ARTICLE IN PRESS

Aquaculture and Fisheries xxx (xxxx) xxx

Contents lists available at ScienceDirect

Aquaculture and Fisheries

journal homepage: www.keaipublishing.com/en/journals/aquaculture-and-fisheries

Original research article

Vertebral column deformity in six species of wild fish at the Coromandel coast, Bay of Bengal India

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ARTICLE INFO

Keywords:
Vertebral column
Abnormality
Kyphosis
Lordosis
Scoliosis
Platyspondyly
Coromandel coast

ABSTRACT

This study reports radiological deformities in the vertebral column of six fishes viz, *Scomberomorus commerson*, *Chanos chanos, Sillago sihama*, *Pampus chinensis, Rastrelliger kanagurta* and *Netuma thalassina* that were collected from the Coromandel coast, Bay of Bengal. Four main different types of vertebral column deformities were found: (*i*) whole body kypho-lordo-kyphosis (*Sillago sihama, Rastrelliger kanagurta, Netuma thalassina*); (*ii*) tail region kypho-lordosis (*Scomberomorus commerson*); (*iii*) tail region lordo-kyphosis (*Chanos chanos*); (*iv*) platyspondyly (*Pampus chinensis*). Seven types of vertebra body deformities, describing the pathology of single vertebrae, were present; reduced intervertebral space, compression, fusion, compresion & fusion, fusion center, dorsal wedge-shaped and compressed & dorsal wed-shaped. The present documentation of deformities in six different species that are also very different with regard to habitat, diet and swimming activity may suggest that fish deformities are widespread in the study area.

1. Introduction

Fish with different types of abnormalities are frequently captured all over the world's oceans. Abberations and deformeties in fish have been researched since the sixteenth century (Gudger, 1936), and since then a large number of studies have reported and documented different types of anomalies in wild and cultured fish (Boglione et al., 2003; Jawad & Hosie, 2007; Jawad and ÖKtoner 2007; Koumoundouros, 2008; Orlov, 2011; Jawad & Al-Mamry, 2012; Rutkayová et al., 2016; Jawad et al., 2016).

Of particular interest are those deformities that affects the vertebral column, the structure that transmit muscular forece to swimming activity. Indeed, deformites in the vertebral column can reduce swimming performance (Basaran et al., 2007a; Powell et al., 2009). With respect to factors that may provoke skeletal deformites in wild fish, parasites (Langdon, 1987; Yokoyama et al., 2005) and pollution (Bengtsson et al., 1979; Lindesjoo et al., 1994) have been suggested important. Deformites in the vertebral column may manifest themselves as different types vertebra body deformites combined or not with different types of curvatures (Witten et al., 2009). There are several reports on different types of skeletal deformities in fish from tropical marine waters: (*i*) *Pampus chinensis* – dorsal fin deformities in the Palk Bay, Southeast coast of India (Vinothkumar et al., 2020); (*ii*) *Pampus argentus* – dorsal and anal fin deformities at the Omani coasts of the Arabian Gulf (Al-Mamry et al., 2010), caudal fin deformities at the Arabian gulf coasts of Omen (Jawad, 2014), different types of deformities in Kuwait waters (Almatar & Chen, 2010), tail loss and dorsal fin deformities in Basrah, Iraq (Jassim et al., 2018); (*iii*) *Scomberomorus commerson* – deformities in the vertebral column at the Karwar coast, southwest coast of India (Mhaddolkar et al., 2013); (*iv*) *Scomber japonicus* – kyphosis at the Oita prefecture, Japan

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https://doi.org/10.1016/j.aaf.2022.05.004
Received 16 February 2022; Received in revised form 11 May 2022; Accepted 13 May 2022

Please cite this article as: Yosuva Mariasingarayan, *Aquaculture and Fisheries*, https://doi.org/10.1016/j.aaf.2022.05.004

(Yokoyama et al., 2005); (*v*) *Scomberomorus maculatus* - scoliosis and lordosis at the barrier islands in Mississippi, Gulf of Mexico (Overstreet, 1978; Overstreet & Hawkins, 2017); (*vi*) *Rastrelliger kanagurta* – snout deformities at the Kalamukku fish landing, Kerala (Jinesh et al., 2016). The reports of deformed fish were available scanty at the Coromandel coast, southeast coast of India. The present radiological study reports skeletal pathology in six different species (*Scomberomorus commerson, Chanos chanos, Sillago sihama, Pampus chinensis, Rastrelliger kanagurta, Netuma thalassina*) collected from the Coromandel coast.

2. Matreials and methods

Specimens of deformed *Scomberomorus commerson*, *Chanos chanos, Sillago sihama, Pampus chinensis, Rastrelliger kanagurta* and *Netuma thalassina* was collected from different landing centres of Coromandal coast, Southeast coast of India (Fig. 1) in 2019. The specimens were caught by drifting gill nets and trawl. Specimen total length and weight were measured (Table 1). Species identification was based on the FAO-Fish Identification sheets and the FISHBASE database (www.fishbase.org). After identification, the specimens were photograped and radiographed (GE AMX4 plus portable X-ray system). The radiographs were examined and type of deformity and location recorded (Witten et al., 2009). The specimens were stored at Institution museum, Centre of Advanced Study in Marine Biology, Annamalai University.

3. Results

The presently analyzed specimens were all assesed as malformed during visual examination based on deviation in body shape from the normal phenotype. Three types of vertebral column deformities, describing the pathology of vertebral column sections, were present: platyspondyly (shortening of the vertebral column without curvature), lordosis (ventral curvature) and kyphosis (dorsal curvature). Some specimens displayed more than one type, creating a division into four main deformity categories: (*i*) platyspondyly; (*ii*) tail region lordo-kyphosis; (*iii*) tail region kypho-lordosis; (*iv*) whole body kypho-lordo-kyphosis. In this catergorization the types are listed in the cranial to caudal direction, i.e. with kypho-lordosis the kyphosis is located more cranially than the lordosis. Seven types of vertebra body deformities, describing the pathology of single vertebrae, were present: (*i*) reduced intervertebral space; (*ii*) compression; (*iii*) fusion; (*iv*) compresion and fusion; (*v*) fusion center; (*vi*) dorsal wedge-shaped; (*vii*) compressed and dorsal wed-shaped. The two latter types were only present at sites of curvature. The type 'reduced intervertebral space' also includes dorso-ventral shifts (Fig. 2). The following section gives a detailed description of each analyzed specimens (Table 2).

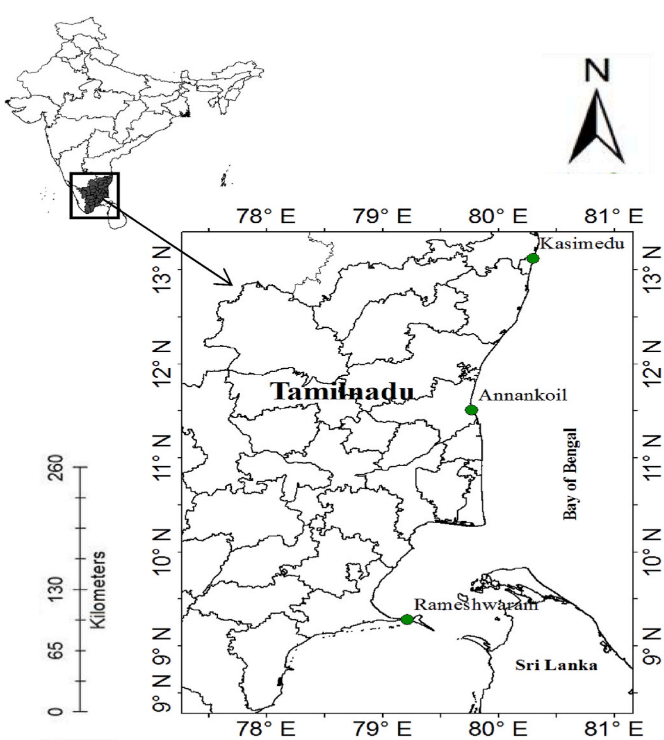

Fig. 1. The locations where the deformed specimens were collected are marked in green.

Table 1
Length and weight of each deformed specimen, number of individuals examined per species and capture location.

Species	Total length (cm)	Weight (g)	Number examined	Location
Scomberomorus commerson	30	420	250	Kasimedu
Chanos chanos	30	210	750	Annankoil, Parangipettai
Sillago sihama	23.4	60	400	Annankoil, Parangipettai
Pampus chinensis	17.3	250	300	Kasimedu
Rastrelliger kanagurta	21	120	1120	Rameswaram
Netuma thalassinus	26.3	160	800	Rameswaram

3.1. Platyspondyly

3.1.1. Pampus chinensis

Externally, short body and deformed tail fin (Fig. 3A). Radiologically, platyspondyly involving the whole vertebral column where all vertebrae display one of the following deformity types: reduced inter vertebral space, compression, or fusion center. A less radio-dense stripe separates the most caudal vertebra and the tail fin, with remains of tail fin lepidothrics on the caudal vertebra side of the stripe (Fig. 3a).

3.2. Tail region lordo-kyphosis

3.2.1. Chanos chanos

Externally, normal trunk and curved tail (Fig. 4B). Radiologically, tail region lordo-kyphosis: The twenty most cranial vertebrae are normal (V1-20), followed by a platyspondyly involving totally eight vertebrae (V21-28) with reduced intervertebral space, then a lordosis composed of totally ten (V29-38) vertebrae with either reduced intervertebral space, dorsal wedge-shape or dorsal wedge-shape and compression, and finally a kyphosis with totally five vertebrae (V39-43) where one is normal vertebra and four are combined into a fusion center (Fig. 4b).

3.3. Tail region kypho-lordosis

3.3.1. Scomberomorus commerson

Externally, normal trunk and curved tail (Fig. 5C). Radiologically, tail region kypho-lordosis: The fifteen most cranial vertebrae (V1-15) are normal, followed by a platyspondyly composed of totally thirteen (V16-28) vertebrae with reduced intervertebral space, then a kyphosis of totally five vertebrae (V29-33) that are combined into a fusion center, a column shortening that involves two vertebrae (V34-35) with reduced intervertebral space, a normal section of two vertebrae (V36-37), and finally a lordosis that involves totally five vertebrae (V38-42) with either compression or compression and fusion (Fig. 5c).

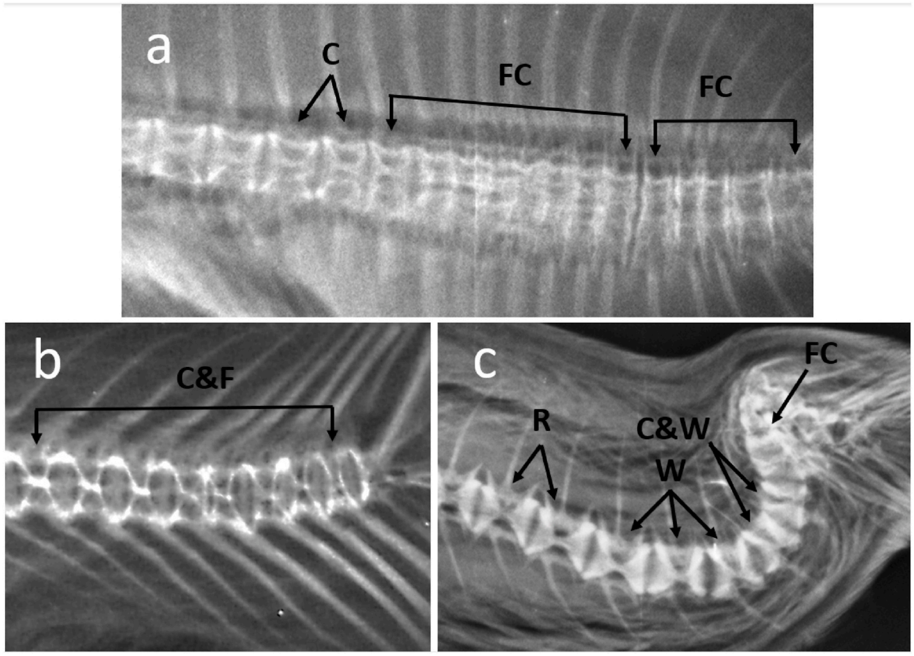

Fig. 2. Lateral radiographs of different types of vertebra body deformities. In (a): compression (C), fusion center (FC). In (b): compression and fusion (C&F). In (c): reduced intervertebral space (R), dorsal wedge-shape (W), compression and dorsal wedge shape (C&F), fusion center (FC). In the present study, 'R' also involves vertebra that have an additional dorso-ventral shift, as in (c).

Table 2
Vertebra (V) deformity classification of six specimens/species of wild fish caught at the Southeast coast of India in 2019. The 8 last columns in the table lists the number of vertebrae per vertebra deformity type: normal (N), reduced intervertebral space (R), compression (C), fusion (F), compression and fusion (C&F), fusion center (FC), dorsally wedge-shaped vertebrae (W), compressed and dorsally wedge-shaped vertebrae (C&W). 'R' also includes dorso-ventral shifts.

Deformity type	Species	V nos.	Vertebral column category	N	R	C	F	C&F	FC	W	C&W
Platyspondyly	*Pampus chinensis*	1–28	Platyspondyly		13	2			13		
Tail region lordo-kyphosis	*Chanos chanos*	1–20	Normal	20							
		21–28	Platyspondyly		8						
		29–38	Lordosis		4					3	3
		39–43	Kyphosis	1					4		
Tail region kypho-lordosis	*Scomberomorus commerson*	1–15	Normal	15							
		16–28	Platyspondyly		12	1					
		29–33	Kyphosis						5		
		34–35	Platyspondyly		2						
		36–37	Normal	2							
		38–42	Lordosis			1		4			
Whole body kypho-lordo-kyphosis	*Sillago sihama*	1–2	Platyspondyly					2			
		3–15	Kyphosis		13						
		16–22	Lordosis		12						
		23–30	Kyphosis		8						
		31–32	Normal	2							
	Rastrelliger kanagurta	1–12	Kyphosis		12						
		13–20	Lordosis		4		2	2			
		21–28	Kyphosis			4	2	2			
		29–30	Normal	2							
	Netuma thalassina	1–15	Kyphosis			3			12		
		16–34	Lordosis			19					
		35–45	Kyphosis			3		8			
		46–47	Platyspondyly					2			

3.4. Whole body kypho-lordo-kyphosis

3.4.1. *Sillago sihama*

Externally, curved trunk and tail (Fig. 6D). Radiologically, whole body kypho-lordo-kyphosis: Most cranially two vertebrae (V1-2) are compressed and fused (platyspondyly), followed by a kyphosis with totally thirteen vertebrae (V3-15) with reduced intervertebral space, then a lordosis composed of totally twelve vertebrae (V16-22) with reduced intervertebral space, a kyphosis with totally eight vertebrae (V23-30) with reduced intervertebral space, and finally two normal vertebrae (V31-32) (Fig. 6d).

3.4.2. *Rastrelliger kanagurta*

Externally, curved trunk and tail (Fig. 6E). Radiologically, whole body kypho-lordo-kyphosis: The twelve most cranial vertebrae (V1-12) have reduced intervertebral space and involves a kyphosis, followed by a lordosis that involves eight vertebrae (V13-20) with either reduced intervertebral space, fusion or compression and fusion, then a kyphosis composed of totally eight vertebrae (V21-28) with either compression, fusion or compression and fusion, and finally a section with two normal

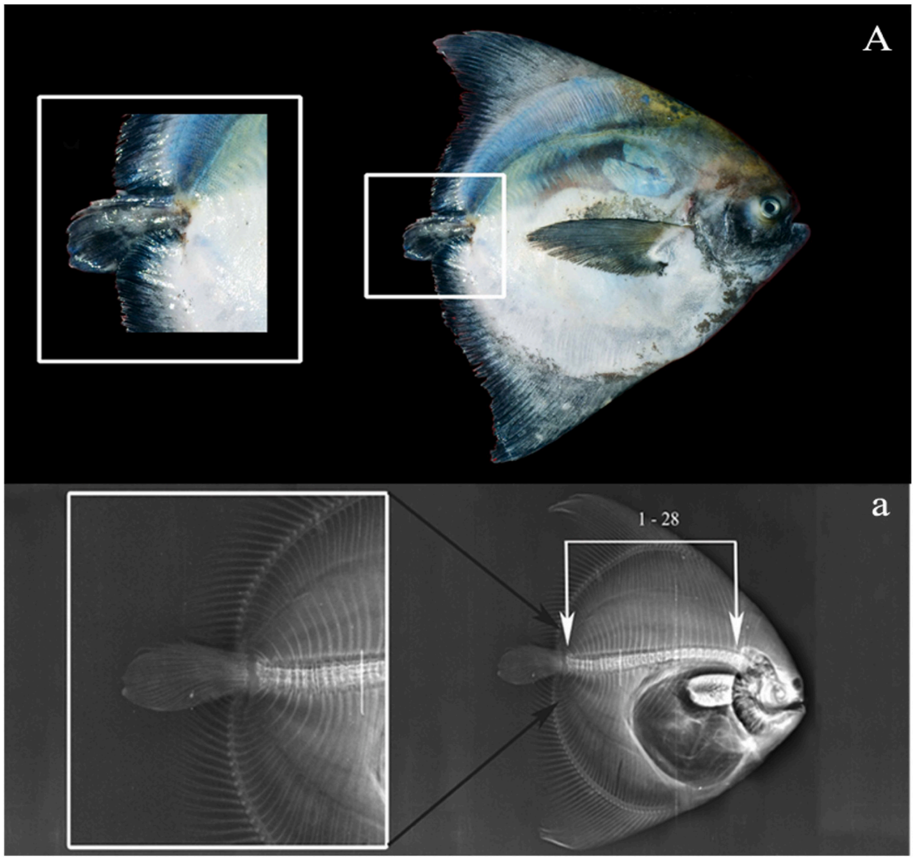

Fig. 3. Platyspondyly. Lateral photography (A) and radiography (a) of *Pampus chinensis.*

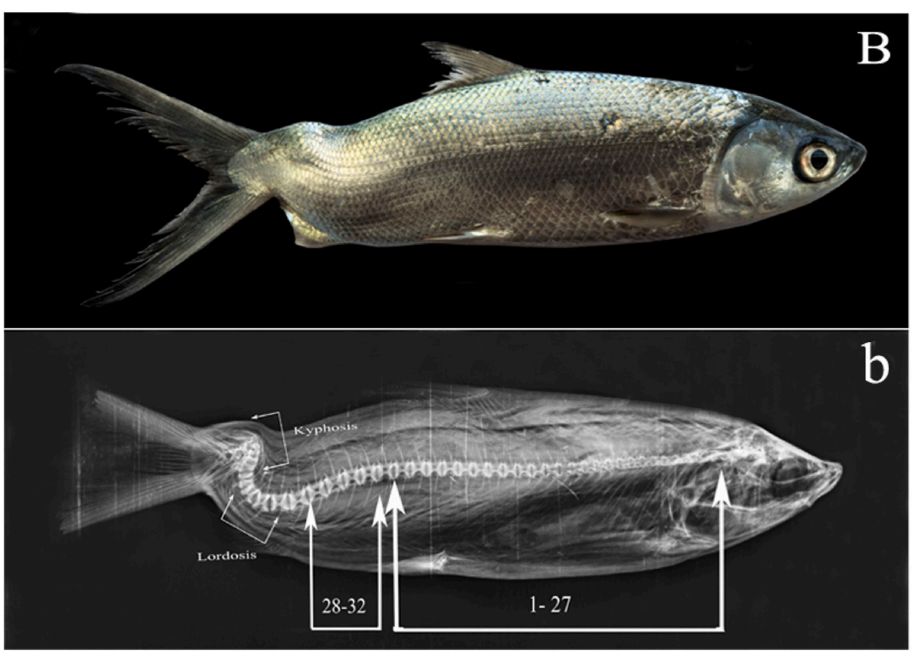

Fig. 4. Tail region lordo-kyphosis. Lateral photography (B) and radiography (b) of *Chanos chanos*.

vertebrae (V29-30) (Fig. 6e).

3.4.3. *Netuma thalassina*

Externally, curved trunk and tail (Fig. 6F). Radiologically, whole body kypho-lordo-kyphosis: The 15 most cranial vertebrae (V1-15) involve a kyphosis composed of vertebrae that are either compressed or combined into a fusion center, followed by a lordosis that are composed of nineteen compressed vertebrae (V16-34), then a kyphosis composed of totally eleven vertebrae (V35-45) with compression or compression and fusion, and finally a platyspondyly with two compressed and fused

Fig. 5. Tail region kypho-lordosis. Lateral photography (C) and radiography (c) of *Scomberomorus commerson*.

vertebrae (V46-47) (Fig. 6f).

4. Discussion

Herein severe deformities were detected in six different species with natural large differences in habitat, diet, and swimming activity. This may suggest that survival of deformed fish is common in the study area. The most common deformity phenotype was vertebral column curvature with similar development across species, which may suggest a common aetiology.

The presently reported tail region kypo-lordotic *Scomberomorus commerson* is the second report of deformed *Scomberomorus commerson* along the Indian coast; the first report was on a specimen with vertebral column curvature in 2013 (Sonali et al., 2013). The latter specimen was not radiographed, but the published picture (Sonali et al., 2013) clearly shows that the fish suffered whole body kypho-lordo-kyphosis. This type of deformity was also discovered herein in *Rastrelliger kanagurta*, a species where similar vertebral column curvatures have been recorded earlier (Noble, 1971). Vertebral column curvature has also been reported in other scombrids. In 1981, a wild *Scomber japonicus* specimen with scoliosis-lordosis was captured near the off-barrier islands in Mississippi (Overstreet & Hawkins, 2017). Later, Yokoyama (2005) reported that kyphosis in cultured *Scomber japonicus* was associated with a brain myxosporean, *Myxobolus acanthogobii*. Scombrids are high speed swimmers and are the top carnivores of the epipelagic zone of the tropical and subtropical zones (Moyle & Cech, 1996). Since they rely on high swimming speed for prey, often small schooling fish and squid, detection and capture it is surprising to find deformed wild scombrids; those cases reported (present study, Noble, 1971, Sonaliet al., 2013; Overstreet & Hawkins, 2017) involved severe vertebral column curvatures that would have a negative impact on swimming ability and speed.

The present study discovered whole body kypho-lordo-kyphosis in *Sillago sihama* and *Netuma thalassina*. There are no earlier reports of skeletal deformities in either of these species. *Sillago sihama* are omnivorous and inhabits shallow sandy bottoms of shores and bays, creeks, estuaries, and coastal waters, where it buries itself into the sand to hide for predators (Philipose et al., 2017). *Netuma thalassina* are often found in estuaries where they feed on crabs, shrimps, small fishes, and molluscs (Bu-Olayan & Thomas, 2020). Tail region lordo-kyphosis was detected herein in *Chanos chanos*. There are no earlier reports of skeletal deformities in wild fish of this species, while this has been reported in culture (Hilomen-Garcia, 1997; Sumagaysay et al., 1999). Juvenile *Chanos chanos* stay in shore-near habitats, while adults are swift and powerful swimmers of the open sea where they feed as opportunistic generalists on both planktonic and benthic plants and animals (Bagarinao, 1991, p. 94).

This study discovered platyspondyly and deformed tail fin skeleton in *Pampus chinensis*, which is a strictly pelagic species where the adults mainly feed on copepods (Pati, 1977). In the present specimen the tail fin was small and under-developed. Normally this species has a large and forked tail fin. The malformed tail fin may have demanded high muscular activity for swimming, which may in turn have induced vertebra deformities (Kihara et al., 2002). The reason behind the less radio-dense stripe that separates the most caudal vertebra and the tail fin lepidothrics in the presently studied specimen is unclear, but it may have been caused by a predator attack earlier in life. If so, a possible scenario for the present deformity development may have been: Fractured tail fin by predator attack → abnormal tail fin development → high muscular activity during swimming → vertebra body compression and platyspondyly development. There is one earlier report of a deformed *Pampus chinensis* specimen from Indian waters, which partly lacked the dorsal fin (Vinothkumar et al., 2020). Similar as herein, the authors of that study suggested that the deformity was caused by physical injury. There are several earlier reports of skeletal deformities in *Pampus argenteus*, including deformity of dorsal-anal fin rays, pterygiophores, and neural- and haemal spines (Al-Mamry et al., 2010), fin deformities including fin loss (Almatar & Chen, 2010), loss of caudal fin (Jassim et al., 2018), and loss of caudal vertebrae, hypural, epurals and parhypural (Jawad, 2014).

The reason behind the herein observed deformities is unknown, but the radiological pathology points to that the platyspondyly observed in *Pampus chinensis* may have a different aetiology than the curvatures observed in *Scomberomorus commerson*, *Chanos chanos, Sillago sihama*, *Rastrelliger kanagurta* and *Netuma thalassina*. The first may be related to a predator attack (Fjelldal et al., 2020) while the latter curvatures may be related to parasite infection (Yokoyama, 2005), pollution (Bengtsson et al., 1979) or climate changes (Woo & Iwama, 2020, p. 244). The currently documented fish were all severely deformed to a degree that would most probably affect feeding, swimming, and predator avoidance abilities, as well as mating attractiveness and spawning behavior. The documentation of deformities in six different species that are also very different with regard to habitat, diet and swimming activity was

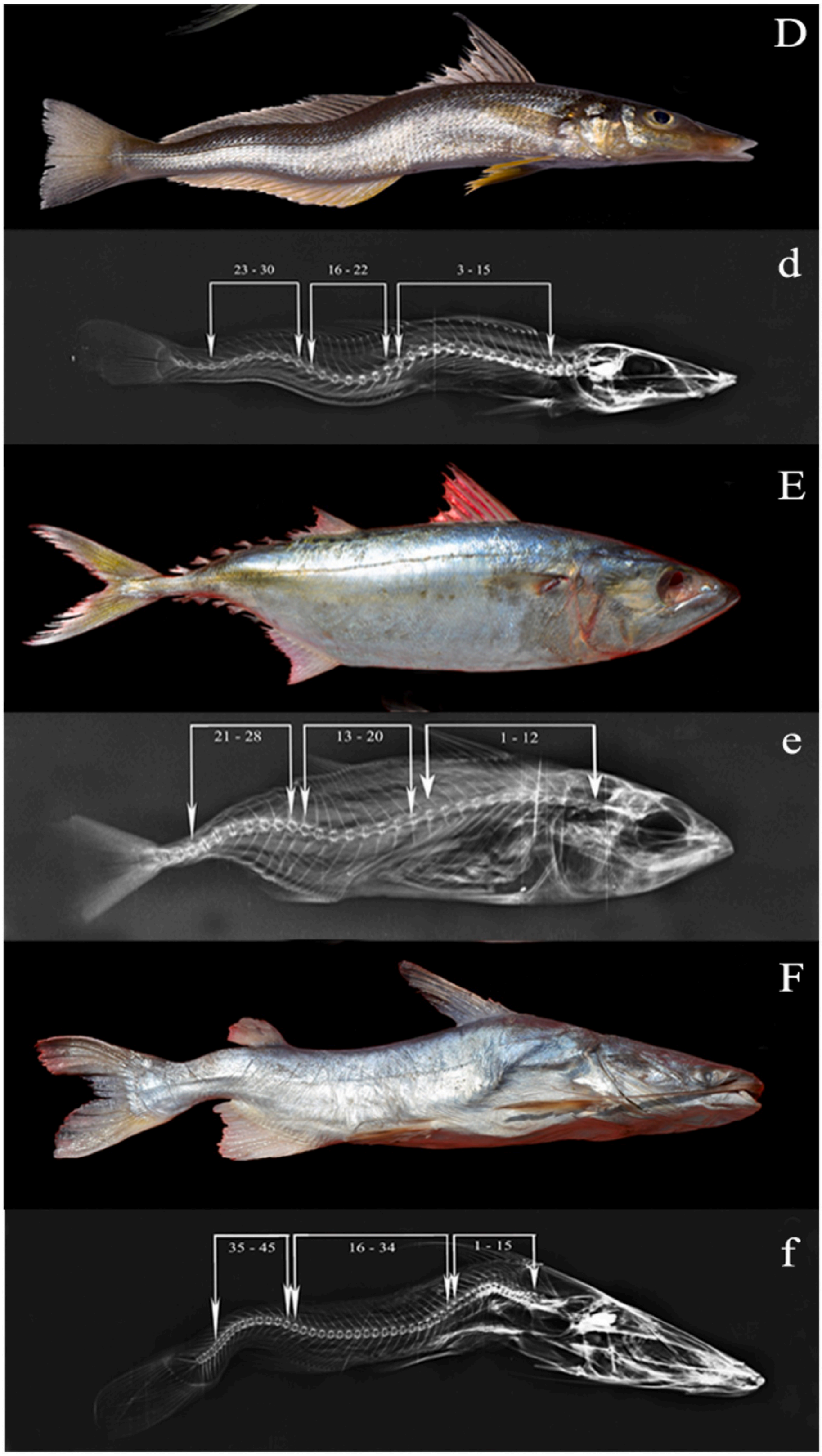

Fig. 6. Whole body kypho-lordo-kyphosis. Lateral photography (D,E,F) and radiography (d,e,f) of *Sillago sihama* (D,d), *Rastrelliger kanagurta* (E,e), *Netuma thalassina* (F,f).

surprising, and may suggest that fish deformities are widespread in the study area. The similarities between the specimens with vertebral column curvature may suggest a common aetiology.

CRediT authorship contribution statement

Yosuva Mariasingarayan: Conceptualization, Methodology, Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Visualization. **Jeyapragash Danaraj:** Conceptualization, Formal analysis, Investigation, Writing – review & editing. **Bharathidasan Veeraiyan:** Data curation, Formal analysis. **Per Gunnar Fjelldal:** Methodology, Validation, Resources, Writing – review & editing, Supervision. **Kannan Karuppiah:** Data curation, Validation, Resources, Formal analysis. **Rajendran Narayanasamy:** Validation, Resources, Formal analysis, Visualization, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The Authors are grateful to the Authorities of Annamalai University and want to thank the anonymous reviewer for helpful comments and suggestions.

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