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Examining the severity of roof-hooking injuries in dolphinfish: a comparison between computed tomography and gross necropsy

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ABSTRACT

We describe hook trauma to the roof of the mouth in dolphinfish *Coryphaena hippurus* and compare computed tomography (CT) scanning to gross necropsy (GN) as a technique for diagnosing hooking injury in fish. Forty-two dolphinfish carcasses spanning a range of hook injuries were collected and CT scanned, and 33 of these were evaluated using GN. Specimens were hooked either in the roof of the mouth, the eye via the roof or upper jaw, or the jaw (control

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group). In 75% of roof-hooked individuals, GN revealed nondisplaced to comminuted fractures of the bones of the suspensorium, hematomas in and laceration of the extraocular muscles, and/or damage to the optic nerve. These injuries have the potential to compromise vision and therefore decrease post-release survival rates of obligate sight-feeding species such as dolphinfish. We evaluated the effectiveness of CT scanning to diagnose injury and found that CT could efficiently and accurately identify fractures and some soft tissue damage, but some injuries found in GN (e.g. optic nerve damage) were not observed on CT scans. Based on our findings, it is likely that mortality is greater in dolphinfish when hooked in the roof of the mouth than in the jaw. This study demonstrates a novel technique that was effective at diagnosing hooking injuries associated with the roof of the mouth.

INTRODUCTION

Evaluation of population status requires knowledge of mortality numbers of fish that are caught, whether due to harvest or catch-and-release (C&R). However, the fate of discarded fishes is often unknown (Davis 2002) and disregarding post-release mortality can lead to uncertainty in stock assessments (Williams 2002, Pollock and Pine 2007). It is important to understand the anatomical effects of hooking and to make use of diagnostic techniques that are best-suited for specific species and their respective injuries. This can allow for more informed C&R mortality rate estimates and allow anglers to make more informed decisions when choosing whether to retain their catch. With increased popularity in C&R, it is valuable to provide information that promotes sustainable angling practices (Brownscombe et al. 2017).

The recreational fishery in the U.S. South Atlantic region targets dolphinfish *Coryphaena hippurus* using hook-and-line gear, and dolphinfish are most often hooked in the jaw, followed by roof, gill, eye, gut, and body, respectively (C.S. Mikles, personal observation). Dolphinfish are pelagic piscivores that are primarily reliant on sight for foraging (Loew and McFarland 1990). Given their abundance and aggressive feeding behavior, dolphinfish have been and continue to be one of the top-ranked recreational fisheries in numbers caught within the U.S. South Atlantic (Rose and Hassler 1969; NOAA 2012). For multiple reasons, including ethical angling, size, and bag limits, dolphinfish in this region are often released after capture (Carter and Liese 2012). Discard mortality of dolphinfish has not been estimated for this fishery or for other fisheries directed toward it throughout its worldwide range.

Many studies that have analyzed C&R mortality rates often incorporate hooking location into these estimates. Hooking location has been established to be the most important contributor to post-release mortality among reviews of C&R studies across species (Muoneke and Childress 1994, Bartholomew and Bohnsack 2005). Hook trauma has been assessed in other recreationally caught fishes but has yet to be characterized in dolphinfish.

Post-release mortality for shallow (jaw, roof, eye) and deep hooking locations (gut and gills) has been studied in several species. Jaw hooking is generally considered to be a location associated with low mortality, averaging between 0-10% (Grover et al. 2002, James et al. 2007, Lyle et al. 2007, Veiga et al. 2011, Campbell et al. 2014). Independent of morphological differences, deep hooking in the gut and gills is often associated with a higher mortality rate than shallow hooking locations (Warner 1976, Domeier et al. 2003, Rudershausen et al. 2014). On the other hand, published estimates of mortality on eye- and roof-hooked fish are more variable, possibly because of the difficulties in observing the degree of injury. Across a number of species, damage to the eye from hooking injuries likely contributes to post-release mortality due to difficulties associated with feeding and predator avoidance (Prince et al. 2002, DuBois and Dubielzig 2004, Cooke and Sneddon 2007). The extent of injuries and rate of catch and release mortality in dolphinfish as a result of hooking injury to each of these anatomical sites is unknown.

Many studies that assess C&R mortality rates do not describe roof hooking or distinguish it from jaw hooking (Murphy et al. 1995, Taylor et al. 2001, Stachura et al. 2012, Bergmann et al. 2014). This may be due to a perception that roof-hooked fish have mortality rates similar to fish hooked in the jaw or to the difficulty in observing damage to this location without necropsy (Belle 1997). Mortality for this hooking location ranges from being used as a control (i.e. assuming 0% mortality) in Chinook salmon *Oncorhynchus tshawytscha* (Grover et al. 2002) to rates as high as 80% in pelagic fishes (Falterman and Graves 2002). This variability is likely due to differences in morphology and feeding behavior across species. Given such variation it is important to assess injuries to the roof of the mouth on a species-specific basis. The roof of the mouth in dolphinfish lies in close proximity to the bottom of the eye, which led us to explore different techniques to examine injuries in these tissues.

The objectives of this study were to describe roof-hooking injuries in dolphinfish and compare computed tomography (CT) scanning to gross necropsy (GN) as a technique for diagnosing hooking injury in fish. CT scanning has applications in aquatic veterinary medicine to diagnose disease (Garland et al. 2002) but this technique has not been used in published work to investigate the effects of hooking damage in fish and to better understand the impacts of C&R. We hypothesized that hooking location influences the level of injury and predicted that roof-hooked fish will have greater injury relative to jaw-hooked fish.

METHODS

Carcass Collection and Hook Location Assignment

Dolphinfish carcasses were collected from May through July of 2016 and 2017 at the Morehead City, North Carolina waterfront. Fish were collected opportunistically from a cleaning operation that fillets fish landed by recreational charter boats between 2 and 10 hours after they are boated; therefore, exact gear type, hook size, and landing methods were unknown. While fishing practices differ among boats, the charter fleet typically angles dolphinfish by trolling with J hooks with dead natural baits and/or artificial lures, or by bailing with circle hooks with dead natural bait (Rudershausen et al. 2012). Additionally, dolphinfish are gaffed or brought on board without gaffing; after boating, dolphinfish are put directly on ice. None of the dolphinfish retained for CT scanning were gaffed in the head. The fork lengths of the fish were measured, and carcasses were examined for hooking location and external damage. The hooking location was determined through observation of wounds left by hooks or from hooks left in place.

Dolphinfish retained for CT scanning were hooked either in the jaw, eye, or roof of the mouth (Table 1). Fish hooked in the jaw served as controls for CT analysis and injury characterization. Having very minimal injury (see below), jaw hooked fish also controlled for differences in angling practices and any potential damage inflicted on fish prior to collection.

Computed Tomography (CT) Scanning

The carcasses collected at the Morehead City waterfront were frozen at -20˚C. All heads were scanned at the North Carolina State University College of Veterinary Medicine using the Siemens SOMATOM Sensation 16 (Siemens Medical Solutions, Malvern, PA), with a veterinary small adult ear setting at a slice thickness of 0.75 mm and a reconstruction increment of 0.4 mm. After CT scanning, heads were stored and thawed at 4ºC for subsequent gross necropsy (below).

The scanned images were examined in Horos® DICOM medical image viewer (*https://www.horosproject.org*). The CT scans were first naïvely evaluated by the image analyzer with no knowledge of the hooking location or the extent of injury. The CT scans were reevaluated a second time after we became more familiar with the images and internal anatomy as well as cross-referencing with dockside hooking location designations. Cross-referencing is an important tool to diagnose conditions and understand the extent of injuries (Cockcroft and Holmes 2003).

The CT scans were examined in both transverse and coronal sections. Within the CT scan images, bone structure appears white (radio-opaque, mineral opacity), soft tissue and hematoma grey (soft tissue opacity), and air-influx black (gas opacity, radiolucent). Gas is expected in the oral and gill cavities since they are exposed to air after the fish is boated, but air is also introduced through fractures in the bone and can be traceable from the fracture site. Gas as an artifact is sometimes present and can be attributed to air introduced by decapitation or decomposition; control fish served to represent the effects of decapitation and freezing/thawing. Assessing the degree of bilateral symmetry between injured and uninjured sides of the same individual can be used as an internal control since hooking injury occurred only to one side of each individual that we collected.

Roof anatomical evaluations focused on the palate, or suspensorium, which in dolphinfish is a delicate structure composed of a series of thin bones and cartilages (Fig 2a, b). Specifically, the endopterygoid, ectopterygoid, metapterygoid, palatine, and quadrate form the suspensorium (Hilton 2011). The endopterygoid is the bone most susceptible to fracture caused by hook trauma, due to its thin dorsal shelf that supports and protects the orbital cavity.

We designated three CT injury categories based on our interpretations of the scans: CT 1 - no visible damage or trauma to the suspensorium or to the orbit (Fig. 1a), CT 2 - fracture to bone(s) forming the suspensorium, paired with gas influx continuous from the fracture site extending only into the base of the orbit (gas confined to the orbital floor) (Fig. 1b), and CT 3 – severe fracture (displaced or comminuted) to bone(s) forming the suspensorium, paired with gas influx continuous from the fracture site extending past the orbital floor dorsally to the level of the optic nerve, extraocular muscles, or the eye (Fig. 1c).

Gross Necropsy (GN) and Comparison to CT Scans

We performed GNs to identify the extent of damage caused by hooking and to compare to CT scans. GNs were necessary because soft tissue damage in CT scans was evaluated in terms of gas path and volume and adjacent bone fractures, rather than observing the injuries *in situ*. The eye and surrounding structures were examined from a ventral perspective using the following procedure in order to preserve the integrity of the tissues damaged by hooking. First, the opercula and gill arches on both sides of the fish were removed. The lower jaw was removed at the articulation between the maxilla and quadrate and the dentary, exposing the length of the roof of the mouth. The mucosa of the roof was examined for any signs of potential hooking damage (e.g. laceration that penetrates the mucosa), and the outer (ventral) layer was removed, exposing the superficial muscle and the endopterygoid. The muscle and surface of the endopterygoid were examined and then carefully removed, exposing the orbit and the extraocular muscles. The interior surface of the eye and the extraocular muscles were evaluated for damage, then the extraocular muscles were carefully removed. The optic nerve was evaluated for damage or laceration, then the conjunctiva was cut and the surrounding muscles and mucosa removed to evaluate the state of the eye and optic nerve further. Finally, the uninjured contralateral orbit was examined as an internal control.

We established three GN injury categories: GN 1 - no visible damage or trauma to the suspensorium or to the orbit, any laceration is minimal and superficial, GN 2 - visible laceration of the mucosa and fracture to the endopterygoid, damage to muscle is superficial, and GN 3 - visible laceration of the mucosa, and fracture to the endopterygoid and/or the ectopterygoid, paired with damage to at least one of the extraocular muscles and/or the optic nerve.

The percentage agreement between CT and GN categories were determined to assess the ability to predict GN injuries from CT scans. Additionally, a Kolmogorov-Smirnov goodness of fit test for discrete ordinal data (Zar 1996) was used to compare the observed CT counts to expected counts (based on GN results) for fish hooked in the roof of the mouth. To provide a qualitative measure of the relative injuries between jaw, eye and roof-hooked dolphinfish, we calculated a weighted average of injury by hooking location using the number of fish assigned to GN and CT scores. The weighted average was:

$$\frac{(n.1*1)+(n.2*2)+(n.3*3)}{\sum n},$$

where *n* is number of fish in one of the three GN or CT injury categories and 1, 2, and 3 are the GN or CT injury scores. We performed a Kruskal-Wallis test with Dunn post-hoc tests to determine the relationship between hooking location and injury scores assigned through CT and GN (Sokal and Rohlf 1995). Significance was assessed at alpha = 0.05. Statistical analyses were conducted in R using the packages “dpylr” and “FSA” (Wickham 2018, Ogle 2018, R Core Team 2018).

RESULTS

Carcass Collection and Hook Location Assignment

Forty-two dolphinfish carcasses were collected across the three hooking locations (roof of the mouth, eye via the roof or upper jaw, and jaw), and fish ranged in fork length from 480-985 mm (Table 1). The 14 control fish examined in the laboratory had no injuries to the roof or the eye, confirming the dockside assignment of jaw hooking.

Computed Tomography (CT) Interpretations

The CT scans showed no evidence of fractured bones and gas intrusion in the control fish; however, these injuries were observable on CT scans in 23 out of 28 non-control fish (Figure 1). Fractures to the bones of the suspensorium could be identified and were categorized as non-displaced, displaced, or comminuted. Fractures were observed in the endopterygoid more frequently than in any other bones of the suspensorium. Gas artifact could be seen in the eyes and surrounding the orbital cavity in both non-control individuals and control fish, and can be attributed to the effects of decapitation, decomposition and freezing/thawing. However, the volume of gas artifact was minimal and distinguishable from gas influx from a fracture site in non-control fish, since it appeared random and scattered instead of intruding directly from an epithelial location.

We assigned 14 controls, five roof, and one eye hooked fish to CT 1 (Table 2; Figure 1a). There were six roof and three eye hooked fish assigned to the CT 2 condition where scans identified non-displaced fractures to the bones of the suspensorium and minimal gas intrusion (Table 2; Figure 1b). Scans from fish in CT 3 showed displaced or comminuted fractures to the bones of the suspensorium paired with obvious gas intrusion that was traceable to the level of the orbital floor (Figure 1c); this condition was found in five roof and eight eye hooked fish (Table 2). The highest proportion of fish in CT 3 were hooked in the eye, followed by roof.

Gross Necropsy (GN) and Comparison to Computed Tomography (CT) Scanning

Gross necropsies were performed on all roof- and eye-hooked fish, and five control fish (total=33). The remainder of the control fish were examined for external damage but not dissected. Damage seen by dissection was a result of hook injury, all fish were assigned one of the three gross necropsy injury categories (Table 2). All 14 control fish fell into GN 1; full dissections of all control fish were not necessary to determine their placement in GN 1 as nine control fish not fully dissected were consistent with five control fish that were fully dissected.

The proportions of fish in GN1, GN2, and GN3 for roof- and eye-hooked fish were similar to the proportions in the CT categories (Table 2). In a few instances, the CT categories overestimated or underestimated the degree of damage as determined by GN but had a total percent agreement of 80.9% with GN. Discrepancies mostly occurred between categories 2 and 3; the CT interpretation underestimated the damage in five cases and overestimated it in three. For roof-hooked fish, there was no statistical difference in injury score assignment between the CT and GN (K-S test: $d_{max} = 2$, $p > 0.50$).

For fish in GN 1 (n=19), all damage was superficial. Lacerations to the mucosa in the roof of the mouth were observed but no fracture was observed, and no damage occurred to the superficial muscle. The CT assessment scored 1 and the GN scored 2 for only one individual, which had a chip fracture in the endopterygoid, along with slight damage to the surrounding superficial muscle.

For fish in GN 2 (n=9), fractures of varying types and severities to the endopterygoid were observed but soft tissue damage did not extend past the superficial muscle, which was often bruised or torn. Of the nine fish scored as CT 2, five of these were also scored as GN 2.

For fish in GN 3 (n=14), fractures of varying types and severities occurred to the endopterygoid and ectopterygoid. The superficial muscle was damaged, and damage occurred to the extraocular muscles and/or to the optic nerve. Hematoma was often present in the orbital floor. One roof-hooked fish and three eye-hooked fish sustained injuries to the optic nerve. Of the 13 fish scored as CT 3, 10 were also scored as GN 3.

Of the 16 fish hooked in the roof, four fell into GN 1, five in GN 2, and seven in GN 3. Of the 12 fish hooked in the eye (globe or fornix) via the roof or upper jaw, one was placed in GN 1, four in GN 2, and seven in GN 3. All control fish were placed in GN 1. Twelve out of 16 (75%) roof-hooked fish sustained a combination of fractures to the suspensorium, laceration of extraocular muscles, and/or optic nerve damage. Assessment by CT never diagnosed damage where none was detected by gross necropsy. There was no identifiable consistent manner in which the endopterygoid was fractured, except that the thinnest parts of the bone were most susceptible to damage.

The weighted average GN injury scores for jaw-, roof-, and eye-hooked dolphinfish were 1.0, 2.2, and 2.5, respectively, and were 1.0, 2.0, and 2.6 for CT scores. The results of the Kruskal-Wallis test showed differences in the severity of hooking injuries among jaw-, roof-, and eye-hooked fish for CT ($\chi^2 = 22.6$, $p < 0.001$) and GN techniques ($\chi^2 = 22.3$, $p < 0.001$). Post-hoc analyses for each categorization revealed differences between jaw and roof ($p < 0.002$) and jaw and eye ($p < 0.001$) for both GN and CT techniques; however, there were no differences in injury scores between roof and eye ($p > 0.05$) for either technique. Thus, roof-hooked dolphinfish have injury levels that are closer to eye-hooked relative to jaw-hooked dolphinfish.

DISCUSSION

The effects of roof hooking in contributing to C&R mortality have seldom been studied compared to the total number of C&R mortality estimates. Our prediction that dolphinfish hooked in the roof of the mouth would sustain injuries that are more severe than jaw-hooked fish was supported by computed tomography (CT) and gross necropsy (GN) findings. While our sample of 16 roof-hooked fish is modest, the extent and variability in injury was extensive.

There was a high percentage (75%) of roof-hooked dolphinfish with damage to the bones of the suspensorium, extraocular muscles, and/or optic nerve. The same injuries were observed 92% of the time in eye-hooked fish. CT scans and GN results had similar findings when the bones of the suspensorium were fractured; however, there was ambiguity in determining the extent of soft tissue damage with CT. CT scans more accurately show bone structure, so differences in fracture severity were easily discernable to categorize fish in either CT 2 or 3. Tracing the path of gas influx provided some indication of the extent of damage present, but results from gross necropsies were more definitive. For roof- and eye-hooked fish, internal damage to the musculature, nerve pathways, and the orbit can vary in severity and is not necessarily correlated with the severity of fracture. The gross necropsies served to validate the diagnoses from the scans, and also provided more specific information on soft tissue damage. The diagnoses from the CT agreed with the GN around 80% of the time. We have demonstrated the use of CT for comparing the severity of hooking injuries across hooking locations that are difficult to observe and have not been previously studied in dolphinfish.

The endopterygoid and superficial muscle provide a thin layer of protection between the oral and orbital cavities and are not suited to withstand hook damage. Our understanding of these injuries provides insight into the potential for post-release survival. The injuries we describe can result in severe eye damage and potentially impair vision. For example, damage to the lens or the sclera, intraocular hemorrhage, and enucleation were designated as injuries most likely to result in long-term visual impairment of stream trout (DuBois and Dubielzig 2004). Fish hooked in eye-associated tissues will likely suffer a degree of vision loss, which has been associated with higher mortality (Warner 1976, Pauley and Thomas 1993). If selectively harvesting, anglers may consider choosing to keep individuals with greater hooking damage (Brownscombe et al. 2017). Given the importance of sight-feeding to dolphinfish, we recommend retaining individuals of legal size with eye or roof-hooking over fish hooked in the jaw. Additionally, trolling with circle hooks would reduce the amount of deep (e.g. eye and roof) hooking (Rudershausen et al. 2012).

Dolphinfish hooked in the roof of the mouth sustained higher degrees of damage than jaw hooked fish. Thus, hooking in the roof of the mouth would likely result in higher mortality than jaw hooking based on the injuries that we observed. Fractures and muscle damage often cause blood loss, and these hook injuries can create pathways through which seawater and pathogens may be introduced to vital areas. Depending on the severity and location of hooking damage, the presence of bleeding is often linked to post-release mortality, as it is dependent on the perfusion of vasculature and critical organs (Arlinghaus et al. 2007). Numerous studies have found that bleeding, along with hooking location, are the most important factors when assessing mortality of angler-caught fish (Nuhfer and Alexander 1992, Meka 2004, Weltersbach and Strehlow 2013, Gargan et al. 2014). We did not observe bleeding immediately after angling, although hematoma was often present in the orbital cavity in roof-hooked fish with medium (GN2) or high degrees of damage (GN3). While the degree of physical trauma can be a good predictor of mortality (Domeier et al. 2003, Skomal 2007), we recommend a more quantitative estimate of C&R mortality by hooking location in dolphinfish using experimental caging (Grover et al. 2002, Gutowsky et al 2015), large-scale mark-recapture study (Pine et al. 2003, Rudershausen et al. 2014), telemetry (Capizanno et al. 2016), or use of accelerometer loggers (Brownscombe et al. 2013, Lennox et al. 2018).

Of the studies that have examined injuries and mortality for roof-hooked fish, the results have been mixed and are likely species-specific. Roof hooking has been observed and described in other pelagic fishes (Falterman and Graves 2002, Prince et al. 2002, Prince et al. 2007). Falterman and Graves (2002) assessed hooking mortality among pelagic fishes and determined a discard mortality rate of 80% for fish hooked in the roof of the mouth; however, the sample size was small (n=5), and the mortality rate determined for jaw-hooked fish (corner and lower jaw) was also notably high (48.9%). The injuries to roof-hooked dolphinfish were very similar to those described by Prince et al. (2002, 2007) for roof-hooked Atlantic sailfish *Istiophorus* *platypterus*. Hooking in the roof of the mouth resulted in lacerations to the rear palate and hemorrhaging of the eye in sailfish (Prince et al. 2007). The authors classified hooking in the roof to be an undesirable location that may lead to post-release mortality due to latent injuries to the eye. The resemblance of roof hooking injuries between our study and Prince's (2002, 2007) findings are likely a result of similarities in anatomy, as both dolphinfish and sailfish have an insubstantial palate. Among more distantly related fishes inhabiting different environments, results for roof hooking were increasingly varied. For example, in cutthroat trout *Oncorhynchus clarkii* individuals hooked in the jaw had an estimated mortality rate of 6%, while those hooked in the roof of the mouth showed a mortality of 29%. (Pauley and Thomas 1993). In pumpkinseed *Lepomis gibbosus* with molariform teeth, roof hooking was insignificant in discard mortality estimates (Cooke et al. 2003), and in Chinook salmon, the roof of the mouth was designated as a location with minimal injury and treated as a control for mortality estimates (Grover et al. 2002). We recommend future research on hook injuries for fishes known to have mouth and eye morphologies similar to dolphinfish and sailfish.

We observed severe injuries to a peripheral hooking location that outwardly does not appear to result in severe injury. This has also been the case for roof injuries to bluefin tuna *Thunnus thynnus*, in which the same injury could only be characterized by performing gross necropsies (Belle 1997). In sharks, hooking damage to the basihyal was suggested to result in high mortality, which was unexpected (Danylchuk et al. 2014). Serious injuries from hooking are likely found in other fishes and is an area worthy of future research. Increased use of these diagnostic tools for specific species and fisheries will aid to the understanding of hooking injuries to different locations and allow anglers to make more informed decisions when practicing catch-and-release.

Our research is unique in that it used detailed necropsy and medical imaging to reveal cryptic hooking injuries. CT scanning may be a tool that C&R researchers choose to use in future studies given the agreement between approaches and the time savings of CT scanning. Additionally, CT scanning could be used as a first approach to identify severely-injured fish for GNs. GNs were more insightful but required considerably more time than scanning. However, GN validated the CT interpretation and revealed the mechanism and character of the respective injuries.

While this study was specific to dolphinfish, we demonstrate a novel application of CT techniques that are becoming more accessible with improved technology, free imaging software, and scientific interest of scanning fish. In tandem with detailed necropsies, CT offers an enhanced technique to characterize injuries that provides insight into potential risk for post-release mortality. The application of similar methods to other fish species with similar anatomies could expand our current understanding of the various injuries caused by hooking.

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Figure Descriptions

Figure 1. Computed Tomography (CT) scan diagnoses of dolphinfish *Coryphaena hippurus* by category. Each increment of scale bar on leftmost side of the image represents 1 cm.

1a. CT 1 – No visible damage or trauma to the suspensorium or to the orbit. Individual was hooked in the jaw, and served as a control. Gas present in small quantities bilaterally in and behind the eyes is attributed to decapitation and/or decomposition. Arrows indicate the intact bone structure of the endopterygoid in transverse (left) and coronal (right) sections.

1b. CT 2 – Fracture to bone(s) forming the suspensorium paired with asymmetrical gas influx continuous from the fracture site extending into the base of the orbit (gas is confined to the orbital floor). Individual was hooked in the roof of the mouth. Arrows indicate fracture site of endopterygoid (oblique, displaced). Gas is continuous from the oral cavity to the base of the orbital floor.

1c. CT 3 – Severe fracture (displaced or comminuted) to bone(s) forming the suspensorium, paired with asymmetrical gas influx continuous from the fracture site extending past the orbital floor to the level of the optic nerve, extraocular muscles, or the eye. Individual was hooked in the roof of the mouth. Left arrow indicates gas influx while right arrow indicates the fracture site of endopterygoid (comminuted). Gas is continuous from the oral cavity past the orbital floor, including around the globe.

Figure 2. Suspensorium of dolphinfish *Coryphaena hippurus* in lateral view (a) and ventral view (b). Abbreviations: ecp=ectopterygoid; enp=endopterygoid; mpt=metapterygoid; pal=palatine; para=parasphenoid; q=quadrate; vom=vomer.

Figure 1a.

Figure 1b.

Figure 1c.

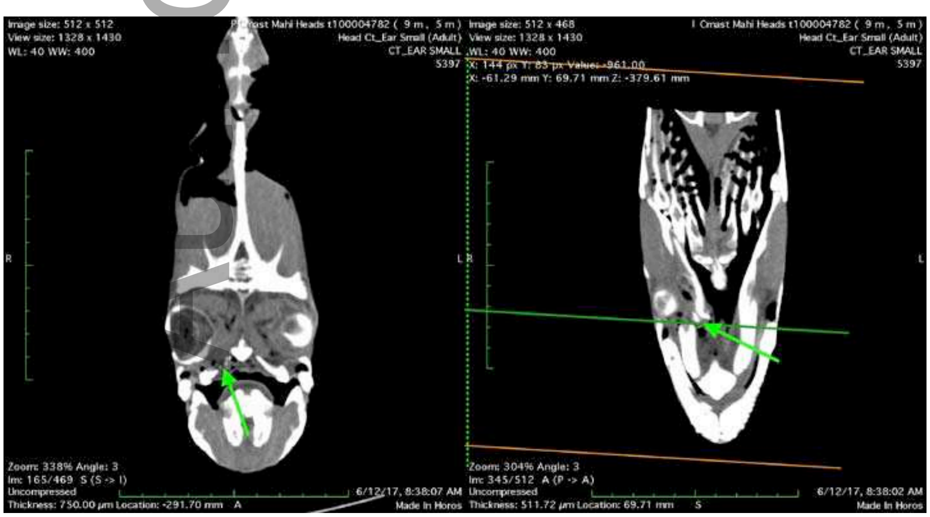

Figure 2

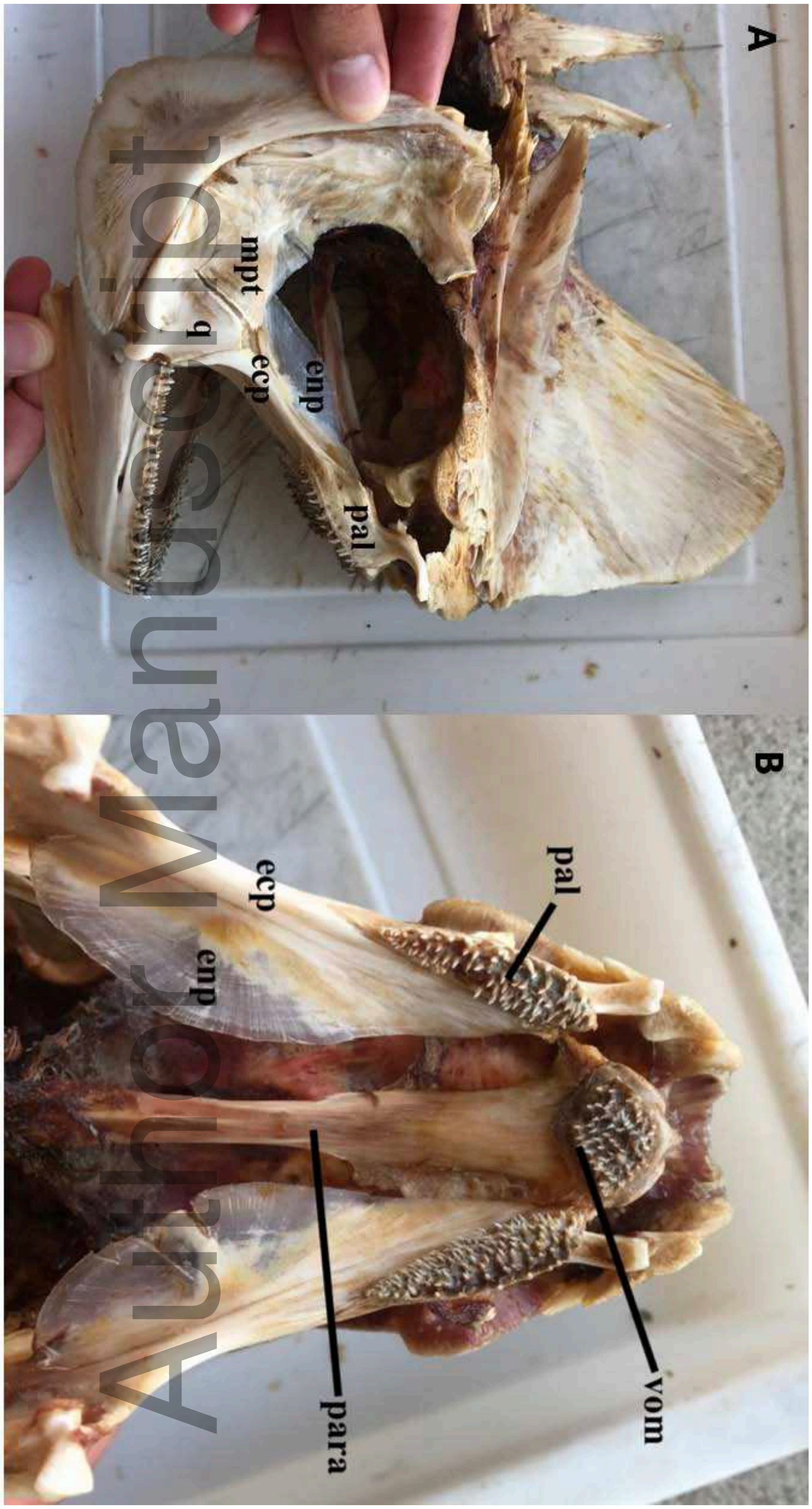

Table Descriptions

Table 1. Number of fish collected per dockside-designated hooking location, and mean and range of fork lengths of all fish and locations. Four fish were not measured or included in these averages.

Table 2. Computed tomography (CT) and gross necropsy (GN) categorization of all fish based on dockside-designated hooking locations.

Table 1.

Hook location	Number of Fish	Average fork length (mm)	Range (mm)
All fish	42	679	480-985
Roof of the mouth	16	746	504-985
Eye	12	748	505-950
Jaw	14	584	480-880

Table 2.

	Roof (16)	Eye (12)	Jaw (14)	Total (42)
CT 1	5	1	14	20
CT 2	6	3	0	9
CT 3	5	8	0	13
GN 1	4	1	14	19
GN 2	5	4	0	9
GN 3	7	7	0	14