data prior to evaluating differences across treatment groups. Similarly, there were no significant differences found in recapture rates between fish recompressed in the cage compared to the recompression tool at the same depths for either focal species, so these data were also pooled. The data analysis for this paper was generated using SAS software. Copyright, SAS Institute Inc. SAS and all other SAS Institute Inc. product or service names are registered trademarks or trademarks of SAS Institute Inc., Cary, NC, USA.

Results

Recapture rates for Red Snapper were higher for recompressed fish (11.42%) than vented ones (5.60%; 95% CI for exact odds ratio = 1.1744 (1.062, 3.025), p = 0.03). There were no detectable differences found between fish that were not vented (9.75%) compared with those that were recompressed (95% CI for exact odds ratio= 1.245 (0.292,11.21) p=1). Recapture rates were higher for fish recompressed to both 3 atmospheres (14.50%; 95% CI for exact odds ratio =0.447 (0.208,0.964), p = 0.04) and 4 atmospheres (12.86%; 95% CI for exact odds ratio =0.460 (0.237,0.866), p = 0.01) compared to those recompressed to 2 atmospheres (10.52%). Recapture rates did not differ between fish recompressed to 3 versus 4 atmospheres (Table 2, Figure 4). None of the Red Snapper recompressed to 5 atmospheres were recaptured (Figure 2).

Recapture rates for Red Grouper did not differ between those that were recompressed (13%) and those that were vented (20%, 95% CI for exact odds ratio= 2.458 (0.544,22.891), p=0.3659). There also were no differences among capture rates across depths of recompression based on the odds ratios. Recapture rates for recompressed Red Grouper were 22.72% at 2 atmospheres, 9.23% at 3 atmospheres, 11.36% at 4 atmospheres, and 18.8% at 5 atmospheres (Table 3, Figure 5).

Discussion

This study addressed the problem of regulatory discards in the GOM and provided evidence that recompression can be an effective method for management of Red Snapper. Indeed, recapture rates of Red Snapper were higher for recompressed fish compared to vented ones. In addition, recompression to at least 3 atmospheres provided increased survival than those released at shallower depths. In contrast, I did not find a significant benefit to recompression for Red Grouper. Thus, the results of the study were contextual upon species, possibly due to differences in the ways the fisheries operate for each species, their management, and physiology.

The difference in efficacy of recompression between Red Snapper and Red Grouper may have been due to differences in how the fisheries for each species operates. This study focused on depths between 30 meters and 50 meters where discards in the recreational hook-and-line fishery were expected to benefit most from re-submergence. For the Red Snapper trials, survival rates (based on recapture) were higher for recompressed fish than those vented at the surface. This result is important for Red Snapper since most discards for this species occur in depths of over 20 meters (Sauls et al, 2014). Additionally, since 2008 the fishing season for Red Snapper in the Gulf of Mexico has been reduced to less than 75 days a year (NOAA) so discarding rates for all sizes of this species are high most of the year. While recompressing Red Snapper deeper showed improvements over descending them to a shallower release depth, it was not necessary to recompress Red Snapper all the way to the bottom. This could allow anglers to effectively recompress more fish when catch rates are high.

In contrast for the Red Grouper trials, survival did not differ between being surface released versus recompressed. Although sample sizes for this species may not have been sufficient to detect differences in recapture percentages between treatments, there are also physiological differences in the swim bladders between the two species that may explain the different responses. Red Grouper have a larger swim bladder in relation to body size so they contain more gases and the swim bladder walls are thinner, producing larger tears in the bladder (Burns 2009). In the recreational fishery, most of the Red Grouper are discarded at depths of less than 21 meters (Sauls et al. 2014), and recompressing fish at these shallow depths might not provide any additional benefits to quickly releasing them at the surface without venting. Unlike Red Snapper, legal size Red Grouper are open to harvest most of the year and a low proportion of discards are observed from depths of >40 meters (9.8%) (Sauls et al. 2014).

The method used in this study of comparing mark-recapture rates among fish released in different conditions was described by Hueter et al. (2006) as an effective method for evaluating latent mortality under true environmental conditions, where fish may be exposed to multiple, highly variable stressors. A lab study by Campbell et al. (2010) found that Red Snapper suffered greater impairment when the additional effect of temperature increase (to simulate fish retrieved from beneath the thermocline to the surface) was included in experimental trials. Since this study was conducted during months when water temperatures in the GOM reach their peak, this could explain why results for Red Snapper differed between this study and a more controlled lab study.

Summer months are also when harvest seasons for many reef fishes are typically open and recreational anglers are more likely to pursue snapper and grouper (Simard et al. 2016). A recent literature review on the role of temperature in post-release mortality concluded that the addition of thermal stressors increases the likelihood for mortality, even when exposure is within the preferred optimum range for the species (Gale et al. 2013). While tropical reef fish are more adapted to warm temperatures, increased thermal gradients during summer months between the bottom and the surface represent an added stressor for discards (Diamond and Campbell 2009).

The results of this study do not agree with a study conducted by Diamond et al. (2011) who showed that a bottom release device did not increase survival over fish vented and released at the surface. While the results from this study do not corroborate some of the results from a study that monitored subsequent survival of Red Snapper under laboratory conditions over 21 days where survival rates were higher for fish for that were vented than fish that were not vented, it does support the findings that rapid recompression was a better alternative to releasing fish at the surface (Drumhiller et al. 2014). The results of this study do agree with Stunz and Curtis (2012) where recompressed Red Snapper are more likely to survive than fish vented and released at the surface.

Increases in the numbers of discarded fish and high mortality rates can reduce the effectiveness of regulatory policies designed to speed up the recovery of stressed fish stocks. While recompression has proven conservation benefits in recreational fisheries for the Pacific rockfishes (*Sebastes* spp.) (Jarvis and Lowe 2008, Rogers et al. 2011, Hannah et al. 2012, Pribyl et al. 2012), little work has been done in the GOM recreational fishery where discarding rates for Red Snapper and Red Grouper exceed 80% of total catch (NMFS 2010). In this region, the recreational fishery occurs in a greatly reduced range of relatively shallow depths. A study of the for-hire recreational charter and headboat fisheries in the eastern GOM found that the majority of Red Snapper discards occurred from trips that took place in depths between 21 and 40 meters, with some discards occurring in depths up to 50 meters (Sauls et al. 2014). Red Grouper are more abundant along the broad slope of the West Florida Shelf, where most discarding was observed from shallower depths less than 21 meters, and a low proportion were observed from depths >40 meters (9.8%) (Sauls et al. 2014). Even though depth gradients where the reef fish fisheries operate are less extreme in the GOM compared to those targeting Pacific rockfishes, the relationships between capture depth, release condition, and survival are well documented for reef fishes (Burns 2009, Rummer 2007, Campbell et al. 2014, Sauls, 2014). While reef fishes retrieved from shallow depths are frequently able to re-submerge without mitigation, they do require assistance more often in deeper depths (Burns and Restrepo 1999, Collins et al. 1999).

The combined results of this study indicate that there were species specific differences in the benefits of recompression and this could assist fishery managers in providing guidance to anglers on where, when, and how and to use recompression devices more effectively to increase buy in from stakeholders.

Further research to evaluate differences in surface release methods at a wide range of depths should be undertaken since there is a great deal of uncertainty on the benefits of venting fish and releasing them at the surface. In a compilation of 17 studies, Wilde (2009) concluded there was little evidence that venting increased survival and it was possible that it may be detrimental to fish survival. Improper venting techniques may damage internal organs such as the heart, gills, and liver (Scyphers et al. 2013). Additional work is needed to determine if recompression may be a better alternative than rapidly releasing fish at the surface without venting since using recompression devices takes additional handling time and increases exposure to air and possibly stress to the fish. It is also possible that differences in the sizes of the released fish may affect discard mortality. Continued research in these areas will provide management with more information to guide and educate anglers on the potential benefits of recompression for both Red Snapper and Red Grouper as well as other reef fish species that may suffer from barotrauma induced mortality.

Conclusion

In the area where this study was conducted, fishing takes place primarily in shallow depths and returning fish to the water quickly is generally preferred over venting. Given that placing fish on a descending tool results in additional handling time, it may be more beneficial for fish caught from shallow depths to be returned to the water without attempting to mitigate barotrauma, which is likely to be mild and easily overcome by fish released in good condition. This is supported by a large-scale mark-recapture study of recreational discards observed within the for-hire fisheries that operate in the same region, which found that a high proportion of surface-released Red Snapper, Red Grouper and Gag observed in the recreational fishery re-submerge on their own and survive better than fish that required venting (Sauls et al. 2014).

Studies in the Gulf region to look at the potential benefits of rapid recompression as an alternative to venting and release at the surface are limited, but new results are beginning to emerge in published literature. This is one of the first studies in the GOM to evaluate the recompression depth necessary for fish to successfully return to bottom habitats from which they were displaced in an open-access fishery. This study indicates that when fishing in depths >30 meters, Red Snapper benefit more from recompression than venting. A release depth of at least 2 atmospheres was enough to increase the survival of Red Snapper but releasing them to 3 atmospheres is better. These results show that that the depth to which fish are descended to during rapid recompression does have an impact on ultimate survival of Red Snapper, and a release depth of 20 meters is better than 10 meters. This is an important result for fishery managers in the South Atlantic and the GOM considering that the discard rates for this fish are very high most of the year due to an extremely short fishing season and this fish is usually targeted in deeper depths. In the case of Red Grouper, current regulations allow the harvest of this species during most of the year and discarding rates are not as high as for Red Snapper. Additionally, the fishery for this species generally takes place in shallower waters where barotrauma is minimal and assistance to return to the bottom may not be necessary.

This result may also help managers guide anglers about safely releasing fish that are impaired. Care should be taken when providing guidance to the angling public regarding the use of recompression tools and it should be communicated that venting surface-released fish is not a universal solution for mitigating negative impacts of catch-and-release in all situations or for all reef fish species. Physiological differences between different reef fish should be considered since not all species respond in the same way to barotrauma and can be affected differently. For example, there are known physiological differences between the sizes of Red Snapper and Red Grouper swim bladders that might affect their response to barotrauma and impact survival rates. Red Grouper have larger (in relation to body size) thinner swim bladders than Red Snapper (Burns 2009) possibly making them more susceptible to the effects of recompression.

In conclusion, relative survival was improved for Red Snapper that were rapidly recompressed, and this method is a better alternative than venting and surface release. It is also not necessary to recompress these fish beyond 3 atmospheres. While recompression proved beneficial for Red Snapper, it did not have a negative impact on Red Grouper. Red Grouper ultimately survived equally well whether they were released at the surface or descended to various depths for recompression.

Even though recompression can assist fish in resubmerging, it might not be necessary all the time, especially when fishing in shallower depths. While it may not be necessary to descend fish all the way to the bottom, more work needs to be done on individual species and on fish that are caught at deeper depths. Other methods such as passive or acoustic tagging may provide additional information on both immediate or delayed mortality that could assist fishery managers in developing more effective regulations to reduce discard mortality. Managed stocks in the region could stand to benefit from adoption of the recompression method, particularly given the magnitude of recreational discarding. Implementing measures that target specific species or fisheries where recompression methods have been proven successful will provide greater conservation benefits than implementing measures on all species and under all circumstances.

TABLES AND FIGURES

Table 1.

	Surface		Depth			
Species	VT1	NV1	RA2	RA3	RA4	RA5
Red grouper n=183	36	5	22	65	44	11
Red snapper n=1043	369	41	266	193	171	3

Numbers of tagged and released fish by species, treatment and depth. This only includes fish that were lip hooked. Surface treatments were either vented (VT) or not vented (NV) and released at one atmosphere. All recompressed fish (RA) were released at depths of 2, 3, 4 and 5 atmospheres.

Table 2.

Treatment	Estimate	p-value
(1) VT1 vs NV1	4.026 (0.058, 95.58)	0.6604
(2) VT1 vs RA	**1.764 (1.062, 3.025)**	**0.0265**
(3) NV1 vs RA	1.245 (0.292, 11.21)	1
(4) RC3 vs RT3	4.114 (0.572, 182.1)	0.2604
(5) RC4 vs RT4	1.883 (0.752, 5.382)	0.213
(6) RA2 vs RA3	**0.447 (0.208, 0.964)**	**0.0395**
(7) RA2 vs RA4	**0.460 (0.237, 0.866)**	**0.0143**
(8) RA3 vs RA4	1.029 (0.514, 1.999)	1

Exact odds (and 95% CI) of recapture for Red Snapper (Lutjanus campechanus) among release treatments. Release treatments at the surface include vented (VT) and non-vented (NV) fish. Individual recompression treatments include all fish that were recompressed (RA), all fish recompressed in the cage (RC) and all fish recompressed with the tool (RT). Numbers following the treatments indicate depths of release at 1, 2, 3, 4 and 5 atmospheres. Confidence intervals that do not overlap 1.0 are in bold, indicating that the odds of recapture are significantly different between comparison groups (p-value < 0.005). Treatment numbers in parenthesis correspond to those reported in figure 5.

Table 3.

Treatments	Estimate	p-value
(1) VT1 vs NV1	4.026 (0.058, 95.580)	0.6604
(2) VT1 vs RA	2.458 (0.544, 22.891)	0.3659
(3) NV1 vs RA	0.583 (0.054, 30.166)	1
(4) RC3 vs RT3	0.791 (0.098, 6.403)	1
(5) RC4 vs RT4	0.939 (0.095, 12.471)	1
(6) RC5 vs RT5	0.535 (0.005, 52.213)	1
(7) RA2 vs RA3	2.850 (0.609, 12.833)	0.2087
(8) RA2 vs RA4	2.263 (0.456, 11.293)	0.3916
(9) RA2 vs RA5	1.313 (0.169, 16.415)	1
(10) RA3 vs RA4	0.795 (0.187, 3.535)	0.9556
(11) RA3 vs RA5	0.463 (0.067, 5.381)	0.6524
(12) RA4 vs RA5	0.583 (0.078, 7.058)	0.857

Exact odds (and 95% CI) of recapture for Red grouper (Epinephelus morio) among release treatments. Release treatments at the surface include vented (VT) and non-vented (NV) fish. Individual recompression treatments include all fish that were recompressed (RA), all fish recompressed in the cage (RC) and all fish recompressed with the tool (RT). Numbers following the treatments indicate depths of release at 1, 2, 3, 4 and 5 atmospheres. Treatment numbers in parenthesis correspond to those reported in figure 4. Confidence intervals do not overlap 1.0, indicating that the odds of recapture are not significantly different between comparison groups.

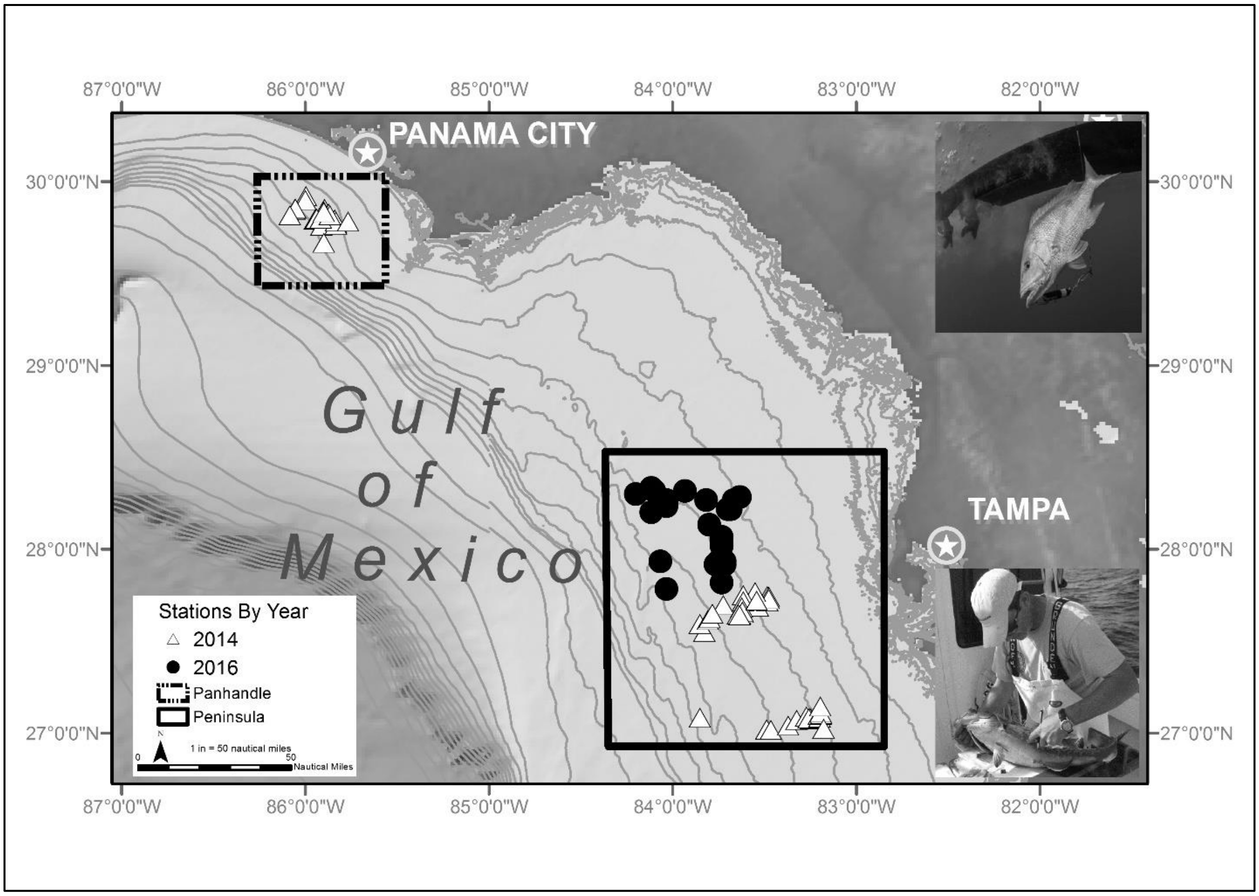

Figure 1. Map of all stations sampled. Stations in white diamonds correspond to all 2014 trips and stations in black circles correspond to all 2016 trips. Trips from the Peninsula were conducted further offshore than trips from the Panhandle. Embedded in the map are images of a fish being vented prior to release at the surface and a recompression tool used to descend fish to depth.

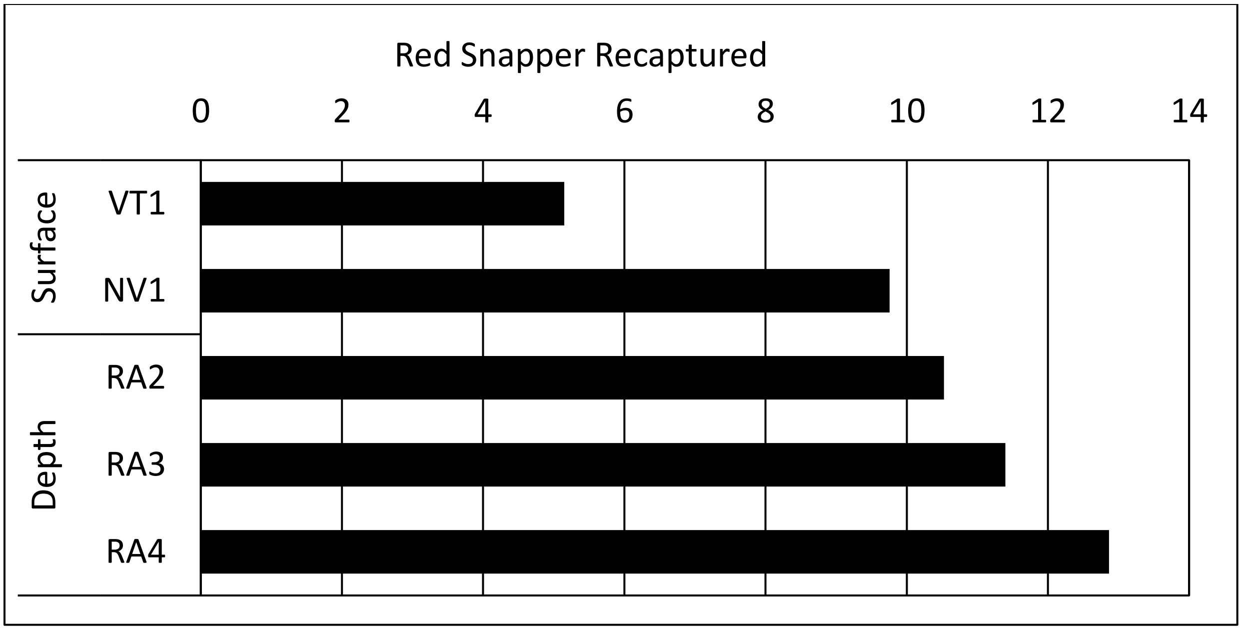

Figure 2. Red Snapper recapture rates for all trips by treatment and depth in both regions. Surface treatments include both vented fish (VT) and non-vented fish (NV) that were released at one atmosphere. Fish in the combined recompression treatments (RA) were released at 2, 3 and 4 atmospheres.

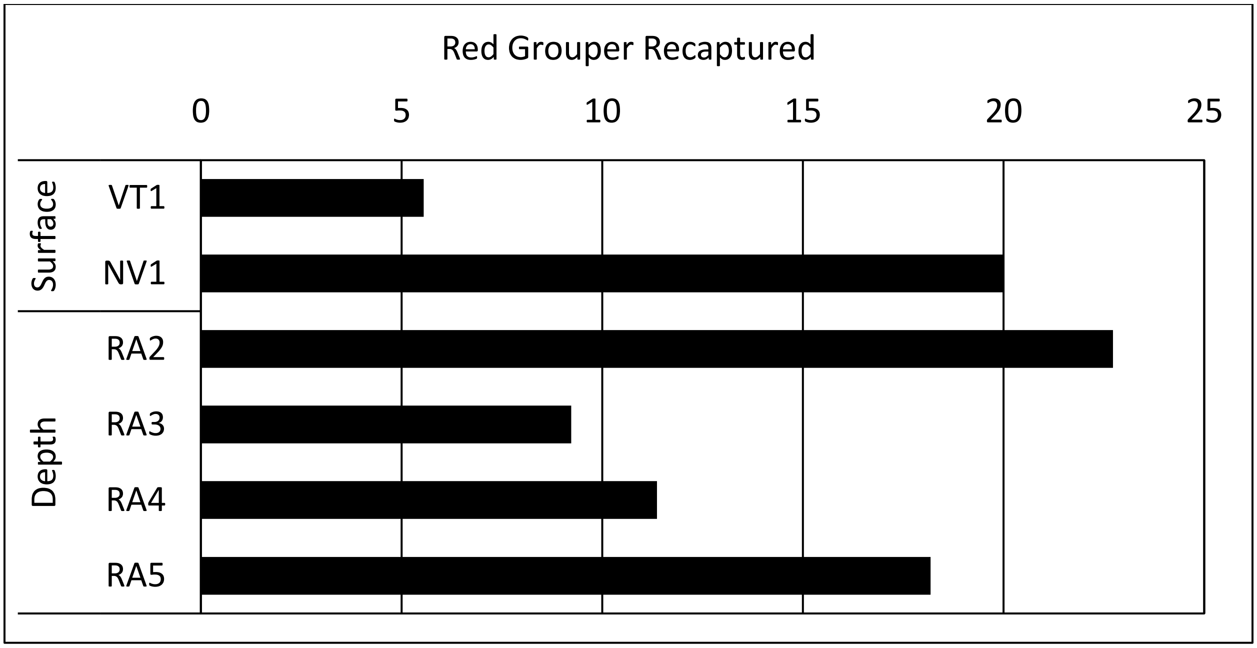

Figure 3. Red Grouper recapture rates for all trips by treatment and depth in the Peninsula. Surface treatments include both vented fish (VT) and non-vented fish (NV) that were released at one atmosphere. Fish in the combined recompression treatments (RA) were released at 2, 3, 4 and 5 atmospheres.

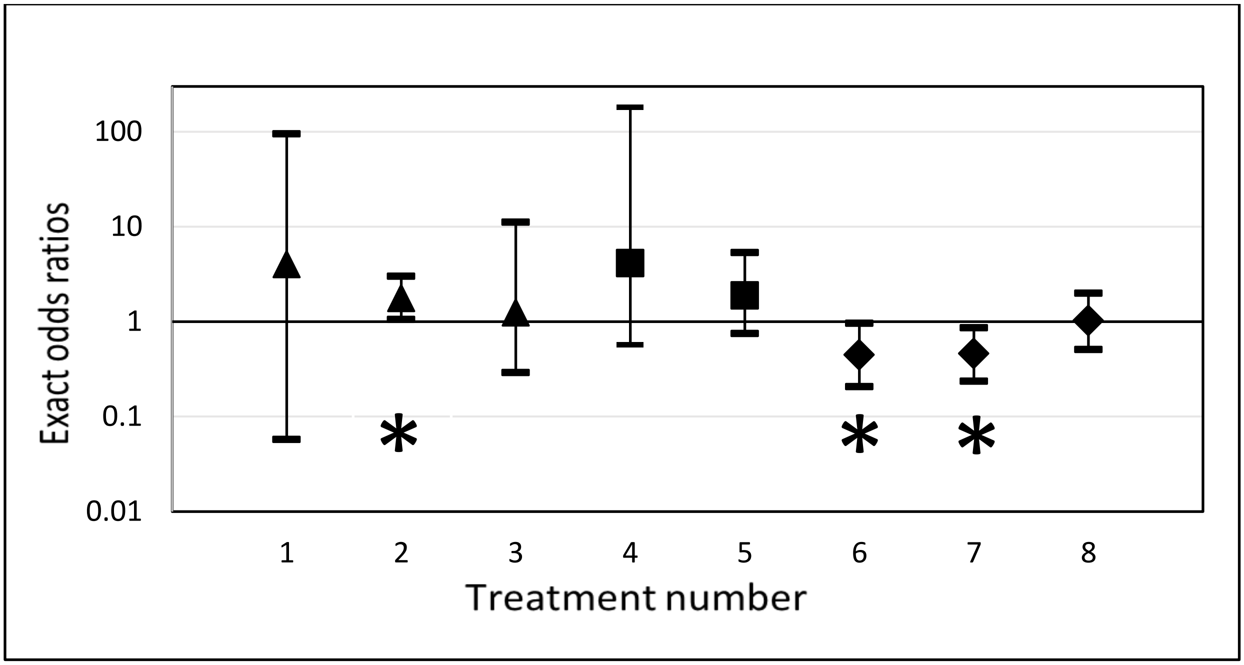

Figure 4. Exact odds ratios for Red Snapper by treatments and depths. Rectangles compare surface treatments to all recompressed fish. Squares compare recompression treatments by type (cage and tool) at each depth. Diamonds compare the combined treatments by depth. Odds ratios that do not overlap 1 are significant (p-value < 0.005). Asterisks indicate treatments that are significant.

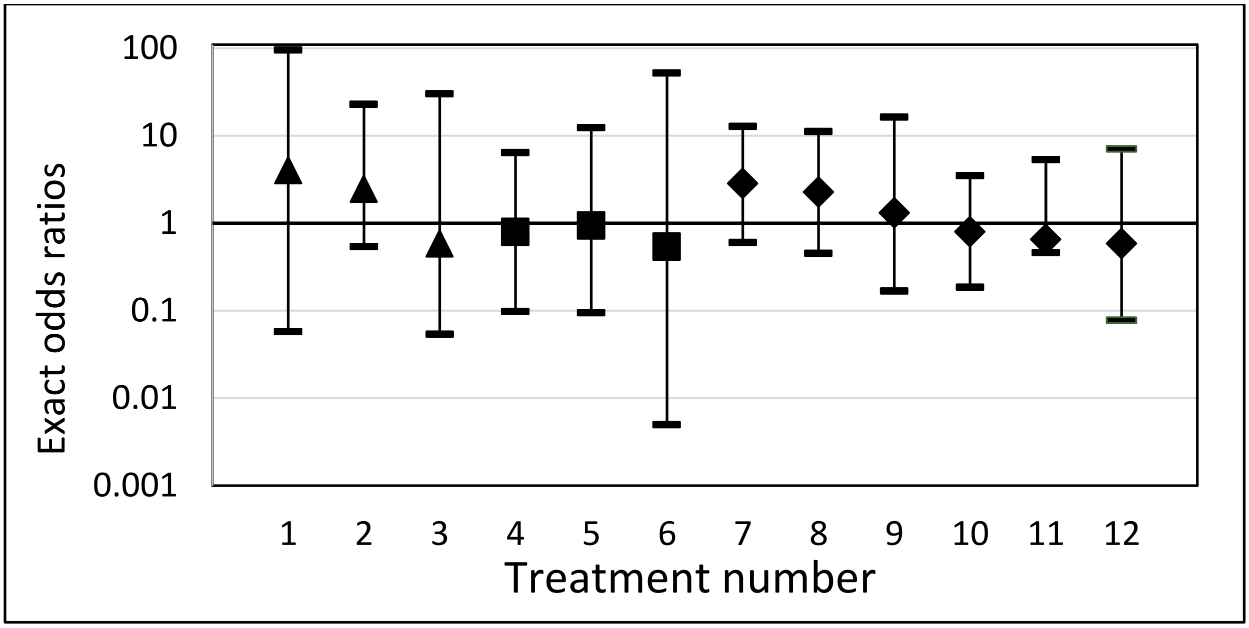

Figure 5. Exact odds ratios for Red Grouper by treatments and depths. Triangles compare surface treatments to all recompressed fish. Squares compare recompression treatments by type (cage and tool) at each depth. Diamonds compare the combined treatments by depth. Odds ratios that do not overlap 1 are significant (p-value < 0.005).

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