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Vertebral Anomalies in *Mullus barbatus* (Actinopterygiidae: Osteichthyes: Mullidae), Collected from Izmir Bay, North-eastern Aegean Sea, Turkey

Laith A. Jawad [1] ✉, Okan Akyol [2]
1 Flat Bush, Manukau, Auckland 2016, New Zealand
2 Department of Fishing Technology, Faculty of Fisheries, Ege University, Urla, Izmir, Turkey
✉ Corresponding author email: laith_jawad@hotmail.com
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Abstract Vertebral deformity, vertebral coalescence, hyperostosis and some minor anomalies are observed in one specimen of red mullet, *Mullus barbatus*, collected from the coast of Urla, Izmir Bay, North-eastern Aegean Sea. All abnormalities were found in the abdominal and caudal regions. Factors such as environmental and genetic could be behind such deformities.
Keywords Vertebral deformities; *Mullus barbatus*; Fusion; Coalescence; Hyperostosis

Background

The most essential problem in fish development is skeletal anomalies that disrupt significantly the survival of fish. In the wild, fish specimens also showed different sorts of abnormalities, but these cases are infrequent (Ferreri et al., 2000; Gavaia et al., 2009; Jawad et al., 2013; 2014). Two main types of anomalies can be seen in fish, severe and they can affect the fitness of the animal, and minor which has slight effect on the survival of the fish and not affecting. Such deformities could be as a result of an environmental of intrinsic causes (Yershow, 2008).

The red mullet, *Mullus barbatus* Linnaeus, 1758 is a marine fish with a demersal habit living at depth range 10 - 328 m (Mytilineou et al., 2005). It found in the eastern Atlantic, Mediterranean and Black Sea and reported from Azores and it is considered among the most commercial fish species in the areas within its range of distribution (Hureau, 1986).

Due to the importance of locating and archiving the different cases of fish anomalies for fisheries studies and since this is the first time for description of such a case to be reported for *M. barbatus* from the Turkish waters, therefore, the aim is to make available for scientists around the world the description of this case in order to take it into consideration in the future management of fish stocks in the region.

1 Materials and Methods

On 25 July 2014, a single normal (145 mm total length, TL) and abnormal (127 mm TL) specimens of *Mullus barbatus* (Figure 1A; Figure 1B) was captured by a small-scale fisherman using trammel net (36 mm stretched mesh size) at a depth of 20 m on a sandy and muddy bottom from the coast of Urla, Izmir Bay, North-eastern Aegean Sea (38°22’N-26°46’E) (Figure 2). Normal fish specimen was used and attained from the same locality for comparison. Both normal and abnormal specimens were radiographed in order to verify the degree of the anomalies (vertebral deformity, vertebral coalescence, hyperostosis) using Siemens Mammomat 3000 nova mammography at an exposure time of 100 kilovolts, 30 mas, 3 seconds (Figure 3; Figure 4). The ratio between the length of the vertebral column, taken from the anterior margin of the first vertebra to the posterior margin of the last vertebra, and fish total length was calculated for both normal and abnormal vertebral column to generate a ratio that is used to evaluate the severity of the deformity (Severity of deformity = length of the vertebral column/Fish total length). The osteological terms were used in the present study following their definition given by (Chapleau, 1988; Ramzu and Meunier, 1999; Nowroozi, 2012). The specimens were fixed in a 10% formaldehyde solution and preserved in 70% ethanol prior storing in the fish collection of the Ege University, Fisheries Faculty (ESFM-PIS/2014-07). In Table 1, the morphometrics of both the normal and abnormal specimens were given.

Figure 1 *Mullus barbatus*, A, Normal, 145 mm Total length; B, abnormal 127 mm TL

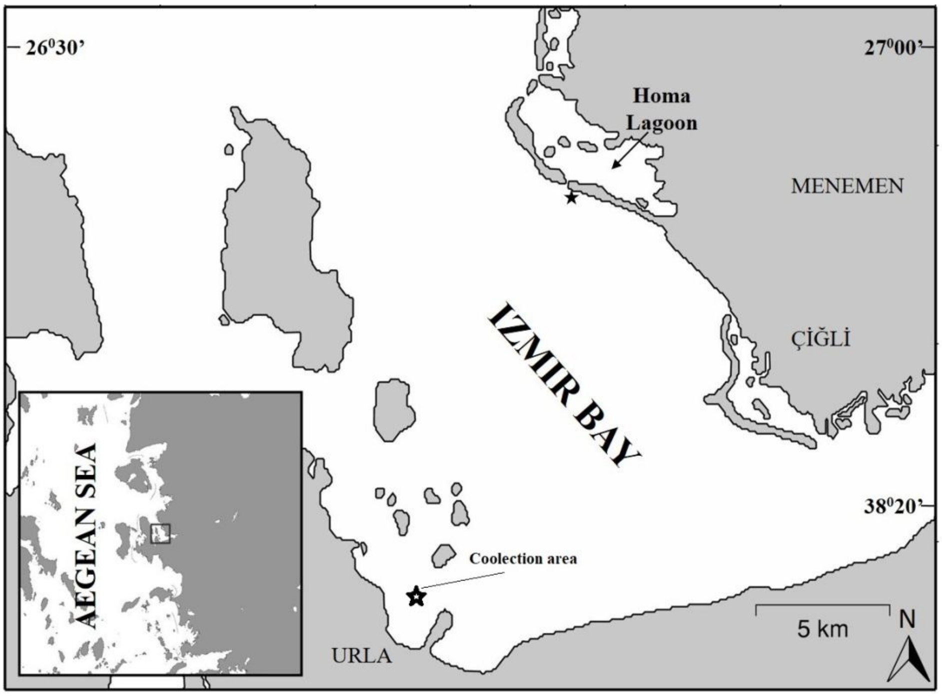

Figure 2 Map showing collecting area

2 Results

There are three types of abnormalities observed in the specimen of *M. barbatus* examined in this study, the severe case and the minor case. The severe deformity includes vertebral coalescence, vertebral deformity and hyperostosis. The vertebral coalescence occurs in the abdominal region where the 5^{th} - 8^{th} abdominal vertebrae are showed to have lost their posterior part of their vertebral centra.

In the vertebral deformity, the 3rd, 4th and 9th abdominal vertebrae and 1st, 4th and 5th caudal vertebrae were involved. The centra of the 3rd and 4th abdominal vertebrae shown to have irregular thickening and makes the sides of the centra rough. For the 9th abdominal centrum, ventral side is reduced intensely and the reduction occurred at the ventro-posterior side. The 1st caudal vertebra shown to have lost the posterior part of its centrum and the centrum of the 4th and 5th caudal vertebra appeared to have irregular thickening at the posterior and anterior parts of their centra, respectively.

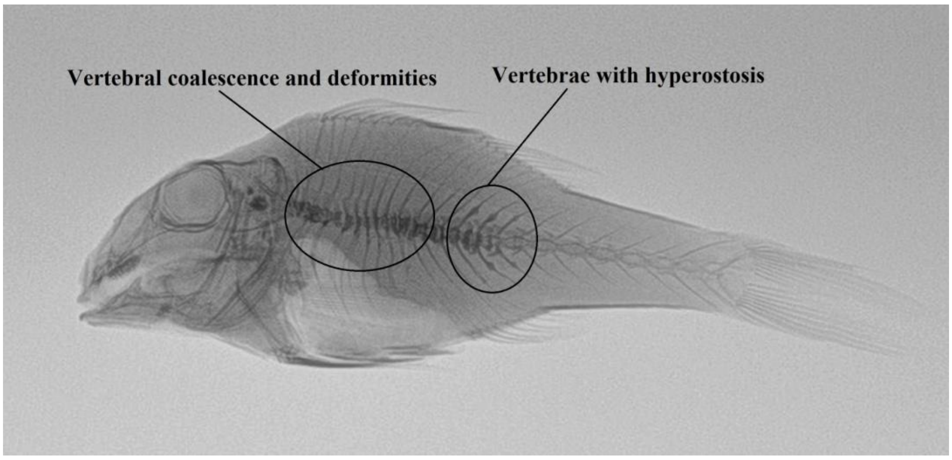

Figure 3 A specimen of *Mullus barbatus*, 127 mm TL, showing deformed vertebral column

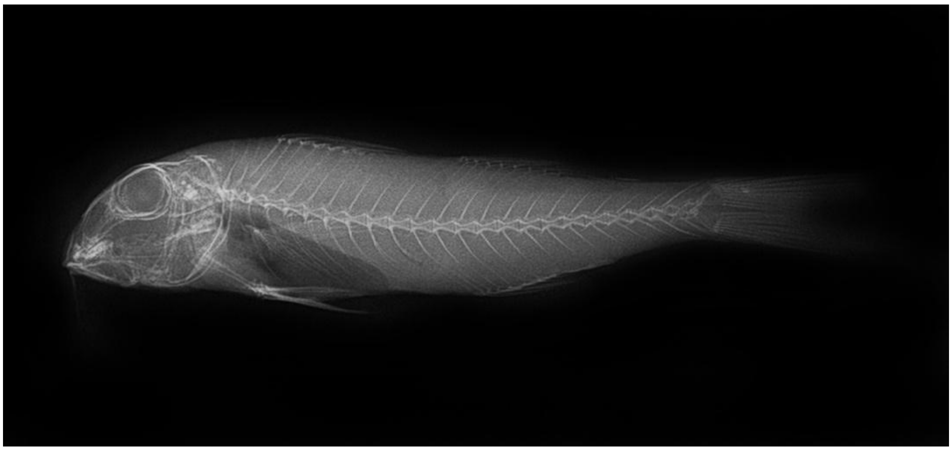

Figure 4 A specimen of *Mullus barbatus,* 145 mm TL, showing normal vertebral column

The hyperostotic regions of the species in question are present on the neural and haemal spines of the caudal vertebrae. There are three hyperostotic neural spines of caudal vertebrae 4–6. The hyperostosis varies in size, shape, and position on the spine (Figure 3). The hyperostotic regions range in length between 0.5 and 2.4 mm in diameter. The largest hyperostotic bone is that of the neural spine of the fifth caudal vertebra and the smallest is that of the haemal spine of fourth caudal vertebra. The shapes are irregular-spherical, pear-shape and spherical for the fourth, fifth, and sixth caudal vertebrae, respectively. Three of the hyperostotic regions are situated in descendent positions on the neural spines of the caudal vertebrae with that of the 6th vertebra being the highest. The other three hyperostotic regions are located near the tip of the haemal spine of the 4th caudal vertebra, while those of the 5th and 6th vertebrae being the lowest (Figure 3).

The minor abnormalities observed in this specimen include irregular shape of the pleural ribs of the 8th and 9th vertebrae and displacement of those of the other abdominal vertebrae making the sides of the body bulging side-way; twisting of the neural spine of the 4th vertebra; slight twisting of the pterygiophores supporting the soft part of the dorsal fin; a humpback at the position of the dorsal fin; and downward extension of the mouth and the preorbital area. The ratio of the vertebral column to the fish total length of the deformed specimen is 0.85, while it is 0.99 in the normal specimen.

Table 1 Morphometric (mm) and meristic characteristics of the two red mullets, *Mullus barbatus* from the Bay of Izmir, NE Aegean Sea

Characteristics	Normal specimen	Abnormal specimen
Total length (TL)	145	127
Standard length (SL)	131	99
Fork length (FL)	133	109
Head length (HL)	31	35
Preorbital length	11	13
Eye diameter	10	10
Iris diameter	4	4
Interorbital length	9	10
Maximal body depth	29	36
Body width	18	21
1st predorsal length	36	39
2nd predorsal length	65	60
Prepectoral length	35	31
Preanal length	79	60
Prepelvic length	37	31
Pectoral fin length	26	26
Left barbell length	19	18
Right barbell length	19	18
1st dorsal fin	VIII	VIII
2nd dorsal fin	9	8
Anal fin	7	7
Pectoral fin	16	16
Pelvic fin	I+5	I+5

3 Discussion

The amount of literature on fish anomalies in the wild is getting greater recently (Divanach et al., 1996; Jawad et al., 2014) that define the reasons behind the different anomalies. These studies have shown that genetic factors (Ishikawa, 1990) and non-genetic factors as a possible causes of such deformities (Fjelldal et al., 2009) in addition to the several environmental (Chatain, 1994; Gavaia et al., 2009).

Usually the spinal fusion observed in this specimen is characterised by the occurrence of variations in the extracellular matrix constituents (ECM) and mineralization of intervertebral sites and arch centra (Ytteborg et al., 2010). It could be that the present specimen has confronted an adverse environmental factors that lead to such deformity.

During the early stages of fish development, skeletal abnormalities normally originated, thus this fish might have been living for several years with its abnormalities (Haaker, 1977; Ribeiro-Prado et al., 2008). The deformation in *M. barbatus* was not fatal, but we do not know if it affected the mobility in some way. All the fins were found in apparently perfect condition. It is difficult to determine the cause of this abnormality; multiple causes can be suggested (genetic, climatic conditions, malnutrition, parasites, pollution etc.), however, further studies and monitoring are necessary to elucidate the occurrence of this phenomenon.

To explicate the severity of the deformities cases examined in the present study, the ratio of the vertebral column to the total fish length was assessed and showed to be lower than that of the normal specimen. Chang et al. (2010) have reached to analogous results on thornfish, *Terapon jarbu* and by Louiz et al. (2007) on some members of the family Gobiidae.

Comparing the morphology of the normal and abnormal specimens, Table 1 showed that the main body proportions that have been affected by the abnormalities are the total, standard, fork, head and preorbital length.

The body depth and the other body measurements are affected but to a lesser extent. Vertebral deformities examined showed no effect on the count of meristic characters.

The distribution, presence and characteristics of hyperostosis in examined fish specimen fishes are similar to those stated by Smith-Vaniz et al. (1995).

Several authors such as Olsen (1971), Desse et al. (1981), Gauldie and Czochanska (1990) and Smith-Vaniz et al. (1995) have believed that hyperostosis a non-pathological case. Among the acceptable causes to not contain hyperostosis within the pathological case is that it is related to the species of the fish.

In Izmir Bay, the environment is described to have diverse levels of pollution (Kayamakçı et al., 2001; Dogan et al., 2006; Oral et al., 2007; Oral, 2012; Kostopoulou et al., 2013) that could affect the fitness of fishes.

Pollutants shown to interrupt number of internal mechanisms of the fish during the development (Kihara et al., 2002). Such pollutants could raise the level of carbon dioxide, which may cause bone decalcification due to the occurrence of extreme carbonic acid produced as blood pH normalises (Sarkar and Kapoor, 1956; Andrades et al., 1996).

It is quite clear that varieties in the genetic pool can control variations in the developmental design. Developmental turbulences is a factor which can theoretically encourage phenotype differences in genetically indistinguishable individuals developing in identical environments (Divananch et al., 1996). In this condition, morphological unevenness in a genetically related population can supply a “size” of the developmental disorder. In this respect, Soulè (1982) suggested that an increase of the phenotypic variations is a typical of the biologic systems subjected to environmental pressure and that developmental chaos discloses itself as a decrease of the intracellular order. With the environment as a factor, this contains the effects implemented by outside circumstances (Divananch et al., 1996).

Economic outcomes of vertebral deformities are important in terms of reduced weight and being unfavourable by the customers. Therefore, further efforts to improve the management of fisheries industries should be made to explore the various etiological causes of deformities before further critical choices are made.

For Turkey as for other Mediterranean Sea states, the fisheries business is very important from both social and economic viewpoints and the relevant fisheries agencies need put more efforts on the management of this sector. As a recommendation, in order to comprehend the precise reason and effects of the fish deformity examined in the present study further researches are required to examine the variability of the anomalies discussed in the present work in both juvenile and adult commercial fish species in different locations and years, keeping in mind the issue of the mortalities that linked to these anomalies. Therefore, additional data are required to support the biotic and abiotic hypotheses in causing the deformities examined in this study.

Authors’ contributions

All authors have contributed equally toward the publication of this paper.

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