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**R Vinoth**

Project Scientist, Centre for  
Peninsular Aquatic Genetic  
Resources, Kochi, ICAR - National  
Bureau of Fish Genetic Resources,  
Lucknow, Uttar Pradesh, India

**S Kumaresan**

Assistant Professor, Centre of  
Advanced Study in Marine Biology,  
Annamalai University, Parangipettai,  
Tamil Nadu, India

**S Jeyaprakash Sabari**

Project Associate, Centre for  
Peninsular Aquatic Genetic  
Resources, Kochi, ICAR - National  
Bureau of Fish Genetic Resources,  
Lucknow, Uttar Pradesh, India

**M Priyadharshini**

Project Associate, Centre for  
Peninsular Aquatic Genetic  
Resources, Kochi, ICAR - National  
Bureau of Fish Genetic Resources,  
Lucknow, Uttar Pradesh, India

**Divya PR**

Principal Scientist, Centre for  
Peninsular Aquatic Genetic  
Resources, Kochi, ICAR - National  
Bureau of Fish Genetic Resources,  
Lucknow, Uttar Pradesh, India

**UK Sarkar**

Director, ICAR-National Bureau of  
Fish Genetic Resources, Canal Ring  
Road, P.O. Dilkusha, Lucknow, India

**TT Ajith Kumar**

Principal Scientist and Head,  
Centre for Peninsular Aquatic Genetic  
Resources, Kochi, ICAR - National  
Bureau of Fish Genetic Resources,  
Lucknow, Uttar Pradesh, India

**Corresponding Author:****TT Ajith Kumar**

Principal Scientist and Head,  
Centre for Peninsular Aquatic Genetic  
Resources, Kochi, ICAR - National  
Bureau of Fish Genetic Resources,  
Lucknow, Uttar Pradesh, India

## Teratogenic skeletal abnormality in *Etroplus Suratensis* (Bloch, 1790): Insights from the Vellar estuary, southeast coast of India

**R Vinoth, S Kumaresan, S Jeyaprakash Sabari, M Priyadharshini, Divya PR, UK Sarkar and TT Ajith Kumar**

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### Abstract

This study represents the initial observational documentation of taillessness deformity in the green chromide fish, *Etroplus suratensis*, collected from the Vellar estuary along the southeast coast of India. This species, valued commercially and ornamentally, habitats in estuarine and freshwater. Skeletal abnormalities, particularly during development, can significantly affect fish health, often signaling environmental contamination, especially by toxic elements. The study employed morphometric and meristic analyses to reveal distinct differences in body shape and skeletal structure between tailless and normal fish, confirming vertebral deformity in tailless specimens. The radiographic examination also supported these findings. Previous studies on heavy metal levels in the study area have indicated significant cadmium presence, a known inducer of fish abnormalities, suggesting a potential link between the deformity and cadmium contamination in Vellar estuary. Additionally, it highlights fish abnormalities as potential indicators of changing environmental conditions, including temperature, salinity, and pH fluctuations, which are reported to vary significantly in the study area.

**Keywords:** *Etroplus suratensis*, skeletal abnormalities, taillessness, environmental factors, heavy metals

### 1. Introduction

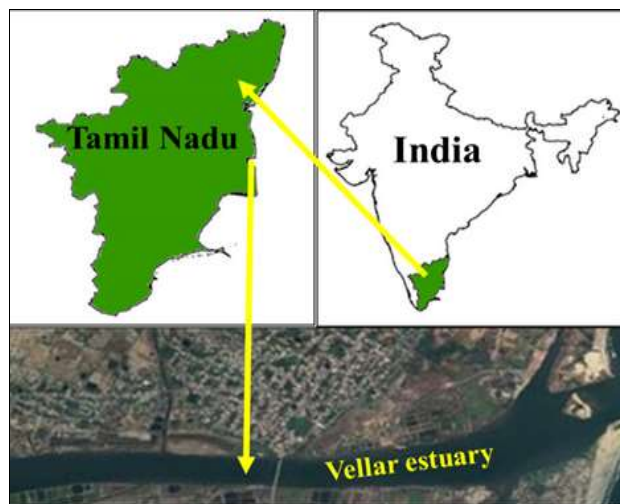
*Etroplus suratensis*, commonly known as 'green chromide' or 'pearl spot' fish, was unexpectedly observed with taillessness (abnormality) for the first time in the Vellar estuary near Parangipettai, Southeast coast of India. This species is endemic to Asia and widely distributed in India <sup>[1]</sup>, typically inhabits the muddy and sandy bottom of estuaries / backwaters and freshwater zones. This species is also being cultured on both brackish and freshwater farms and is a popular choice in the ornamental fish trade due to its attractive colour pattern on its body <sup>[2]</sup>, besides a delicacy table fish in Kerala. In general, this fish undergoes crucial processes during its developmental stages, particularly during skeletal development. Any abnormalities in the development stages would affect normal growth and induce deformities in fish <sup>[3]</sup>. Fish displaying abnormalities can indicate water pollution due to their frequent occurrence in polluted areas <sup>[4]</sup>. The abnormalities in fish have been reported through several studies at regular intervals, especially in the skeletal growth of the fish for many years. The frequency of this incidence was reported to have increased in the recent past <sup>[5-6-7-8-9-10-11-12]</sup>.

The majority of available reports focused on the missing region of the caudal peduncle and caudal fin, or (taillessness) <sup>[8, 13, 14-16]</sup>. *Epinephelus coioides* was reported to have taillessness in the same study area in 2015 <sup>[17]</sup>. In this context, the present study is the subsequent report on the missing caudal peduncle region or taillessness in *E. suratensis*.

### 2. Materials and Methods

#### 2.1. Study Area

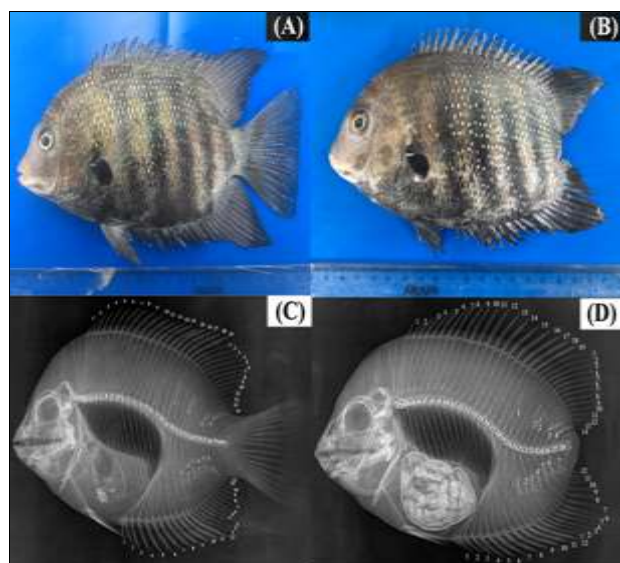
The Vellar estuary, situated in Tamil Nadu, India, is approximately 200 km south of Chennai near Parangipettai (At Latitude 11° 29'N and Longitude 79° 46'E) and is formed by the Vellar River, tributary of Cauvery (Figure 1). It spans approximately 20 km in length, with a narrow width of 200-500 m and shallow depths ranging from 2-4 m.



**Fig 1:** Sampling site, Vellar estuary

## 2.2 Specimen collection and analysis

An anomalous fish (*E. suratensis*) exhibiting taillessness was observed accidentally. The normal fishes of the same species of the locality were also collected for better comparison and understanding (Figure 2). It was confirmed that this species was captured using a cast net by local fishermen. Fish identification was done using a fish identification manual [18-19]. Meristic characteristics were examined using the available methods [20]. Subsequently, measurements of total length, weight, and radiography have been performed to make a comparative analysis between abnormal and normal fishes.

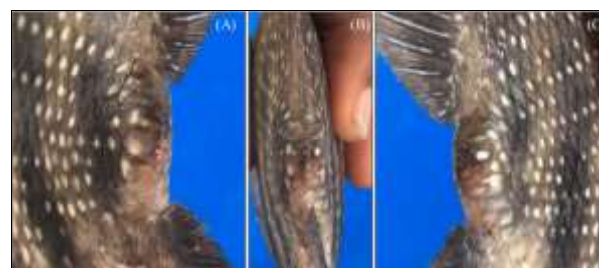


**Fig 2:** (A) Normal Fish (B) Abnormal (or) Taillessness Fish (C) Radiographs of normal Fish and (D) Radiographs of abnormal (or) taillessness fishes of *E. suratensis* and the white outline indicate a substantial calciferous mass within the intestinal system

## 3. Results

The present study proceeded with further analysis after collecting abnormal fish (*E. suratensis*) to identify credible reasons for taillessness by comparing them with normal fishes and correlating them with environmental factors. The assessed characteristic features of meristic and morphometric parameters are given in (Table 1). Notably, abnormal fish exhibited apparent variations in body shape compared to their

normal counterparts. Regarding meristic characters, both normal and abnormal fishes showed similar numbers, except variations in the caudal peduncle and caudal fin. The caudal peduncle of the abnormal fish was found absent in the last vertebral column. Consequently, the caudal fin was found undeveloped in abnormal fish, and the end of the deformed area in the anal and dorsal fins region was covered with scales. It showed no visible scarring or concavity (Figure 3), and hence, it was confirmed that the defect might have occurred during the developmental stages and it was further substantiated through the analysis of dorsal and anal fins that were found extended to the posterior edges in the abnormal fish, when compared to normal fish. Although the soft rays of these fins were unaffected, they exhibited more branches than the normal fish (Figure 4). Radiography analysis revealed distinct vertebral deformities between normal and abnormal fish. The normal fish exhibited total of 31 vertebrae whereas, the abnormal fish was found with 28 vertebrae devoid of caudal complex. Despite the absence of the caudal peduncle in the vertebral column, soft rays of the dorsal and anal fins remained unaffected by this deformity. Furthermore, the deposition of calciferous mass in the stomach region of abnormal fish was observed to be higher than that of normal fish. The arrangement of neural spines and pterygiophores supporting the dorsal and anal spines and varied characteristics of soft rays were noticed in the abnormal fish, when compared to normal fish (Tables 2-3). The caudal fin region was adorned with scales and there were no indications of breaks or injuries in the final vertebrae of abnormal fish.



**Fig 3:** (A) Left side (B) Center side (C) Right side of abnormal fish



**Fig 4:** A and B-Normal and abnormal fish: Dorsal soft rays; C and D-Normal and abnormal fish: Anal soft rays (b-branches indicated)

**Table 1:** Morphometric & Meristic data of *Etroplus suratensis*

Morphometric characters	Normal Fish	Abnormal Fish
Weight (gm)	200.00	201.00
Total length (cm)	21.4	-
Standard length (cm)	16.2	14.4
Head length (cm)	5.3	5.1
Eye diameter (cm)	1.1	1.4
Snout length (cm)	2.1	1.8
Post orbital length (cm)	2.1	1.9
Interorbital length (cm)	1.3	1.5
Maximum body depth (cm)	9.2	9.1
Pre-dorsal distance (cm)	5.3	5.3
Pre-pectoral distance (cm)	5.0	4.3
Pre-ventral distance (cm)	5.3	5.3
Pre-anal distance (cm)	7.6	7.5
Dorsal fin base length (cm)	13.8	12.2
Anal fin base length (cm)	11.8	9.8
Pectoral fin length (cm)	4.9	4.4
Ventral fin length (cm)	3.5	3.1
Meristic Characters	Normal Fish	Abnormal Fish
Dorsal fin ray and spine	XV-XIX	XV-XIX
Pectoral fin ray	XVI	XV
Ventral fin rays and spines	1, 5	1,5
Anal fin ray and spine	XII-XII	XII-XII
Caudal fin ray	16	-

**Table 2:** Variation between the dorsal spine and dorsal soft rays in normal and tailless *E. suratensis*

S. No	Normal Specimen	Abnormal Specimen
1.	The 19 <sup>th</sup> dorsal spine and 1 <sup>st</sup> soft rays of pterygiophores are located between the 19 <sup>th</sup> and 20 <sup>th</sup> neural spines.	The 19 <sup>th</sup> dorsal spine pterygiophore is situated alongside the 19 <sup>th</sup> and 20 <sup>th</sup> neural spines, and the 1 <sup>st</sup> soft ray's pterygiophores are among the 20 <sup>th</sup> and 21 <sup>st</sup> neural spines.
2.	The 5 <sup>th</sup> and 6 <sup>th</sup> soft rays of pterygiophores are positioned between the 22 <sup>nd</sup> and 23 <sup>rd</sup> neural spines, and the 7 <sup>th</sup> soft rays are between the 23 <sup>rd</sup> and 24 <sup>th</sup> neural spines.	The 5 <sup>th</sup> soft rays of pterygiophores are located between the 22 <sup>nd</sup> and 23 <sup>rd</sup> neural spines and the 6 <sup>th</sup> and 7 <sup>th</sup> soft rays are situated between the 23 <sup>rd</sup> and 24 <sup>th</sup> neural spines.
3.	The 10 <sup>th</sup> and 11 <sup>th</sup> soft rays of pterygiophores are positioned between the 25 <sup>th</sup> and 26 <sup>th</sup> neural spines.	The soft rays of pterygiophores, specifically the 10 <sup>th</sup> , 11 <sup>th</sup> , and 12 <sup>th</sup> , are positioned between the 25 <sup>th</sup> and 26 <sup>th</sup> neural spines.
4.	The last three soft rays, namely the 12 <sup>th</sup> , 13 <sup>th</sup> , and 14 <sup>th</sup> soft rays of pterygiophores, are positioned between the 26 <sup>th</sup> and 27 <sup>th</sup> neural spines.	The 13 <sup>th</sup> and 14 <sup>th</sup> soft rays of pterygiophores are positioned between the 26 <sup>th</sup> and 27 <sup>th</sup> neural spines

**Table 3:** Variation between the anal spine and anal soft rays in normal and abnormal fishes

S. No	Normal Specimen	Abnormal Specimen
1.	The 1 <sup>st</sup> anal soft ray of pterygiophores is positioned from the 21 <sup>st</sup> to the 22 <sup>nd</sup> neural spines.	The 12 <sup>th</sup> anal spine and anal soft ray of pterygiophores are positioned from the 20 <sup>th</sup> to the 21 <sup>st</sup> neural spines.
2.	The 2 <sup>nd</sup> and 3 <sup>rd</sup> anal soft rays of pterygiophores lie between the 22 <sup>nd</sup> and 23 <sup>rd</sup> neural spines.	The 2 <sup>nd</sup> anal soft ray of pterygiophores is positioned from the 21 <sup>st</sup> to the 22 <sup>nd</sup> neural spines.
3.	The 4 <sup>th</sup> and 5 <sup>th</sup> anal soft rays of pterygiophores lie between the 23 <sup>rd</sup> and 24 <sup>th</sup> neural spines.	The 3 <sup>rd</sup> and 4 <sup>th</sup> anal soft rays of pterygiophores lie between the 22 <sup>nd</sup> and 23 <sup>rd</sup> neural spines.
4.	The 6 <sup>th</sup> and 7 <sup>th</sup> anal soft rays of pterygiophores lie between the 24 <sup>th</sup> and 25 <sup>th</sup> neural spines.	The 5 <sup>th</sup> and 6 <sup>th</sup> anal soft rays of pterygiophores lie between the 23 <sup>rd</sup> and 24 <sup>th</sup> neural spines.
5.	The 8 <sup>th</sup> and 9 <sup>th</sup> anal soft rays of pterygiophores lie between the 25 <sup>th</sup> and 26 <sup>th</sup> neural spines.	The 7 <sup>th</sup> and 8 <sup>th</sup> anal soft rays of pterygiophores are situated between the 24 <sup>th</sup> and 25 <sup>th</sup> neural spines, with the 7 <sup>th</sup> anal soft rays appearing thicker compared to the normal specimen (see Figure 2)
6.	The 10 <sup>th</sup> , 11 <sup>th</sup> , and 12 <sup>th</sup> anal soft rays of pterygiophores lie between the 26 <sup>th</sup> and 27 <sup>th</sup> neural spines.	The 9 <sup>th</sup> and 10 <sup>th</sup> anal soft rays of pterygiophores lie between the 25 <sup>th</sup> and 26 <sup>th</sup> neural spines.
7.	-	The 11 <sup>th</sup> and 12 <sup>th</sup> anal soft rays of pterygiophores lie between the 26 <sup>th</sup> and 27 <sup>th</sup> neural spines.

#### 4. Discussion

The tailless / abnormal fish *Etroplus suratensis* collected from the Vellar estuary was involved for further analysis. In the preliminary assessment, the caudal peduncle region and caudal fins were found absent and subsequently, it was observed that there was enlargement and hyper calcification in the otoliths. The primary aim of the further assessment was to ascertain the teratogenic effect on caudal fin deformities and to reason out by correlating with various environmental

factors, including certain dominant pollutants particularly, heavy metals, that were recorded previously in the study area. It is widely recognized that the caudal fin is a crucial anatomical feature of fish, essential for locomotor movements, facilitating both forward motion and turning, since it is set in the rearmost section of the vertebral axis in fishes [44]. The causes of fish malformations can be categorized into five main groups: genetic factors, developmental damage, injuries during embryonic stages,



diseases, and environmental factors causing damage <sup>[45]</sup>. Various studies have confirmed that fish abnormalities can result from a range of factors, often associated with mutations and teratogenicity effects triggered by adverse environmental conditions <sup>[46]</sup>. These abnormalities frequently manifested during the embryonic stage or in the development of the larval stage <sup>[47]</sup>. In addition, there were evidence suggesting that the deformities might be induced by variations in water temperature <sup>[48-50]</sup>, salinity <sup>[51]</sup>, dissolved oxygen <sup>[52]</sup>, heavy metals <sup>[53]</sup> and hydrocarbons <sup>[54]</sup>, as it is believed to be the cause of deformity influenced by environmental factors. It was also reported that the extreme variations of water and sediment quality parameters might be the major causes of such abnormalities <sup>[55]</sup>. All these factors, one way or other

influence the occurrence of skeletal deformity in fishes. As recorded in the present study, otolith hypercalcification deformities have also been reported <sup>[56-57]</sup>. Those studies indicated that these deformities occurred in response to adverse environmental conditions that led to physiological pressure during the early developmental stages of fish. This study also confirms that the deformity might have occurred during the developmental stages and not by injury etc. It was also substantiated that this would occur during the embryonic development in the early growth stage of fish as reported by <sup>[58]</sup>. The structure of the caudal fin is to efficiently handle hydrodynamic pressures, thereby minimizing the energy <sup>[59-61]</sup>. Previous reports on the causes of abnormalities in the study area remain inconclusive <sup>[17-60-61]</sup> (Table 4).

**Table 4:** Heavy metals, their concentration and effect on various fishes

S. No	Heavy Metal	Species	Concentration	Type of deformity	Source
1.	Cd	<i>Pagrus major</i>	0 to 3.2 mg/L	Skeletal deformities spine, tail and fins.	[25]
		<i>Cyprinus carpio</i>	0.06 to 0.3 mg/L	Vertebral column.	[26]
		<i>Oryzias latipes</i>	0.18 to 19.8 µg/L	Deformities of the spine.	[27]
		<i>Rhamdia quelen</i>	0.0005 to 0.018 mg/L	Spinal column abnormalities.	[28]
2.	Cr	<i>Odontesthes bonariensis</i>	4 to 40 µg/L	Morphological alteration (C-shaped body).	[29]
3.	Cu	<i>Carassius auratus</i>	0.1 to 1 mg/L	Curved tails and Scoliosis.	[30]
		<i>Cyprinus carpio</i>	0.2 mg/L	Spinal curvature and C-shaped larva	[31]
4.	Hg	<i>Danio rerio</i>	20 and 30 mg/L	Abnormal fin and flexure of the posterior tail region.	[32]
5.	Zn	<i>Pagrus major</i>	0.1, 0.3, 0.5, 0.7, 1.0, 1.5, 2.0, 2.5 mg/L	Hooked tail and spinal deformity	[33]
		<i>Melanotaenia fluviatilis</i>	0.33 to 33.3 mg/L	Deformities of the spine	[34]

Similar observations were reported on caudal fin abnormalities that were documented in several commercially important fish species inhabiting the waters off the Saudi Arabian coast and the Arabian Gulf <sup>[15]</sup>. Mohammad Sadegh Alavi-Yeganeh *et al.*, (2019) <sup>[16]</sup> reported the incidence of the caudal fin being missing, alongside partial caudal peduncle and skeletal deformities, in the two-striped piggy *Pomadourus stridens*. Previous reports also showed complete deformation and fusion in the caudal region in *Epinephelus coioides* and *Cynoglossus cynoglossus* found on the southeast coast of India <sup>[17]</sup>.

According to Jayaprabha *et al.*, <sup>[62]</sup>, the initial documentation of saddleback syndrome in *Etroplus suratensis* was attributed to pollutants that interfere in the embryonic development stages, resulting in this specific abnormality. There were reports on deformities in fishes, such as taillessness indicating

that predation could be the possible reason <sup>[63]</sup>, but it was unlikely that predation was the cause of taillessness for our candidate fish *E. suratensis*. Injuries resulting from attempted predation typically lead to external scarring, which can persist for years in case of severe damage. In such instances, scales may not regenerate following epidermal healing at injury sites and predatory behaviors would create noticeable indented injuries or bite marks <sup>[64]</sup>. In the current observation, no scarring or concavity was found in the tail region of the deformed fragment. Additionally, there were no signs of fractures or damage to the terminal vertebral column.

The existing reports showed significant levels of physico-chemical parameters of waters as well as heavy metal and hydrocarbon contamination in Parangipettai coastal waters, Vellar estuarine regions, including <sup>[65]</sup>, sediments <sup>[66-67-68]</sup> and marine organisms, counting fishes <sup>[69-70-71]</sup> (Table 5 & 6).

**Table 5:** Heavy metal concentration in the Vellar estuary, Parangipettai

S. No	Heavy Metal	Metal Concentration	Source
1.	Cd	01.8000 µg/l	[21]
		00.0119 µg/l	[22]
		00.0090 ppm	[23]
2.	Cr	36.0800 µg/l	[21]
		66.4900 µg/l	[22]
3.	Cu	30.6000 µg/l	[21]
		75.2200 mg/l	[24]
		00.3850 ppm	[23]
4.	Zn	44.7200 µg/l	[21]
		00.7820 ppm	[23]
		37.1600 µg/l	[22]

**Table 6:** Physico chemical parameters of Vellar estuary

S. No	Temperature (°C)	Salinity (‰)	pH	Dissolved oxygen mg/L	Sources
1.	25.00-34.40	15.00-34.10	6.90-7.50	4.50-7.60	[35]
2.	24.00-29.80	03.65-36.41	7.15-8.52	3.97-5.65	[36]
3.	28.60-31.50	15.00-35.50	7.20-8.70	3.00-8.50	[37]
4.	27.15-32.48	27.11-34.33	7.50-8.20	4.23-5.50	[38]
5.	24.13-34.80	26.60-36.80	7.50-8.60	3.90-5.36	[39]
6.	24.133-34.8	26.60-36.80	7.50-8.60	3.40-5.30	[40]
7.	23.20-33.00	00.58-33.30	7.40-8.31	3.51-8.92	[41]
8.	27.15-32.48	27.11-34.33	7.5-8.2	4.23-5.50	[42]
9.	24.20-25.70	34.00-36.60	8.20-8.00	3.60-4.20	[23]
10.	26.20-28.90	30.00-34.00	7.90-8.10	5.00-5.80	[43]

Therefore, the present study is also in the opinion that the accumulation of metals by the fishes during the embryonic development stage might have induced this deformity. In an experimental study, it was reported that *Cyprinus carpio* eggs, when were treated with Pb, Cu, and Cd, the blastomeres displayed uneven and irregular distribution during the cleavage stage, resulting in the deformation of the entire blastula [72]. Studies confirmed that the deformities could be noticed through early signs of damage in embryonic development, such as abnormal cell divisions, spine deformities, and premature lifting of the head and tail in fish embryos from the yolk sac [73]. Cheng *et al.*, [74] identified various deformities in *Danio rerio* embryos exposed to cadmium, such as head and eye underdevelopment, reduced pigmentation, heart swelling, yolk sac abnormalities, altered spine curvature, and tail deformities, highlighting significant developmental impacts of cadmium toxicity.

Additionally, Lugowska [75] identified two additional types of deformations in their experiments a fractured vertebral column accompanied by increased muscular thickness and the absence of the tail fin. There were experimental studies proved that, creation deformities in the vertebral column by cadmium exposure to the fishes at 0 to 3.2 mg/L [25], at 0.06 to 0.3 mg/L [26], at 0.18-19.8 µg/l [27] and 0.0005–0.018 mg/l [72]. Considering the above experiments in view, this study validates that the cadmium contamination could be the possible reason for the observed abnormality in *E. suratensis* in the Vellar estuary, Parangipettai, since the comparable level of cadmium was reported as 01.8000 µg/l [21], 00.0090 ppm by [23] and 00.0119 µg/l [22] in the sediments of Vellar estuary.

## 5. Conclusion

This study presents the initial documentation of taillessness / abnormality in the pearl spot fish, *Etroplus suratensis*, within Indian waters, as no prior reports have been made regarding this aspect on this fish. The observed skeletal deformities, likely influenced by environmental factors such as changes in salinity, temperature, and contamination by heavy metals, particularly cadmium, underscore the shifting environmental conditions in the study area. These findings suggest that heavy metal contamination, notably cadmium, may play a significant role in inducing such abnormalities. Consequently, ongoing environmental monitoring and mitigation efforts are essential to safeguard aquatic ecosystems and the species they support.

## 6. Acknowledgment

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## 7. References

1. Ward JA, Wyman RL. Ethology and Ecology of Cichlid fishes of genus *Etroplus* in Sri Lanka: Preliminary findings. *Environmental Biology of Fishes*. 1977;2(2):137-145.
2. Sahadevan P. Aqua tourism: evaluation of pearl spot as a candidate species for angling. *International Journal of Fisheries and Aquatic Studies*. 2017;5(2):85-89.
3. Bogutskaya NG, Zuykov MA, Naseka AM, Anderson EB. Normal axial skeleton structure in common roach *Rutilus rutilus* (Actinopterygii: Cyprinidae) and malformations due to radiation contamination in the area of the Mayak (Chelyabinsk Province, Russia) nuclear plant. *Journal of Fish Biology*. 2011;79(4):991-1016.
4. Bengtsson A, Bengtsson BE, Lithner G. Vertebral defects in fourhorn sculpin, *Myoxocephalus quadricornis* L., exposed to heavy metal pollution in the Gulf of Bothnia. *Journal of Fish Biology*. 1988;33(4):517-529.
5. Jawad LA, Hosie A. On the record of pug-headedness in snapper, *Pagrus auratus* (Forster, 1801) (Perciformes, Sparidae) from New Zealand. *Acta Adriatica*. 2007;48(2):205-210.
6. Jawad LA, Oktner A. Incidence of lordosis in the freshwater mullet, *Liza abu* (Heckel, 1843) collected from Atatürk Dam Lake, Turkey. *Annales de Biologia*. 2007;29:105-113.
7. Koumoundouros G. First record of saddleback syndrome in wild parrotfish *Sparisoma cretense* (L., 1758) (Perciformes, Scaridae). *Journal of Fish Biology*. 2008;72(3):737-741.
8. Orlov AM. Record of a tailless Richardson's ray *Bathyrhaja richardsoni* (Garrrick, 1961) (Rajiformes: Arhynchobatidae) caught off the Mid-Atlantic ridge. *Pan-American Journal of Aquatic Sciences*. 2011;6(3):232-236.
9. Jawad LA, Murat C, Ates C. Occurrence of scoliosis, pugheadness and disappearance of pelvic fin in three marine fish species from Turkey. *International Journal of Marine Science*. 2014;77(728):275-283.
10. Rutkayova J, Jawad L, Nebesaoova J, Benes K, Petraskova E, Naslund J. First records of scale deformities in seven freshwater fish species (Actinopterygii: Percidae and Cyprinidae) collected from three ponds in the Czech Republic. *Acta Ichthyologica et Piscatoria*. 2016;46(3):225-238.
11. Jawad LA, Fjellidal PG, Hansen T. First report on vertebral abnormality in the fivebeard rockling *Ciliata mustela* (Linnaeus, 1758) (Osteichthyes: Lotidae) from Masfjorden, Western Norway. *Marine Biodiversity*. 2016;48(2):1-5.
12. Jawad LA, Guclu SS, Lu GM, Karakus US, Ayata KM.

- The first record of pectoral and pelvic fins deformity in the freshwater blenny *Salaria fluviatilis* (Pisces: Blenniidae) collected from Kızılırmak River, Turkey. *Proceedings of the Zoological Institute*. 2022;326(3):143-150.
13. Tyler James C, David Johnson G, Laith Jawad, Edward, Brothers B. A developmentally tail-less adult cowfish, *Lactoria cornuta*, from Oman (Ostraciidae, Tetraodontiformes). *Proceedings of the Biological Society of Washington*. 2014;127(2):311-322.
  14. Jawad LA, Mamry AJM. Caudal fin deformity in longfin mullet, *Moolgarda pedaraki* (Valenciennes, 1836) (Pisces: Mugillidae). *Croatian Journal of Fisheries*. 2012;70(2):65-69.
  15. Jawad LA, Ibrahim M, Waryani B. Incidences of caudal fin malformation in fishes from Jubail City, Saudi Arabia, Arabian Gulf. *Fisheries & Aquatic Life*. 2018;26(1):65-71.
  16. Yeganeh MSA, Razavi S, Egan JP. Taillessness and skeletal deformity in striped piggy *Pomadourys stridens* (Osteichthyes: Haemulidae) from the Persian Gulf. *Diseases of Aquatic Organisms*. 2019;132(3):209-213.
  17. Nagamuthu J, Sambandamoorthy P, Muthukumaraswamy S. First record of abnormal fishes *Epinephelus coioides* and *Cynoglossus cynoglossus* from the south-east coast of India. *Marine Biodiversity Records*. 2015;8(24):1-5.
  18. Strauss RE, Bond CE. Taxonomic methods: morphology. In: *Methods for Fish Biology*. Ed, Moyle P, Schreck C, American Fisheries Society, Special Publication; c1990, 109-140.
  19. Fischer W, Bianchi G. FAO Species identification sheets for fishery purposes. Western Indian Ocean; (Fishing Area 51). Prepared and printed with the support of the Danish International Development Agency (DANIDA). Rome, Food and Agricultural Organization of the United Nations; c1984, 1-6.
  20. Jenny K, Pragashraj R. Phenotypic Examination of *Etroplus suratensis* (Bloch, 1790) in lower Anicut, Tamilnadu, South India. *International Journal of Recent Scientific Research*. 2018;9(4):26186-26190.
  21. Sundaramanickam A, Shanmugam N, Cholan S, Kumaresan S, Perumal Madeswaran P, Balasubramanian T. Spatial variability of heavy metals in estuarine, mangrove, and coastal ecosystems along Parangipettai, Southeast coast of India. *Environmental Pollution*. 2016;218:186-195.
  22. Justin AA, Sangamesh U, Ananthan G. Bioaccumulation of Minerals and Heavy Metals in *Crassostrea madrasensis* (Oyster) from Vellar Estuary, Parangipettai Southeast Coast of Tamil Nadu. *Journal of Aquaculture Research & Development*. 2024;15(1):1-8.
  23. Selvaraj P, Murugesan P, Punniyamoorthy R, Parthasarathy P, Marigoudar SR. Assessment of the ecological health of Vellar and Ennore estuarine ecosystems using health indices. *Indian Journal of Geo-Marine Sciences*. 2019;48(10):1580-1592.
  24. Shameem Rani K. Seasonal variation of heavy metals in Vellar estuary, South East Coast of India, Tamilnadu. *International Journal of Engineering Development and Research*. 2018;6(3):180-185.
  25. Cao L, Huang W, Shan X, Xiao Z, Wang Q, Dou S. Cadmium toxicity to embryonic-larval development and survival in red sea bream *Pagrus major*. *Ecotoxicology and Environmental Safety*. 2009;72(7):1966-1974.
  26. Zeinab A El-Greisy, Hakim AA, El-Gamal. Experimental studies on the effect of cadmium chloride, zinc acetate, their mixture and the mitigation with vitamin C supplementation on hatchability, size and quality of newly hatched larvae of common carp, *Cyprinus carpio*. *The Egyptian Journal of Aquatic Research*. 2015;41(2):219-226.
  27. Barjhoux I, Baudrimont M, Morin B, Landi L, Gonzalez P, Cachot J. Effects of copper and cadmium spiked-sediments on embryonic development of Japanese medaka (*Oryzias latipes*). *Ecotoxicology and Environmental Safety*. 2012 79:272-282.
  28. Benaduce APS, Kochhann D, Flores EMM, Dressler VL, Baldisserotto B. Toxicity of cadmium for silver catfish *Rhamdia quelen* (Heptapteridae) embryos and larvae at different alkalinities. *Archives of Environmental Contamination and Toxicology*. 2008;54:274-282.
  29. Garriz A, Miranda LA. Effects of metals on sperm quality, fertilization and hatching rates, and embryo and larval survival of pejerrey fish (*Odontesthes bonariensis*). *Ecotoxicology*. 2020;29(7):1072-1082.
  30. Kong X, Jiang H, Wang S, Wu X, Fei W, Li L, et al. Effects of copper exposure on the hatching status and antioxidant defense at different developmental stages of embryos and larvae of goldfish *Carassius auratus*. *Chemosphere*. 2013;92(11):1458-1464.
  31. Witeska M, Lugowska K. The effect of copper exposure during embryonic development on deformations of newly hatched common carp larvae and further consequences. *Electronic Journal of Polish Agricultural Universities*. 2004;7(2):57-65.
  32. Samson JC, Shenker J. The teratogenic effects of methyl mercury on early development of the zebrafish, *Danio rerio*. *Aquatic Toxicology*. 2000; 48(2-3):343-354.
  33. Huang W, Cao L, Shan X, Xiao Z, Wang Q, Dou S. Toxic effects of zinc on the development, growth and survival of red sea bream *Pagrus major* embryos and larvae. *Archives of environmental contamination and toxicology*. 2010;58(1):140-150.
  34. Williams ND, Holdway DA. The effects of pulse-exposed cadmium and zinc on embryo hatchability, larval development, and survival of Australian crimson spotted rainbow fish (*Melanotaenia fluviatilis*). *Environmental Toxicology*. 2000;15(3):165-173.
  35. Brinda S, Srinivasan M, Balakrishnan S. Studies on Diversity of Fin Fish Larvae in Vellar Estuary, Southeast Coast of India. *World Journal of Fish and Marine Sciences*. 2010;2(1):44-50.
  36. Jagadeesan L, Manju M, Perumal P, Anantharaman P. Temporal Variations of Water Quality Characteristics and Their Principal Sources in Tropical Vellar Estuary, South East Coast of India. *Research Journal of Environmental Sciences*. 2011;5(8):703-713.
  37. Santhanam P, Perumal P, Ananth S, Shenbaga Devi A. Copepod population in Vellar estuary, Parangipettai coast in relation to environmental conditions. *Journal of Environmental Biology*. 2012;33(6):1003-1010.
  38. Kumar SC, Prabu AV. Physico-chemical parameters in Parangipettai coastal waters and Vellar estuary, Southeast coast of India. *International Journal of Microbiology and Applied Science*. 2014;3(9):85-93.
  39. Arokiasundaram A, Lenin T, Veerapandian N, Sampathkumar P. Distribution of Chl an in vellar estuary and Coastal waters of Parangipettai and Southeast coast

- of India. International Journal of Advanced Research in Biological Sciences. 2014;1(9):272-282.
40. Arokiasundaram A, Lenin T, Veerapandian N, Sampathkumar P. Distribution of Chl A in Vellar Estuary and coastal waters of Parangipettai and southeast coast of India. The International Journal of Science Inventions Today. 2015;4(1):1-14.
  41. Yuvaraj P, Satheeswaran T, Damotharan P, Karthikeyan V, Dilip Kumar J, Dharani G, *et al.* Evaluation of the environmental quality of Parangipettai, Southeast Coast of India, by using multivariate and geospatial tool. Marine Pollution Bulletin. 2018;131:239-247.
  42. Vajravelu M, Martin Y, Ayyappan S, Mayakrishnan M. Seasonal influence of physico-chemical parameters on phytoplankton diversity, community structure and abundance at Parangipettai coastal waters, Bay of Bengal, South East Coast of India. Oceanologia. 2018;60(2):114-127.
  43. Vajravelu M, Sarangi RK, Ayyappan S. Variability in catch composition and CPUE of bottom trawl fishery along Parangipettai, Cuddalore and Pazhayar, Southeast coast of India, Bay of Bengal. Indian Journal of Geo Marine Sciences. 2023;52(3):145-154.
  44. Lauder GV. Function of the Caudal Fin during Locomotion in Fishes: Kinematics, Flow Visualization, and Evolutionary Patterns. American Zoologist. 2000;40(1):101-122.
  45. Schaperclaus W. Fish Diseases, Ed, Balkema AA, Rotterdam, The Netherlands. 1992;1(2):1398.
  46. Lein NTH. Morphological abnormalities in African catfish *Clarias gariepinus* larvae exposed to malathion. Chemosphere. 1997;35(7):1475-1486.
  47. Vogel G. Zebrafish earns its stripes in genetic screens. Science. 2000;19(288):1160-1161.
  48. Milton JB. Meristic abnormalities in *Fundulus heteroclitus*. Marine Science Research Centre, State University of New York. 1971;9:34.
  49. Kurokawa T, Okamoto T, Gen K, Uji S. Influence of water temperature on morphological deformities in cultured larvae of Japanese eel, *Anguilla japonica*, at completion of yolk resorption. Journal of the World Aquaculture Society. 2008;39(6):726-735.
  50. Georgakopoulou E, Katharios P, Divanach P, Koumoundouros G. Effect of temperature on the development of skeletal deformities in gilthead sea bream (*Sparus aurata* Linnaeus, 1758). Aquaculture. 2010;308(1-2):13-19.
  51. Okamoto T, Kurokawa T, Gen K, Murashita K, Nomura K, Kim SK *et al.* Influence of salinity on morphological deformities in cultured larvae of Japanese eel, *Anguilla japonica*, at completion of yolk resorption. Aquaculture. 2009;293(1-2):113-118.
  52. Turner JL, Farley TC. Effects of temperature, salinity and dissolved oxygen on the survival of striped bass eggs and larvae. California Fish and Game. 1971;57(4):268-73.
  53. Sfakianakis DG, Renieri E, Kentouri M, Tsatsakis AM. Effect of heavy metals on fish larvae deformities: a review. Environmental Research. 2015;137:246-255.
  54. Wassenberg DM, Nerlinger AL, Battle LP, Di Giulio RT. Effects of the polycyclic aromatic hydrocarbon heterocycles, carbazole and dibenzothiophene, on *in vivo* and *in vitro* cyp1a activity and polycyclic aromatic hydrocarbon-derived embryonic deformities. Environmental Toxicology and Chemistry. 2005;24(10):2526-2532.
  55. Brown CL, Nunez JM. Fish Diseases and Disorders. Volume 2, Oxon: CABI Publishing; c1998. p. 1-17.
  56. Payan P, Pontual De H, Boeuf G, Gostan NM. Endolymph chemistry and otolith growth in fish. Comptes Rendus Palevol. 2004;3(6-7):535-547.
  57. Alavi Yeganeh SM, Razavi S, Egan PJ. Taillessness and skeletal deformity in striped piggy *Pomadasys stridens* (Osteichthyes: Haemulidae) from the Persian Gulf. Diseases of Aquatic Organisms. 2019;132(3):209-213.
  58. Koumoundouros G, Gagliardi F, Divanach P, Boglione C, Cataudella S, Kentouri M. Normal and abnormal osteological development of caudal fin in *Sparus aurata* L. fry. Aquaculture. 1997;149(3):215-226.
  59. Boglione C, Marino G, Bertolini B, Rossi A, Ferreri F, Cataudella S. Larval and post larval monitoring in sea bass: morphological approach to evaluate finfish seed quality, in: Barnabe, G. *et al.* Production, environment and quality: Proceedings of the International Conference Bordeaux Aquaculture '92, Bordeaux, France. EAS Special Publication. 1992;18:189-204.
  60. Bhatt S, Srinivasan M, Rathiesh AC. Record of abnormal *Scylla olivacea* from the southeast coast of Cuddalore, Tamil Nadu. International Journal of Fisheries and Aquatic Studies. 2017;5(4):136-137.
  61. Mariasingarayan Y, Danaraj J, Bharathidasan V, Fjellidal GP, Karuppiah K, Narayanasamy R. Vertebral column deformity in six species of wild fish at the Coromandel coast, Bay of Bengal India. Aquaculture and Fisheries. 2022;10(5):59-68.
  62. Jayaprabha N, Purusothaman S, Srinivasan M. First record of saddleback syndrome in wild species, *Etroplus suratensis* (Bloch, 1790) from the southeast coast of India. Indian Journal of Geo Marine Science. 2016;45(11):1536-1539.
  63. Tutman P, Dulcic J, Caleta M. A note on caudal fin absence in *Symphodus roissali*, Risso 1810 (Pisces: Labridae) recorded in the Northern Adriatic. Ribarstvo. 2010;68(4):175-179.
  64. Honma Y. Droplets from the Sado Marine Biological Station, Niigata University-VII. Further notes on some anomalous fishes. Report of the Sado Marine Biological Station Niigata University. 1994;24:11-21.
  65. Arockiamary A, Vijayalakshmi S, Balasubramanian T. Occurrence of different types of eggs and the physico-chemical parameters of Vellar estuary, Parangipettai, South East Coast of India. Archives of Applied Science Research. 2011;3(6):41-49.
  66. Veerasingam S, Raja P, Venkatachalapathy R, Mohan R. Distribution of petroleum hydrocarbon Concentrations in coastal sediments along Tamil Nadu Coast, India. Carpathian Journal of Earth and Environmental Sciences. 2010; 5(2):5-8.
  67. Solai A, Suresh Gandhi M, Sriram E. Implications of physical parameters and trace elements in surface water off Pondicherry, Bay of Bengal, South East Coast of India. International Journal of Environmental Sciences. 2010;1(4):529-542.
  68. Lyla S, Manokaran S, Khan A. Petroleum hydrocarbon distribution in continental shelf region of southeast coast of India. International Journal of Sediment Research. 2012;27(1):73-83.
  69. Senthil LS, Kumar ATT, Pandi MT, Dhaneesh KV, Murugan BJ, Balasubramanian T. Metal contagion in ecologically important estuary located in Bay of Bengal.



- Water Quality Exposure and Health. 2012;4(3):137-142.
70. Thiagarajan D, Dhaneesh KV, Kumar ATT, Kumaresan S, Balasubramanian T. Metals in fish along the southeast coast of India. *Bulletin of Environmental Contamination and Toxicology*. 2012;88:582-588.
71. Jayaprabha N, Balakrishnan S, Purusothaman S, Indira K, Srinivasan M, Anantharaman P. Bioaccumulation of heavy metals in flying fishes along southeast coast of India. *International Food Research Journal*. 2014;21(4):1381-1386.
72. Jezierska B, Lugowska K, Witeska M. The effects of heavy metals on embryonic development of fish (A review). *Fish Physiology and Biochemistry*. 2008;35(4):625-640.
73. Meinelt T, Staaks G. The embryo-larval-test with zebrafish (*Brachydanio rerio* Hamilton-Buchanan). Validity limits-perspectives. EIFAC/XVII/92/Symp. 1992;19:1-12.
74. Cheng SH, Wai AWK, So CH, Wu RSS. Cellular and molecular basis of cadmium-induced deformities in zebrafish embryos. *Environmental Toxicology and Chemistry*. 2000;19(12):3024-3031.
75. Lugowska K. The effects of copper and cadmium on embryonic development, and quality of newly hatched common carp (*Cyprinus carpio* L.) Larvae. Ph.D. Thesis, University of Podlasie (In Polish). 2005