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ABSTRACT

The Gulf of Mexico greater amberjack (*Seriola dumerili*) stock has been designated as "overfished" by the National Marine Fisheries Service and is currently under a rebuilding plan. Its fishery in the Gulf of Mexico is dominated by recreational landings, where 75% of the total recreational catch are regulatory discards; as such, uncertainty regarding the post-release mortality rate represents a data deficiency in the stock assessment. To determine post-release mortality, a combination of acoustic and pop-up satellite archival transmitting (PSAT) tags were used to monitor the release fate and depth-use of greater amberjack. Thirty-six greater amberjack were tagged with acoustic transmitters at two sites in the northern GOM and monitored for up to 30 days. Sublegal-sized fish (n = 18) ranged from 591 to 740 mm FL (mean = 674.6 ± 40.6 SE) and legal-sized fish (n = 18) ranged from 768 to 1081 mm FL (mean = 871.3 ± 77.5 SE). All 36 fish were detected in the array after release. Based on examination of time series depth profiles, post-release mortality was estimated to be 18.8% ± 6.9%, strikingly similar to the estimate used in the most recent stock assessment. Stepwise model selection using AIC identified the Cox proportional hazards model containing only release condition as the most parsimonious model to predict post-release mortality. Despite differences in depth between the two tagging sites, fish showed slight, but consistent, size-specific segregation patterns. Our findingsadd to a body of literature demonstrating that biotelemetry is an effective tool in catch and release mortality studies, and provide best practices that can aid in the recovery of this stock.

1. Introduction

Analysis of global marine ecosystems indicates that predatory fish biomass has declined over the past 100 years (Christensen et al., 2014). Recreational fishery removals are now known to contribute to declines in fish stocks, which were historically attributed to commercial over-harvest. (Coleman et al., 2004; Cooke and Cowx, 2004). In the United States, recreational harvest disproportionally affects populations that are considered by NMFS to be overfished or experiencing overfishing. In these fisheries, minimum size limits, bag limits, and/or seasonal closures are common tools used by fishery managers to reduce fishing mortality, and may result in a number of regulatory discards (Pollock and Pine, 2007).

The above mentioned regulatory actions are intended to reduce fishing mortality, yet post-release mortality is widespread among fisheries (Muoneke and Chilkdress, 1994; Bartholomew and Bohnsack, 2005). Post-release mortality was traditionally quantified through observation of immediate mortality (e.g. Murie and Parkyn, 2013) or confinement methods such as cages or pens (e.g. Campbell et al., 2010), but advances in biotelemetry have enhanced our ability to measure this parameter (Donaldson et al., 2008). Acoustic telemetry is particularly useful for estimating long-term post-release mortality, typically defined as mortality up to 72 h post-release (Donaldson et al., 2008). Examples where the application of acoustic telemetry has successfully been used to assess post-release mortality include Atlantic red snapper (*Lutjanus campechanus*, Curtis et al., 2015) and Atlantic cod (*Gadhus morhua*, Capizzano et al., 2016), both fisheries with significant recreational components.

For greater amberjack (*Seriola dumerili*) in the Gulf of Mexico, recreational landings far exceed commercial landings (SEDAR, 2014). In addition, 75% of the total recreational catch of greater amberjack is made up of releases (SEDAR, 2014). During the most recent assessment, a post-release mortality rate of 20% was used; however, this rate was based primarily on surface observations, which only characterize immediate mortality. Post-release mortality has been estimated at 0% (Murie et al., 2011), but this was based on 5 telemetered fish. More recently, tag and recapture studies have been used to estimate immediate mortality of greater amberjack (Murie and Parkyn, 2013; Sauls

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and Cermak, 2013), and have found relatively low rates (0–2.4%). While immediate discard mortality rates appear to be low for greater amberjack, data to estimate delayed mortality are currently lacking.

Gulf of Mexico greater amberjack are overfished and under a rebuilding plan (SEDAR, 2014); as such, steps are needed to ensure stock biomass is rebuilt as quickly as possible. A recent update to the stock assessment (SEDAR, 2014) indicates that discard rates in the recreational fishery are even higher than originally estimated. Given the importance of discards in the recreational fishery, increasing our understanding of fishing mortality beyond immediate release mortality is critical to ensuring the stock meets its rebuilding target. The goal of the current study is to estimate post-release mortality of greater amberjack in the Gulf of Mexico using a combination of acoustic and PSAT tags.

2. Methods

2.1. Hydrophone array

To examine post-release mortality of greater amberjack, two artificial reefs, termed the Boat site and the Rig site (50 m and 70 m depth, respectively) were designated as tagging locations within the Tatum-Winn South general permit area located off the coast of Alabama in the northcentral Gulf of Mexico (Fig. 1). The Boat site is a toppled platform jacket in three pieces, with ~10–12 m of vertical relief. The Rig site is a metal boat with ~5–6 m of vertical relief. Both locations encompass large two-dimensional footprints and were chosen based on pilot sampling in March of 2013 to ensure that sufficient numbers of greater amberjack were available for tagging. At each location, a semi-permanent acoustic hydrophone array was deployed, containing four Lotek WHS 3050 (Lotek Wireless Inc., St. Johns, Canada) submersible dataloggers arranged in a square. Each hydrophone was moored so that it was positioned 10 m above the seafloor with a submerged plastic subsurface buoy attached to a 12.7 mm twisted polypropylene line equipped with a galvanic release (International Fishing Devices, Inc.) set to deteriorate after 30 days. Hydrophones thus recorded data for 30 days before surfacing for retrieval (Fig. 2)

During deployment, hydrophones were tested at each site to determine the detection range. Each hydrophone was tested with a control tag positioned at all four cardinal positions at varying distances from the receiver for 1 min each at surface, midwater, and bottom depths (Kessel et al., 2014). The greatest detection efficiency was achieved when the control tag was positioned 200–300 m from the hydrophone. Detection range (maximum distance over which the receiver detected the control tag) was approximately 525 m; however, a range of 203–613 m was observed (Fig. 2)

2.2. Tagging

Greater amberjack were caught and tagged using typical recreational fishing methods aboard a chartered boat, the *F/V* Lady Ann. Recreational gear consisted of Penn Senator 6/0 reels on 1.8 m bottom fishing rods with 12/0 circle hooks and 10–12 oz. egg weights on 60 lb. test monofilament. Tagging events took place during two tagging trips in fall 2014: one on 13–14th September and another on 20–21st September. Each time a fish was hooked, the fight time, defined as the time from initial hook to landing, and handling time, defined as the amount of time spent on deck, were recorded. Upon landing, the hook was removed from the fish by hand or with pliers as necessary. During handling, a constant flow of seawater was pumped through a hose into the mouth and over the gills. All greater amberjack were measured for fork length (FL) and stretched total length (STL) to the nearest mm and weighed (kg) using a Pesola spring scale. All fish were vented 5–7 cm posterior of the pectoral fin using a 16-gauge, 3.75 cm Novak venting tool developed by Sea Grant. Despite the potential adverse effects that can result from venting (Brownscombe et al., 2016), our decision to vent was based on previous work that found the majority of greater amberjack tagged and released at depths greater than ~60 m had turgid swim bladders that required venting (Murie and Parkyn, 2013). The depth of the sites selected for tagging in the current study were 50 and 70 m at the Boat and Rig sites, respectively; therefore, all greater amberjack were vented to avoid introducing an additional treatment that may confound estimates of post-release mortality. Multi-mode acoustic transmitters equipped with pressure and motion sensors (Lotek Wireless Inc., St. Johns, Canada, MM-MR-16-50-PM) were implanted prior to release. To implant the acoustic tag, a No. 21 scalpel was used to make a ~1 cm incision on the ventral surface, 1–2 cm left of midline and 5 cm anterior to the anal fin. After the transmitter was implanted, the incision was then closed using a simple interrupted suture (No. 2 Ethicon 3.0 metric KS nylon), and a topical antibiotic was applied to prevent infection. Surgical tools and materials were cleaned with methanol after each use and only one person performed the surgery to maintain consistency in technique. In addition, a laminated internal

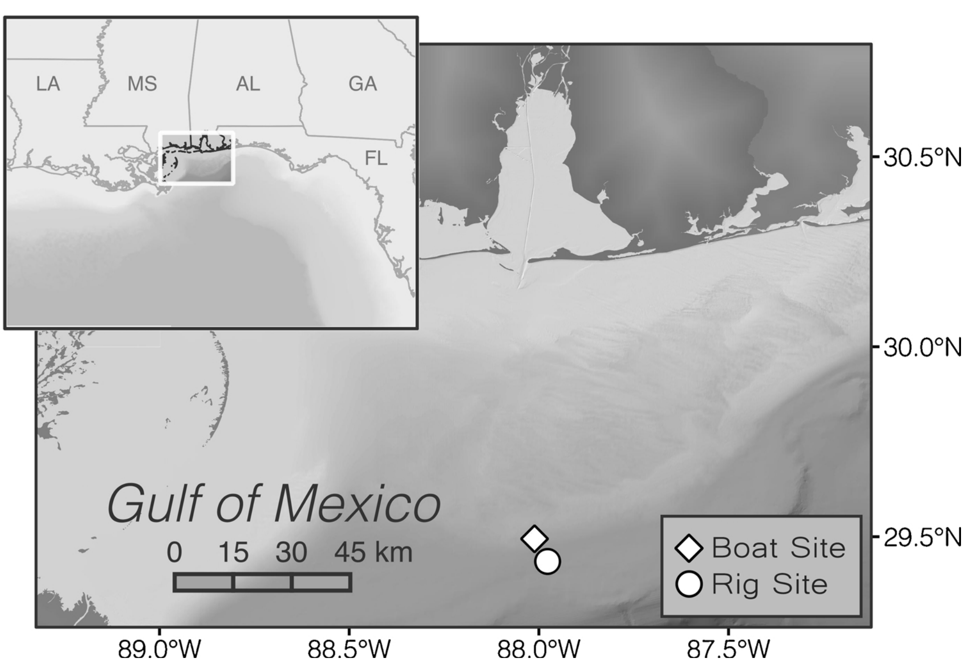

Fig. 1. Map of two artificial reefs within the Tatum-Winn South general permit area off the coast of Alabama in the northcentral Gulf of Mexico. The left inset denotes the Gulf of Mexico with a box showing the location of the enlarged area. The diamond denotes the Boat site (50 m) and the circle denotes the Rig site (70 m). These sites were designated as tagging locations based on pilot work completed in March 2013.

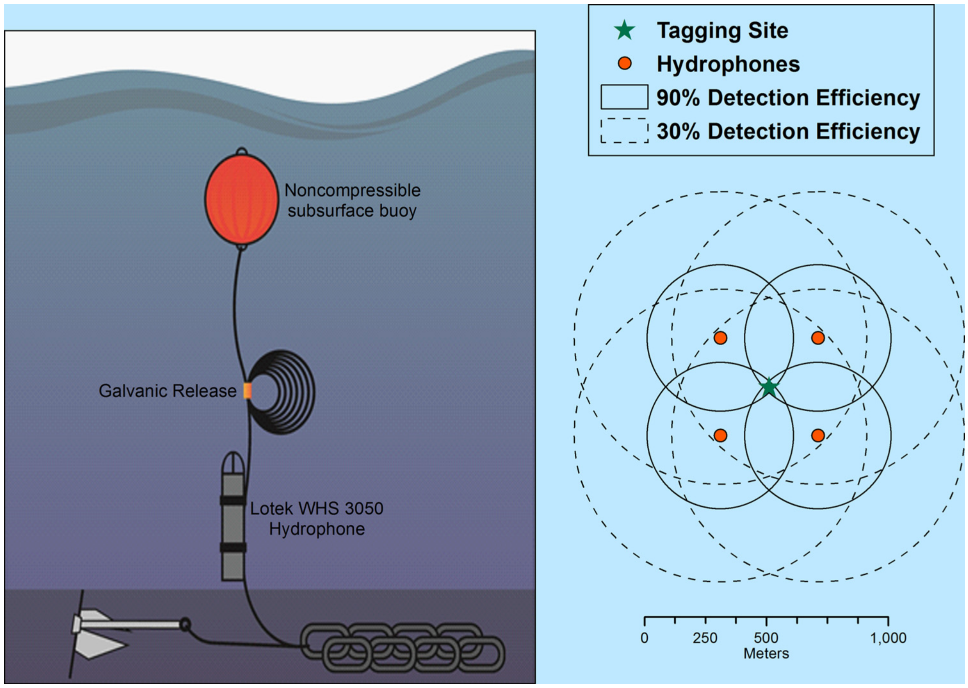

Fig. 2. Schematic of the subsurface hydrophone mooring and detection efficiency of the hydrophones as revealed through range testing.

anchor tag (FLOY FM-95W) was implanted near the acoustic tag closure to enhance fisher recapture reporting. Following the procedure, each fish was lowered into the water and released. The release condition was recorded on a five-point scale (1 = excellent condition and 5 = dead after release) (Patterson et al., 2001).

In addition to the acoustic tags, five LAT 3400 PSAT tags (dimensions 19 × 125 mm, 89 g in air, Lotek Wireless Inc., St. Johns, Canada) attached to titanium darts (64 mm L × 16 mm W × 1 mm H) using 400 lb. test were inserted just below the first dorsal fin and anchored in the pterygiophores anterior to the neural spines. Each tag was programmed to release 12 months after deployment to transmit data to the Advanced Research and Global Observation Satellite system (ARGOS). These tags recorded light intensity, temperature (accuracy ± 0.2 °C, resolution 0.05 °C), and pressure (accuracy ± 1%, resolution 0.05%), every 20 s. The PSAT tags were programmed to activate an emergency release from moribund fish, and this threshold was defined as constant depth reading (within 5 dbar) for 3 days.

2.3. Data analysis

Hydrophone data were downloaded and imported into R version 3.2.5 (R Core Team, 2016) for filtering and data analysis. False detections were defined as any detection with a pressure reading that resulted in depths greater than 50 and 70 m for the Boat and Rig sites, respectively, and/or was only detected once within a 10-min interval on the receivers at a given site. These detections made up a very small proportion (< 0.001%) of the total detections and were excluded from further analyses. The fates of released fish were determined using time series depth profiles recorded by the acoustic (Yergey et al., 2012; Curtis et al., 2015) and PSAT (Horodysky and Graves, 2005; Kerstetter and Graves, 2006; Moyes et al., 2006) tags. A depth profile was plotted for each fish on every hydrophone it was detected on over the entire detection period (up to 30 days). These profiles were used to classify fish fate as follows: survival, mortality, or unknown. Fish that survived showed changes in depth following release, whereas fish experiencing immediate or delayed mortality exhibited constant depth-use profiles. Fish that were detected in the acoustic array for less than 4 h (n = 4) were classified as unknown and were excluded from survival analysis (Curtis et al., 2015). However, these fish were included in the Cox proportional hazards model until emigration. Survival was calculated following Pollock and Pine (2007) and Curtis et al. (2015):

$$\hat{S} = \frac{x}{n},$$

with a standard error (SE) of

$$SE(\hat{S}) = \sqrt{\frac{\hat{S}(1-\hat{S})}{n}},$$

where x is the number of fish classified as survivors, and n is the number of fish with an assigned fate (i.e. total fish tagged minus fish classified as unknown). The Cox proportional hazards model (Cox, 1972), with a time-step of 1 h, was used to calculate how the variables FL (mm), weight (kg), site, fight time (minutes), handling time (minutes), and release condition affected the fate of released fish using the following formula:

$$h(t) = h_o(t)\exp\left(\sum_{i=1}^{p} \beta_i X_i\right),$$

where $h_o(t)$ is an unspecified function representing the baseline hazard, β_i is the regression coefficient, and X_i is the explanatory variable(s) in the model (Curtis et al., 2015). All fish were included in the model after release and were censored after emigration. The Cox proportional hazards model was implemented using the "survival" package (Therneau and Grambsch, 2000) in R. The best-fitting Cox proportional hazards model was selected with a stepwise procedure (R function "stepAIC"), using both forward and backward selection, where the most parsimonious model had the lowest Akaike information criteria (AIC) value.

2.4. Depth-use statistics

Pressure data from the acoustic tags were used to describe depth-use for each of the surviving fish. The resolution from the pressure sensor allowed the following depth readings: 0, 6.8, 13.6, 20.4, 27.2, 34.0, 40.8, 47.6, 54.4, 61.2, and 68.0 m. The number of detections of each depth bin was then divided by the total number of detections for each fish to calculate the percentage of time spent at each depth. Differences

Table 1
Characteristics of tagged fish. All fish were fitted with acoustic tags. Fish that also received a PSAT tag are denoted with (*) next to the fish number. Individuals and their fate are listed as follows: "U" for unknown (fish detected less than 4 h), "A" for alive, "D" for dead, "R" for recaptured, and "E" for fish that emigrated before hydrophone collection. The release condition was recorded (1 = excellent, 5 = dead).

Fish	Acoustic tag	Site	Tagging Date	Last Detection	Size Category	Fork Length (mm)	Weight (kg)	Fight Time	Handling Time	RC	Fate
1	56112	Boat	13-09-2014	14-09-2014	S	618	4.5	00:58	02:31	1	A,E
2	56164	Boat	13-09-2014	13-09-2014	S	740	6.5	06:50	03:13	4	U
* 3	56216	Boat	13-09-2014	13-09-2014	L	900	11.5	02:47	03:30	1	U
4	56268	Rig	13-09-2014	21-10-2014	S	644	4.5	01:22	02:48	1	A
5	56320	Boat	13-09-2014	21-10-2014	S	721	6.5	01:47	02:36	1	D
* 6	56372	Rig	14-09-2014	21-10-2014	L	927	10.5	03:27	03:24	1	A,R
7	56424	Boat	13-09-2014	25-09-2014	L	920	13	01:49	03:24	1	A,E
8	56528	Rig	14-09-2014	21-10-2014	S	667	4.5	01:34	02:56	1	A
9	56580	Rig	14-09-2014	21-10-2014	L	846	10.5	02:21	02:48	1.5	D
10	56632	Boat	13-09-2014	26-09-2014	S	677	5.5	01:45	02:18	1	A,E
11	56684	Boat	14-09-2014	21-10-2014	L	778	8	01:45	02:45	1	A
12	56736	Boat	14-09-2014	14-09-2014	L	768	7.5	04:03	02:35	1	U
13	56788	Rig	21-09-2014	21-10-2014	S	665	5.5	01:01	03:25	1	A,R
14	56840	Rig	14-09-2014	01-10-2014	S	640	4.3	01:02	02:41	1.5	A,E
15	56892	Boat	14-09-2014	11-10-2014	S	660	5.2	03:35	02:32	1	D
16	56944	Rig	14-09-2014	21-10-2014	S	715	6.4	01:48	02:25	1	A
17	56996	Boat	14-09-2014	21-10-2014	S	695	5.6	01:23	02:33	1	A
18	57048	Rig	21-09-2014	21-10-2014	S	639	5.5	01:12	02:46	1	A
19	57100	Rig	13-09-2014	21-10-2014	L	800	8.5	02:45	04:18	1	A
* 20	57152	Boat	13-09-2014	21-10-2014	L	888	12.4	03:06	03:31	3	D
21	57204	Boat	14-09-2014	14-10-2014	S	720	6.5	01:33	02:19	1	A,E
* 22	57256	Rig	21-09-2014	21-10-2014	L	1002	17	03:30	03:05	2	D
23	57308	Rig	21-09-2014	21-10-2014	L	814	9.3	01:48	02:21	1	A
24	57360	Boat	13-09-2014	06-10-2014	S	591	3.5	01:48	02:48	1	A,E
25	57412	Boat	13-09-2014	13-09-2014	L	910	12.4	01:57	03:21	1	U
26	57464	Rig	14-09-2014	21-10-2014	L	867	10	02:33	02:50	1	A, R
27	57568	Rig	21-09-2014	21-10-2014	L	878	12.5	03:20	03:00	1	A
28	57620	Boat	14-09-2016	18-10-2014	S	703	6.3	02:25	02:28	1	A,E
29	57672	Rig	21-09-2014	21-10-2014	S	697	6	01:30	02:00	1	A
30	57724	Rig	21-09-2014	11-10-2014	S	642	5.5	02:00	02:06	1	A,E
* 31	57776	Rig	13-09-2014	21-10-2014	L	1081	17	04:35	02:52	1	A,R
32	57828	Rig	14-09-2014	21-10-2014	L	814	9.5	02:40	02:52	1	A,R
33	57880	Boat	14-09-2014	21-10-2014	L	813	9.5	02:07	02:51	1	A
34	57984	Boat	14-09-2014	21-10-2014	L	806	8.2	01:50	02:57	2	D
35	58036	Rig	21-09-2014	21-10-2014	S	709	6.5	01:01	02:11	1	A
36	58088	Rig	13-09-2014	21-10-2014	L	855	10	01:43	03:49	1	A

S: Sublegal, L: Legal, RC: Release condition

in vertical habitat use between sublegal (< 30 in FL) and legal fish (> 30 in FL) was qualitatively examined by fitting a LOESS smoothing function to the detection data by depth. To examine diel differences in depth-use, depth readings were stratified into day and night bins according to estimates provided by the US Naval Observatory (http://aa.usno.navy.mil).

3. Results

3.1. Fish tagging

Thirty-six greater amberjack were tagged with acoustic transmitters (Table 1) during the study. Sublegal-sized fish (n = 18) ranged from 591 to 740 mm FL (mean = 674.6 ± 40.6 SE) and legal-sized fish (n = 18) ranged from 768 to 1081 mm FL (mean = 871.3 ± 77.5 SE). Five legal-sized fish also received a PSAT tag; these fish ranged in FL from 888 to 1081 mm and had an average weight of 13.5 kg ± 1.46 SE. Air temperatures recorded on each of the tagging trips were as follows: 13 September 2014 (mean = 26.67 °C ± 0.09 SE), 14 September 2014 (mean = 25.56 °C ± 0.02 SE), and 21 September 2014 (mean = 25.0 °C ± 0.14 SE). No fish were dead upon retrieval or considered to be in critical condition, and fish had an average release condition of 1.2; only one fish had a release condition of 4. Most of the fish (n = 30) received a release condition of 1, indicating excellent condition at release. Fight times ranged from 58 to 410 s (mean = 138 s). Time spent on deck ranged from 120 to 258 s (mean = 171 s). All fish submerged after release.

All PSAT tags transmitted data to the ARGOS system when released; however, all tags released prior to their scheduled pop-off date. Three tags released after 6 days, one tag released after 9 days, and one tag released after 22 days of recording. Unfortunately, the data retrieved from the PSAT tags were insufficient for quantitatively examining whether these fish were consumed by a predator (Tolentino et al., 2017), but examination of the pressure data from the acoustic tags for these fish showed changes in depth consistent with the other tagged greater amberjack, suggesting premature release was not due to mortality or predation of the fish.

3.2. Fate classification and post-release mortality

All 36 tagged fish were detected in the array after release. Based on examination of time series depth profiles, six fish were classified as mortalities, four fish were detected for less than 4 h and thus assigned a fate of "unknown", and 26 fish were classified as survivors (Table 1). Mortality was clear in telemetered fish, with constant detections at depth equivalent to the bottom either on a single receiver (Fig. 3a) or across multiple receivers (Fig. 4a). Both the Boat and Rig sites also had fish that emigrated before the hydrophones were retrieved (n = 8); however, there was sufficient data for fate determination of these fish (Table 1, Figs. 3b and 4 b). Most telemetered fish remained near the site they were tagged (n = 18) and were detected over the 30-day period during which the array was deployed (Figs. 3c and 4 c). Using the equations from Pollock and Pine (2007), survivorship was 81.3% (±6.9% SE), i.e. post-release mortality was 18.8%. The Cox

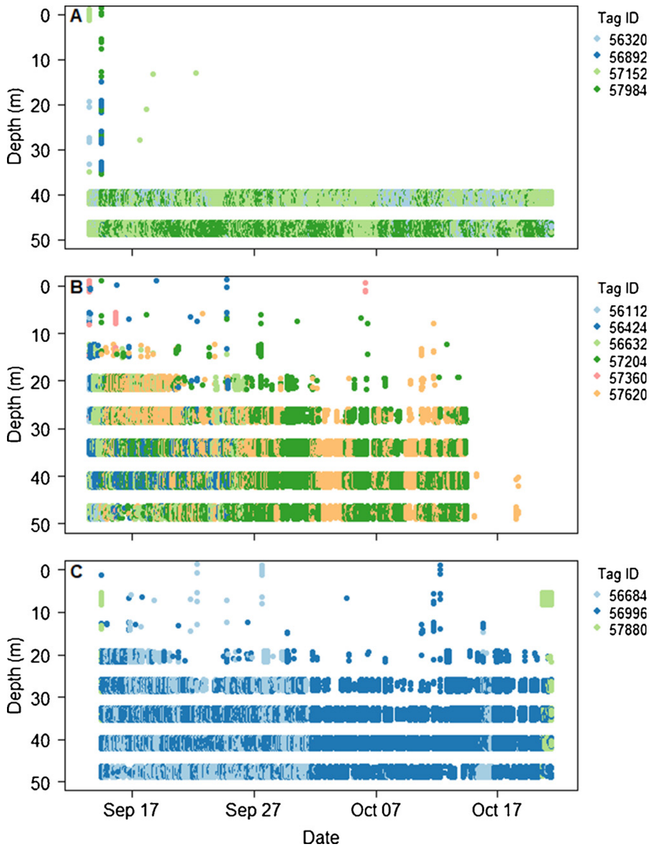

Fig. 3. Acoustic telemetry depth profiles of all greater amberjack tagged at the Boat site, except for fish with unknown fate (n = 4). Panels are as follows, A) fish that experienced post release mortality (n = 4), B) alive and emigrated (n = 6), and C) alive and resident (n = 3). Each point corresponds to a single detection and points were randomly scattered around depth bins to aid in visualization.

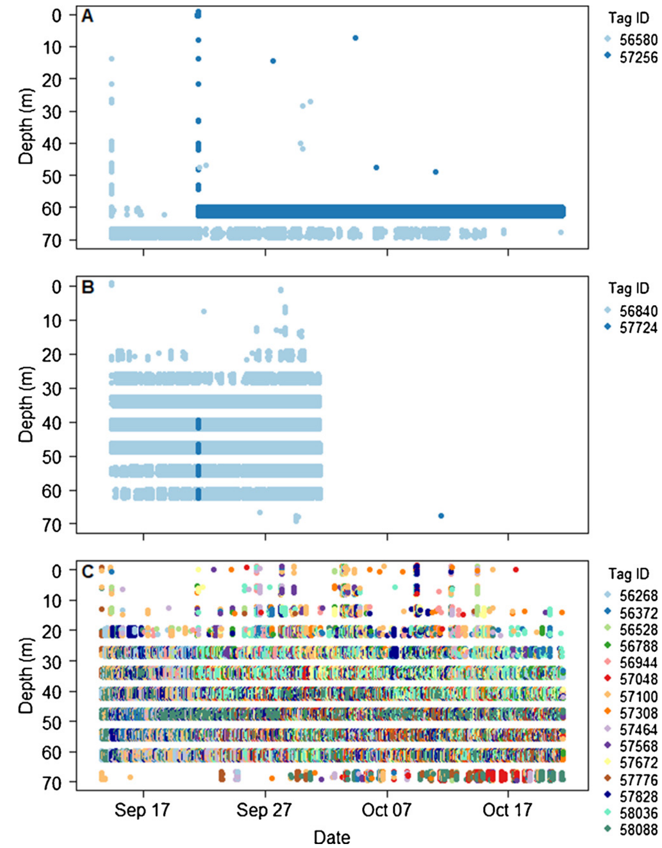

Fig. 4. Acoustic telemetry depth profiles of all greater amberjack tagged at the Rig site. Panels are as follows, A) fish that experienced post release mortality (n = 2), B) alive and emigrated (n = 2), and C) alive and resident (n = 15). Each point corresponds to a single detection and points were randomly scattered around depth bins to aid in visualization.

proportional hazards model that contained only release condition was identified as the most parsimonious for predicting post-release mortality (Table 2, Log-rank test: $\chi^2 = 30.07$, df = 3, p = 0.002, n = 36) where fish assigned a worse release condition are more likely to die (Table 2).

3.3. Vertical habitat use

Vertical habitat use was also examined for the surviving fish that remained in the detection area (n = 26). Regardless of size and site, greater amberjack spent less than 1% of their total time within the top 20 m of the water column. All fish spent a majority of time between 30–50 m depth, and the 40 m depth contour contained the greatest number of detections (Fig. 5). Despite differences in the depth between the two tagging sites, fish showed slight, but consistent, size-specific segregation patterns. At the shallower (Boat) site, most (82%) sublegal fish detections were from 30 to 40 m, whereas only 5% of detections came from depths below 40 m. Conversely, legal fish at that site were most often detected at depths deeper than 45 m (Fig. 5a). A similar, but less pronounced shift in vertical habitat use between sublegal and legal fish was also noted at the deeper (Rig) site (Fig. 5b). To investigate possible diel patterns, depth-use data was separated into day and night categories by site. Visual inspection of these data revealed no diel differences. Overall, both legal and sublegal fish spent most of their time close to the reef where they were tagged, and negligible time in the upper 20 m of the water column.

3.4. Tag recoveries

To date, seven acoustic tags and one PSAT tag have been returned by fishermen, including two fish tagged with acoustic transmitters from pilot work not reported on in the current study. The first of these pilot study fish was recaptured after 957 days at liberty, and 25 km from its original tagging location. The second of these fish was recaptured after 721 days at liberty at the original tagging location. From the current study, Fish 6, 26, 31 and 32 were tagged at the Rig site and recaptured the following year at the same location after 194 days at liberty. Interestingly, two of those four fish (Fish 6 and 31) were originally fit with PSAT tags. Fish 13 was tagged at the Rig site and recaptured the following year after 321 days at liberty. Based on the original analysis of acoustic telemetry data, these fish were all classified as surviving fish; thus, recapture of these fish confirms the fate suggested via acoustic telemetry. A single PSAT tag was returned from a beach near Port Aransas, TX on 13 January 2015. The PSAT was in relatively good condition with some external scratches and was returned without the tag tether attached.

4. Discussion

The estimated post-release mortality in this study is nearly identical to estimates used in the most recent stock assessment for Gulf of Mexico greater amberjack. This is striking, given that most studies examining post-release mortality in this species focused solely on quantification of discard (i.e. immediate) mortality. For example, Murie and Parkyn (2013) tagged 1550 greater amberjack in the northern Gulf of Mexico and recorded immediate mortality (dead on deck or died from

Table 2
Results of the Cox proportional hazards model using fork length, fight time and release condition as covariates.

Model	AIC	Predictor	Coefficient (b)	SE	Hazard Ratio (e^b)	95% CI for e^b	*P*
Best	22.02	Release Condition	3.39	1.32	29.78	2.222–399.043	0.01
Full	24.77	Site	−1.45	1.91	0.23	0.01–9.97	0.45
		Fork Length	−0.08	0.07	0.93	0.81–1.06	0.28
		Weight	3.18	2.65	24.00	0.13–4358.00	0.23
		Fight Time	−0.01	0.01	0.99	0.97–1.01	0.44
		Handling Time	−0.11	0.08	0.90	0.76–1.05	0.18
		Release Condition	7.50	4.26	1823.00	0.43–774,700.00	0.08
Null	29.89	none					

The coefficient (b) measures the effect size of the covariates.

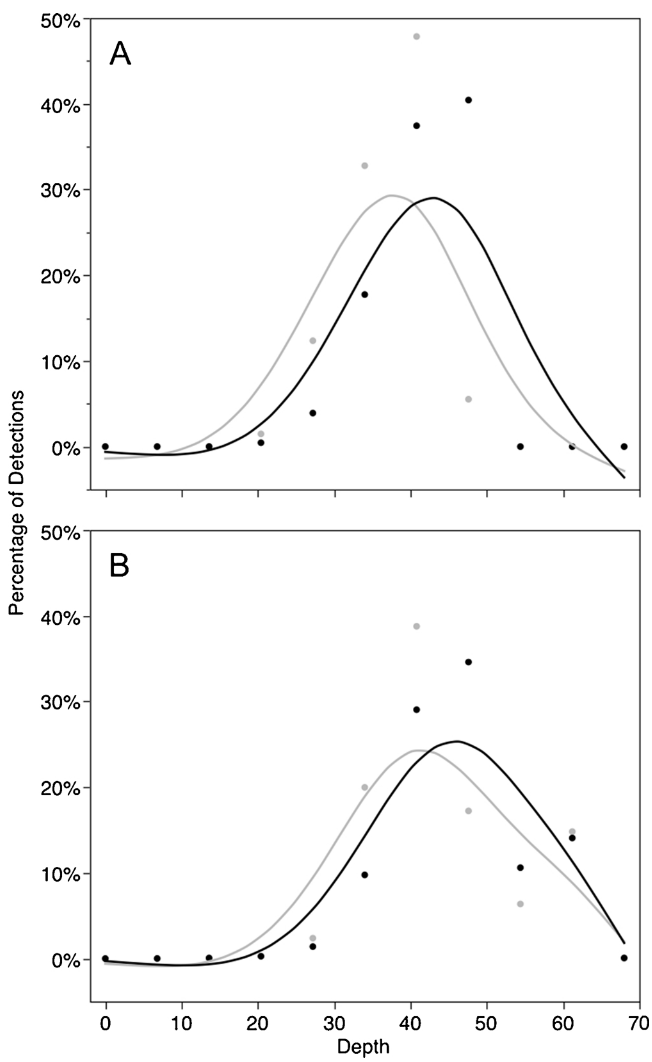

Fig. 5. Size-specific depth-use for greater amberjack tagged with acoustic transmitters at the A) Boat and B) Rig sites. Sub-legal fish are shown in gray and legal-sized fish are shown in black.

predation) during tagging events; this study resulted in a release mortality estimate of 0.7%. Similarly, recreational observer data aboard headboat and charter boat trips estimated 2.4% and 1.8% immediate release mortality, respectively (Sauls and Cermak, 2013). Long-term mortality of greater amberjack has previously been estimated by Murie et al. (2011) as 0%, but this estimate was based on five PSAT tags deployed off the coast of Louisiana to locate potential spawning grounds. Thus, to our knowledge, this study is the first to specifically investigate long-term post-release mortality of greater amberjack in the Gulf of Mexico, and provides evidence to support the post-release mortality estimate used in the most recent stock assessment.

Previous estimates of release mortality for this species have not considered the effects of size, which are critical for the development of effective regulations. The rebuilding plan for greater amberjack was established in 2000, after the stock was first declared overfished and undergoing overfishing in 1998 (Turner et al., 2000). During this time, the recreational minimum size limit was 28 in (FL), and this limit was increased to 30 in. FL in 2008 (GMFMC, 2008). After several years, the stock failed to rebuild (GMFMC, 2012; SEDAR, 2014), and the recreational minimum size limit was raised to 34 in FL (GMFMC, 2015). These regulatory increases in minimum size had profound impacts on the proportion of mature females in the landings, from 11% mature at 30 in. to 84% mature at 34 in. (GMFMC, 2015). Such dramatic increases in the proportion of mature individuals in the catch align with one of three simple indicators to promote the recovery of overfished stocks, i.e. "let them spawn!" (Froese, 2004). Despite the clear benefits of increasing the minimum size limit, two potential problems arise. First, such an increase leads to more regulatory discards, and hence higher potential for post-release mortality. However, analysis of the recreational landings data indicates the most commonly landed size of greater amberjack is 34 in FL (GMFMC, 2015), so potential increases in post-release mortality may be minimal. Second, our findings suggest that post-release mortality in greater amberjack varies as a function of FL, where larger fish have a slightly higher probability of suffering post-release mortality relative to smaller fish. Nonetheless, we argue that the potential benefit to the greater amberjack spawning stock realized from a 34-in FL regulatory minimum outweighs the drawbacks associated with higher discards of individuals with higher post-release mortality.

Despite differences in depth between tagging locations, depth was not a significant predictor of post-release mortality; however, interesting patterns in depth-use emerged for surviving fish. These results, along with those from existing studies, suggest that greater amberjack are resilient to capture at depth (Murie and Parkyn, 2013; Sauls and Cermak, 2013). Murie and Parkyn (2013) proposed a self-ventilating mechanism, where fish may expel bubbles as they ascend, thereby reducing the extremity of any barotrauma. In general, tagged fish rarely used surface waters. Moreover, a slightly deeper maximum depth-use was shown by fish at the deeper site; given their strong association with structure, it is perhaps not surprising that greater amberjack occupied the vertical space nearest the structure. While overall depth use differed slightly between the two tagging locations, an interesting pattern of depth partitioning was evident at both sites, where sublegal fish used slightly shallower depths compared to legal-sized fish. Given the relative imperviousness of greater amberjack to the depth-related effects of barotrauma, this trend of increasing fish size with depth may provide a practical means of reducing the capture of regulatory discards. To realize this benefit will require informing recreational anglers of this trend and encouraging subtle shifts in the depths at which they target greater amberjack.

The hazards model identified release condition as a significant predictor of post-release mortality, but aspects of the fishery and biology of greater amberjack limit the applicability of this metric. Post-release condition determined through a scoring system has been used as a proxy for delayed mortality (Rundershausen et al., 2007). These data are most powerful when collected by fishery observers onboard commercial fishing vessels (e.g. Pulver, 2017), and hence are of limited use in the fishery for greater amberjack, which is dominated by the recreational sector. Fishery-dependent approaches also benefit from large sample sizes. Conversely, in the current study, only six fish were classified as dead via acoustic telemetry, and of these, only four were assigned release scores other than 1; however, two of these four fish had PSAT tags, which confounds the interpretation of the release condition. In addition, greater amberjack are fairly impervious to barotrauma (Murie and Parkyn, 2013); therefore, the outward signs that are useful in assigning barotrauma (distended stomachs, bulging eyes, expanded swim bladders) for other species often are not visible in this species, and this confounds the accurate assignment of release conditions.

Temperature has been identified as an important factor influencing post-release mortality (Gale et al., 2013). The tagging portion of this study was conducted in September when water and air temperatures were mild (range = 25–27 °C); thus, we did not test the effect of temperature on the fate of greater amberjack post-release mortality. Although thermal tolerance is likely species-specific, juvenile yellowtail kingfish (*Seriola lalandi*), a related species, display negative physiological consequences such as decreased food intake and higher energy demand from exposure to high temperatures (Abbink et al., 2012). Other species in the Gulf of Mexico have seasonally-dependent post-release mortality. For instance, an acoustic telemetry study estimated that red snapper (*Lutjanus campechanus*) tagged and released in the summer were five times as likely to perish as those tagged in the spring, and two and a half times as likely to perish as those tagged in the winter (Curtis et al., 2015). The recreational season for greater amberjack in the Gulf of Mexico has previously extended throughout most of the year, with a closed season of 1 June-31 July; thus, a seasonal effect of release mortality could exist for greater amberjack. As such, our findings regarding post-release mortality for greater amberjack should be considered as “best-case scenario”. Future work should be conducted during summer months to evaluate any potential temperature-related impact on post-release mortality.

Acoustic telemetry offers a reasonable approach for estimating release mortality of greater amberjack, yet suffers from disadvantages that are largely associated with cost, which have implications on sample size and statistical power. The implantation of acoustic tags could introduce some additional effects that could artificially elevate the release mortality estimate. Sources of mortality not associated with the study may include infection from tag implantation and stress from the tagging procedure; however, given that several fish tagged with acoustic transmitters were recaptured, these effects are likely minimal. The observed deaths were likely not a result of infection, as these fish died within the first three hours; however, it is uncertain how the tagging procedure may affect the fish post-release. During tagging, fish were provided a constant flow of water over their gills while on deck, a procedure not used in the recreational fishery which could have had a positive effect on release mortality.

Our findings add to studies that demonstrate biotelemetry as an effective tool in catch and release mortality studies (Donaldson et al., 2008). This study design and semi-permanent acoustic array is applicable to other reef associated species that demonstrate strong site fidelity, and can be used for observing latent mortality and post-release swimming behavior. In addition, the use of biotelemetry can provide important ecological information such as depth-use that can help assess catchability and could assist in efforts to decrease future bycatch.

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