ISSN 0032-9452, Journal of Ichthyology, 2018, Vol. 58, No. 3, pp. 401–409. © Pleiades Publishing, Ltd., 2018.

Saddleback Deformities in Fish Species Collected from the Arabian Gulf Coast of Jubail City, Saudi Arabia[1]

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Received September 11, 2017

Abstract—The saddleback syndromes were observed in several commercial fishes obtained from Saudi Arabian coast of the Arabian Gulf. These deformities resulting in missing dorsal spines or rays, sometimes accompanied by a depression in the dorsal profile, were found in ten fish species from seven families. Other morphological abnormalities such as scale disturbances, lateral line deformity, and kyphosis, the presence of a lesion, slight ambicoloration, and supraneural deformities accompanying the saddleback deformity were also observed. The occurrence of similar deformities across such a spectrum of fishes from the same location suggests that the abnormalities were induced by something in the environment common to all these species.

Keywords: dorsal fin, aberration, lateral line, kyphosis, ambicoloration, Teleostei, Saudi Arabia

DOI: 10.1134/S0032945218030049

INTRODUCTION

The 16th century marks the first documentation of fish morphological anomalies (Gudger, 1936). Since then, the cases of deformities have attracted the attention of several investigators and a great number of studies document the appearance of various types of abnormalities (Dawson 1964, 1966, 1971; Dawson and Heal, 1971; Browder et al., 1993; Jawad, 2005; Al-Jufaily et al., 2005; Boglione et al., 2006; Jawad and Hosie, 2007; Jawad and Öktoner, 2007; Koumoundouros, 2008; Pollock, 2015a, 2015b). Due to unfavorable environmental conditions and different pollution types, skeletal deformities developed during the early life stages (Lemly, 1993; Sfakianakis et al., 2006). Such anomalies also happened due to inbreeding and mutations (Gjerde et al., 2005). Therefore, skeletal deformities have been considered as an important indicator of the environmentally induced stress of fish in the wild (Lemly, 1993; Boglione et al., 2006; Koumoundouros, 2008). In addition, they give a frequent problem for product quality in finfish aquaculture (Boglione et al., 2013). The effect of the skeletal deformities covers squamation, body pigmentation, and body shape at different frequencies reaching up to 100% (Koumoundouros, 2010).

Tave et al. (1983) were considered the first to use the term saddleback syndrome in abnormality cases of different degrees of lack of dorsal fin in tilapia *Sarotherodon aureus*. Later, investigators in fish anomaly field have associated saddleback syndrome with severe deformities of the dorsal profile of the fish resulted from deformed dorsal fin pterygiophores. Reports of the saddleback syndrome from aquaculture have dominated the literature of this anomaly. (Koumoundouros et al., 2001; Boglione et al., 2003; Setiadi et al., 2006; Koumoundouros, 2010; Cobcroft and Battaglene, 2013). Furthermore, the saddleback syndrome has been described in wild fish around the world (Browder et al., 1993; Koumoundouros, 2008; Jawad and Al-Mamry, 2012; Diggles, 2013; Boglione et al., 2013; Pollock, 2015; Fragkoulis et al., 2017).

Causes of the saddleback syndrome in the wild population have been related to physical injuries (James and Badrudeen, 1968; Almatar and Chen, 2010), development in non-healthy water conditions (Browder et al., 1993; Lemly, 1993; Jawad and Al-Mamry, 2012), and genetic factors (Tave et al., 1983).

Reports on the cases of the saddleback syndrome have only recently been on record in the literature about fishes living in the Sea of Oman and the Arabian Gulf areas (Almatar and Chen, 2010; Jawad and Al-Mamry, 2012). All these records were originated from the Arabian Gulf area and observed in the reared silver pomfret from Kuwait (Almatar and Chen, 2010) and from wild populations of *Pampus argenteus* from Sultanate of Oman (Jawad and Al-Mamry, 2012).

There were no previous records of the saddleback syndrome from the Arabian coasts of Saudi Arabia. Therefore, the aims of the present study are as follows: (1) documenting 17 cases of saddleback syndrome

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Table 1. Fish specimens collected from the vicinity of Jubail City, Saudi Arabia shoed saddleback syndrome

Species	Family	Number of specimens	Length, mm		Index of SBS		
			total	standard	depth	width	location
Epinephelus areolatus	Epinephelidae	2	325, 330	317, 318	11.6, 6.6	8.6, 8.9	92.3, 73.6
Epinephelus epistictus	Epinephelidae	1	326	317	18.7	4.2	55.2
Carangoides bajad	Carangidae	2	335, 401	322, 390	3.3, 10.38	13.8, 6.4	40.1, 37.7
Diagramma pictum	Haemulidae	2	390, 395	381, 384	6.2, 6.0	6.4, 14.8	25.6, 48.6
Plectorhinchus sordidus	Haemulidae	2	367, 389	356, 377	6.9, 3.5	17.1, 11.8	29.4, 28.9
Acanthopagrus bifasciatus	Sparidae	2	334, 336	323, 325	49, 5.3	7.9. 14.9	21.2, 51.5
Argyrops spinifer	Sparidae	2	330, 450	318, 446	11.2,7.3	8.8, 11.1	24,54
Lethrinus nebulosus	Lethrinidae	1	340	331	12.9	16.8	45.2
Nemipterus japonicus	Nemipteridae	1	276	265	4.3	7.5	14.7
Platax teira	Ephippidae	1	446	435	11.4	25.2	54.5

SBS—saddleback syndrome.

observed in ten teleosts species; and (2) describe these cases from the anatomical point of view.

MATERIALS AND METHODS

Saddleback syndrome (Table 1). They were captured in the period from February 26, 2013 to September 21, 2016 in the waters of Jubail City, Saudi Arabia. The specimens were collected by local fishermen using drifting gill nets. Normal specimens with normal body shape were used for a comparison. Body and fins were examined carefully for external parasites, malformations, amputations, and any other morphological anomalies. The specimens were deposited in the fish collection of the Fish Welfare Branch, Jubail, Saudi Arabia. Once in the laboratory, measurements were recorded to the nearest millimeter. To examine the skeletal abnormalities in the specimens studied, fish were transferred to Jubail Hospital for radiography.

The measurements of Dsbs, the distance from the dorsal margin to the deepest extent of the deformity; Db, the largest vertical distance from the dorsal margin to the ventral margin; Wsbs, Wsbs is the length of the deformity on the dorsal margin; and Lsbs, Lsbs is the anterior-posterior distance from the mouth to the deepest part of the deformity were made to the nearest mm. for all the examined specimens to calculate the three indices used to calculate the extent and location of the saddleback deformity. The relative depth of the deformity into the dorsal margin.

Index of SBS depth = Dsbs/Db × 100, where Dsbs is the distance from the dorsal margin to the deepest extent of the deformity, and Db is the largest vertical distance from the dorsal margin to the ventral margin. The relative width of this deformity along the dorsal margin:

Index of SBS width = Wsbs/*TL* × 100, where Wsbs is the length of the deformity on the dorsal margin, and *TL* is the total length (Fig. 1). The relative anterior-posterior position of the deformity on the dorsal margin:

Index of SBS location = Lsbs/*TL* × 100, where Lsbs is the anterior-posterior distance from the mouth to the deepest part of the deformity.

RESULTS

Partially and completely deformed dorsal fin cases were observed in ten species of seven families studied. The description of the saddleback syndrome deformity in each species studied is given.

Family: Epinephelidae

Epinephelus areolatus (Forsskäl, 1775), *specimen no. 1,* 325 mm *TL*, 317 mm *SL* (Fig. 2a). The saddleback is located in the soft ray part of the dorsal fin. The first three rays were deformed and four to nine rays were absent. The affected area is 17 mm depth and 28 mm long. No other fish body parts have been affected by the saddleback syndrome.

Specimen no. 2, 330 mm *TL*, 318 mm *SL* (Fig. 2b). The spinous part of the dorsal fin is affected with the saddleback. The spines 4–6 were completely absent. Another saddleback is located at the posterior end of the soft part of the dorsal affecting the rays nine to 13. The anterior area of the saddleback is 8.8 mm depth and 29.4 mm long. The posterior saddleback area is ten mm depth and 31.2 mm long. No anomalies have been shown.

Epinephelus epistictus (Temminck and Schlegel, 1842), 326 mm *TL*, 317 mm *SL* (Fig. 2c).

The saddleback is located in the middle of the spinous part of the dorsal fin. No spines were missing, but the 5–7 and the penultimate spines were deformed. The rays in the soft part of the dorsal fin

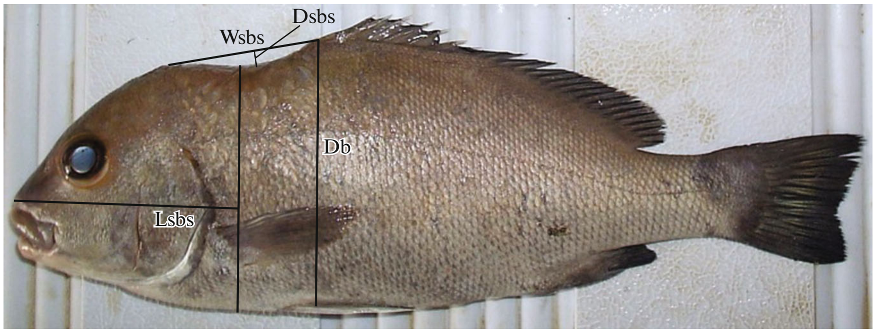

Fig. 1. *Plectorhinchus sordidus*, 367 mm *TL*, 356 mm *SL* showing saddleback posterior to the skull. It also shows body measurements to assist the evaluation of the saddleback. Dsbs—distance from the dorsal margin to the deepest extent of the deformity, Db—largest vertical distance from the dorsal margin to the ventral margin, Wsbs—length of the deformity on the dorsal margin, Lsbs—anterior-posterior distance from the mouth to the deepest part of the deformity.

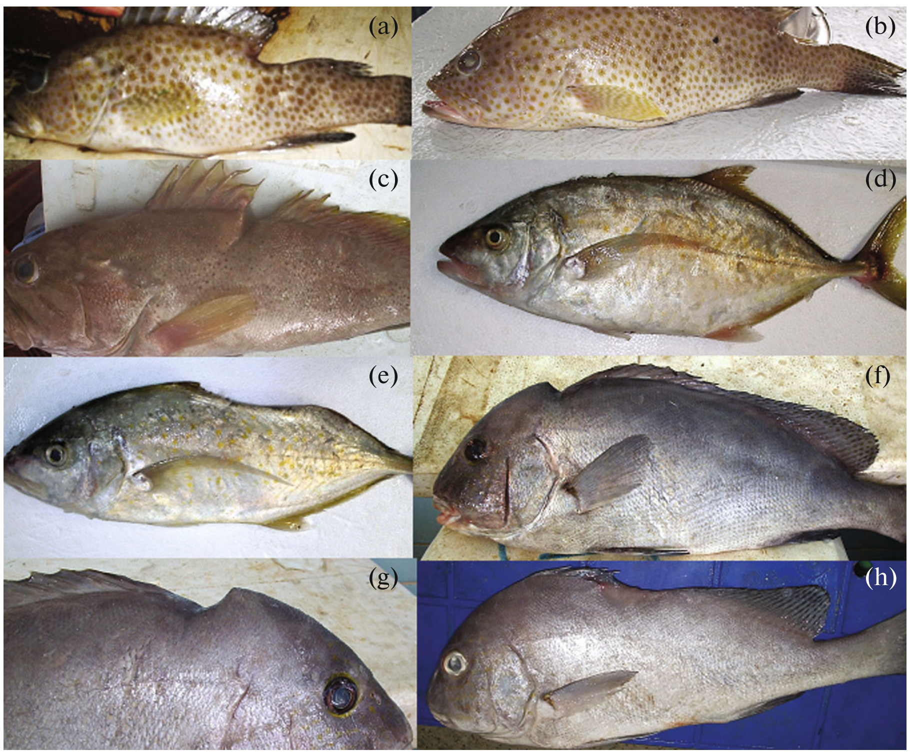

Fig. 2. *Epinephelus areolatus*, 325 mm *TL*, 317 mm *SL* (a); *Epinephelus areolatus*, 330 mm *TL*, 318 mm SL (b); *Epinephelus epistictus*, 326 mm *TL*, 317 mm *SL* (c); *Carangoides bajad*, 333 mm *TL*, 322 mm *SL* (d); *Carangoides bajad*, 401 mm *TL*, 390 mm *SL* (e); *Diagramma pictum*, 390 mm *TL*, 381 mm *SL* (f); *Diagramma pictum*, 390 mm *TL*, 381 mm *SL*, close up image (g); *Diagramma pictum*, 395 mm *TL*, 384 mm *SL* (h).

were wavy instead of being straight as in the normal state. The shape of the saddleback is in a form of deep and narrow trench reaching to the lateral line, with 20 mm depth and 16.7 mm long. The anterior few scales of the lateral line shown to be deformed, no other anomalies were detected on the fish body.

Family: Carangidae

Carangoides bajad (Forsskäl, 1775), *specimen no. 1*, 333 mm *TL*, 322 mm *SL* (Fig. 2d). The saddleback affecting the whole spinous part of the dorsal fin. The soft part of the dorsal fin, other fins and other parts of the fish body shown to be normal. The saddleback was shallow and not extending deep in the dorsal profile of the fish body, with depth of 3.8 mm and length 46 mm.

Specimen no. 2, 401 mm *TL*, 390 mm *SL* (Fig. 2e). Most of the spinous and small parts of the dorsal fin were affected by the saddleback. The spines 1–2 of the dorsal fin were left deformed. The area saddleback area is 13.6 mm depth and 25.5 mm long. No other anomalies were found.

Fig. 3. *Plectorhinchus sordidus*, 389 mm *TL*, 377 mm *SL* (a); *Acanthopagrus bifasciatus*, 334 mm *TL*, 323 mm *SL* (b); *Acanthopagrus bifasciatus*, 336 mm *TL*, 325 mm *SL* (c); D, *Argyrops spinifer*, 330 mm *TL*, 318 mm *SL* (d); Radiograph of *Argyrops spinifer*, 330 mm *TL*, 318 mm *SL* (e); *Argyrops spinifer*, 450 mm *TL*, 446 mm *SL* (f); *Lethrinus nebulosus*, 340 mm *TL*, 331 mm *SL*, lateral view (g); *Lethrinus nebulosus*, 340 mm *TL*, 331 mm *SL*, dorsal view (h).

Family: Haemulidae

Diagramma pictum (Thunberg, 1792), *specimen no. 1*, 390 mm *TL*, 381 mm *SL* (Figs. 2f, 2g). The area affected by the saddleback is the posterior part of the skull and the anterior edge of the dorsal fin. The 1st dorsal pine showed a slight deformity. The saddleback area is 8.3 mm depth and 25 mm long. No observed deformities appeared in the other parts of the fish body.

Specimen no. 2, 395 mm *TL*, 384 mm *SL* (Fig. 2h).

The saddleback is affecting most of the spinous and the anterior parts of the dorsal fin. The spines 5–10 were absent and the 1–2 soft rays were deformed. The affected area is 8.3 mm depth and 58.3 mm long. In addition to the saddleback deformity, a circular area of 25 mm in diameter was devoid of scales. No other abnormalities were shown.

Plectorhinchus sordidus (Klunzinger, 1870), *specimen no. 1*, 367 mm *TL*, 356 mm *SL* (Fig. 1). The saddleback area is located just at the posterior edge of the skull and affecting the anterior part of the spines of the dorsal spines. The spines 1–2 were absent. The affected area is 8.3 mm depth and 62.5 mm long. The lateral line below the saddleback area shown to be flat and disturbed in the caudal peduncle area instead of being curved and straight as in its normal state respectively. Also, the scales in the area between the saddleback and the deformed lateral line part shown to be disturbed. No other deformities were shown.

Specimen no. 2, 389 mm *TL*, 377 mm *SL* (Fig. 3a). The saddleback is located at the posterior edge of the skull away from the anterior edge of the dorsal fin. The scales arrangement in the saddleback area is disturbed and the displacement of the scales reaches the anterior end of the lateral line. Slight ambicoloration on the body was observed, otherwise, no other abnormality was noticed. The saddleback area with 5 mm depth and 45.8 mm long.

Family: Sparidae

Acanthopagrus bifasciatus (Forsskäl, 1775), *specimen no. 1*, 334 mm *TL*, 323 mm *SL* (Fig. 3b). The posterior edge of the skull was involved with the saddleback. The dorsal fin was not affected. The scales in both the saddleback area and the anterior part of the lateral line appeared to be slightly deformed. No other abnormalities have been shown to the fish body. The saddleback area with 7.1 mm depth and 26.4 mm long.

Specimen no. 2, 336 mm *TL*, 325 mm *SL* (Fig. 3c).

The middle of the dorsal fin was affected with the saddleback. The spines 1–5 were the only hard spines remained from the dorsal fin, with deformed 5th spine. The anterior part of the soft part of the dorsal fin is

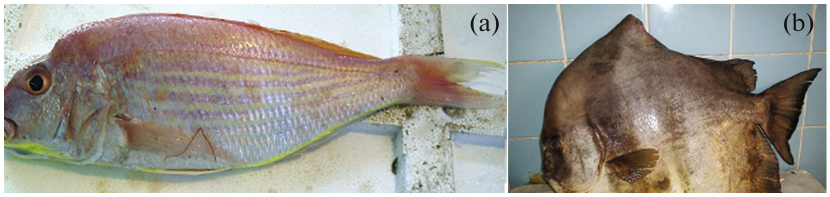

Fig. 4. *Nemipterus japonicus*, 276 mm *TL*, 265 mm *SL* (a); *Platax teira*, 446 mm *TL*, 435 mm *SL* (b).

also lost. The saddleback area with 7.1 mm depth and 50 mm long. No other deformities were shown in the body of the fish.

Argyrops spinifer (Forsskäl, 1775), *specimen no. 1*, 330 mm *TL*, 318 mm *SL* (Figs. 3d, 3e).

The saddleback is located at the posterior and anterior edges of the skull and the dorsal fin respectively. The saddleback looks like a deep trench of 18.2 mm deep and 29.1 mm long. The dorsal posterior edge of the skull is rounded. All spines and rays in the dorsal fin are normal. Externally, no other abnormalities have been observed. The radiograph image showed that 4 supraneurals and the pterygiophore supporting the 1st dorsal spine were packed backward, but with no deformation (Fig. 3e). No other internal skeletal deformities were observed.

Specimen no. 2, 450 mm *TL*, 446 mm *SL* (Fig. 3f).

The saddleback is found in the middle of the spinous part of the dorsal fin. Spines 1–7 and the last spine were present. The middle 3 spines were lost. All the rays in the soft part of the dorsal fin appeared to be normal. The saddleback area is 15 mm deep and 50 mm long. Scales showed to be disturbed in the saddleback area, otherwise, no other morphological anomalies shown.

Family: Lethrinidae

Lethrinus nebulosus (Forsskäl, 1775), 340 mm *TL*, 331 mm *SL* (Figs. 3g, 3h).

The spinous part of the dorsal fin housed the saddleback, with the absence of 6 spines. The 1st and the last three spines were shown to be normal. The area of saddleback with 15.7 mm depth and 57.1 mm long. Scales in the area of the saddleback were disturbed (Fig. 3g). Dorsally, the area of the saddleback showed a red lesion and the vertebral column in the caudal peduncle area showed slight kyphosis (Fig. 3h). No other anomalies were shown in the body of the fish.

Family: Nemipteridae

Nemipterus japonicus (Bloch, 1791), 276 mm *TL*, 265 mm *SL* (Fig. 4a).

The saddleback is located at the posterior edge of the eye. The parietal bones were shown to be highly depressed to the dorsal level of the eyes. The area of the saddleback with 4.1 mm depth and 20.6 mm long. No other anomalies have been observed.

Family: Ephippidae

Platax teira (Forsskäl, 1775), 446 mm *TL*, 435 mm *SL* (Fig. 4b).

The saddleback is located in the middle of the dorsal fin. All 5 dorsal spines and 19 anterior rays were lost as a result of this deformity. The frontal bones of the skull shown to be wavy. The area of the saddleback with 37.5 mm depth and 112.5 mm long. No other morphological abnormalities have seen.

The 16 specimens that showed saddleback having one saddleback area except for one specimen of *E. areolatus* that had two. Those with one saddleback area can be divided on the base of whether the saddleback affecting the dorsal fin or not. The results showed that there are five specimens belonging to five species with saddleback not located on the dorsal fin: *A. bifasciatus*, *A. spinifer*; *D. pictum*, *N. japonicus* and *P. sordidus*. The remaining specimens with saddleback affecting the dorsal fin can be divided into two groups: 1) saddleback located on the anterior part of the dorsal fin as shown in specimens of *E. areolatus*, *D. pictum* and *P. sordidus* and 2) saddleback found in the middle of the dorsal fin as shown in the specimens of *A. bifasciatus*, *A. spinifer*, *C. bajad*, *D. pictum*, *E. areolatus*, *E. epistictus*, *L. nebulosus* and *P. teira*.

Other morphological anomalies were observed in association of the saddleback deformity. The disturbance of the scales in an adjoining area of the saddleback is the common deformity noticed, it appeared in specimens of *P. sordidus*, *A. bifasciatus*, *A. spinifer*, and *L. nebulosus*. The area around the saddleback deformity shown devoid of scales as in one specimen of *D. pictum*. The other deformity is on the lateral line and can be seen twice in one specimen of *P. sordidus* (below the saddleback and caudal peduncle areas) and once in *A. bifasciatus*. Slight ambicoloration of the body, red lesion in the saddleback area, depressed parietal bones and packed supraneural bones were shown in *P. sordidus*, *L. nebulosus*, *N. japonicus* and *A. spinifer* respectively.

The maximum value of saddleback depth was 18.7 one specimen of *E. epistictus* and the minimum value is 3.3 in a specimen of *C. bajad*. The maximum saddleback width index was 25. 2 observed in *P. teira* and the minimum of 4.2 in *E. epistictus*. The maximum saddleback location index was 92.3 observed in E. areolatus and the minimum value was 14.7 shown by *N. japonicus* (Table 1).

DISCUSSION

Saddleback syndrome has been always related to an abnormality of the dorsal fin, which leads to missing spinous and soft parts of the fin hard spines and probably the lepidotrichia. According to such deformity, the pterygiophores supporting the spines and rays usually appeared with severe abnormalities (Tave et al., 1983; Koumoundouros et al., 2001; Koumoundouros, 2008; Cobcroft and Battaglene, 2013; Diggles, 2013). Unlike other studies, in the specimens of the ten species examined, saddleback has shown to affect either the anterior or the posterior part of the dorsal fin (Tave et al., 1983). Such results agree with those of Diggles (2013), Pollock (2015), and Koumoundouros et al. (2001). Moreover, for the first time, at least in the grouper *E. areolatus* it was shown that there are two saddleback areas occurred in the same specimen. The results are also showed that the lack of the spinous part in one specimen of *C. bajad* is not necessarily linked to abnormalities of the subjacent pterygiophores. A similar result was obtained by Fragkoulis et al. (2017) on the European sea bass *Dicentrarchus labrax*.

The first criterion that fish consumers usually look for in the fish they would like to buy is the general shape of the body of the fish. If the body shape is probably affected by skeletal anomalies, then severe or minor alteration might occur that deter the buyer from such specimen. The continuous range and discontinuous effects are two categories that can be resulted from the alteration of the fish body shape, which both depend on the severity of the anomaly. Continuous range is expressed through the haemal lordosis (Sfakianakis et al., 2006). On the other hand, discontinuous effects can be represented in the gill-cover anomalies or the saddleback syndrome since their presence may be associated with other severe morphological alterations (Koumoundouros et al., 1997; Setiadi et al., 2006).

From the present results, it is obvious that the anomalies observed in ten species collected from waters in the vicinity of Jubail City, Saudi Arabia, can be described as saddleback syndrome, identical in most aspects to those reported in several other groups of fish in different parts of the world (Browder et al., 1993; Koumoundouros et al., 2001; Korkut et al., 2009, Fragkoulis et al., 2012; Boglione et al., 2013). Except for one specimen of *D. pictum* with healing scar and *L. nebulosus* with a lesion in the saddleback area, there were no visible signs of physical injury or healed scarring in the dorsal area of any of the saddleback affected fish species examined in this study. This suggests that physical injuries were not the cause of the saddleback deformities. That physical injuries are caused by trapping fish in gill nets, is an assumption that was deemed at the time of the emergence of this deformity in some part of the world (Browder et al., 1993).

The issue of several fish species, belonging to a wide taxonomic spectrum, collected from the same geographical area having saddleback deformity may shade a light on the suggestion of Browder et al. (1993). Tave et al. (1983) found that saddleback in tilapia *Oreochromis aurea*, had a genetic basis and might be due to developmental deformities. On the other hand, Browder et al. (1993) believed a gene hypothesis is highly unlikely for wild fish populations due to their large population sizes compared to aquaculture populations. Environmental factors were suggested instead by Browder et al. (1993) as their observations showed that ten fish species belonging to different groups were contributing to outbreaks of saddleback anomaly within certain contaminated areas in Biscayne Bay. This case is exactly the same as that considered in the present study, where ten species belong to 7 families.

What happened in the wild is the environmental factors that induce genetic mutation of some genes that have the ability to change and are shared by all affected fish groups, which develop saddleback abnormality. This mechanism was proposed by Browder et al. (1993) and Koumoundouros et al. (2001).

In the wild, saddleback deformity has been related to the environmental contamination (Browder et al., 1993; Koumoundouros et al., 2001). Pollution resulted from anthropogenic activities may have an influence on early life history stages of fish directly (Browder et al., 1993; Lemly, 1993; Gagnon and Rawson, 2009). Indirect effects may be through increased rates of disease (Sindermann, 1996) or through bone development disorder by exposure to other anthropogenically mediated emphases such as hypoxia or pH fluctuations (Witten and Huysseune, 2009). Hypoxia is known to cause increased rates of abnormalities and reduced survival rate during the early life history of species of the genus *Acanthopagrus* (Hassell et al., 2008a, 2008b). Such an event is evident in the water of Arabian Gulf waters in general and in waters of Saudi Arabia, in particular, due to high air temperature (Mearns et al., 2011; Wei et al., 2016).

Deformities in the lateral line of saddleback in affected fish specimens were reported in several fish species. In the reared *S. aurata*, scales from the lateral line were missing or having zigzag patterns (Carrillo et al., 2001). Sfakianakis et al. (2013) stated the presence of lateral-line abnormalities in *D. labrax* and *S. aurata* in the form of missing sectors or double pattern. Pollock (2015) showed that saddleback may be associated with abnormally missing sectors of the lateral line. The correlation of the two deformities, saddleback might suggest that they both are the ontogenetic result of the epidermal abnormalities developing at the flexion and metamorphosis phase (Pollock, 2015). The mechanism of such epidermal anomalies might interrupt the development of epithelial ridge and the canal development at each neuromast (Webb, 1989). Specimens of two species, *E. epistictus* and *P. sordidus* examined in the present study showed lateral line deformity together with saddleback anomaly.

Scales disturbance and deformity from either the lateral line or from the body regions seem to be related to the saddleback deformity. A case that has been reported by Pollock (2015) in *Acanthopagrus australis* rejected the hypothesis that scale deformities result from physical injuries. At this stage, it is not possible to decide on the origin of the scale deformities found in the specimens of seven species as they have been collected from a wild population. On the other hand, the predation by other fish species on these specimens during early life history remains possible as the fish fauna of the Arabian Gulf coasts of Saudi Arabia contains several predator fish species (Carpenter et al., 1997). Injuring by seabirds might also feasible as the examined specimens during the juveniles and preadult stages swam near the surface of the water. Previous evidence of seabird attacks on fishes was reported from the waters of the Arabian Gulf in General and the Saudi waters in particular (Gallagher et al., 1984; Ansi et al., 2002; El Gendy et al., 2015; Nadim et al., 2015).

Another possibility for scale disturbance and deformity might arise from the fishing operations. Fish individuals may escape from the fishing net after having hard time staying in the crowd within the net. Injuries to fish as a result of net damage attracted several investigators (Chopin and Arimoto, 1995). Gill-netting showed that fish individuals suffer a wide range of injuries. Hickford and Schiel (1996) reported several damage categories for inshore fishes of New Zealand. These wounds range from chafing or scale loss, minor lesions and fin damage, major lesions and flesh loss, and to loss of skeletal material. Pollock (2015) suggested that such injuries accompanied the saddleback deformity in *Acanthopagrus australis*.

As there are a limited number of specimens available for examination, the ranges of the saddleback location, width and depth on individuals of different species showed wide variation. Similar result was obtained by Diggles (2013). *E. epistictus*, *P. teira* and *E. areolatus* were the species that showed severe saddleback, while *C. bajad*, *E. epistictus* and *N. japonicus* were the species that showed mild saddleback. Using a large number of specimens will give a reasonable result (Pollock, 2015). Therefore, the value of the indices obtained in the present study represents preliminary values and should be repeated on large sample number of each species.

Infectious vectors have been shown to be related to skin damage in fish (Noga, 2000). It is impossible at this stage to decide about the role of the infectious agents in producing the saddleback deformity. More studies are required to investigate such a role in producing abnormalities of the primordial marginal fin fold in the fish species in question.

There is a debate about the survivorship of the fish with a saddleback deformity. Koumoundouros (2008) suggested this deformity might not drastically affect fish survival as it has been shown in adult individuals in the wild. On the other hand, Tave et al. (1983) linked saddleback with a loss of viability for fish over the first 3 months of life in a laboratory environment (i.e. in the absence of natural stresses). Since all of 17 saddleback cases were obtained from adult fishes living in a wild population, the present results support the suggestion of Koumoundouros (2008). Those specimens survived and reached a size at which they became a target for the fisheries activities.

In the Saudi Arabia as in other Arabian Gulf states, the fisheries industry is very important in both social and economic aspects. Many commercial fish species are still in need of proper management and monitoring by fisheries agencies. Further research is important to understand the exact cause and impacts of saddleback deformity and associated abnormalities on commercial fish species. Specifically, future research is required to study the variability of saddleback in both juvenile and adult commercial fish species in different locations and years, taking into consideration the mortality related to saddleback anomaly. Through the experiments, it is important to identify the specific mechanism(s) responsible for this deformity, whether the causes are genetic or epigenetic.

ACKNOWLEDGMENTS

We are grateful to the Ministry of Agriculture, Fish Welfare Branch, Jubail Province, Saudi Arabia for giving us the opportunity to examine and study the deformed fish specimens. Our thanks are also due to Sergey Bogorodsky of Station of Naturalists, Omsk, Russia and Ronald Fricke of Staatliches Museum für Naturkunde, Rosenstein, Germany, William Smith-Vaniz, Florida Museum of Natural History, for identification of the species.

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