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ARTICLE

Postrelease Mortality of Angled Tarpon in Puerto Rico

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Abstract

Tarpon *Megalops atlanticus* is a popular and economically important inshore sport fish in Puerto Rico, and the pursuit of this species by local anglers and tourists contributes to the economy. This species is managed as a no-take fishery, which aims to preserve populations by catching and releasing fish that would otherwise be subjected to harvest and removal from the population. The approach assumes minimal mortality and/or reduced fitness of released fish, yet the process of angling can produce many sublethal side effects or direct mortality. In this study, charter angling for Tarpon in the San Juan lagoon system in Puerto Rico was examined to determine postrelease mortality. Angled fish were externally tagged with acoustic transmitters and relocated periodically to determine the fate after release. Postrelease mortality was at least 4.5% (two fish observed dead) and at most 18.2% (observed dead plus classified dead based on lack of movement; confidence interval [CI] = 7.5–28.9%). Some tag loss was observed, which could have artificially elevated classified mortality estimates. Potential factors that contribute to mortality are discussed and compared to the literature. Hook type, gear action, landing procedures, and air exposure were key areas of possible improvement. Recommendations to minimize fish harm during angling include the use of heavier action gear to reduce fight time, a circle hook requirement for live bait to reduce deep hooking, maintaining fish in the water during landing and photography, and limiting air exposure to 2 min or less if fish are removed from the water.

The goal of catch-and-release angling is that captured fish survive to be caught again (Pollock and Pine 2007). This requires that fish are not physiologically compromised after release (Orr 2009). Despite the intent of catch-and-release practices, angling can cause acute stress and physical damage to fish, with potential lethal or sublethal consequences (Mazeaud et al. 1977; Skomal 2006). Visible injuries may include hooking wounds, physical deformities from repetitive hooking and handling, and bacterial/fungal infections (Meka 2004). Subsequent to capture, fish can experience respiratory issues and compromised immune systems, leading to behavioral changes (Cooke et al. 2002; Wilson et al. 2014). Other physiological impairments include damage to the reflex response, increased risk of predation, and decreased individual fitness (Campbell et al. 2010; Brownscombe et al. 2017). These stressors may act individually or synergistically to result in the death of released fish. Mortality may vary by duration and magnitude of the stressors (Meka and McCormick 2005) and are influenced by gear type (Sass et al. 2018), environmental conditions (Suski et al. 2006), and postcapture handling and release practices (Guindon 2011).

Acoustic telemetry is often used to determine in situ mortality over a period of hours to weeks following release (Prince et al. 2002; FFWCC 2013). For example, Red Snapper *Lutjanus campechanus* tagged with acoustic transmitters demonstrated angling mortality occurred within 72 h following release (Eberts and Somers 2017). Results from acoustic telemetry of Bonefish *Albula vulpes*

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suggested angling-induced mortality often occurs within minutes of fish being released (Danylchuk et al. 2007). Furthermore, 43% of 30 Bonefish succumbed to angling-induced predation within a 2-week times pan (Moxham et al. 2019). These studies utilized external attachment of transmitters to avoid intrusive surgical procedures. Although external tagging has been found to reduce growth and long-term survival, direct mortality from external tagging is rare (see review by Jepsen et al. 2015).

Tarpon *Megalops atlanticus* is a popular inshore sport fish species, and this popularity derives from its large size, powerful fight when hooked, and accessibility, as Tarpon are mainly fished inshore and in calm coastal waters (Guindon 2011). In Puerto Rico, the pursuit of this species by local anglers and island visitors contributes significantly to the economy (Garcia-Moliner et al. 2002). However, Tarpon fisheries in Puerto Rico previously were prone to population declines due to angling and harvest (Zerbi et al. 2001). Between 2000 and 2003, up to 10,189 kg of Tarpon were harvested annually, with negative effects on population size (Guerrero Pérez et al. 2013). In response, the Puerto Rico Department of Natural and Environmental Resources (DNER) imposed a harvest prohibition on Tarpon in 2004 to protect stocks for angling by locals and tourists (Guerrero Pérez et al. 2013). Currently, Tarpon angling is only catch and release in Puerto Rico by law.

Data on catch, angling effort, and postrelease mortality of Tarpon have not been collected in Puerto Rico (Guerrero Pérez et al. 2013). Guindon (2011) and Edwards (1998) reported low postrelease mortality in South Florida, but the results may differ for fish angled in other locations. Tarpon are widely distributed (Winemiller and Dailey 2002), and environmental parameters (i.e., water quality and chemistry; Leichter et al. 2006) and varying angling techniques (Brownscombe et al. 2017) may influence the postrelease fate of fish. Therefore, this study evaluated catch-and-release mortality of recreationally angled Tarpon in Puerto Rico using acoustic telemetry. The specific research objective was to evaluate the fate (alive or dead) of Tarpon using acoustic telemetry. Factors influencing postrelease fate are discussed, and this information can be used to decrease the impact of catch-and-release angling on the Tarpon fishery.

METHODS

Study site.—San José, Los Corozos, La Torrecilla, and Piñones Lagoon and associated interconnected canals lie within the metropolitan area of San Juan, Puerto Rico (Figure 1) and are collectively identified as one of the world's top Tarpon angling destinations by the media. Tidal cycles influence water quality and salinity, as does rainfall input via feeder streams and canals. Lagoons are surrounded by red mangrove *Rhizophora mangle*, black mangrove *Avicennia germinans*, and white mangrove *Laguncularia racemosa*forests (Pool et al. 1977). Due to dredging, landfills, and other anthropogenic activities, the hydrological characteristics of the estuary have changed considerably over the past century (Villanueva et al. 2000). Hydrological characteristics that have been altered by urbanization in the San Juan lagoon system include disconnection from San Juan Bay, sediment denitrification, and fluxes of ammonium, nitrate, and phosphorus nutrients (Pérez-Villalona et al. 2015). These modifications have resulted in a relatively closed system with a single small connection to the Atlantic Ocean through the narrow passage of Boca de Cangrejos, in the locality of Piñones.

Angling and telemetry.—This research was conducted in partnership with a local charter company that specializes in San Juan lagoon Tarpon angling. The guides hosted researchers on chartered trips with clients from May to July 2021. When a client hooked a Tarpon, information about the angling process was recorded from hook set until landing. Here, the angling process included fight duration, the number of jumps, rod action (light, medium, or heavy), and handling on deck (i.e., hook removal and body support for photography). We also recorded the geographic location of capture. Tarpon were only captured using spinning or bait-casting gear, with live bait on circle hooks during the study. To land each fish, the guide would grab the fish by the lower jaw (hand lipped), and fish were pulled into the boat over the gunwale or bow and on to the deck. Data on landing condition and procedures included hook location on the fish, observed injury such as bleeding, and handling procedure during photography. Once clients were done with their captured fish, it was handed over to the researchers for measurement of total length (mm) and possible tag implantation prior to release. We randomly selected Tarpon for tag implantation. For fish not selected, blood was drawn for another study prior to release.

Transmitter implantation and telemetry.—Acoustic tag assemblies consisted of a Sonotronics (Tucson, Arizona) (CT-82-2-E) transmitter attached to a titanium anchor (Ti Small, Wildlife Computers, Redmond, Washington) with a stainless-steel leader (42.2 kg test, 0.005 cm diameter) and crimp sleeves (double barrel size 7, 0.135 cm diameter). The length of the leader was adjusted to fish size so that the transmitter did not reach to or interfere with the dorsal fin. Tag assemblies were attached to the fish's left side, two scale rows below the insert of the dorsal fin. Using forceps, two to four scales were removed from the location of tag insertion to facilitate implantation of the anchor. The tag anchor was inserted with a tag pole (comprised by AZ-TAGPOLE-004; Swobbit Tagging Pole

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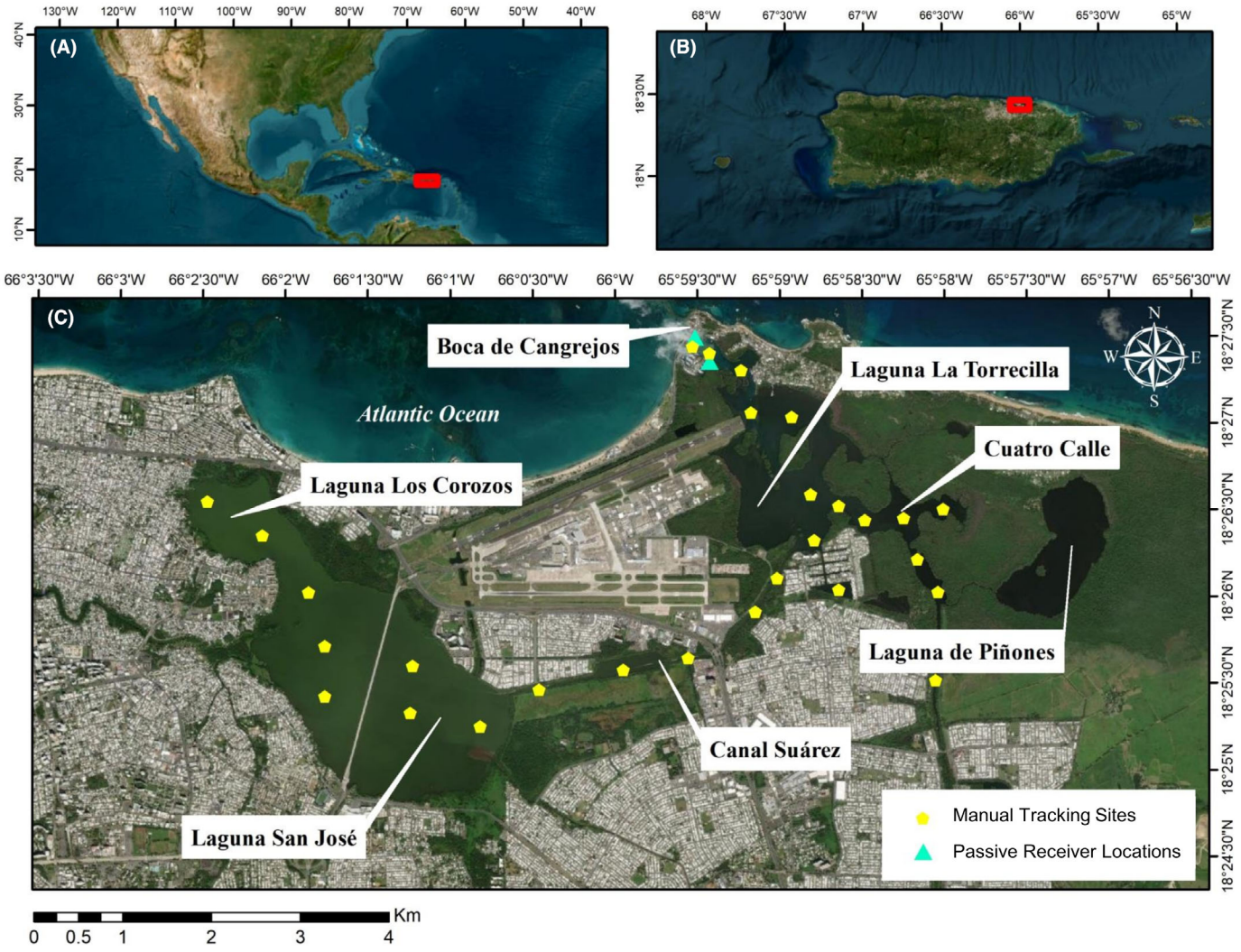

FIGURE 1. Map of **(A)** the location of Puerto Rico in the Caribbean Sea, **(B)** the location of the San Juan lagoon system in Puerto Rico, and **(C)** a close-up of the San Juan lagoon system and surrounding area with the location of tracking sites and passive receivers; Boca de Cangrejos connects the system to the Atlantic Ocean. Maps were produced by Karold Coronado-Franco.

16.51 cm length, AZ-DARTBUSH-001; Dart Bushing fits 1.91 cm pole, and AZ-DARTAPP-011; Dart Applicator 1/4–28; Wildlife Computers) within the scale removal zone through the musculature and between the pterygiophores. Fish were immediately released back to the site of capture.

Relocation efforts were conducted using active tracking once per week with a Sonotronics Manual Tracking Kit (MANTRAK; which contains a USR-14 receiver, DH-4 directional hydrophone, TH-2 towed omnidirectional hydrophone, and accessories). Prior to the study, researchers established 28 listening stations, each selected to optimize lagoon coverage by utilizing a maximum line of sight distance of no more than 1 km between listening zones (Figure 1). During each telemetry period, the boat was maneuvered to each listening station and the omnidirectional hydrophone was lowered into the water and all frequencies were scanned. When a tagged fish was detected, approximate location was determined using the directional hydrophone. When all tag frequencies had been scanned, the boat was maneuvered to the next listening station.

Because Tarpon are highly mobile (e.g., Duffing Romero et al. 2021), the lagoon system is large and complex, and time to conduct telemetry was limited to 1 d per week, exact locations using triangulation were not determined. Instead, the protracted telemetry period was used to confirm whether a fish was nonmobile and presumed dead or mobile and alive. In this study, postrelease fate was assessed by relocating fish weekly for up to 9 weeks. The postrelease evaluation period was set at 5 d, so to

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classify a fish as alive, movement must be detected 5 d or more after release.

Classification rules were developed to interpret fish status based on movement (see Figure 2 for examples). Rules were based on previous studies that inferred fish status by classifying and grouping patterns of telemetry data from receivers (Heupel and Simpfendorfer 2002; Villegas-Ríos et al. 2020; Weinz et al. 2020). For a fish to be considered "alive," it must meet *all three* of the following criteria (Figure 2B):

1. fish were relocated at two or more different listening stations at least 1 week apart;
2. observed movement occurred at least 5 d after release (indicating it was alive through 5 d); and
3. listening stations cannot have overlapping fields of detection (i.e., >1 km).

For a fish to be considered "dead," it must meet *any* of the following criteria (Figure 2C):

1. during all weekly detections after day 5 with a minimum of three detections, fish was detected in the same area (within the 1 km receiver range);
2. researchers recovered the dead fish; or
3. researchers received reports of a fish being dead within the 5-d evaluation period, and it was relocated in the reported location for two or more weekly tracking periods.

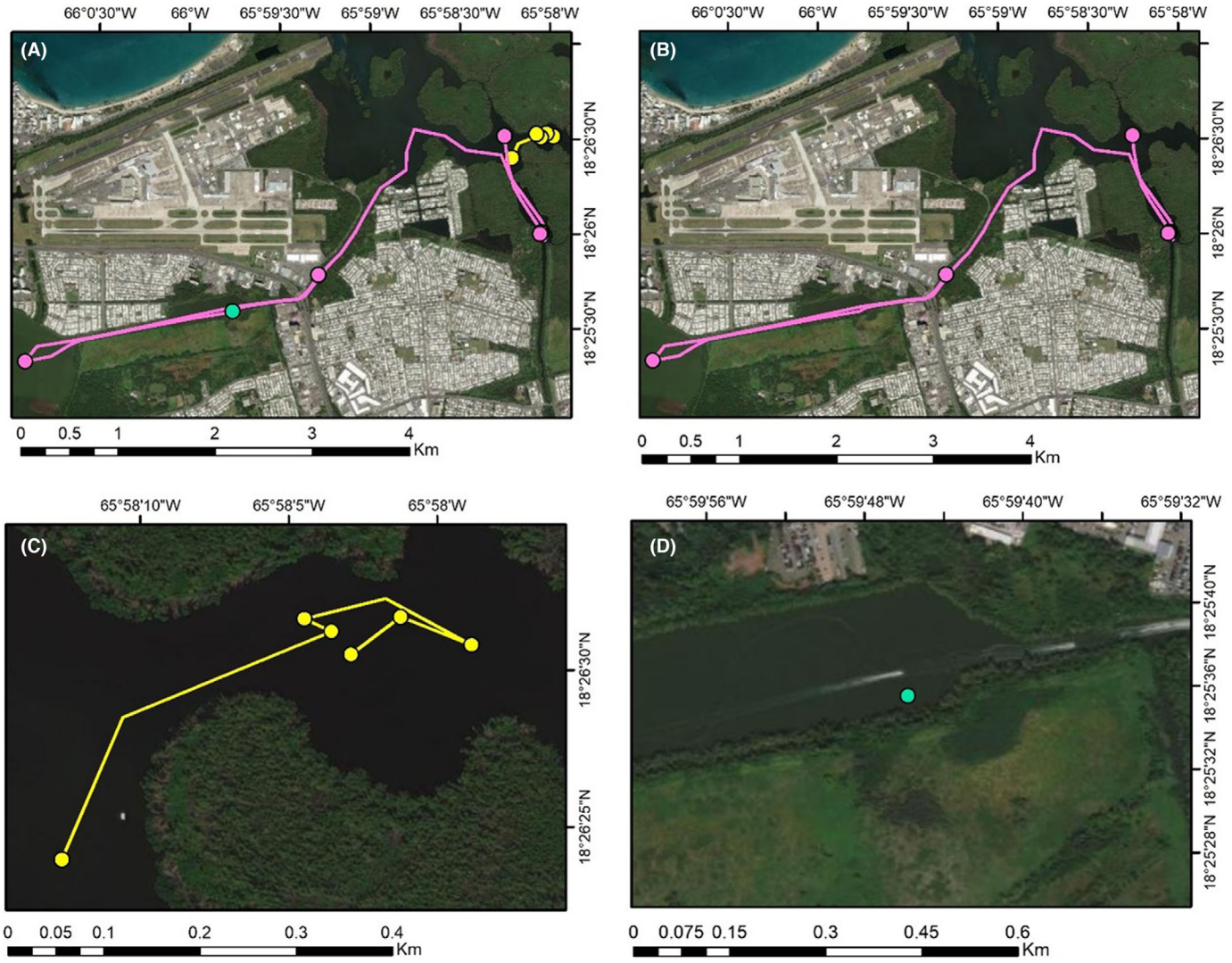

FIGURE 2. Examples of fish movement and status classification as alive, dead, or censored based on rules. **(A)** Comparative map of all three classifications represented by panels (B–D). **(B)** Fish considered alive because of significantly movement after 5 d. **(C)** Fish considered dead, as it moved from the initial site of capture but did not move significantly following the 5-d evaluation period. **(D)** Fish unable to be classified and censored from analyses. Maps were produced by Karold Coronado-Franco.

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For a fish's status to be unknown and the data "censored from analyses," it must meet *any* of the following criteria (Figure 2D):

1. the fish was found just once (indicating it could have left the system, experienced tag failure, etc.);
2. fish had only two detections, with the first detection occurring within the 5-d evaluation period; or
3. fish had only two detections in the same location or overlapping fields of detection immediately following the 5-d evaluation period on consecutive tracking days and then disappeared.

Two passive Submersible Ultrasonic Receivers (SURs; Sonotronics) were placed at the mouth of the lagoon system to determine if fish exited to the Atlantic Ocean (Figure 1). Before deployment, passive receiver bodies (excluding the transducer) were wrapped in black plastic and electrical tape to reduce biofouling. Mounts were constructed of PVC poles (5.08 cm diameter × 1.22 m height) inserted in concrete bases; PVC was spray-painted black for concealment. Receivers were attached to PVC mounts with 550 paracord and nylon cable ties. Once deployed, SUR mounts were tethered to dock pylons to prevent lateral movement.

Data analysis.—SurSoft DPCsa v1.0.8(c1) software (Sonotronics) was used to download and analyze passive receiver data. Detections from these receivers were combined with active telemetry data for the assessment of fish status. Combined fish location data were plotted in ArcMap (10.8.1) to analyze fish movement for determination of fish status. Satellite basemaps were retrieved from the ArcGIS website (ESRI; https://www.esri.com/). Confidence intervals for mortality were based on methods used by Wilde (2002) to determine confidence of status around fish using acoustic tracking.

Summary statistics included all fish caught during the study (including those not receiving transmitters). Linear regression assessed whether fish size influenced the duration of the fight. Prior to regression, the response and predictor variables were log-transformed to correct for normality and to linearize the relationship. Regression was implemented in R (version 4.1.3; R Foundation for Statistical Computing, Vienna).

RESULTS

Angling Process

Angling procedures were evaluated for 93 angled Tarpon that ranged from 47 to 200 (mean = 88) cm in total length. Fish size directly influenced fight time (adjusted $r^2 = 0.55$, $P < 0.0001$) (Figure 3). Fight time ranged from 1 to 41 min but was skewed towards shorter times with a mean (±SD) of 5 (±7) min. Observed jumps ranged from 0 to 14 (mean ± SD = 3 ± 2).

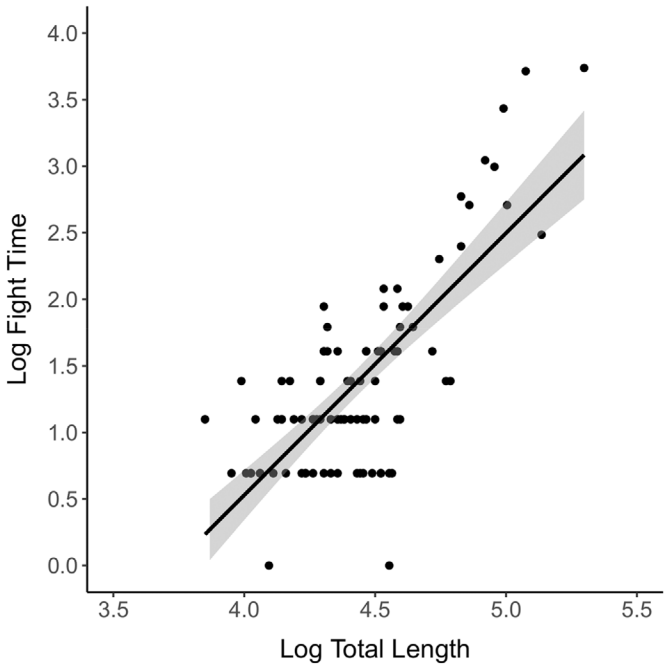

FIGURE 3. Linear regression showing the relationship of fish total length (cm) with fight time (min).

The charter company with whom we partnered primarily used light action rods, live bait, and circle hooks for chartered angling trips (Figure 4). With circle hooks, most fish were caught in either the corner of the mouth or upper jaw, and most (90%) were released after the hooks were removed; however, when hooking occurred in the throat or deeper, lines were cut leaving the hook in place to reduce injury. Little to no bleeding was observed among most angled fish (Figure 4). Following hook removal, clients could take photographs with the fish and choose the position to hold the fish. Horizontal photography was the most popular and encouraged by the guides to better grasp the fish (Figure 4). This practice had the client support the fish's body weight with one hand on the abdomen while controlling the fish by holding the lip with the other hand. Larger fish were often photographed lying on the deck.

Postrelease Mortality

Tagged Tarpon moved considerably between lagoons, suggesting that the classification rules based on movement are valid. Three fish were detected at the lagoon entrance, but no fish exited to the Atlantic Ocean during the study. Of the 49 tagged fish, 5 were censored from further analyses due to insufficient data to classify a fish as alive or dead. Of the remaining 44 classified fish, 36 were classified as alive based on observed movement following the 5-d evaluation period (81.8%). Conversely, eight fish were classified as dead based on lack of movement (18.2%).

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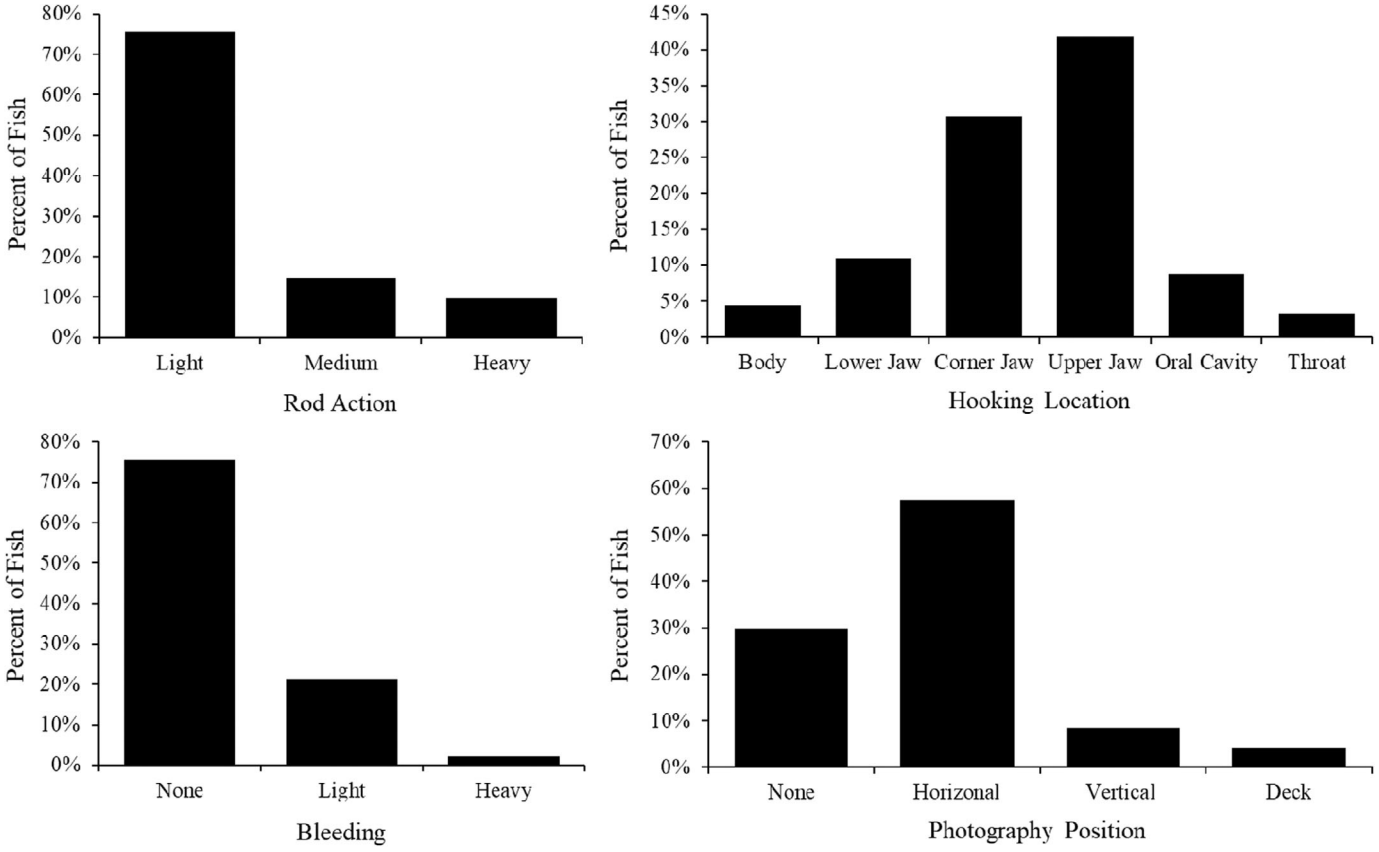

FIGURE 4. Factors during the angling process that could influence mortality. Rod action (top left), hooking location (top right), observed bleeding (bottom left), and handling position during photography (bottom right) are presented.

One fish died soon after angling and the transmitter was retrieved; another fish was reported floating dead, and although not physically recovered, it was relocated consistently in the area reported. This yields a confirmed mortality of 4.5% (fish encountered dead), and a potential mortality of up to 18.2% estimated using fish status criteria (fish considered dead based on postrelease movement, including confirmed mortality). The CI of the mortality estimate using fish status criteria was 7.5–28.9%.

DISCUSSION

This study was the first to investigate catch-and-release mortality within the Tarpon's tropical range. Mortality within 5 d of angling was at least 4.5% and at most 18.2%, based on confirmed and classified mortalities, respectively. The two confirmed mortalities occurred within 24 h of release. This suggests that postrelease mortality occurs quickly, and the 5-d evaluation period was adequate to assess the effect of angling. It is possible that some classified mortalities represented tag shedding instead of fish death during the 5-d evaluation period, as the loss rate of external transmitters can be substantial and has been reported to be as high as 100% in some studies (see review by Jepsen et al. 2015). Two Tarpon were reportedly captured by other charters that had scarring consistent with tag loss, and a third was captured with the tether in place but the transmitter missing, lending credence to this assertion. This study did not collect data on tag retention. Tag loss that occurred after the initial classification period (after postrelease movement was confirmed) would not affect the results.

The range of postrelease mortality from this study was comparable to one estimate from Florida, where Guindon (2011) reported a 13% mortality rate (95% CI: 6–21%) in angled Tarpon ($n = 82$). That study described predation on released Tarpon by shark species to be a major vector of mortality (8.3%). Shark predation rates of nearly 28% were recorded in another large-scale satellite tagging study of Tarpon ($n = 292$) extending from North Carolina throughout the Gulf of Mexico (Luo et al. 2020). Such a high predation rate by sharks may, however, be an artifact of the study since sharks are likely attracted to the electric field generated by satellite tags and the predation rate increased in areas with high shark density (Luo et al. 2020). The current study did not

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observe predation on Tarpon, and predatory shark species are not common in the lagoon complex. Another study from Florida ($n = 27$) reported lower mortality (3.7%) of angled Tarpon, and the authors attributed this low rate to angling practices, including style and size of hook, use of heavy gear, and aggressive angling techniques to bring the fish to the boat as quickly as possible, and releasing the Tarpon by not taking it out of the water (Edwards 1998). Angling in the current study utilized circle hooks, which reduced deep hooking. However, light action spinning rods were the primary gear, which prolonged fight times and likely increased the time of physical and physiological stress (Roth et al. 2018). Likewise, the Puerto Rico charter guides typically remove Tarpon from the water for landing and photography, inducing additional stress and air exposure.

Certain factors have been identified in the literature that reduce mortality during the angling process. Hooking location can affect angling mortality in Tarpon (Guindon 2011) and other species (e.g., Rainbow Trout *Oncorhynchus mykiss*, Meka 2004). Potentially lethal hooking locations can include the eye, gills, and esophagus (Ostrand et al. 2005). For example, Derbio *Trachynotus ovatus* hooked internally had an 85% mortality rate (Alós et al. 2008). Similarly, 95% and 75% of Spotted Seatrout *Cynoscion nebulosus* died when hooked in the esophagus and gills, respectively, compared to only 10% when hooked in the bony mouth (James et al. 2007). The use of circle hooks in the current study contributed to the prevalence of nonlethal hooking locations (Cooke et al. 2003). Most ($n = 78$) Tarpon were hooked in the corner of the mouth or in the upper or lower jaw, with few ($n = 15$) fish hooked in other locations (i.e., outer head or body, inner oral cavity, or esophagus).

Most (91%) of the fish had the hook removed prior to release. Only hooks that were too deep to safely remove were left in the fish by cutting the line. When fish have deeply ingested hooks, it is often more beneficial to leave the hook in the individual, as attempting to remove the hook often results in additional injuries and increased mortality (Butcher et al. 2007). In White Seabass *Atractoscion nobilis*, for example, leaving deeply embedded hooks increased survival rates, and 39% of hooks that were deeply ingested could pass through the organism's system (Aalbers et al. 2004). When looking at simulated angling in Sand Whiting *Sillago ciliate*, 23% of fish that ingested a hook died, but surviving fish were able to feed, and some fish passed ingested hooks with limited long-term physiological impacts documented (McGrath et al. 2009).

Hooking location can determine whether bleeding occurs, especially when the hook penetrates soft or highly vascularized tissues such as the gills and esophagus. Although some bleeding was observed in this study, 76% of the individuals experienced no bleeding, with only two individuals (2%) experiencing heavy bleeding (gill hooked), one of which was confirmed dead. Previous studies have noted bleeding intensity with hooking location causing increased mortality (e.g., Schisler and Bergersen 1996). Conversely, hooking location did correlate with bleeding intensity but not mortality in Arctic Grayling *Thymallus arcticus* (Casselman 2005).

Roth et al. (2018) asserted that longer fight times may cause physiological disturbances that can lead to a greater risk of postrelease mortality. Increased fight time in Shortfin Mako *Isurus oxyrinchus* did increase physiological stress factors such as lactate and glucose but did not impact survival (French et al. 2015). For Brook Trout *Salvelinus fontinalis*, mortality was independent of fight time (Kerr et al. 2017). Similarly, Guindon (2011) reported the average fight time of Tarpon was 23.7 min for fish that survived and 16.5 min for fish that experienced mortality, which is contrary to Roth et al.'s (2018) hypothesis. The mean fight time in the current study (5 ± 7 min) was 3–5 times less than the Guindon (2011) study, despite angling primarily using light action gear. Rod action relates to how easily and where along the shaft a rod bends when tension is applied to the tip. Many studies previously have noted the action of the gear used but did not relate it to angling mortality (Jones 2005; Danylchuk et al. 2014; Holder et al. 2020). Catching the fish faster reduces the intensity of the fight and stress to the fish, but charter companies may prefer a longer angling experience for clients. Lowering the action creates more exciting and challenging fight for customers.

The disparity in fight time between Guindon (2011) and the current study was largely due to fish size. Although larger Tarpon are captured in the San Juan lagoon system, the fishery is largely supported by smaller fish. Tarpon evaluated during the current study averaged 88 cm total length (±27 cm), whereas fish in the Florida evaluation averaged 160.8 cm for fish that survived and 146.5 cm for fish that experienced mortality (Guindon 2011). The lack of a relationship between fish size and postrelease mortality reported by Guindon (2011) was further supported by a meta-analysis of the catch-and-release literature (Bartholomew and Bohnsack 2005). This is a surprising finding because larger fish tend to have greater fight times and presumably more angling-induced stress response (Guindon 2011). Fish size was positively correlated with fight time and handling time in the current study, and other studies support this finding (e.g., Danylchuk et al. 2014; Pinder et al. 2017). For Brook Trout, fight time was not correlated with total length (Kerr et al. 2017), suggesting the relationship of fight time and length is most likely species-dependent.

Tarpon can be acrobatic and leap from the water during angling, attempting to dislodge the hook

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(Kokomoor 2010). In a confined mangrove environment like the San Juan lagoon system, jumping behavior has potential to injure via impact with mangroves and other obstacles, or with the water surface, but this has not been empirically established (Luo and Ault 2012). In this study, Tarpon averaged 3 (±2) jumps during the angling process. Schlenker et al. (2016) observed that jumping by White Marlin *Kajikia albida* increases fish exhaustion and adds additional stress to the individual (Schlenker et al. 2016). Further, jumping by angled Rainbow Trout correlated with increased risk of injury, as jumping often led to deeper hook wounds and entanglement of the fish in the line (Meka 2004). It is likely that jumping behavior at the very least adds to the stress response during angling.

Landing is a relatively stressful process, particularly for larger Tarpon, which were dragged by the lower jaw over the edge of the gunwale or bow and into the floor or deck of the vessel. In the evaluation by Edwards (1998), Tarpon were supported in the water, thus eliminating air exposure and related injury, and survival rates were high, at 96.3%. Although Tarpon are facultative air breathers (Geiger et al. 2000), this raises the question of whether Tarpon have greater survival when left in the water to prevent air exposure and the effects of gravity outside a liquid medium. Water supports the weight of a fish, and removal from the water can cause injury to internal organs, mandibular bone breaks and separated tongue (Danylchuk et al. 2008), and vertebral separation (Gould and Grace 2009; Frawley 2015), and unexpected fish movement can lead to accidental drops and impact injuries. Increased air exposure has been correlated with increased stress in fish (Ferguson and Tufts 1992; Brownscombe et al. 2017) and an increased amount of time required for the fish to recover from the capture event (Cooke et al. 2001; Brownscombe et al. 2017). Guindon (2011) suggested limiting air exposure of Tarpon to 2 min or less and reported no significant physiological difference in blood chemistry response with 1 min air exposure. Whereas evidence suggests longer air exposure has adverse effects on the survivability of some species (Arlinghaus and Hallermann 2007), it might be advantageous to minimize air exposure, as suggested by Edwards (1998) for Tarpon.

Anglers like to share their experience with others, especially through photography. Clients were encouraged to hold fish horizontally supported (58%) when taking photographs; only a few fish (13%) were supported vertically or on the deck, particularly for larger fish due to their heavy weight. All fish were gently revived and released back into the water after capture. Horizontally supporting and gently releasing the fish minimizes injury and stress (Frawley 2015). Practicing these efforts are now considered etiquette and part of safe handling practices of catch-and-release angling. Some researchers recommend leaving the fish in the water for hook removal and photography, minimizing air exposure and possible injury (Cooke and Sneddon 2007).

It is common for Tarpon to show "partial migration," that is, intraspecific variation in migration distance, and the species commonly resides in estuarine habitat for part of the year (Luo et al. 2020). The uniqueness of the San Juan lagoon network is that Tarpon are contained within a semiclosed system and can only enter and exit via a shallow opening (Boca de Cangrejos, Figure 1C) that is about 35 m wide. It is unclear whether Tarpon in the San Juan lagoon network are year-round residents or migrate out of the system during some part of the year. In this study, only three fish approached the exit to the Atlantic Ocean but did not leave for any significant duration within the 9-week observation period. If fish are year-round residents, it raises concern about how continuous angling pressure impacts individuals confined within a semiclosed system. Although the angling effort was not measured, it is substantial, with many charter outfits with client anglers and private recreational anglers using their personal watercraft daily. It was common during this study to be targeting Tarpon within a small area with five or more other boats nearby. Further, telemetered fish from this study were caught multiple times by different angling charters, as researchers received multiple reports of tagged fish being caught. While this indicates that some fish recover quickly and return to normal feeding behavior (Cooke et al. 2013), it also suggests that fish in this lagoon fishery are repeatedly exposed to the risk of injury, air exposure, and postrelease mortality.

Caution is warranted when using the upper mortality rate estimates, due to the classification process. Immobile fish were classified as mortalities without verification. There were two reports of fish captured that looked like the tag was pulled out and another that was disconnected from the anchor line. This indicates that tag shedding occurred, but the timing and effect is currently unknown. Tag loss soon after tagging would lead to potential false classifications if those fish survived after shedding the tag. Further, this research occurred only during the summer. Although environmental conditions are relatively stable in Puerto Rico, some seasonal variation occurs and could influence seasonal results. Summer water temperatures are greater and therefore may represent a period of greater thermal stress. Finally, this study assessed specific practices of a single angling charter operator. The angling and handling techniques of other charter companies, freelancing captains, and independent anglers may differ (Brownscombe et al. 2017).

With optimal angling and handling practices, catch-and-release angling can be successful, with minimal

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mortality (Brownscombe et al. 2017). Angler techniques can be altered to minimize catch-and-release angling from having negative impacts (Bartholomew and Bohnsack 2005). Hook type, gear action, landing procedures, and air exposure were discussed as areas where modifications could yield a significant improvement in postrelease survival. The use of heavier action rods and greater line test could reduce fight time, shortening the period of angling stress (Mohan et al. 2020). This may not be the best option to maximize the angling experience, as anglers pursue Tarpon for the fight. Circle hooks are well researched to reduce deep hooking, and a circle hook requirement when using natural bait could increase postrelease survival (see reviews by Cooke and Suski 2004; Keller et al. 2020). Maintaining fish in the water during landing and photography would eliminate air exposure and injuries related to lifting fish from the support water provides (Edwards 1998). If the fish must be removed from the water, it is necessary to provide support to the body and reduce potential for injury. Finally, when Tarpon are exposed to air, the exposure time should be kept at 2 min or less (Guindon 2011). Although most released Tarpon survived, angling pressure in the San Juan lagoon system is intense and these recommendations could help reduce the risk to fish that are subjected to multiple capture events.

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