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Survival of Amputated Striped Corvina *Cynoscion reticulatus* (Pisces: Sciaenidae) off the Southeast Coast of the Gulf of California

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HIGHLIGHTS

- Striped corvina were able to swim and compete for resources despite amputation.
- Results could be useful in trophic and swimming modeling, and fitness survival.

Abstract: Records of amputated teleost fish in the aquatic environment are becoming more frequent; however, it is difficult to find the causes of amputation when there is little evidence. For this reason, this study focused on describing the damage and causes of the amputations of two striped corvina *Cynoscion reticulatus* specimens collected from landing sites of a small-scale fishery in northwestern Mexico, and determining if the damaged organisms could survive in the environment. Specimens were sexed and whole-body radiographs of amputated specimens and of a normal specimen were taken. Morphometric measurements (TL, SL, MDF, BD, HL, and TW) of the amputees and of 54 normal specimens were recorded. The TL of amputees was estimated and compared to that of normal specimens; stomach contents were also analyzed. The first organism was male, it was missing 1 ½ vertebra and had an estimated TL of 36.64 cm; the second was a female, it was missing 3 ½ vertebrae, with an estimated TL of 38.59 cm; both had bite marks, skin regeneration, and scales in the affected area. Stomach analysis showed Engraulidae fish of the *Anchoa* genus in stomach contents. There were no significant differences in the measurements of the two amputated and 54 normal organisms ($p>0.05$). Based on this evidence, it was determined that amputated fish could survive, escape from predators, feed, and obtain energy to heal wounds; the amputations were attributed to the bottlenose dolphin *Tursiops truncatus*, a potential predator of croakers in the study area and other regions.

Keywords: injuries; tailless; healing; predator bite; small-scale fishery.

INTRODUCTION

Fish suffer various anatomical injuries in the aquatic environment (e.g., loss of scales, spines, rays, fins, and vertebrae) [1, 2] due to pathogenic organisms such as bacteria, fungi [3], and parasites [4, 5, 6]; bites from fish and marine mammals [7, 8]; and fishing lines or nets [9], and polluting plastics such as six-pack rings and remains of fishing gear [10]. All of these conditions, plus interspecific and intraspecific competition and environmental conditions, result in constant stress on organisms.

The most commonly reported injury in recent studies on free-living marine fish has been fin loss, especially the caudal fin and peduncle. However, it has been reported that fish have developed physiological abilities that allow them to heal their wounds in a short time. For example, there are reports of two specimens of striped piggy *Pomadasys stridens* (Forsskal, 1775) in the Persian Gulf [7] and two croakers *Micropogonias undulatus* (Linnaeus, 1766) from Biloxi Bay and the Mississippi Sound [1] presenting amputation of the fin and caudal peduncle; however, the affected area presented scarring and was covered by scales. Additionally, it has been reported that upon suffering amputation of the caudal fin, morid cod *Physiculus cyanostrophus* [11] from the eastern tropical Atlantic [12] and zebrafish *Danio rerio* (Hamilton-Buchanan, 1822) [13] regenerated the fin completely after 2 to 3 weeks. Although fish can heal their wounds, the loss of a caudal fin makes feeding difficult, it decreases body condition, the efficiency of escape from predators, and affects other daily activities [14; 15], as this appendage provides the fish with thrust and direction during swimming [16]. Many of the reports on amputations in wild fish highlight the difficulty of defining the origin of these injuries when there is little evidence, and it is recommended to address such explanations based on the biological knowledge of the species, environmental conditions, and the anthropogenic activity in the area where the records were made.

The present study documents for the first time the presence of two striped corvina *Cynoscion reticulatus* (Günther, 1864) specimens lacking a caudal fin and caudal peduncle, found by fishers in southern Sinaloa. This croaker species is distributed from Baja California Sur, Gulf of California, to Colombia [17], and it is an important socioeconomic resource along its distribution area [18, 19, 20]. For more than 20 years, *Cynoscion reticulatus* has been part of a Mexican artisanal fishery that uses 3" to 6" mesh size nets of variable length (100 to 500 m); it is also captured as bycatch by shrimp boats using trawls, gillnets, and hand lines [21]. Regarding its ecology, it is a fourth-level predator (4.0 ± 0.24), a carnivore, and its preferred diet includes fish, shrimp, and cephalopods [22]. It is preyed upon by large fish such as groupers, sharks, and rays [23], as well as some marine mammals, such as the sea lion *Zalophus californianus* (Lesson, 1828) [24, 25] and the vaquita *Phocoena sinus* (Norris & McFarland, 1958) [8] in the Gulf of California and to the southeast of this region. Therefore, the objective of this work was to describe the injuries, body condition, and most probable cause of the amputations. The following questions were raised: 1.-Which of all the factors described as causing amputations in fish could be the one that affected the striped corvinas? 2.- Could the amputated croakers have survived and developed correctly in their environment? To answer these questions, the following hypotheses were raised: 1. The main cause of damage to the fin and caudal peduncle of striped corvinas was due to a bite from one of their predators; 2. Amputated striped corvinas can survive in the environment as long as they can feed and maintain good physical condition.

MATERIAL AND METHODS

Two sampling trips were undertaken in August and October 2021; specimens were obtained from small-scale fishery landings in southern Sinaloa. This fishery targets fish in the area comprising from Punta Prieta (23°36'N, 106°54'W) to Chametla (22°45'N, 106°02'W), using >300 m long gillnets with 3” and 3 ½” mesh size, at depths below 50 m. Two tailless specimens and 54 normal (non-amputated) specimens of the striped corvina *Cynoscion reticulatus* (n= 25 August 2021 and n= 29 October 2021) were obtained (Figure 1a). These fishers have permits for commercial fishing of marine finfish, authorized by the National Commission for Fisheries and Aquaculture through the Secretary of Agriculture and Rural Development of the Government of Mexico; since the fish were already dead when they were collected, no permit was required to handle them.

Figure 1. Photographic comparison of a tailless (a) male and (b) female versus a tailed (c) female *Cynoscion reticulatus* from the southeast Gulf of California.

The total length (TL), standard length (SL), length from the mouth to the end of the second dorsal fin (MDF), body depth (BD), head length (HL), and total weight (TW) were obtained for all specimens. Detailed photographs of the amputation area of both specimens were taken, (Figure 2) and X-ray images (Figure 3) of the two tailless and one tailed fish to describe possible injuries to the bone system. The specimens were dissected to determine sex by gonadal visualization and the stomach was removed to verify if the amputated fish could feed despite their condition. The taxonomic analysis of the target species and of prey was based on the keys by [17, 26]. The Total length of the two amputated organisms was estimated using, the average percentage represented by the MDF with respect to the TL of the 54 non-amputated organisms, and the MDF was extrapolated to the TL using the percentage mean result as a factor:

$$Factor = \left(\frac{\frac{TL_1}{MDF_1} + \frac{TL_2}{MDF_2} + \frac{TL_3}{MDF_3} + \frac{TL_4}{MDF_4}{}_{\dots} \frac{TL_n}{MDF_n}}{n} \right) * 100$$

Where $\boldsymbol{n}$= 54 non-amputated organisms. After calculating the factor, the following arithmetic operation was performed.

$$\boldsymbol{LT_{Amputated} = MDF_{Amputated} \times Factor}$$

Finally, the measurements (TL, MDF, BD, HL, and TW) of the two tailless organisms and of the 54 normal croakers were compared (Table 1) using a *t*-student test for independent samples [27].

RESULTS

The two amputated organisms were dissected, and the external and internal morphologies were analyzed. Based on the macroscopic observation of the gonads, we determined that the first tailless specimen found in August 2021 was a sexually immature male presenting signs of amputation of the caudal fin. We observed that the dermal tissue of the injured area showed recent scarring, and the absence of scales was evident; instead of scales, there was increasing pigmentation of the dermis, although the vertebral bone tissue could be seen through the skin (Figure 2a). The second specimen lacking a caudal fin was found in October 2021 (Figure 1b); it was identified as a sexually mature female (the ovaries presented secondary-growth oocytes). This specimen presented advanced scarring of the amputated area, slight skin pigmentation, and like in the first specimen, the vertebral tissue could be observed through the muscular tissue (Figure 2b).

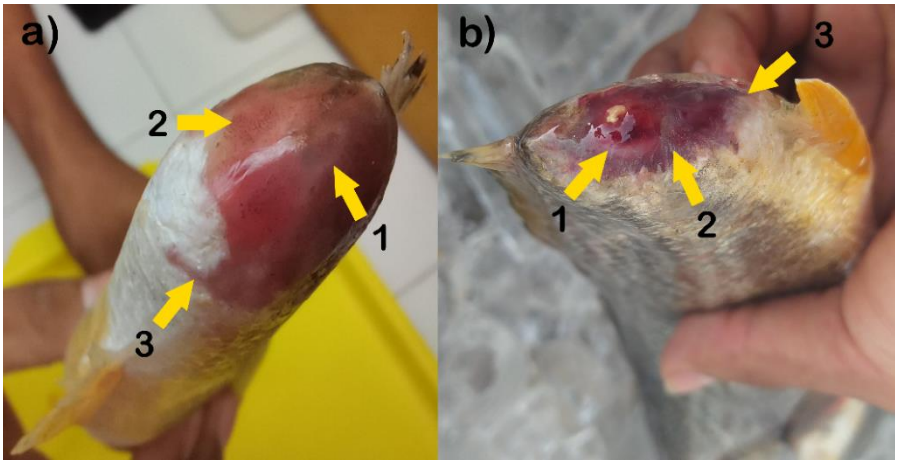

Figure 2. Amputated region of *Cynoscion reticulatus* (a) male and (b) female specimens from the entrance to the Gulf of California. 1. Vertebral bone tissue; 2. Pigmentation of scar tissue; 3. Evidence of bite or other tissue damage.

The analysis of the X-ray image showed that the first specimen (August 2021) had 13 precaudal vertebrae (PrCv) and 10 ½ caudal vertebrae (Cv), for a total of 23 ½ vertebrae (Figure 3a). We could also observe bone damage, recovery of scale cover in the amputated area, and healing in spines V, VI, X, and XI, as well as in rays 1-8 of the dorsal fin, as shown by the white dotted circles 1 and 2 in Figure 3a. This image also allowed us to identify the presence of food in the stomach; the dissection showed a pair of small sagitta otoliths and two fish from the family Engraulidae. The entire contents (otoliths and fish) were identified as anchovies from the genus *Anchoa*. The second specimen (October 2021) had a total of 13 PrCv and 8 ½ Cv, for a total of 21 ½ vertebrae (Figure 3b). Regarding stomach contents, only two pairs of small sagitta otoliths belonging to fish from the family Engraulidae, genus *Anchoa*, could be found. The estimated factor for the extrapolation of the TL of the two amputated striped corvinas was 1.308 ± 0.024; therefore, the estimated TL for the first striped corvina was 36.64 cm and 38.59 cm for the second.

The third analyzed striped corvina (not amputated) was a sexually mature female measuring 36.56 cm TL (Figure 1c). This specimen was used as reference for the bone structure of a specimen not lacking appendages. According to the X-ray image, it presented 13 PrCv and 12 Cv, for a total of 25 vertebrae (Figure 3c). The stomach analysis showed stomach contents (one fish with 18 vertebrae at an advanced state of digestion that could not be identified), which can be observed in Figure 3a, shown by a dotted circle in the abdominal region.

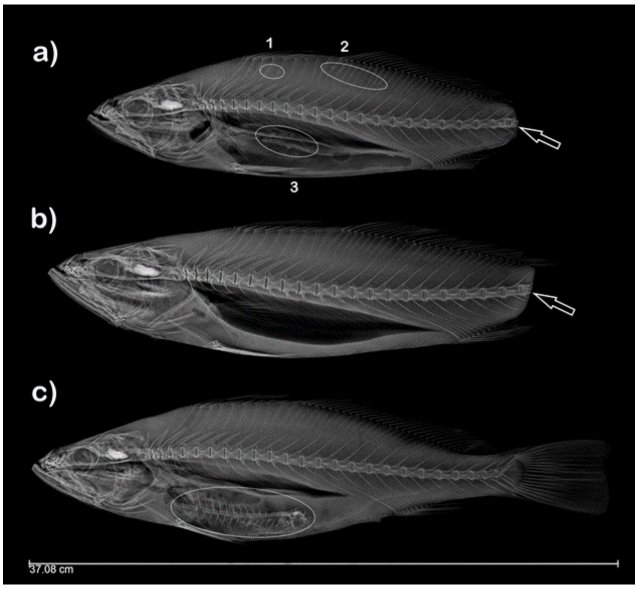

Figure 3. X-ray comparison of normal and tailless *Cynoscion reticulatus* specimens from the entrance to the Gulf of California. a) Tailless female (white arrow) with bone damage to the spines and rays (dotted circles 1 and 2) and presence of food in the stomach (dotted circle 3); b) Tailless male (white arrow); c) Normal female with presence of food in the stomach (dotted circles).

Finally, the comparison of measurements (TL, MDF, BD, HL, and TW) of the two tailless organisms and the 54 normal croakers did not show significant differences (P>0.05; Table 1).

Table 1. Morphology of normal and amputated organisms of striped corvina *Cynoscion reticulatus*.

Measurements (cm)	1st tailless male	2nd tailless female	Average size of normal fish
TL	36.64	38.59	37.18 ± 3.54
SL			32.5 ± 3.31
MDF	28.01	29.51	28.37 ± 2.95
BD	7.23	7	7.79 ± 0.81
HL	8.89	9.7	9.08 ± 0.92
TW	215	321	488.61 ± 138.85

DISCUSSION

The characteristics of the two striped corvinas *Cynoscion reticulatus* that were lacking a tail or caudal peduncle (e.g., mid vertebrae, lack of complete vertebrae, scarring, pigmentation, damage to spines and dorsal rays, and bite features in the damaged area) indicated that the main cause of injury was due to a bite from one of their predators (e.g. grouper, shark, ray, sea lion, vaquita, or dolphin) [8, 24, 25], the distribution and hunting strategy of these predators were reviewed to found the most probable one. The vaquita was ruled out since its distribution area is limited to the upper Gulf of California [28], in addition, as the wounds of the striped corvina were recent, and their swimming ability impaired, it would not be able to move that far (Southeast of the Gulf of California). Groupers and rays were also discarded, it is unlikely that they can cut the appendices of the medium fishes due to the type of teeth they have (small canines in groupers and dental plates in rays) [29, 30], in addition their feeding strategy is based on suction, which would otherwise favor the capturing of the entire prey [31, 32]. Although there are various hunting strategies within elasmobranchs, from the possible ones related to depth, some specialize in suction in the benthic zone, while most epibenthic and pelagic elasmobranchs with generalist habits use the lunge, suck, and bite strategy to catch prey [33]. Considering the type of dentition of the sharks that inhabit the Southeastern region of the Gulf of California (*Sphyrna spp*., *Rhizoprionodon longurio*, *Carcharhinus spp*., *Nasolamia velox*, *Galeocerdo cuvier*) [17], the attack strategy and biting pattern they use to feed, we deduce that this group is among the possible causes of amputations. Another viable species would be the sea lion (*Zalophus californianus*) and the bottlenose dolphin (*Tursiops truncatus*), both use ramming (impulse towards the prey with the mouth semi-closed and open) as their feeding strategy, as well as cooperative hunting through grouping for more efficiently feeding [34, 35, 36], being able to bite and tear prey. Therefore, this would respond to the first hypothesis.

The evidence found in the two amputated croakers indicated that the bite was recent and that the specimens were part of the same population, because in addition to the fact that the wounds were healed, their condition was similar to that of normal croakers. This was confirmed by the fact that no significant differences were found when comparing body dimensions (TL, MDF, BD, HL, and TW), and was also corroborated by the diet analysis, as both amputated and normal croakers presented food remains in the stomach. These results were decisive to accept the second hypothesis. Responding to the second hypothesis, this would demonstrated that although the croakers had a swimming disability, they could compete for the same resources in the environment where they were found, which could be understood as a benefit of gregarious intraspecific relationships (e.g., fish schools).

Fish anomalies have been reported sporadically in the past. For the study area, in the Urias Estuary in Mazatlán, Sinaloa (an area adjacent to the study area), the absence of pelvic fins in a yellow snapper *Lutjanus argentiventris* was reported, highlighting the fact that the lack of fins was due to congenital causes and not predation, fishing gear, or environmental factors, because when compared with a normal fish from the same species, it had the same physical condition and anatomical organization, except for the absence of pelvic fins [37]. Regarding reports of injuries in croakers, there is a study by [1] on three Atlantic croakers *Micropogonias undulatus* caught with trawl nets in Biloxi Bay and the Mississippi Sound, which presented amputation of the caudal fin and peduncle, with scarring and covering with scales of the affected area (similar to what was found in the present study). This damage was attributed to bites from predators, as they were not the only fish found with bites. The authors also found a tailless Atlantic spade fish *Chaetodipterus faber*; two Gulf menhaden *Brevoortia patronus*, the first with a halfmoon bite on the abdomen and the other with a lesion on the back, both with scarring and absence of scales in the affected area; and a tailless female lined seahorse *Hippocampus erectus* with scarring of the wound.

These conditions have also been identified in other species; for example, in the Bay of Bengal in the Indian Ocean, [38] an orange-spotted grouper *Epinephelus coioides* presenting a stump in the caudal region and a Bengal tongue sole *Cynoglossus cynoglossus* with a small caudal fin in regeneration were recorded; both fishes showed signs of having suffered recent damage. However, causes were attributed to the environment, as there are several reports of fish with abnormalities in that study area.

Another specific condition known as "fin rot" or "fin erosion" disease in fish, associated with degraded coastal or estuarine environments, has been reported in the weakfish *Cynoscion regalis* and summer flounder *Paralichthys dentatus* from the Atlantic Ocean [39]. *Vibrio* sp. has been described as a possible determinant of erosions in the anal, caudal, and pelvic fins of weak fish; as well as erosions in large areas of the edges of the fins of the summer flounder.

Finally, if potential predators are considered, among the ones found in the region, sea lions, sharks, and bottlenose dolphins, the latter might be the most likely candidate for the amputations found in the striped corvina, at least, for the southern Gulf of California, as it has been recorded as one of the top predators of corvina for other areas in the Pacific Northwest [40], Southern Africa [41], the Southeastern United States [42], and the Pacific coast of South America [43]. Adding to this hypothesis, it has been reported that in the Gulf of Mexico (Laguna Tamiahua, Veracruz), the bottlenose dolphin developed a particular hunting strategy, it only bites the posterior body area of catfish (*Ariopsis felis* and *Bagre marinus*) to avoid choking on the dorsal and pectoral fin spines [44]. The results of this work can be useful in studies focused on the hunting strategies of the main predators of striped corvina or similar members of the scianidae family, ecosystem trophic modelling, swimming capacity modelling, healing capacity and survival of this and other corvinas species.

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