Proceedings of the Zoological Institute RAS
Vol. 328, No. 1, 2024, pp. 66–75
10.31610/trudyzin/2024.328.1.66

UDC 597.2/.5

Saddleback syndrome in the firemouth cichlid *Thorichthys meeki* (Cichliformes: Cichlidae) in Campeche, Mexico

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Submitted November 14, 2023; revised February 12, 2024; accepted February 15, 2024.

ABSTRACT

There are several external and internal abnormalities that affect development in both wild and farmed fish. One of these abnormalities is known as saddleback syndrome (SBS), characterized by abnormalities in the shape, number, or absence of dorsal pterygiophores, causing a concavity in the dorsal region and absence of fin sections. The causes of this syndrome are not yet clear, but could be caused by fishing or predator damage, nutritional deficiencies, genetic conditions and environmental stress from pollutants that may cause alteration in the ontogenetic development of the fish. This study recorded for the first time the SBS in a wild-caught specimen of *Thorichthys meeki* Brind, 1918 (Cichlidae). Specimens were collected in the locality of Chekubul, municipality of Carmen, Campeche, México on November 18, 2022. The development of the dorsal fin begins from the first to the ninth dorsal spine where there is a dorsal concavity, which ends with the last three dorsal spines. There is no evidence of scoliosis or lordosis from the X-ray analysis; however, the dorsal pterygiophores show irregularities in their development. The specimen with the syndrome showed no other body abnormalities that would have prevented its development to adulthood, although the causative agent is unclear.

Key words: body deformation, Cichlidae, dorsal fin, freshwater Fishes, Mesoamerican cichlids, *Thorichthys meeki*, saddleback syndrome

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Синдром седловидной спины у огненноротой цихлиды *Thorichthys meeki* (Cichliformes: Cichlidae) в Кампече, Мексика

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Представлена 14 ноября 2023; после доработки 12 февраля 2024; принята 15 февраля 2024.

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РЕЗЮМЕ

Существует несколько внешних и внутренних аномалий, влияющих на развитие как диких, так и культивируемых рыб. Одна из таких аномалий известна под названием «синдром седловины» (SBS); она характеризуется нарушением формы и числа спинных птеригиофоров или их отсутствием, что приводит к вогнутости спинной области и отсутствию сегментов плавников. Причины возникновения этого синдрома пока не ясны, но они могут быть обусловлены повреждениями рыб при промысле или атаке хищников, а также недостатком питания, генетическими факторами или экологическими стрессами при загрязнении среды, которые могут вызвать изменения в онтогенетическом развитии рыбы. В данном исследовании впервые зафиксирован синдром SBS у диких экземпляров *Thorichthys meeki* Brind, 1918 (Cichlidae). У рыб, пойманных в ноябре 2022 г. в районе Чекубул (муниципалитет Кармен, Кампече, Мексика), колючие лучи спинного плавника от первого до девятого развиты нормально; далее в плавнике имеется выемка, за которой следуют три последних колючих луча. При анализе рентгенограмм признаки сколиоза или лордоза не выявлены, но дорсальные птеригиофоры развиты неравномерно. Причина аномалии неизвестна. У экземпляра с этим синдромом не обнаружены другие аномалии тела, которые могли бы помешать его развитию до взрослого состояния.

Ключевые слова: деформация тела, Cichlidae, спинной плавник, пресноводные рыбы, мезоамериканские цихлиды, *Thorichthys meeki*, синдром седловины

INTRODUCTION

Different external or internal abnormalities have been reported in commercial fish, and unlike wild ichthyofauna, fishery resources obtained from aquaculture have the largest number of records due to their economic importance (Campbell and Landers 2013). One of the anomalies that affect fishes is Saddleback Syndrome (SBS). This syndrome is characterized by abnormal conditions in the shape, number, position and/or absence of dorsal pterygiophores, causing a concavity in the dorsal region to the naked eye, and the absence of one or more dorsal spines (Koumoundouros et al. 2001), although the way in which this syndrome manifests itself differs between species (Campbell and Landers 2013; Jayaprabha et al. 2016).

The cause of this syndrome is not very clear, although there are some factors that may be related (Table 1), such as nutrition, genetic conditions, environmental stress, or the presence of high levels of pollutants, heavy metals and chemicals to which the fish are exposed and which could affect the reproductive system of the parental organisms, which have endocrine disrupting effects (Sun et al. 2009; Al-Mamry et al. 2010; Campbell and Landers 2013). Saddleback Syndrome may be a defect and disturbance in the ontogenetic development of fish (Sun et al. 2009; Campbell and Landers 2013).

In wild fish populations, the incidence of SBS has been documented by Code (1950) who reported this condition in *Oncorhynchus clarkii* (Richardson 1836), Lewis (1961) recorded it in *O. nerka* (Walbaum 1792), family Salmonidae. Lemly (1993) mentioned that the cause of deformities in 10 fish species, including *Lepomis cyanellus* Rafinesque, 1819 (Centrarchidae), is selenium contamination. Browder et al. (1993) recorded this syndrome in species of the families Haemulidae, Lutjanidae, Sparidae attributed to aquatic pollution. Koumoundouros (2008) and Bhushan et al. (2020) identified this syndrome in a species of the family Labridae and Stromateidae respectively.

This syndrome has been reported in only three species of the family Cichlidae, in *Etroplus suratensis* (Bloch, 1790), *Heros severus* Heckel, 1840 and *Oreochromis aureus* (Steindachner, 1864) (Tave et al. 1983, 2011; Jayaprabha et al. 2016; Rahmati-Holasoo et al. 2016). This study documents for the first time saddleback syndrome in a wild-caught firemouth cichlid *Thorichthys meeki* Brind, 1918, a species widely distributed on the Atlantic slope of south-eastern Mexico (López-Segovia 2021).

MATERIAL AND METHODS

Specimens of *T. meeki* were collected by trawling net 3 m long and 1 cm mesh in an aquatic system known locally as “Ojo de Agua” (18°49'37.6" N; 91°00'57.2" W), in the locality of Chekubul, municipality of Carmen, Campeche, Mexico on 18 November 2022 (Fig. 1).

Organisms were fixed with formaldehyde (10%), preserved in ethyl alcohol (70%) and deposited in the Ichthyological Collection of the Facultad de

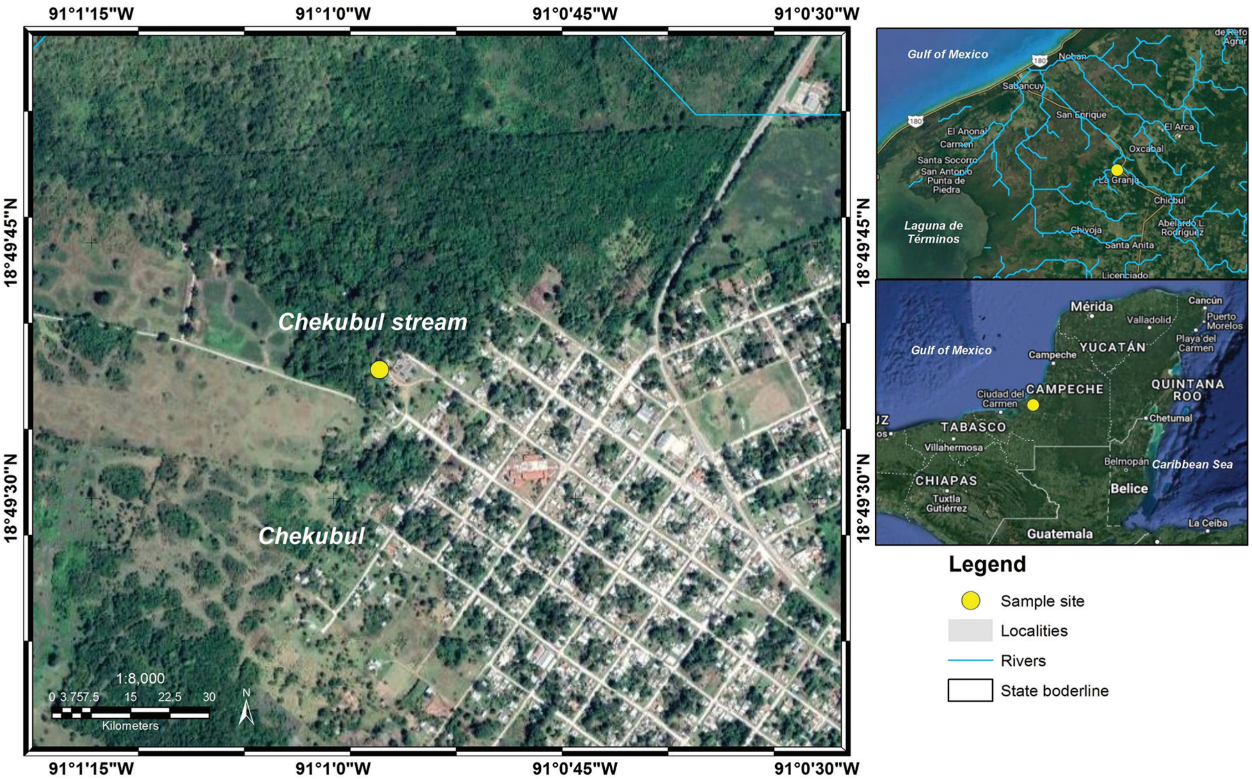

Fig. 1. Sample site of *Thorichthys meeki* in "Ojo de Agua" (18°49'37.6" N; 91°00'57.2" W), Chekubul, Campeche, Mexico.

Estudios Superiores Iztacala (CIFI-2142), Universidad Nacional Autónoma de México. Meristic data and morphological measurements were taken from each specimen with a vernier (±0.01 mm) (Table 1). Their identity was corroborated at a specific level using specialized keys (Miller et al. 2009). The specimens were photographed *in situ* and the anatomical description of the anomaly was complemented by comparative X-ray analysis. Five specimens of *T. meeki* without anomalies were diaphonized with KOH solution (10%) and stained with alizarin red to corroborate and compare bone structure, meristics and fin support elements.

RESULTS

Sixteen specimens of *T. meeki* (44.3–60.5 mm standard length [*SL*]) were obtained (Fig. 2A), which showed normal development of the even and odd fins and no body anomalies. Specimens without anomalies had a dorsal fin with XV–XVII (regularly XVI) spines and 8–10 (9) dorsal rays and an anal fin with VIII–X (IX) spines, 7–8 anal rays and 24 dorsal pterygiophores. However, one of them (53.2 mm *SL*) had a malformation in the dorsal region (Fig. 2B). The meristic data are consistent with those recorded for the species with the exception of the dorsal fin radial formula 12 (9+3) spines in the anomalous specimen.

The anomalous specimen showed a normal development of the dorsal fin from the first to the ninth dorsal spine, from this spine begins the dorsal concavity typical of the syndrome, and the absence of X to XIII dorsal spines (Fig. 3B). The dorsal fin continues with normal growth with the presence of three dorsal spines and 8 dorsal rays without modifications in its development, as well as the distal and middle pterygiophores (10–13), which must be articulated by the proximal pterygiophores (10 to 13) (Fig. 3B,C). The proximal pterygiophores showed an underdevelopment or modification on the dorsal surface of the bone connecting to the base of the dorsal fin and are smaller than the proximal pterygiophores 1–9 and 14 onwards, which showed no abnormalities (Fig. 3). In

Table 1. Saddleback syndrome reported in fish species, body abnormalities identified and possible causes.

Order / Family / Species	Abnormalities	Causes	Region, country	Reference
SALMONIFORMES				
Salmonidae				
Oncorhynchus clarkii (Richardson, 1836)	Dorsal fin and dorsal concavity absent	Unidentified	Sheep Creek, Utah, United States	Code 1950
Oncorhynchus nerka (Walbaum, 1792)	Dorsal fin rays, distal and proximal bones absent. No dorsal curvature	Dorsal fin underdevelopment	Kvichak River, Alaska, United States	Lewis 1961
SCOMBRIFORMES				
Stromateidae				
Pampus argenteus (Euphrasen, 1788)	Dorsal region and fin deformed, pterygiophores absent	High levels of pollution by heavy metals and hydrocarbon in water	Khasab area, Omani coast of the Arabian Gulf, Oman	Jawad and Al-Mamry 2012
Pampus argenteus (Euphrasen, 1788)	Dorsal fin rays and pterygiophores absent. Dorsal curvature	Possible physical injuries from fishing gear	Satpati landing centre, Maharastra, India	Bhushan et al. 2020
CARANGIFORMES				
Carangidae				
Parastromateus niger (Bloch, 1795)	Abnormal neural spines, pterygiophores and spines absent. Dorsal curvature	Unidentified	Visakhapatnam fishing harbour, Andhra Pradesh, South East coast, India	Silambarasan et al. 2021
CICHLIFORMES				
Cichlidae				
Etroplus suratensis (Bloch, 1790)	Pterygiophores absent, dorsal fin deformed. Dorsal curvature	Genetics, water quality, rearing conditions, injury or pollution	Parangipettai landing centre, southeast coast, India	Jayaprabha et al. 2016
Heros severus (Heckel, 1840)	Vertebrae, anal and dorsal pterygiophores deformed. Dorsal spines absent. Dorsal curvature	Genetics, absence of natural selection, inbreeding	Ornamental fish farm of Karaj and Theran, Iran	Rahmati-Holasoo et al. 2016
Oreochromis aureus (Steindachner, 1864)	Vertebrae 1–3 deformed. Dorsal fin and pterygiophores partial or complete absent. Dorsal curvature	By an autosomal dominant lethal allele	Ponds at Auburn University, United States	Tave et al., 1983; Tave et al. 2011
Thorichthys meeki (Brind, 1918)	Pterygiophores slightly deformed. Dorsal fin spines absent. Dorsal curvature	Aquatic contamination, predation injury or developmental defect	Campeche, México	This study
PERCIFORMES				
Epinephelidae				
Epinephelus akaara (Temminck and Schlegel, 1843)	Pterygiophores and neural spines deformed. Dorsal curvature	Developmental defect	Tsuda, Sanuki, Kagawa, Japan	Akashi and Abe 2011
Labridae				
Sparisoma cretense (Linnaeus, 1758)	Dorsal fin spines and pterygiophores absence. Dorsal curvature	Ontogenetic abnormalities	Leipsoi island, Dodecanese, eastern Aegean Sea, Greece	Koumoundouros 2008
Scorpaenidae				
Pterois miles (Bennett, 1828)	Dorsal depression, pterygiophores, spines and rays fins short or absent	Possible physical injuries from fishing gear	Cape Kiti, Konnos Bay, Cyprus	Jimenez et al. 2022

Order / Family / Species	Abnormalities	Causes	Region, country	Reference
Pterois volitans (Linnaeus, 1758)	Dorsal fin spines absent, fused pterygiophores. Dorsal curvature	Possible physical injury	Alacranes Reef, Yucatan, Mexico	Aguilar-Perera and Quijano-Puerto 2018
		CENTRARCHIFORMES		
Kyphosidae				
Kyphosus sectatrix (Linnaeus, 1758)	Dorsal fin incomplete, slightly dorsal curvature	Aquatic pollution by heavy metals, chlorinated hydrocarbons (CHC) and polychlorinated biphenyls (PBC's)	Biscayne Bay, Florida, United States	Valentine and Soule 1973; Valentine 1975; Browder et al. 1993
Centrarchidae				
Lepomis cyanellus (Rafinesque, 1819)	Pterygiophores absent. Dorsal curvature	Aquatic contamination by selenium	Belews Lake, High Rock Lake, Badin Lake, North Carolina, USA	Lemly 1993
		ACANTHURIFORMES		
Moronidae				
Dicentrarchus labrax (Linnaeus, 1758)	Partial or complete absence of lepidotrichia and pterygiophores deformed	Developmental defect appearing at the beginning of ontogeny	Commercial hatchery	Fragkoulis et al. 2017
Lutjanidae				
Lutjanus griseus (Linnaeus, 1758)	Incomplete dorsal fin and dorsal spines absent	Aquatic pollution by heavy metals, chlorinated hydrocarbons (CHC) and polychlorinated biphenyls (PBC's)	Biscayne Bay, Florida, USA	Valentine and Soule 1973; Valentine 1975; Browder et al. 1993
Haemulidae				
Haemulon parra (Desmarest, 1823)	Incomplete dorsal fin. Dorsal curvature	Aquatic pollution by heavy metals, CHC, PBC's	Biscayne Bay, Florida, USA	Valentine and Soule 1973; Valentine 1975; Browder et al. 1993
Haemulon plumierii (Lacepède, 1801)	Incomplete dorsal fin. Dorsal curvature	Aquatic pollution by heavy metals, CHC, PBC's	Biscayne Bay, Florida, USA	Valentine and Soule 1973; Valentine 1975; Browder et al. 1993
Haemulon sciurus (Shaw, 1803)	Incomplete dorsal fin and dorsal curvature	Aquatic pollution by heavy metals, CHC, PBC's	Biscayne Bay, Florida, USA	Valentine and Soule 1973; Valentine 1975; Browder et al. 1993
Sparidae				
Acanthopagrus australis (Günther, 1859)	Dorsal spines and pterygiophores absent. Dorsal curvature	Industrial pollutans	South Stradbroke Island, Gold Coast, Queensland, Australia	Campbell and Landers 2013
Acanthopagrus australis (Günther, 1859)	Dorsal curvature and partial absence of the dorsal fin	Physical injuries by piscivorous birds, predatory fish or fishing gear, ectoparasite injuries	Logan River, Nerang River, Moreton Bay, Australia	Pollock 2015
Archosargus rhomboidalis (Linnaeus, 1758)	Dorsal fin incomplete, slightly dorsal curvature	Aquatic pollution by heavy metals, CHC, PBC's	Biscayne Bay, Florida, USA	Valentine and Soule 1973; Valentine 1975; Browder et al. 1993

Order / Family / Species	Abnormalities	Causes	Region, country	Reference
Diplodus argenteus (Valenciennes, 1830)	Dorsal fin incomplete, dorsal curvature	Aquatic pollution by heavy metals, CHC, PBC's.	Biscayne Bay, Florida, USA	Valentine and Soule 1973; Valentine 1975; Browder et al. 1993
Lagodon rhomboides (Linnaeus, 1766)	Incomplete dorsal fin	Aquatic pollution by heavy metals, CHC, PBC's	Biscayne Bay, Florida, USA	Valentine and Soule 1973; Valentine 1975; Browder et al. 1993
Dentex dentex (Linnaeus, 1758)	Abnormal pterygiophores. Dorsal spines absent	Ontogenetic abnormalities	Fish farm	Koumoundourous et al. 2001
Diplodus sargus (Linnaeus, 1758)	Pterygiophores deformed and dislocated. V-shaped dorsal profile	Ontogenetic abnormalities	Fish farm	Sfakianakis et al. 2003
		TETRAODONTIFORMES		
Ostraciidae				
Acanthostracion quadricornis (Linnaeus, 1758)	Antero-dorsal curvature	Aquatic pollution by heavy metals, CHC, PBC's	Biscayne Bay, Florida, USA	Valentine and Soule 1973; Valentine 1975; Browder et al. 1993
Sphoeroides testudineus (Linnaeus, 1758)	Dorsal curvature	Aquatic pollution by heavy metals, CHC, PBC's	Biscayne Bay, Florida, USA	Valentine and Soule 1973; Valentine 1975; Browder et al. 1993

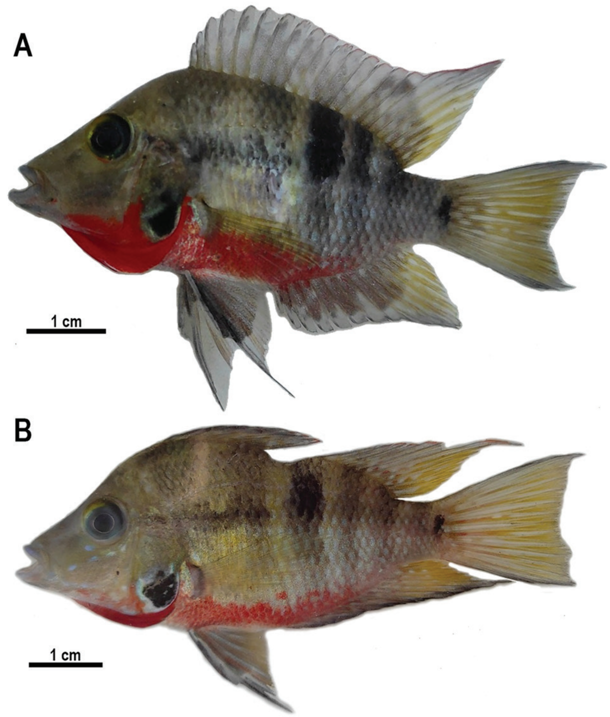

Fig. 2. Specimens of *Thorichthys meeki* collected in the Chekubul stream, Campeche: A – Specimen without vertebral deformation (CIFI-2142); B – Specimen with mid-dorsal saddleback syndrome and interrupted dorsal fin (CIFI-2030).

lateral view, this syndrome begins at the end of the second lateral bar and ends at the end of the third, the area occupied by the lateral dark spot. The rest of the body shows a normal development of which no irregularities are evident (Fig. 2).

Internally, the anomalous specimen showed no alterations in the development of the skeletal structures, and there was no increase or reduction in the number or shape of the abdominal vertebrae (12), caudal vertebrae (12) or in the neural spines that support them. Neither did it show scoliosis or lordosis, which could have hindered its development in the wild (Fig. 3B, C).

The length of the dorsal fin base was not reduced compared to the normal *T. meeki* (Fig. 3). Likewise, the color of the fish is similar to the rest of its congeners. The cephalic region showed no visually discernible abnormalities and/or modifications in the predorsal area. Similarly, the odd and even fins did not show any alterations in their development.

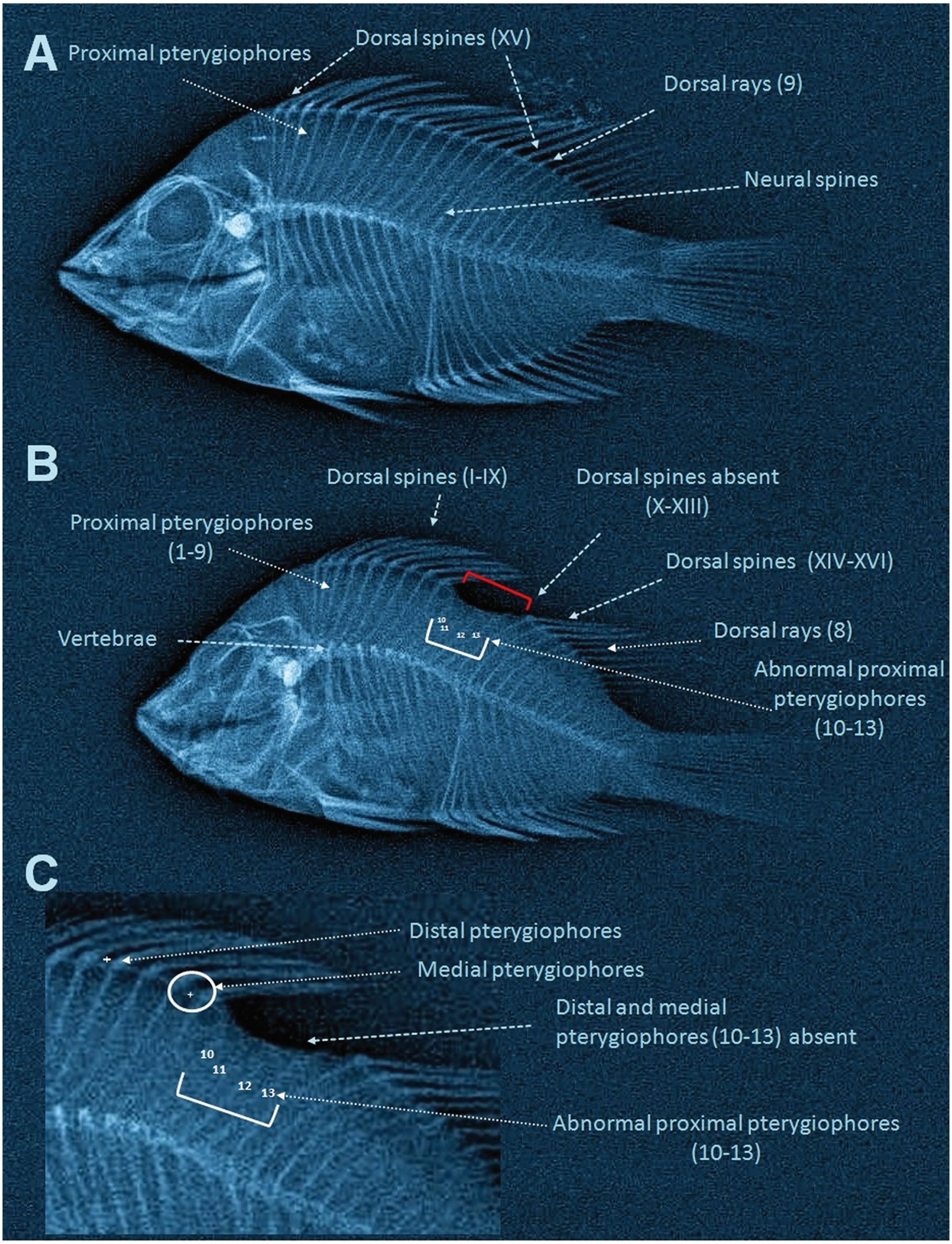

Fig. 3. Radiographs of *Thorichthys meeki* specimens: A – Specimen with normal body development, 60.5 cm *SL* (CIFI-2142); B, C – Specimen with saddleback syndrome (53.2 mm *SL*; CIFI-2030), interruption of the dorsal fin is indicated by arrows. Dotted arrows indicate the pterygiophores and the red line indicates the modified pterygiophores (10–13) and the region, where the saddleback syndrome is located.

DISCUSSION

Saddleback syndrome has been identified in wild fish and aquaculture farms in Asia, Oceania, the Persian Gulf, the Mediterranean Sea and America (Table 1). The causes of saddleback syndrome are diverse, but it is mainly associated with developmental ontogenetic defects, aquatic contamination by chemical pollutants or pollutants of industrial origin, or to a lesser extent physical injury (Valentine and Soule 1973; Valentine 1975; Browder et al. 1993; Koumoundouros 2008; Campbell and Landers 2013; Aguilar-Perera and Quijano-Puerto 2018). This abnormality has been identified in 26 species and 14 families, with the families Salmonidae, Haemulidae and Cichlidae with the most records, and the United States being the region with the highest number of affected species (14 species) (Table 1).

In Mexico the only record of saddleback syndrome is in *Pterois volitans* (Linnaeus, 1758), an invasive species in the southern Gulf of Mexico, the possible cause of this anomaly was attributed to a physical injury (Aguilar-Perera and Quijano-Puerto 2018). This could be a cause of the development of SBS in the anomalous specimen of *T. meeki* (Fig 2B), from a predator attack in the juvenile stage, as in *Pterois volitans*, however, no other larger fish species or other vertebrate species were identified as possible predators at the collection site. In fact, the occurrence of saddleback syndrome in wild specimens attributed to predation is rare (Almatar and Chen 2010; Pollock 2015; Jawad et al. 2017; Aguilar-Perera and Quijano-Puerto 2018) (Table 1).

Browder et al. (1993) recorded 17 species belonging to 12 families in Biscayne Bay with some deformity, of which 10 developed saddleback syndrome (Table 1). However, the cause was not attributed to physical injury but to some common agent that may have caused the deformity in the species as the organisms showed no evidence of scarring. Valentine and Soule (1973) end Valentine (1975) suggested that the factors causing skeletal abnormalities in fishes are the effects of heavy metal contamination, chlorinated hydrocarbons and polychlorinated biphenyls (PBC's) (Table 1). Also, selenium contamination has been reported to cause abnormalities in 22 fish species, such as lordosis, kyphosis, fin anomalies, exophthalmia, included the saddleback syndrome reported in *Lepomis cyanellus* with the absence of pterygiophores (Browder et al. 1993; Lemly 1993).

The development of saddleback syndrome in fishes caused by contaminants was also reported by Jayaprabha et al. (2016) in *E. suratensis* (Bloch, 1790), whose deformation was found in the first three dorsal spines, similar to that reported by Koumoundouros (2008) in *Sparisoma cretense* (Linnaeus 1758), with the absence of the first two dorsal spines and in *Acanthopagrus australis* (Günther, 1859) (Campbell and Landers 2013). In these cases there is the absence of the proximal dorsal pterygiophores in the affected area as well as in *T. meeki*. Jawad and Al-Mamry (2012) reported on specimens of *Pampus argenteus* (Euphrasen, 1788) with more severe anomalies, where the dorsal fin was deformed or completely absent and all neural spines and thoracic vertebrae were anomalous. These abnormalities are associated with high levels of heavy metals and hydrocarbon contamination (Table 1).

In addition, fishes with saddleback syndrome may develop other body abnormalities that are not associated with the bony structures primarily affected in SBS (proximal, medial, distal pterygiophores, neural spines and dorsal fin). Among the anomalies recorded are the lateral line deformities developed in *Acanthopagrus australis* (Pollock, 2015), short body profile in *Pampus argenteus* (Bhushan et al. 2020), deformities in the ventral region (Rahmati-Holasoo et al. 2016), absence or deformation of pectoral, pelvic or anal fins (Tave et al. 1983; Tave et al. 2011; Fragkoulis et al. 2017), deformation in caudal vertebrae or caudal fin (Akashi and Abe 2011; Koumoundouros 2008) (Table 1). However no other body anomalies were identified in the abnormal *T. meeki* specimen, also it was not possible to identify in this species whether the incidence of SBS is associated with aquatic contamination at the collection site (Fig. 3).

There is evidence that saddleback syndrome affects the survival of fishes and this abnormality interferes with biological activities such as feeding, and growth rate which is often slower, however some fishes can live to the adult stage (Pollock 2015; Rahmati-Holasoo et al. 2016; Ribeiro-Prado et al. 2008). As a case, Rahmati-Holasoo et al. (2016) kept alive an adult *H. severus*, which had SBS and had difficulty swimming and was slower compared to its congeners.

The firemouth cichlid is known for its aggressiveness in defending its territory against other competitors or predators, in order to appear more dominant it tends to expand its opercular region and its fins, mainly the dorsal fin. The development of saddleback syndrome in *T. meeki* (Fig. 2), which caused the malformation of the dorsal fin, may have contributed to the abnormal function and thus affected their behavior, defense, reproduction or mobility as they use the dorsal fin to maintain stability (Al-Mamry et al. 2010; Aguilar-Perera and Quijano-Puerto 2018; Jawad et al. 2018).

According to the different records of saddleback syndrome (Table 1), it is evident that this condition often manifests itself in different ways and may contribute to the development of other body or skeletal abnormalities in fishes. Campbell and Landers (2013), suggested that further studies are needed to determine the associated factors and the difference between saddleback syndrome (no presence of dorsal pterygiophores, dorsal elements and the presence of a dorsal concavity) with respect to the similar deformities found in specimens of *Epinephelus akaara* (Temminck and Schlegel, 1843) and *Diplodus sargus* (Linnaeus, 1758), in which dorsal pterygiophores are present but modified or deformed (Sfakianakis et al. 2003; Akashi and Abe 2011). These studies allow us to better understand how the syndrome affects the species and the factors involved, as well as to begin to establish strategies for the sustainable maintenance of fisheries resources.

CONCLUSION

The main causes of the development of saddleback syndrome in fishes are correlated with aquatic pollution, abnormal ontogenetic development and less by physical injury. A study focused on the analysis of the physico-chemical parameters of the aquatic system of Chekubul would allow the identification of factors that could cause the development of this syndrome in *T. meeki* or if it is causing other affections in other fish species. Furthermore, such studies would be relevant in this site, since this spring functions as a recreational site for the local people, so identifying any toxic factor could prevent a public health situation that could put the inhabitants of Chekubul at risk and at the same time, contribute to the conservation of the natural resources in this region.

ACKNOWLEDGEMENTS

The first author is grateful to the Posgrado en Ciencias del Mar y Limnología and the Missing H, Scholarship (932500). LFDMF thanks SNI-CONAHCYT and to Programa de Apoyo a Proyectos de Apoyo a Proyectos de Investigación e Innovación Tecnológica (PAPIIT-UNAM IA207820), Universidad Nacional Autónoma de México for the support provided.

REFERENCES

Aguilar-Perera A. and Quijano-Puerto L. 2018. Saddleback syndrome in the lionfish *Pterois volitans* (Linnaeus 1758) (Scorpaenidae) in the southern Gulf of Mexico. *Cahiers de Biologie Marine*, **59**(3): 301–304. https://doi.org/10.21411/CBM.A.AA897A72

Akashi H. and Abe Y. 2011. Saddleback syndrome deformity in hatchery-reared red spotted grouper *Epinephelus akaara*, and its possible use in stock separation studies. *Bulletin of the Kagawa Prefectural Fisheries Experimental Station*, **12**: 13–18. https://doi.org/10.1007/s12562-017-1068-2

Al-Mamry J.M., Jawad L.A., Al-Rasady I.H. and Al-Habsi S.H. 2010. First record of dorsal and anal fin deformities in silver pomfrets *Pampus argenteus* (Stromateidae, Actinopterygii). *Anales de Biología*, **32**: 73–77.

Almatar S. and Chen W. 2010. Deformities in silver pomfrey *Pampus argenteus* caught from Kuwait waters. *Chinese Journal of Oceanology and Limnology*, **28**(6): 1227–1229. https://doi.org/10.1007/s00343-010-0082-3

Bhushan S., Murugesan S.H., Nama S. and Shahana S. 2020. Occurrence of saddle back syndrome in *Pampus argenteus* from North-West Coast of India. *Journal of Krishi Vigyan*, **9**(si): 214–217. https://doi.org/10.5958/2349-4433.2020.00107.5

Browder J.A., McClellan D.B., Harper D.E., Kandrashoff M.G. and Kandrashoff W. 1993. A major developmental defect observed in several Biscayne Bay, Florida, fish species. *Environmental Biology of Fishes*, **37**(2): 181–188. https://doi.org/10.1007/BF00000593

Campbell M.J. and Landers M. 2013. Tactical Research Fund: Incidence and Possible Causes of saddleback syndrome in the fish species of south East Queensland. FRDC Final Reports. Fisheries Research and Development Corporation, 53 p.

Code M.R. 1950. Cutthroat trout without dorsal fins. *The Progressive Fish-Culturist*, **12**(2): 85–86. https://doi.org/10.1577/1548-8640(1950)12[85:CTWDF]2.0.CO;2

Fragkoulis S., Paliogiannis H., Kokkinias P., Chiers K., Adriaens D. and Koumoundouros G. 2017. Saddleback syndrome in European sea bass *Dicentrarchus labrax* (Linnaeus, 1758): anatomy, ontogeny and correlation with lateral-line, anal and pelvic fin abnormalities. *Journal of fish diseases*, **40**(1): 83–95. https://doi.org/10.1111/jfd.12494

Jawad L.A. and Al-Mamry J.M. 2012. Saddleback syndrome in wild silver pomfret *Pampus argenteus* (Euphrasen, 1788) (Family: Stromatidae) from the Arabian Gulf coasts of Oman. *Croatian Journal of Fisheries: Ribarstvo*, **70**(3): 135–142.

Jawad L.A., Akyol O. and Aydin D. 2017. First records of saddleback syndrome and Pughead deformities in the common Pandora *Pagellus erythrinus* (Linnaeus, 1758) (Teleostei: Sparidae) from wild population in the Northern Aegean Sea, Turkey. *International Journal of Marine Science*, **7**(19): 183–187.

Jawad L., Ibrahim M. and Waryani B. 2018. Incidences of caudal fin malformation in fishes from Jubail City, Saudi Arabia, Arabian Gulf. *Fisheries & Aquatic Life*, **26**(1): 65–71. https://doi.org/10.2478/aopf-2018-0008

Jayaprabha N., Purushothaman S. and Srinivasan M. 2016. First record of saddle back syndrome in wild species, *Etroplus suratensis* (Bloch, 1790) from the southeast coast of India. *Indian Journal of Geo Marine Sciences*, **45**(11): 1536–1539.

Jimenez C., Aguilar-Perera A., Dimitriou A.C., Papatheodoulou M. and Patsalou P. 2022. Saddleback syndrome in the common Lionfish *Pterois miles* (Scorpaeniformes: Scorpaenidae) off Cyprus, Eastern Mediterranean Sea. *Thalassas*, **38**: 487–492. https://doi.org/10.1007/s41208-022-00403-x

Koumoundouros G. 2008. First record of saddleback syndrome in wild parrotfish *Sparisoma cretense* (L., 1758) (Perciformes, Scaridae). *Journal of Fish Biology*, **72**(3): 737–741. https://doi.org/10.1111/j.1095-8649.2007.01714.x

Koumoundouros G., Divanach P. and Kentouri M. 2001. The effect of rearing conditions on development of saddleback syndrome and caudal fin deformities in *Dentex dentex* (L.). *Aquaculture*, **200**: 285–304. https://doi.org/10.1016/S0044-8486(01)00552-X

Lemly A. 1993. Teratogenic effects of selenium in natural populations of freshwater fish. *Ecotoxicology and Environmental Safety*, **26**(2): 181–181. https://doi.org/10.1006/eesa.1993.1049

Lewis D.E. 1961. Sockeye Salmon *Oncorhynchus nerka* without a dorsal fin. *Copeia,* **1961**(1): 116–117. https://doi.org/10.2307/1440192

López-Segovia E. 2021. Sistemática y biogeografía del género *Thorichthys* (Actinopterygii; Cichlidae) en México. MS thesis. Posgrado en Ciencias del Mar y Limnología, Universidad Nacional Autónoma de México, CDMX. México, 177 p.

Miller R.R., Minckley W.L. and Norris S.M. 2009. Peces dulceacuícolas de México. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, Sociedad Ictiológica Mexicana A. C., El Colegio de la Frontera Sur y Consejo de los Peces del Desierto México Estados Unidos, Ciudad de México, 559 p.

Pollock B.R. 2015. Saddleback syndrome in yellowfin bream *Acanthopagrus australis* (Günther, 1859) in Moreton Bay, Australia: its form, occurrence, association with other abnormalities and cause. *Journal of Applied Ichthyology,* **31**(3): 487–493. https://doi.org/10.1111/jai.12437

Rahmati-Holasoo H., Isfahani F., Rostami A., Vajhi A., Ebrahimzadeh-Mousavi H. and Sattari M. 2016. Skeletal deformities in banded cichlid (*Heros severus*): clinical and radiographic diagnosis. *Iranian Association of Aquatic Animal Health,* **2**(1): 73–79. https://doi.org/10.18869/acadpub.ijaah.2.1.73; http://ijaah.ir/article-1-102-en.pdf

Ribeiro-Prado C.C., Oddone M.C., Bueno-Gonzalez M.M.B., Ferreira de Amorim A. and Capapé C. 2008. Morphological abnormalities in skates and rays (Chondrichthyes) from off southeastern Brazil. *Arquivos de Ciências do Mar del Fortaleza*, **41**(2): 21–28. https://doi.org/10.32360/acmar.v41i2.6058

Sfakianakis D.G., Koumoundouros G., Anezaki L., Divanach P. and Kentouri M. 2003. Development of a saddleback-like syndrome in reared white seabream *Diplodus sargus* (Linnaeus, 1758). *Aquaculture,* **217**(1–4): 673–676. https://doi.org/10.1016/S0044-8486(02)00199-0

Silambarasan K., Govindaraj K., Kar A.B., Prasad G.V.A., Pattnayak S.K. and Ramalingam L. 2021. Saddleback Syndrome in Wild Black Pomfret *Parastromateus niger* (Bloch, 1795), From Southeast Coast of India. *Thalassas,* **37**: 209–214. https://doi.org/10.1007/s41208-021-00287-3

Sun P.L., Hawkins W.E., Overstreet R.M. and Brown-Peterson N.J. 2009. Morphological deformities as biomarkers in fish from contaminated rivers in Taiwan. *International Journal Environmental Research and Public Health*, **6**(8): 2307–2331. https://doi.org/10.3390/ijerph6082307

Tave D., Bartels J.E. and Smitherman R.O. 1983. Saddleback: a dominant, lethal gene in *Sarotherodon aureus* (Steindachner) (=*Tilapia aurea*). *Journal of Fish Diseases*, **6**(1): 59–73. https://doi.org/10.1111/j.1365-2761.1983.tb00051.x

Tave D., Jo J.Y. and Kim D.S. 2011. Gross abnormalities in tilapia. *Fisheries and Aquatic Sciences*, **14**(2): 148–160. https://doi.org/10.5657/FAS.2011.0148

Valentine D.W. and Soule M.E. 1973. Effect of p,p'-DDT on developmental stability of pectoral fin rays in the grunion, *Leuresthes tennuis*. *Fishery Bulletin*, **71**(4): 921–926.

Valentine D.W. 1975. Skeletal anomalies in marine teleosts. In: W.E. Ribelin and G. Migaki (Eds). The Pathology of Fishes. University of Wisconsin Press, Madison, WI: 695–718.