Spinal Curvature in the Carangid Fish *Seriola aureovittata* from Miyake-jima, Japan

Noritomo Komada and Jack T. Moyer

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Spinal curvature, hump-backed conditions and malformations involving individual vertebrae have been reported rather frequently for many species of fishes throughout the world (Dawson, 1964, 1966, 1971; Matsuzato, 1973; Dawson and Heal, 1976), but to our knowledge there is no record of vertebral anomalies in the carangid ("hiramasa"), *Seriola aureovittata* Temminck et Schlegel. On 18 September 1980, a specimen of "hiramasa" with severe spinal curvature was caught by set net at Miyake-jima, Japan (34°05′N, 139°30′E). In this study, the forms of vertebral centra in the deformed fish are described in detail to attempt to clarify the mechanism and time of occurrence of vertebral anomaly in this commercially important species.

Materials and methods

Our specimen of *S. aureovittata* was examined externally for morphological abnormalities. The length of selected portions, body weight and number of dorsal fin rays were measured and counted. The deformed fish was radiographed and then dissected and stained with 1.0% KOH solution of 0.1% alizarin red S. The vertebral number was counted from atlas to urostyle (Clothier, 1950). The length and width at 9 points on each vertebral centrum were measured with vernier calipers (1/20 mm) (Fig. 1). Finally, the fat was removed from the vertebrae with Benzene for 2 days at 40°C and the dry weight was measured.

Results and discussion

The specimen showed severe spinal curvature (lordosis) anteriorly, a gentle curvature (kyphosis) posteriorly, and shortened fin rays on the first dorsal fin (Fig. 2). Selected measurements and counts are shown in Table 1. The number of segmentally arranged structures in the deformed fish did not differ from those of normal fish (Yamada, 1961; Abe, 1976). The epaxial

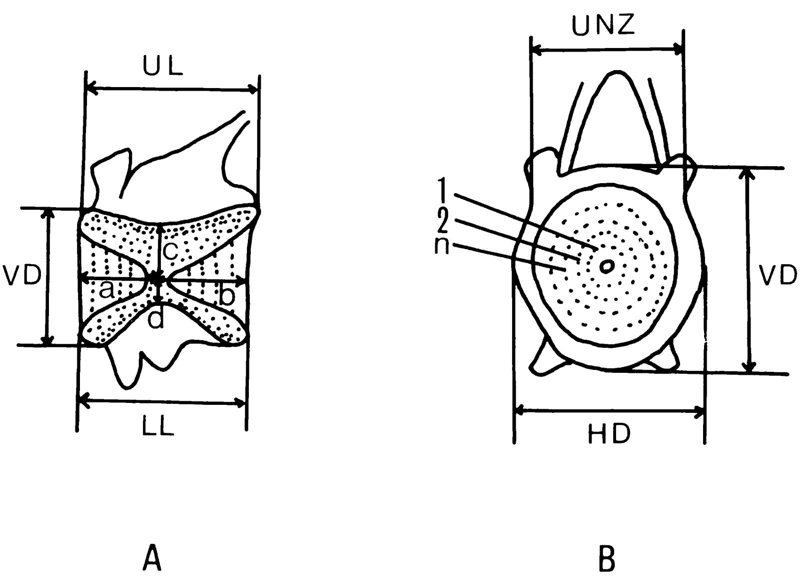

Fig. 1. Nine measured parts of vertebra. A, vertical section; B, frontal view; UL, longitudinal length of upper edge of centrum; LL, longitudinal length of lower edge of centrum; VD, vertical diameter; HD, horizontal diameter; UNZ, distance between the two anterior neural zygapophysis; a, b, c, d, distance from apex of cone to edge of centrum; 1 ~ n, number of rings of centrum.

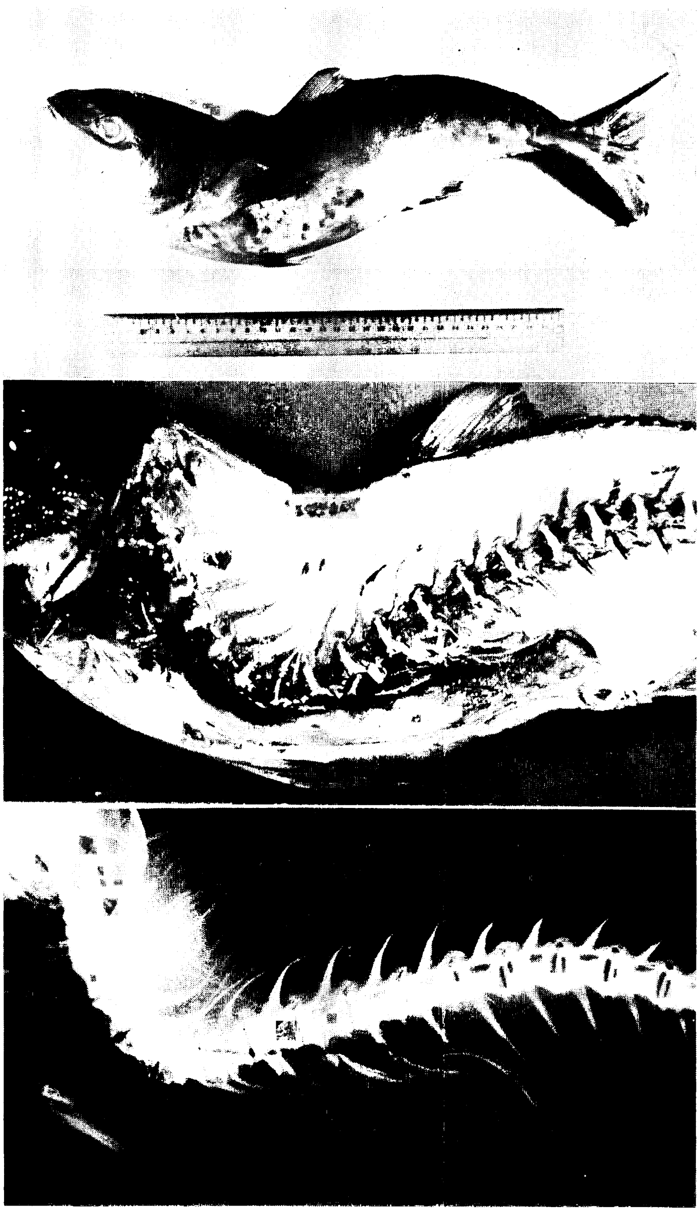

Fig. 2. A specimen of carangid fish with severe spinal curvature (top); internal structure (middle); radiograph (bottom).

portion (from the vertebral column to the dorsal surface) at the deformed region was clearly wider than the other regions of the vertebral column. Ligaments of the interspines at the deformed region were shifted. The vertebral column was severely curved upward in the vicinity of the 7th and 8th vertebrae in the abdominal region (Figs. 2, 3). Although severe curvature of the spinal column occurs more frequently posteriorly (Moore and Hixon, 1977), this specimen showed such spinal curvature in the anterior part. The body cavity (cavum pleuroperitanei) was narrow due to projection of the curved column, and the digestive organs were compressed (Figs. 2, 3).

Yamada (1961) reported that the vertebral length (VLC) of *S. aureovittata* does not vary in proportion to body size. Judging from the

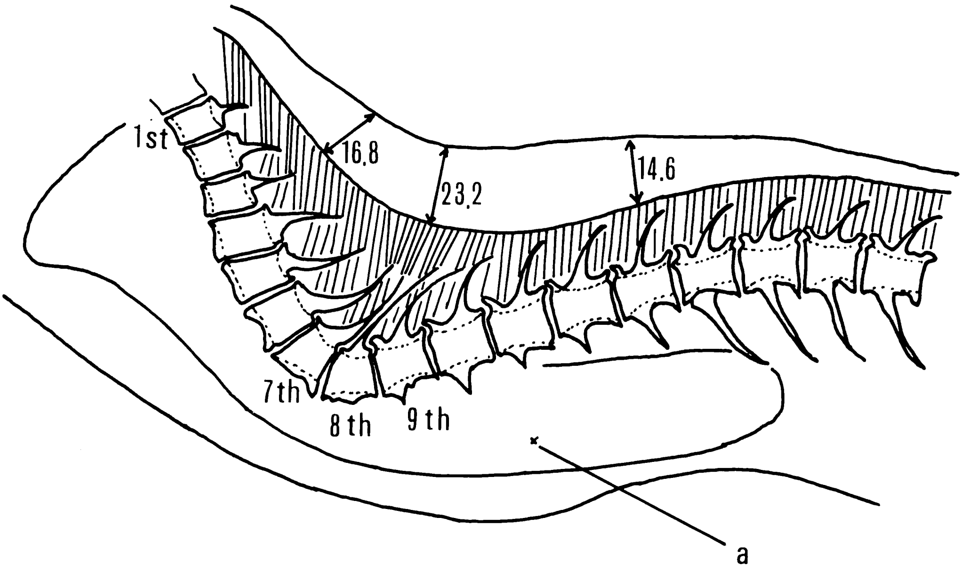

Fig. 3. Abdominal part of a deformed carangid fish. a, body cavity (cavum pleuroperitanei); length in mm.

vertebral length curve (Yamada, 1961) and the results of this study (Table 2), the upper portion of both the 7th and 8th vertebrae were compressed (shortened) and expanded (Figs. 4, 5). In the 7th and 8th vertebrae, the lengths of the upper edges of the centra compared with the lower edges were 70.9% and 64.7%, respectively. The distance between the two anterior neural zygapophysis on the 7th and 8th vertebrae was larger than those on the 6th and 9th vertebrae (Table 2). That is, the two vertebrae appeared wedged. Furthermore, the abnormal centra were curved upwards. Although these defective vertebrae showed poorly developed centra, the neural spine, anterior and posterior neural zygapophysis were distinct. The 1st, 2nd and 3rd rings at the middle part of the defective vertebrae were normal, but, the 4th ring disappeared at the upper portion (Table 2) (Fig. 5). Gaps of 3.0 mm and 3.9 mm were found between the

Table 1. Counts and measurements of the deformed carangid fish.

Standard length (mm)	370.0
Head length (mm)	120.0
Snout length (mm)	38.0
Diameter of eye (mm)	20.2
Number of first dorsal fin rays	VII
second dorsal fin rays	I, 33
anal fin rays	II, 21
vertebrae (including urostyle)	25
Body weight (g)	844.0

Table 2. Length (mm) of each of 9 measured parts and number of rings in each centrum of the deformed carangid fish.

Centrum	UL	LL	VD	HD	UNZ	a	b	c	d*	Number of rings
5th	10.10	10.80	9.35	8.85	7.40	4.30	5.45	3.50	3.45	4
6th	11.30	11.40	9.50	8.80	7.05	4.70	5.50	3.70	3.75	4
7th	8.65	12.20	9.70	8.80	7.50	4.80	5.60	4.40	2.40	4**
8th	7.50	11.60	9.80	9.10	7.95	4.30	6.00	4.90	2.10	4**
9th	12.50	12.00	9.35	8.80	6.00	5.40	6.70	3.25	2.30	4
10th	12.50	12.20	9.25	8.80	5.80	5.50	6.60	3.20	2.70	4
16th	13.00	13.10	11.60	9.00	5.75	6.20	5.70	2.70	3.55	4

* UL ~ d are shown in Fig. 1. ** 4th ring is imperfect at the upper portion of centrum.

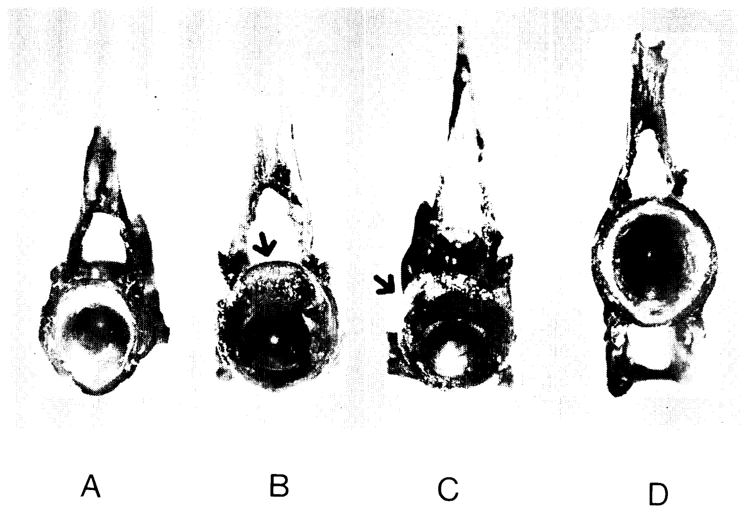

Fig. 4. Frontal view of 5th (A), 7th (B), 8th (C) and 9th (D) vertebrae of the deformed carangid fish. Arrow shows the abnormal points.

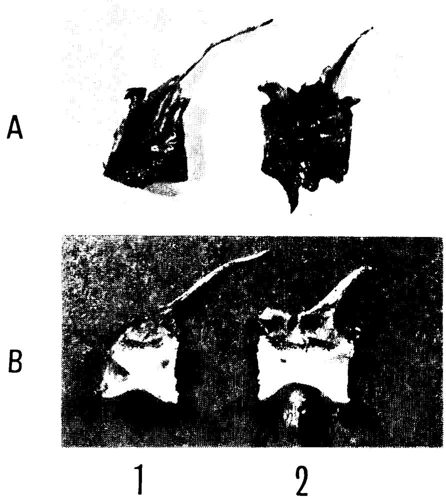

Fig. 5. Lateral view (A) and vertical section (B) of 8th (1) and 9th (2) vertebrae of the deformed carangid fish.

lower edge of the 7th and 8th vertebrae and 8th and 9th vertebrae, respectively, but gaps at the upper edges were only about 1.0 mm and 0.9 mm. Layers of connective tissue attaching the vertebrae to one another were clearly recognized, and the neural spines of the 7th and 8th vertebrae were in contact. These conditions are associated with spinal curvature (lordosis) at the abdominal vertebrae.

Generally in fishes, the incidence of shortened and fused vertebrae is higher in the caudal region than elsewhere on the vertebral column (Komada, 1979, 1980). Komada (1979) reported that in dumpy and humpbacked conditions, frequencies of abnormal vertebrae are higher near the area of transition from abdominal to caudal vertebrae than in the other regions. In this specimen, the wedged centra occurred at the middle part of the abdominal vertebrae. Such conditions may be related to the mode of swimming of fishes. Though the vertebral column gently curved at the caudal region in this specimen, the posterior vertebral centra of the column did not show morphological abnormality.

On the other hand, the dry weight of the 7th and 8th wedged vertebrae were 0.49 g and 0.48 g, and those of the 6th and 9th were 0.48 g and 0.50 g, respectively. There was, therefore, no difference between the former and the latter. That is, the two wedged vertebrae weighed the same as normal vertebrae.

Komada (1982, 1983) reported that the helical sutures of centra and abnormal calcium deposits may cause the occurrence of fused vertebrae in fishes. Furthermore, Komada (1979) suggested that compressed and shortened vertebrae were probably caused by abnormal growth ratios of centra of the spinal column in fishes. Vertebral anomalies occurring in several vertebrae during larval and juvenile stages may not cause spinal curvature (scoliosis, lordosis, kyphosis) in the adult stage. Also, Komada (1979) reported that in lordosic and kyphosic conditions in *Tribolodon hakonensis*, some fish (about 10%) showed normal vertebrae throughout the vertebral column. In the present specimen, the caudal vertebrae did not show morphological abnormality, though the fish showed some spinal curvature in the caudal region. Generally, abnormal vertebrae (shortened, compressed, wedged, fused) may occur with abnormal ossification in the centrum or with secondary deformation by curvature of the vertebral column. The results of this study suggest that the wedged vertebrae in this specimen may have been caused by severe curvature of the vertebral column resulting from poor balance of lateral muscles. Irregular curvature of the vertebral column of our specimen may have resulted from unfavorable environmental conditions during the young stage.

Acknowledgments

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(NK: Department of General Anatomy, Gifu College of Dentistry, 1851 Takano, Hozumi-cho, Motosu-gun, Gifu-ken 501-02, Japan; JTM: Tatsuo Tanaka Memorial Biological Station, Ako, Miyake-jima, Tokyo 100-12, Japan)

三宅島でとれた脊柱彎曲ヒラマサ

駒田格知・Jack T. Moyer

三宅島沿岸において1980年9月18日に採捕された脊柱彎曲ヒラマサ（体長 37.0 cm）の脊椎骨について記載し，発現時期や原因について検討した．脊柱彎曲(後彎)は腹椎で認められ，第7および第8脊椎骨で椎体の上部が著るしく圧迫・短縮され（下部の 60～70%）て楔状椎体を呈し，さらに，脊椎骨間隔も上縁部で下縁部の約 30% に減少し，これらが脊柱後彎の要素となっていた．この場合，彎曲部位では棘間靱帯も引っぱられるようにずれていた．この脊柱彎曲のために腹椎が下方に突出して，腹腔は著るしく圧迫・狭められていた．しかし，体幹後部でゆるやかな前彎を呈しているにもかかわらず，他の部位の脊椎骨では異常はみられず，また，異常脊椎骨と他の脊椎骨の間で重さや骨の組織像についても差はみられなかった．以上の結果から，この脊椎骨異常は，何らかの外的要因による体側筋の異常緊張によって脊柱の彎曲が生じた後の二次的変性として発現し，しかも発現時期は，発生初期ではなくて採捕前かなり近い時期に発生したものと考えられる．

(駒田：501-02 岐阜県本巣郡穂積町高野　岐阜歯科大学解剖学教室；Moyer：100-12　東京都三宅島阿古田中達男記念生物実験所)