

ANNALES

Anali za istrske in mediteranske študije
Annali di Studi istriani e mediterranee
Annals for Istrian and Mediterranean Studies
Series Historia Naturalis, 33, 2023, 1





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Series Historia Naturalis, 33, 2023, 1

ISSN 1408-533X
e-ISSN 2591-1783

UDK 5

Letnik 33, leto 2023, številka 1

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Založništvo PADRE d.o.o.

Izdajatelj/Editori/Published by:

Zgodovinsko društvo za južno Primorsko - Koper / Società storica del Litorale - Capodistria®

Inštitut IRRIS za raziskave, razvoj in strategije družbe, kulture in okolja / Institute IRRIS for Research, Development and Strategies of Society, Culture and Environment / Istituto IRRIS di ricerca, sviluppo e strategie della società, cultura e ambiente®

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e-mail: annales@mbss.org, **internet:** www.zdjp.si

Redakcija te številke je bila zaključena 23. 06. 2023.

**Sofinancirajo/Supporto finanziario/
Financially supported by:**

Javna agencija za raziskovalno dejavnost Republike Slovenije (ARRS) in Mestna občina Koper

Annales - Series Historia Naturalis izhaja dvakrat letno.

Naklada/Tiratura/Circulation:

300 izvodov/copie/copies

Revija Annales, Series Historia Naturalis je vključena v naslednje podatkovne baze / La rivista Annales, series Historia Naturalis è inserita nei seguenti data base / Articles appearing in this journal are abstracted and indexed in: BIOSIS-Zoological Record (UK); Aquatic Sciences and Fisheries Abstracts (ASFA); Elsevier B.V.: SCOPUS (NL); Directory of Open Access Journals (DOAJ).

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received: 2022-11-22

DOI 10.19233/ASHN.2023.12

SKELETAL ABNORMALITIES IN A *SPHYRAENA SPHYRAENA* (LINNAEUS, 1758) AND A *TRACHINUS RADIATUS* CUVIER, 1829 COLLECTED FROM THE NORTH-EASTERN AEGEAN SEA, IZMIR, TURKEY

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ABSTRACT

This study targeted the skeletal anomalies in a European barracuda, Sphyraena sphyraena, and a starry weever, Trachinus radiatus obtained from the wild population of the north-eastern Aegean Sea, Izmir, Turkey. A severe case of consecutive repetition of lordosis-kyphosis was observed in the S. sphyraena, and a mild case of cranial lordosis, ankylosis, and hyperostosis in the T. radiatus. These records are equally important for fisheries biologists and aquaculturists as this is the first such report for the European barracuda and the starry weever, which supplements the abnormality incidences already recorded from Turkish waters. The evaluation of the anomalies in the investigated specimens was carried out based on morphological identification and using radiography. Possible reasons for such abnormalities are discussed. Additional investigation would be necessary to link specific contaminants with the examined types of anomaly.

Key words: deformities, pollution, vertebral column, lordosis, kyphosis, hyperostosis

ANOMALIE SCHELETRICHE IN *SPHYRAENA SPHYRAENA* (LINNAEUS, 1758) E *TRACHINUS RADIATUS* CUVIER, 1829 PROVENIENTI DALL'EGEO NORD-ORIENTALE, IZMIR, TURCHIA

SINTESI

Lo studio prende in esame le anomalie scheletriche del luccio di mare, Sphyraena sphyraena, e della tracina raggiata, Trachinus radiatus, appartenenti alla popolazione selvatica dell'Egeo nord-orientale, vicino a Izmir, in Turchia. È stato osservato un caso grave di ripetizione consecutiva di lordosi-cifosi in S. sphyraena e un caso lieve di lordosi cranica, anchilosi e iperostosi in T. radiatus. Questi dati sono importanti sia per i biologi della pesca che per gli acquacoltori, poiché si tratta della prima segnalazione di tali malformazioni per queste due specie, che va a integrare le incidenze di anomalie già registrate nelle acque turche. La valutazione delle anomalie negli esemplari esaminati è stata effettuata in base dell'identificazione morfologica e utilizzando la radiografia. Vengono discusse le possibili ragioni di tali anomalie. Sarebbero necessarie ulteriori indagini per collegare specifici contaminanti con i tipi di anomalia esaminati.

Parole chiave: deformità, inquinamento, colonna vertebrale, lordosi, cifosi, iperostosi

INTRODUCTION

The European barracuda, *Sphyraena sphyraena*, is a marine species living in the pelagic-neritic region in the depth range of 0–100 m (Reiner, 1996). It reaches a maximum total length of 1650 mm (Bauchot, 1987) and a maximum reported weight of 3.6 kg (IGFA, 2001). Individuals of this species are distributed in the eastern Atlantic Ocean from the Bay of Biscay to Mossamedes, Angola, including the Mediterranean and the Black Sea, the Canary Islands, and the Azores. They are also reported from the western Atlantic Ocean in Bermuda and Brazil. Torcu *et al.* (2001) suggests that the European barracuda should be listed among the highly commercial fish species in the Mediterranean Sea and the seas around Turkey.

The starry weever, *Trachinus radiatus*, is a marine species inhabiting demersal environments in the depth range of 1–150 m (Roux, 1990). It attains a maximum total length of 500 mm (Bauchot, 1987). Individuals of this species prefer areas with sand and mud bottoms on the continental shelf, from the shoreline to a depth of about 150 m (Roux, 1990). The females are oviparous (Tortonese, 1986). This species is distributed in the eastern Atlantic Ocean region from Gibraltar to the Gulf of Guinea, possibly more to the south. It is also reported from the Mediterranean Sea (Fischer *et al.*, 1987). Akyol (2003) included *T. radiatus* in the list of commercial and genuine trash catches from beach-seining. Conversely, Aytaç *et al.* (2020) suggested that this species is not among the important commercial fish species in Turkey.

Like all wild marine and freshwater fishes, *S. sphyraena* and *T. radiatus* face the possibility of a wide range of skeletal abnormalities due to several factors. In general, skeletal anomalies in fish is a critical issue for fisheries as well as the aquaculture sectors (Kužir *et al.*, 2015). Numerous incidents of various anomalies have been reported in wild and reared fishes (Afonso *et al.*, 2000; Sato, 2006; Jawad *et al.*, 2017b; Jawad & Ibrahim, 2018). It has been known that these anomalies can impact several areas of the fish body (De La Cruz-Aguero & Perezgomez-Alvarez, 2001). These deformities have been revealed to negatively influence the life of fish and curtail the market value of certain fish species (Raja *et al.*, 2016; Majeed *et al.*, 2018). In the fish that live in the wild, skeletal deformities, which may occur during the phase of development, may produce problems, for instance, in their abilities to defend the habitat (Sato, 2006; Majeed *et al.*, 2018) or contend for a mate (Sato, 2006), and lessen fisheries production (Noble *et al.*, 2012). In aquaculture facilities, these anomalies could disturb the fish by stalling their development (Hansen

et al. 2010), impairing their feeding capability (López-Olmeda *et al.*, 2012; Okamura *et al.*, 2018), increasing the risk of contamination (Janakiram *et al.*, 2018) and escalating mortality rates (Jara *et al.*, 2017). Additionally, these unwanted impacts of skeletal abnormalities will indirectly affect the economy of fish farms (Bogliione, 2013; Yıldırım *et al.*, 2014).

Deformities in the fish skeleton are often perceived and defined in numerous fish taxa, and these can be vertebral centra deformities (including kyphosis and lordosis). These can be severe or mild both in aquaculture and wild individuals (Jawad & Ibrahim, 2018; Näslund & Jawad, 2021). In case of severe deformity of the vertebral centra (compression or a combination of compression and fusion of the vertebrae) the fish will have trouble swimming (Witten *et al.*, 2006). Lordosis is another often designated axis anomaly in fish. It can be present in any part of the vertebral column, including pre-haemal and haemal locations (Bogliione *et al.*, 1995). When occurring in the pre-hemal region it is associated with swim bladder inflation failure (Chatain, 1994). Other types of lordosis comprise haemal lordosis, which is a common fish abnormality (Jawad *et al.*, 2014; Fjelldal *et al.*, 2009), cranial lordosis (affecting the most anterior vertebrae), and caudal lordosis (affecting the centra of the caudal peduncle). Kyphosis is considered less common than lordosis (Bogliione *et al.*, 2013).

Commonly, hyperostosis was thought to be an osteoma, a non-carcinogenic bone neoplasm. In English, these formations are called hyperostotic bones, swollen bones, or even “Tilly bones” (named after the late Tilly Edinger, an enthusiastic student of these structures, see Konnerth, 1966; Smith Vaniz *et al.*, 1995). They are almost exclusively limited to marine teleosts and frequently affect members of the Carangidae family in response to hormonal changes that generally occur (Smith-Vaniz *et al.*, 1995). While these structures have been observed in at least 92 marine teleost fishes belonging to 22 families (Smith-Vaniz *et al.*, 1995), they are also typical of specific fish species such as trichiurids, carangids, and sciaenids, where hormonal imbalance occurs (Giarratana *et al.*, 2012; Meunier *et al.*, 2008; Smith-Vaniz *et al.*, 1995). Further, in the over 28 years since Smith-Vaniz *et al.* (1995), 21 fish species with hyperostosis appearance belonging to 14 families have been recognised (Fjelldal *et al.*, 2012; Jawad, 2013; Jawad & Bannai, 2014; Jawad & Ibrahim, 2017; Mahmoud & Ibrahim, 2021; Matić-Skoko & Ferri, 2009; Meunier *et al.*, 1999; Meunier *et al.*, 2010; Paig-Tran *et al.*, 2016; Smith-Vaniz & Carpenter, 2007; Tuna *et al.*, 2021).

For marine fish species collected from Turkish waters, cases of lordosis-kyphosis have been recorded in *Atherina boyeri* (Jawad *et al.*, 2017a) and *Mullus barbatus* (Jawad *et al.*, 2018). Recently, Jawad *et al.* (2022) described cases of lordosis-kyphosis in specimens of *Merluccius merluccius*, *Trachurus trachurus*, and *Mullus surmuletus* from the Sea of Marmara.

The present study discusses a severe case of consecutive repetition of lordosis-kyphosis in a *S. sphyraena* and a mild case of cranial lordosis, ankylosis, and hyperostosis in a *T. radiatus*. These fish specimens were captured in the Bay of Çandarlı and off the coasts of Çeşme, Izmir, respectively, in the north-eastern Aegean Sea, Turkey. The two records are considered essential for both fisheries biologists and aquaculturists as they are the first such cases to be reported for the European barracuda and the starry weever and will importantly complement the records of abnormality incidences collected from Turkish waters so far.

Tab. 1: Morphometric (mm) and meristic characteristics of the two *Sphyraena sphyraena* captured in the Bay of Çandarlı, Izmir, NE Aegean Sea.

Tab. 1: Morfometrične (mm) in meristične značilnosti dveh primerkov vrste *Sphyraena sphyraena*, ujetih v zalivu Çandarlı, Izmir, SV Egejsko morje.
ža; GN: zabodna mreža; HL: ročna vrvica).

Characteristics	Normal specimen	Abnormal specimen
Total length	329	256
Standard length	295	223
Fork length	310	232
Head length	89	75
Preorbital length	40	35
Eye diameter	15	14
Interorbital length	13	13
Pre-first dorsal fin length	126	103
Prepectotal fin length	88	73
Preanal fin length	215	167
Number of spines of the first dorsal fin	V	V
Number of spines of the second dorsal fin	9	9
Number of rays in the anal fin	I+9	I+9
Number of rays in the pectoral fin	13	13
Number of spines and rays in the pelvic fin	I+5	I+5

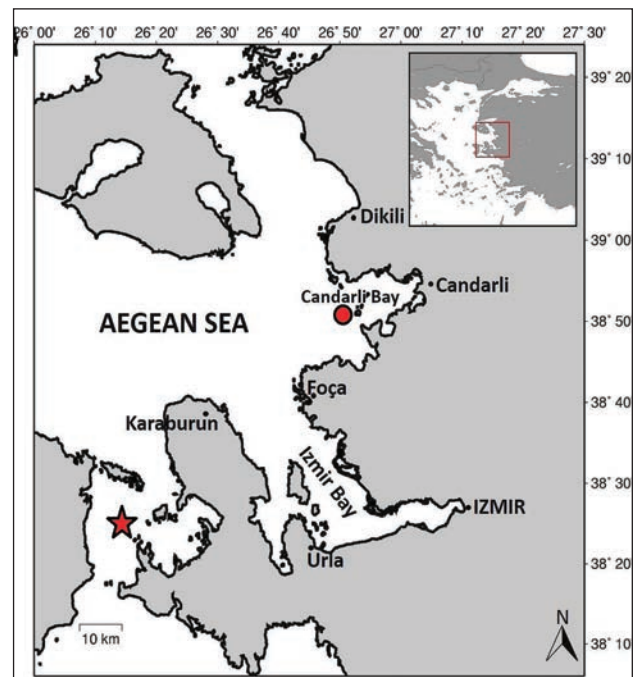


Fig. 1: Map showing sampling localities of *Sphyraena sphyraena* (red dot) and *Trachinus radiatus* (red star).

Sl. 1: Zemljevid z označenimi vzorčevalnimi postajami ulova primerkov vrst *Sphyraena sphyraena* (rdeča pika) in *Trachinus radiatus* (rdeča zvezdica).

MATERIAL AND METHODS

One abnormal specimen of *S. sphyraena* (256 mm TL) and one of *T. radiatus* (239 mm TL) were captured, respectively, off the coast of Çandarlı Bay, NE Aegean Sea (38°52' N - 26°51' E) (Fig. 1) on 19 August 2016, and off the coast of Çeşme, NE Aegean Sea (38°25' N - 26°16' E) (Fig. 1) on 30 March 2018. No such abnormalities were observed in these two fish species after the date of March 2018. Both specimens were caught by bottom trawl, the *S. sphyraena* at 50 m and the *T. radiatus* at 80 m of depth. They were fixed in a 10% formaldehyde solution and deposited in the fish collection at the Museum of the Faculty of Fisheries at Ege University, Faculty of Fisheries under museum numbers ESFM-PIS/2016-04 for *S. sphyraena* and ESFM-PIS/2018-05 for *T. radiatus*. For the purpose of comparison, two normal specimens of *S. sphyraena* (329 mm TL) and *T. radiatus* (314 mm TL) were obtained from the same localities. In defining the anomalies of the vertebral column of the fishes, all the vertebrae missing haemal spines were labelled "abdominal vertebrae" and those exhibiting haemal spines were termed "caudal vertebrae".

Tab. 2: Morphometric (mm) and meristic characteristics of the two *Trachinus radiatus* captured off Çeşme, Izmir, NE Aegean Sea.**Tab. 2: Morfometrične (mm) in meristične značilnosti dveh primerkov vrste *Trachinus radiatus*, ujetih blizu Çeşme, Izmir, SV Egejsko morje.**

Characteristics	Normal specimen	Abnormal specimen
Total length	314	239
Standard length	281	205
Head length	79	66
Preorbital length	11	11
Eye diameter	13	13
Interorbital length	11	10
Pre-first dorsal fin length	65	48
Prepectotal fin length	76	63
Preal fin length	84	68
Number of spines of the first dorsal fin	VI	VI
Number of spines of the second dorsal fin	25	24
Number of rays in the anal fin	I+26	I+26
Number of rays in the pectoral fin	16	16
Number of spines and rays in the pelvic fin	I+5	I+5

The specimen of *S. sphyraena* displayed a severe case of consecutive repetition of lordosis-kyphosis, and the *T. radiatus* a mild case of dorsal lordosis. Both specimens showed additional malformations, deletions, and morphological deformities.

To examine the vertebral columns of the two deformed fish specimens the Amadeo V mini II x-ray machine was used. The angle of the vertebral anomaly was recorded from the centre of the abnormality (located in the caudal region for *S. sphyraena* and in the thoracic region for *T. radiatus*) by using a digital protractor. To measure the degree of aberration in the anomalous individuals, the height of the curvature of the spinal column (HC) was measured. This paralleled with the distance between the tangent to the apical vertebra and a straight line passing through the bases of the two vertebrae limiting the curvature. The morphometric measures for both species were taken using a digital caliper and recorded to the nearest 0.01 mm following De Sylva (1990) for *S. sphyraena* and Roux (1990) for *T. radiatus* (Tables 1 and 2). The depth of the curvature (DC) was recorded using the following relationship given by Louiz *et al.* (2007):

$$DC = (HC / SL) \times 100 \text{ (SL = standard length of fish)}$$

RESULTS

Described below are the case of consecutive repetition of lordosis-kyphosis in the specimen of *S. sphyraena* below, and three types of deformity – i.e., mild cranial lordosis, ankylosis, and hyperostosis – observed in the abnormal specimen of *T. radiatus*.

Family: Sphyraenidae

Sphyraena sphyraena (Figs. 2 & 3)

A severe case of consecutive repetition of lordosis-kyphosis

The structures of the vertebral columns of the normal and abnormal specimens of *S. sphyraena* are shown in Figs. 2a and 2b. In this radiograph, the anomalous specimen of *S. sphyraena* exhibits three lordotic and two kyphotic areas spreading along all vertebrae from V2 to V23. Every part of these anomalies affects several vertebrae. The vertebrae composing the first lordotic arch are V1–V4, the first kyphotic arch is confined to vertebrae 5–11, the second lordotic arch includes vertebrae 12–15, the second kyphotic arch vertebrae 16–20, and the third lordotic arch encompasses vertebrae 21–23 (Fig. 2a). The value of the first lordotic angle “A” is 160°, of the first kyphotic angle “B” 150°, of the second lordotic angle “C” 137°, of

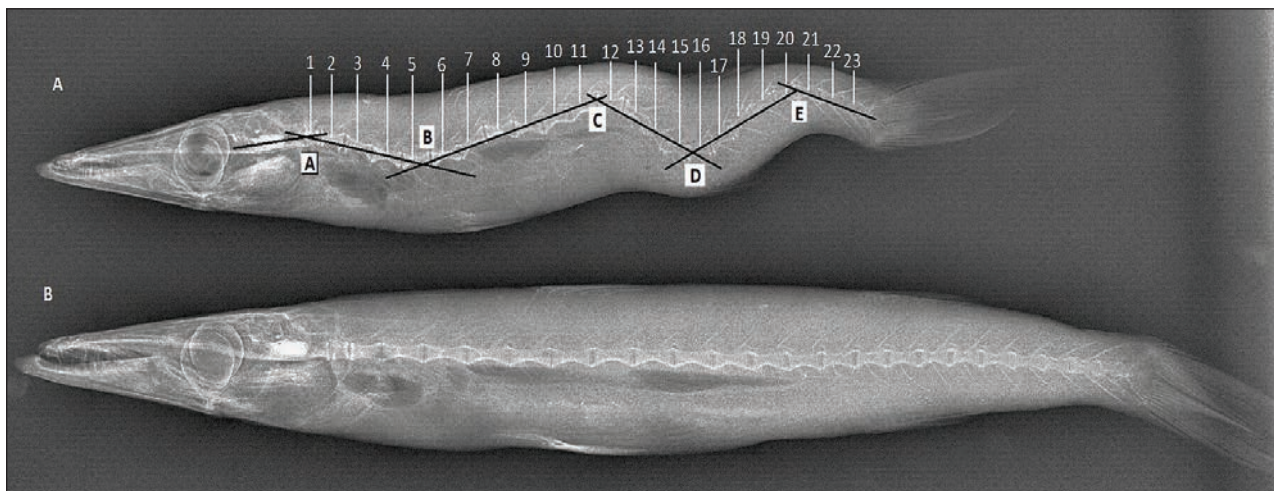


Fig. 2: Radiograph of *Sphyraena sphyraena* – a) abnormal specimen, 256 mm TL, exhibiting consecutive repetition of lordosis-kyphosis; b) normal specimen, 329 mm TL.

Sl. 2: Radiografija primerkov vrste *Sphyraena sphyraena* – a) abnormalen primerek, 256 mm TL, z zaporednim pojavljanjem lordoze-kifoze; b) normal primerek, 329 mm TL.



Fig. 3: *Sphyraena sphyraena* – a) normal specimen, 329 mm TL; b) abnormal specimen, 256 mm TL.

Sl. 3: *Sphyraena sphyraena* – a) normalen primerek, 329 mm TL; b) abnormalen primerek, 256 mm TL.

the second kyphotic angle "D" 130°, and of the third lordotic angle "E" 138°. Generally, the sizes of the vertebrae involved in lordosis-kyphosis repetition are not disturbed. The depths of the curvature (DC) of angles A, B, C, D, and E are 5.1, 5.7, 10.2, 10.9, and 10.4 mm, respectively. Compared to the normal specimen of *S. sphyraena* (Fig. 3a), the external morphology of the abnormal specimen showed two lordotic arches and one kyphotic arch (Fig. 3b).

Family: Trachinidae

Trachinus radiatus (Figs. 4 & 5)

Mild cranial lordosis

The images of abnormal and normal specimens of *T. radiatus* are shown in Fig. 4a and 4b. In comparison with the normal specimen, the abnormal specimen exhibits one cranial lordotic arch located just under the dorsal fin. The radiographs of the abnormal and normal specimens (Figs. 5a and 5b) show that the abnormal specimen has



Fig. 4: *Trachinus radiatus* – a) **abnormal specimen, 239 mm TL**; b) **normal specimen, 314 mm TL**.
Sl. 4: *Trachinus radiatus* – a) **abnormalen primerek, 239 mm TL**; b) **normalen primerek, 314 mm TL**.

one cranial lordotic arch involving thoracic vertebrae 1–5, and one thoracic kyphotic arch including thoracic vertebrae 6–10. The value of the first lordotic angle “A” is 150°, the value of the kyphotic angle “B” 155°. The depths of the curvature (DC) of angles A and B were 4.2 and 3.3 mm, respectively (Fig. 4b).

Ankylosis

Viewed externally, the distance between the posterior edge of the operculum and the anterior end of the dorsal fin is shorter in the abnormal specimen than in the normal specimen (Figs. 4a & 4b). The radiograph reveals that thoracic vertebrae 2–4 and 5–7 are compressed, deformed, and ankylosed together. In addition, vertebrae 8–14 are compressed. Finally, vertebrae number 15 is evidently compressed and deformed.

Hyperostosis

The abnormal specimen does not show any sign of abnormality related to the hyperostosis case it has (Fig. 4a). The radiograph of the abnormal specimen (Fig. 5a) shows hyperostotic deformities in two regions of the vertebral column: in the neural spine of the 16th and in the haemal spines of the 15th–17th caudal vertebrae. The diameter of the hyperostotic part of the neural spine of the 16th caudal vertebra is 2.9 mm, the sizes

of the hyperostotic parts of the haemal spines of the 15th–16th caudal vertebrae are 4.3 x 1.4 and 5.7 x 1.4 mm, respectively. The diameter of the hyperostotic part of the 17th caudal vertebrae is 2.1 mm. The shapes of the hyperostotic parts of the neural spine of the 16th and of the haemal spine of the 17th caudal vertebrae are spherical, while the shapes of the hyperostotic parts of the haemal spine of the 15th and the 16th caudal vertebrae are elongated.

DISCUSSION

This is the first report investigating the incidence and types of vertebral deformity in adult wild teleost fish species from the Aegean Sea, Izmir, Turkey. The objective was to identify skeletal deformities and define a potential link between these anomalies and environmental impacts.

There is an extensive number of publications on wild fish deformities (Divanach *et al.*, 1996; Jawad *et al.*, 2013; Jawad & Liu, 2015) that investigate both genetic (Ishikawa, 1990) and epigenetic issues as plausible reasons for such abnormalities (Boglione *et al.*, 1995), as well as environmental issues such as temperature, light, salinity, pH, low oxygen concentrations, and inadequate hydrodynamic conditions.

The morphological anomalies in the vertebral column in the form of lordosis and kyphosis observed in the specimens of *S. sphyraena* and *T. radiatus* were associated with anterior-posterior (i.e., cranial-caudal) compression along the spine. Radiographs of the deformed specimens showed structural anomalies; the normal amphicoelous (hourglass) shape of the vertebrae was imprecise, with vertebral height reduced on the convex and increased on the concave side of the vertebral column. In addition, vertebrae at the approximate bottom centre of the curvature (in the case of lordotic arch) were wedged, with the length on the concave side of the vertebral column reduced compared to the convex length of the vertebral column. Comparable differences were perceived in *Poecilia reticulata* by Gorman *et al.* (2010). They suggested that the observed deviancies in vertebral bone structure might be due to either (1) distortion of normal vertebral shape or (2) active remodelling of vertebral osteoid bone as an outcome of exterior influences. They also commented that vertebral development in fish is unlike that of other animal models. The *Poecilia reticulata* which they examined had vertebrae containing an acellular bone (i.e., without entrenched osteocytes and formed by intramembranous ossification) (reviewed in Witten & Huysseune, 2009). Accordingly, in the future, additional examinations of vertebral wedging in the two teleost fish species studied herein as well as in other fish species displaying lordosis and kyphosis should be conducted to test the cellular activity at the intervertebral region, i.e., the alleged growth zone of guppy vertebrae (Inohaya *et al.*, 2007), and determine any variation of growth in curved individuals.

The cases of lordosis, kyphosis and consecutive recurrence of lordosis-kyphosis examined herein are related to similar cases observed in other fish species collected from Turkish waters. Jawad & Ökten (2007) studied these abnormalities in *Liza* (= *Planiliza*) *abu* from Atatürk Dam Lake. Jawad *et al.* (2017a,b) and Jawad *et al.* (2018) described cases of lordosis, kyphosis, and consecutive repetition of lordosis-kyphosis in the *Atherina boyeri* collected from the Homa Lagoon, Izmir, and in the *Mullus barbatus* and *Mugil cephalus* obtained from the northern Aegean Sea, respectively. The lordosis and kyphosis in the specimens of *Liza* (= *Planiliza*) *abu* and *M. cephalus* were similar in intensity to those of the *S. sphyraena* specimen in the current study. Also, the severity of the consecutive repetition of lordosis-kyphosis described for *A. boyeri* (Jawad *et al.*, 2017a) and *Mullus barbatus* (Jawad *et al.*, 2018) was similar to that observed in the *S. sphyraena* specimen from the study at hand. Moreover, Jawad *et al.* (2022) reported similar cases of lordosis-ky-

phosis repetition in *Trachurus trachurus* and *Mullus surmuletus* collected from the Sea of Marmara. These cases are similar in severity to the case of *S. sphyraena* investigated in the current study.

Several authors have shown that bone-forming may be disturbed in waters with decreased oxygen levels through its impact on bone mineral configuration (Martens *et al.*, 2006). In the waters of the Aegean Sea in general, the annual variations of temperature would seem to suggest similar discrepancies in oxygen levels, with tremendously low levels in summer, when the temperature and salinity are at their highest (Eronat & Sayin, 2014; Tukenmez & Altıok, 2022). Hypoxia or oxygen shortage is a recognised cause of teratogenic malformations in the musculoskeletal system throughout the embryonic growth and first larval stage. Hypoxia can also initiate cell apoptosis, a key procedure in these stages (Shin *et al.*, 2004). Sub-lethal hypoxia during growth can escalate the occurrence of malformations in fish (Eva *et al.*, 2004). Instances of hypoxia have been reported from different regions of the Aegean Sea (Kalemci *et al.*, 2015; Yalçın *et al.*, 2017). Any anomaly in the morphology of the vertebrae will have a direct impact on the swimming ability of a fish and its existence (Koumoundouros *et al.*, 1997); in fact, a significant link between the severity of lordosis and swimming function has already been established in sea bass (*Dicentrarchus labrax*), at least in juveniles (Peruzzi *et al.*, 2007).

Ytteborg *et al.* (2012) proposed four characterising phases of vertebral fusion that may produce spinal fusion (as in *T. radiatus*): (i) the early phases in the merging procedure are characterised by disorderly and multiplying osteoblasts and chondroblasts; (ii) subsequently, the proliferating cells undergo a metaplastic shift: the proliferating osteoblasts co-express a mixed signal of both chondrogenic and osteogenic markers, and the proliferating chondroblasts alter transcription to a more osteogenic profile; (iii) as the pathology progresses, the elastic membrane contiguous to the notochord becomes disjointed and the notochordal sheath loses its integrity; (iv) finally, the mineralisation of intervertebral regions and arch centra becomes visible.

Indications from numerous mammalian investigations suggest that deviances in the balance between cell death and cell propagation might lead to defects (Kanda & Miur, 2004). The results of the examinations conducted by Ytteborg *et al.* (2012) propose that a boosted growth of osteoblasts in progress zones can partially be fixed by increased cell death; subsequently, the phase of metaplastic shift to vertebral fusion takes place, followed by a period of notochordal sheath vitiation, where this sheath presents itself in a reinstated shape after brief

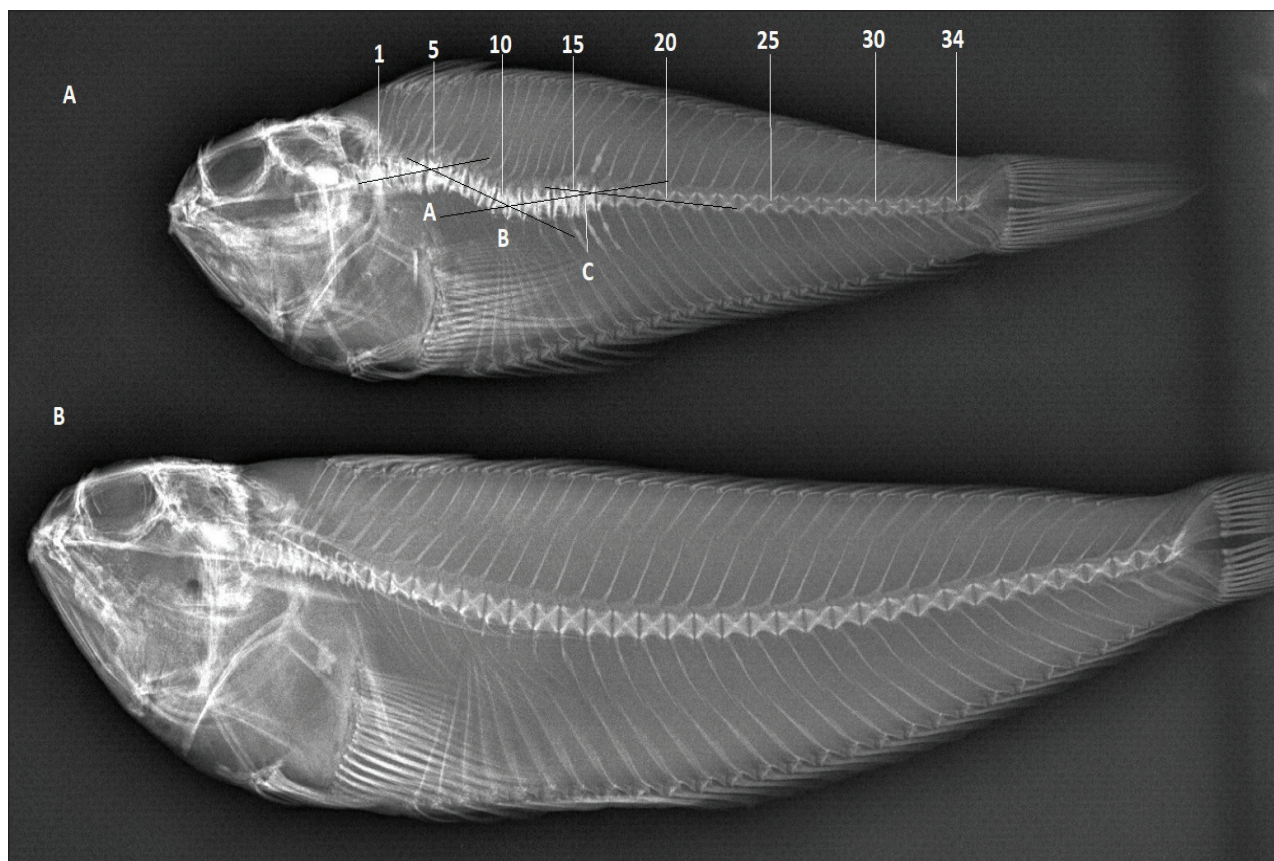


Fig. 5: Radiograph of *Trachinus radiatus*: a) abnormal specimen, 239 mm TL; b) normal specimen, 314 mm TL.

Sl. 5: Radiografija primerka vrste *Trachinus radiatus*: a) abnormalen primerek, 239 mm TL; b) normalen primerek, 314 mm TL.

deformation (Yu *et al.*, 2005); accordingly, a tear in this sheath might lead to a spinal abnormality.

It is likely that the deformed specimens of *S. sphyraena* and *T. radiatus* were exposed to unfavourable environmental impacts that might have led to such type of vertebral anomaly. Since the specimens reached a sub-adult stage, the deformity, clearly, was not fatal; nevertheless, it would have certainly impaired their swimming ability in some way when the fish attained adulthood.

Papers on hyperostosis are frequently published in relation to teleosts fishes (see Meunier *et al.* 1999 for review). A number of specimens from the following taxa have already been discussed: Clupeidae (Gaudant & Meunier, 1996), Cyprinidae (Chang *et al.*, 2008), Cyprinodontidae (Meunier & Gaudant, 1987), Carangidae (Fierstine, 1968), Cichlidae (Schlüter *et al.*, 1992), and Tetraodontidae (Tyler *et al.*, 1992).

Hyperostosis has been used by taxonomists as a taxonomic tool (Johnson, 1973; Weiler, 1973; Gauldie & Czochanska, 1990; Smith-Vaniz *et al.*, 1995; Smith Vaniz & Carpenter, 2007) and by archeoichthyologists (Béarez, 1997; Olsen, 1969;

von den Driesch, 1994) as an accurate diagnostic criterion.

Smith-Vaniz *et al.* (1995) give an account of the occurrence and dispersal of hyperostosis in fishes. The features of the hyperostotic bones shown in the starry weever *T. radiatus* investigated herein are comparable to those given by Smith-Vaniz *et al.* (1995), and to those given by other authors (Murty, 1967; Jawad, 2013; Jawad & Bannai, 2014; Jawad *et al.*, 2015; Jawad & Ibrahim, 2017).

Since only one specimen was obtained for *T. radiatus*, it would not have been plausible to verify the suggestion of Capasso (2005) that the number of hyperostotic bones in a specimen could be associated with increased body weight that would enable bottom browsing.

There are no clear data on the possible advantages or confirmed cause of any hyperostotic incidence reported so far, but some suggestions have been put forward: the affected bones may provide assistance in fin erection or in neutral buoyancy, and may be the result of ageing, high temperatures, metabolic abnormality, ionic poisoning, fungal infestation, tumours, genetic factors etc. (see review in Meunier

& Desse 1986). Schlüter & Kohring (2002) speculated that hyperostosis could be linked to the high content of fluorine in specific habitats. Previously, Greenwood (1992) also suggested that the formation of hyperostosis could be owed to high calcium carbonate content in the water, as seen in *Tilapia guinasana* from Lake Guinas.

Apart from Bhati and Murti (1960) and Selvaraj *et al.* (1973), researchers agree that hyperostoses are not clinical occurrences (Desse *et al.*, 1981; Gaudie & Czochanska, 1990; Olsen, 1971). It also seems that fishes with swollen bones exhibit normal activity (Johnson, 1973). For instance, hyperostotic developments seem predictable in the jack mackerel, *Trachurus trachurus* (Carangidae), since a high number of individuals demonstrate swollen bones at the end of their lives (Desse *et al.*, 1981). As these fish do not display anomalous behaviour, we can assume that the phenomenon is not pathologic (Smith-Vaniz *et al.*, 1995; Smith-Vaniz & Carpenter, 2007).

The occurrence of a large number of deformed fish in commercial catch regions can significantly affect the local fisheries economy. Such deformities have the potential to reduce the weight of the fish

and their value per kg. Therefore, more effort should be put into improving the management of the fisheries industry and discovering the etiological reasons behind the anomalies. Also, in order to assess the economic factors, we should ascertain the prevailing types of anomalies in the wild.

CONCLUSIONS

In this study, four types of skeletal abnormalities – ankylosis, lordosis, hyperostosis and kyphosis – were observed in two marine fish species collected from the north-eastern Aegean Sea, Izmir, Turkey. These deformities were observed in both the abdominal and caudal regions of the vertebral column and occurred in mild and severe forms. The *S. sphyraena* species showed higher vulnerability to the factors causing such abnormalities than the *T. radiatus* that we examined. The results of the present study can be considered as preliminary health status markers for the Aegean Sea and suggest that this sea environment should be investigated further in terms of pollution in order to suitably and precisely regulate its condition.

SKELETNE ANOMALIJE NA PRIMERKIH VRST *SPHYRAENA SPHYRAENA* (LINNAEUS, 1758) IN *TRACHINUS RADIATUS* CUVIER, 1829, UJETIH V SEVEROVZHODEN EGEJSKEM MORJU (IZMIR, TURČIJA)

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POVZETEK

Raziskava obravnava skeletne anomalije na morski ščuki (*Sphyrna sphyrna*), in črnoglavem morskem zmaju (*Trachinus radiatus*), ujetih v severovzhodnem Egejskem morju (Izmir, Turčija). Pri vrsti *S. sphyrna* je bil ugotovljen hud primer zaporednega pojavljanja lordoze-kifoze, pri vrsti *T. radiatus* pa blag primer kranialne lordoze, ankiloze in hiperostoze. Tovrstni primeri so pomembni tako za ribiške biologe kot tudi za gojitelje rib, saj gre za prvo poročilo o takšnih deformacijah za ti dve vrsti, ki dopolnjuje pojavnost anomalij, ki so že zabeležene v turških morjih. Vrednotenje anomalij na pregledanih primerkih so opravili na podlagi morfološke identifikacije in z radiografijo. Avtorji nadalje razpravljajo o možnih vzrokih za takšne anomalije. Potrebne bi bile nadaljnje preiskave za povezavo raziskanih anomalij s specifičnimi onesnaževali.

Ključne besede: deformacije, onesnaževanje, hrbtnica, lordoza, kifoza, hiperostoza

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