

1. Title Page

Project Title: Estimating and mitigating the discard mortality rate of black sea bass in offshore recreational rod-and-reel fisheries

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ASMFC Contract Number: 16-0403

Total Project Award: \$219,344

Project Timeline: April 1, 2016 through December 31, 2017

This report was prepared by our project team under Agreement #16-043 between the Partnership for Mid-Atlantic Fisheries Science and the Atlantic States Marine Fisheries Commission with funding provided through the Collaborative Research Program of the Mid-Atlantic Fishery Management Council.

Report submitted February 15, 2018



2. Executive Summary

In late fall and winter, black sea bass migrate offshore towards the edge of the continental shelf and overwinter at deep shipwrecks and reefs (45-80+ m). The recreational fishery catches black sea bass offshore during the winter both as the target species and as bycatch while targeting other species (e.g., scup, pollock, hakes, cod, tilefish). Black sea bass are often discarded by recreational anglers during these offshore winter fisheries due to factors such as size restrictions, daily possession limits, “high-grading”, or closed seasons. The discard mortality rate of black sea bass has been previously investigated for inshore fisheries conducted in relatively shallow water and warmer seasons (i.e., spring through fall), but the discard mortality rate of black sea bass in the winter offshore recreational fishery has not been previously investigated. As a result, this project focused on providing a robust discard mortality rate estimate for the offshore black sea bass recreational fishery in the Mid-Atlantic to inform stock assessments and fishery management, and provide best-practice recommendations for anglers to reduce discard mortality.

We conducted an extensive tagging study involving collaboration among recreational fishing industry stakeholders, volunteer anglers, commercial fishermen, and scientists. Fieldwork was conducted from November 2016 through March 2017, and included eight research tagging charters aboard recreational headboats. Our primary study site was the Ice Cream Cone shipwreck, which is situated in 45 m depth and ~85 km southeast of Sea Isle City, NJ. A total of five research tagging charters were completed to the Ice Cream Cone shipwreck from early December 2016 through early February 2017. Two additional tagging trips were completed to the Baltimore Rocks (67 m depth) in February 2017 and one trip to the Indian Arrow shipwreck (58 m depth) in late March 2017. On all tagging trips, volunteer anglers were provided with standardized terminal tackle rigs, whose configuration was established based on a survey of 282 recreational black sea bass anglers. The use of this standardized terminal tackle ensured that black sea bass were captured under authentic scenarios that are representative of the Mid-Atlantic offshore recreational fishery. For each captured black sea bass, a series of technical (e.g., capture depth, angler experience level, fight time, unhooking time, handling time, hooking location, hook removal method), biological (e.g., total length [TL], release behavior, injury, barotrauma symptoms), and environmental (air temperature, sea surface and bottom water temperature) variables were recorded to investigate which factors significantly influenced discard mortality.

Since black sea bass captured in deep water often experience barotrauma, we also examined the effect of swim bladder venting (when done properly) on fish submergence (i.e., the ability to swim back down to the bottom after release) and discard mortality. To accomplish this, fish were released at the sea surface either with no intervening measures (i.e., unvented) or following swim bladder venting with a hollow needle by a trained scientist. At the Ice Cream Cone shipwreck, we tagged a subsample of fish with pressure sensing Vemco acoustic transmitters and monitored their movements post-release using an array of 30 acoustic receivers maintained in collaboration with commercial fishermen. Almost all other sampled fish were tagged with conventional t-bar anchor tags and released to investigate migration patterns and confirm survival if recaptured.

A total of 1,823 black sea bass (136 - 612 mm TL) were sampled throughout the three study sites. Of all sampled fish, 1,713 were released (i.e., some were retained for ageing), including 957 that were vented and 756 unvented. A total of 1,467 fish were tagged with conventional t-bar anchor tags. At our main study site, the Ice Cream Cone shipwreck, 566 fish were sampled, and a subset of 96 fish (278 - 546 mm TL) tagged with acoustic transmitters, 48 of which were vented (278 - 546 mm TL) and 48 were not vented (279 - 485 mm TL). Fight times for captured fish

ranged from 12 - 251 (Mean \pm SD: 78 ± 32) seconds for the full sample. Capture of larger fish at deeper depths by low speed reels, or capture as part of a double header increased fight time. The majority of fish were hooked in the mouth. Released black sea bass exhibited four release behaviors including erratic swimming, sinking, floating, and swimming down, with the vast majority exhibiting the latter two behaviors. Results of a logistic regression indicated that fish total length, capture depth, venting, and the presence of exophthalmia influenced release behavior, with larger fish, that were not vented, caught at deeper depths, and experienced exophthalmia had a lower probability of swimming down.

A total of 304 (17%) black sea bass incurred injuries (i.e., wounds > 2 cm), mostly as a result of hooking trauma and/or the hook removal process. Twelve individuals (0.4%) were dead upon landing, with most having been bitten in half by predators or experienced ripped gills from hooking. The majority (82%) of captured individuals exhibited no injury. The vast majority (95%) of captured black sea bass exhibited symptoms of barotrauma. Stomach eversion was the predominant barotrauma symptom, with stomach eversion score 2 (i.e., stomach protruding from the mouth cavity) being present in 68% of all captured fish. Exophthalmia was present in $\sim 10\%$ of all captured fish. Barotrauma symptoms were generally more prevalent at deeper depths, particularly exophthalmia, which was most prevalent at the deepest capture depth of 67 m.

Acoustic detection data were obtained for 94 of the 96 black sea bass tagged with acoustic transmitters. The two undetected fish exhibited floating behavior and both possibly experienced avian predation. Survivorship of individual black sea bass tagged with acoustic transmitters was objectively determined by a multi-step process that compared their vertical and horizontal movements to those of 'known alive' (positive controls, $n=7$) and 'known dead' (negative controls, $n=2$) fish. Of the 94 black sea bass that were detected within the receiver array, 61 survived the capture and handling process and were considered to be alive and 33 died after release. Of the 33 mortalities, nine were attributed to predation following re-submergence. All predation events occurred within 1.8 - 18.4 (7.2 ± 4.5) hours of release. All of the remaining 24 mortalities were assumed to have occurred due to the fishing event, and occurred from 5.0 - 128.0 (17.1 ± 26.7) hours post-release. Of these, 19 (79.2%) mortalities occurred within 24 hours of release, four from 24 - 72 hours post-release (16.7%), and one (4.2%) >72 hours post-release (95.8% of mortality occurred within 72 hours).

Final black sea bass survivorship data were analyzed with the non-parametric Kaplan-Meier estimator and the semi-parametric Cox proportional hazards model to evaluate the suitability of capture-related variables (i.e., covariates) for predicting survival and to identify a parsimonious subset of covariates that best predict survival. Once the subset of influential covariates was identified, a parametric survival analysis modeling approach was used to assess potential models that can describe survivorship over time and estimate overall discard mortality. The results of our survival analyses suggested that swim bladder venting was the most significant predictor of mortality in released black sea bass. Based on the model results, the mean total fishing-related (i.e., discard) mortality rate at the Ice Cream Cone shipwreck in 45 m depth was 0.21 (95% CI: 0.12, 0.37) for vented black sea bass and 0.52 (95% CI: 0.38, 0.67) for unvented black sea bass. When looking only at unvented fish, fight time was the most significant predictor of mortality, with increased fight time (>54 seconds) resulting in a markedly higher discard mortality rate. Based on these findings, discard mortality for both vented and unvented fish may have been elevated at the deeper locations due to the higher mean fight times of 80 seconds at the Indian Arrow shipwreck (58 m) and 94 seconds at the Baltimore Rocks (67 m).

Given that swim bladder venting (when done correctly) was the most influential factor on discard mortality and increased submergence success over all depths, we recommend that anglers vent all black sea bass that are captured during the offshore winter fishery before they are released, particularly those that experience barotrauma symptoms. However, full realization of the benefits of venting will require continued education and outreach on proper venting techniques and recommended venting tools. Based on this study, swim bladder venting would be the best practice for reducing discard mortality, but given that longer fight times significantly increased discard mortality of unvented fish, we recommend the following practices as additional options for reducing fight time and therefore also discard mortality: target black sea bass in as shallow of water as possible, reel in fish at a moderate to fast pace, use appropriate strength tackle that can easily land black sea bass in deep water, and consider using single hook rigs given that double header catches had longer fight times. In addition, the impacts of dead discards could be reduced by avoiding the targeting of other species in fishing locations and seasons when black sea bass retention is prohibited, or avoiding locations and seasons when undersized black sea bass that have to be released are the primary catch.

In conclusion, our study estimated mean discard mortality rates of 21% for vented and 52% for unvented black sea bass following capture and release in 45 m depth. Given that venting is not commonly practiced in the fishery, the 52% estimate for unvented fish is most representative of the current discard mortality rate when the fishery operates at (or near) this depth. However, due to increased fight times, the discard mortality rate is expected to be higher at greater depths. Current black sea bass stock assessments and fishery management plans assume a 25% discard mortality rate for the coastwide, year-round black sea bass recreational fishery. Based on our results, we recommend further evaluation of the appropriateness of this assumption in terms of being able to provide the best possible estimate of total fishery removals and for developing management plans. Because swim bladder venting was the single greatest factor that reduced the discard mortality rate and increased submergence success, fishery managers might consider encouraging, or even mandating, the venting of black sea bass released in offshore and deep water winter recreational fisheries. Yet, as previously stated, this would require extensive education of fishery participants on proper venting technique and tools. Additionally, given that predation events by other fishes primarily occurred early in our field season and that deeper depths had to be fished to catch black sea bass later in the winter, it may be most advantageous to open the fishery in our study areas off southern New Jersey from the period of mid- or late-December through January, which is when fish are more likely to be accessible at 'shallower' depths (i.e., <~55 m) and predation risk is lower. The results of our study are also applicable to other deep water regional fisheries in which black sea bass experience barotrauma, and therefore should assist with the development of regulations that would reduce the number of discards and discard mortality of black sea bass.

3. Introduction

Recreational rod-and-reel fishing is a popular activity that produces significant socioeconomic benefits to coastal communities (Lovell et al., 2013). Each year, a substantial portion of the total recreational catch is discarded due to management measures (e.g., minimum landing sizes, possession limits, closed seasons) or personal conservation ethics (Tufts et al., 2015). However, reliable discard mortality rate estimates are often difficult to obtain, despite being vital for estimating total fishing mortality in stock assessments and for developing fishery management plans. Previous studies on recreational fisheries have indicated that discard mortality rates are species-specific and often influenced by various capture-related variables, including tackle type, fish handling method, air/water temperature, capture depth, and degree of physical injury (e.g., Diodati and Richards, 1996; Hochhalter and Reed, 2011; Curtis et al., 2015). Increased research related to discard mortality in recreational fisheries and associated outreach efforts to educate anglers have also recently been identified as key strategies for addressing challenges in managing recreational fisheries (FishSmart, 2014; NOAA, 2014).

Black sea bass (*Centropristis striata*) are commonly captured along the east coast of the United States by recreational anglers (Shepherd and Nieland, 2010). Throughout their range, the species is caught as part of numerous seasonal recreational fisheries that utilize multiple different gear and tackle types, and occur over a range of water depths, water temperatures, and air temperatures. Accordingly, published black sea bass discard mortality rates vary considerably by region (e.g., 4.7% to 39%), with an increase in mortality rate evident in deeper capture depths (Bugley and Shepherd, 1991; Collins et al., 1999; Rudershausen et al., 2014). Currently, black sea bass stock assessments and fishery management plans assume a 25% discard mortality rate for the coast-wide recreational fishery (Shepherd and Nieland, 2010), but the wide range of published estimates indicate that this rate may not be representative of all regional fisheries.

In late fall and winter, black sea bass migrate offshore towards the edge of the continental shelf (Moser and Shepherd, 2009) and overwinter on deep shipwrecks and reefs (45-80+ m). Within this time and area, large numbers of fish can be discarded by recreational anglers during directed and non-directed (e.g., scup, cod, tilefish) trips due to size restrictions, daily possession limits, “high-grading”, or closed seasons. The discard mortality rate of black sea bass in this offshore fishery is uncertain. Collins et al. (1999) reported black sea bass discard mortality rates up to 39% following rod-and-reel capture in a similar depth range (43-54 m) off South Carolina, but it is unclear the extent to which this estimate is applicable to the Mid-Atlantic offshore recreational fishery that occurs in colder water and air temperatures, sometimes at deeper depths, and in different ecosystem conditions (i.e., predator species and abundance). In addition, the estimates derived by Collins et al. (1999) for the 43-54 m depth range were based on low sample sizes (n=25) and by monitoring fish in cages for 24 h post-release, which is a technique that can bias mortality estimates and potentially serve as under- (i.e., shielding from predation) or over-estimates (i.e., impacts on feeding) of discard mortality (Davis, 2002). Consequently, further research was needed to provide a more robust discard mortality rate estimate for the offshore black sea bass recreational fishery in the Mid-Atlantic to inform stock assessments and fishery management.

This project addressed the Mid-Atlantic Fishery Management Council 2016–2017 Collaborative Fisheries Research Program Priority #4 by determining the discard mortality rate of black sea bass captured by recreational anglers using rod-and-reel fishing gear in the fall/winter Mid-Atlantic offshore fishery. In addition, this project established best practices guidelines to

reduce the discard mortality rate of black sea bass in both the offshore and inshore fisheries. These goals were achieved by meeting the following originally proposed research objectives:

- (1) Estimate the discard mortality rate of black sea bass following capture with rod-and-reel fishing gear at a deepwater offshore shipwreck in the Mid-Atlantic using passive acoustic telemetry and a longitudinal survival analysis.
- (2) Identify the capture-related factors that influence black sea bass discard mortality.
- (3) Utilize the results from (2) to establish “best practice” guidelines for reducing the mortality of discarded black sea bass.
- (4) Conduct a broad outreach effort to disseminate project results from (1) and (3) to invested stakeholder groups (e.g., fishery managers and scientists, recreational fishing community).
- (5) Describe the residency, behavior, and habitat use of black sea bass at an offshore shipwreck in the Mid-Atlantic.

4. Methods

Study Timeline: Fieldwork was conducted from November 2016 through March 2017, which covers the winter period of highest offshore recreational fishing effort for black sea bass in the Mid-Atlantic.

Study Sites:

Ice Cream Cone Wreck (main study site): This study utilized input from a range of industry collaborators to ensure selection of a suitable study site that provided an accurate representation of the winter offshore recreational black sea bass fishery in the Mid-Atlantic, and was in a location conducive for maintaining an acoustic telemetry receiver array. Following extensive conversation with industry collaborators, including those who are part of the Starfish Fleet in Sea Isle City, NJ (e.g., Captain Bob Rush, Capt. Mike Weigel), captains from the United Boatmen of New Jersey, and industry stakeholders from the Partnership for Mid-Atlantic Fisheries Science, it was decided to have the main study site be the “Ice Cream Cone Wreck”, which is located ~85 km southeast of Sea Isle City, NJ in 45 m depth (Figure 1). This location is an area with consistently high black sea bass catch rates and a depth range that is representative of common offshore fishing grounds for black sea bass.

Baltimore Rocks and Indian Arrow Wreck: Black sea bass catch rates at the Ice Cream Cone Wreck slowed considerably beginning in the middle of January 2017. In fact, only 14 fish were captured during the last tagging trip to the site on February 3, 2017. In an effort to achieve our target number of observations (i.e., ~1,200 fish) and to investigate how our observations and discard mortality might vary by depth, the decision was made to conduct future trips at alternative, deeper fishing locations that were further from port and are locations where black sea bass have historically been captured later in the winter fishing season. Three additional trips were made, including two trips to the Baltimore Rocks (67 m in depth) and one trip to the Indian Arrow wreck (58 m), during February and March, respectively (Table 1). Not only did the execution of these trips allow us to reach our target sample size, but they also permitted the observation of fish captured at deeper

depths, and the investigation of potential effects of capture depth on barotrauma and fish survival (see Findings section below).

Tagging Methods:

Our team collaborated with the Vemco staff (Halifax, Canada) in order to select the most appropriate pressuring-sensing acoustic transmitters (model V9P-2H; Vemco AMIRIX Systems, Inc., Nova Scotia) and optimal transmitter programming configurations (e.g., tag power, battery life, depth sensor resolution, and transmission schedule; Table 2) to match the study site depth and study objectives. Similarly, our team worked with the Floy tag manufacturing company (Seattle, WA) to design and purchase the conventional t-bar anchor tags most appropriate for black sea bass tagging, including Pedersen discs used to attach the acoustic transmitters (see below).

Transmitter attachment and retention study: Prior to any tagging trips, a holding tank study was conducted in order to test multiple transmitter attachment methods, and evaluate the minimum acceptable fish tagging size, transmitter retention rate, and tagging-induced mortality rate for each method. In collaboration with Bill Hoffman from the Massachusetts (MA) Division of Marine Fisheries, 35 live black sea bass (Total lengths: 27 – 42 cm) were collected while fishing with rod-and-reel aboard the *R/V Mya* in Buzzards Bay, MA on 9/12/2016. Following capture, fish were kept in onboard holding tanks during transport to the Seawater Laboratory at the University of Massachusetts Dartmouth School for Marine Science and Technology in New Bedford, MA. All methods related to the holding tank experiment were performed under approval by the Institutional Animal Care and Use Committees (IACUC) at both Rutgers University and the University of Massachusetts Dartmouth (Appendix 1).

Two methods for externally attaching acoustic transmitters were tested beginning on 9/20/2016. Method 1 involved the use of Floy spaghetti tag material, which was passed through the dorsal musculature of the fish with a hollow needle and tied around the transmitter end cap to secure it in place (n=10 fish; Figure 2A). Method 2 involved the use of 22.7 kg test monofilament line, 0.25 – 0.75” Pedersen discs, and copper crimps (n=5 fish; Figure 2B). For this method, a 20 cm length of monofilament line was first tied to the transmitter end cap. Next, a small baffle and Pedersen disc were threaded onto the line and pushed flush against the transmitter. Using a hollow needle, the monofilament line was threaded through the dorsal musculature of the fish, and a Pedersen disc and baffle were threaded onto the tag end of the line. Finally, Pedersen discs were snugged in place on either side of the fish’s body and a small, single sleeve, copper crimp was threaded onto the tag end, positioned flush against the baffle/disc assembly, and secured in place by a crimping tool. The monofilament line tag end was then cut.

After 62 days of observation following tagging with each method, there was zero tag shedding or mortality at the termination of the study on 11/21/2016. Given this, (1) any mortality observed in the field could be assumed to be due to the capture, handling, and release processes, rather than the tagging process, and (2) tag shedding is unlikely to occur during this time window. Although both attachment methods were successful, Method 1 resulted in a high prevalence of skin lesions and tissue irritation. Thus, Method 2 was chosen as the preferred attachment method, because it did not cause as much harm to the fish (i.e., fewer and less severe tag-induced lesions were observed) and was generally thought to provide a more solid attachment of acoustic transmitters to black sea bass. The minimum acceptable fish size for tagging was also established at 27 cm, which is consistent with the size of the smallest fish monitored in this holding study and

permitted the tagging of black sea bass that are under the current federal minimum size limit (12.5" or 31.75 cm).

Field protocol, tagging strategy, and data collection:

Determining standardized terminal tackle: Prior to any sampling, we conducted an extensive survey of recreational black sea bass anglers and captains to determine the reel type (e.g., conventional, spinning, or electric), tackle (e.g., line type and strength, hook type and size, etc.), and rigging techniques (e.g., use of monofilament topshot, topshot length, etc.) that are most commonly used in the Mid-Atlantic recreational offshore black sea bass fishery. This survey was hosted on SurveyMonkey during October and November 2016, and was distributed primarily via online message boards for recreational anglers (e.g., www.thebassbarn.com, www.noreast.com, and www.njffishing.com). A total of 282 anglers responded to the survey. This survey was originally intended to designate standardized rod-and-reel setups and terminal tackle rigging for use by all volunteer anglers during all research tagging charters. However, it was ultimately only used to select standardized terminal tackle rigging, because the volunteer anglers wanted to use their personal rods and reels while fishing. Our research team permitted this, because rod choice is not expected to impact discard mortality and it gave us the opportunity to investigate how other factors such as reel speed/retrieve ratio might impact discard mortality while still keeping the terminal tackle rigging standardized. Based on the results of the online tackle survey (Table 3), our standardized terminal tackle rigging was a High-Low rig made with 50 lb. (22.7 kg) monofilament leader material and two 5/0 Octopus J-hooks (Mustad Ref. # 92553-BN) (Figure 3). All terminal tackle rigs were tied by co-PI D. Zemeckis. Anglers were provided the appropriately sized lead sinkers for the current sea conditions that day to keep the baits on the bottom to catch black sea bass (i.e., 10 - 20 ounces, 284 - 567 grams).

Tagging trips: Eight for-hire charter trips were conducted from December 2016 – March 2017 (Table 1). Research tagging charters to deploy acoustic transmitters at the Ice Cream Cone wreck were conducted aboard the *F/V Susan Hudson* from Sea Isle City, NJ, from December 2016 – February 2017 (n=4 trips), and one charter aboard the *F/V Porgy IV* sailing from Cape May, NJ, in January 2017. The final three tagging trips were all completed aboard the *F/V Susan Hudson*, with two trips fishing the Baltimore Rocks and the final trip fishing the Indian Arrow shipwreck. Each tagging trip had 6 - 14 volunteer anglers of varying experience levels (as quantified by questionnaire) and up to four scientific personnel. Prior to the commencement of fishing activity on each trip, each volunteer angler was required to complete an angler questionnaire that quantified their experience level (Appendix 2). For all fishing activities, volunteer anglers were given the option to fish with their own fishing rod-and-reel setup as long as their terminal tackle rig was the standardized design as described above. If the angler did not have their own rod and reel setup they were provided one that was rigged accordingly by scientific staff. All anglers were provided the same bait (chopped sea clam or squid, provided by the chartered vessel) and allowed to determine how best to fish, handle, and unhook their catch to promote authentic scenarios. Each volunteer angler was provided a stopwatch in order to record the following times for each fish: fight time, unhooking time, and handling time.

For each captured black sea bass, a series of technical variables that describe the capture event were recorded, including: capture depth, angler experience level, fight time, unhooking time, handling time, hook location (Figure 4), and hook removal method. Biological variables including total length (TL), air and water temperature, and release behavior were also recorded. Each fish

was also assigned a physical injury score (i.e., present or absent), as well as exophthalmia and stomach eversion scores, which assessed the impacts of the capture process and barotrauma, respectively. See Table 4 for a description of all recorded variables. To monitor post-release fate, a subset of 96 black sea bass were tagged with Vemco acoustic transmitters. Captured fish not tagged with acoustic transmitters were tagged with conventional t-bar anchor tags (Floy FD-94; n=1,467) to confirm survival or identify movement patterns if recaptured, or otherwise retained for biological sampling (i.e., ageing: n = 74). The remaining 282 captured fish were not tagged due to logistical issues (e.g., too many fish that needed processing during a very short period of time) or after our conventional t-bar tag supply was exhausted.

Previous research on black sea bass indicated that swim bladder venting may decrease discard mortality (Collins et al., 1999), and anecdotal reports from the industry suggest that the inability to submerge (due to barotrauma) is a major contributor to discard mortality (Gary Shepherd, pers. comm.). To examine the true extent to which swim bladder venting impacts submergence success and discard mortality rate, a subset of captured black sea bass were vented using a Ventafish VF-1 Fish Venting Tool following techniques outlined at www.catchandrelease.org. This tool included a 16 gauge replaceable needle with a 45 degree front end. To minimize risk of internal injury to the fish from improper technique, all fish were vented by a single trained scientist (co-PI D. Zemeckis) by placing the fish flat on the measuring board and inserting the needle into the swim bladder behind the pectoral fin while using the spring-loaded button on the tool to insert the needle and let the gas release out of the vent holes on the needle. Having one trained scientist perform all of the venting of the fish ensured that we were able to test the influence of proper venting technique on black sea bass discard mortality. An equal number of vented and non-vented fish were tagged with acoustic transmitters (n=48 fish per treatment), and efforts were made to vent fish over all observed lengths and in an equal ratio for all other capture observations.

Tag recaptures and lottery: A toll free phone number was maintained through Rutgers University to retrieve fishery-dependent recapture information. That number was printed on all conventional t-bar anchor tags and Pedersen discs used for attaching acoustic transmitters so that whenever a tagged fish was recaptured it would hopefully be reported to our research team. A database of all reported recaptures was maintained and a lottery reward system was used to randomly award three anglers (who reported tag recaptures) a \$500 reward on three separate occasions during the project (i.e., June, September, and December of 2017).

Acoustic receiver array design, deployment, and monitoring: To monitor the fate of fish tagged with acoustic transmitters, an array of 30 acoustic receivers (Vemco model VR2W) was strategically deployed based upon extensive communication among the project team and fishing industry collaborators in order to maximize the coverage of the Ice Cream Cone shipwreck and surrounding areas and to minimize the risk of losing equipment (Figure 1). All receivers were deployed using an established mooring system based on that depicted in Figure 5A. Twenty five receivers (Stations: SB1 - SB25) were deployed on November 28, 2016 in cooperation with Captain Eric Burcaw aboard the *F/V Rachel Marie* from Sea Isle City, NJ and an additional five receivers (Stations: SB26 - SB30) were deployed on January 17, 2017 in cooperation with the *F/V Porgy IV* (Figure 5B). These five additional receivers were deployed based on preliminary data that showed a high degree of movement towards the southern portion of the acoustic array and our desire to increase our ability to monitor movements in this direction. HOBO Pendant temperature

loggers (Onset Computer Company, Onset, MA) were placed at the surface and bottom of receiver mooring lines at stations SB1, SB8, SB21, and SB23 and were programmed to record water temperature every 5 minutes (Figure 1B). Three trips (12/20/2016; 1/21/2017; 2/21/2017) were conducted aboard the *F/V Rachel Marie* to download, clean, and maintain acoustic receivers, with most receivers being permanently hauled and downloaded on 3/27/2017. Three acoustic receivers were lost over the period of November 28 to March 27 (SB3, SB10, SB24). All downloaded acoustic telemetry detection data were backed-up on external drives and quality controlled for data analysis.

Three acoustic receivers (SB12, 13, and 15: Figure 5B) positioned in close proximity to the shipwreck were left in place after 3/27/2017 to continue monitoring the study site in case tagged black sea bass visited this location during their inshore spring migration. Unfortunately, all three acoustic receivers and mooring systems were lost when they were attempted to be retrieved by Captain Burcaw during one of his commercial fishing trips on 6/4/2017. Efforts were made to grapple at the location at which each receiver was set, but Captain Burcaw was unable to recover any of the gear. Although these receivers were positioned around the shipwreck and were not previously disturbed or lost, it's possible that there was a negative interaction with another trap or scallop dredge fisherman in the spring, or perhaps a passing cargo ship or tugboat. Despite these losses, the loss of only six total receivers was viewed as being relatively minor given the distance of the receiver array from shore, the rough winter weather, and the regular presence of passing cargo ships in the study site, as well as the presence of commercial sea scallop fishing vessels near and inside the array in March 2017. Further, the loss of only three receivers during the main study period, including no losses around the wreck, permitted excellent data recovery to meet study objectives.

Given the importance of 'known alive' (i.e., positive control, see below) fish to the analysis, a last attempt to monitor for any acoustically-tagged black sea bass that may have remained at or returned to the Ice Cream Cone wreck was made in December 2017. To accomplish this, we provided the *F/V Susan Hudson* with a single acoustic receiver to deploy during one of their charter fishing trips to the wreck. This receiver was deployed as planned, however, no acoustic detections were obtained.

Statistical analysis: All statistical analyses were performed with the statistical computing software R (R Foundation for Statistical Computing, 2018). Significance was accepted at a level of $p < 0.05$. To investigate the relationship between fight time and fish TL, capture depth, capture as part of a 'double header' (i.e., two fish captured simultaneously, one on each hook), and reel ratio (i.e., high or low speed reels) a generalized additive mixed effect model with an inverse link function was performed using the 'mgcv' package (Wood, 2011) in R. To account for variation resulting from angler behavior, 'Angler' was included as a random effect. All model variants were compared using the Akaike Information Criterion (AIC; Akaike, 1973) to examine the effect of each factor on fight time, with the model variant with the lowest AIC score being chosen as the best fitting model.

A fixed-effects logistic regression was also employed to evaluate the relationship between release behavior and several capture-related variables, including depth, fish TL, physical injury, presence of exophthalmia, presence of stomach eversion, and venting. A parsimonious set of these variables were selected with a stepwise forward model selection process using AIC following Benoit et al. (2010). In brief, variables were added incrementally to an intercept-only model and retained only if the AIC score was reduced by at least three units. If final models had an equal

number yet different composition of variables and an AIC score ≤ 3 units, both were kept and considered equally plausible.

Survivorship assessment: Survivorship of individual black sea bass tagged with acoustic transmitters was objectively determined by comparing vertical and horizontal movement against black sea bass with known statuses (see below). Following procedures detailed by Capizzano et al. (2016), prior to analysis all transmitter data were initially vetted for false detections using the FDA Analyzer tool in VEMCO's User Environment (version 2.2.2) and irrational detection data that coincided with transmitter failures.

Dead controls (known dead fish): Accurate identification of the post-release fate of black sea bass is predicated upon a thorough understanding of the horizontal and vertical movements that are exhibited by a dead fish. For example, surface currents can move dead fish as it sinks to the bottom and bottom currents can cause a carcass to drift along the bottom, providing the perception of directed movement (i.e., a living fish). To identify behaviors that were indicative of a dead fish, five dead fish were tagged with acoustic transmitters and released at the study site. Preliminary data from dead controls released early in the study suggested that carcasses tended to drift out of the array, thus, to obtain a representation of a stationary fish (i.e., a dead fish that was resting in one place), an additional transmitter was deployed on a stationary mooring line within the acoustic array (Figure 1B). Resulting dead control data were used as standards by which to determine the fate of all other acoustically-tagged fish. Reliable data were obtained from two of the fish dead control fish released within the receiver array; data from the three other dead controls were determined to be insufficient due to the extreme brevity of their monitoring period (i.e., hours).

Positive controls (known alive fish): Throughout the study period, seven acoustically-tagged black sea bass were confirmed to be alive either by acoustic detection (n=4), or fishery-dependent recapture (n=3). Acoustic detections were obtained for these fish in collaboration with the Atlantic Cooperative Telemetry (ACT) Network (Table 5). Since the fate of these fish was known (i.e., 'alive'), they were treated as positive controls and used as standards by which to determine the fate of all other acoustically-tagged fish.

Given the impact of misclassifying mortality events on subsequent longitudinal survival results (see below), we employed a three-step approach to determine individual fish fate. Step (1) of our approach involved the use of a discriminant function analysis, which creates a function capable of classifying individuals of unknown origin into groups based on metrics from individuals of known origin (White and Ruttenberg, 2007) using solely acoustic detection data. A discriminant function was created using gross movement metrics from positive and negative controls, specifically maximum depth variance, minimum depth, and the proportion of total depth observations that were shallower than an individual's mean overall observed depth minus the mean depth variance of dead control fish, using the R package "MASS" (version 7.3-45; Venables and Ripley, 2002). Discriminant function results included a fate assignment (alive or dead) for each fish.

Step (2) included the application of a depth variance test applied to depth observations recorded at defined intervals throughout the detection history of each acoustically-tagged fish. Because transmitters were programmed to emit transmissions on a phased schedule, acoustic detection data were binned into specific time intervals post-release to maintain a consistent number of expected detections per interval (Capizzano et al., 2016). Only bins with at least 10 observations

were included in the analysis. To account for the effect of tide height on individual depth observations, the study site's tidal cycle was estimated and subsequently removed from each transmitter's depth record using the R package "oce" (version 09-21; Kelley and Richards, 2017). The variance of tide corrected depth observations in each time bin were compared to that of the negative controls for each fish using a one-tailed t-test of the absolute difference from the median (modified Browne–Forsythe–Levene test for homogeneity of population variance; Lyman Ott and Longnecker, 2010); from now on referred to as the depth-variance survival test. Tide-adjusted depth data of negative controls were assumed to be representative of dead black sea bass in the study area since they interacted with the area's bathymetric features over time. Due to the infrequency of off-bottom movement exhibited by black sea bass, when a tagged black sea bass's depth-variance was significantly different ($p < 0.05$) from the negative controls during one or more time intervals, the fish was classified as being alive.

Following Steps 1 and 2, all fish that were detected for >2 days whose fate was predicted to be the same by both the discriminant analysis and depth variance test ($n=50$ fish) were assigned the appropriate fate (e.g., Discriminant analysis result = ALIVE, Depth variance test result = ALIVE, Final fate = ALIVE). For the remaining 44 detected fish, due to the brevity of their monitoring period (i.e., the lack of critical movement data) and the discrepancy between the discriminant analysis and depth variance results, each fish was subsequently subjected to a semi-quantitative analysis that used multiple metrics to objectively infer their final fate. This analysis included: (1) a semi-qualitative assessment of the horizontal and vertical movement patterns of each fish that placed particular emphasis on the comparison of their movements to those evident in both positive and negative controls; and (2) the analysis of the trajectory of horizontal movements in relation to surface and bottom currents predicted at the study site by the Regional Ocean Modeling System (ROMS) (data available at <https://www.myroms.org/>).

For (1), individual horizontal and vertical movement plots (see Appendix 3 for example plots) were first examined to determine if the general pattern of movement was consistent with either positive (characterized by bottom-oriented behavior with some vertical movements up to ~20 m and more extensive horizontal movements, including non-linear emigration from the receiver array) or negative control fish (characterized by small vertical movements on the order of the depth range evident in the study site and no or limited horizontal movement restricted to straight line emigration from the array). In nine instances, vertical movements, represented by repeated, extensive movements from the bottom to 15 - 20 m that commenced at the onset of darkness (night), that were not observed in either positive or negative control fish were evident (Fish #'s: 3358, 3359, 3365, 3367, 3370, 3372, 3374, 3376, 3379; Appendix 3). Based on the observation of numerous predation events (e.g., the capture of fish that were bitten while being brought to the surface) that occurred during each of the research trips on which these nine fish were tagged, each fish was considered to have been predated upon following release. Based on conversations with vessel captains and crews, there is strong evidence that predation events such as these commonly occur during the early part of the offshore black sea bass fishing season (e.g., November and December when dogfish and bluefish abundance are highest at these locations), thus, all predation events were included in the survival analysis as 'dead' fish (see below).

For (2), the trajectory of horizontal movements exhibited by each fish during periods when they were floating at the surface (i.e., depth = 0 m) or moving along the bottom in a manner that resulted in their emigration from the receiver array was compared with ROMS current predictions at the study site (at the time of detection) to determine if movements were indicative of active swimming or drifting behavior. In brief, examination of directional movement data from both

positive and negative controls indicated that while positive controls (i.e., known alive fish) often moved in opposition or tangential to the direction of the prevailing current (i.e., into the current), dead control fish (i.e., known dead fish) almost always drifted in the direction of the prevailing current (i.e., with the current). Furthermore, positive control fish also generally exhibited straight line movement out of the array over a much shorter period (<10,000 seconds) than dead controls (>10,000 seconds), thereby providing evidence of active movement. Given these observations, the fate of all remaining fish (n=35) was determined by comparing the duration and trajectory of their movement in relation to the bottom current direction, with fish that slowly moved along the bottom (i.e., with only small differences in depth evident) in the direction of the current being classified as ‘dead’ and those that moved more rapidly against or tangential to the direction of the bottom current being classified as ‘alive’.

Analysis of survival data: Final black sea bass survivorship data were analyzed to address the following objectives: (1) to evaluate the suitability of capture-related variables (i.e., covariates) for predicting survival and to identify a parsimonious subset of these that best predict survival; and (2) to use this subset of covariates to assess potential models that can describe survival over time and estimate overall discard survival. Event times for both dead (i.e., time of death) and surviving (i.e., time of last observation) black sea bass, along with the values for a suite of capture-related variables that may affect survival (i.e., covariates) were compiled following methods described by Benoît et al. (2015) and Capizzano et al. (2016). Such event times were categorized as one of three types of data censoring: (1) fish that were inferred to have died within the acoustic receiver array (i.e., uncensored), (2) fish that died during capture and handling or release (i.e., left-censored), and (3) fish released alive whose death was not inferred/observed during the experiment (i.e., right-censored).

A combination of non-parametric and semi-parametric longitudinal survival analyses were used to address objective (1) following procedures outlined by Knotek et al. (2018). First, the empirical Kaplan-Meier (KM) estimator was used to visually assess the influence of biological, technical, and environmental covariates on the survival function (cumulative probability of survivorship over time; Cox and Oakes 1984). Because the KM estimator is non-parametric, it follows the proportion of individuals alive as a function of time in the absence of censored observations. Log-rank tests, specifically the Peto & Peto modification of the Gehan-Wilcoxon test, were performed to accept or reject the null hypothesis that there was no statistical difference between survival functions for categorical covariates. The median for covariates with continuous data were used to establish broad categories for the KM estimator and log-rank tests.

A mixed-effects Cox proportional hazards model (CPHM) was then used following Knotek et al. (2018) to objectively evaluate the suitability of covariates as predictors of survival given the model’s ability to simultaneously evaluate the additive effect of multiple covariates (Cox 1972; Therneau and Grambsch, 2000). The model is expressed as:

$$h(t) = h_0(t)\exp(X' + Z'b) \quad (\text{Eq. 1})$$

where $h(t)$ is the instantaneous probability of mortality at time t conditional on having survived to time t (i.e., the estimated hazard function), which is a function of a non-parametric baseline hazard function $h_0(t)$, a vector of covariates X' and a Gaussian random effect Z' . Because this class of survival analysis is semi-parametric, it makes no assumption about the shape of $h_0(t)$ but assumes that the ratio of hazards for two individuals is constant over time and is a function of both the

covariates and random effects (Cox, 1972). To identify a parsimonious subset of covariates, the stepwise forward selection process using Akaike's Information Criterion corrected for small sample sizes (AICc; Burnham and Anderson 2002) was used as per Benoit et al. (2010). The random effect ('sampling trip') was considered to incorporate any within-trip correlations (e.g., Benoit et al. 2010) as outlined by Knotek et al. (2018). Seven sensible covariates were identified *a priori* and with KM estimators as potentially influencing discard mortality in black sea bass and were included in the model selection procedure: fight time, handling time, TL, physical injury, air temperature, sea surface temperature, season (fall and winter), and venting. The release behavior covariate was dropped due to insufficient sample size of fish that floated after release ($n=10$). Covariates that produced the best fit model were used in the subsequent modeling as the predictors for survival.

Despite their ability to fit the data, non-parametric and semi-parametric models cannot be used to parse out different mortality sources (e.g., capture-handling, post-release) or provide mechanistic interpretations of survivorship patterns over time (Benoit et al. 2015). Therefore, the parametric survival modeling approach developed by Benoit et al. (2015) was used due to its ability to explicitly account for these types of mortality and provide estimates for each. Specifically, this model assumes that there are two general groups of fish (i.e., fish that have been adversely affected by the fishing event and will die vs. fish unaffected by the fishing event and will not die). The KM estimator of the survival function suggested the presence of two types of mortality over time when viewing survival across all observations: capture and handling mortality that occurred prior to release, and capture-related post-release mortality which occurred within days of release (Figure 6; Benoit et al. 2012, 2015). The survival function for this model ($S(t)$; probability of surviving to time t) is expressed as:

$$S(t) = (\exp[-(t)^\alpha] + (1-\tau)) \quad (\text{Eq. 2})$$

where τ is the probability of surviving capture and handling, π controls the probability that an individual was adversely affected by the fishing event, and α and γ are respectively the scale and shape parameters of an underlying Weibull distribution that determines the mortality patterns over time for the adversely affected individuals. From Equation (2), it is clear that at $t = 0$, $S(t) = \tau$. Therefore, as $t \rightarrow \infty$, the term $\exp[-(t)^\alpha] \rightarrow 0$ (i.e., all affected fish die) and $S(t) \rightarrow (1-\pi)$ (i.e., only unaffected individuals remain alive). Thus, π is the conditional post-release mortality rate (i.e., the mortality rate for individuals that were alive when released but subsequently died as a direct result of discard mortality), and $1-\pi$ is the total discard mortality probability.

After determining the basic model and appropriate terms to include, model variants of Equation (2) were developed and fit with the parsimonious subset of covariates. The influence of capture-related variables that may affect survival can be included in the model via the α , γ , τ , and π terms but the effects are most often and strongly observed on the two latter terms (e.g., Benoit et al. 2012, 2015; Capizzano et al. 2016). Three model variants of Equation (2) were considered for model selection procedures (Table 6). Model variants were fit with selected covariates from the CPHM using maximum likelihood and constructed with the same forward selection procedure using AICc.

Because venting may be difficult to implement, the non-parametric KM estimator and semi-parametric CPHM survival analyses were performed on unvented fish to examine the suitability of covariates for predicting survival. Eight sensible covariates determined *a priori* and with KM estimators were included in CPHM model selection with the forward selection procedure

using AICc: fight time, handling time, TL, physical injury, sea surface temperature, temperature differential between bottom water and air, season (fall and winter), and release behavior. Since no parametric survival analysis was applied to these data, only general trends are provided.

5. Problems Encountered

Some unanticipated problems were encountered during the project, but these problems did not prevent us from addressing our core objectives. With regard to fieldwork (tagging trips and receiver deployment and maintenance), we experienced some difficulty completing offshore tagging trips due to the rough weather conditions, particularly during January 2017. There were also some mechanical and logistical issues that arose with the primary tagging vessel, the *F/V Susan Hudson*, which was unavailable for approximately three weeks in January 2017, because of repairs that needed to be performed following an inspection by the United States Coast Guard. However, the recruitment of a backup vessel (*F/V Porgy IV*, Cape May, NJ) allowed us to quickly capitalize on a nice weather window and not only deploy all of our acoustic transmitters on schedule, but also exceed our target number of black sea bass capture observations by almost 50%. We were also able to spread the acoustic transmitter releases over a variety of weather conditions, and collect observations at multiple locations.

As communicated above, the acoustic receiver array was expanded on January 17, 2017 to provide increased monitoring at the southern extent of the array. This helped to counter the problems observed in data from the first acoustic telemetry receiver download on 12/20/2017, which indicated that the majority of the fish that emigrated from the array did so in a south/southwest direction. In addition to the six acoustic receiver mooring systems that were completely lost during this study (see above), there were three mooring systems that had their surface buoys destroyed by ship strikes. This became evident after they were recovered off the seafloor using a grappling system that couldn't have been employed without the expertise of the collaborating commercial fishermen. Recovery of this equipment not only salvaged the expensive research gear, but also permitted downloading of the valuable data stored on the acoustic receivers. Therefore, strategically rigging our mooring systems and collaborating with commercial fishermen helped to minimize the amount of lost equipment and data.

Due to the complex and diverse nature of the black sea bass movements and behavior in the study site, the need to allow the maximum amount of time for tag recaptures and detections (i.e., the establishment of positive controls), and the complexity of the final survival analysis, the final estimation of discard mortality rate and the identification of the capture-related factors that were predictors of mortality were slightly delayed until later in the project timeline than expected. However, this thoroughness resulted in the most robust results as possible for inclusion in this final report, but it did delay our ability to conduct broad outreach efforts to disseminate our results and educated anglers on recommended best practices for reducing discard mortality (i.e., Objective 3). But, due to the overwhelming importance of the positive control fish to both the accurate identification of individual fish fate and the estimation of the discard mortality rate, it was necessary to obtain as many positive control fish as possible in an effort to maximize the validity of our results. As outlined below, we did begin to disseminate our results to the scientific community and recreational fishing community, and have outlined a detailed plan for completing those efforts with the finalization of our results for this final project report.

6. Findings

Summary of capture events: During the eight research tagging charters conducted from December 2016 to March 2017, a total of 1,823 black sea bass ranging in size from 136 - 612 mm TL were captured over three depths (45, 58, and 67 meters; Figure 7). Due to the sometimes high volume nature of the fishery (i.e., many fish being captured over a short time), a complete set of data for all quantified variables was not available for all captured fish, hence the discrepancies in sample size presented throughout this report. All fishing activities were performed with the standardized High-Low, two-hook terminal tackle setup that was chosen as the most representative gear configuration used in the offshore black sea bass fishery. A total of 50 volunteer anglers of all experience levels participated in tagging trips, however, there were markedly more experienced (scores 5 - 9; n=43 anglers, n=1,663 capture events) than inexperienced (scores 0 - 4; n=7 anglers, n=155 capture events) anglers. However, we feel as though this relationship is representative of true conditions, given that more experienced (i.e., 'die hard') fishermen tend to participate in this fishery given its offshore nature and occurrence during characteristically cold and rough winter months.

Anglers used a fairly wide range of conventional fishing reels, with retrieve gear ratios from 2.5:1 to 7.1:1. For analysis, these reel retrieve ratios were broadly classified as 'low' (reel retrieve ratio <5.0:1; n=891 capture events) and 'high' (reel retrieve ratio >5.0:1; n=927 capture events) speed. All captured black sea bass were lifted onboard while still attached to the hook, no fish were netted or gaffed. A total of 321 capture events were classified as 'double headers', with two fish captured simultaneously (one on each hook). Of the 1,823 captured fish, 1,713 were released including 957 that were vented and 756 that were not vented (Table 7). A total of 1,467 fish were tagged with conventional Floy tags, 766 of which were double tagged (to estimate tag shedding rate). A subset of 96 fish (278 - 546 mm TL) were tagged with Vemco acoustic transmitters, 48 of which were vented (278 - 546 mm TL) and 48 of which were not vented (279 - 485 mm TL).

Technical variables: Fight times ranged from 12 - 251 (Mean SD: 78 ± 32) seconds for the overall sample, with transmitter-tagged fish being fought for 17 - 225 (56 ± 24) seconds (Table 8). Results of a generalized additive mixed effect model indicated that fight time was influenced by fish TL, capture depth, capture as part of a double header, and reel ratio (Table 9). Comparison of delta AIC scores suggested that depth was the most influential factor impacting fight time, with fish captured at the deepest depth (67 m) experiencing the longest fight times (Figure 8). There was a positive relationship between fight time and TL, with larger fish being fought for longer periods (Figure 9). At each depth, interpolation of mean fight time suggested that fish >491 mm TL were fought for longer than average durations. Capture as part of a double header and by low gear (speed) reels also increased fight time (Figures 10 and 11).

Unhooking times and handling times for all observations and transmitter-tagged fish are presented in Table 8. The majority of fish were unhooked by the capturing angler (Figure 12), however, there was no apparent difference in unhooking time between anglers and fishing vessel mates/deckhands or between experienced and inexperienced anglers (Table 8). The majority of fish were hooked in the mouth (shallow or medium mouth), but fish were hooked in various locations of the body throughout the study (Table 10).

Biological variables: Released black sea bass exhibited four behaviors including erratic swimming, sinking, floating, and swimming down, with the vast majority of fish exhibiting the

latter two behaviors (Table 11; Figure 13). Results of a logistic regression indicated that fish TL, capture depth, venting, and the presence of exophthalmia influenced release behavior, with larger fish, that were not vented, caught at deeper depths, and experienced exophthalmia had a lower probability of swimming down (Tables 12&13; Figure 14). Air, sea surface water, bottom water, and deltaT (the difference between surface and bottom temperature) temperatures experienced by fish are presented in Table 8. Bottom and surface water temperature at the Ice Cream Cone study site ranged from 6.1 - 14.5 C from the first to last day of monitoring (Figure 15).

Injury score: A total of 304 (17%) black sea bass incurred injuries (i.e., wounds > 2 cm), mostly as a result of hooking trauma and/or the hook removal process. Twelve individuals (0.4%) were dead upon landing, with most having been bitten in half (n=8) or experienced ripped gills (n=2). The majority (82%) of captured individuals exhibited no injury.

Barotrauma: The vast majority (95%) of captured black sea bass exhibited symptoms of barotrauma. Stomach eversion was the predominant barotrauma symptom, with stomach eversion score 2 (i.e., stomach protruding from the mouth cavity) being present in 68% of all captured fish (Figure 16). All four stomach eversion scores were observed in fish tagged with acoustic transmitters, with the relative distribution of scores being comparable to the broader sample (Table 14). Exophthalmia was present in ~10% (n=172) of all captured fish, and in ~6% of fish tagged with acoustic transmitters (Table 14). Barotrauma symptoms were generally more prevalent at deeper depths, particularly exophthalmia, which was most prevalent at the deepest capture depth (67m; Figures 16 & 17).

Survivorship assessment (Objectives 1 & 2): Acoustic detection data were obtained for 94 of the 96 black sea bass that were tagged with acoustic transmitters. The two fish that were not detected after release (Transmitters 3360 and 3375), were both captured during December (5 & 13th) sampling trips, exhibited ‘floating’ release behavior, and were among the smallest individuals that were acoustically-tagged (286 - 287 mm TL). Given that several other acoustically-tagged fish were detected for extended periods (i.e., minutes to hours) while they floated at the surface (e.g., Fish 3418, 3419; Appendix 3) and these weren’t, it is highly possible that these two undetected fish experienced avian predation shortly after release. Avian predators, primarily herring and black-backed seagulls, were present in abundance during each of these sampling trips, and were observed to actively predate upon other released fish at distances of 15 m or more from the anchored vessel. Regardless, due to the lack of acoustic detection, these individuals were not included in the survival analysis, because avian predation events could not have been visually confirmed for these fish despite our research team observing acoustically-tagged fish floating at the sea surface for as long as possible.

Of the 94 black sea bass that were detected within the receiver array, 61 survived the capture and handling process and were considered to be alive and 33 died after release. Of the black sea bass determined to be alive, 60 emigrated from the receiver array during the monitoring period. The single fish that was detected within the acoustic array on the last day of monitoring (3/27/2017) was later detected by a receiver array off Maryland, thereby confirming its survival. Of the 33 mortalities, nine were attributed to predation following re-submergence (i.e., as the animal swam or sank towards the bottom or after it reached the bottom). All predation events occurred within 1.8 - 18.4 (7.2 ± 4.5) hours of release. The remaining 24 mortalities were assumed to have occurred due to the capture and handling process or natural mortality, and occurred from

5.0 - 128.0 (17.1 ± 26.7) hours post-release. Of these, 19 (79.2%) mortalities occurred within 24 hours of release, four from 24 - 72 hours post-release (16.7%), and one (4.2%) >72 hours post-release (95.8% of mortality occurred within 72 hours).

Analysis of survival data (Objectives 1 & 2):

A fixed-effects CPHM was selected because the inclusion of a random effect did not reduce the AICc by more than three units (-0.651). The best-fit CPHM for black sea bass survival data retained only the effect of venting (Table 15). Results of individual KM estimator survival functions by covariate are reported in Appendix 4. Of note, KM plots suggested that release behavior was a significant predictor of mortality with floating fish exhibiting higher discard mortality than those that swam down (Figure A3; Appendix 4). However, because release behavior was highly correlated with venting and the low sample size for fish that floated, only venting was included in the CPHM model selection.

An effect of venting on only the probability that a fish was adversely affected by discard mortality (π) reduced the AICc by 5.21 units and produced the best model fit (Table 16; model variant 2). The inclusion of venting in model variants 1 (effect on both the capture and handling mortality [τ] and the probability that a fish was adversely affected by discard mortality post-release [π]) and 3 (effect only on the probability that a fish was adversely affected by discard mortality post-release [π]) did not lower the AICc by three units. Consequently, these variants were not considered further. The selected model produced estimates that matched well with those from the empirical KM estimator (Figure 18). Most of the black sea bass mortality is estimated to have occurred post-release (Table 17; Figure 18). Mean post-release mortality rates for non-vented fish were nearly two and a half times greater than vented fish. The mean total fishing-related (i.e., discard) mortality rate was 0.21 (95% CI: 0.12, 0.37) for vented black sea bass and 0.52 (95% CI: 0.38, 0.67) for non-vented black sea bass.

With respect to the unvented black sea bass in the acoustic subsample, a fixed-effects model was selected because the random effect failed to reduce the AICc by more than three units (-3.11). Only fight time was found to predict survival for unvented fish using the CPHM (Table 18; Figure 19). The hazard ratio from the CPHM model summary results suggest that fight time is positively associated with the event probability (i.e., increased fight times increase the chance of mortality; Table 19). Results of individual KM survival function tests by parameter are reported in Appendix 4.

Best-practice capture and handling guidelines (Objective 3): The successful identification of factors that influenced mortality, and therefore the discard mortality rate, of black sea bass in the winter offshore Mid-Atlantic recreational fishery (Objective 2) permitted the formulation of best-practice capture and handling guidelines for reducing discard mortality. Based on the findings that swim bladder venting (when done correctly) was the most influential factor impacting discard mortality and increased submergence success over all depths (i.e., reduced the incidence of floating), we recommend that anglers vent all black fish that are captured during the offshore winter fishery before they are released, particularly those that experience barotrauma symptoms (e.g., exophthalmia or stomach eversion). Given previous documentation of the negative impacts from improper venting technique (e.g., increased injury and mortality: Wilde, 2009), full realization of the benefit of venting will require a broad education and outreach campaign to educate anglers on proper venting techniques and recommended venting tools (see Project Outreach section below).

In light of the extent of the Mid-Atlantic deepwater black sea bass fishery and the large number of anglers who participate in it, educating the majority of participants on proper venting technique may be difficult. As an alternative, particularly if a mandatory venting policy is considered for this fishery, one option would be to focus on educating for-hire (e.g., charter and headboat) vessel captains and crews (e.g., mates/deckhands) about proper venting technique and recommend that anglers who are unfamiliar or uncomfortable with venting protocols to have their catch unhooked and vented by these personnel. This approach would be advantageous since it would focus on properly educating a smaller population, and likely work to reduce the occurrence of improper venting by maximizing the number of ventings that are performed by trained individuals. In addition, these trained individuals will be able to educate other anglers, which, in combination with our team's education and outreach efforts, will help to create a larger population of anglers who are educated on how to properly vent black sea bass. This will be important given the frequently high catch rates in this fishery and the fact that crew members are unlikely to be able to vent all black sea bass that are to be released.

Based on the finding that longer fight time (i.e., >54 seconds) increased mortality in the acoustic subsample, another logical best-practice guideline is to explore methods to minimize the time black sea bass spend on the line while being reeled to the surface. Examination of the GAMM model results indicated that depth of capture had the greatest influence on fight time, thus, we recommend that anglers target black sea bass in as shallow of water as possible (see Management recommendations below). Regarding reel retrieve ratio, although lower speed reels yielded longer fight times (on average), the effect of individual angler had a seemingly large impact on the apparent relationship. In other words, angler behavior (i.e., whether they may have turned the reel handle faster or slower than average) seemed to influence the impact that reel gear had on fight time more than the reel gear ratio itself. Given this, it seems more logical (and practical) to recommend that anglers reel their catch to the surface at a moderate to fast pace, rather than implement restrictions on reel speeds/retrieve ratios. It should be noted, however, that we do not recommend that anglers reel fish to the surface as quickly as possible, because it is possible that this could lead to greater injury to the fish and possible more severe barotrauma-related injury such as swim bladder or stomach rupture.

Capture as part of a double header also resulted in increased fight time. Given this, discard mortality may be reduced if anglers fish with only one hook (as this will eliminate the chance of catching a double header). However, given the deepwater nature of the fishery and the clear indication that the vast majority of anglers use a two-hook high-low rig (as determined by our tackle survey), it is likely that a one-hook recommendation or restriction would be met with strong opposition. Instead, we recommend that anglers use fishing gear (i.e., rod and reel, line) of appropriate strength for the area in which they are fishing (i.e., water depth, size of fish being caught, potential for double headers, etc.) to avoid unnecessary increases in fight time.

Lastly, due to the aforementioned logistical issues with swim bladder venting, reducing fight time may be a more practical recommendation to provide anglers. However, it should be noted that the restriction of fight time will likely not result in the same reduction in mortality that is evident with swim bladder venting.

Anglers can reduce the overall number of black sea bass that are discarded when targeting other species (e.g., cod, pollock, scup, tilefish) by avoiding fishing locations and seasons when black sea bass retention is prohibited, or by avoiding locations and seasons when primarily undersized fish are caught. Also, it is recommended that anglers avoid the practice of "high-

grading” (i.e., discarding keeper-sized fish in search of larger fish) to reduce the number of black sea bass that are discarded.

Movements, habitat use, and residency (Objective 5): Movement patterns, habitat use, and residency times at the shipwreck were examined for the 61 fish that were considered to be alive. Detection periods for these fish ranged from 0.07 - 52.07 (12.39 ± 11.70) days. The majority of fish remained at or in close proximity to the shipwreck during their residency within the receiver array, being detected at or directly adjacent to the wreck for continuous periods of 0.00 - 52.06 (12.33 ± 11.73) days (Appendix 3). Excluding fish that emigrated from the wreck within one day of tagging ($n=6$), 23 fish (41.8%) remained resident at the wreck for periods of 1-7 days, 13 (23.6%) for 7-14 days, 6 (10.9%) for 14-21 days, and 13 (23.6%) for >21 days. By month of tagging, residency times at the wreck were as follows: December: 0.00 - 44.26 (12.12 ± 11.74) days; January: 3.41 - 6.4 (5.87 ± 0.89); and February: 1.83 - 52.07 (13.74 ± 21.48) days. This pattern suggests that cohorts of fish may have been migrating through the study site during their offshore migration, with some individuals remaining at the wreck for longer periods and others spending only brief periods (i.e., <3 days) at the wreck before continuing offshore. The majority of fish emigrated from the array to the southeast ($n=35$) or south ($n=17$), with the remaining moving out to the southwest ($n=5$), east ($n=2$), and west ($n=1$). Some additional preliminary habitat use results are presented in Appendix 5 (Winton et al., *In review*), and expanded investigation into black sea bass spatial ecology is planned once those advanced methods are published.

A total of 37 fisheries-dependent recaptures were recorded as of the composition of this report. In general, these recaptures primarily occurred in the Mid-Atlantic region, however, a single fish was recaptured south of Cape Cod, MA (Figure 20). Minimum linear displacements for recaptures ranged from 0 - 464 (89 ± 75) km, and times at liberty from 56 - 365 (160 ± 70) days. Of the recaptured fish, 24 were vented (13 not vented), and 28 swam down at release while 7 floated. A single fish was recaptured at the Ice Cream Cone wreck exactly one year after tagging (12/21/2016 - 12/21/2017).

Project Outreach (Objective 4): An oral presentation was given at the monthly meeting of the Sunrise Rod and Gun Club in Red Bank, NJ on June 2, 2017, entitled “Estimating and mitigating discard mortality in recreational fisheries”. Approximately 40 recreational anglers were in attendance and the presentation communicated preliminary results from our project and recommended best practices for reducing discard mortality based on the findings of other published studies. On February 4, 2017, a booth was manned at the Raritan Bay Anglers Club fishing tackle flea market in New Brunswick, NJ. The booth included project materials and plots of preliminary acoustic telemetry results to communicate to anglers the importance of adopting recommended best practices in catch-and-release to reduce discard mortality. Most anglers who visited the booth were very interested in the research and excited to see this type of work being completed to improve the sustainability of the recreational black sea bass fishery. Furthermore, each offshore tagging trip conducted for this project included up to 14 volunteer anglers. Communications with these anglers, which included emails, online message board posts, and phone conversations, also contributed to the outreach component of this project and helped to spread the word about the research objectives and early findings. In addition, when recovered tags were reported it was an excellent opportunity to convey information on the project objectives, as well as preliminary findings and best-practice recommendations. Co-PI D. Zemeckis also recently appeared on a one hour session of Mike Shepherd’s fishing talk radio show, “Shep of Fishing” on

News Talk 1400 AM WOND on January 20, 2018. Black sea bass discard mortality was discussed during this radio show and results from the study were shared with listeners.

Given that the project has been completed and recommended best-practices have been developed for reducing black sea bass discard mortality in recreational fisheries, we will continue our outreach efforts to educate recreational anglers and fishery managers on these recommended best practices. Although these efforts have been delayed while completing the data collection and analysis for the project, our project team is actually now better prepared to perform outreach given that co-PI D. Zemeckis recently became an Extension Professor of Fisheries and Aquaculture at Rutgers University. Therefore, in addition to the outreach outlets of other project partners (e.g., the New England Aquarium and MA Division of Marine Fisheries), we will now be able to capitalize on the wide reach of Rutgers Cooperative Extension. In fact, co-PI D. Zemeckis already has the following presentations scheduled in order to educate recreational anglers on project results and recommended best practices for reducing discard mortality:

- Saltwater Anglers of Bergen County (SWABC), monthly meeting, February 20, 2018, Rochelle Park, NJ
- Saltwater Fishing Expo, March 16-18, 2018, Edison, NJ (<http://www.sportshows.com/saltwater/>)
- Sunrise Rod and Gun Club, monthly meeting, April 4, 2018, Red Bank, NJ
- New Jersey Federation of Sportsmen's Clubs, annual banquet, April 21, 2018, Ocean City, NJ

In addition to these already scheduled presentations, our project team will seek more opportunities to speak at meetings involving recreational anglers. We will also prepare appropriate educational materials (e.g., flyers, infographics) for dissemination on recreational fishing message boards, websites of our collaborating institutions (e.g., Rutgers University, New England Aquarium, MA Division of Marine Fisheries) and other regional partners (e.g., NJ Department of Environmental Protection, Cape Cod Charterboat Association), at booths at saltwater and outdoorsmen shows, and other opportunities that arise for connecting with the recreational fishing industry. Therefore, these ongoing efforts, during which Mid-Atlantic Fishery Management Council funding will be acknowledged, will allow for widespread dissemination of our results and recommended best-practices for reducing the discard mortality of black sea bass.

Dissemination of preliminary project results to the scientific community and fishery managers was accomplished at the 2017 annual meeting of the American Fisheries Society in Tampa, FL when co-PI D. Zemeckis delivered a presentation entitled "Estimating and mitigating discard mortality in recreational fisheries: Case Studies from the northeast U.S." in a symposium focused on bycatch reduction in fisheries. Co-PI D. Zemeckis also delivered a presentation including preliminary results on this project at the 2017 annual meeting of the Mid-Atlantic Chapter of the American Fisheries Society in October 2017 in Dover, DE, entitled "Utilizing collaborative scientist-industry partnerships to estimate and reduce discard mortality in recreational fisheries". Preliminary results were also shared by co-PI D. Zemeckis in a seminar presentation delivered at the NOAA NEFSC James J. Howard Laboratory in Sandy Hook, NJ in December 2017, as part of a talk entitled "Applying previous experiences in marine sciences to expand Rutgers' marine extension program". Co-PIs D. Zemeckis and J. Kneebone are also co-Organizers of a relevant symposium at the 2018 annual meeting of the American Fisheries Society and this project will be the focus of a presentation at that meeting.

After submission of this final report, copies will be disseminated to members of the scientific community who have interest in topics such as black sea bass, discard mortality, fisheries

management, electronic tagging, and recreational fisheries. This final report will also be reformatted for publication in a peer-reviewed scientific journal, such as *Fisheries Research* or *Transactions of the American Fisheries Society*, which will allow for expanded and wide dissemination of our results to the scientific community and fishery managers. In addition, a scientific manuscript that seeks to publish new analytical approaches of acoustic telemetry data, with inclusion of data from this black sea bass discard mortality study, is presently in review with the journal of *Methods in Ecology and Evolution* (see submitted draft in Appendix 5). This paper includes co-authorship by co-PIs J. Kneebone and D. Zemeckis:

M.V. Winton, J. Kneebone, D.R. Zemeckis, and G. Fay. *In Review*. A spatial point process model to estimate individual centers of activity from passive acoustic telemetry data. *Methods in Ecology and Evolution* (draft was submitted for publication on December 31, 2017).

7. Discussion

This project represented a collaborative research effort involving recreational fishing industry stakeholders, volunteer anglers, commercial fishermen, and scientists to address an important data gap in our understanding of black sea bass discard mortality in the winter, deepwater, offshore Mid-Atlantic recreational rod-and-reel fishery. Meaningfully involving industry stakeholders in this project helped to ensure that our methods provided an accurate representation of actual fishery conditions, thereby maximizing the applicability of our results for consideration in stock assessments and fishery management plans. Additionally, findings from this project have improved our general understanding of black sea bass biology, discard mortality in recreational fisheries, methods to reduce discard mortality, and the impacts of bycatch in recreational and commercial fisheries.

Our study estimated mean total fishing-related discard mortality rates of 21% for vented and 52% for unvented black sea bass following capture and release in 45 m depth. Acknowledging that venting is not commonly practiced in the fishery, the 52% estimate (for unvented fish) is therefore representative of the current discard mortality rate that is evident when the fishery operates at (or near) this depth. This discard mortality rate is higher than previous estimates generated for a similar depth range (43-54 m) by Collins et al. (1999), who reported discard mortality rates of up to 39% after monitoring fish in cages for 24 hrs. However, this difference could be due in part to the methods in which fish were monitored after release in both studies. For example, while Collins et al. (1999) briefly monitored post-release fate in cages where animals were shielded from predation, while our electronic tagging approach was able to account for predation and monitor mortality over a longer monitoring period. In contrast, Rudershausen et al. (2014) estimated a 19% mean discard mortality rate for non-vented black sea bass following capture at depths of 20-35 m, which is less than half of our estimate for 45 m depth. This discrepancy may be due differences in fight times that were evident between the two capture depths (i.e., 20-35 m vs. 45 m), given our finding that longer fight times (which were evident at deeper depths) resulted in reduced submergence success and higher mortality.

Current black sea bass stock assessments and fishery management plans assume a 25% discard mortality rate for the coastwide, year-round black sea bass recreational fishery. Our results, as well as those reported in Collins et al. (1999), suggest that this rate is not representative of the discard mortality rate that is evident in the offshore, deepwater, winter recreational fishery. Given this, it is recommended that stock assessment scientists and fishery managers re-evaluate the validity of the currently assumed 25% estimate and consider whether a single mean discard

mortality rate is still appropriate for accurately estimating total recreational fishery removals for the diverse, coastwide recreational fishery. This could be particularly important moving forward, because according to accounts from multiple stakeholder groups, the winter offshore fishery may not be well monitored and there have been many options presented in recent years with respect to opening certain months to black sea bass fishing during the winter period.

Venting the swim bladder of black sea bass significantly reduced discard mortality, with vented fish being more than two times as likely to survive than unvented fish. This finding is at odds with a previous review by Wilde (2009) who concluded that venting fish should not only be discouraged by fishery management agencies, but be prohibited rather than required by regulation given the possibility that venting may adversely affect survival of fish captured from deep water. However, a more recent meta-analysis by Eberts and Somers (2017) found that swim bladder venting, along with the use of descending devices, had positive effects on reducing discard mortality. As a result, Eberts and Somers (2017) recommended that fishery managers consider barotrauma relief options carefully on a case-by-case basis. This study provides robust results indicating that swim bladder venting can reduce the discard mortality rate of black sea bass in the offshore recreational fishery in the Mid-Atlantic. However, as communicated in other papers (e.g., Scyphers et al., 2013; Brownscombe et al., 2016), it is imperative that anglers are educated on proper venting technique to maximize the benefits of this practice and minimize the risk of potentially increasing discard mortality from improper technique. Therefore, as outlined above, our project team will continue our outreach and education efforts in order to share our project findings, including recommended best practices for reducing discard mortality and proper swim bladder venting techniques for black sea bass.

Avian predation is another potential source of mortality in the Mid-Atlantic offshore black sea bass fishery that was not well accounted for by our study. Due to the high catch rates on many of the tagging trips it was difficult or impossible to monitor the disposition of floating fish for more than a few minutes post-release as they drifted away from the anchored vessel. Despite this, there is strong evidence that two acoustically-tagged fish that were floating were consumed by avian predators due to the lack of any acoustic detections for these fish (see Findings). Regardless, although the frequency of avian predation could not be estimated by our study, swim bladder venting will reduce its occurrence given that vented fish will experience higher submergence success and therefore be able to escape avian predators.

Tackle recommendations, such as the use of different hook types (e.g., circle hooks), are often offered as methods to reduce injury and discard mortality in both recreational and commercial fisheries. However, in the Mid-Atlantic offshore black sea bass fishery, hooking location and injury were not found to be significant predictors of mortality, and there was a low incidence of ‘deep’ or ‘internal’ hooking (i.e., in the gills or internal organs). This low incidence of deep mouth hooking may be due in large part to the fact that the most common terminal tackle setup is a High-Low rig with short leaders from the main line to each hook (i.e., dropper loops of 3-5”, or 7.6 - 12.7 cm). As suggested by Capizzano et al. (2016), this configuration does not leave much opportunity for the fish to swallow the hook, and therefore results in a high incidence of mouth hooking. Given this, circle hooks, which have been demonstrated to increase the incidence of mouth hooking in other fisheries, may not offer an added conservation benefit for black sea bass in the offshore Mid-Atlantic fishery.

Future work

Although our results convincingly demonstrate that swim bladder venting (when done properly) can reduce discard mortality rate, future research should investigate the relative benefit of descending devices as an additional option for reducing the discard mortality rate of black sea bass in deep water fisheries. Previous research has shown that the descending devices can increase the submergence success of black sea bass (Musick et al., 2015), but no studies have been conducted to quantify the relative benefits of descending devices for reducing black sea bass discard mortality. In this study, our project team opted to test swim bladder venting as a method to mitigate barotrauma-related mortality because it is a relatively quick process that is already adopted by some recreational anglers, and therefore was considered more likely to be adopted by anglers in a fishery with high catch rates (such as the offshore black sea bass fishery). However, it would be valuable to evaluate the relative benefits of swim bladder venting and descending devices for reducing discard mortality, and, depending on the differences, educate anglers on the best practices that would provide maximum benefit for reducing discard mortality.

The movement patterns and population structure of black sea bass in offshore Mid-Atlantic waters is another issue that requires additional research. Many of our volunteer anglers and fishing industry partners hypothesized that the large black sea bass that are caught at some of these offshore locations in the Mid-Atlantic would migrate seasonally from southern New England (e.g., Rhode Island and Massachusetts), which is supported by some previous tagging research (Moser and Shepherd, 2009). However, we only had one tag recapture from a fish migrating to the area off Cape Cod (Figure 20) despite tagging hundreds of large fish. Nonetheless, the stock structure of black sea bass remains a largely unresolved issue (NEFSC, 2017). Based on the previous research and our limited observations of movement patterns, we recommend that additional research on black sea bass stock structure be conducted in the future. Our findings of relatively low discard mortality in vented black sea bass at these offshore depths presents the opportunity to expand future tagging efforts to these offshore locations.

Management implications

The results of our study have direct and significant implications for the management of the offshore recreational black sea bass fishery in the Mid-Atlantic, and likely beyond. Given our findings that swim bladder venting was the single greatest factor that reduced the discard mortality rate and increased submergence success, there is strong evidence that total mortality would be greatly reduced if anglers were encouraged, or possibly even required, to vent all black sea bass that are released in the Mid-Atlantic offshore fishery. Furthermore, our results provide strong support that venting will increase the post-release survival of black sea bass that experience barotrauma in any other fishery that occurs along the coast. However, as previously mentioned, such reductions in mortality are predicated upon the widespread education of recreational anglers about and adoption of proper venting technique. Therefore, substantial and continued outreach would be necessary to maximize the benefits of venting.

Observations of the timing of post-release predation events, the negative impact of extended fight times on survival, and the relationship between fight time and capture depth also hold strong management implications for the fishery. Based on our survivorship assessment, predation (at-depth both during capture and post-release) by other fishes was evident in the acoustically-tagged subsample only during early December, primarily on the first research trip on December 5, 2016. Based on previous experiences of our research team and discussions with the captain and crew of the *F/V Susan Hudson*, predation events such as those observed are common

in the early part of the offshore fishing season before predators such as bluefish and spiny dogfish migrate further offshore or south as waters cool with the onset of winter. Interestingly, subsequent sampling trips to the Ice Cream Cone wreck on December 21st and January 17th experienced one or no predation events by other fishes, respectively, and there were no predation events by other fishes observed during the trips to deeper fishing spots in mid-February through late-March.

Although predation by other fishes was absent during the latter tagging trips to the Indian Arrow wreck (58 m depth) and Baltimore Rocks (67 m depth), discard mortality may have actually been elevated at these locations due to the increased fight times that were evident. Results of our survival analysis on unvented fish suggest that longer fight times (>54 seconds) resulted in markedly higher mortality. Thus, since mean fight times for the 58 and 67 m capture depths were 80 and 94 seconds, respectively, it is likely that the discard mortality rate of both vented and unvented fish captured at these deeper depths was higher than those estimated for 45 m depth at the Ice Cream Cone wreck. In addition, based on the data collected during this study, the overall mortality resulting from discarding of fish would be expected to be higher at the Baltimore Rocks (i.e., the deepest fishing location) due to the fact that nearly half of the black sea bass captured at this location were less than the 12.5" (318 mm) federal and New Jersey minimum size limit, and would have been mandated to be released (Figure 7). Taken together, the occurrence of predation events by other fishes primarily at the beginning of the season and the need to fish at deeper depths during the latter part of the season (due to the continued offshore migration of black sea bass during the winter), our results suggest that in order to reduce the impacts of discards it may be most advantageous to open the fishery from the period of mid- or late-December through January, which is when fish are more likely to still be accessible at 'shallower' depths (i.e., <~55 m) and predation risk is lower. However, these observations are based on the 2016-2017 fishery off southern New Jersey and there could be variation inter-annually and along the coast. Therefore, it is recommended that fishery managers consider and apply these findings for each local and regional fishery.

8. Acknowledgements

This study would not have been possible without the contributions of many people. We are indebted to the captain and crews of the *F/V Susan Hudson* (Captain Mike Weigel, Crewmember Kevin Moran, Captain Bob Rush) and *F/V Porgy IV* (Captain Paul Thompson and crew) for providing vessels for all tagging trips and for remaining flexible with trip planning. Captain Eric Burcaw and his crew members (*F/V Rachel Marie*) were also indispensable parts of the project, enabling the successful deployment, maintenance, and recovery of the acoustic receivers. Many thanks to the numerous volunteer anglers who participated in tagging trips, including: Adam Fitzsimmons, Arsenio Gonzalez, Barry Paull, Ben Bauer, Bill Fish, Bill Hadik, Bob Rush Sr., Brian Jamison, David Thompson, Fred Bakely, Gary Schwartz, George Clark, James Neville, Jeff Dement, Jerzy Ligorki, Joe Buda, John Fernandez, John Pratt, Julie Schumacher, Kenneth Oswald, Lenny Zemeckis, Leroy Fortcher, Lynn Clark, Mark Grimm, Melissa Alcorn, Michael Farmer, Mike Blaus, Mike Brennan, Naomi Jainarine, Owen Mulvey, Paul Black, Richard Yip, Robert Mangold, Robert Wilson, Ronald Kennedy, Sean Culleton. Sean Martin, Stephen Brooks, Tom Siciliano, Tony Lambiase, Wesley Bowlby, and Zachary Visconti. Thank you to our data recorders Brendan Campbell, Michael Carvino, Max DiSanto, Chris Free, Abigail Golden, Andrew Hassal, Shawn Hazlett, and Bill Maxwell, many of whom also found time to reel in a fish or two during tagging trips. We are grateful to Josh Kohut and Hugh Roarty of Rutgers University for facilitating the acquisition of oceanographic data from the Rutgers Ocean Model and Chang Liu for assisting

with data collection and formatting. Thank you also to Hugues Benoit for assistance with the survival analysis. Lastly, thank you to all of the captains and fishermen who reported recaptured tags, and to personnel from the University of Delaware (Danielle Haulsee), University of Maryland (Ella Rothermel), and Stony Brook University (Evan Ingram) for providing acoustic detections via the ACT Network.

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10. Tables

Table 1 – Summary of tagging trips by location and tagging vessel. The depth fished during each trip as well as the number of volunteer anglers, number of acoustic transmitters deployed, number of convention t-bar tags deployed, and total capture observations are reported.

Date	Vessel	Fishing Location	Depth (m)	Number of anglers	Transmitters	t-bar tags	Total observations
Dec 5, 2016	F/V Susan Hudson	Ice Cream Cone	45	7	20	172	197
Dec 13, 2016	F/V Susan Hudson	Ice Cream Cone	45	7	24	168	202
Dec 21, 2016	F/V Susan Hudson	Ice Cream Cone	45	7	24	73	98
Jan 17, 2017	F/V Porgy IV	Ice Cream Cone	45	10	18	37	55
Feb 3, 2017	F/V Susan Hudson	Ice Cream Cone	45	7	10	4	14
Feb 18, 2017	F/V Susan Hudson	Baltimore Rocks	67	14	0	316	362
Feb 24, 2017	F/V Susan Hudson	Baltimore Rocks	67	14	0	427	440
Mar 21, 2017	F/V Susan Hudson	Indian Arrow	58	13	0	270	455
Total				50	96	1467	1823

Table 2 – Programming specification for the Vemco acoustic transmitters used in this study.

Tag Model	Est tag life (days)	Step 1			Step 2			Step 3		
		End Time (dy hr:min:sec)	Min Delay (sec)	Max Delay (sec)	End Time (dy hr:min:sec)	Min Delay (sec)	Max Delay (sec)	End Time (dy hr:min:sec)	Min Delay (sec)	Max Delay (sec)
V13-2H	673	15 00:00:00	60	180	15 00:00:00	220	340	660 00:00:00	360	480

Table 3 – Results from online tackle survey (n=282 respondents) to select standardized terminal tackle rigging.

Type of Reel	No. Respondents	Proportion	J-Hook Type	No. Respondents	Proportion	Topshot	Average	Mode
Conventional	268	0.95	Octopus	58	0.5	lb test	40	40
Electric	3	0.01	Baitholder	54	0.47	length (ft)	15	20
Spinning	11	0.04	Virginia	2	0.02			
Total	282		O'Shaughnessy	1	0.01			
			Total	115				
Type of Main Line	No. Respondents	Proportion	Hooks/rig	No. Respondents	Proportion	Main Line	Average	Mode
Braided	262	0.93	One	7	0.04	lb. test	43	50
Monofilament	20	0.07	Two	163	0.85			
Total	282		Three	21	0.11	Bait J-Hook	Average	Mode
			Four	0	0	Size	4.25	5
			Five	1	0.01			
			Total	192				
Topshot	No. Respondents	Proportion	Hook Size	No. Respondents	Proportion			
Yes	209	0.8	1/0	3	0.01			
No	53	0.2	2/0	19	0.09			
Total	262		3/0	41	0.2			
			4/0	48	0.23			
			5/0	69	0.33			
			6/0	19	0.09			
			7/0	9	0.04			
			8/0	2	0.01			
			Total	210				
Rigging Setup	No. Respondents	Proportion						
Bait	252	0.9						
Jig	27	0.1						
Total	279							
Bait Hook Type	No. Respondents	Proportion						
J-Hook	220	0.89						
Circle	24	0.1						
Total	244							
High-Low Bait Rig	No. Respondents	Proportion						
Yes	234	0.96						
No	10	0.04						
Total	244							

Table 4 – Description of all of the technical and biological capture-related variables and the injury and barotrauma scores that were recorded for each captured black sea bass.

Variable	Description
<i>Technical</i>	
Capture depth	Water depth at the location of capture
Angler experience	Angler experience score as quantified by questionnaire
Fight time	Elapsed time from when a fish was hooked to when it reached the surface
Unhooking time	Elapsed time from surfacing until the fish was unhooked
Handling time	Elapsed time from surfacing until fish was released (time out of water)
Hook location	Location where the fish was hooked on the body
Hook removal method	Manner in which the fish was unhooked
Angler hand	Fish was unhooked by hand by the capturing angler
Mate hand	Fish was unhooked by hand by a fishing vessel mate/deckhand
<i>Biological</i>	
Total length	Length from the tip of the snout to the tip of the center of the tail
Air temperature	On deck temperature at the time of capture
Surface temperature	Water temperature at the surface
Bottom temperature	Water temperature at the bottom/wreck
Delta temperature	Difference between surface and bottom water temperatures
Release behavior	Observed behavior exhibited by a fish immediately upon release
Floating	Fish floated on surface
Swam down	Fish swam down towards bottom
Erratic swimming	Fish swam erratically and appeared disoriented
Sinking	Fish sank without swimming
<i>Injury score</i>	
Present (1)	Hook or other wound present >2 cm in length
Absent (0)	Injury limited to hook entry/exit
<i>Barotrauma score</i>	
<i>Exophthalmia</i>	
Present (1)	Eyes bulging from orbitals, bubbles may be present in eyes
Absent (0)	Eyes not bulging from orbitals
<i>Stomach eversion</i>	
0	Stomach not everted
1	Stomach everted but remains within mouth cavity
2	Stomach everted but is protruding from the mouth
3	Stomach everted and ruptured

Table 5 – Summary of acoustic detections received for four transmitters in collaboration with the Atlantic Cooperative Telemetry Network. Note: these four fish were used as positive controls.

Transmitter	Date released	Date detected	Latitude	Longitude	Detections	Detecting institution
3356	12/21/2016	9/9/2017	38.37	-74.54	1	University of Maryland
3357	12/21/2016	6/8/2017	40.38	-73.59	2	Stony Brook University
3385	12/13/2016	6/20 – 6/26/2017	38.73	-74.61	42	University of Delaware
3441	2/3/2017	9/22/2017	38.37	-74.54	4	University of Maryland

Table 6 - Assumptions for the capture and handling (CH; τ) and the probability of being adversely affected by the fishing event post-release (π) parameters of Equation (2) used to define the three competing model variants for analyzing black sea bass survival data.

Variant	Parameters	Description
1	$\tau = [1 + \exp(-X'\beta_1)]^{-1}$ $\pi = [1 + \exp(-X'B_2)]^{-1}$	Covariate effects on the CH mortality and the probability of being adversely affected by the fishing event post-release
2	$\pi = [1 + \exp(-X'B_3)]^{-1}$	Covariate effect on the probability of being adversely affected by the fishing event post-release only
3	$\tau = [1 + \exp(-X'\beta_4)]^{-1}$	Covariate effect on the CH mortality only

Footnote: X is the design matrix for the covariate(s) and β is the vector of parameters for the effect of the covariates.

Table 7 – Summary of capture variables for all vented and non-vented black sea bass ('All observations'), including the 96 fish that were tagged with acoustic transmitters ('Transmitters'). Values in parentheses represent the mean \pm standard deviation.

Category	Number of fish	Length range (mm)	Range of time (seconds)		
			Fight	Unhooking	Handling
<i>All observations</i>					
Vented	957	136-612 (349±66)	12-251 (80±32)	2-215 (17±18)	16-420 (141±77)
Non-vented	756	194-548 (323±69)	18-240 (75±69)	3-189 (18±19)	13-575 (142±81)
Total	1713	136-612 (339±70)	12-251 (78±32)	2-215 (17±19)	13-575 (142±81)
<i>Transmitters</i>					
Vented	48	278-546 (351±61)	17-225 (57±31)	2-42 (12±10)	80-326 (158±50)
Non-vented	48	279-485 (357±52)	29-90 (55±13)	3-52 (17±12)	91-310 (171±51)
Total	96	278-546 (354±57)	17-225 (56±24)	0-52 (15±11)	80-326 (164±51)

Table 8 – Summary of capture variables recorded for all captured black sea bass ('All observations') and the subset of 96 fish that were tagged with acoustic transmitters ('Transmitters'). Values in parentheses represent the mean \pm standard deviation.

Variable	Transmitters	All observations
Capture depth (m)	45	45, 58, 67
Total length (mm)	278 – 546 (354 \pm 57)	136 – 612 (339 \pm 70)
Fight time (s)	17 – 225 (56 \pm 24)	12 – 251 (78 \pm 32)
45 m	17 – 225 (56 \pm 24)	12 – 225 (55 \pm 22)
58 m	-	32 – 240 (80 \pm 27)
67 m	-	35 – 251 (94 \pm 30)
Unhooking time (s)	2 – 52 (15 \pm 11)	10 – 215 (17 \pm 19)
Angler hand	2 – 49 (15 \pm 11)	1 – 215 (18 \pm 20)
Mate hand	3 – 52 (15 \pm 12)	2 – 173 (17 \pm 17)
Experienced anglers	2 – 52 (14 \pm 11)	1 – 189 (17 \pm 19)
Inexperienced anglers	13 – 36 (29 \pm 9)	2 – 215 (19 \pm 21)
Handling time (s)	80 – 326 (164 \pm 51)	13 – 575 (142 \pm 81)
Air temperature (°C)	5.9 – 15.1 (10.7 \pm 2.3)	4.7 – 17.4 (13.9 \pm 2.4)
Sea surface temperature (°C)	7.4 – 13.8 (11.4 \pm 2.1)	7.2 – 13.9 (12.4 \pm 1.7)*
Bottom temperature (°C)	7.4 – 13.8 (11.3 \pm 2.0)	7.5 – 13.4 (12.2 \pm 1.4)*
Delta temperature (°C)	-0.6 – 0.4 (0.1 \pm 0.3)	-0.3 – 0.5 (0.3 \pm 0.3)*

* Data only available for trips to the Ice Cream Cone wreck

Table 9 – Model selection results for the generalized additive mixed effect model examining the relationship of each variable on fight time. The model with the lowest Akaike Information Criterion (AIC) value is in bold. TL=total length; DH=double header

Model	Estimated degrees of freedom	Deviance explained	AIC	Δ AIC
Fight time ~ s(TL) + Depth + DH+Reel_gear	51.52	64.3%	15088	0
Fight time ~ s(TL) + Depth + DH	50.64	64.0%	15102	14
Fight time ~s(TL) + DH + Reel_gear	50.22	55.5%	15480	392
Fight time ~ s(TL) + Depth+ Reel_gear	50.37	63.4%	15132	43
Fight time ~s(TL) + DH	49.29	55.5%	15479	391
Fight time ~ s(TL) + Depth	49.46	63.1%	15147	58
Fight time ~s(TL) + Reel_gear	49.23	54.2%	15530	441
Fight time ~s(TL)	48.29	54.2%	15528	440
Fight time ~ 1	47.32	49.9%	15685	597

Table 10 – Summary of hooking locations for all captured black sea bass (‘All observations’) and the 96 fish that were tagged with acoustic transmitters (‘Transmitters’). Percentages represent the percent of total observations in each group.

Hook Location	Transmitters		All Observations	
	Observations	%	Observations	%
Shallow mouth	47	49.5%	955	54.0%
Medium mouth	38	40.0%	675	38.2%
Deep mouth			9	0.5%
Eye	1	1.1%	5	0.3%
Gills			6	0.3%
Head	1	1.1%	8	0.5%
Isthmus	7	7.4%	96	5.4%
Operculum			5	0.3%
Dorsal surface			5	0.3%
Ventral surface	1	1.1%	4	0.2%
Total	95		1768	

Table 11 – Summary of the number of black sea bass that exhibited each release behavior in the full set of observations ('All observations') and the subset of 96 fish that were tagged with acoustic transmitters ('Transmitters'). ES=Erratic swimming; F=Floating; S=Sinking; SD=Swam down

Category	Release behavior			
	ES	F	S	SD
<i>All observations</i>				
Vented	3	190	6	724
Non-vented	4	234	4	465
Total	7	427	10	1190
<i>Transmitters</i>				
Vented		1		47
Non-vented		11		37
Total		12		84

Table 12 - Forward selection process for the logistic regression model that evaluated release behavior against a set of sensible covariates for all released black sea bass ($n=1594$). Covariates that produced a conservative corrected Akaike Information Criterion (AICc) reduction of three or more units from the previous model were retained (see ΔAICc). An asterisk (*) denotes the final model.

Run	Covariates	AICc	ΔAICc
1	~1	1832.163	
2	~depth	1783.034	49.129
3	~depth + venting	1747.244	35.79
4	~depth + venting + total length	1740.044	7.2
5*	~depth + venting + total length + exophthalmia	1736.882	3.162
6	~depth + venting + total length + exophthalmia + injury	1738.367	-1.485

Table 13 - Regression output coefficient table of the logistic regression model used to analyze the impact of covariates on release behavior for all black sea bass ($n=1594$). Parameter estimates for covariates are listed and include estimates for the regression coefficient, standard error of the regression coefficient (Std. error), the exponentiated coefficient called the odds ratio, the Wald statistics value (z -value), and overall statistical significance (p -value).

Coefficients:	<i>Estimate</i>	<i>Std. error</i>	<i>Odds ratio</i>	<i>z-value</i>	<i>p-value</i>
(Intercept)	2.190271	0.308884	8.937631	7.091	1.33E-12
Exophthalmia					
Presence	-0.42472	0.184109	0.653956	-2.307	0.02106
Depth					
57.912 m	-0.252	0.185813	0.777247	-1.356	0.17504
67.056 m	-0.92272	0.149485	0.397439	-6.173	6.72E-10
Venting technique					
Vented	0.800121	0.122604	2.225811	6.526	6.75E-11
Total length	-0.02957	0.009175	0.970866	-3.223	0.00127

Table 14 – Summary of the number of black sea bass that exhibited exophthalmia and each stomach eversion score in the full set of observations (‘All observations’) and the subset of 96 fish that were tagged with acoustic transmitters (‘Transmitters’).

Category	Exophthalmia		Stomach Eversion Score			
	Present	Absent	0	1	2	3
<i>All observations</i>						
Vented	92	863	30	193	714	18
Non-vented	80	670	65	207	442	36
Total	172	1533	95	400	1156	54
<i>Transmitters</i>						
Vented	1	47	2	8	35	3
Non-vented	5	43	4	13	29	2
Total	6	90	6	21	64	5

Table 15 - Forward selection process for the Cox Proportional Hazards Model that evaluated the survival function for black sea bass in the acoustic transmitter subsample over a set of sensible covariates determined from Figures A1 – A3 and Table A1 (Appendix 4). Covariates that produced a conservative AICc reduction of three or more units from the previous model were retained (see ΔAICc). An asterisk (*) denotes the final model and parsimonious set of covariates to be considered in the parametric survival analysis. Note: model variants 2 and 3 were indistinguishable by AICc, thus, the most parsimonious model (run 2) was selected as the final model.

Run	Covariates	AICc	ΔAICc
1	~1	285.175	
2*	~ venting	278.2613	6.913218
3	~ venting + total length	277.8582	0.403035

Table 16 - Summary of model variant and covariate selection results using maximum likelihood and a forward selection procedure for black sea bass in the acoustic transmitter subsample. An asterisk denotes the strongest evidence was for variant 2 of the model with the effect of venting covariate on the mixture model component only.

Run	Covariates	Variant	AICc	Δ AICc
1	~1		134.9005	
2*	~venting	2	129.4044	5.4961
2	~venting	1	132.5241	2.3764
2	~venting	3	146.05	-11.1495

Table 17 - Sample sizes and estimates of key parameters for the analysis of survival data for vented black sea bass. The number of fish that died upon release (dead), that died during capture and handling or immediately after release (left-censored), and that were last seen alive (right-censored) are presented. Estimates (95% confidence intervals) of the capture and handling mortality rate ($1-\tau$), the conditional post-release mortality rate ($\tau\pi$) and the total mortality rate associated with the fishing event (i.e., discard mortality; $1-\tau+\tau\pi$) are presented by treatment group.

Season	Numbers				Fishing mortality rates		
	Total	Dead	Left	Right	Capture- Handling	Post-Release	Total
Vented	48	9	1	38	0.017 (0.001, 0.158)	0.203 (0.107, 0.351)	0.219 (0.131, 0.406)
Not vented	46	18	5	23	0.017 (0.001, 0.158)	0.487 (0.319, 0.633)	0.504 (0.362, 0.662)

Table 18 - Forward selection process for the Cox proportional hazards regression model that evaluated the survival function for only unvented black sea bass in the acoustic subsample over a set of sensible covariates determined from Figures A4 – A6 and Table A2 (Appendix 4). Covariates that produced a conservative AICc reduction of three or more units from the previous model were retained (see ΔAICc). An asterisk (*) denotes the final model

Run	Covariates	AICc	ΔAICc
1	~1	162.0427	
2*	~ fight time	154.6790	7.3637
3	~ fight time + handling time	155.7066	-1.0276

Table 19 - Regression output coefficient table of the Cox proportional hazards regression model used to analyze the impact of fight time on the overall survival of unvented black sea bass in the acoustic subsample ($n=46$). Parameter estimates for fight time are listed and include estimates for the regression coefficient, standard error of the regression coefficient (Std. error), the exponentiated coefficient called the hazard ratio, 95% confidence intervals (CI) for the hazard ratio, the Wald statistics value (z -value), and overall statistical significance (p -value).

Coefficients:	<i>Estimate</i>	<i>Std. error</i>	<i>Hazard ratio</i>	<i>Lower CI</i>	<i>Upper CI</i>	<i>z-value</i>	<i>p-value</i>
Fight time	0.05284	0.0169	1.05426	1.02	1.09	3.126	0.00177

11. Figures

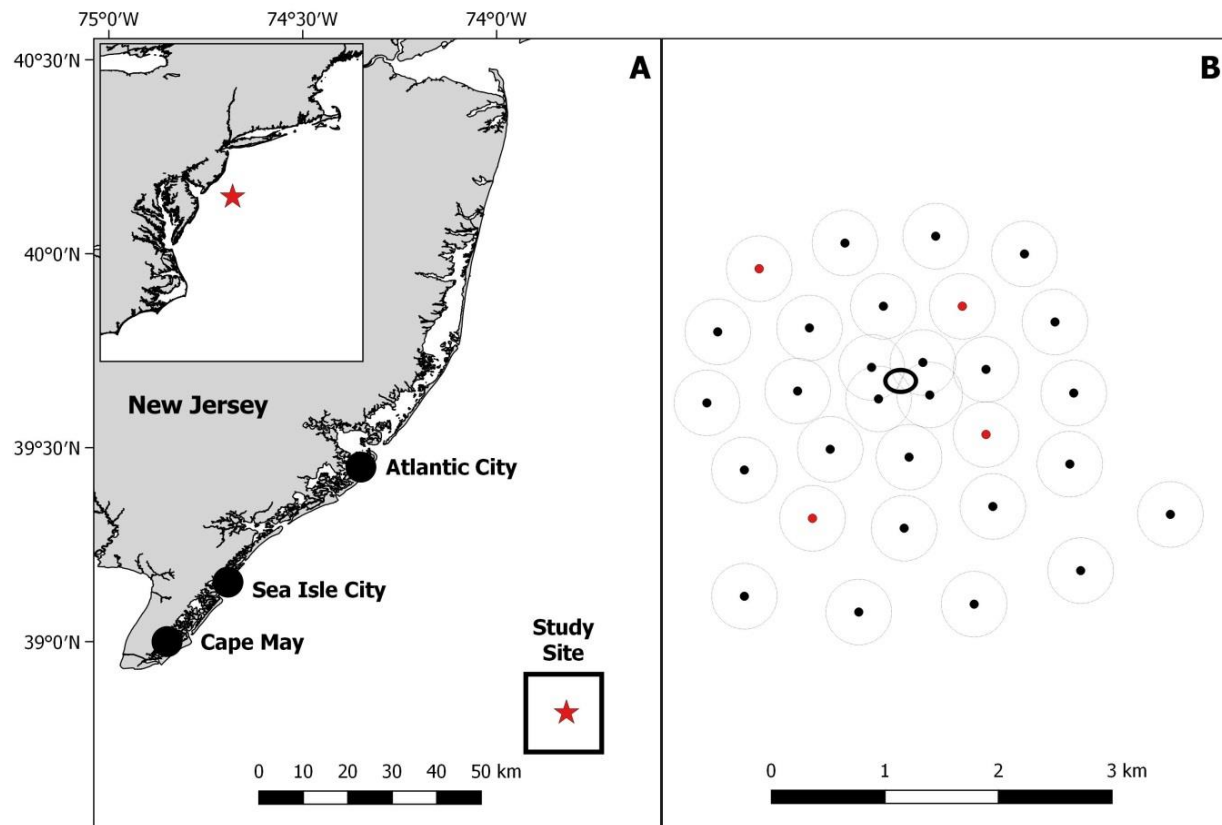


Figure 1 - Map of the approximate location of the “Ice Cream Cone” shipwreck (A: red star and B: black oval), which was the primary study site for this project (A), and the acoustic receiver array that was deployed to monitor the post-release fate of tagged black sea bass around the wreck (B). Individual acoustic receiver locations (small circles) with (red) and without (black) temperature loggers deployed on their mooring lines are presented. Estimated individual receiver detection range (dotted circles) are presented around each receiver location. The location of the stationary (dead) negative control tag (red diamond, B) is also presented.

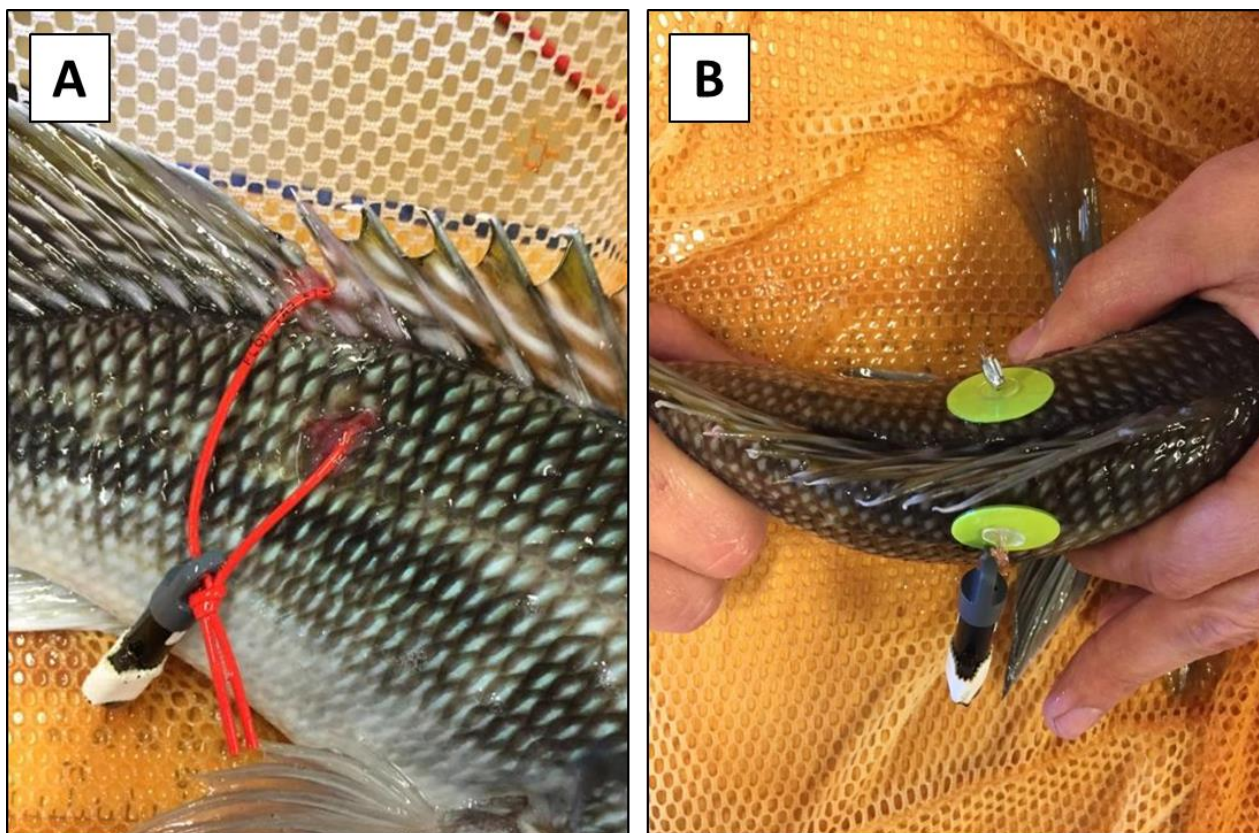


Figure 2 – Example of acoustic transmitter attachment method 1 (A) and method 2 (B) used in the experimental holding tank study. Lesions that were evident with method 1 are visible in A. Note: smaller Pedersen discs were used when tagging black sea bass in the discard mortality component of the study.

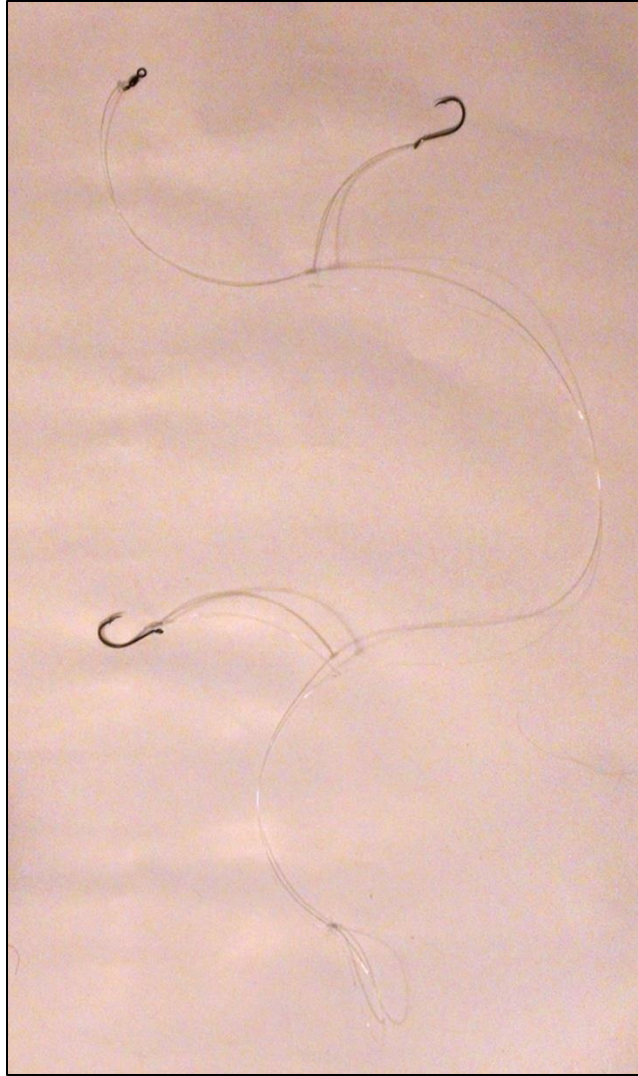


Figure 3 – Example of the standardized ‘high-low’ terminal tackle setup that was used during all sampling trips. This setup was determined to be most representative of the deep water Mid-Atlantic black sea bass fishery based on results of an extensive survey of 282 recreational anglers.

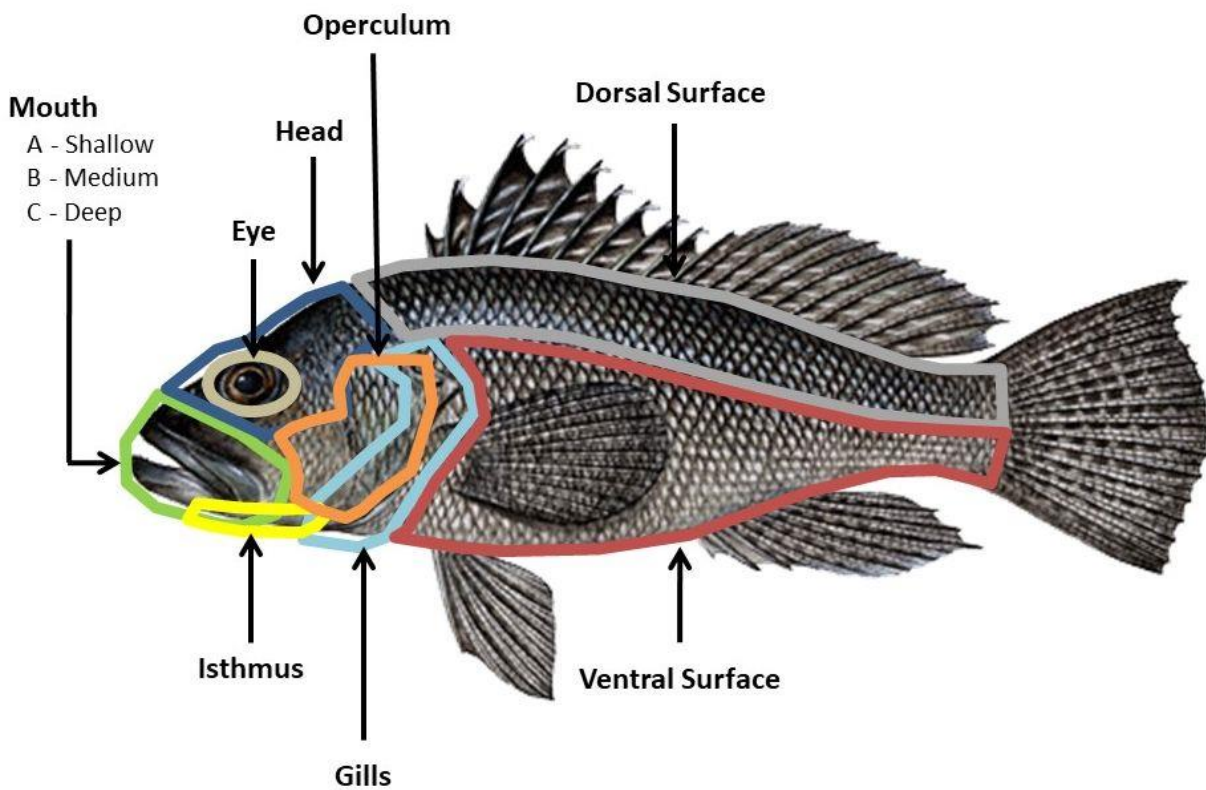


Figure 4 - Designations for hooking locations of black sea bass. Note: 'Gills' denotes the internal hooking location.

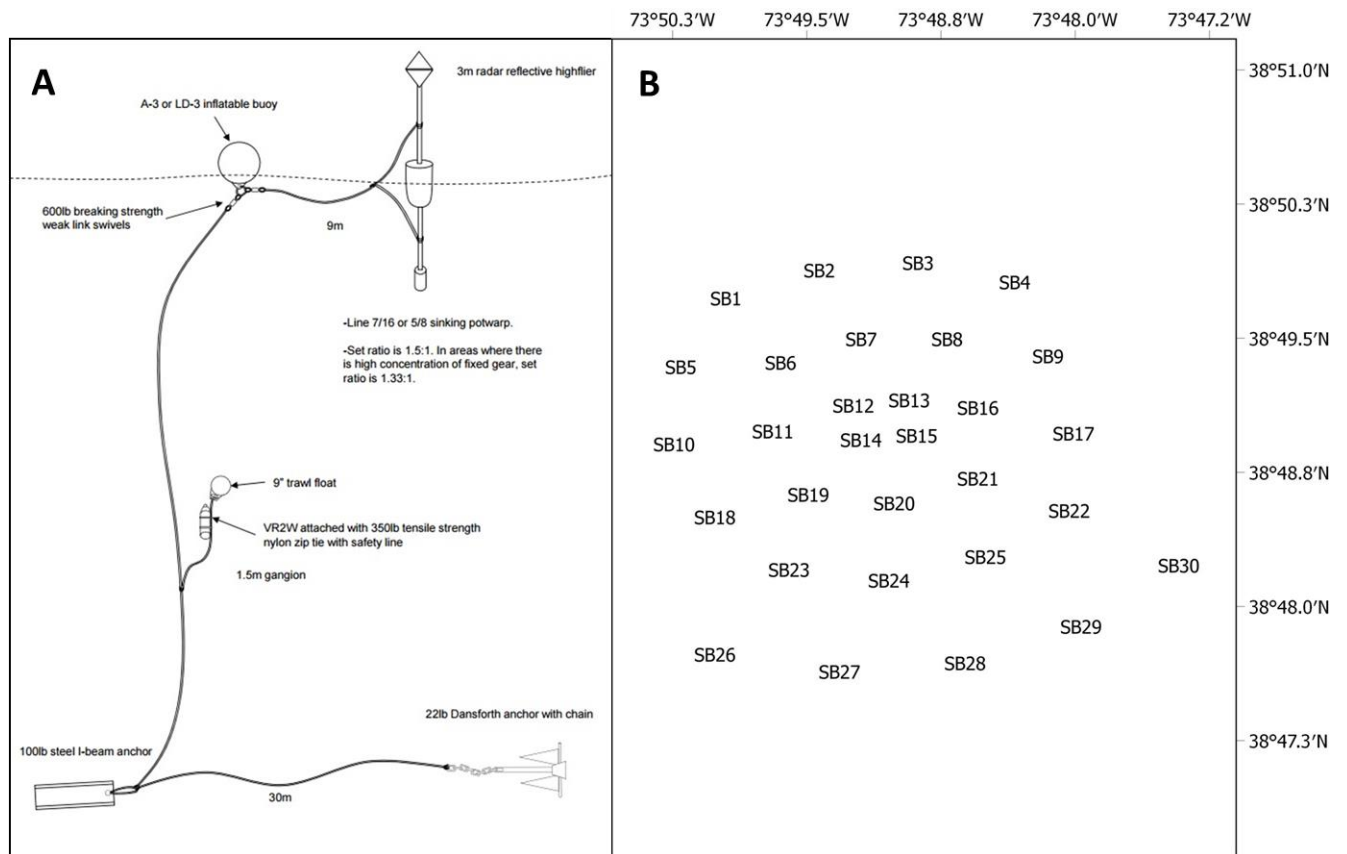


Figure 5 – Schematic of acoustic receiver mooring system (A) and the station identification labels for each receiver that was deployed in the array (B). Note that pot-style buoys with sticks were used as surface floats instead of highfliers with radar reflectors.

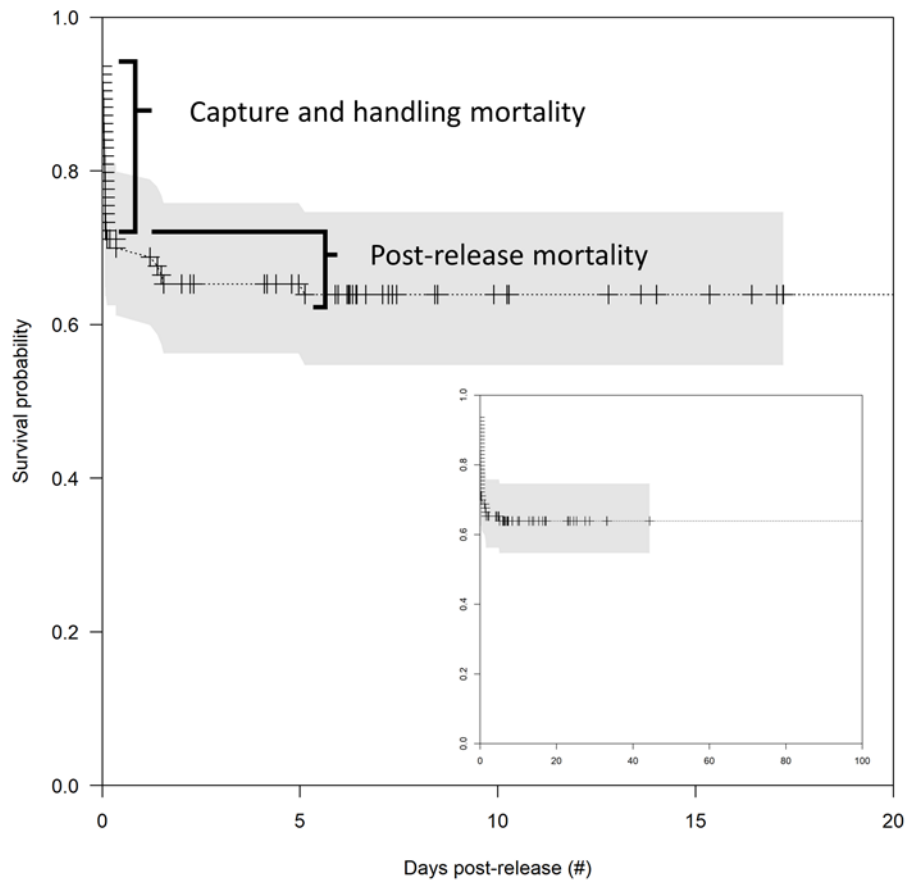


Figure 6 - Plot of the Kaplan-Meier estimator of the overall survival function for all tagged and released black sea bass over the first 20 days, with the 95% confidence interval indicated by shaded areas, and times of right censoring indicated with circles. Time zero is the time of release back into the water. The plot is annotated to indicate the presence of two types of mortality over time for black sea bass that were captured and released (no evidence of natural mortality). The inset plot displays the Kaplan-Meier estimator of the overall survival function for these fish over 100 days.

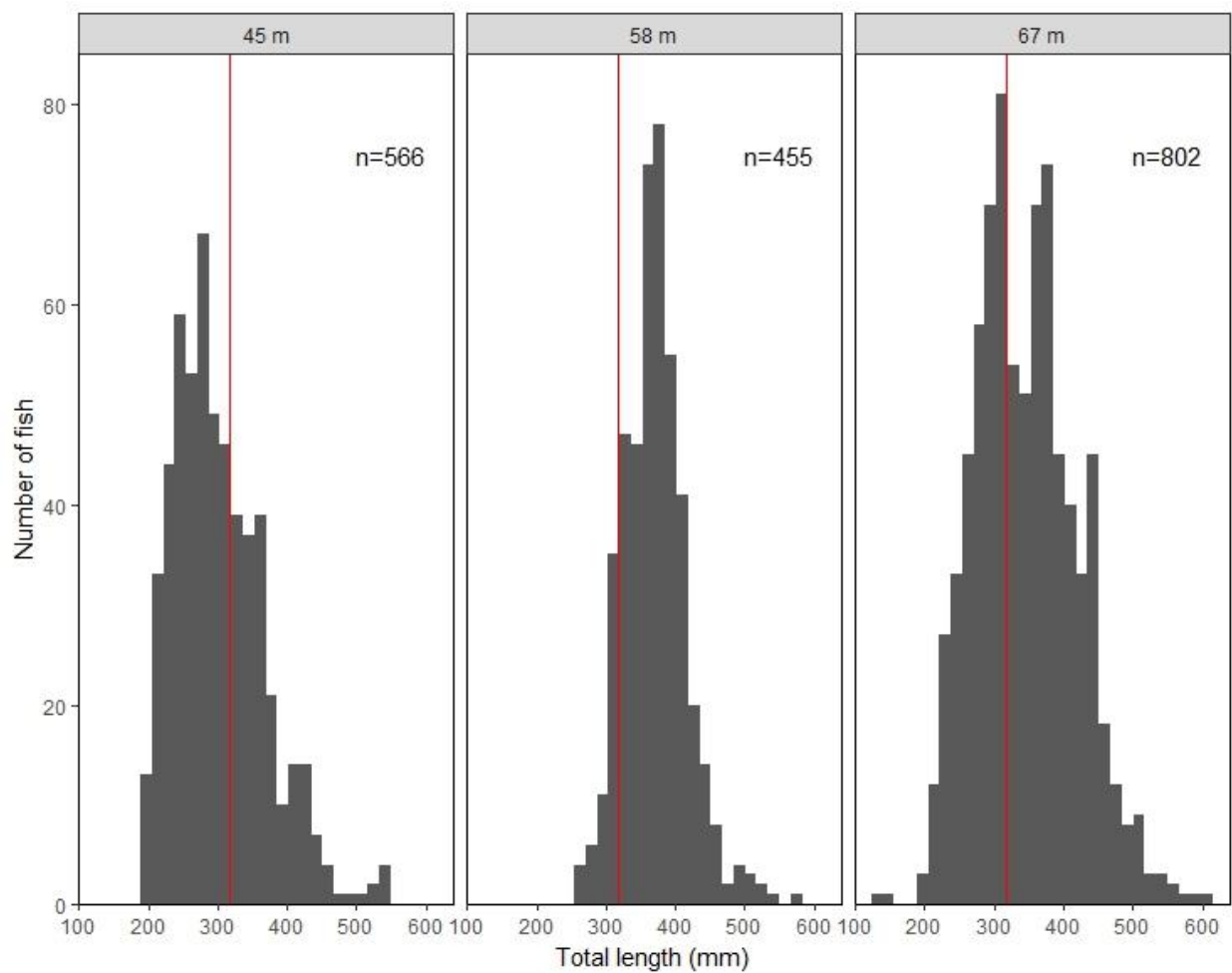


Figure 7 – Length frequency histograms of black sea bass captured at each depth. Sample sizes are presented for each depth. Red lines represent the federal minimum black sea bass size limit (12.5”, 318 mm).

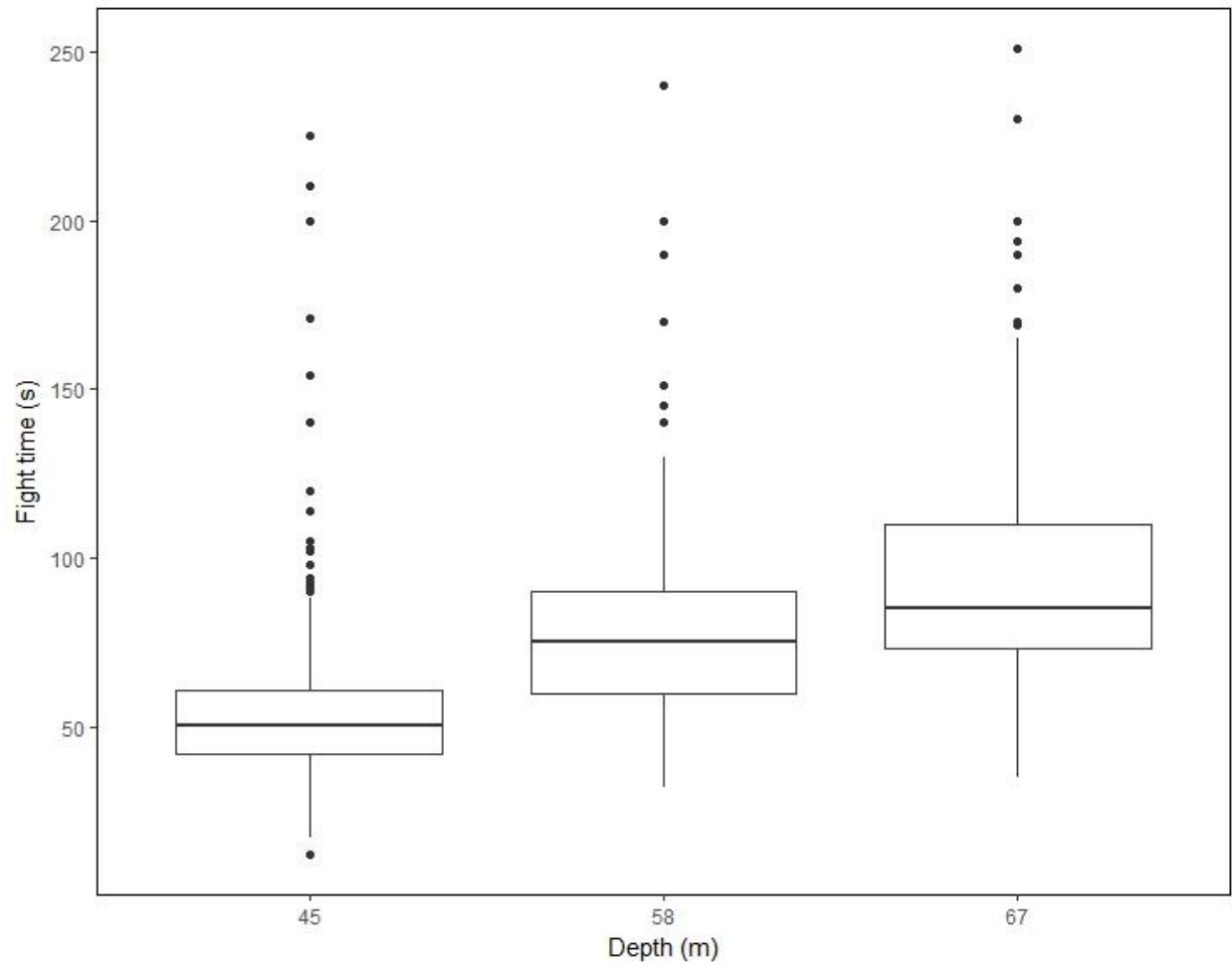


Figure 8 – Boxplot demonstrating the relationship between fight time (seconds) and capture depth (meters). Whiskers represent upper (75%) and lower (25%) quantiles and the black line represents the median value.

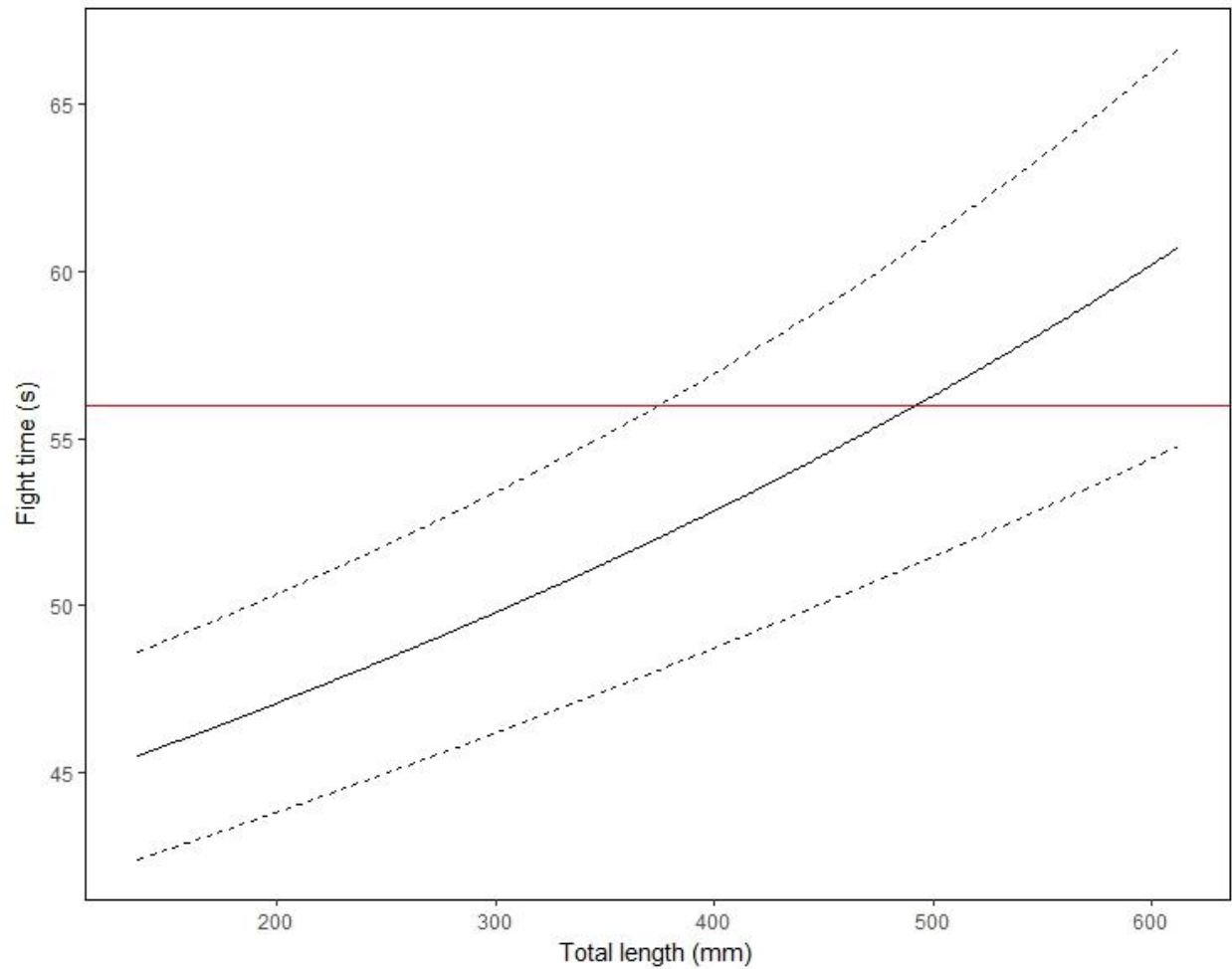


Figure 9 – Relationship between fight time and total length as predicted by the best-fitting generalized additive mixed effect model (solid black line). Upper and lower 95% confidence intervals (dotted lines) are also presented. Red horizontal line demonstrates the mean fight time for the model intercept depth (45 m), and suggests that fish >491 mm total length were generally fought longer than average.

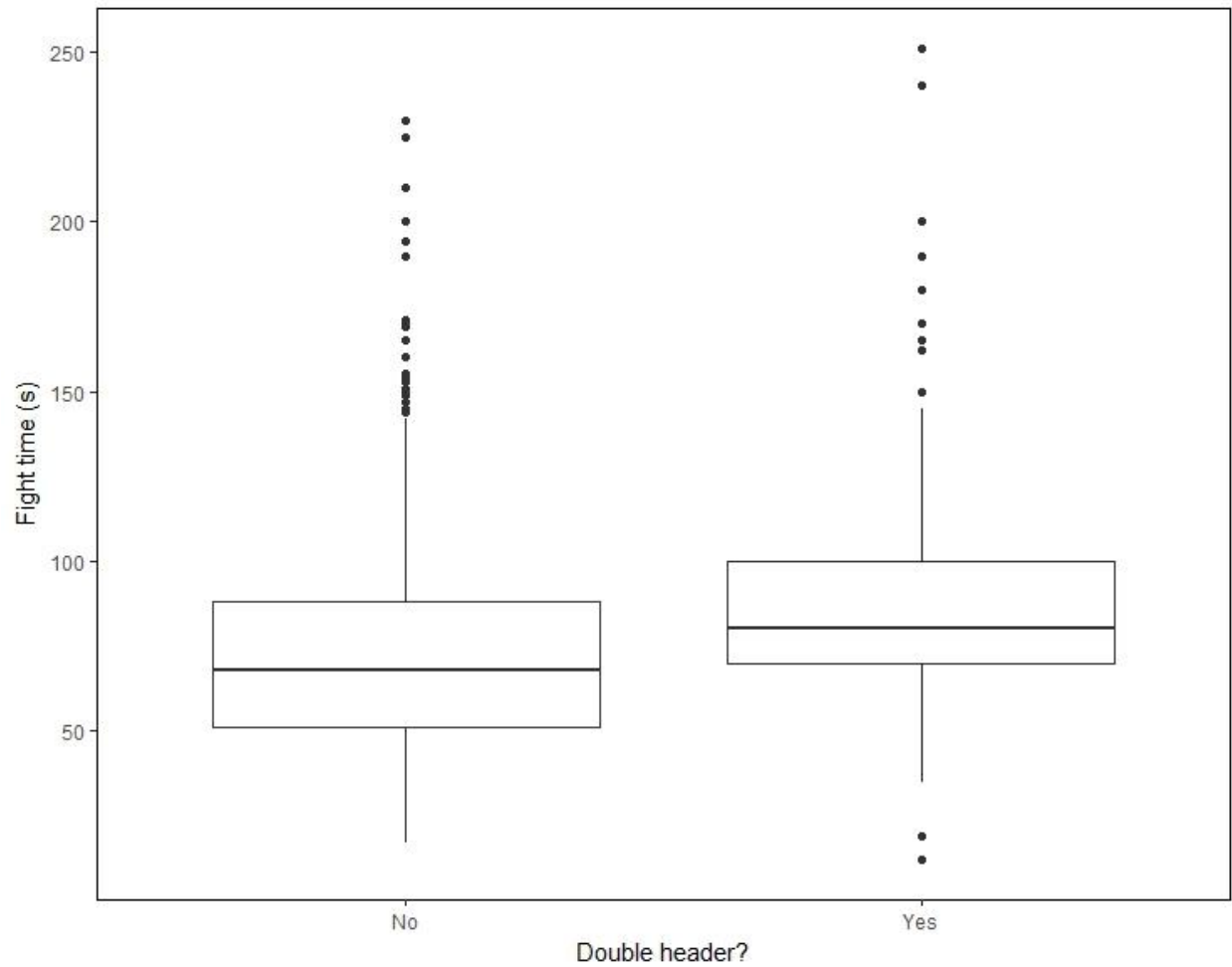


Figure 10 – Boxplot demonstrating the relationship between fight time and capture of fish as part of a double header (i.e., two fish captured simultaneously, one on each hook). Whiskers represent upper (75%) and lower (25%) quantiles and the black line represents the median value.

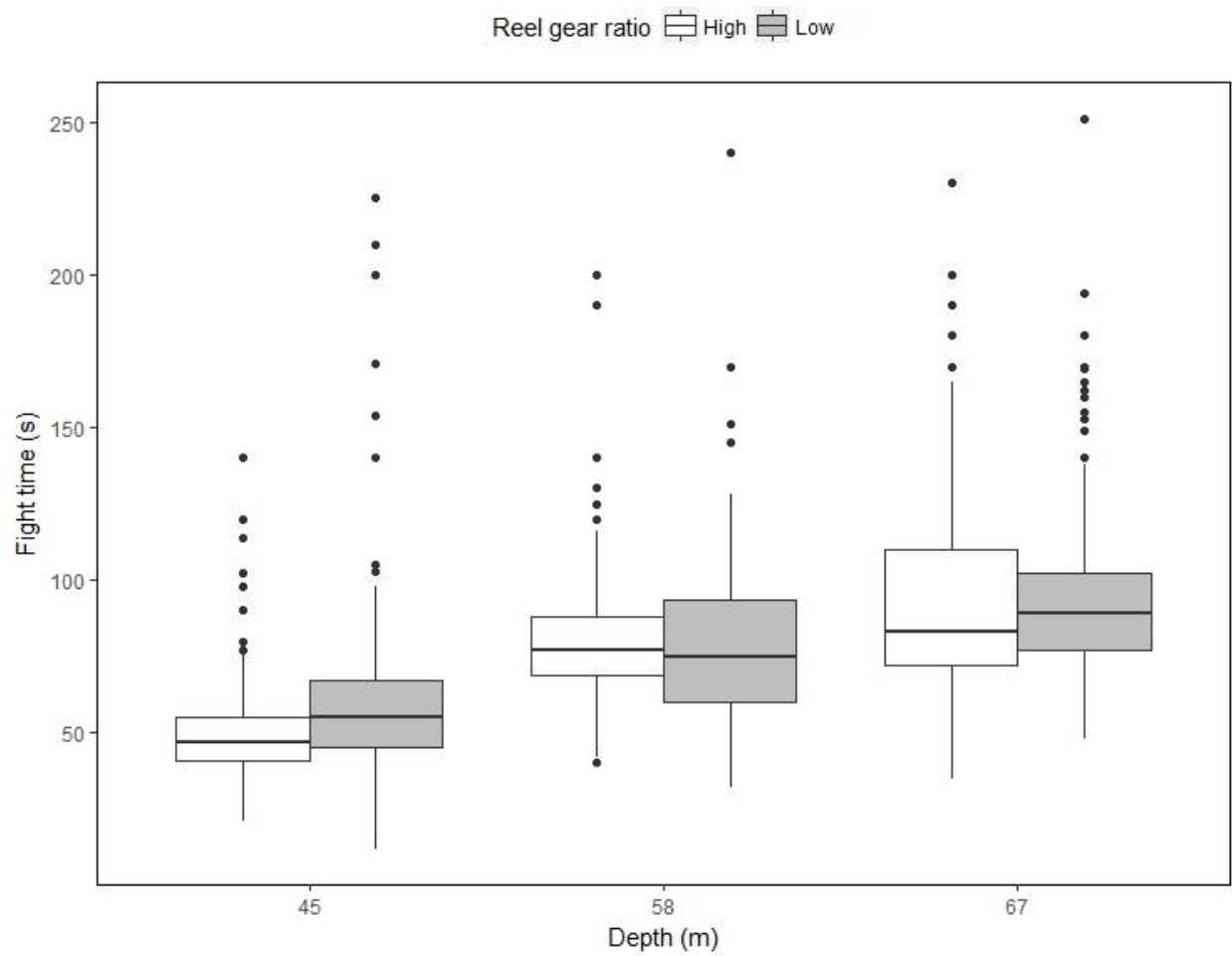


Figure 11 – Boxplot demonstrating the relationship between fight time and capture depth for each reel gear retrieve ratio (‘reel gear’). Whiskers represent upper (75%) and lower (25%) quantiles and the black line represents the median value.

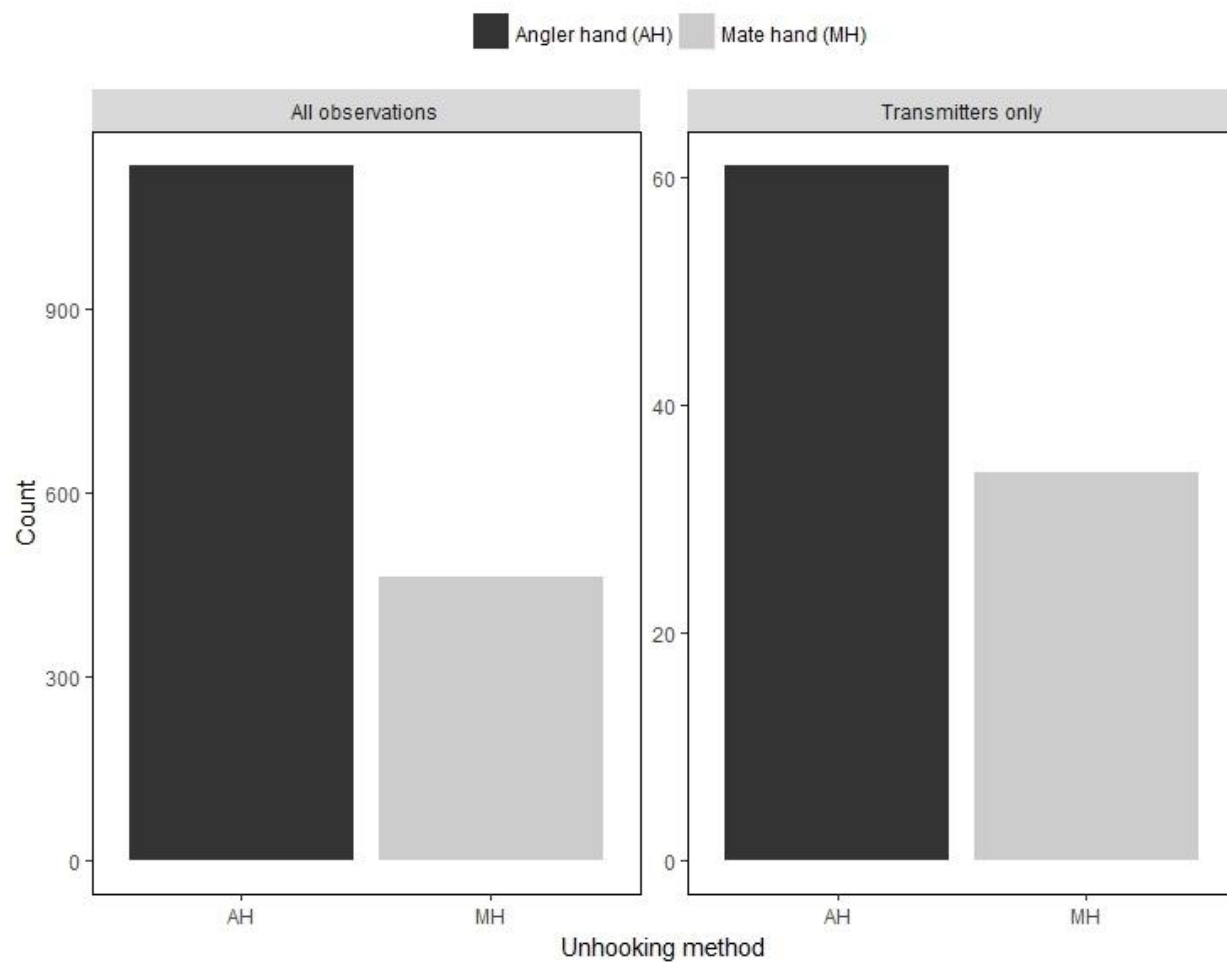


Figure 12 – Histogram of the number of black sea bass that were unhooked by hand by the capturing angler (‘Angler hand’) or by fishing vessel crew/mate (‘Mate hand’) for all capture observations and the 96 fish that were tagged with acoustic transmitters.

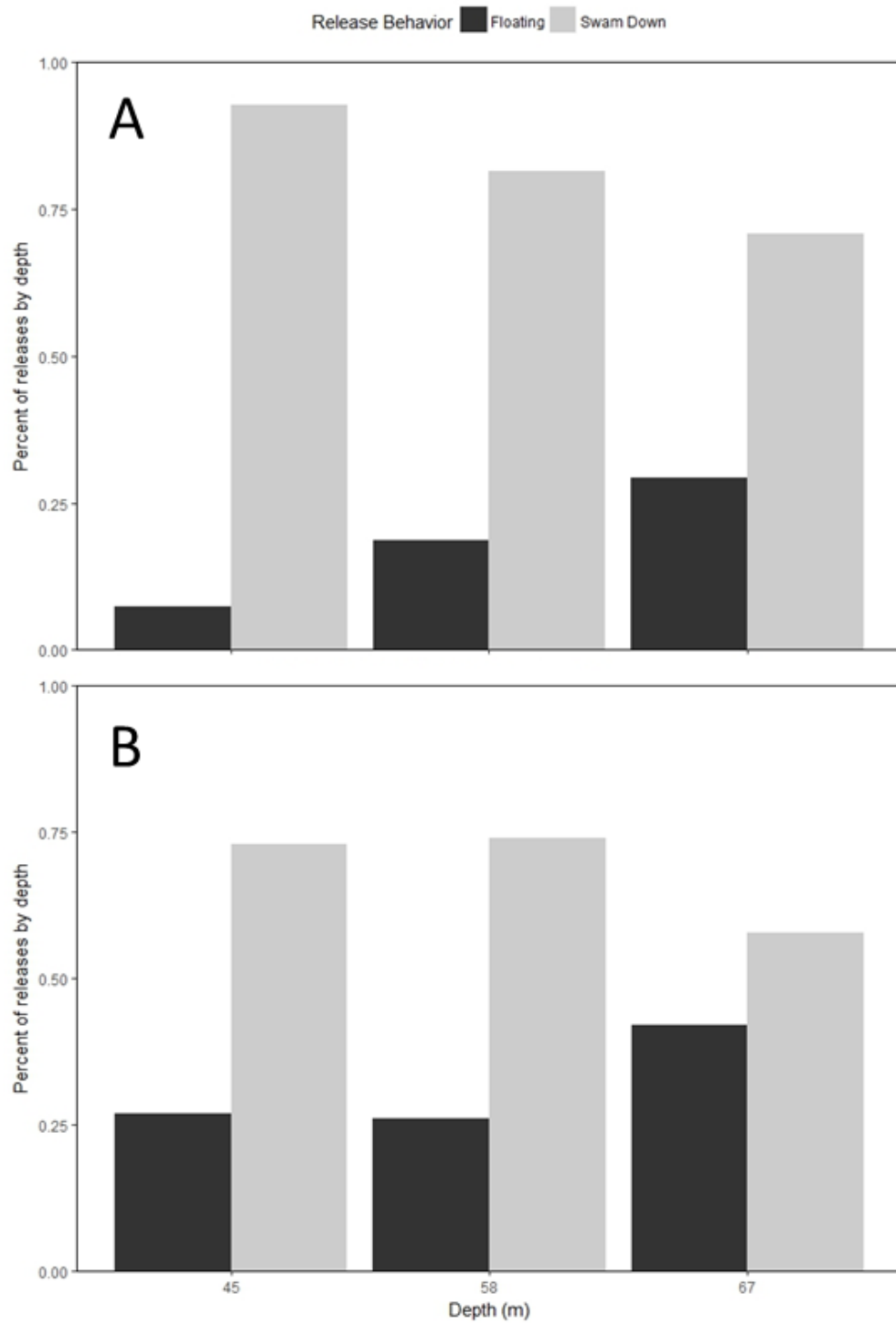


Figure 13 – Histogram of the prevalence of ‘floating’ and ‘swam down’ release behaviors by depth for vented (A) and non-vented (B) fish.

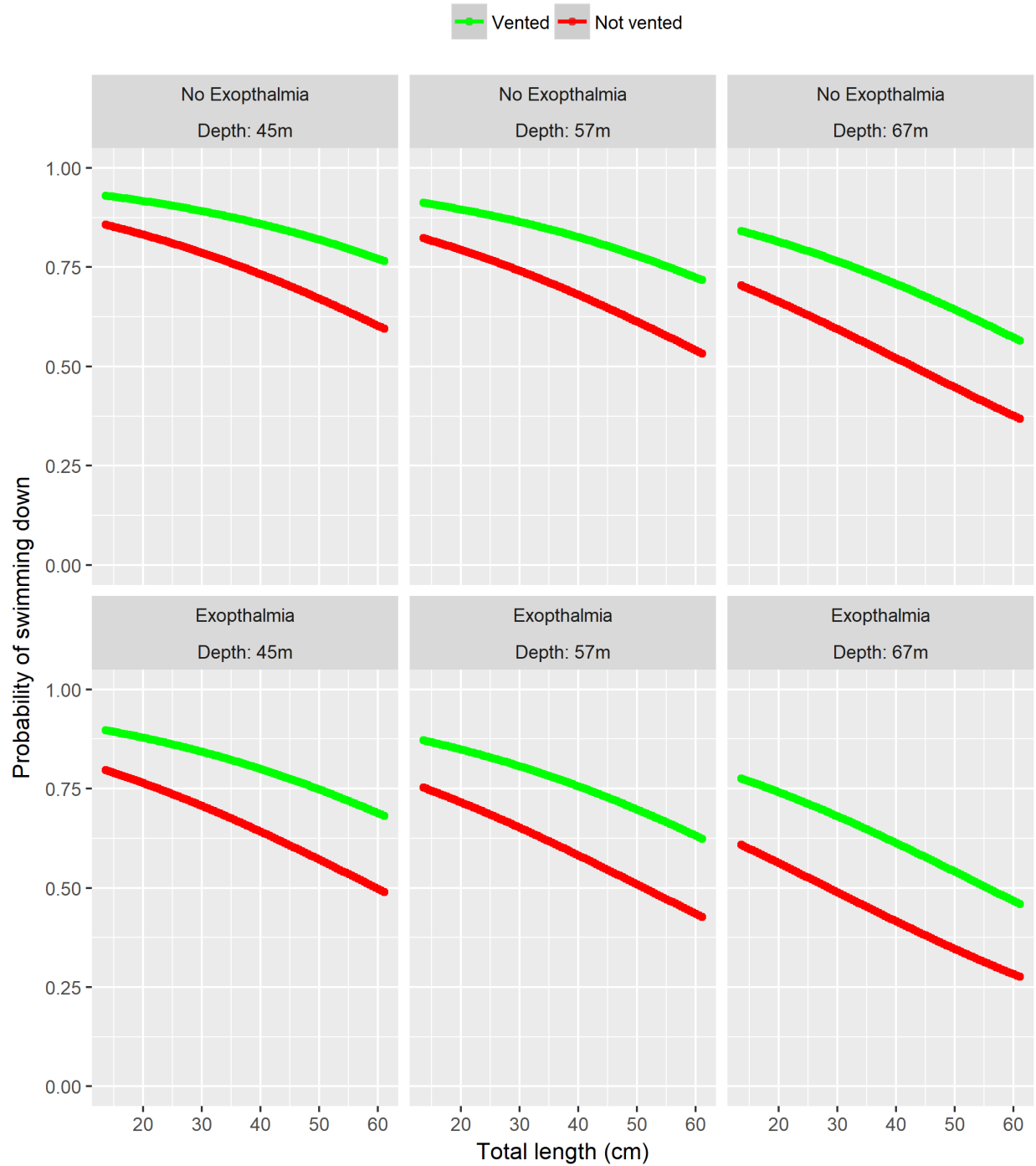


Figure 14 - Probability that a released black sea bass will actively swim down as a function of venting as well as total length, capture depth, and presence of exophthalmia. Larger fish, that were not vented, caught at deeper depths, and experienced exophthalmia had a lower probability of swimming down (i.e., higher probability of floating upon release).

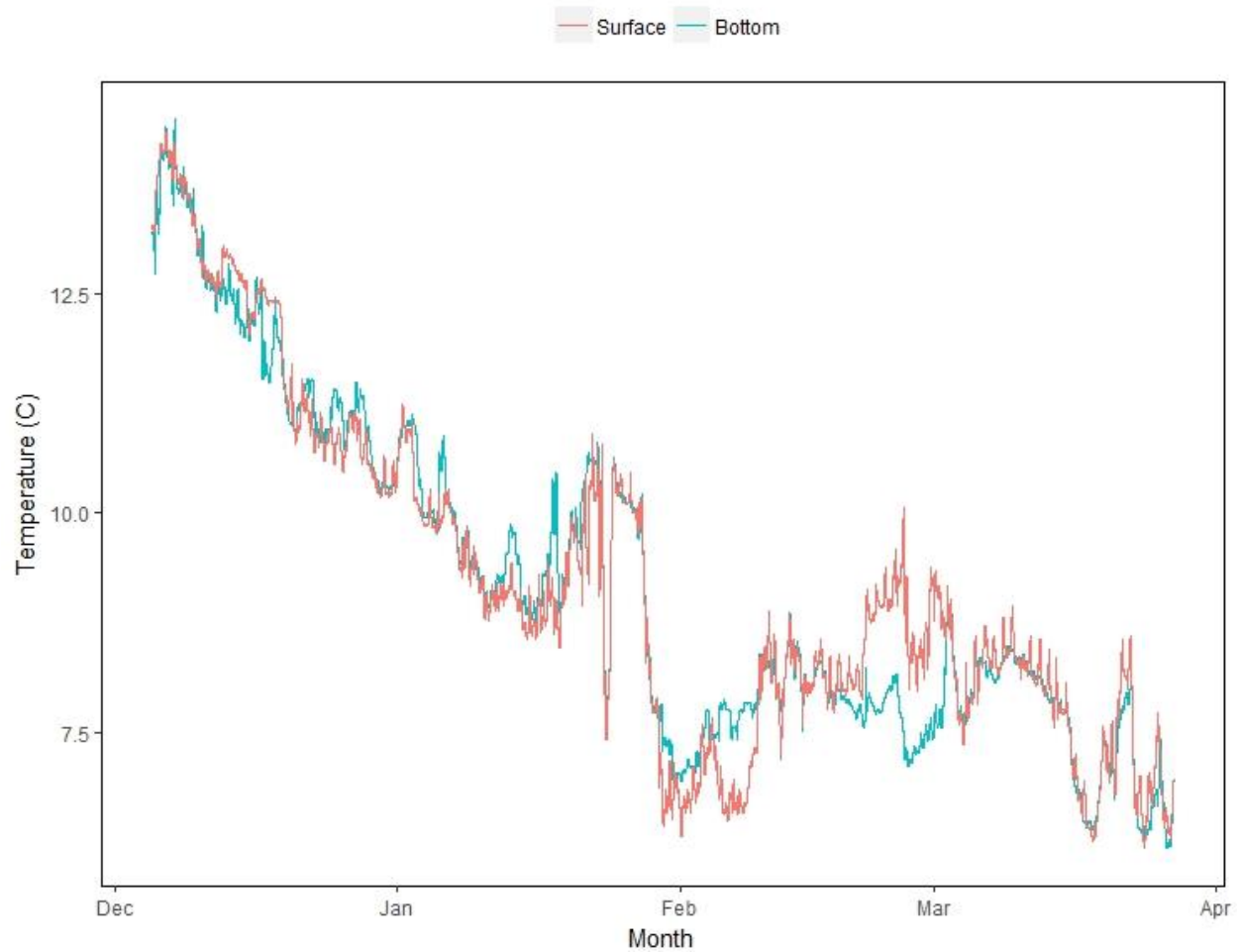


Figure 15 – Surface and bottom water temperatures measured by HOBO Pendant temperature loggers placed on the station SB8 receiver mooring from December 5, 2016 to March 27, 2017. All acoustically tagged black sea bass were monitored between these dates. Note that fishing slowed dramatically at the wreck on February 3, 2017, shortly after a significant drop in surface and bottom temperature.

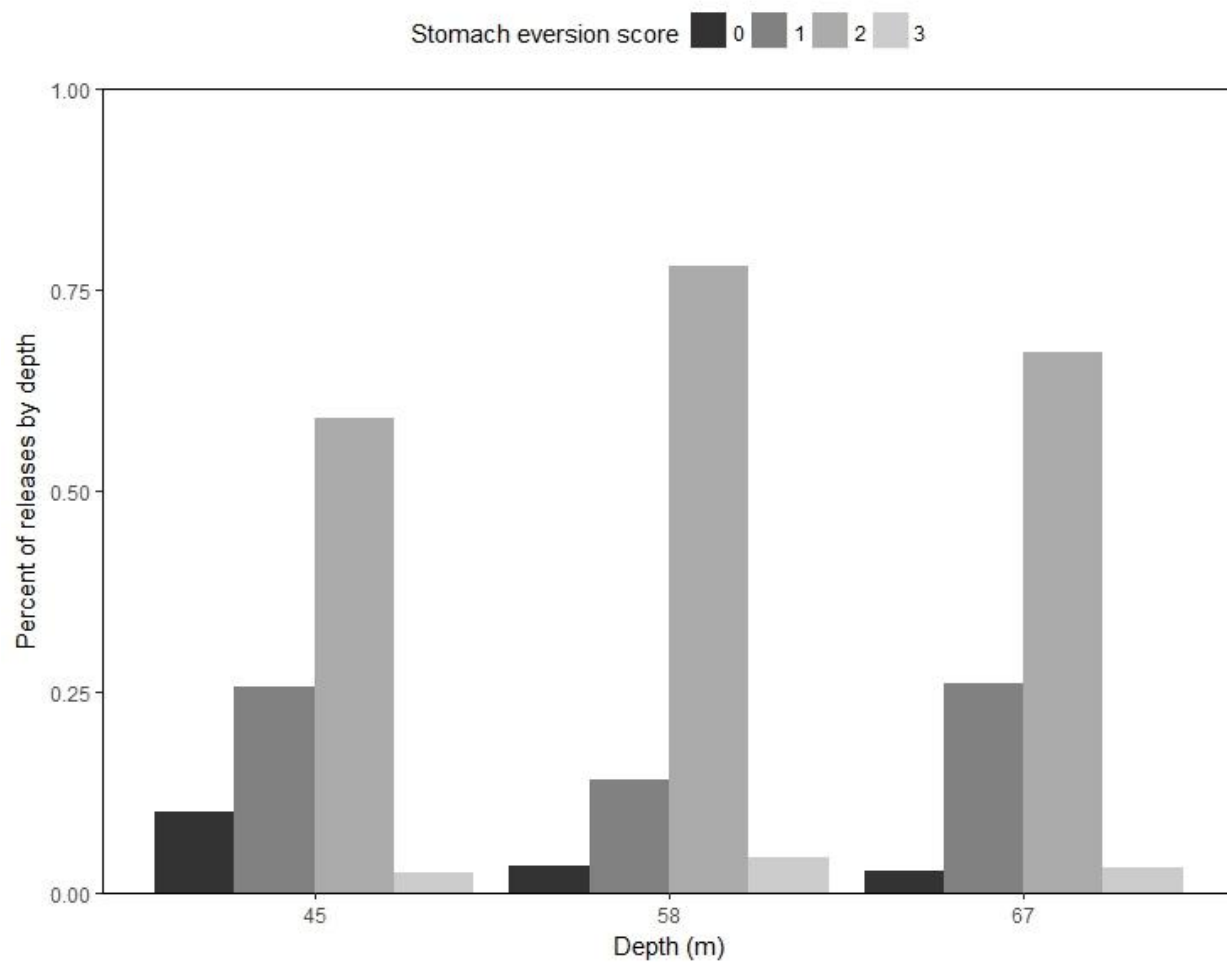


Figure 16 – Histogram of the percent of total fish releases that experienced stomach eversion scores 0, 1, 2, and 3 for each capture depth. Score 0: Stomach not everted; Score 1: Stomach everted but remains within mouth cavity; Score 2: Stomach everted but is protruding from the mouth; Score 3: Stomach everted and ruptured.

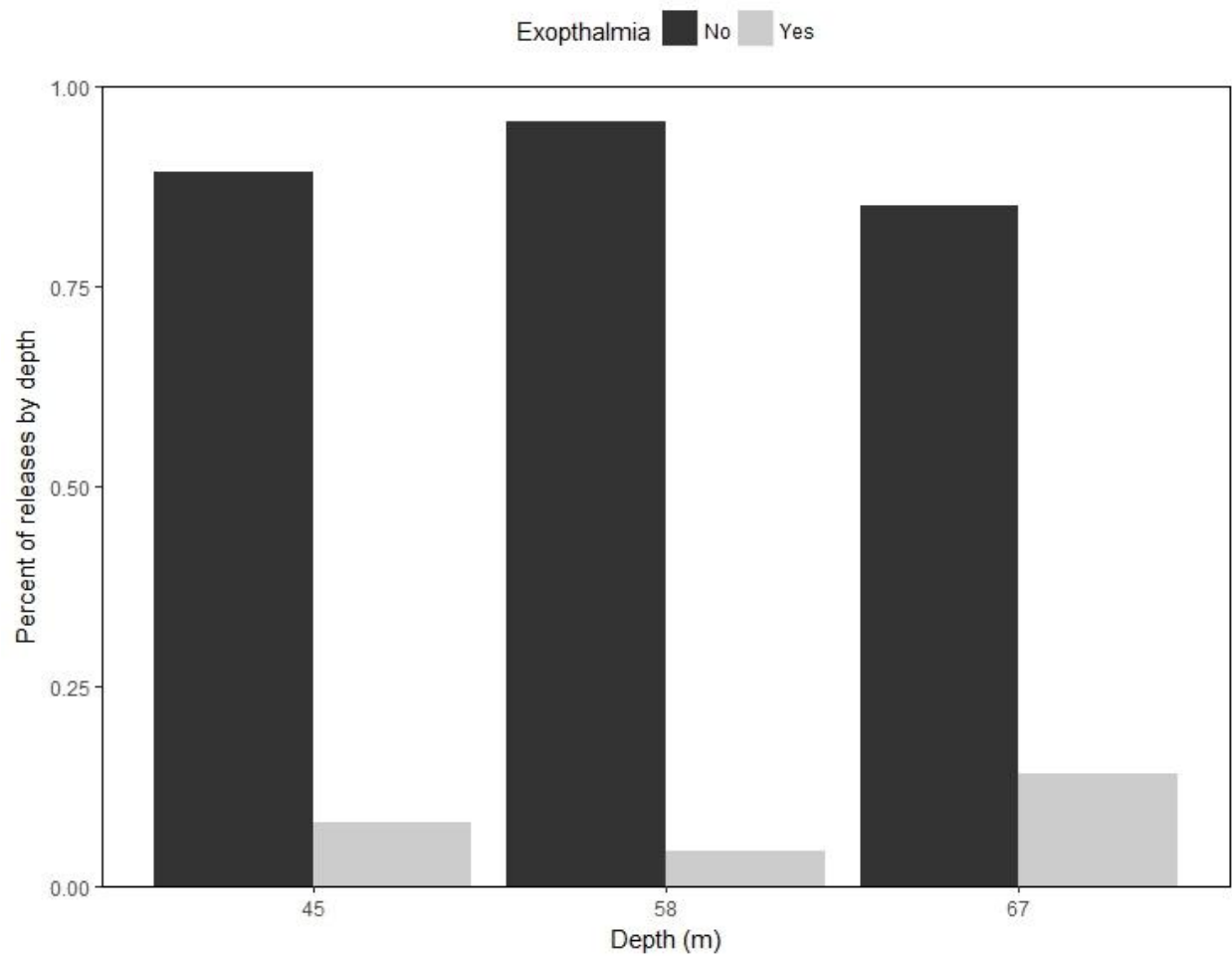


Figure 17 – Histogram of the percent of total fish released by depth that experienced exophthalmia.

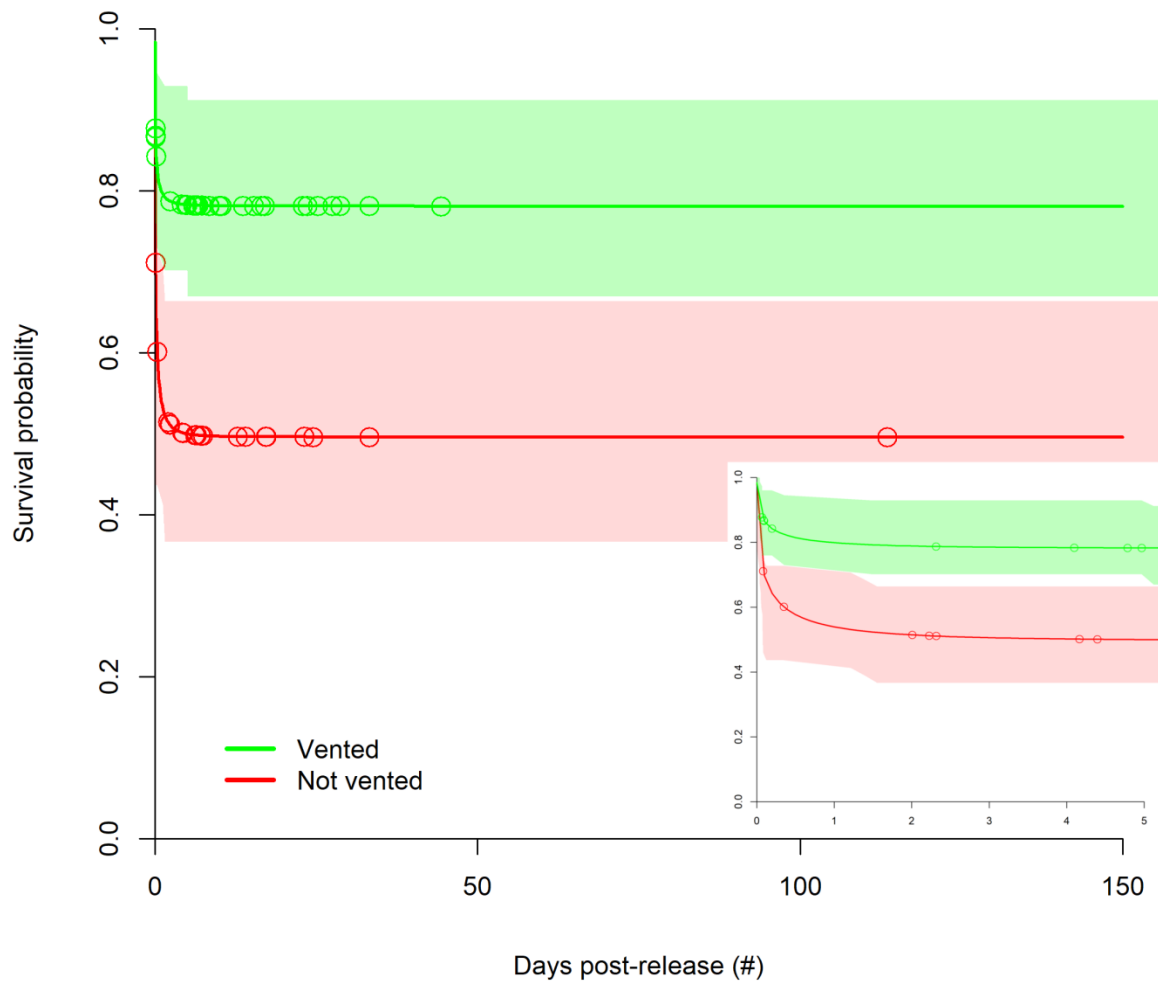


Figure 18 - Nonparametric and model-based estimates of survival functions for black sea bass that were either vented (green) or not vented (red) prior to release, where time zero is the time of release back into the water. Shaded areas indicate the 95% confidence band for the Kaplan-Meier survivor function estimates, the solid lines are estimates from the preferred survival model, and the circle location and size indicate the occurrence and relative number of right-censored observations. The inset plots in each panel show the finer scale survival functions during the first five days after release, when all of the discard-related mortality is estimated to have occurred.

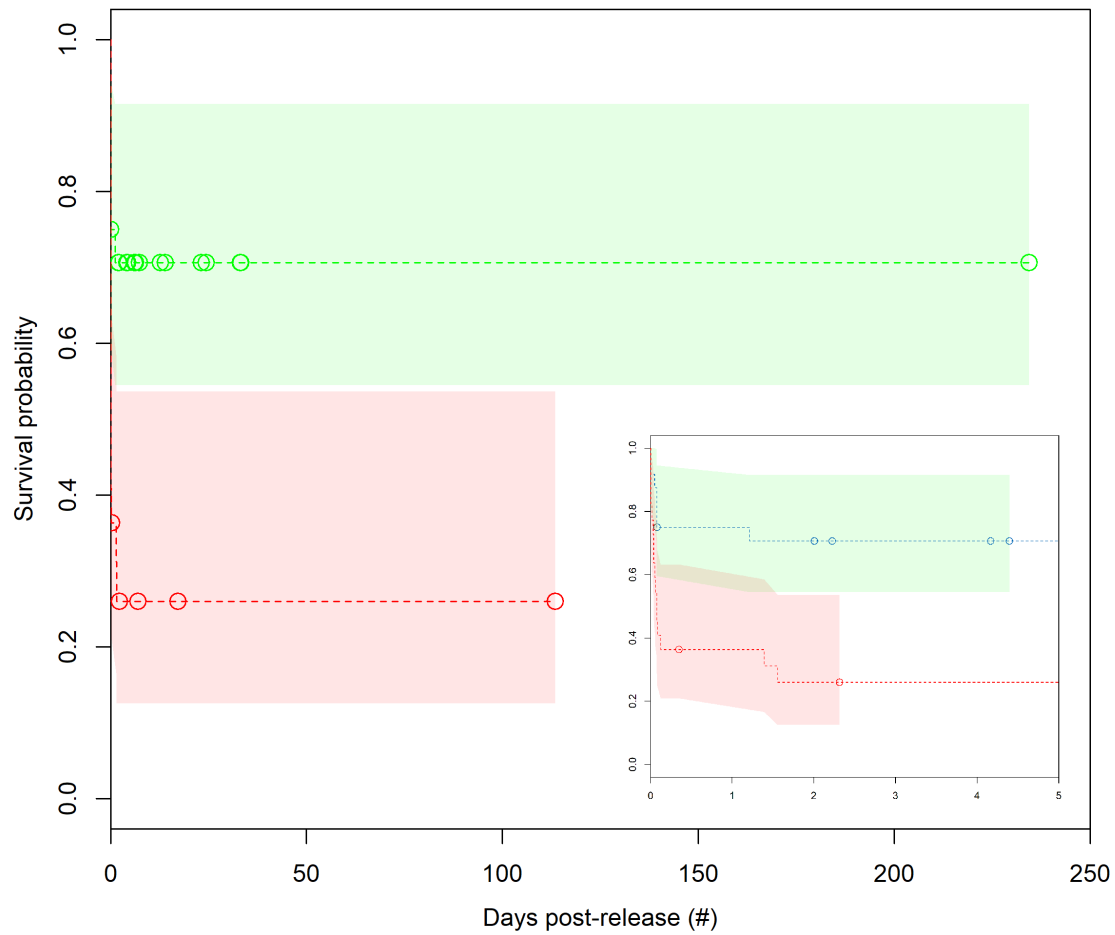


Figure 19 - Plot of the Kaplan-Meier survival function estimate for only unvented black sea bass in the acoustic subsample by low (≤ 54 s) and high (> 54 s) fight times. Shaded areas indicate the 95% confidence interval and circles indicate the time when an individual was last observed alive (i.e., right-censored). Time zero is the time of release back into the water. The inset plot shows the finer scale survival functions during the first five days after release.

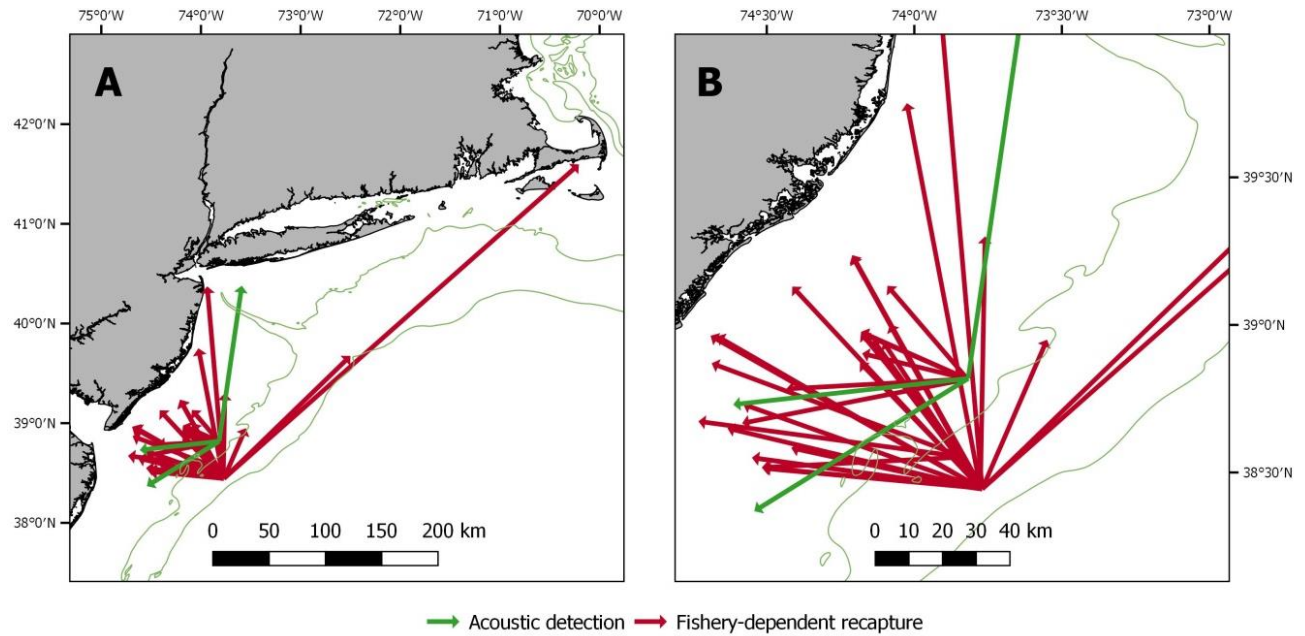


Figure 20 – Plot of fishery-dependent recaptures and acoustic detection events that occurred as of February 1, 2018. Directional arrows depict minimum linear displacement vectors. Note: three acoustic transmitters were reported as fishery-dependent recaptures. Panel A represents the full geographic area over which recaptures or detections occurred and panel B is a zoom of the southern New Jersey region.

PMAFS MAFMC Black Sea Bass Project - Final							
Rutgers University Budget			Monies Spent	Modified Budget	Modified Balance	Rutgers Match	
Salary							
Bochenek (Co-PI)	1.0 mo @8106/mo			\$31,277			
Zemeckis (Co-PI)	4 mo @4584/mo			\$0			
Grothues -researcher	0.5 mo @6885/mo			\$4,835			
Total Salary and Fringe			\$36,109.03	\$36,112	\$2.97		
Rental Wet Lab	1 mo@500/mo			\$0			
Rent Rutgers boat	4 trips@\$2404/day		\$5,950.00	\$5,950	0		
Subtotal				\$42,062.00	\$2.97		
Rutgers indirect @15% for PMAFS			\$5,416.39	\$5,417.00	\$0.61	\$14,445.21	
Rutgers Total			\$47,475.42	\$47,479.00	\$3.58	\$14,445.21	
PMAFS Budget							
partyboat	8 trips @2,750/trip		\$19,250.00	\$19,250.00	\$0.00		
Commercial boat rental			\$9,616.00	\$9,616.00	\$0.00		
Travel			\$4,703.42	\$4,896.00	\$192.58		
Supplies			\$85,627.41	\$85,627.00	-\$0.41		
Accouonting/bookkeeping			\$1,500.00	\$1,500.00	\$0.00		
Consultant -Kneebone			\$34,201.00	\$34,201.00	\$0.00		
PMAFS Subtotal			\$202,373.25	\$202,569.00	\$195.75		
PMAFS ICR 10%			\$16,755.73	\$16,775.00	\$19.27		
Total PMAFS Budget			\$219,128.98	\$219,344.00	\$215.02		
			s				