Utility of rapid recompression devices in the Gulf of Mexico red snapper fishery

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UTILITY OF RAPID RECOMPRESSION DEVICES IN THE GULF OF MEXICO RED SNAPPER FISHERY

A Thesis

by

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This thesis meets the standards for scope and quality of
Texas A&M University-Corpus Christi and is hereby approved.

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ABSTRACT

Reducing discard mortality in Gulf of Mexico (GOM) Red Snapper *Lutjanus campechanus* remains an important parameter for stock rebuilding. Red Snapper discard mortality remains high due to barotrauma injury sustained during capture and high catch rates, but recent development of fish descender devices can mitigate these declines. To estimate discard mortality rates associated with descender devices, Red Snapper were captured from the bottom via hook-and-line methods and released with descender devices across a depth gradient of 30 to 80 m. At each depth, fish were randomly assigned to three release treatment groups: one-third of their capture depth, two-thirds of their capture depth, and release at the seafloor. A subset of fish from each release treatment were tagged with ultrasonic acoustic transmitters to estimate short-term survival. The fate of released fish was classified using a combination of visual observation, acoustic profiles, and underwater video footage. Results showed strong depth effects, with the odds of survival decreasing by 50% with every 10 m increase in capture depth. Survival was independent of the depth at which descender devices released fish, suggesting that rapid recompression even to shallow depths will reduce discard mortality. Underwater video footage of descended fish revealed substantial depredation may occur, and was greater with increasing depth. Barotrauma impairment reached a maximum around 55 meters and decreased thereafter, resulting in seemingly less impaired fish at greater depths, despite low survival. In addition to rigorous field experimentation, the perceptions, opinions, and attitudes of over 500 recreational anglers were surveyed regarding the use of descender devices in the GOM and South Atlantic recreational Red Snapper fishery. Over 1,100 free descender devices were distributed to recreational anglers from North Carolina to Texas. After using the devices during a normal fishing season, recipients completed a survey assessing their perceptions of the devices. While

72% of respondents had little to no knowledge of the devices prior to the study, 70% changed their preferred release method from venting to descending. Anglers released over 7,000 Red Snapper and 4,000 other reef fish species with descender devices during this study, and 76% were likely to continue employing the devices on their vessel. Eighty-nine percent of respondents believed descending Red Snapper would significantly reduce discard mortality in Red Snapper. These findings help achieve better calculations of overall mortality, and provide managers with information on how descender devices may improve survival of discarded Red Snapper. The key finding was recreational anglers perceive descender devices to be highly useful in reducing discard mortality and are willing to employ the devices when releasing reef fish experiencing barotrauma.

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GENERAL INTRODUCTION

CATCH-AND-RELEASE FISHING AND GULF OF MEXICO RED SNAPPER

Throughout the past several decades, global fish populations have generally experienced significant ecological shifts and large declines due to the overexploitation of fishery resources (Jackson et al. 2001; Pauly 2002; Myers and Worm 2003; Daskalov et al. 2007; Worm et al. 2009). While the bulk of these global declines have been attributed to industrialized commercial fishing (Cooke and Cowx 2002), the role of recreational fisheries in the overharvest of fish stocks have been of more recent debate. To combat large-scale fishery declines and prevent adverse economic impacts, the United States created the Magnuson-Stevens Fishery Management and Conservation Act (MSFMCA) in 1976 to ensure the long-term sustainability of both recreationally and commercially targeted fish stocks. Due to the increased popularity of recreational angling over the past century, the practice of catch-and-release fishing (i.e., "regulatory discards") has become required in many fisheries to cope with increased effort (Cooke and Schramm 2007). While it is an effective way of preventing the overharvest of various stocks, the implementation and impacts of regulations requiring catch-and-release can be highly complex and regionally specific (Bartholomew and Bohnsack 2005; Arlinghaus et al. 2007; Cooke and Schramm 2007).

Red Snapper represent the most important reef fish fishery in the Gulf of Mexico (GOM), but are also considered the most controversially managed due to years of contentious regulations that followed severe stock declines in the 1980's. Despite extremely short recreational fishing seasons, reduced bag limits, and regulatory measures that limited access to the fishery, the stock is still rebuilding (SEDAR 2015). The cumulative effects of numerous regulations, high abundance of Red Snapper, and very high catch rates have resulted in a recreational fishery that is largely catch-and-release except during the short season. This dynamic has created a major impediment to stock recovery due to low survival rates associated with decompression related injuries sustained during capture (Rummer and Bennet 2005; Rummer 2007; Drumhiller et al. 2014). In an effort to improve catch-and-release survival, techniques have been developed to mitigate the effects of depth-related injuries and have shown high success under certain circumstances (Drumhiller et al. 2014; Curtis et al. 2015; Stunz et al. 2017). The most successful technique found to reduce discard mortality is to rapidly recompress fish by manually returning them to depth with descender devices (Jarvis and Lowe 2008; Curtis et al. 2015, Stunz et al. 2017). Refining best-use practices for these devices and determining to what extent anglers employ them is imperative for future management considerations. Regulatory measures that lead to a healthier fishery and earlier recovery improve trust between anglers and managing bodies (Behnke 1989). Moreover, the inclusion of angler knowledge and perceptions in the regulatory process can supplement the research and management required to ensure sustainability of the resource (Aswani et al. 2004; Granek et al. 2008; Boudreau and Worm 2010; Brownscombe et al. 2016). Reducing discard mortality in Red Snapper can yield more favorable fishery conditions for recreational anglers and may eventually lead to increased access to this popular GOM reef fish.

CHAPTER I

ASSESSING DISCARD MORTALITY IN RED SNAPPER USING DESCENDER DEVICES AND ACOUSTIC TELEMETRY

INTRODUCTION

GOM Red Snapper Management

Red Snapper represent the most important reef fish fishery in the GOM. The recreational fishery has experienced a long history of strict management measures eventually resulting in severely decreased access to the resource. Various key stock parameters such as discard mortality lack necessary data for proper management. The implementation of numerous restrictions has increased the number of regulatory discards and exacerbated other controversial efforts to manage the stock. GOM Red Snapper have been exploited since the mid 1800's and were unmanaged until the implementation of the Magnuson-Stevens Fishery Management and Conservation Act (MSFMCA) in 1976 (Hood et al. 2007). By 1984, the GMFMC created the first bag and size limits for GOM Red Snapper, which required fish not meeting these restrictions to be released as 'regulatory discards'. Four years later the stock was determined to be overfished (Goodyear 1988), and began a long history of stringent regulatory measures including increased season closures, stricter bag, size, and trip limits, and programs that limited access to the fishery (Hood et al 2007). In addition to overfishing, the stock also experienced large declines as a result of juvenile bycatch in the shrimp trawl fishery. Goodyear (1995) determined the shrimp trawl fishery accounted for 80% of Red Snapper juvenile mortality. However, current estimates found only 4% of juvenile mortality was attributed to shrimp trawl bycatch (Gallaway et al. 2017). A stock assessment in 1990 discovered the spawning stock biomass ratio (SSBR) to be less than 1% of the target SSBR of 20%, a ratio low enough to place a moratorium on the fishery.

Amendment 1 was implemented by the GMFMC in 1990 and set the GOM catch ratio to 51% commercial and 49% recreational. In 1991, a rebuilding target was set for 2007, which was later extended numerous times after the GMFMC decided against rebuilding measures that could potentially cause negative economic impacts (Hood et al. 2007). It was later decided to set the rebuilding target to 2032 and cease overfishing between 2009 and 2010. Amendment 27 went into effect in 2008, further reducing the bag limit and increasing the size limit, but more importantly, required that all boats fishing for federally managed reef fish carry onboard their vessel a venting needle and dehooking device and use only non-stainless steel circle hooks when using natural bait (GMFMC 2007). Soon after the implementation of this amendment, the usefulness of venting fish was investigated (Wilde 2009, Scyphers et al. 2013, Drumhiller et al. 2014). A 2009 stock assessment update concluded the fishery was no longer experiencing overfishing, but was still overfished, resulting in an increased quota (GMFMC 2010). In 2013, the requirement to carry a venting needle in federal waters was lifted due to a lack of angler knowledge and data supporting the benefit of venting reef fish (GMFMC 2013). Amendment 40: sector separation, passed in 2014 and divided the recreational sector into two components, private anglers and federally permitted for-hire vessels (GMFMC 2014). The private component consists of exclusively private anglers and holds 57.7% of the recreational allocation. The federally permitted for-hire component consists of exclusively headboats and charter boats and holds 42.3% of the recreational allocation. In 2016, with a quota of 4.15 million pounds, the private season was set for nine days, while the federally permitted for-hire season was set for 46 days, with a quota of 3.042 million pounds. Beginning in 2016, the GOM Red Snapper quota was reallocated to 48.5% commercial and 51.5% recreational (GMFMC 2015), but was later changed back to 51% commercial and 49% recreational following a court ruling that overturned the previously altered allocations.

Species Description

Red Snapper (*Lutjanus campechanus*) are a perciform fish in the family Lutjanidae. Their geographic range extends from the Yucatan Peninsula to Massachusetts, and are often found at depths between 30-130 m, with fish in the northern range usually inhabiting deeper water (Allen 1985). Red Snapper are known to inhabit shallower depths (15-30 m) during summer months and deeper depths during winter months (35-60 m), and have been captured as deep as 146 m (Moran 1988). Even at these shallower depth, this species experience symptoms of barotrauma.

Newly settled juvenile Red Snapper prefer low-relief environments such as near-shore mud and shell habitats (Wells and Cowan, Jr. 2007). Adult fish prefer more high-relief habitat such as offshore natural banks and artificial reefs and show a high degree of site fidelity to these structures (Szedlmayer and Schroepfer 2005, Topping and Szedlmayer 2011a, Westmeyer et al. 2007). Larger fish exhibit more movement and may emigrate off high relief habitat in favor of low relief habitat such as mud flats or shell ridges (Gallaway et al. 2009, Topping and Szedlmayer 2011b).

Red Snapper are a long-lived fish, reaching ages of 50 years or more, and growing to lengths of over one meter (Wilson and Nieland 2001). Growth occurs rapidly in the first 10 years of life, followed by an asymptotic effect (Fischer et al. 2004). In the northern Gulf of Mexico (GOM), female Red Snapper become sexually mature as early as age two and approximately 300 mm fork-length, with minor differences in age and size at maturation occurring regionally (Collins et al. 1996, Woods et al. 2003). The Red Snapper spawning season occurs during the warmer months from May through September, and individual females may spawn multiple times during this period. A 10 year-old female Red Snapper may produce as many as 60 million eggs in a single spawning season. Of those 60 million eggs, approximately 450 would recruit as newly settled juveniles (Gallaway et al. 2009).

Barotrauma and Discard Mortality

Regulatory measures resulting in high discard mortality have been a great impediment to stock recovery. With increased regulations resulting in a short summer season, minimum size requirement, and large commercial and recreational sectors, a large portion of the overall GOM Red Snapper catch is returned to the ocean as regulatory discards. As a deep-water demersal reef fish, Red Snapper often sustain pressure-related injuries during the capture event as a result of the expansion of gases in the swim bladder and other internal organs. These various injuries, collectively referred to as barotrauma, cause a significant portion of discarded fish to succumb to post-release mortality (Rummer 2007). Externally visible Red Snapper barotrauma symptoms may include exophthalmia, distended stomach, swollen swim bladder, everted anus, subcutaneous air bubbles, and bleeding from the gills and orifices (Diamond and Campbell 2009a). As the swim bladder inflates, it compresses and displaces other vital organs, potentially resulting in life-threatening internal injuries and delayed mortality (Rummer and Bennett 2005). Multiple factors affect the intensity of barotrauma injuries and may ultimately determine the fate of the discard. Both capture depth and season have been known to affect survival in discarded Red Snapper (Diamond and Campbell 2009a, Campbell et al. 2012, Drumhiller et al. 2014, Curtis et al. 2015). Many studies examining a variety of deep-water demersal fish have concluded that barotrauma impairment intensifies as capture depth increases (Gitschlag and

Renaud 1994, Burns et al. 2004, Alós 2008, Hannah et al. 2008, Brown et al. 2010, Campbell et al. 2010a, Curtis et al. 2015). Water temperature has also been found to play a significant role in release mortality, with warmer water contributing to higher mortality in released fish (Render and Wilson 1994, Bartholomew and Bohnsack 2005, Gingerich et al. 2007, Diamond and Campbell 2009a, Curtis et al. 2015). Additionally, higher water temperatures in the summer months during the federal Red Snapper season may create a situation where discarded fish are required to swim through a layer of warm water that exceeds their thermal tolerance, resulting in increased physiological stress.

Various tools have been employed by fishery managers in an attempt to reduce discard mortality. While deflating the overinflated swim bladder using hollow needles (i.e. venting tools) proved successful in some species (Keniry et al. 1996; Collins et al. 1999; Sumpton et al. 2008, Drumhiller et al. 2014), and was publicly promoted (FSG 2005), the effectiveness of the devices across a broad scale was unclear. Wilde (2009) examined 17 studies assessing the usefulness of venting, and concluded that venting should not only be discouraged, but banned. He also noted there appeared to be a relationship between capture depth and venting success, where shallow-caught fish were more likely to receive the benefits of venting than deep-caught fish. Scyphers et al. (2013) examined the efficacy and perceptions of venting fish with barotrauma, and concluded that most anglers perceive venting to be successful in reducing discard mortality, although their knowledge on correct use of the device was poor, resulting in an increased likelihood of mortality (Scyphers et al. 2013). The study also surveyed experienced and unexperienced tournament anglers on the correct location of insertion for a venting needle. Less than 30% of the participants chose the correct location for venting needle insertion, and fishing experience was entirely unrelated to knowledge on correct use of the tool. Drumhiller et al. (2014) discovered venting to be highly successful in reducing discard mortality in Red Snapper, suggesting that barotrauma mitigation techniques should be examined on a species level and explored across various parameters.

An alternative option to venting, and one that requires less knowledge of fish physiology to operate successfully, is to rapidly recompress the fish by returning it to depth. Devices designed to complete such a task are commonly referred to as fish descender devices. Various descender devices are available to the public and allow anglers to release fish at predetermined depths in the water column or at the seafloor. Simple descender devices can be manually constructed using large inverted barbless fishing hooks attached to a rope, while others, like SeaQualizers™, are complex devices that allow the user to set the device to release the fish at a predetermined depth. Previous studies suggest descender devices are successful in reducing discard mortality in other deep-water demersal fish such as snappers, groupers, emperors, and rockfish (Jarvis and Lowe 2008, Sumpton et al. 2010). Few studies have directly examined the efficacy of descender devices in the GOM Red Snapper fishery. Drumhiller et al. (2014) used hyperbaric chambers to simulate capture and release conditions using venting needles and descender devices at 30 and 60 m capture depths. Survival of simulated descended Red Snapper for the 30 m treatment was 100% and 83% for the 60 m treatment. Curtis et al. (2015) compared Red Snapper post-release mortality across multiple seasons, capture depths, and release methods using acoustic telemetry. Fish released with descender devices demonstrated the highest survival rates during the spring and summer trials.

Accurately quantifying release mortality in Red Snapper has proven to be challenging due to several factors. Using proxies for survival such as post-release behavior at the surface or the ability to swim back to depth may ignore key factors affecting discard mortality (Campbell et al. 2010b). Additional factors complicating the process include tracking fish at great depths, seasonal fluctuations in water temperature and thermocline formation, and assessing mortality over a gradient of capture depths. Past field studies attempting to quantify release mortality in Red Snapper have involved caging experiments replicating rapid recompression (Gitschlag and Renaud 1994; Diamond and Cammpbell 2009), comparing release methods (Curtis et al. 2015; Stunz et al. 2017; Drumhiller et al. 2014), assessing mortality across multiple seasons and capture depths (Curtis et al. 2015; Stunz et al. 2017; Sauls 2012, Rummer 2007), and using condition indices to predict survival (Campbell et al. 2010a; Campbell et al. 2010b). More recently, scientists have employed advanced strategies that use acoustic telemetry to track the movements and behavior of discarded fish for extended periods of time after release. These methods have proven highly successful for monitoring survival in released Red Snapper (Curtis et al. 2015); however, there is still a level of uncertainty involved in acoustic studies due to the potential for predation, emigration from the acoustic array, and tag shedding.

By coupling underwater video footage of released fish with acoustic telemetry, this study will provide new insights into classifying the fate of discards. While descender devices have been proven to successfully reduce discard mortality in GOM Red Snapper (Curtis et al. 2015; Drumhiller et al. 2014; Stunz et al. 2017), refining best-use practices across a variety of capture depths and release depths is vital if managers wish to implement the use of the devices in the fishery. Improving knowledge associated with relating barotrauma impairment indices to post-release survival is also imperative, so anglers can identify and mitigate when necessary. Red Snapper discard mortality remains a difficult limitation to stock rebuilding, but obtaining additional knowledge regarding ideal release practices and post-release fate across multiple capture depths will provide managers best information for improving fish handling techniques and better data for refining mortality estimates for future stock assessments.

The **purpose** of this chapter is to refine best-use practices of descender devices across a capture depth gradient and relate barotrauma impairment to release condition and post-release mortality using field experimentation, acoustic telemetry, and underwater video footage. The **objectives** of this chapter are to:

1. Compare the utility of midwater release and bottom release descender devices in the recreational Red Snapper fishery in the Gulf of Mexico and determine optimal conditions for release that minimize discard mortality.

   H_{A1}: Descender device release depth will influence post-release mortality.

   H_{A2}: Overall utility and ease of use will be greater with certain devices.

2. Link degree of barotrauma impairment to survival in descended Red Snapper across a depth gradient.

   H_{A1}: Barotrauma impairment and severity will influence post-release mortality.

   H_{A2}: Barotrauma impairment will reach a threshold due to catastrophic decompression.

3. Compare descender device release behavior to post-release mortality and determine if release score classification is a valid proxy for survival using underwater video footage.

   H_{A1}: Release score classification will be a valid proxy for post-release survival.

H_{A2}: Descender device release behavior will deteriorate with increasing capture depth.

The results from this thesis will provide managers with essential information regarding the viability of descender devices and to what degree barotrauma impairment affects discard mortality in the recreational GOM Red Snapper fishery.

METHODS

Study Site

To assess discard mortality across various capture depths, five sampling sites across a depth gradient of 30-80 m were selected: one site each at 30, 40, 50, 60, and 80 m (Figure 1.1). Sampling sites consisted of three artificial reef complexes composed of cutoff and toppled oil and gas platforms (MI-703, MU-828, and MI-A-7), one active standing gas platform (MU-A-85ST), and one inactive standing gas platform (MI-686ST). Available underwater habitat at these locations was highly complex, and the depth at which structure began varied from site to site. For example, two standing gas platforms provided vertical and horizontal relief from the seafloor to the surface. Although the three artificial reef complex sites contained similar structure types, the beginning of the structure did not occur until depths of 15 m at the 40 m site and 28 m at the 50 and 60-m sites. All sites were located between 35 and 89 km offshore of Port Aransas, TX.

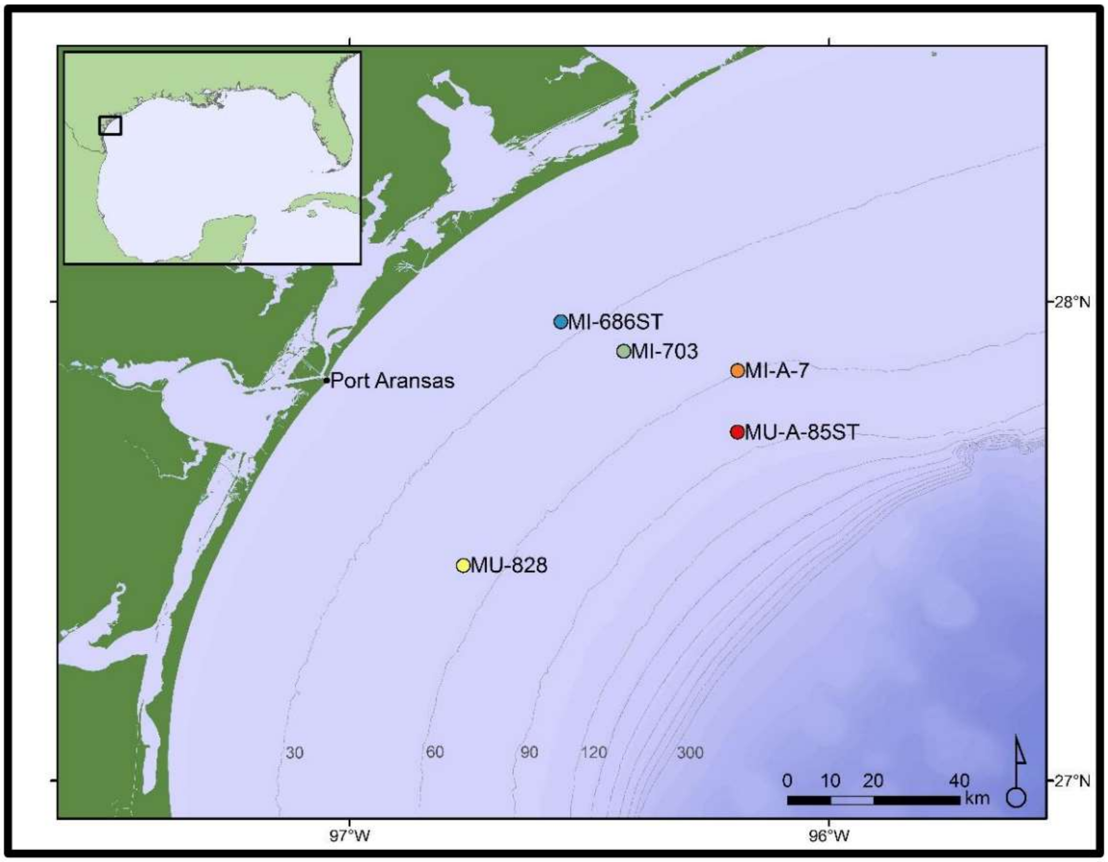

Figure 1.1: A map of the five field sampling sites offshore of Port Aransas, TX. MI-686ST (27.9604, -96.56495) is at a bottom depth of 29 m and consists of an inactive standing 6-pile jacket gas platform. MI-703 (27.89517, -96.43333) is at a depth of 39 m and is comprised of the cutoff top and base of a 4-pile jacket. MU-828 (27.4501, -96.76288) is at a depth of 49 m and consists of seven toppled 4-pile jackets and one toppled 8-pile jacket. MI-A-7 (27.85705, -96.19228) is at a depth of 57 m and consists of six toppled 4-pile jackets and three toppled 6-pile jackets. MU-A-85ST (27.72737, -96.19132) is at a depth of 82 m and consists of an active standing 8-pile jacket platform.

Collection Procedure

At each site, between fifty-five and sixty Red Snapper were captured at the bottom using standard recreational hook-and-line fishing methods. Both natural and artificial baits were used. Natural baits consisted of Atlantic Mackerel *Scomber scombrus*, Round Scad *Decapterus punctatus*, and Squid *Loligo* spp. on 7/0 and 8/0 circle hooks. Artificial baits consisted of vertical jigging spoons and large soft plastics on a weighted jig head.

During fishing, time (hh:mm:ss format) was recorded when fish were initially hooked at the bottom, again when the fish reached the surface, and again when the fish was returned to the water after tagging was complete. This process enabled me to calculate the amount of time required to land a fish, measure and tag it, and then release it using a descender device. Immediately upon capture, fish were visually inspected for external barotrauma symptoms. Fish were also examined for catastrophic decompression by visually observing for "fizzing" during the last few meters of descent, a phenomenon where a large plume of bubbles exit from the fish as a result of swim bladder rupture. There were six possible externally visible barotrauma symptoms to record upon capturing a fish: (1) everted stomach; (2) swollen or hard abdomen as a result of an overinflated swim bladder; (3) exophthalmia (eyes forced from orbits); (4) distended intestines from the anus; (5) subcutaneous gas bubbles; and (6) bleeding from the gills unrelated to hook-induced trauma (Diamond and Campbell 2009b, Campbell et al. 2010a). Barotrauma impairment (BI) scores were assigned by dividing the total number of visible barotrauma symptoms by the total number of possible visible barotrauma symptoms. This scoring procedure resulted in an index between 0 and 1, with scores closer to 1 representing fish with higher levels of barotrauma impairment. BI scores were later compared with survival rates and capture depth to identify a capture depth-survival threshold. Fish were then placed into a measuring cradle suspended in a large ice chest filled with seawater (Figure 1.2). Total lengths were recorded, while the gills were completely submerged in seawater.

Water quality measurements were taken each trip using a Hydrolab DS-5 multiparameter data sonde. The sonde was lowered at 2.5 m increments every 40 seconds until it reached the seafloor. Temperature at depth profiles were created to identify thermocline location, if present. To eliminate the effects of water temperature and thermocline presence, data from days with thoroughly mixed water temperatures were subset and re-analyzed using identical methods. Survival rates, BI scores, and BRS were compared between the two subsets of data.

Figure 1.2: Image of the tagging cradle used to measure and tag Red Snapper. This fish was fitted with a Lotek MM-M-8-SO-TP series ultrasonic acoustic transmitter. The gills of fish were submerged in seawater during the measuring and tagging process.

Tagging Procedure

A random subset of fish from each sampling site were fitted with Lotek MM-M-8-SO-TP series ultrasonic acoustic transmitters. Transmitters were programmed with pressure and temperature sensors to monitor the fish's depth and transmitted at a rate of one transmission every two seconds to obtain frequent profiles of the fish's movements through the water column. Transmitters used in this study were small (47 mm long, 9 mm diameter), resulting in an estimated battery life of eight days. Transmitters were externally attached 2-3 cm below the dorsal edge using proven procedures (Johnson et al. 2015; Curtis et al. 2015). Fish were punctured with a sterile hollow surgical needle between the second and third pterygiophores below the anterior dorsal spines. A plastic cinch-up external Hallprint® tag was fed through the hollow needle, attached to the acoustic transmitter, and passed back through a second hollow needle between the fourth and fifth pterygiophores and secured so that the orientation of the transmitter was parallel to the fish and on the opposite side of the point of attachment. A brightly colored externally visible dart tag containing contact and reward information was inserted into the posterior dorsal spine region of each released fish in the event the fish was recaptured by anglers.

Release Procedure

To compare the utility and refine best-use practices of descender devices and in particular release depth effects, one-third of the fish from each capture depth were descended to and released at one-third of that capture depth (treatment 1), one-third of the fish were released at two-thirds of the capture depth (treatment 2), and one-third were released at the seafloor (treatment 3). Each release treatment was used at each capture depth on an equal number of fish. By releasing fish at depths relative to their original capture depth, an equal proportion of pressure was relieved from the swim bladder for any fish from a specific release treatment regardless of capture depth. Fish descended to the bottom were released with the Blacktip Catch and Release Recompression Tool™ (Figure 1.3a), a descender device designed to release fish at the seafloor. The Blacktip recompression tool releases the fish when the device comes in contact with the seafloor, releasing an inner mechanism that alleviates the grip on the fish's lower mandible. All fish released mid-water (release treatment 1 and 2) were released using a SeaQualizer™ (Figure 1.3b), a popular descender device designed to release fish at a one of three predetermined depths. Three different models of SeaQualizers were available: a shallow model (30, 50, and 70 ft), a standard model (50, 100, and 150 ft), and a deep model (100, 200, and 300 ft). Two of the three models were employed during this study, the shallow and standard models. Fish were released closest to precisely one-third or two-thirds of the capture depth as possible using the various preset release depths on shallow and standard SeaQualizer models.

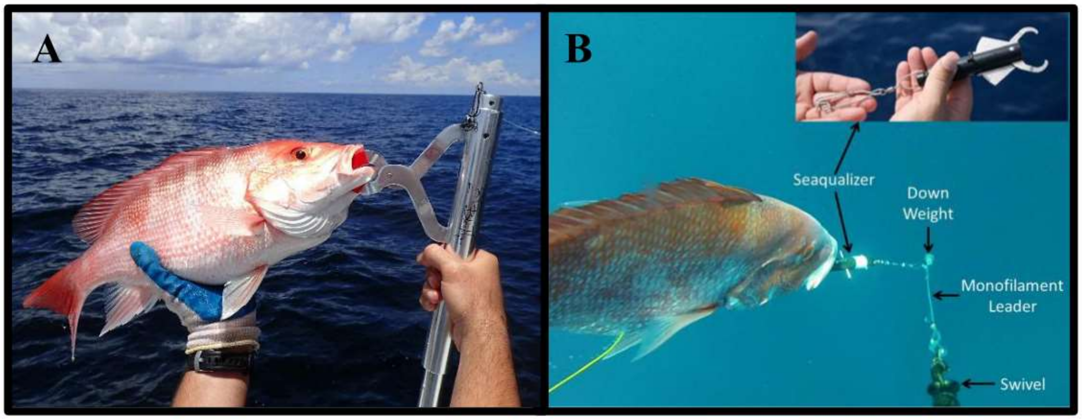

Figure 1.3: The two descender devices used in this study. A) The Blacktip Catch and Release Recompression Tool is attached to the lower mandible of a Red Snapper. When the device reaches the seafloor, the jaws unclamp from the fish's mandible and releases the fish. B) The contraption used to descend and release fish with a SeaQualizer using rod and reel. The depth is set on the posterior portion of the device. The jaws are clamped onto the fish manually and release when the device's preset depth is reached.

All released fish were returned to depth using one of the two descender devices attached to the catch and release system for scoring barotrauma outcomes (CRSSBO). The CRSSBO is composed of a camera array and descender device mounting platform. It was designed with ¾" and ½" PVC pipe attached and cemented to a central PVC socket cross (Figure 1.4). Each terminal end of the CRSSBO housed a GoPro HERO4 HD camera pointed towards the center of the apparatus. Bolted through the larger PVC diameter in the center of the CRSSBO was a stainless steel eye-bolt used for descender device attachment via tuna clip or snap-swivel. The CRSSBO was weighted with a 2.3 kg bank sinker lead weight attached to a large brass swivel. To use the device, 300 lb mainline from a manual crank bandit reel was attached to the top of the

CRSSBO using a large brass swivel. When a fish was ready to be released, I attached the descender device to the lower mandible of the fish and released the bandit reel brake. Two team members started each of the four cameras simultaneously to record the four videos in sync. Premeasured marks on the bandit reel's monofilament line allowed me to stop the CRSSBO at a predetermined depth so the cameras would record release behavior of the fish after detaching from the descender device. The CRSSBO remained at release depth for approximately 45 seconds to record immediate release behavior. A scuba depth gauge was attached directly beneath camera 1 to record exact release depth.

Figure 1.4: The catch and release system for scoring barotrauma outcomes (CRSSBO). This device allowed for easy attachment of a SeaQualizer or Blacktip recompression tool to an eye bolt located in the center of the device (red circle). At each terminal end of the PVC pipe sits a GoPro HERO4 HD camera to monitor rapid recompression device release behavior at depth. The CRSSBO is descended to depth using a manual-crank bandit reel. Cameras were designated numbers to organize video files.

Acoustic Array

Upon arrival to the fishing site, four Lotek WHS3250 hydrophones were deployed vertically on a single line cleated to the fishing vessel. Hydrophones were cable-tied to a rope and spaced equally throughout the water column. Two were positioned below the thermocline, if present, and two above. The presence of a thermocline between an acoustic transmitter and hydrophone reduces the total number of acoustic detections (Huveneers et al. 2016; Westmeyer et al. 2007), so by positioning hydrophones both above and below the thermocline, the possibility of losing acoustic detections as a result of a thermocline was minimized.

Hydrophones were left underwater to receive acoustic transmitter detections as long as the vessel remained on site. At the 80-m site, one hydrophone was permanently installed on a leg of the gas platform at 33 m to capture delayed mortality events. By installing a permanent receiver at the deepest site, we were able to assess a 'worst case scenario' of what delayed mortality may have been missed by only accounting for acoustic detections while the vessel was on site at the other four capture depths. The hydrophone remained on site approximately one week longer than estimated transmitter battery life.

Video Analysis

All videos were processed in HAM Multiplayer, a program that uses an interface designed to view multiple videos simultaneously on the same screen (Figure 1.5). Video assessment was performed by observing the release event from the moment the fish was returned to the water to the point where the fish was no longer visible. Specific behavior related to release condition such as tail beats, gill movement, eye movement, ability to swim right-side-up, and ability to escape predators was recorded. Individual fish were designated a qualitative behavioral release (BR) score between 1 and 3 depending on release condition behaviors (Table 1.1). Fish consumed or depredated before or after release were classified as P. The BR score classification procedure was defined using methods adapted from Patterson et al. (2002) where researchers scored the behavior and ability to swim back to depth in surface released Red Snapper.

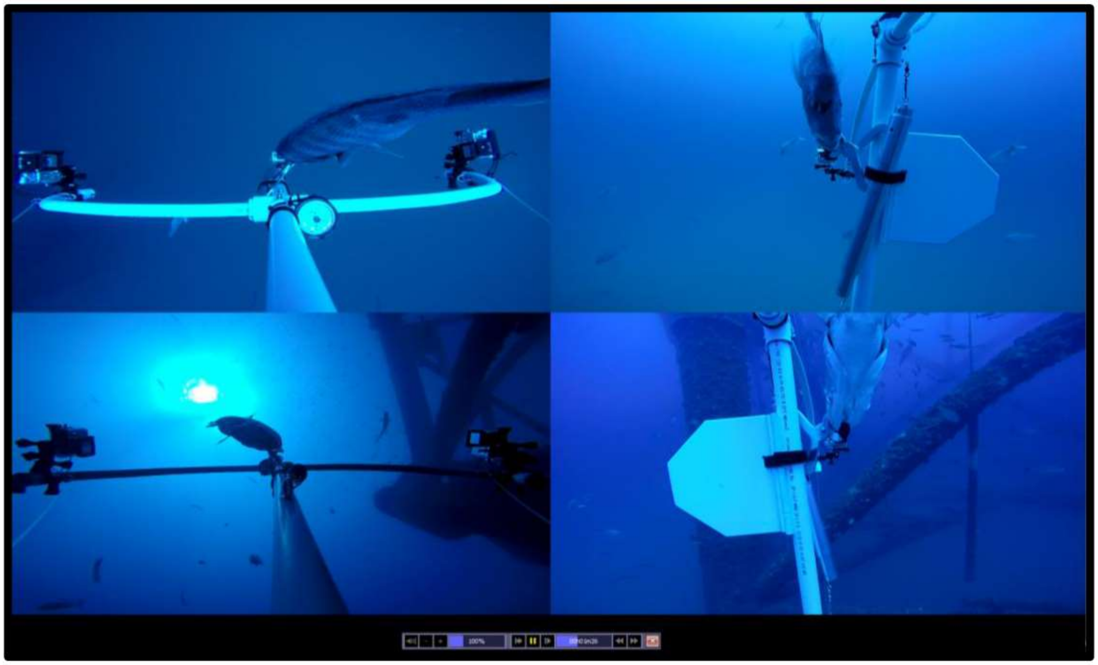

Figure 1.5: User interface of HamMultiPlayer media player program. Top left quadrant plays video from camera 1, top right plays camera 2, bottom right plays camera 3 and bottom left plays camera 4. Individual fish were assigned behavioral release scores according to the criteria exhibited in Table 1.1.

Table 1.1: The qualitative scoring procedure used to assess descender device release behavior. Methods were adapted from Patterson et al. (2002) where researchers devised a qualitative scoring system to assess Red Snapper surface release behavior.

BRS	Rapid Recompression Device Release Behavior
1	Fish swam vigorously away from device upon release
2	Fish appeared disoriented upon release but swam away slowly
3	Fish floated back towards surface or appeared dead upon release
P	Fish was consumed by a predator during or immediately after release

Depth Profiles

Mortality rates were estimated by creating depth profiles of acoustically tagged individuals. Hydrophone data were converted to text files and uploaded to R. Depth in meters was calculated from the hydrophone pressure detection value using the following conversion:

$$\text{Depth(meters)} = 3\ (0.6975\ (\text{hydrophone pressure detection}))$$

A plot of individual acoustic detections with depth on the y-axis and time on the x-axis was created for each acoustically tagged individual. Fish were classified as survivors (1 = success) if their post-release behavior involved active movement through the water column following detachment from the descender device. If post-release movements were highly sporadic, consisted of frequent rapid vertical movements to the surface, and demonstrated significant time spent in the upper half of the water column, the fish was classified as consumed (0 = failure). If a depth profile appeared the fish was consumed by a predator, CRSSBO video was observed for a visible predation event. If fish detached from the rapid recompression device, immediately sank to the bottom, and continued to demonstrate zero vertical movement for the remainder of the hydrophone's detection period, the fish was classified as dead (0 = failure). Unknown classifications were identified as such if an insufficient amount of acoustic detections were captured by the hydrophone to be classified as alive or dead.

SeaQualizer Performance

To validate the performance and accuracy of the SeaQualizers used in this study, actual release depths were recorded for each descended fish using underwater GoPro video footage obtained with the CRSSBO. Actual release depths were compared with labeled preset depths on the various SeaQualizer models. Only two of the three SeaQualizer models were used during fish tagging, shallow and standard, as the deepest two-third depth release treatment only required the use of the 150 ft release setting on the standard SeaQualizer model.

Statistical Analysis

Hydrological Data

Hydrolab data were used to plot temperature against depth at each site. Survival between days with thermoclines and days without thermoclines was compared using logistic regression (LR; $\alpha = 0.05$) with a logit link function. An interaction term between release treatment and capture depth was added to the model to correct for any depth effects. To test if releasing fish above or below the thermocline affected survival, days with thermoclines existing between one-third and two-thirds of the bottom depth were subset and all fish released at the bottom were excluded from the dataset. Using the new dataset, LR ($\alpha = 0.05$) with a logit link function was performed to assess if releasing above or below the thermocline affected survival. An interaction term between release depth and bottom depth was added to the model to correct for any depth effects. Hosmer-Lemeshow goodness-of-fit tests were performed to assess model fit. All statistical analyses were performed in R (R Core Team 2017).

Field Data Comparisons

An analysis of variance (ANOVA; $\alpha = 0.05$) was performed to compare fight time, deck time, fish total length, and barotrauma impairment among release treatments, sites, and trips. Post-hoc comparisons on significant ANOVA tests were made using Westfall's adjustment to the Tukey test where data were balanced, and Shaffer's multiple comparison procedure where data were unbalanced ($\alpha = 0.10$). The Westfall and Shaffer tests from the 'multcomp' package

(Hothorn et al. 2008) in R are step-down tests that implement logically constraint multiplicity adjustments to *p*-values resulting in a more statistically powerful multiple comparison test than Tukey's HSD (Shaffer 1986; Westfall 1997).

Post-release Survival

To determine the relationship among experimental treatments, barotrauma impairment, field collected variables, and post-release survival of Red Snapper, a multiple LR ($\alpha = 0.1$) was performed using the following variables as predictors of survival: release treatment, capture depth, BI scores, fish total length, and time spent on deck. The most parsimonious model was selected using the dredge and relative variable importance (RVI) function from the 'MuMin' package in R (Barton 2016). For visualization of the effect of capture depth on survival rates, one-way LR ($\alpha = 0.1$) was performed using capture depth to predict survival. Amount of deviance explained was compared between models using McFadden's pseudo-R-squared. Predictive ability of models were assessed using the cv.glm cross-validation function from the 'boot' package in R (Canty and Ripley 2016; Davison and Hinkley 1997). Hosmer-Lemeshow goodness-of-fit tests were performed to assess model fit. Plotting of the final model was performed using the logistic.plot function designed by Sterba-Boatwright. Groupings of binary survival values were compiled into 11 distinct groups so that plotting aesthetics were based on those that best represented the fitted model.

Post-release Behavior

To examine the relationship between barotrauma impairment, field collected data, and release behavior, a multiple ordinal logistic regression (OLR; $\alpha = 0.1$) was performed using the following variables to predict BR scores: release treatment, capture depth, BI scores, fish total length, and time spent on deck. The 'MuMin' package dredge and RVI function in R were used to select the most parsimonious model. To observe the effect of capture depth on BR scores, one-way OLR was performed using capture depth to predict BR scores. Modified Hosmer-Lemeshow tests were performed on OLR models to assess model fit.

RESULTS

Fish Tagging

A total of 272 Red Snapper ranging from 291 to 688 mm total length (mean ± SE = 500 ± 4.5 mm) were captured at the bottom, assessed for barotrauma impairment, and released with one of two rapid recompression devices between July and November of 2016. Between 52 and 57 Red Snapper were captured and released at each site (Table 1.2). Catches from standing rigs (30-m and 80-m sites) were comprised of significantly smaller fish than the other three tagging locations (ANOVA, $F_{4, 267} = 12.71$, $p < 0.0001$). Using a SeaQualizer, 94 and 89 fish were released with treatment 1 and treatment 2, respectively. Eighty-nine fish were descended to the bottom using the Blacktip recompression tool. No significant differences in total length existed among release treatments (ANOVA, $F_{2, 269} = 0.71$, $p = 0.494$). An ANOVA found significant differences in fight times among sites (ANOVA, $F_{4, 266} = 9.58$, $p < 0.0001$), however, a post-hoc Westfall test determined significant differences did not exist among each site and was likely due to variation in angler experience. Post-hoc analysis determined fish spent significantly more time on deck at the 50-m and 60-m sites than the other three sites.

Table 1.2: Table providing actual bottom depths of sites and the number of acoustically tagged and non-acoustically tagged fish released with each experimental treatment. Additional information includes means and standard errors of fish total lengths, barotrauma impairment scores, and behavioral release scores by site and treatment.

	MI-686ST	MI-703	MU-828	MI-A-7	MU-A-85ST
Bottom depth	29 m	39 m	49 m	58 m	81 m
Total released (*n*)	56	54	52	53	57
1/3 release	19	19	15	19	22
2/3 release	18	18	18	16	19
Bottom release	19	17	19	18	16
Acoustically tagged (*n*)	14	12	14	14	15
1/3 release	5	5	5	4	5
2/3 release	4	4	5	4	4
Bottom release	5	3	4	6	6
Total Length	459 ± 11 mm	518 ± 11 mm	532 ± 7 mm	526 ± 9 mm	474 ± 8 mm
Barotrauma Impairment	0.29 ± 0.01	0.32 ± 0.01	0.35 ± 0.02	0.3 ± 0.02	0.27 ± 0.03
Behavioral Release	1.25 ± 0.06	1.61 ± 0.10	1.81 ± 0.11	2.02 ± 0.09	2.34 ± 0.11
1/3 release	1.21 ± 0.10	1.68 ± 0.17	1.40 ± 0.13	1.94 ± 0.19	2.45 ± 0.17
2/3 release	1.29 ± 0.11	1.61 ± 0.16	1.83 ± 0.22	2.06 ± 0.11	2.22 ± 0.17
Bottom release	1.24 ± 0.11	1.53 ± 0.17	2.11 ± 0.17	2.06 ± 0.18	2.30 ± 0.26

A total of 218 fish experienced increased pressure in their abdomen due to swim bladder overexpansion: 200 had an everted stomach, 41 were captured with gas escaping from subcutaneous tissues, 29 had an everted anus, 23 experienced exophthalmia, and one fish bled from the skin due to subcutaneous hemorrhaging. Twenty fish experienced no external signs of barotrauma impairment, 11 of which were from the deepest site. BI scores at the 50-m site were found to be significantly higher than the 30-m and 80-m site using a post-hoc Westfall test. Impairment increased from the 30-m site to 50-m site, then began to decrease as capture depth increased (Figure 1.6). Catastrophic decompression began occurring at 50 m with seven, 15, and 28 fish experiencing little to no external barotrauma symptoms at the 50-m, 60-m, and 80-m sites, respectively. The number of fish captured with a hard swim bladder decreased from 46 at the 50-m site to 29 at 80-m site, while the number of fish captured with an everted stomach increased from 36 at the 50-m site to 48 at 80-m site.

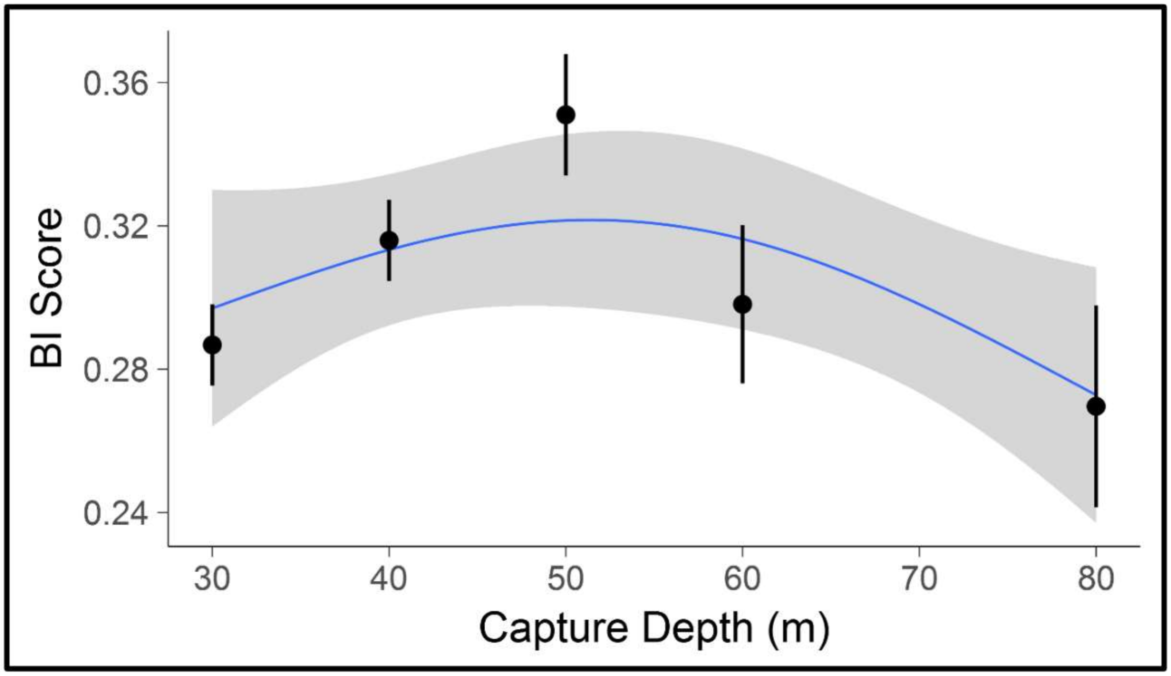

Figure 1.6: Plot showing the effect of capture depth on barotrauma impairment (BI) scores. Black dots correspond to the mean BI score of all fish captured from one site. Black lines represent standard error of the mean BI score. The blue smoothing line was fitted to the data using a GAM. Gray shading corresponds to the 95% confidence interval of the GAM.

Sixty-nine of the 272 captured fish were fitted with Lotek MM-M-8-SO-TP series ultrasonic acoustic transmitters to monitor post-release survival. Mean deck time for acoustically tagged fish was 133 ± 7 (mean ± SE) seconds. Acoustically tagged individuals spent significantly more time on deck than non-acoustically tagged individuals (ANOVA; $F_{1, 271}$ = 28.14, $P < 0.0001$), but no significant differences in total length or barotrauma impairment existed between the two groups (ANOVA; $F_{1, 269} = 1.16$, $P = 0.2820$; ANOVA; $F_{1, 269} = 0.41$, $P = 0.5220$, respectively). During tagging, numerous unscheduled releases occurred using the

Blacktip recompression tool. Acoustic transmitters were retrieved from fish that floated back to the surface and surgically attached to a new individual.

Hydrological Data

Thermocline presence and depth varied by site and trip. All tagging at the 50 m and 60 m sites occurred on 25 August 2016 and 26 August 2016, respectively, with thermocline depths at approximately 20 m at the 50 m site and 25 m for the 60 m site. One trip each at the 30 m, 40 m, and 80 m sites was completed when water temperatures were thoroughly mixed, with the remainder of trips to these sites occurring in a weak to strong thermocline. Surface to bottom temperature differentials varied widely during the three trips to the 30 m site (Figure 1.7). One trip at the 40 m site was performed during a strong thermocline while the other was performed in a generally mixed water column (Figure 1.8). Hydrological data from the seafloor was not obtained from the 40 m site on 3 September due to technical issues with the Hydrolab DS-5. Tagging trips to the 50 m and 60 m site were performed during the presence of strong thermoclines (Figure 1.9 and 1.10). Hydrological data was not collected on 19 October 2016 at the deepest site due to technical issues with the Hydrolab DS-5. Sea surface temperature data obtained from the National Oceanic and Atmospheric Administration - National Data Buoy Center Station 42019 for 19 October 2016 listed a range from 29.0 to 29.4°C during daylight hours. On 15 November 2016 at the 80 m site, water temperatures remained very similar throughout the water column with a range of 26.5° at the surface to 26.3°C at the seafloor (Figure 1.11).

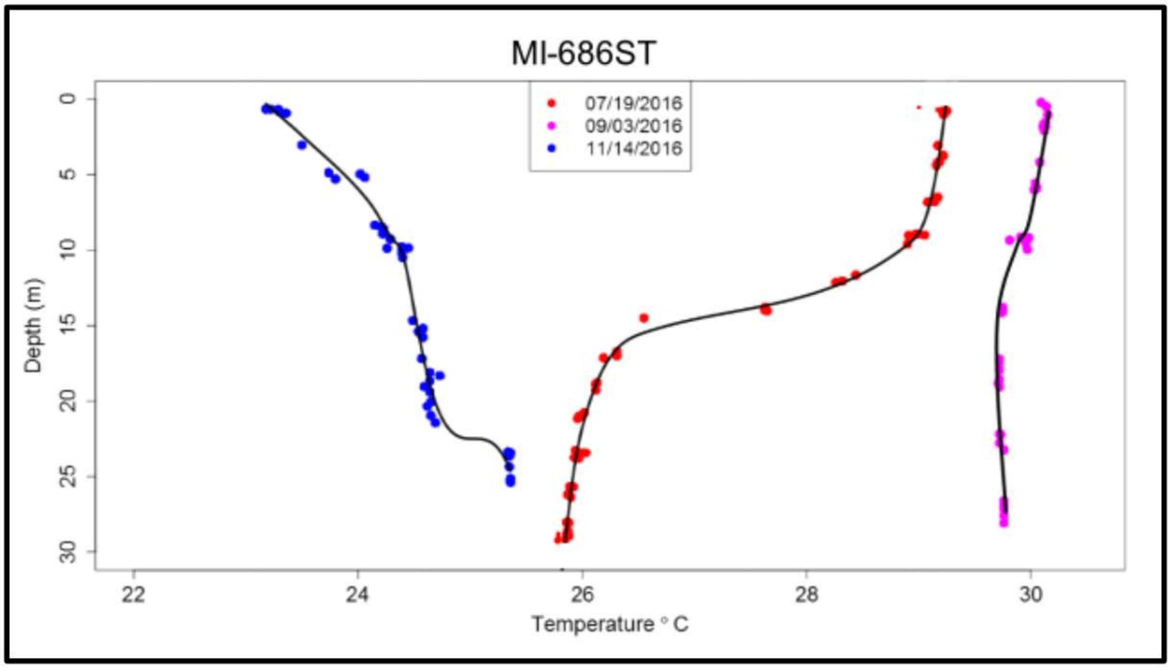

Figure 1.7: Temperature versus depth profiles created using hydrological data sampled with the Hydrolab DS-5 from the 30-m site. Red points are data collected 19 July 2016, magenta points are data collected 3 September 2016, and blue points are data collected 14 November 2016. Black smoothing lines were fit to the temperature data using a loess model.

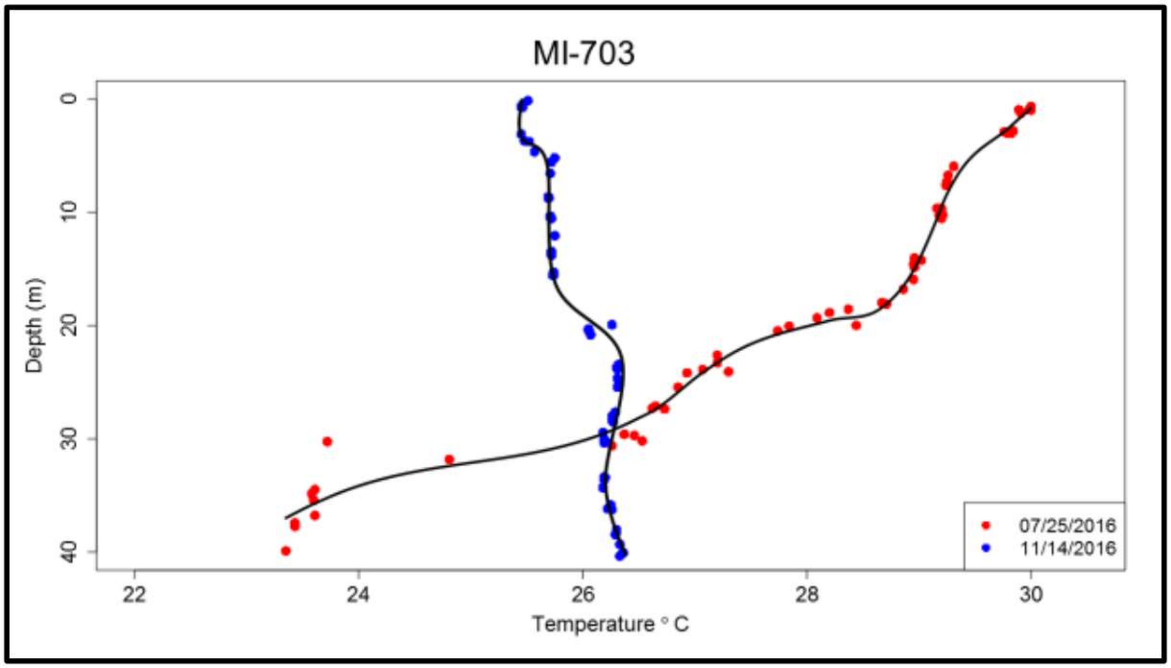

Figure 1.8: Temperature versus depth profiles created using hydrological data sampled with the Hydrolab DS-5 from the 40-m site. Red points are data collected 25 July 2016 and blue points are data collected 14 November 2016. Black smoothing lines were fit to the temperature data using a loess model.

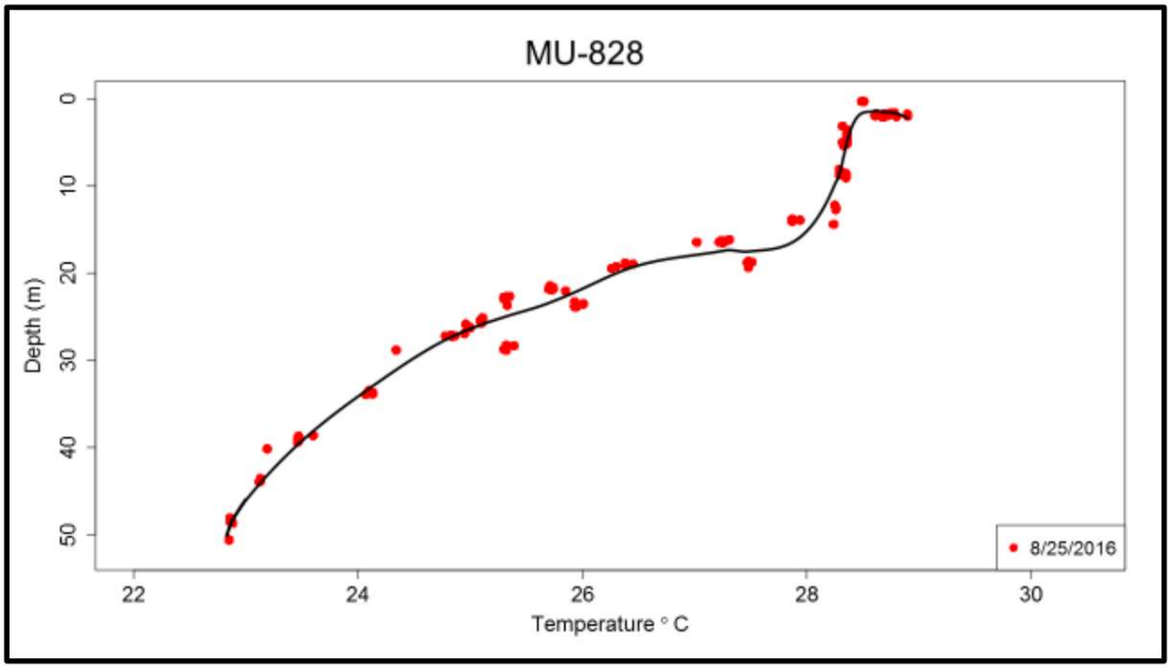

Figure 1.9: Temperature versus depth profile created using hydrological data sampled with the Hydrolab DS-5 from the 50-m site. All data points were collected during the single trip to MU-828 on 25 August 2016. Black smoothing line was fit to the temperature data using a loess model.

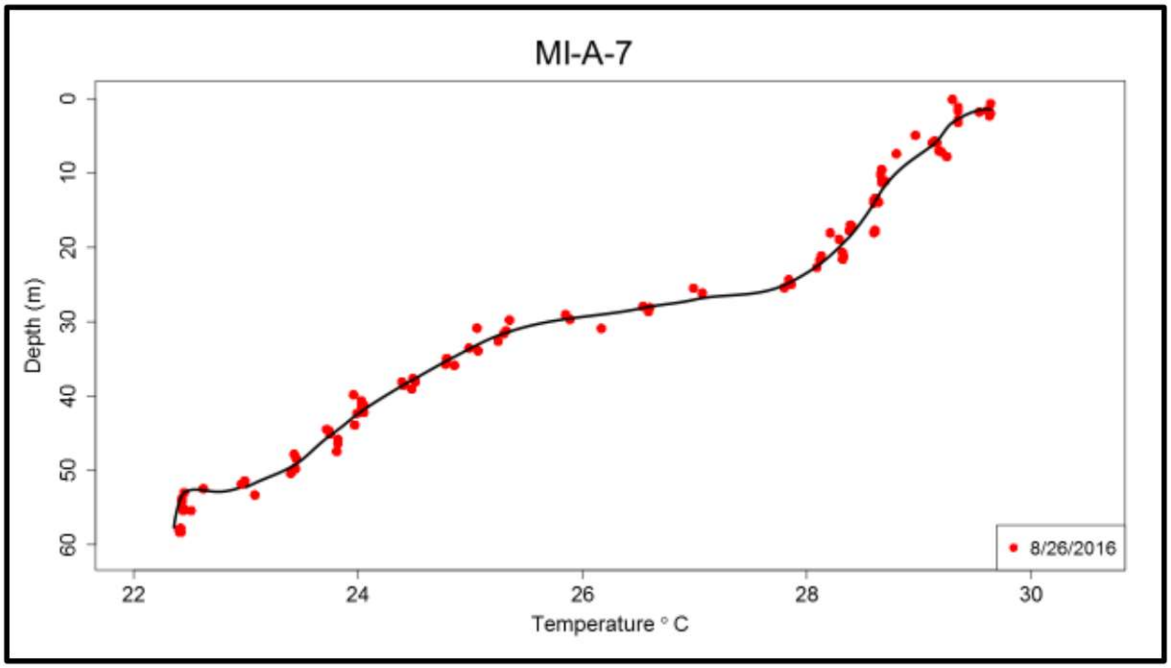

Figure 1.10: Temperature versus depth profile created using hydrological data sampled with the Hydrolab DS-5 from the 60-m site. All data points were collected during the single trip to MI-A-7 on 26 August 2016. Black smoothing line was fit to the temperature data using a loess model.

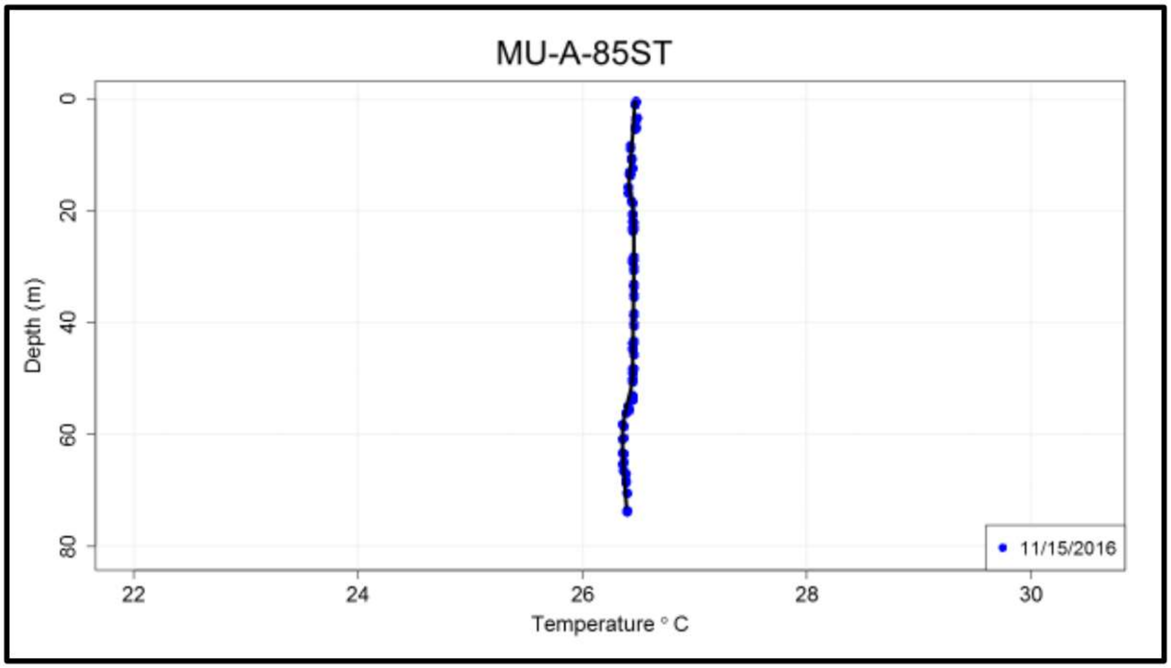

Figure 1.11: Temperature versus depth profile created using hydrological data sampled with the Hydrolab DS-5 from 80-m site. All data points were collected during the trip to the 80-m site on 15 November 2016. Hydrological data was not collected on 16 October 2016 due to Hydrolab technical difficulties. Black smoothing line was fit to the temperature data using a loess model.

Survival Analysis

Acoustic Data

Using a SeaQualizer, 45 Red Snapper were descended with treatment 1 and treatment 2. Twenty-four fish were released with treatment 3 using the Blacktip recompression tool. One fish from treatment 1 was an unintentional surface release and was removed from the analysis. One acoustic transmitter from treatment 1 failed to report pressure values, resulting in its removal from the analysis. Three fish from the treatment 3 were unintentional surface releases and one was a premature release (released at 3.1 m depth) that could not be reclassified to treatment 1 or 2. These four fish were removed from the analysis. Two prematurely released fish from the Blacktip recompression tool were reclassified to treatment 1, and two were reclassified to treatment 2 due to their close proximity to actual SeaQualizer release depths as verified through video analysis. Final sample sizes by treatment used in the survival analysis were 24, 23, and 16 fish descended using treatment 1, 2, and 3, respectively.

Depth profiles created in R using the 'ggplot2' package allowed for the classification of fates. Survivors were considered those fish that were released and exhibited active vertical movement through the water column. Fish were considered dead if they did not exhibit any movement during the time period the acoustic array was in place. If fish were observed being consumed by predators, depth profiles were referenced to verify mortality.

Percent survival was similar among release treatments. Fish descended to one-third of their capture depth experienced the lowest survival (46% ± 10%), while those descended to two-thirds of their capture depth experienced the highest survival (52% ± 13%). Fish descended to the bottom using the Blacktip recompression tool experienced 50% ± 10% survival. However, percent survival by release treatment exhibited no clear pattern (Figure 1.12). Overall post-release survival across all treatments and sites was 49% ± 6%. Survival was highest at the 30-m site (86% ± 9%) and lowest at the 80-m site (14% ± 9%), and decreased substantially with each incremental increase in capture depth (Figure 1.13).

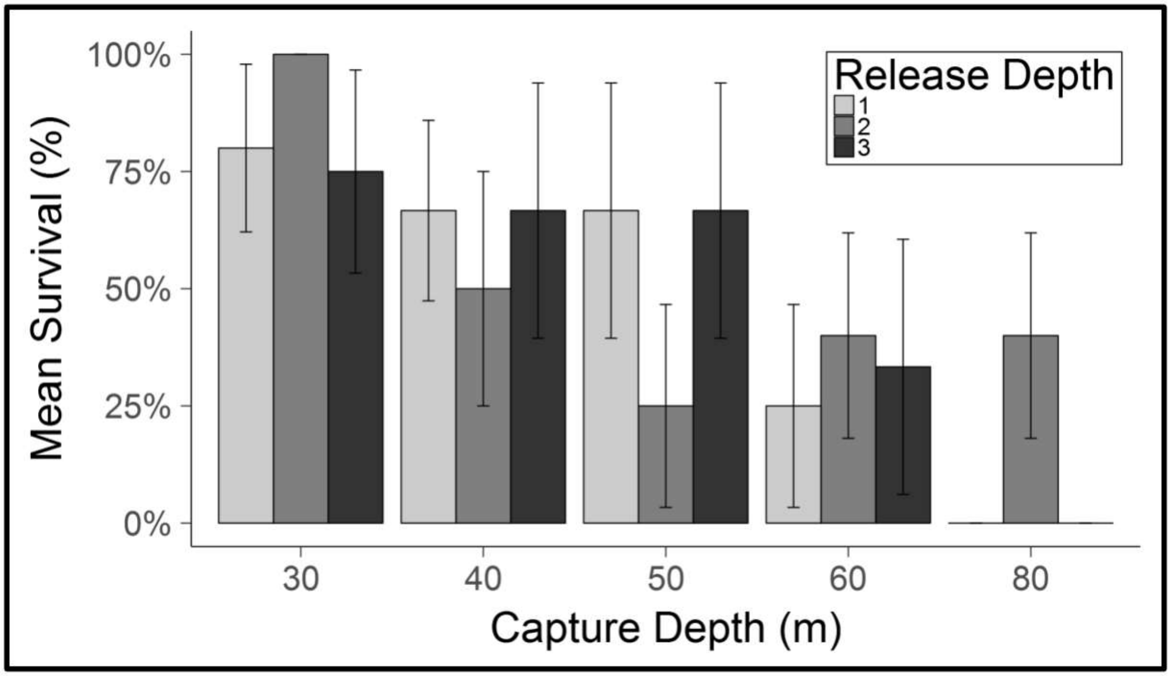

Figure 1.12: Bar graph showing mean percent survival by descender device release depth treatment and capture depth. Release depth 1 corresponds to fish released at one-third of the capture depth, 2 corresponds to release at two-thirds of the capture depth, and 3 corresponds to release at the bottom. Data making up a single column represents the mean survival for a specific treatment at a specific capture depth. Error bars represent the standard error of the mean.

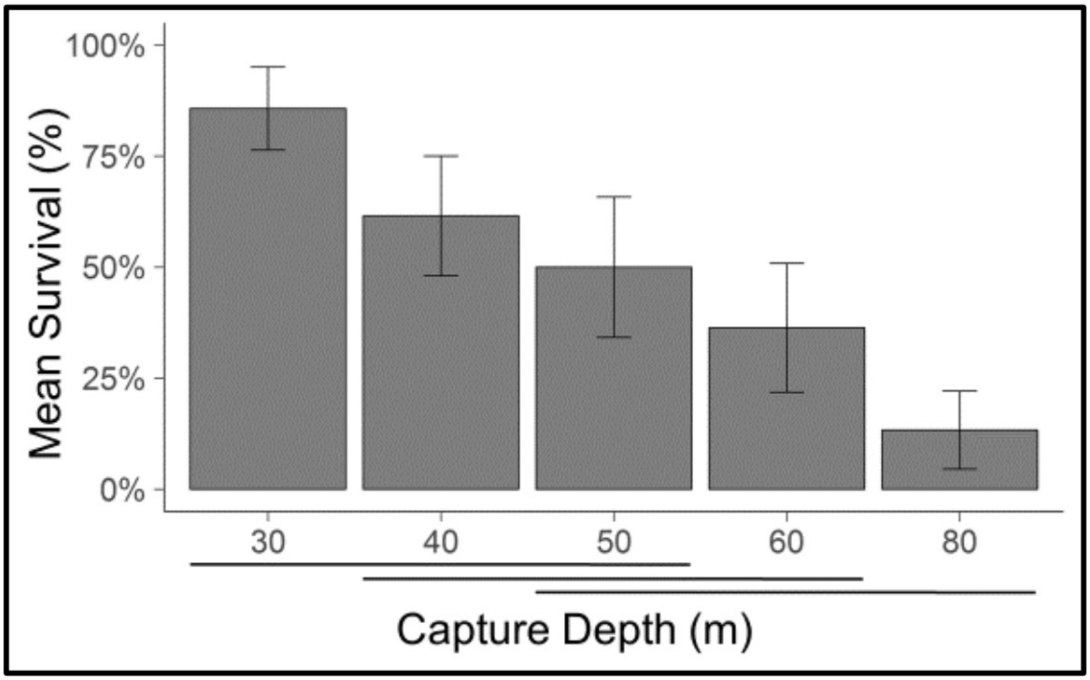

Figure 1.13 Bar graph showing mean percent survival by capture depth. Release depth 1 corresponds to fish released at one-third of the capture depth, 2 corresponds to release at two-thirds of the capture depth, and 3 corresponds to release at the bottom. Data making up a single column represents the mean survival among all treatments for that specific capture depth. Error bars represent the standard error of the mean. Capture depths not connected by black lines are significantly different.

Multiple LR was performed to identify influential variables for predicting survival rates. The initial model included five variables: capture depth, barotrauma impairment, deck time, fish total length, and release treatment (Table 1.3). Using RVI and list of component models based on AIC it was determined the only important variable in the initial model was capture depth (RVI: capture depth = 1.00). The second most important variable was fish total length (RVI = 0.40), followed by deck time (RVI = 0.34). The two least important variables were release treatment (RVI = 0.24) and barotrauma impairment (RVI = 0.24). Hosmer-Lemeshow test determined the model was an adequate fit (HL test; $p = 0.3162$).

The reduced logistic model included capture depth as the only predictor of survival and demonstrated a significant negative correlation ($p < 0.001$; Table 1.3). Goodness-of-fit was again determined to be adequate using the Hosmer-Lemeshow test (HL test; $p = 0.7889$). Using McFadden's pseudo-R^2, the amount of deviance explained decreased 2.9% from the initial model to the reduced model (Initial model: 0.228, reduced model: 0.199). Overall model predictive accuracy was 71.4% (i.e. 18 wrong out of 63 predictions). Twenty-five percent survival was predicted at 67 m, 50% survival at 51 m, and 75% survival at 35 m (Figure 1.14).

Table 1.3: Logistic regression (LR) results from the initial and reduced model used to predict survival. The term β refers to the LR coefficients, SE is standard error, *df* is degrees of freedom used by that predictor, Wald is the Wald test statistic defined as $(\beta / SE)^2$, *P* is the probability, and odds ratio (OR) is the exponentiation of β.

Survival Predictor	β	SE	df	Wald	*P*	OR
Initial Model						
Capture Depth	-0.0655	0.0185	1	11.8928	0.0005	0.9365
Barotrauma Impairment	0.2968	2.3057	1	0.0164	0.8980	1.3455
Deck Time	0.0113	0.0110	1	1.0395	0.3079	1.0114
Fish Total Length	-0.0057	0.0047	1	1.5333	0.2156	0.9943
Release Treatment	-0.0471	0.4034	1	0.0136	0.9071	0.9540
Intercept constant	4.5741	3.1432	1	--	0.1456	--
Reduced Model						
Capture Depth (m)	-0.0678	0.0190	1	12.7876	0.0003	0.9345
Intercept constant	3.4394	0.9902	1	--	0.0007	--

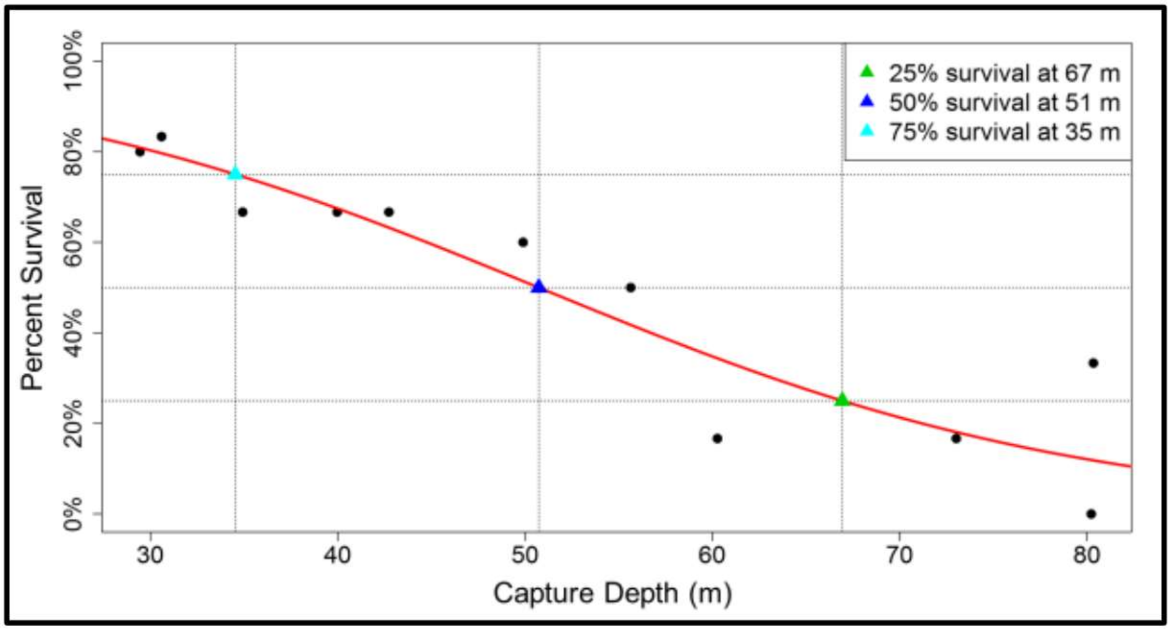

Figure 1.14: Logistic plot showing percent survival by capture depth. Groupings of binary survival values were compiled into 11 distinct groups so that plotting aesthetics were based on those that best represented the fitted model. Red line is the fitted line from the logistic regression model where capture depth was used to predict survival. Triangles are predicted bottom depths for 25%, 50%, and 75% survival.

Survival and Water Temperature

Thermocline presence or absence showed no significant effect on survival rates of released fish (Table 1.4). The depth at which fish were released in relation to thermocline location within the water column (when present) was also not a significant predictor of survival (Table 1.4). Varying water temperature showed no significant effect on the survival of released fish.

Table 1.4: Logistic regression (LR) results from the models created to test if thermocline presence or absence and release depth in relation to thermocline location affected survival rates. Thermocline P/A corresponds to the model where presence or absence was used to predict survival and Thermocline A/B corresponds to the model where releasing above or below the thermocline was used to predict survival. The term β refers to the LR coefficients, SE is standard error, *df* is degrees of freedom used by that predictor, Wald is the Wald test statistic defined as $(\beta \div \text{SE})^2$, p is the probability, and the odds ratio (OR) is the exponentiation of β.

Survival Predictor	β	SE	df	Wald	*P*	OR
Thermocline P/A						
Capture Depth	-0.0883	0.0291	1	9.1780	0.0025	0.9155
Thermocline P/A	-2.8065	2.5395	1	1.2214	0.2691	0.0604
Depth*Thermo P/A	0.0303	0.0436	1	0.4816	0.4877	1.0307
Intercept constant	5.4164	2.0444	1	--	0.0081	--
Thermocline A/B						
Capture Depth	-0.0991	0.0420	1	5.5700	0.0183	0.9057
Thermocline A/B	-2.8275	2.4210	1	1.3640	0.2429	0.0592
Depth*Thermo A/B	0.0645	0.0492	1	1.7225	0.1894	1.0666
Intercept constant	4.6448	1.9721	1	--	0.0185	--

Video and Behavioral Release Analysis

Of the 272 Red Snapper released in this experiment, 244 were released from the CRSSBO on a SeaQualizer or Blacktip and assigned a BR score using the scoring criteria defined in Table 1.1. Twelve individuals were inadvertently released at the surface and could not be assigned a BR score. The presence of a nepheloid layer, a turbid stratum of water comprised of suspended bottom sediments common in the Gulf of Mexico, prevented assignment of BR scores to 16 more individuals. Due to the absence of a BR score, a total of 28 individuals were omitted from the behavioral release analysis. To successfully model an OLR, all levels of the dependent variable must be on an ordinal scale, therefore, fish that were classified as ‘P’ (consumed or fatally attacked by a predator during or immediately after release) were reclassified as '3' in OLR models.

The BR scores were similar among release treatments (Figure 1.14). Mean BR scores were 1.83 ± 0.08, 1.84 ± 0.08, and 1.78 ± 0.10 for release treatments 1, 2, and 3, respectively. When compared among capture depths, BR scores exhibited a positive correlation with capture depth. Mean BR scores were lowest at the 30-m site (1.25 ± 0.06) and highest at the 80-m site (2.43 ± 0.10), and increased with each capture depth.

The presence of predators in CRSSBO videos increased with capture depth. The 50-m, 60-m, and 80-m sites supported high densities of Great Barracuda *Sphyraena barracuda* and Greater Amberjack *Seriola dumerili*. Additional potential Red Snapper predators observed at these sites included Sandbar shark *Carcharhinus plumbeus*, Silky shark *Carcharhinus falciformis*, Spinner shark *Carcharhinus brevipinna*, Blacktip shark *Carcharhinus limbatus*, Scalloped Hammerhead shark *Sphyrna lewini*, Bottlenose Dolphin *Tursiops truncatus*, and large groupers (Serranidae). Using CRSSBO video, a total of 18 Red Snapper were visibly consumed or fatally attacked by a predator or group of predators. Thirteen of these depredation events occurred at the 80-m site, two at the 60-m site, and three at 50-m site. The most common predator to attack descended fish was Great Barracuda, followed by Greater Amberjack. One Red Snapper was observed being eaten by a Bottlenose Dolphin at 44 m depth.

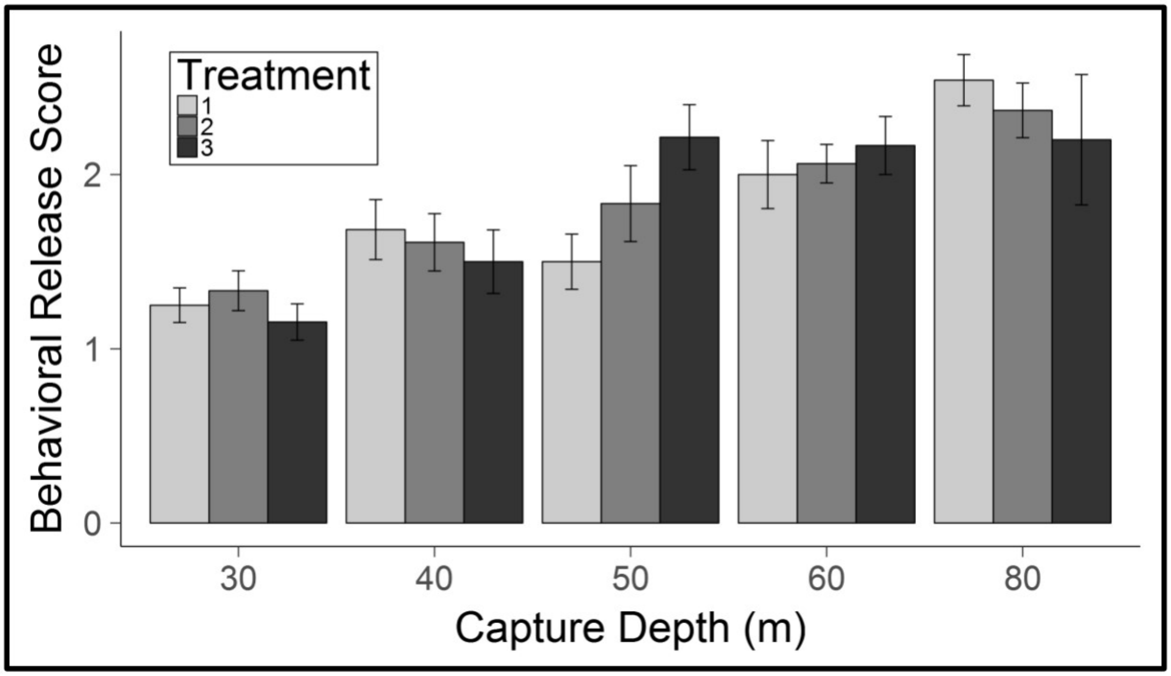

Figure 1.15: Bar graph showing mean BR score by release treatment and capture depth. Release depth 1 corresponds to fish released at one-third of the capture depth, 2 corresponds to release at two-thirds of the capture depth, and 3 corresponds to release at the bottom. Data making up a single column represents the mean BR score for a specific release treatment at a specific capture depth. Error bars represent the standard error of the mean.

Modeling Behavioral Release Scores

The initial OLR model included the following explanatory variables: capture depth, barotrauma impairment, deck time, fish total length, and release treatment. The only two significant predictors from the initial model were capture depth and deck time (Table 1.4). A modified Hosmer-Lemeshow goodness-of-fit test designed for OLR models was applied and determined the initial model was an adequate fit to the data (HL test; $p = 0.5447$). Using the RVI and list of component models based on AIC, it was determined capture depth and deck time were the only important explanatory variables in the initial model (RVI: capture depth = 1.00, deck time = 0.92). Barotrauma impairment, fish total length, and release treatment exhibited no significant relationship with BR score and were removed from the initial model. The reduced model contained two explanatory variables: capture depth and deck time, and were both positively correlated with BR score (Table 1.4). A goodness-of-fit test concluded the model was an adequate fit (HL test; $P = 0.4163$).

Table 1.4: Ordinal logistic regression (OLR) results from the initial and reduced model used to predict behavioral release scores assigned during CRSSBO video assessment. The term β refers to the OLR coefficients, SE is standard error, *df* is degrees of freedom used by that predictor, Wald is the Wald test statistic defined as $(\beta / \mathrm{SE})^2$, p is the probability, and OR is odds ratio defined as the exponentiation of β.

BR Score Predictor	β	SE	df	Wald	P	OR
Initial Model						
Capture Depth	0.0661	0.0084	1	61.8442	2.89E-15	1.0683
Barotrauma Impairment	-0.6044	0.9390	1	0.4143	0.5198	0.5464
Deck Time	0.0052	0.0020	1	6.7600	0.0101	1.0052
Fish Total Length	-0.0003	0.0017	1	0.0311	0.8707	0.9997
Release Treatment	0.0280	0.1675	1	0.0279	0.8673	1.0284
Reduced Model						
Capture Depth	0.0659	0.0083	1	63.03977	2.17E-15	1.0682
Deck Time	0.0051	0.0020	1	6.5025	0.0097	1.0051

<u>Comparison of Behavioral Release Scores and Capture Depth</u>

To understand how BR scores were affected by capture depth, an OLR was performed using BR scores as the ordinal dependent variable and capture depth as the independent variable. There was a significant positive logistic correlation between BR scores and capture depth (OLR; $\beta = 0.0653$, $\chi = 62.3071$, $p < 0.0001$). As capture depth increased, fish were more likely to be scored higher on the behavioral release scoring scale. The odds ratio calculated for capture depth was 1.0675 and could be interpreted by the following: the odds of being scored a 3 versus a 1 or 2 increased 6.75% with each incremental increase of one meter capture depth. Fish caught at 30 m had 5% chance of receiving a BR score of 3, while fish captured at 80 m had a 58% chance of being scored a 3 (Figure 1.15). A goodness-of-fit test determined the model was an adequate fit (HL test; $P = 0.6139$).

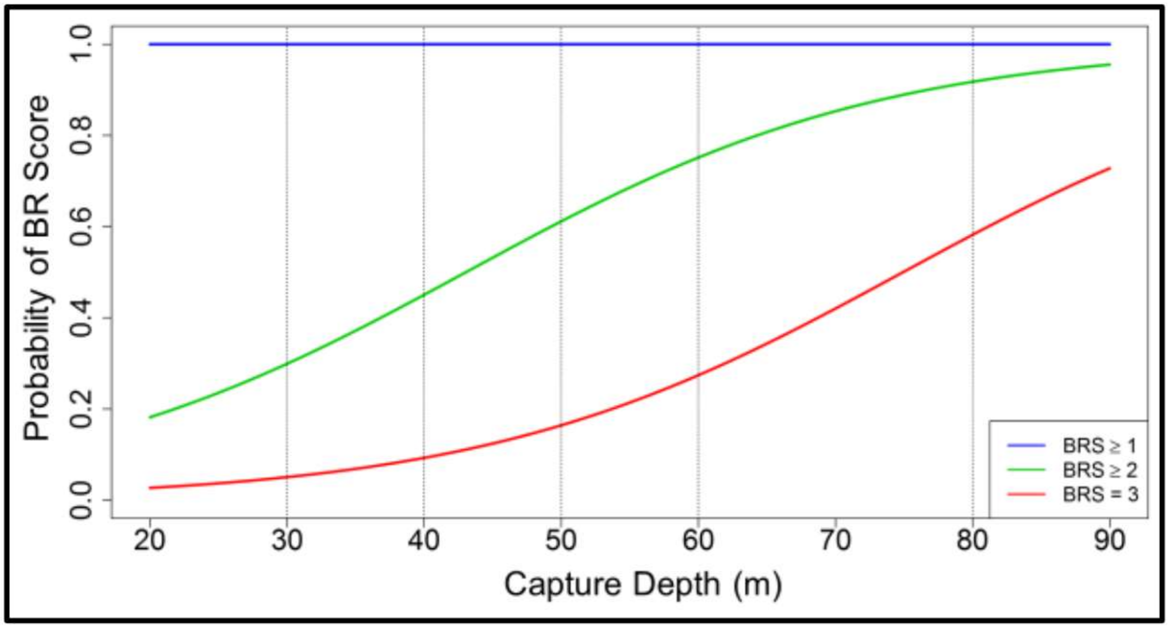

Figure 1.16: Logistic plot from the ordinal logistic regression model predicting BR scores using capture depth. The y-axis is the probability of being classified a BR score and the x-axis is capture depth in meters. The red line represents the change in probability of being scored a 3 as capture depth increases. The green line represents the change in probability of being scored a 2 or greater as capture depth increases. The blue line represents the probability of being scored a 1 or greater, and is constant. Dashed vertical lines mark the capture depths of the sites visited during this study.

<u>SeaQualizer Performance</u>

A total of five programmed pop-off settings (30 ft, 50 ft, 70 ft, 100 ft, 150 ft) were used on two different SeaQualizer models (shallow and standard) during the experiment. All but one setting (70 ft) yielded actual pop-off depths shallower than the programmed setting. Mean actual pop-off depths for the 30, 50, 70, 100, and 150 ft release settings were 25, 42, 75, 85, and 141 ft, respectively. Variation in actual pop-off depth was much higher for the 100 and 150 ft settings (Figure 1.15).

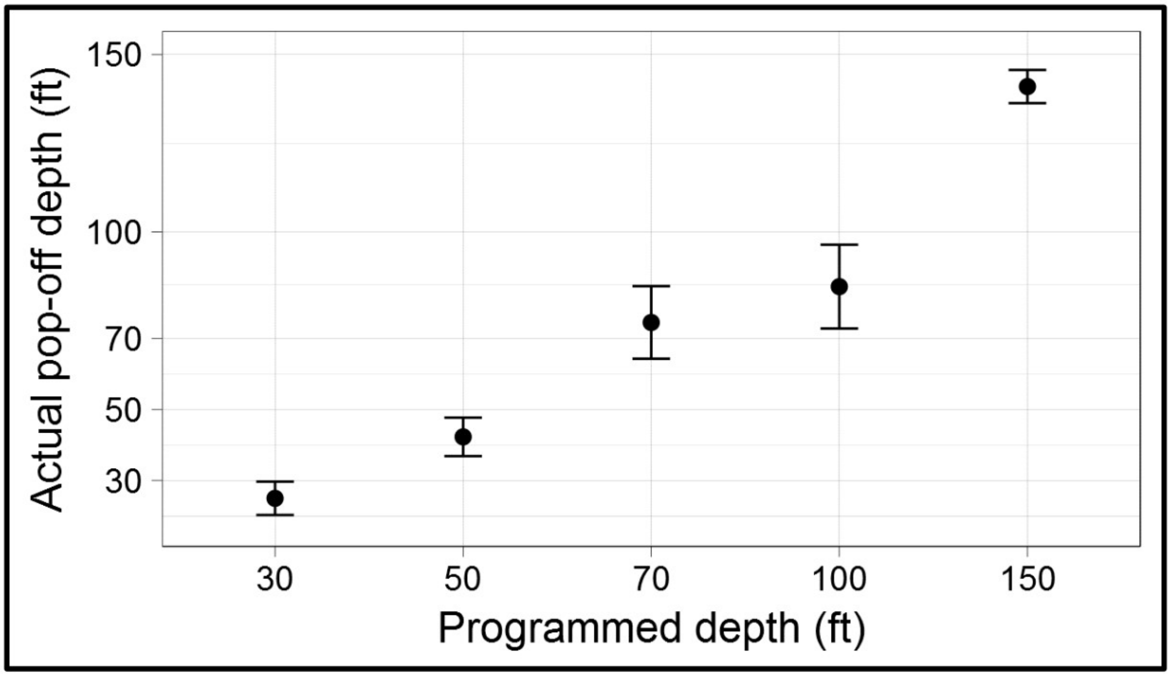

Figure 1.17: Plot comparing actual SeaQualizer pop-off depths to programmed pop-off depths. SeaQualizer depth settings are measured in feet, so the subsequent plot units are in feet. Black dots represent the mean pop-off depth associated with the programmed pop-off depth of all releases during the experiment for that specific setting. Error bars represent standard deviation.

DISCUSSION

The goal of this study was to refine best-use practices of descender devices across a capture depth gradient and relate barotrauma impairment to release condition and post-release mortality using field experimentation, acoustic telemetry, and underwater video footage. Survival was not affected by release treatment, which suggests that as long as discards are recompressed to at least one-third of their capture depth, odds of survival are similar to releasing a discard at the seafloor. However, survival decreased substantially with increased capture depth, a situation observed frequently in the literature. Predation of released fish also increased dramatically with capture depth, suggesting the compounding effects of depth and potential for predation substantially decrease the odds of survival in deep-caught fish. Externally visible barotrauma symptoms increased from the 30-m site to the 50-m site but decreased from the 50-m site to the 80-m site. Lowest barotrauma impairment scores were observed at the deepest site. This decrease in visible barotrauma symptoms is attributed to catastrophic decompression, which causes swim bladder rupture and a consequent decrease in visible barotrauma impairment. Fish caught deeper than 50 m experienced greater than 50% mortality, suggesting there may be a survival threshold at approximately 55 m capture depth. Anglers should use caution if utilizing barotrauma impairment indices to predict long-term survival of released Red Snapper.

Rapid recompression through the use of cages and descender devices have become increasingly popular in recent years and many studies have proved their effectiveness in reducing discard mortality in a variety of deep-water fish species (Jarvis and Lowe 2008, Hocchalter and Reed 2011, Rogers et al. 2011, Hannah et al. 2012, Pribyl et al. 2012, Sumpton et al. 2010, Brown et al. 2010, Butcher et al. 2012, Drumhiller et al. 2015, Curtis et al. 2015). Similar to the GMFMC and South Atlantic Fishery Management Council (SAFMC), the Pacific Fishery Management Council (PFMC) has been faced with managing deep-water species with high discard mortality rates. As recreational fishing became more prevalent in the Pacific offshore region, the PFMC implemented various no-take zones and constrained fishing areas due to high discard mortality rates associated with multiple Rockfish species (*Sebastes* spp.). In an attempt to alleviate mortality, recreational anglers began voluntarily employing the use of rapid recompression to release Rockfish in regions still open to fishing so managers would recognize its benefit to the fishery (Dick 2017). In 2014, the PFMC adopted improved discard mortality rates for three species (Cowcod *S. levis*, Canary *S. pinniger*, and Yelloweye *S. ruberimus*) of Rockfish when released with descender devices (GMT 2014). Due to deteriorating reef fish fishing seasons, these external success stories have spurred debate among both anglers and managing agencies in the GOM and South Atlantic. Reducing discard mortality with descender devices has been recognized by both scientists and anglers as a potential means to improve this situation. Therefore, studies refining the knowledge associated with the use of descender devices on Red Snapper are crucial if future management efforts plan to implement their required use in federal waters of the GOM.

Studies performed by Curtis et al. (2015) and Stunz et al. (2017) provided evidence that descender devices can significantly improve survival in released Red Snapper, and in most cases, outperform traditional venting techniques. Defining ideal practices for these devices is essential if implementation of a requirement to employ them is a possibility. I found descender device release depth was not related to post-release survival, concluding that anglers can simply recompress discards to at least one-third of the capture depth instead of descending to the seafloor. Not only was survival unaffected by release depth, descender device release behavior was also unaffected. Predation frequency was less for fish released at the bottom, but these results may be biased due to the inability to observe video evidence of predation near the seafloor due to the presence of a nepheloid layer. During descent, some predators shadowed the CRSSBO until the fish was released, even if that meant the predator descending from surface waters to the seafloor. If a predator desired to consume a discard during this study, the outcome was inevitable. Considering survival was similar across all three release depths, releasing discards at one-third of their capture depth ultimately allows anglers to save time when using a descender device, an essential improvement in an otherwise time-consuming process. Time spent venting fish and massaging excess expanded air out of the body cavity could instead be used rapidly recompressing. Moreover, immediately placing discards onto a descender device and back in the water reduces the amount of handling time and increases oxygen uptake, resulting in an increased chance of long-term survival (Pollock and Pine 2007, Alós 2008, Tomasso et al. 1996, Wood et al. 1983).

Venting fish requires sufficient knowledge of the discard's physiology to properly insert the needle into the swim bladder and release the trapped gases accumulated during capture. Often, recreational anglers are unfamiliar with the proper venting techniques, and the resulting complications of improper venting can result in substantially negative consequences to a fishery, particularly when the majority of anglers are employing the devices improperly (Scyphers et al. 2013). Unlike venting tools, descender devices such as the SeaQualizer and Blacktip recompression tool do not require users to fully understand the complex anatomy of the species being released. Proper release practices instead require knowledge on the correct operation of the device itself, which concerning the SeaQualizer and Blacktip, is rather simple. When comparing utility between the two devices used in this study, I found the SeaQualizer to be considerably more user friendly, efficient, and expeditious than the Blacktip, especially when releasing discards at greater depths. Constant tension was required for the Blacktip jaws to remain clamped on the discarded fish's jaw, making initial attachment of the fish cumbersome. One researcher was forced to position the fish at a precise angle while another researcher alleviated the weight on the Blacktip jaws. The two then had to function in unison to reposition the weight that allowed the jaws to clamp onto the fish. If tension was released during any point in this process, the fish was released from the device. Once underwater, medium sized waves often produced sufficient slack in the line to prematurely release a fish even when additional weight was added to provide supplementary tension. Surface releases were also common due to the difficulty associated with initially placing the fish in the water while simultaneously maintaining tension. Sumpton et al. (2010) reported similar circumstances when using an inverted weighted hook to release Red Emperor and also noted larger fish released prematurely more often than smaller fish. Similar to Red Emperor, larger Red Snapper were able to unclamp themselves from the Blacktip when violent headshakes were performed. Conversely, no premature or surface releases occurred when employing the SeaQualizer. Video footage obtained with the CRSSBO verified Red Snapper remained on the device until the predetermined depth was reached, even if larger fish violently shook their heads attempting to escape. Moreover, employment of the SeaQualizer only involves a single user, whereas the Blacktip requires two for effective operation. Given the abundant positive qualities and uses of the SeaQualizer, it is highly recommended that recreational anglers wishing to improve survival in released Red Snapper use descender devices.

Acoustic telemetry studies involving the attachment of transmitters to live fish are generally accompanied with considerable difficulty, especially when attempting to minimize the effect of extraneous variables on experimental outcomes. After tagging fish at the 30-m and 40-m sites, it was discovered that a large number of acoustic transmitters were shipped with malfunctioning batteries and were never able to transmit to the hydrophone array despite video evidence of tags passing within one meter of a hydrophone. Due to tag malfunctions and the inability to capture fish at various locations, fish tagging was performed over a six-month period where atmospheric and hydrological conditions fluctuated substantially, many of which held the potential to affect survival of released fish. Season and corresponding fluctuations in water temperatures have been shown to significantly affect post-release survival in Red Snapper (Campbell et al. 2014, Curtis et al. 2015, Render and Wilson 1994). While there was no treatment to assess the effect of season on survival in this study, fish were inadvertently captured and released during summer and fall months. Thermoclines were present for approximately half of the tagging trips and seafloor temperatures ranged from 22°C to nearly 30°C while sea surface temperatures ranged from 23°C to 30°C. However, neither post-release survival nor external barotrauma symptoms were significantly affected by these varying environmental conditions. Curtis et al. (2015) found significant effects of season on survival in Red Snapper, but despite varying temperature differentials observed in my study, survivability was unaffected. Manually descending Red Snapper back to depth prevented fish from exerting excess energy to submerge in water temperatures exceeding their thermal maximum. While vented fish are no longer buoyant, energy is expended swimming back to depth in warm waters which may further reduce the chance of survival. Additionally, they will become easy targets for predators during their recovery period.

The mean number of observed external barotrauma symptoms was highest in fish captured from 50 m and lowest when captured from 80 m. Impairment increased up to the 50-m site when anglers began to notice 'fizzing', which occurs when the swim bladder of a fish ruptures due to the immense pressure accumulated in the organ during ascent. Catastrophic decompression (or "fizzing"), can be identified by large plumes of bubbles exiting the fish's orifices during the last few meters of ascent. External barotrauma symptoms virtually disappear if a fish experiences catastrophic decompression, unless the stomach or intestines remain distended or substantial subcutaneous hemorrhaging has occurred (Rummer 2007; Rogers et al. 2008; Roach et al. 2011; Campbell et al. 2013). I discovered when the frequency of catastrophic decompression increased from the 50-m to 80m sites, external signs of barotrauma decreased dramatically. Brown et al. (2010) reported similar results in Red Emperor, where the proportion of Red Emperor with barotrauma was significantly less if caught from 40-50 m rather than 30-40 m. Post-capture dissections of barotrauma-symptom-free fish confirmed that swim bladders had ruptured in the majority of Red Emperor captured in depths greater than 40 m. Stunz et al (2017) reported a maximum barotrauma impairment score at approximately 55 m bottom depth in Red Snapper. These results imply that catastrophic decompression may occur when a maximum threshold capture depth is reached. BI scores began to decrease dramatically at the 60 m site, followed by the lowest scores of any site at 80 m. The GAM model in Figure 1.6 predicted the decrease in BI scores to begin occurring at 53 m, matching results from Stunz et al. (2017). It is vital for anglers to realize that, although external signs of trauma may be absent, internal injuries associated with catastrophic decompression severely decrease the chance of survival (Rummer and Bennet 2005). Fish with ruptured swim bladders can seem entirely unharmed and will likely submerge immediately when released, suggesting to anglers it is sufficiently healthy to survive long-term. Sixty-eight percent of recreational anglers use the ability of a fish to submerge as a viable means to gauge post-release survival (Tompkins unpublished data). Unfortunately, barotrauma indices and submergence ability are not valid techniques to gauge potential survivability of released Red Snapper, particularly when capturing fish from 50 m or greater. Therefore, it is vital for anglers and observers to recognize that catastrophic decompression may not show instantaneous effects on fish, but instead significantly increases the possibility of succumbing to immediate or delayed mortality.

Various studies attempting to determine the causes of mortality in deep water fish concluded that capture depth is a crucial factor in predicting survival (Gitschlag and Renaud 1994, Burns et al. 2004, Alós 2008, Hannah et al. 2008, Brown et al. 2010, Campbell et al. 2010a, Curtis et al. 2015). Rummer and Bennet (2005) found increasingly traumatic injuries to multiple vital organs in Red Snapper as capture depth increased, and in some scenarios ascent from greater depths resulted in catastrophic decompression. I discovered that, if fishing in 30 m or greater, for every 10-m increase in capture depth, the odds of survival decrease by 52%. While the negative effect of capture depth on survival has been well documented in the literature, I found that 50% mortality coincided with the commencement of frequent catastrophic decompression symptoms. These findings indicate a capture depth threshold for survivability in Red Snapper. Results from Stunz et al. (2017) reported identical results from a larger sample size confirming the existence of such a threshold. Injuries sustained from catastrophic decompression often resulted in nonresponsive fish when released from the descender device. This is likely due to swim bladder rupture which hinders the ability of discards to regulate buoyancy and subsequent location in the water column, providing predators an easy target. When coupled with the increased frequency of predators at greater depths, catastrophically decompressed fish were confronted with progressively lower odds of survival.

Acoustic telemetry has recently become a valuable tool for estimating post-release mortality in deep-water fishes (Curtis et al. 2015; Stunz et al. 2017; Johnson et al. 2015; Topping and Szedlmayer 2011a; O'Dor et al. 1998). While this is an innovative method to track fish after release, the true fate of the fish is still unknown due to the potential for predation, tag shedding, and emigration from the acoustic array. Using underwater video footage to capture the release of acoustically tagged individuals, I was able to correctly classify the immediate fate of fish. Immediate predation was observed on 18 occasions, with 13 of those occurring at the 80-m site. I was able to couple depth profiles of acoustically tagged individuals to observed predation events. This allowed me to compare the depth profile of a known survived fish to that of a fish that was observed being consumed by a predator. While differences existed, depth profiles belonging to predators that ingested an acoustic transmitter were strikingly similar to known survived discards. Side-by-side comparisons provided indications on how to classify a profile as a survived fish or a predator. After careful examination of fish depth profiles derived from other acoustic telemetry studies, high potential was found for falsely classifying predator profiles as survived discards. Video evidence of predation provided new insights into the fate of descended fish and even allowed the classification of non-acoustically tagged fish as predation events.

Post-release or simulated post-release behavior of Red Snapper has been examined in past studies (Gitschlag and Renaud 1994; Szedlmayer and Schroepfer 2005; Campbell et al. 2010a; Campbell et al. 2010b; Topping and Szedlmayer 2011a; Curtis et al. 2015; Drumhiller et al. 2015); however, relating underwater release behavior to post-release mortality in Red Snapper exhibiting barotrauma has not been examined. Using a behavioral release scoring criteria, I was able to correlate descender device release behavior with immediate mortality. As capture depth increased, fish grew increasingly impaired due to barotrauma injuries, and this impairment was displayed in the immediate behavior of released fish. Using OLR, I discovered that released fish captured from 80 m had a 92% chance of being classified a BR score of 2 or 3, while fish captured from 30 m had a 5% chance of being classified a BR score of 3. Fish classified as 3 either appeared dead or were so severely impaired that swimming ability was substantially compromised. Predators recognized this impairment and responded swiftly to motionless, slowly sinking fish. Likewise, Campbell et al. (2010) reported reduced predator avoidance ability in Red Snapper for up to 15 minutes after simulated capture and release from 40 m or greater. Predation frequency and overall predator abundance increased dramatically from the 50-m to 80-m sites. Thirty percent of the mortality observed at the three deepest sites was caused by predation and was likely triggered by opportunistic predators exploiting the elevated impairment experienced by catastrophically decompressed fish (Raby et al. 2014). While post-release mortality was very high at deeper sites, it is imperative for anglers to understand the benefit of recompressing fish instead of releasing at the surface. Descending a fish back to or near its swimming depth, regardless of catastrophic decompression impairment, will locate that fish closer to a potential position on the reef where predators avoidance and recovery from barotrauma injuries can ensue. Surface released fish are forced to swim past high densities of predators suspended throughout the water column, increasing the risk for predation and stress during an already highly vulnerable situation.

SeaQualizer performance was validated by comparing preset release depths to actual pop-off depths using a scuba depth gauge attached within the field-of-view of a GoPro on the CRSSBO. I found that all preset release depths, except for the 70 ft setting that opened 5 ft deeper on average, released prior to reaching the prescribed depth. The 100 ft setting resulted in actual pop-off depths shallower than all other settings (85 ft). The tendency for SeaQualizers to release fish shallower than the prescribed settings is unlikely a mere consequence. Excluding the 70 ft release setting, anglers can confidently set their SeaQualizer to release when a setting is chosen at or slightly shallower than their fishing depth without the concern of reeling up a fish that was not released. In most cases, it would be ideal for the device to release earlier rather than later, especially when anglers employ a designated fishing rod for SeaQualizer deployment where distances are marked on their fishing line. Not once during this study did the SeaQualizer release prematurely or delayed to the point where it affected experimental design.

Determining effective release methods to reduce discard mortality in recreationally caught Red Snapper is essential for improving survival and potentially increasing access to the fishery, extending restricted fishing seasons, and simply promoting wise and ethical conservation practices. Descender devices provide managers an advanced, but simple, strategy to increase post-release survival of Red Snapper. This study refined the best-use practices for such devices, provided guidance for successfully employing them, and can offer anglers increased confidence that their discard will survive long-term. Moreover, this study also provided new insights into the immediate fate of discards released with descender devices. Predation is an often overlooked and understudied challenge associated with releasing impaired fish back into the environment (Raby et al. 2014), but descender devices deliver an easily employed tactic to improve survival compared with traditional methods. With a refined understanding of discard mortality rates associated with descender devices managers can integrate these findings into stock assessments to reduce the uncertainty concerning discard mortality in the Red Snapper fishery.

CHAPTER II

ASSESSING RECREATIONAL ANGLER PERCEPTIONS OF DESCENDER DEVICES IN THE GULF OF MEXICO AND SOUTH ATLANTIC REEF FISH FISHERIES

INTRODUCTION

Recreational fishing is an important outdoor leisure activity to over 33 million people in the U.S. (Southwick Associates 2012). It generates substantial income to local, regional, and national economies while providing users an alternative means of domestic consumption (Arlinghaus et al. 2007). According to U.S. Fish and Wildlife Service, recreational fishing is one of the most popular outdoor activities, with economic impacts totaling over $63 billion annually (NMFS 2015) and producing over 828,000 jobs in 2011 (USFWS 2012). The highest concentration of saltwater recreational anglers reside in the southeast U.S. (North Carolina to Texas), a region that supports over 5 million saltwater recreational anglers and generates $15 billion in revenue for the economy (NMFS 2012), making it an important location to study angler perceptions on fishery-related issues.

Over 50 species of reef associated fish from nine families are managed by the South Atlantic Fishery Management Council (SAFMC) and Gulf of Mexico Fishery Management Council (GMFMC), many of which have been historically overfished or are still experiencing overexploitation. Combined recreational landings for the South Atlantic and Gulf of Mexico (GOM) totaled over 12 million pounds in 2016 (SAFMC 2017; GMFMC 2017), making this southeast region the largest federally managed recreational fishery in the nation. Many fisheries in the region are overfished and rely on closed seasons when only catch-and-release fishing is permitted. For species such as Red Snapper, discard rates are higher outside of the directed fishery due to short, or even absent, summer fishing seasons.

While many recreational anglers retain their catch for consumption, approximately 57% of fish caught in the U.S. are released (Bartholomew and Bohnsack 2005). Catch-and-release fishing has become an increasingly popular method to conserve fishery resources through both voluntary practices and mandated regulations (Cowx 2002; Brownscombe et al. 2016). Moreover, increasing reductions in season and bag limits for many species results in very high discard rates, and in some cases are greater than the directed fishery. For example, GOM Red Snapper recreational discard rates are several times higher out of season than in season (SEDAR 2015). Moreover, many anglers targeting other species unintentionally catch Red Snapper, and these discards must be accounted for in stock assessments. The decision to discard a captured fish can rely on various reasons such as the fish being perceived as bycatch, a regulation in place requiring release (bag limits, size limits, closed season), belief that the fish will survive to be captured at a later date, and for ethical reasons (Cooke and Suski 2005). An essential assumption in the catch-and-release/discard process is that the fish survive long-term. While this assumption holds true for many species, post-release survival for deep-water, physoclistous (no connection between esophagus and swim bladder) reef fish is complicated by pressure-related injuries.

A suite of injuries collectively referred to as barotrauma occurs due to rapid decompression experienced during ascent, and has the potential to significantly reduce the odds of survival in Red Snapper and other deep-water reef fish (Rummer and Bennet 2005). Overcoming the issues surrounding barotrauma in catch-and-release fisheries is arguably one of the most important and unresolved complications facing managers today (Arlinghaus et al. 2007). New research is emerging that show positive effects of either venting or rapid recompression on the survival of reef fishes (Drumhiller et al. 2014; Curtis et al. 2015).

Fishery managers previously attempted to address the barotrauma issue in the GOM reef fish fishery by promulgating regulations that required anglers to possess a venting needle onboard any vessel fishing in federal waters (GMFMC 2007). Studies emerged soon after the enactment of the amendment that challenged the efficacy of venting reef fish exhibiting barotrauma, particularly as they related to misuse. For example, Scyphers et al. (2013) determined angler experience and knowledge on proper use of the tools was poor, and the popularity of the devices was high, potentially resulting in thousands of fish being injured by the process instead of benefitting. Wilde (2009) performed a broad meta-analysis to examine the effectiveness of venting to reduce discard mortality in a variety of fish species. His results concluded that venting should be avoided; however, another meta-analysis discovered venting to have positive effects (Eberts and Somers 2017), and their benefit to survival has been shown in other studies (Drumhiller et al. 2014; Curtis et al. 2015). Also, the recent development of alternate methods to mitigate barotrauma, such as descender devices, were becoming popular at the time, but the regulation did not allow for use of these alternative devices. Thus, in 2013, the requirement to possess a venting needle in federal waters of the GOM was rescinded. Recently, several fishery governing bodies have initiated a means to incorporate descending devices into their fishery management plans.

Due to increasingly shorter federal fishing seasons for popular species such as Red Snapper, managers in the GOM and South Atlantic have begun to explore new technologies to reduce discard mortality rates. One option, particularly targeted in recent studies, is rapidly recompressing fish through the employment of descender devices. The efficacy of these devices to reduce discard mortality in offshore reef fishes has been shown numerous times in the literature (Parker et al. 2006, Jarvis and Lowe 2008, Brown et al. 2010, Sumpton et al. 2010, Drumhiller et al. 2014, Curtis et al. 2015). One popular rapid recompression tool is the SeaQualizer, which offers users the option to descend and release a discard at one of three predetermined depths in the water column. SeaQualizers were designed to be deployed with a designated fishing rod and a weight heavy enough to rapidly sink positively buoyant fish. Despite their popularity among recreational anglers, no studies have examined angler perceptions or their willingness to use them in specific fisheries. Filling this data gap is an absolute necessity if managing entities eventually wish to require anglers to recompress discarded fish experiencing potentially fatal barotrauma symptoms. Dick (2017) interviewed fishery specialists, scientists, and managers to determine various challenges involved with the devices and to what extent mandating their use in the South Atlantic Red Snapper fishery would be possible. Study participants raised concerns with mandated use due to a lack of scientific research, limited survey data, and the issue with the multispecies complex in the South Atlantic reef fish fishery. Most participants also discussed the importance of angler involvement in the regulatory process and that trust between managers and stakeholders in the fishery would be vital for moving forward. Although Dick (2017) identified many of the issues presented by scientists and managers, the opinions and attitudes of offshore reef fish anglers from the GOM and South Atlantic have yet to be addressed.

A key metric to understanding the utility of descending devices is angler perception. Distributing surveys to users and stakeholders has shed light on previous issues in fisheries management (Scyphers et al. 2013), and understanding angler attitudes towards a tool that may serve as a key ingredient in solving the discard mortality issue is essential. A key fishery to test the perception of these devices is the GOM Red Snapper. Red Snapper anglers in the South Atlantic and GOM have been faced with increasingly shorter summer seasons despite the fisheries having improved dramatically in recent years. Substantial reductions in access and loss of major economic drivers could be curbed if these devices were used in the fishery. Thus, surveying angler opinions and attitudes concerning future regulations can aid in stakeholders regaining confidence in the entities built to provide users the opportunity to target offshore reef fish recreationally.

Thus, the **purpose** of this chapter is to assess the perceptions and opinions of recreational anglers from North Carolina to Texas surrounding the use of descender devices in the offshore reef fish fishery using survey data and scientist observer trips. The **objectives** of this chapter will include:

1. Determine how anglers perceive the utility and effectiveness of rapid recompression devices to reduce discard mortality in offshore reef fish of the South Atlantic and Gulf of Mexico.

    H_{A1}: Anglers will have a generally positive attitude towards rapid recompression devices, specifically, the SeaQualizer, and be willing to use them on their own vessels.

2. Compare those perceptions addressed in objective one among private, guided, and headboat captains.

    H_{A1}: Different sectors of the fishery may have varying perceptions of descended devices, and this may influence their use.

METHODS

SeaQualizer Distribution

To examine recreational angler perceptions regarding the use of descender devices to reduce discard mortality of offshore reef fish in the South Atlantic and GOM, partnerships and collaborations were formed with various sportfishing entities to distribute descender devices to recreational anglers. FishSmart, a science-based program that promotes catch-and-release and mortality-reducing methods of fishing, donated over one-thousand SeaQualizers for distribution to recreational anglers with the assumption that each recipient would complete a survey addressing their opinions of the devices. The target population consisted of offshore recreational anglers of the GOM and South Atlantic that targeted reef fish. The sampling frame was identified by targeting SeaQualizer recipients at fishing tournaments, dockside creel stations, and online at www.takemefishing.org. Methods of identifying potential recipients consisted of a combination of non-probability methods such as purposive and convenience sampling. Agencies from the eight GOM and South Atlantic states (TX, LA, MS, AL, FL, GA, SC, NC) assisted with distribution of the devices by questioning offshore anglers at dockside locations to determine if they target reef fish. All three subsectors of the federal recreational fishing sector (private anglers, charter captains/owners/operators, and headboat captains/owners/operators) were targeted for SeaQualizer distribution. In addition to the free SeaQualizer, participating anglers received a best-use practices pamphlet discussing proper fish handling, mortality-reducing release procedures, and instructions on how to operate the SeaQualizer. Previous to initiation of this project, I was weighmaster and scorekeeper for the Corpus Christi Big Game Fishing Club (CCBGFC), a private offshore fishing club that hosts summer fishing tournaments in Port Aransas, TX. These CCBGFC banquets, tournaments, and get-togethers were attended and used as an essential outlet to distribute SeaQualizers to Texas offshore recreational anglers. Additional devices were distributed at meetings held by the Port Aransas Boatmen's Association, an entity comprised of both private anglers and offshore charter captains. Various fishing club banquets and dinners were also attended to distribute and promote descender devices and disseminate best-use practices for catch-and-release fishing of offshore reef fish. Similar to focus groups, SeaQualizer distributors conversed with recipients to determine what potential survey questions would provide researchers with optimum data regarding descender device perceptions. Those initial attitudes and opinions of anglers were used to assist in the construction of the survey.

Survey Development

To determine how anglers perceive the utility and effectiveness of descender devices to reduce discard mortality in offshore reef fish, participating recreational anglers that received a free SeaQualizer were required to complete an online survey about their perceptions of the device and to what extent they might use them on an everyday fishing excursion. Participants were informed they would be sent the survey via email between December 2016 and February 2017. Survey development was a collaborative effort between the Florida Fish and Wildlife Conservation Commission (FWC), FishSmart, and the Harte Research Institute (HRI). Participants were offered an incentive to complete the survey was a drawing, where they could win one of two prizes: a Shimano offshore fishing rod or reel valued at $269.99 and $549.99, respectively.

Participants were required to classify themselves as belonging to one of the three subsectors of the federal recreational fishing sector: a private recreational angler; charter boat captain, owner, or operator; or a headboat captain, owner, or operator. Participants were also subdivided by the state they fish in most often. Participants were questioned about their opinions and previous knowledge on venting reef fish and to what extent it is successful in reducing discard mortality. Questions also measured previous knowledge concerning descender devices and what barotrauma symptoms and signs they use to determine when a discard needs to be vented or descended instead of simply released at the surface. Participants were asked how often they used their free SeaQualizer and how many Red Snapper and other reef fish species they released since acquiring the device. Estimates of the number of fish released by anglers using a descender device during this study were calculated by extrapolating survey responses. Key questions addressed the participant perceptions regarding the success of the SeaQualizers. These questions asked anglers what percent of fish they believe survive long-term after being released with a descender device and to what extent they will use the device on their vessel in the future. Participants were also asked how successful they believe descender devices would be in reducing discard mortality in the Red Snapper fishery.

To determine if differences in income, education, fishing experience, and fishing habits affected responses, a secondary portion of the survey was designed to evaluate demographic information and fishing practices. Once respondents had completed the initial portion of the survey, they were offered a secondary incentive. After completing the secondary portion of the survey, they would be entered into another free drawing to win a separate Shimano rod or reel valued at $269.99 and $649.99, respectively. Demographic questions included in the secondary portion of the survey addressed gender, age, zip code, combined household income, and highest level of education. To determine participant fishing experience, respondents were asked how many days they fished last year and total number of years they have been targeting offshore reef fish. Additional questions determined their most commonly targeted fishing depths and what distance from shore they most commonly targeted reef fish.

While multiple parties collaborated to design survey questions and answering categories, FishSmart supervised the creation of the survey using SurveyMonkey. Due to the various types of questions asked in the survey, answer categories were comprised of multiple formats. The majority of answers were on an ordinal scale (e.g. very unlikely to very likely); although, not all answers followed the same ordinal categories. For example, the question addressing angler likeliness to use a descender device to release fish when needed yielded an ordinal scale of not likely to use at all to likely to use it on all fish, while the question asking how helpful respondents believe descender devices would be in reducing discard mortality in Red Snapper yielded an ordinal scale of not helpful to very helpful. Other questions provided nominal answers, binary yes or no answers, and percentage "slide-bar" answers. Due to the variety of data collected statistical analysis varied from question to question. Please see appendix A for a full copy of the survey.

Ride-along Observer Trips

To gauge angler perceptions of descender devices in a natural setting, observer trips were attended on recreational fishing vessels out of Port Aransas, TX during the 2016 GOM private and for-hire recreational Red Snapper seasons. The purpose of these trips was to determine if distinct differences existed between recreational subsectors regarding the opinions and feasibility of using descender devices. Using contacts obtained during the distribution of free SeaQualizers, various anglers were contacted, and asked if they were willing to allow a scientist from our group to attend one of their normal fishing trips. In most, but not all cases, captains willing to participate had already received a free SeaQualizer. Captains that had not yet received a SeaQualizer were given one and added to the email list for survey distribution. Participating captains were offered a monetary-based incentive according to the recreational subsector they were classified in. Private recreational captains were offered up to $250 in fuel compensation, charter captains were offered $250 for each attending observer, and individual tickets were purchased for each attending observer on the headboat.

During ride-along trips, data were collected to assess descender device performance and angler perceptions on the feasibility of using the devices on normal fishing excursions. Bottom depth, structure type, bait type, latitude and longitude, environmental conditions, and water temperature were collected prior to fishing a certain location. Items recorded during fishing were number of anglers fishing concurrently, species of fish captured, fight times, deck times, barotrauma symptoms, fish total length, and release depth setting on the SeaQualizer used to release a discard. Barotrauma impairment indices (BI scores) were calculated by dividing the total number of externally visible barotrauma symptoms by the total number possible (6). The resulting index was a number between 0 and 1 where more visually impaired fish yielded higher scores. All discarded Red Snapper were fitted with a dart tag in the event a fish was recaptured. Attitudes of anglers, deckhands, and captains regarding the utility and effectiveness of the SeaQualizer were recorded throughout the trip. After the trips were completed, I briefly questioned the captains and deckhands about their opinions of descender devices and to what extent they believed the devices could improve discard mortality in the Red Snapper fishery.

Statistical Analysis

Survey Data

Due to the variety of data collected from diverse answer categories, statistical analyses were performed on a question by question basis. A major question in this study was defining differences in perceptions and attitudes about descender devices based on what recreational subsector respondents identified. Therefore, analyses assessing significant differences among subsectors were performed. Due to the low amount of respondents in the headboat category (6 respondents) statistical analyses were only performed between private anglers and charter captains, owners, and operators. Ordinal logistic regression (OLR) was performed when answer categories were on an ordinal scale, chi-squared test of independence was performed when answers were nominal, and Kruskal-Wallis test was performed when respondents chose a percentage of 0 to 100% using a slide bar. All tests were performed using the statistical package R (R Core Team 2017).

Ride-along Observer Data

Due to the small number of trips attended during the short GOM Red Snapper season, statistical analysis methods were limited for data collected during ride-along trips. Only one charter and headboat trip were completed with only one fish being released on the charter boat. Instead of performing more complex analyses, simple qualitative comparisons between the three subsectors were more ideal. ANOVA was used when comparing various continuous data between the three subsectors, but general differences in willingness-to-use and attitudes towards descender devices among the three subsectors were noted and discussed.

RESULTS

Free SeaQualizer Distribution

A total of 1,062 SeaQualizers and best-use practices pamphlets were distributed to recreational anglers from North Carolina to Texas by various state, federal, and private entities. The majority of devices were distributed by state agencies at dockside creel stations and fishing tournaments between March and September of 2016. A total of 80 SeaQualizers were distributed to Texas recreational anglers at dockside creel stations, fishing tournaments, and CCBGFC and Port Aransas Boatmen's Association meetings and banquets.

Primary Survey Results

A total of 538 SeaQualizer recipients took the survey sent via email (51% response rate). Of those respondents, 23%, 27%, and 28% most commonly fished saltwater in Texas, Alabama, and Florida, respectively (Figure 2.1). All other states were targeted for saltwater fishing by less than 10% of respondents. The most commonly targeted state for saltwater fishing matched almost identically with the respondents' home state determined by zip code. The vast majority of respondents were private recreational anglers (n = 451, 84%), while only 81 (15%) and 6 (1%) identified as charter boat captains, owners, or operators and headboat captains, owners, or operators, respectively (Figure 2.1). On average, respondents owned their SeaQualizer eight months and used it on 15 trips prior to taking the survey. Fifty-five percent targeted water depths between 75 and 125 ft (23 – 38 m), 13% targeted depths less than 75 ft (< 23 m), and the remaining respondents (14%) targeted waters greater than 125 ft deep (> 38 m). Seventeen percent of respondents targeted distances of 10 miles (16 km) offshore or less, half fished 11 to 30 miles (18 – 48 km) offshore, 15% fished 31 to 40 miles (50 – 64 km) offshore, and the 20%

fished more than 41 miles (66 km) offshore. Over 95% of participants discussed with and involved other anglers in the use of their free SeaQualizer.

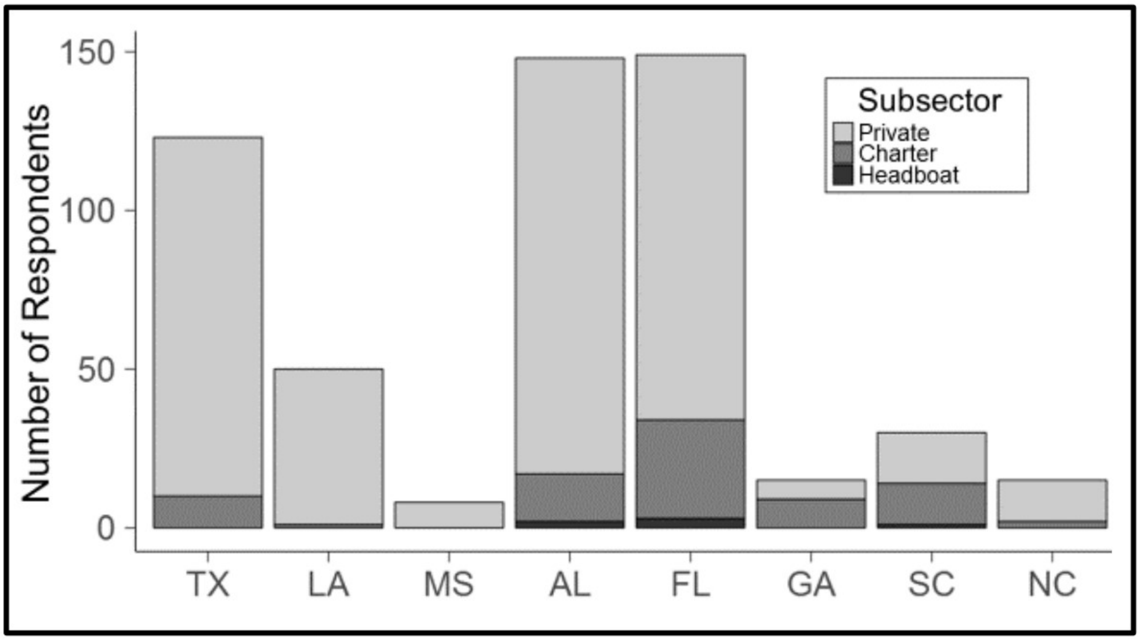

Figure 2.1: Number of survey respondents from each state broken down by recreational fishing subsector: private anglers, charter captains, owners, or operators, and headboat captains, owners, or operators. The total number of respondents was 538. Data here do not represent the actual proportion of different subsector individuals a certain state is comprised of, but simply the proportion from each state that completed the survey.

Most respondents (n = 425) received their SeaQualizer via online registration on FishSmart's website. Depending on the method an individual respondent acquired their SeaQualizer, the possible educational materials they could have received included the following items: articles regarding catch-and-release fishing, best-use practices for descender devices, and videos promoting FishSmart and SeaQualizers. Approximately 95% of recipients believed the combinations of materials they received improved their knowledge and skills regarding recognition of barotrauma and proper fish handling and release methods.

Most respondents had used a venting tool at some point in the past (89%). Significantly more charter respondents used vent tools in the past than private anglers (Chi-squared test; χ = 4.314, $P < 0.05$). When employing vent tools in the past, 78% of respondents vented all or most fish when they exhibited signs of barotrauma. When asked what cues anglers used to determine if venting or descending a fish was necessary, 80%, 75%, 68%, 57%, and 41% considered a protruding stomach, bloated abdomen, inability to submerge, exophthalmia, and sluggishness to be effective cues, respectively. Twenty-three percent of respondents considered all of those symptoms as useful signs. Thirteen percent used a venting or descending tool on all fish regardless of symptoms, while 3% never used either.

Sixty-three percent of respondents stated they still used venting tools to release fish exhibiting barotrauma. Responses were not significantly different between private anglers and charter boat captains (Chi-square test; χ = 1.758, df = 1, P = 0.185). For those that did not currently employ vent tools to release fish, 19% stopped using them because they did not think they work, 17% believed the fish were able to submerge without the help of venting, and 5% stopped using vent tools because they thought they were too time consuming. Sixty-seven percent chose the 'other' category and were required to specify their reason. Of those 150 'other' respondents, 66 specifically mentioned they preferred to use a descending device instead of venting. The mean percentage of fish believed to survive the venting process was 57%, and this was not significantly different between private and charter respondents (Kruskal-Wallis test; χ = 0.152, df = 1, P = 0.697). Mean perceived survival rate after venting for headboats was 62%, similar to the overall mean.

Previous knowledge concerning the use of descender devices was generally low. Seventy-two percent of respondents had little to no knowledge about descender devices prior to acquiring their SeaQualizer. Only 45 of the 517 respondents (< 9%) to the question had a high to very high amount of knowledge prior to receiving their SeaQualizer. Charter boat captains were more likely to possess knowledge on the devices than private anglers (OLR; $\beta = 0.521$, $\chi = 5.365$, $P < 0.05$).

The likelihood of respondents to use a descender device to release fish exhibiting barotrauma was very high (Figure 2.2). Only eight individuals were not likely to use a descender device at all, whereas 33% of respondents were likely to use one to release all fish, 43% to release most fish, and 14% to release approximately half of the fish they catch exhibiting barotrauma. Although there were only six headboat respondents, half of them would not likely release any fish with a descender device. There was no difference in likeliness to use the device between private anglers and charter captains (OLR; $\beta = -0.2095$, $\chi = 0.821$, $P = 0.365$).

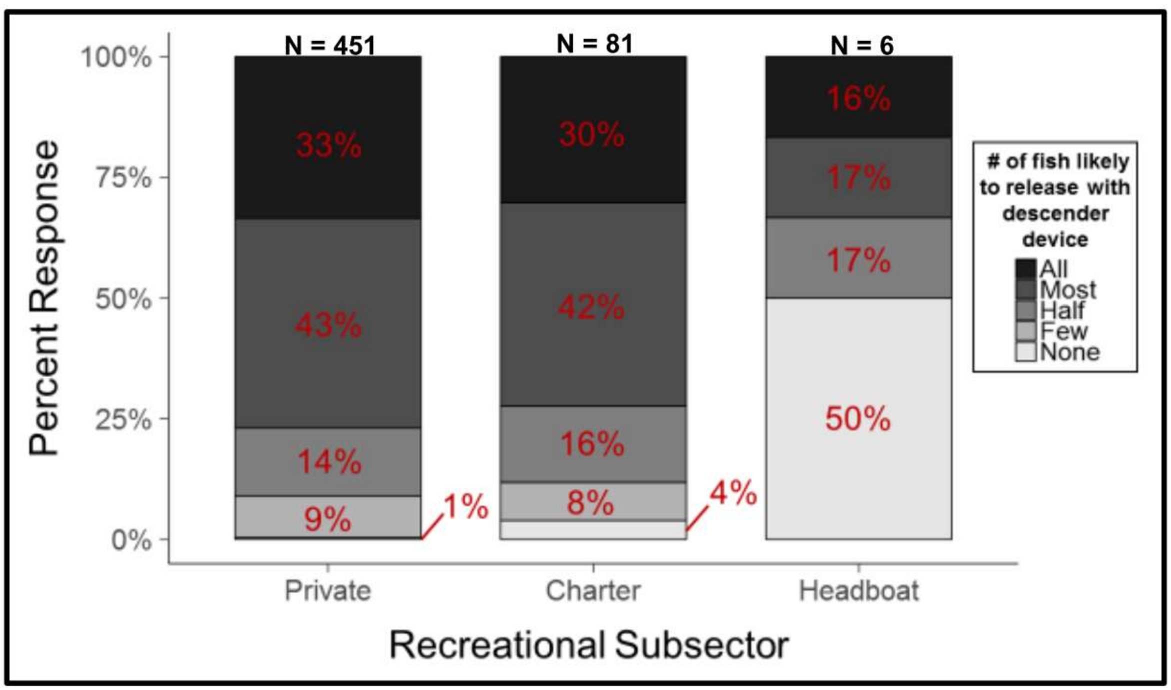

Figure 2.2: Response of private, charter, and headboat survey participants when asked how likely they were to use a descender device to release fish exhibiting barotrauma. Red percentages correspond to proportional response for that recreational subsector.

The vast majority of respondents (89%) believed descender devices would be at least "moderately helpful" in reducing discard mortality in the Red Snapper fishery. Seventy-nine percent believed they would be helpful to very helpful. When answers were compared between private anglers and charter captains, private anglers believed the devices to be only slightly more helpful than charter captains. However, these differences were not statistically significant (OLR; $\beta = -0.407$, $\chi = 2.940$, $P = 0.086$). Three of the six headboat respondents believed the devices would be very helpful, one believed they would be a little helpful, and two believed they would be very little help in reducing Red Snapper discard mortality rates.

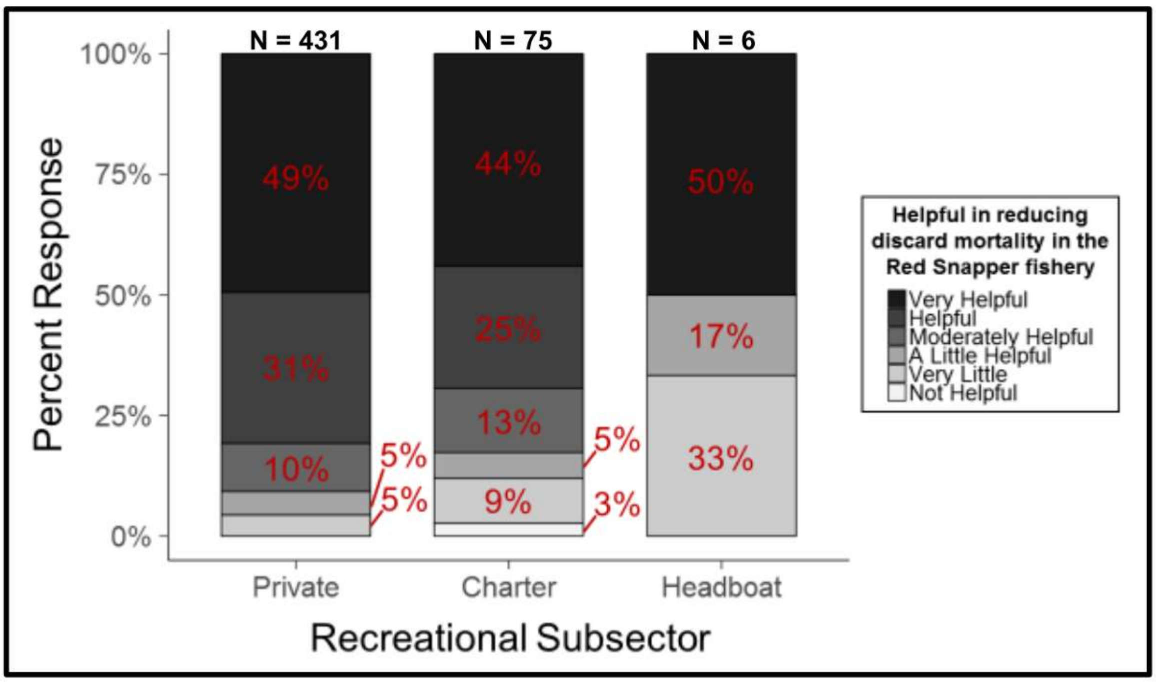

Figure 2.3: Response of private, charter, and headboat survey participants when asked how helpful they believe descender devices would be in improving discard mortality in the Red Snapper fishery. Red percentages correspond to proportional response for that recreational subsector.

Overall, anglers believed more fish survive long-term when released with a descender device than when released after venting. The mean predicted survival rate of fish released with a descender device was very similar between private anglers and charter captains (80% and 81%, respectively). For headboat respondents, mean predicted survival rate of fish released with a vent tool was identical to the predicted rate when released with a descender device (62%).

A range of the approximate total number of fish released by anglers during this study was calculated by multiplying the number of respondents in one category by the range of the minimum and maximum number of fish released in that category. Anglers who took the survey released a minimum of 7,068 to a maximum of 11,235 Red Snapper and a minimum of 4,316 to a maximum of 6,790 other species of fish during the time period from acquiring their SeaQualizer to taking the survey. On average, charter captains and private anglers released approximately 28 Red Snapper and 16 Red Snapper per person throughout the course of the study, respectively. Similar results occurred for species released other than Red Snapper by charter captains and private anglers. The mean number of Red Snapper and other species released per headboat respondent was 29 and 16, respectively.

After receiving and operating the SeaQualizer, 70% of anglers preferred to use a descender device over a venting tool. Results from the chi-squared test determined significant differences existed in preferred release method between private anglers and charter captains (Chi-squared test; $\chi = 24.567$, $P < 0.001$). After operating the SeaQualizer, seventy-four percent of private anglers preferred to release fish with a descender device. Charter captains were less likely to use the devices, with only 54% preferring a descender device over other methods. Likewise, 18% of charter captains still preferred venting compared to only 7% of private anglers. More charter captains preferred to employ both methods than private anglers, but no charter captains preferred to use no methods when releasing fish with barotrauma compared to 4% of private anglers.

Secondary Survey Results

Survey participants were given the option to complete a secondary portion of the survey that addressed demographic information. Of the original 538 survey participants, 476 agreed to complete the second portion on the survey. To gauge fishing experience of survey participants, anglers were asked how many years they have been fishing for offshore reef fish (Figure 2.3). Fifty-four percent of respondents had been fishing for more than 20 years, 20% for 11 to 20 years, 17% for 5 to 10 years, 9% for 1 to 4 years, and only two respondents had been fishing for less than one year (0.4%). Charter captains were more likely to have greater fishing experience than private anglers (OLR; $\beta = 0.862$, $\chi = 10.404$, $P = 0.001$). Four of the six headboat respondents had been fishing for more than 20 years.

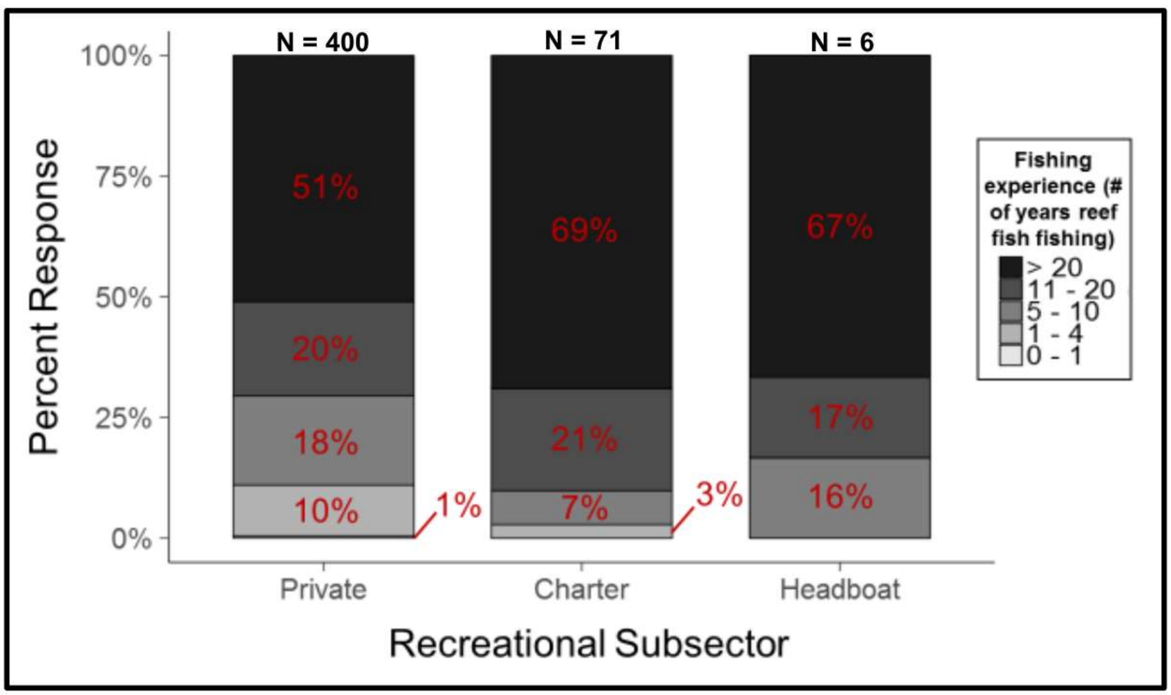

Figure 2.3: Response of private, charter, and headboat survey participants when asked how many years they have been targeting offshore reef fish. Red percentages correspond to proportional response for that recreational subsector.

When asked how many days they targeted reef fish last year, 41% took more than 20 trips, 24% took 11 to 20 trips, and the remaining 34% took 10 trips or less. Charter captains were much more likely to fish more days in the past year than private anglers (OLR; $\beta = 2.349$, $\chi = 50.219$, $P < 0.001$). All headboat respondents had fished more than 20 days in the past year.

The majority of survey participants were males (96%) between the ages of 41 and 65 (66%). Fifty-eight percent of respondents' highest level of education was a Bachelor's degree or higher and 66% held a combined household income of at least $75,000. Compared to charter captains, private anglers were more likely to have earned a higher education (OLR; $\beta = -1.192$, $\chi = 21.824$, $P < 0.001$), and hold a higher household income OLR: $\beta = -0.559$, $\chi = 5.190$, $P = 0.025$,). Headboat respondents held the lowest education level and household income of the three recreational subsectors.

To understand how various demographic characteristics affected anglers' willingness to use a descender device and to what effect they could reduce discard mortality in the Red Snapper fishery, one-way OLR with post-hoc testing was performed. Likelihood ratio tests (LRT) between null models and models including factors of interest were used to determine if variables were significantly correlated with responses. Education was not a significant predictor of either angler willingness to use descender devices (LRT; $P = 0.243$) or of perceived benefit of the devices to reduce discard mortality in the Red Snapper fishery (LRT; $P = 0.123$), nor was fishing experience (LRT; $P = 0.090$ and $P = 0.991$, respectively).

Ride-along Observer Trips

I attended a total of five ride-along trips during the GOM private and for-hire recreational Red Snapper season. Three trips were aboard private recreational fishing vessels, one was aboard a charter boat possessing a federal reef fish permit, and one was aboard a headboat. All observer trips left out of and returned to Port Aransas, TX. Red Snapper were the only species captured aboard the private and charter vessels. Species captured aboard the headboat consisted of Red Snapper, Vermillion Snapper *Rhomboplites aurorubens*, Lane Snapper *Lutjanus synagris*, Gray Snapper *L. griseus*, Gag Grouper *Mycteroperca microlepis*, Rockhind *Epinephelus adscensionis*, Tomtate *Haemulon aurolineatum*, Squirrelfish *Holocentrus adscensionis*, Queen Triggerfish *Balistes vetula*, King Mackerel *Scomberomerus cavalla*, and Spanish Mackerel *S. maculatus*. On average, two anglers targeting Red Snapper would fish simultaneously aboard the private vessels and charter vessel. At certain times aboard the headboat, such as upon arrival to a new fishing site, over 50 anglers would be fishing simultaneously. Fishing site bottom depths ranged from 30 to 61 meters, with the headboat targeting fish in the deepest water (Table 2.1). Captured Red Snapper were largest on the charter boat and smallest on the headboat (ANOVA; $F_{2, 30} = 81.82$, $P < 0.0001$).

Table 2.1: Summary statistics for various field collected variables during ride-along observer trips. An asterisk corresponds to a value that has only one measurement. An NA is present if field data were not available for that specific variable.

	Private	**Charter**	**Headboat**
Mean Fishing Depth (m)	28	37*	61*
Mean Fight Time (s)	71	121	NA
Mean Deck Time (s)	132	64*	NA
# Species	1	1	11
Mean BI Score	0.28	0.47	0.48
Mean Total Length	508	700	390
* = one measurement			

DISCUSSION

The goal of this study was to assess the perceptions, opinions, and attitudes of recreational anglers regarding the use of descender devices to reduce discard mortality in offshore reef fish. The majority of recreational anglers had a very positive perspective on the benefits associated with using descender devices to release regulatory discards experiencing barotrauma. Slight differences in opinions existed between the three subsectors of the federal recreational fishing sector regarding the utility of the devices, but the majority believed they were useful tools for improving catch-and-release survival of offshore reef fish. Headboat captains/deckhands were less likely to use the devices due to the time consuming process required to descend a single discard while meeting client demands, especially when dozens of anglers were capturing undersized fish simultaneously, lines needing tending, baiting, etc. Nevertheless, subsectors perceived descender devices to be beneficial tools in improving discard mortality in the Red Snapper fishery, and the vast majority of respondents changed their preference from venting to descending. These results provide valuable evidence that recreational anglers are on board with descending fish to improve catch-and-release survival. If managers wish to implement future regulations requiring the possession of descender devices on vessels fishing for reef fish in federal waters, this study contributes to the prerequisite knowledge required to successfully enact such a law – that is, they are well received by all sectors of the recreational fishery.

The science is clear as well showing that rapid recompression reduces discard mortality in a variety of marine fish species susceptible to barotrauma injuries (Jarvis and Lowe 2008, Hochhalter and Reed 2011, Rogers et al. 2011, Hannah et al. 2012, Pribyl et al. 2012, Sumpton et al. 2010, Brown et al. 2010, Butcher et al. 2012, Drumhiller et al. 2015, Curtis et al. 2015).

Descender devices such as the SeaQualizer offer anglers a simple, straightforward method to recompress discards without bulky cages and lengthy ropes. Moreover, rapid recompression does not require anglers to possess knowledge regarding the anatomy/physiology of the discard, preventing released fish from experiencing detriment rather than benefit due to angler inexperience. Scyphers et al. (2013) discovered the majority of venting tool users were inserting their hypodermic needles in improper locations, potentially puncturing vital organs and reducing the chance of survival. Situations such as these are prevented if anglers wish to mitigate the effects of barotrauma by employing descender devices. Even when operated properly, venting tools yielded lower survivability of Red Snapper than descender devices (Curtis et al. 2015; Stunz et al. 2017). Survey respondents predicted 80% of fish released with descender devices survive long-term, while only 57% were predicted to survive after venting. Interestingly, when captured from 40 m, Stunz et al. (2017) observed 88% and 57% survival of Red Snapper released with a descender device and venting tool, respectively. High similarity between field-derived survival rates and recreational angler predicted survival rates advocates the noteworthy, and often overlooked, perspective anglers can provide on fisheries management (Granek et al. 2008; Aswani et al. 2004; Boudreau and Worm 2010). Results from a separate study surveying anglers found confidence in venting was far lower than descending, with 68% of anglers requesting additional information on the proper use of venting tools (Crandall et al. *in press*; Hazell et al. 2016). While difficult to provide evidence to support such a claim, it is assumed experienced recreational anglers practicing catch-and-release fishing expect their discarded fish to survive. A general consensus observed among survey respondents and ride-along participants was their positive attitude towards, and desire for, successful catch-and-release fishing practices. I found that 70% of survey respondents changed their barotrauma mitigation preference from venting to descending by the end of the study, suggesting the inclination of recreational anglers to employ descender devices in the GOM and South Atlantic is very high due to their perceived benefit to discarded fish.

In an effort to more evenly allocate GOM recreational sector fishing quotas among groups with differing behaviors and opinions on the resource (Doerpinghaus et al. 2014), the GMFMC enacted an amendment in 2014 that separated the sector into two subsectors, the private sector and charter/for-hire (CFH) sector. The CFH sector consists of both charter captains possessing a federal reef fish fishing permit and headboats. The amendment gave private anglers and CFH captains 57.7% and 42.3% of the recreational quota allocation, respectively. Potential differences among the three groups comprising the two subsectors could affect the way future regulations are approached. Therefore, it is vital to determine how perspectives and opinions regarding discard mortality issues differ between the subsectors if managers expect compliance on new regulations. Although each subsector was targeted during this study, private anglers made up the majority of survey and ride-along data, while headboats comprised a very small portion, making it difficult to draw conclusions regarding attitudes and opinions of headboat operators. Due to this lack of balanced data among groups, this study focused on comparing private anglers and charter captains. Charter respondents had higher levels of fishing experience and possessed more previous knowledge about descender devices than private anglers, but more private anglers preferred descender devices over venting than charter respondents. Charter captains likely experience time-sensitive situations where multiple fish require releasing simultaneously more often than private anglers, potentially resulting in the higher likelihood of charter captains to continue employing the less time-consuming method of venting. Moreover, the three sectors have different motivations, such as meeting the needs of clients, and these demands might influence their willingness to use these devices under certain circumstances. For example, private anglers may prefer to focus more on proper release techniques because they are not required to tend to clients and assist numerous anglers at once. Despite existing dissimilarities in attitudes towards managing the Red Snapper fishery between private and CFH anglers (Doerpinghaus et al. 2014), the vast majority of both private and charter respondents believed descender devices would be beneficial in reducing discard mortality of Red Snapper. Both groups were also very likely to use descender devices to release most or all fish experiencing barotrauma. Recreational anglers in the GOM and South Atlantic have experienced declining federal Red Snapper fishing seasons due to strict regulatory measures enacted to rebuild the stock (Hood et al. 2007; SEDAR 2013; Strelcheck and Hood 2007). Both private and CFH anglers have been negatively affected by those increasingly severe regulations and wish to prevent future regulatory measures from limiting access to other reef fish fisheries, likely resulting in their positive outlook on methods to reduce discard mortality rates. By employing descender devices, discard mortality rates can improve and anglers may even regain lost access to the fishery if those enhancements are successful enough.

Angler fishing experience had no influence on perceived benefit of descender devices to the Red Snapper fishery or angler willingness-to-use one on their own vessel. Recreational anglers in this study, whether fishing from a private vessel, charter vessel, or headboat, prefer to have a longer Red Snapper fishing season and likely understand the role that reducing discard mortality can have on the quota their sector is allocated. One would not expect fishing experience to be related to an angler’s willingness to fish for Red Snapper, which is probably why fishing experience did not affect anglers’ perspectives on the benefit of descender devices. These results further advocate the positive attitude recreational anglers hold towards improving release survival in offshore reef fish with descender devices. One report revealed contrasting results where the majority of Florida offshore recreational anglers preferred venting over descending (Crandall et al. *in press*; Hazell et al. 2016). A key difference between this study and those noted above is that anglers in this study received a free SeaQualizer and used it in the field while making judgments on its efficacy and utility prior to taking the survey, whereas 32% of the anglers in Crandall et al. (*in press*) had never heard of or used such devices prior to survey completion. Moreover, 53% of respondents targeted fishing depths of less than 60 feet, shallow enough that most reef fish would not require barotrauma mitigation techniques. Only 13% of GOM and South Atlantic anglers from this study targeted depths of less than 75 feet and 71% preferred descending over venting after employing a SeaQualizer on their vessel for an average of 8 months, whereas 78% vented all or most fish exhibiting barotrauma prior to acquiring a SeaQualizer. These results conclude that anglers changed their preference of barotrauma mitigation techniques from venting to descending after employing a descender device on their vessel.

Similar to GOM Red Snapper, Pacific Rockfish management faced similar issues surrounding high discard mortality rates and resulted in temporary closures of specific fisheries and regions where multiple overfished species resided (Dick 2017). In efforts to improve release survival, recreational anglers began voluntarily employing descender devices when prohibited species were captured as bycatch. Studies emerged revealing the benefits associated with rapid recompression of Rockfish (Hannah et al. 2012; Hochhalter and Reed 2011; Jarvis and Lowe 2008; Pribyl et al. 2012), and managers eventually adopted decreased discard mortality rates for three species (Cowcod *S. levis*, Canary *S. pinniger*, and Yelloweye *S. ruberimus*) when recompression was performed. Accompanied with the adjusted discard mortality rates were outreach programs and incentives promoting the importance of recompressing discards experiencing inability to submerge. Dick (2017) surveyed various fishery scientists and managers to determine the challenges involved with implementing the required use of descender devices in the South Atlantic Red Snapper fishery. Complications included lack of scientific data supporting the benefit of recompression to various species in the snapper grouper complex and how variations in depth may affect the benefit of recompression. Stunz et al. (2017) and Curtis et al. (2015) assessed mortality of Red Snapper across multiple depths, seasons, and release techniques, and concluded that mortality increases substantially after 55 m depth. Tompkins et al. (*unpublished data*) found a comparable 55 m survival threshold for Red Snapper when released with descender devices. This study found the overwhelming majority of recreational anglers, both private and charter, were willing to use descender devices on their vessels. In many instances, anglers who had not previously known of descender devices were relieved to learn that a device existed preventing users from having to use invasive methods such as insertion of a large needle into already stressed fish. Some that already knew rapid recompression was a viable barotrauma mitigation technique previously designed their own device out of a large barbless hook and leftover lead weights. Thus, anglers are willing to use descender devices and sound science exists detailing their best-use practices.

Ride-along observer trips provided new insight on the utility of descender devices in ‘real-world’ situations. Private and chartered anglers held similar perceptions regarding the usefulness of descender devices. Captains and deckhands of the private and charter vessels believed the devices were highly successful in reducing discard mortality and stated it was a tool they would use on future reef fish fishing trips. Anglers aboard private vessels actively descended each discard until multiple fish were landed simultaneously. During these situations that resulted from double-hook fishing leaders, anglers would instead use a venting needle to save time and effort. Anglers mentioned they would rather vent a discard than have it remain on deck out of water while previous fish were being descended. This problem did not occur on the charter vessel as the captain limited fishing to two anglers at once and fished with single-hook fishing leaders. While aboard the headboat, observers offered deckhands an incentive to assist observers by using the SeaQualizer to descend discards when time allowed. Due to time constraint and an overwhelmingly large number of discards being landed simultaneously, no deckhands were able to operate a SeaQualizer. Deckhand perceptions on rapid recompression device utility on headboats was very poor resulting from the time consuming process required to descend a fish and reel the device back in. With sixty anglers fishing on one vessel, it was difficult for three deckhands to employ a SeaQualizer when dozens of discards were landed within several minutes. The primary method of release employed by headboat deckhands was venting with a venting needle or pocket knife. Knowledge on the correct use of venting needles was poor, with most deckhands inserting the needle or knife too close to the ventral portion of the fish, potentially puncturing vital organs such as the heart, liver, stomach, and gills. In most cases, venting discarded fish resulted in the fish floating at the surface and perishing. One observer noted a mixture of thirty-six Red and Vermillion Snapper floating off of the bow of the headboat during fishing.

A reoccurring theme in studies that challenged the efficacy of venting was the issue involving lack of knowledge required to properly operate the devices (Scyphers et al. 2013; Wilde 2009). There has been an increasing need to communicate scientific findings regarding discard mortality-reducing methods to stakeholders of fisheries, especially when catch-and-release is the dominant form of fishing (Cooke and Schramm 2007). Angler's knowledge and perceptions are often overlooked when formulating hypotheses and methods to improve release mortality. Interestingly, survey respondents from this study were able to predict nearly identical survival rates of Red Snapper as those derived from scientific studies. In many instances, angler opinion, observation, and participation can be highly useful in assisting with research, management, conservation, and sustainable use of fishery resources (Granek et al. 2008; Aswani et al. 2004; Boudreau and Worm 2010; Brownscombe et al. 2016). The failure of the GOM venting regulation may fall on issues such as these. If the GMFMC or SAFMC wish to implement future regulations that require the use of specific tools to reduce mortality in released reef fish, studies such as this are imperative for success. Cooke and Schramm (2007) noted the importance of gathering and disseminating data on the utility and effectiveness of new regulations prior to enforcing them. If it is discovered that angler knowledge regarding the use of such devices is novice, appropriate dissemination of methodological instructions and best-use practices would be required before anglers are expected to use the devices in the fishery. Unlike other barotrauma mitigation techniques, descender devices offer anglers an easy-to-operate tool that does not require extensive knowledge on the physiology of various species, which likely contributed to the general consensus that the devices are an improved method to reduce discard mortality over venting.

Recreational reef fish anglers, both CFH and private, were found to have positive perspectives and attitudes towards descender device use to improve release survival in fish exhibiting barotrauma. Moreover, 70% of survey respondents changed their preference from venting to descending by the end of the study. Despite requiring more time and effort to deploy a descender device, recreational anglers perceived their benefit to outweigh the time saved by venting. Both charter captains and private anglers were very willing to carry a descender device on their vessel to release most fish requiring barotrauma mitigation. Headboat operators were less likely to employ the devices due to the time consuming method required to operate them; however, most believed the devices to be successful in reducing discard mortality. These data provide managers with essential information regarding the opinions of fishery stakeholders towards improving discard mortality using rapid recompression techniques. Distrust and disgruntlement are at an all-time high in the GOM and South Atlantic Red Snapper fisheries and anglers are exploring methods to regain access to fisheries that managing bodies exist to provide reasonable access to. While various regulatory measures and overages have triggered the demise of Red Snapper recreational fishing seasons, improving discard mortality can provide a direct benefit to the overall health of the fishery. Various studies have demonstrated the positive effects of recompressing fish exhibiting barotrauma, and managing bodies such as the GMFMC and SAFMC are beginning to include them in regulatory measures. Rapid recompression provides anglers confidence that their discards will survive to be captured again in the future, and are receptive to the possibility of implementing a requirement to employ descender devices in the recreational reef fish fishery.

BROADER IMPACTS AND CONCLUSIONS

Reducing discard mortality in the GOM Red Snapper recreational fishery remains an important parameter for stock rebuilding. Results from this study showed strong depth effects and suggest that descender devices can increase catch-and-release survival under field conditions favorable to recreational anglers. My survey work clearly showed that these devices are well-received and will be used in the recreational fishery. Survival rates associated with release depth imply that descender device users can save time by recompressing fish to at least one-third of their initial capture depth and expecting ideal survival. Barotrauma impairment reached a maximum around 55 m, the same depth where survival dropped below 50%, and decreased thereafter, resulting in seemingly unimpaired fish at greater depths, despite low survival. This suggests that anglers must use caution if using barotrauma impairment indices as a proxy for post-release survival and should understand that barotrauma mitigation procedures may only provide benefits to fish up to a certain capture depth. Using underwater video footage to obtain BR scores allowed for new insights into the fate of released fish and revealed substantial depredation may occur at greater depths. Incorporating these data into stock assessments will allow for better calculations of overall mortality and provide managers with key information on how descender devices reduce discard mortality in Red Snapper.

In addition to further validating the success of descender devices, the perceptions and knowledge of anglers regarding their use in the reef fish fishery was assessed, and yielded positive results. The vast majority of survey respondents believed rapidly recompressing Red Snapper would significantly improve discard mortality rates in the fishery. Respondents were also highly receptive to employing the devices on their own vessel, with 70% changing their preference to descending by the end of the study. Remarkably, anglers from this study estimated survival rates nearly identical to field derived rates, suggesting they possess respectful knowledge regarding the effects of barotrauma on reef fish, and further advocates the need to include recreational anglers in discard mortality science and regulation. Actual users of the resource provide valuable insights into the fishery and how successful various regulatory measures operate. Thus, their participation in the management process is vital if managers wish to instill confidence in their abilities to properly conserve and allocate a fishery.

These data provide resource managers the evidence they require for moving forward with incorporating descender devices into the management of Red Snapper and other reef fish in the GOM and South Atlantic. Improving diminished fishing seasons and increasing access to the GOM Red Snapper fishery will positively impact local economies by increasing tourism and fishing trips. Despite differences in motivation between private and CFH anglers, the general consensus among recreational anglers is that descender devices are successful, and they are willing to use them. Using the results from this study, fishery managers can now develop management plans to incorporate descender devices into discard mortality-reducing regulatory measures. Due to the existence of a barotrauma impairment threshold, there should be consideration of depth-specific techniques to improve survival. Fish captured beyond 55 m may not experience any significant benefit from venting or descending, suggestive of the need for depth-specific regulations. Anglers from this study most commonly target reef fish at depths of 38 m or less, and these depths are where fish are most likely to receive the benefits from rapid recompression. Regardless of whether these devices are ultimately required on vessels fishing federal waters, anglers should consider employing them due to their ease of use, high success rates, and simply wise conservation practices. With recreational fishing growing more popular each year, discard mortality-reducing strategies will become even more crucial to conserving fish stocks for future generations.

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APPENDIX A

*1. Are you (check only one):

- ○ Charter boat captain/owner/operator
- ○ Head boat captain/owner/operator
- ○ Private recreational angler

*2. Did you receive your SeaQualizer:

- ○ Directly from a dockside interviewer
- ○ Via registration on the web
- ○ From state agency personnel (other than dockside)
- ○ Other (please specify)

*3. From which state do you most often fish saltwater (choose only one):

- ○ AL
- ○ FL
- ○ GA
- ○ LA
- ○ MS
- ○ NC
- ○ SC
- ○ TX

*4. What material do you remember receiving or viewing when you registered for or received your device? (select all that apply)

- ☐ FishSmart Best Practices flyer/brochure
- ☐ "How to Use a SeaQualizer" video
- ☐ FishSmart Video
- ☐ I didn't receive or view any materials

Other (please specify)

*5. Which of the following cues do you use on the water to decide when to use a descending tool or venting tool to release a fish (check all that apply):

- ☐ Fish appears bloated (inflated with air), but otherwise normal
- ☐ Stomach is protruding from mouth
- ☐ Eyes are bulging
- ☐ Fish appears sluggish or unresponsive when brought to the boat

☐ Fish is floating and unable to submerge

☐ I use a venting or descending tool on every fish, even if they exhibit none of the symptoms above

☐ I never use a venting tool or descending tool

☐ Other (please describe)

*6. Have you ever used a venting tool in the past?

○ Yes

○ No

○ I don't know what this is

*7. Why don't you use a venting tool (check all that apply)?

☐ I don't think it works

☐ It is too time consuming

☐ Fish are able to swim down without venting

☐ Other (please specify)

8. What percentage of fish do you believe survive the **venting** process? (Use slider bar to adjust percentage)

0 – 100 percent

*9. How much knowledge did you have about **descender** devices in general before acquiring your SeaQualizer?

○ None

○ Very little

○ Little

○ Moderate

○ High

○ Very high

*10. Considering your normal fishing activity, how likely are you to use a descender device to release fish when needed?

- I would likely use it on all fish
- I would likely use it on most fish
- I would likely use it about half the time
- I would likely use it on very few fish
- I would not likely use it at all

*11. How helpful do you believe descender devices would be in reducing discard mortality in the Red Snapper fishery?

- Not helpful
- Very little
- A little helpful
- Moderately helpful
- Helpful
- Very helpful

12. What percent of fish do you estimate survive long-term after being released with a descender device (use slider bar to adjust percentages)?

0 – 100 percent

*13. When fishing for reef fish, what is your most common targeted fishing depth?

- Less than 75 feet
- 76-125 feet
- 126-175 feet
- 176-225 feet
- 226-275 feet
- Greater than 275 feet

*14. How many months have you had the SeaQualizer supplied as part of this program? (Use slider bar to indicate months)

0 (less than 1 month) 20 months

*15. On approximately how many trips did you use your SeaQualizer?

0 trips 100 or more trips

*16. Approximately how many fish have you released using the SeaQualizer?

	Red Snapper	Other Fish
None	☐ None Red Snapper	☐ None Other Fish
1-5 fish	☐ 1-5 fish Red Snapper	☐ 1-5 fish Other Fish
6-15 fish	☐ 6-15 fish Red Snapper	☐ 6-15 fish Other Fish

	Red Snapper	Other Fish
16-30 fish	☐ 16-30 fish Red Snapper	☐ 16-30 fish Other Fish
31-50 fish	☐ 31-50 fish Red Snapper	☐ 31-50 fish Other Fish
51-75 fish	☐ 51-75 fish Red Snapper	☐ 51-75 fish Other Fish
More than 75 fish	☐ More than 75 fish Red Snapper	☐ More than 75 fish Other Fish
I have no idea	☐ I have no idea Red Snapper	☐ I have no idea Other Fish

*17. After trying out the device, which release tool do you prefer to use for fish exhibiting barotrauma?

○ Descending tool

○ Venting tool

○ Neither

○ Both

*18. How many other people have you talked with about descender devices or have you involved in the use of your SeaQualizer?

	None	1-5	6-10	11-15	More than 15
Other Fisherman	○ Other Fisherman None	○ Other Fisherman 1-5	○ Other Fisherman 6-10	○ Other Fisherman 11-15	○ Other Fisherman More than 15
Customers (charter or head boat)	○ Customers (charter or head boat) None	○ Customers (charter or head boat) 1-5	○ Customers (charter or head boat) 6-10	○ Customers (charter or head boat) 11-15	○ Customers (charter or head boat) More than 15
Non-Fisherman	○ Non-Fisherman None	○ Non-Fisherman 1-5	○ Non-Fisherman 6-10	○ Non-Fisherman 11-15	○ Non-Fisherman More than 15

*19. Part 1 is complete and you can choose to enter a drawing to win a Shimano Talica 16II two-speed lever drag reel, or a Shimano Terez extra heavy fast action 6’6” rod.

Would you be willing to answer a few more questions for a chance to win a Shimano Talica 25II two-speed lever drag reel,or a Shimano Tallus roller stripper tip medium heavy fast action 5’9” rod ?

○ Yes

○ No thanks

*20. How many years have you been fishing for reef fish?

- Less than 1 year
- 1 - 4
- 5 - 10
- 11 - 20
- More than 20

*21. How many days did you fish for reef fish in the last year?

- 0
- 1-5
- 6-10
- 11-20
- More than 20

*22. What distance from shore do you most often fish when fishing for reef fish?

- 0-10 miles
- 11-20 miles
- 21-30 miles
- 31-40 miles
- 41-50 miles
- 51-60 miles
- 61-80 miles
- More than 80 miles

The following questions are for statistical purposes only and will not be associated with your name or any other personally identifiable information.

*23. What is your 5-digit zip code?

*24. What is your gender?

- Male
- Female
- Would rather not say

*25. What is your highest level of education?

- Grammar School
- High School or equivalent
- Vocational or Technical School
- Bachelor's Degree
- dMaster's Degree

- Doctoral Degree
- Professional Degree (MD, JD, etc.)
- Would rather not say
- Other (please specify)

*26. What is your age?

- 25 or under
- 26 - 40
- 41 - 55
- 56 - 65
- 66 or older
- Would rather not say

*27. What is your current household income (include total income from all working members in the household)?

- Under $10,000
- $10,001 - $25,000
- $25,001 - $50,000
- $50,001 - $75,000
- $75,001 - $100,000
- $100,001 - $150,000
- More than $150,000
- Would rather not say

28. Do you have any comments or thoughts regarding your participation in this program or use of descending devices?

29. Thank you for completing this survey. To be eligible for either of the drawings, please provide your name and email below. **We must have an accurate email in order to contact you if you win!**

Please use the same email from which you received this survey link. Only one entry per individual or email address.

First Name

Last Name

30. Email Address:

Winners will be notified by March 1, 2017. Only one prize per person.