Some morphological studies on the vertebral column of the Silver-cheeked toadfish *Lagocephalus sceleratus* (Gmelin, 1789) (Family: Tetraodontidae) Collected from the Sea of Oman

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Abstract

A morphometrical study of the successive vertebrae constituting the vertebral axis of *Lagocephalus scleratus* permits a division of the vertebral column of this species into five morphologically distinct regions. This regionalization is more complicated than the classical division in truncal and caudal parts only. The biometrical study of the length, height and width of the successive vertebrae allows characteristic-looking vertebral profiles to be drawn. The regionalization in the vertebral column of the species in question could be developed through the difference in length of vertebrae in different regions of the vertebral column. These morphological descriptive parameters express a morphotype that may be linked with the Ostraciform mode of swimming of Silver-cheeked toadfish.

Introduction

The puffer fishes are commonly known of all type of fish poisoning and has been recognized from ancient times. It is probably the most common fish poisoning along the coasts of Asia. The *Lagocephalus scleratus* is known to be one of the most dangerous puffer fish species the toxicity of this species and other tetraodontid species is investigated by many authors (Kotb, 1998; Lin *et al.,* 1998). The members of the family Tetraodontidae produce the toxin tetrodotoxin and it is probably the most common poisoning along the coasts of Asia (CDC, 1996). Puffer fish poisoning has been reported in Many Asian countries including Thailand, Malaysia, Bangladesh, Taiwan and particularly Japan have shown cases of puffer fish poisoing (Kanchanapongkul, 2001). The high concentration of tetrodotoxin is present in the liver, ovaries, intestines and skin of puffer fish (Tsunenari *et al.,* 1980). Tetrodotoxin can cause failure of depolarization and propagation of action potential in nerve tissue. It can act on both the central and peripheral nervous systems. The gonad and specially the ovaries have the highest toxicity when compared with the other tested organs (Fuchi *et al.,* 1988; Ali *et al* 1995). Seasonal variation of toxicity is a characteristic feature observed in the majority of animals containing tetrodotoxin and other marine toxins (Koyama *et al.,* 1982; Noguchi *et al.,* 1985). The highest toxicity scores of the puffer fish *L. sceleratus* were recorded during April, May and June for both sexes which coincide with the spawning season (Kotb, 1998) where the toxicity generally begins to increase just before the spawning season and then decreases sharply after spawning activity.

There are as many as 120 species of puffer fish that live mostly tropical seas. They also called blowfish, toadfish, swellfish, globefish and balloon fish (Troda *et al.,* 1973). They are named after their habit of inflating themselves with water or air when threatened, making it difficult for a predator to swallow them.

The puffer fishes are belonging to the order Tetraodontiformes which comprises about 320 species of mostly shallow-water, circumtropical, and subtropical marine forms. This order is divided into two suborders (Sclerodermi or Balistoidei and Gymnodontes or Tetraodontoidei) and into 10 families (Tyler, 1980).

The phylogenetic position at one of the major end lines of teleosts radiation and their great variation in their structure, size, behaviour, way of life and habitat have gave the tetraodontids some biological interest. The tetraodontids show some commercial interest directly through the use of their dried skins and their use as food for human consumption (Tyler, 1965).

Among the tetraodontid fishes is the Silver-cheeked toadfish, *Lagocephalus scleratus* (Gmelin, 1789). It distributed in the Indo- West Pacific Ocean (Smith & Heemstra, 1986), primarily at depths ranging from 18 to 100 m, it is also a reef inhabitant (Randall, 1995).

The vertebral column varies in degree of regionalization across vertebrates. Such differences in the morphology of vertebrae of different regions of vertebral column can be revealed by biometrical studies (Kubo & Asano, 1987; 1990; Desse *et al.,* 1989). The vertebral column of actinopterygian fishes has two distinct regions: the pre-anal abdominal region and post-anal caudal region (Grande & Bemis, 1998). Although the actinopterygian vertebral column has two primary regions (i.e. abdominal and caudal), there is diversity in vertebral form within these regions (Ford, 1937; Pietsch, 1978; Grande & Bemis, 1998; Bemis & Forey, 2001). The abdominal region may include, from anterior to posterior, occipital vertebrae that are incorporated into the skull through ontogeny, anterior vertebrae that are highly modified (e.g. Weberian apparatus in

Ostariphysi and fused vertebrae in Syngnathoidei), and vertebrae that generally bear abdominal ribs. The caudal region includes vertebrae that bear haemal spines and ural vertebrae that bear hypurals. This regional pattern of vertebral structure is probably linked to, and could thus express, the locomotory functions of the vertebral column (RAMZU *et al.,* 1992).

The vertebral column plays a very important mechanical role in fish locomotion (LEARM, 1976; LINDSEY, 1978; WEIHS, 1989). During the developmental stages, this structure is subjected to different types of biological strains which seem to be expressed by local and specific morphological peculiarities (KUBO & ASANO, 1987, 1990; DESSE *et al.,* 1989). The vertebral column has strong anatomical and functional relationships with the axial musculature (LE DANOIS, 1958; LINDSEY, 1978; VRONSKII & NIKOLAITCHOUCK, 1989); therefore it is worth to study its morphological characteristics in order to reveal such relationship.

Among the comprehensive osteological studies on the members of the genus *Lagocephalus* is that of TYLER (1980). In this study, a detailed description of the morphology of the entire skeleton of *L. laevigatus* is given. In several points, the description of this species coincides with that of the species in question.

A follow up study on other teleost species such the species in question will make data available to check the morpho-functional hypothesis in those species. Therefore the present work is aimed to study the biometry of the vertebral column of the Silver-cheeked toadfish *Lagocephalus scleratus* collected from the Arabian Sea coasts of Oman as there is no such information is available in the literature for this species.

MATERIALS AND METHODS

Fishes of *L. scleratus* were collected from the vicinity of Salalah City at the Arabian Sea coasts of Oman on June 2010 (Figure 1). To prepare the vertebral columns, fish specimens were boiled and flesh strip off the bone. Additional removal of tissue was done by brushing the vertebral column with soft teeth brush under running water. The columns were dried, and the vertebrae were separated and numbered then measured with a digital 1/100 caliper. Three vertebral parameters were selected: the length of the vertebra (VL), which represents the distance along the left mid-ventral line, the anterior height (VH) corresponds to the maximum vertical distance of the anterior side of the vertebrae and width of vertebra (VW), which represents the maximum horizontal of the anterior side of the vertebrae. From these three measurements, it is possible to establish a vertebral profile which reflects the variation of these three parameters along the vertebral axis (DESSE *et al.,* 1989; RAMZU, 1994; KACEM *et al.,* 1998; RAMZU & MEUNIER, 1999). To avoid individual variation and to facilitate future comparisons with other samples, even other species, each vertebral measurement was converted into a vertebral index V_i is calculated separately for VL, VH and VW:

$$V_i = P/SL$$

Where, P is the vertebral parameter (VL, VH and VW) and SL the standard length. Profiles of the vertebral column were drawn by plotting LV, LH and LW against the ordinal number of the vertebrae.

Abdominal vertebrae were defined as those that were cranial to vertebrae with fused haemal arches. The caudal region was defined as the region from the first fused haemal arch posterior to the last centrum including the ural centrum.

Fig. 1. Map showing the collection site of the specimens of *Lagocephalus sceleratus*.

RESULTS

There are 18 vertebrae in the vertebral column of *L. scleratus*. Each vertebra is equipped with biconcave centra, except the last, which ends posteriorly in the modified urostyle and fusion with some of the hypurals (Figure 2).

It is possible to divide the vertebral column of the species in question into two main regions: an anterior region made of abdominal vertebrae without haemal spine and posterior region with caudal vertebrae with modified two haemal arches. The anterior region is divided into two regions, the postcranial (V1-V2) and the anterior middle region (V3-V8). Similarly, the posterior region is divided into posterior middle region (V9-V12) and ural region (V13-V18). The limit between abdominal and caudal vertebrae is located at the level of vertebra number 8. The 8 anterior vertebrae, or precaudal vertebrae (V1-V8), define the abdominal region or truncal, delimited by the presence of the gut. In all specimens studied, the abdominal vertebrae numbered eight. The neural spine of V1-V3 bifid vertically directed relatively short getting longer and directed backward at V4. Neural arch of V1-V4 form complete bony roof over the neural canal. The first vertebra articulates with the posterior end of the skull by posterioventrally projecting spine-like exoccipital condyles. It also articulates poaterodorsally at a shallow concavity on its lateral surface with the neural prezygapophysis of the second vertebra. From its posteroventrallateral edge, large process extends posteriorly to fit under a shallow groove on the anterior half of the ventrolateral surface of the centrum of the second vertebra. The fourth abdominal vertebra, however, has the neural spine bifid anteriorly but single posteriorly. All the

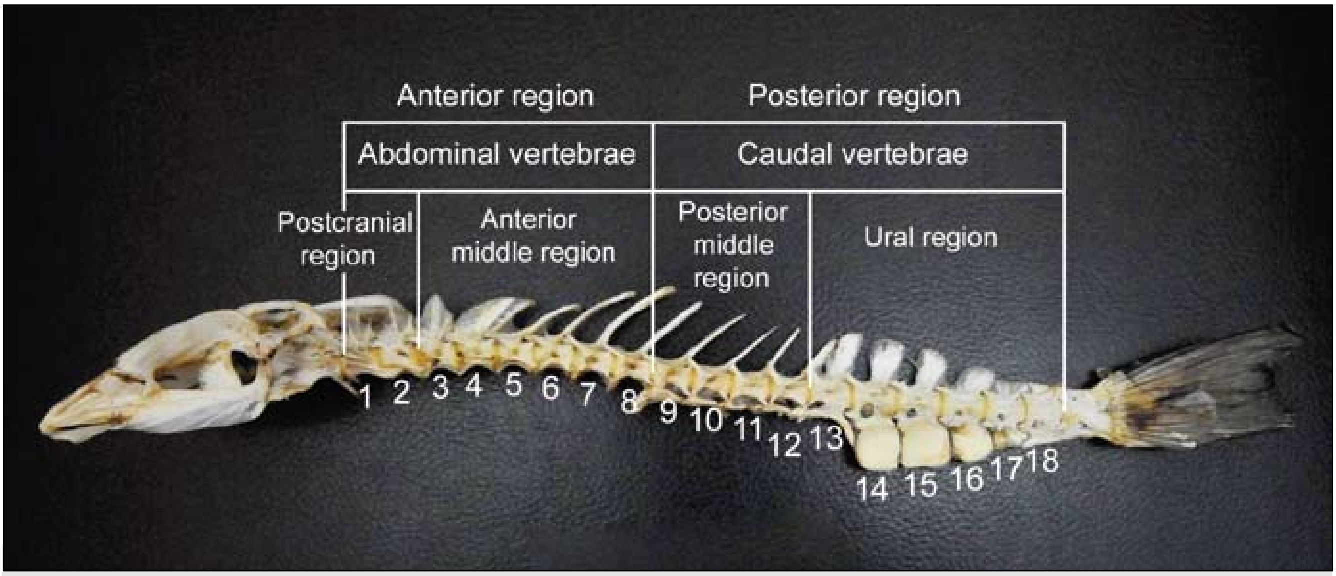

Fig. 2. Vertebral column of *Lagocephalus sceleratus* showing different regions.

vertebrae, both abdominal and caudal, posterior to the fourth abdominal vertebra have undivided neural spines. In V5-V8 abdominal vertebrae, the neural spines become increasingly thinner and longer. The neural and haemal prezygapophyses of the abdominal vertebrae, V2-V8 are gradually increase in length and no haemal arches or spines are present.

Out of 32 specimens studied, ten specimens have the caudal vertebrae started at V10 and in three specimens, caudal vertebra is started at V9. The distinctive character of the caudal vertebrae and only the caudal vertebrae is the presence of haemal arches. The caudal vertebrae V6-V8 that falls just below and posterior to the last basal pterygiophore of the anal fin possess large haemal spines. In the first four caudal vertebrae (those without conspicuous haemal spines), the haemal arches are modified for articulation by fibrous tissue with the dorsal ends of the basal pterygiophores of the anal fin. There is one projection directed anteriorly and another posteriomedially from the haemal prezygapophyses of each of these vertebrae.

On each side of the vertebra, the anterior projections from the haemal prezygapophyses do not meet in the midline under the centrum. On the other hand, the posteromedial projections from each side fuse in the midline under the centrum at the open area between the anterior projections from the haemal prezygapophyses of the vertebra behind it. Therefore, the haemal arch is formed from the haemal prezygapophyses which are displaced posteriordorsally from their normal position. On the other hand, and except in the case of the first caudal vertebra the anterior projection is greatly enlarged and ventrally directed to support of the dorsal end of the first basal pterygiophore. The fifth caudal vertebra, in all of the studied specimens, possesses a haemal spine. In the fifth caudal vertebra, and in addition to the fuse of the posteriormedial projections to each other in the midline, they also fuse to the ventrolateral edges of the centrum. Such fusion leaves an open medial canal beneath the centrum and enclosing a large foramen laterally. A long haemal spine is projected ventrally from the area of fusion with the centrum.

In the V6, V7, V8 and V10 caudal vertebrae the haemal arch fuse posterolaterally to the centrum and completely enclose the haemal canal, except laterally at the foramen. The haemal spines of the sixth, seventh and eighth caudal vertebrae are the largest of those of the caudal vertebrae. In all specimens these three haemal spines become enlarged and swollen, taking on the hyperostotic consistency. The haemal structures of the last two vertebrae are autogenous. The neural spines of the first five caudal vertebrae are slender rods. They arise from the posterodorsal surface of the neural arches at the region of the neural postzygapophyses. The neural spine of the fifth caudal vertebra is largest among the caudal vertebrae 1-5, but it is relatively small in comparison to the neural spine of the sixth, seventh and eighth caudal vertebrae. The neural spine of the vertebrae posterior to the sixth vertebra becomes progressively smaller. Whereas the haemal spines of the sixth, seventh and eighth caudal vertebrae are swollen and spongy in the studied specimens, their neural spines are normal thin hard plates.

Generally, the profiles corresponding to the three parameters measured on all the vertebrae were the same in all the specimens studied, indicating a similar trend (Figure 3, Table 1). The morphometric analysis shows that the vertebral axis of *L. scleratus* has complex division. Four regions can be characterized along the vertebral axis according to the changes of the three parameters measured from one vertebra to another.

The vertebral profile given by the variation of the vertebral length along the axis shows two maxima: one anterior at V6, the other at posterior end at V15. Between V1 and the first maximum vertebral length value at V6, the vertebral length increases steadily; then it slightly decreases and steadily increases again until reaching the second maximum value at V15. After that, the value decreases sharply reaching to its minimum value at V18.

The vertebral profile revealed by the vertebral height shows the following changes along the axis of the vertebral column: a steadily increase between V2 and V5 then a gradual decrease until reaching the minimum vale at V11. The height values

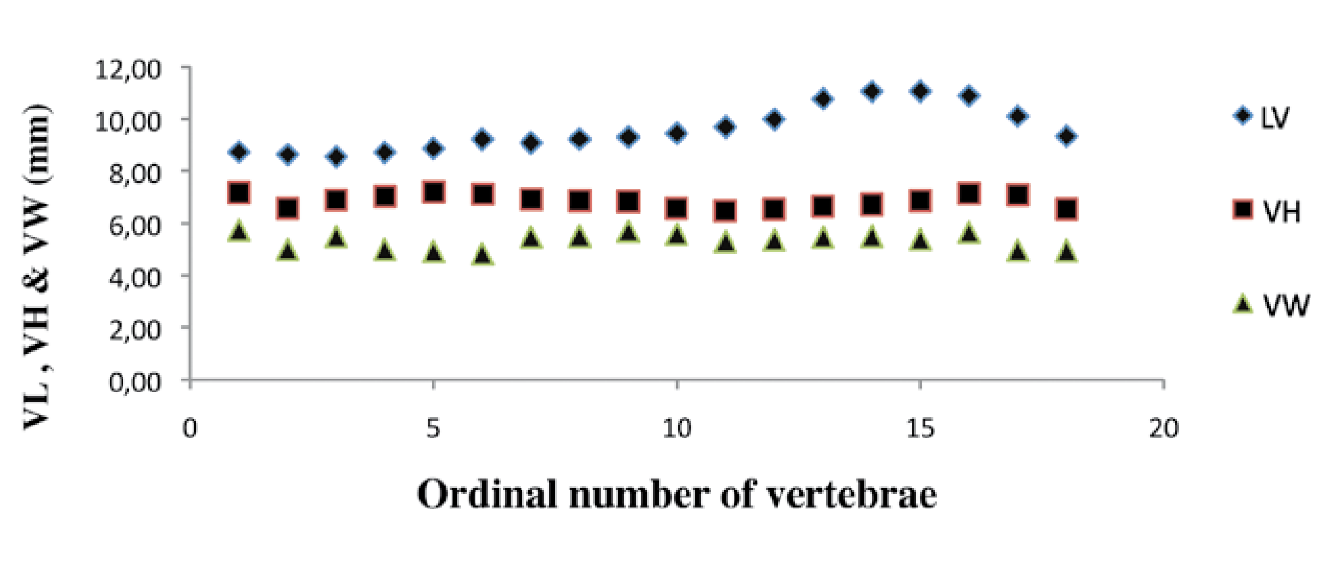

Fig. 3. Vertebral profiles of *Lagocephalus sceleratus*. VL, central length; VH, central height; VW, central width.

increased slowly reaching to its highest value at V16 then decrease to its minimum value at V18.

There are two minima shown by the vertebral width profile, one at V2 and the other at the posterior end of the vertebral column at V18. After a decrease and rise in the value between V1 and V3, the vertebral width values decrease steadily until V7 and fluctuate between V7 and V16. The vertebral width drops steadily reaching to V18.

The total number of vertebrae of *L. scleratus* is 18. Out of this number; there are 8 vertebrae as abdominal vertebrae and 10 as caudal vertebrae. The vertebral aspect ratio is 1.00 and 1.02 for the abdominal and caudal regions respectively and the index of vertebral column elongation.

Discussion

The analysis of the variation of the length, height and width of vertebrae along the vertebral column of *L. scleratus* shows that its structure is more complex than simple division in two areas, precaudaland caudal. This biometric study suggests the division of the vertebral column in four regions: 1) a poscranial (anterior truncal); 2) anterior middle region; 3) posterior middle region; and 4) ural region. The regions 1 & 4 are characterized by strong variation in vertebral parameters; in the regions 2 & 3, these variations are more regular and characterized by a cline on both side of the maximum value of the length, height and width of vertebrae.

The postcranial region, immediately at the back of the head, ensures the articulation with the skull. The first three vertebrae V1-V2 form a morphological set resulting mainly into specific parameters of vertebral length, height and width. However these three vertebrae do not show completely different morphological characteristics compared to the other vertebrae (except for the first one). For *L. scleratus*, the first vertebra plays as anterior ventral concavity which is articulated with the basioccipital. This first post-cephalic vertebra is designed to articulate with the posterior region of the skull, forming with the next vertebra a link between the two main elements of the axial skeleton, which is a function that requires some morphological specificity (VIDELER, 1993). The four vertebrae beyond V2-V6 could be considered like transition vertebrae because they show an increase in the vertebral biometric parameters (RAMZU & MEUNIER, 1999).

The middle regions include the limit between the precaudaland caudal regions (V3-V8 and V9-V12) which correspond to the haemal arch closing. It is therefore composed of truncal vertebrae and caudal vertebrae and forms morphological units. In these two regions the increase is regular until a maximum value before decreasing progressively.

The ural region starts with the 13th vertebra. It corresponds to the tail and is characterized by a slight increase then decrease of the three values of the analyzed parameters. The last five vertebrae of this region are with different anatomy of haemal arches and spines.

As in other teleost fishes (RAMZU *et al.*, 1992), the substitution of classical anatomical precaudal and caudal region by more than two regions is probably linked to the mechanical constraints of swimming. This is the case of the species in question, *L. scleratus*. Moreover, the anterior-posterior development of the three morphological parameters studied with the sudden variations of the postcranial and ural regions on the one hand, and the maximum of the middle regions on the other, favors this hypothesis (RAMZU *et al.*, 1992). The Silver-cheeked toad fish is known to present an ostraciform mode of swimming (BREDER, 1926; LINDSEY, 1978; WEBB, 1978), where the caudal peduncle and fin beat in a sculling action of caudal fin-like rowing.

The fact that the maximum of the length of the vertebra (VL) occurs around the vertebrae V14-V16; this can be the structure response of these vertebrae to the local presence of maximal mechanical constraints.

Regarding the fourth region of the vertebral column, its specific parametrical variation might express the major role performed by the caudal vertebrae in the motor process of swimming. The

ORDINAL NUMBER OF VERTEBRAE	VL		VH		VW	
	M	SD	M	SD	M	SD
1	8.72	1.67	7.16	1.41	5.73	1.40
2	8.63	1.58	6.55	1.54	5.00	1.55
3	8.54	1.36	6.88	1.40	5.48	1.42
4	8.71	1.28	7.02	1.48	4.98	1.47
5	8.87	1.34	7.20	1.59	4.92	1.58
6	9.21	1.41	7.12	1.52	4.05	1.51
7	9.08	1.37	6.92	1.29	5.45	1.28
8	9.22	1.45	6.86	1.17	5.50	1.15
9	9.30	1.25	6.84	1.06	5.67	1.04
10	9.44	1.32	6.56	1.13	5.56	1.11
11	9.68	1.18	6.47	0.97	5.29	0.96
12	9.98	1.29	6.53	1.05	5.34	1.03
13	10.77	1.61	6.65	1.08	5.46	1.06
14	11.05	2.13	6.71	1.30	5.50	1.28
15	11.06	1.93	6.86	1.18	5.38	1.16
16	10.89	1.92	7.15	1.19	5.66	1.17
17	10.10	1.81	7.07	1.33	4.97	1.31
18	9.33	1.68	6.53	1.17	4.95	1.15

Tab. 1. Average values (M) (mm) of length (LV), height (LH) and anterior width (LW) for the successive vertebrae if the vertebral column of *Lagocephalus sceleratus* (SD = standard deviation)

caudal skeleton responds to the alternate contraction of the intrinsic muscles on the lateral sides of this region, thus a torsion of the caudal peduncle is created, when they slightly increase or decrease the surface area of the caudal fin at different phases of one beat (Bainbridg, 1963), thereby creating a support on water. No body waves are present and body remains rigid useful for the odd-shaped of the fish.

The morphometric analysis of the vertebral column has revealed no significant difference between the variation of the vertebral length, height and width studied taken on each vertebra of *L. scleratus*. Therefore, characterization of one vertebra along the vertebral column would be sufficient if it based only on one of these two parameters (Desse *et al.,* 1989).

The regionalization in the vertebral column of the species in question could be developed through the difference in length of vertebrae in different regions of the vertebral column that in turn is due to different mechanisms that regulate growth of vertebrae in each region (Fjelldal *et al.,* 2005). The similarity in the value of the aspect ratio of both abdominal and caudal region obtained in this study may indicate that the changes in the vertebral length in abdominal and caudal regions are closely linked (Ward & Brainerd, 2007).

Acknowledgements

We would like to thank the Ministry of Agriculture and Fisheries Wealth, the directorate of Agriculture and Fisheries Development Fund and the Marine Science and Fisheries Centre for giving me the opportunity to work on fish samples from the Sultanate of Oman and for providing the appropriate financial support. My thanks are also due to James C. Tyler, National Museum of Natural History, Smithsonian Institution, Washington, for reviewing the manuscript and for his valuable advice and suggestions.

References

Ali A.E., Sherif N.H.S., Abbas M.M. & Mohamed A.S., 1995 - Toxicity of pufferfish; *Arthron stellatus* and *A. hispidus* in the North-Western part of the Red Sea. *Journal of Egypt-German Society of Zoology*, 17: 79-91.

Bainbridge R., 1963 - Caudal fin and body movements in the propulsion of some fish. *Journal of Experimental Biology*, 40: 23-56.

Bemis W.E. & Forey P.L., 2001 - *Occipital structure and the posterior limits of the skull in actinopterygians.* In: Ahlberg, P. (ed.). *Major events in vertebrate evolution*. London, Taylor & Francis, 350-369.

Breder C.M., 1926 - The locomotion of fishes. *Zoologica*, 4: 159-256.

Centre For Disease Control And Prevention (CDC), 1996 -Tetrodotoxin poisoning associated with eating pufferfish imported from Japan. *MMWR. Morb Mortal Weekly Report*, 45: 389-391

Desse J., Desse-Berset N. & Rocheteau M., 1989 - Les profils rachidiens globaux. Reconstitution de lataille des poisons etappréciation du nombre minimal d'individus à partir des pieces rachidiennes *Review of Paléobiology*, 8: 89-94.

Fjelldal P.G., Nordgarden U., Berg A., Grotmol S., Totland G.K., Wargelius A. & Hansen T., 2005 - Vertebrae of the trunk and tail display different growth rates in response to photoperiod in Atlantic salmon, *Salmo salar* L., post-smolts. *Aquaculture*, 250: 516-524.

Ford E., 1937 - Vertebral variation in teleostean fishes. *Journal of Marine Biological Association*, 22: 1-60.

Fuchi Y., Morisaki S., Nagata T., Shimazaki K., Noguchi T., Ohtomo N. & Hashimoto K., 1988 - Determination of tetrodotoxin in pufferfish and shellfish by high performance liquid chromatography. *Food and Hygiene Society of Japan*, 29: 305- 312.

Grande I. & Bemis W., 1998 - A comprehensive phylogenetic study of amiid fishes (Amiidae) based on comparative skeletal anatomy. An empirical search for interconnected patterns of natural history. *Journal of Vertebrate Paleontology*, 18: 1-690.

Kacem A., Meunier F.J. & Bagliniere J.L., 1998 - A quantitative study of morphological changes in the skeleton of *Salmo salar* during its anadromous migration. *Journal of Fish Biology*, 53: 1096-1109.

KANCHANAPONGKUL J., 2001 - Puffer fish poisoning: clinical features and management experience in 25 cases. *Journal of Medical Association of Thailand*, 84:385-389.

KOTB S.A., 1998 - Biochemical studies on toxicity of *Pleurancanthus scelertus* (El- Karad) in the Red Sea. Ph.D Thesis Faculty of Science. Department of biochemistry. Alexandria University.

KOYAMA K., NOGUCHI T., UZU A. & HASHIMOTO K., 1982 - Resistibility of toxic and non-toxic crabs against paralytic shellfish poison and tetrodotoxin. *Nippon Suisan Gakkaishi*, 49: 485-489.

KUBO Y. & ASANO H., 1987 - Growth type of vertebral centra and the hard tissue observed by microradiography of the rainbow trout. *Nippon Suisan Gakkaishi*, 53: 1367-1372.

KUBO Y. & ASANO H., 1990 - Relative growth pattern and hard tissue of vertebral centra by microradiography of Bluefin tuna, bigeye tuna and skipjack. *Nippon Suisan Gakkaishi* 56: 1021-1027.

LE DANOIS Y., 1958 - *Système musculaire*. In: Grassé, P.P. (eds.), *Traité de Zoologie*, 13: 783-817, Masson, Paris.

LEARM J., 1976 - The development, function, and design of amphicoelous vertebrae in teleost fishes. *Zoological Journal of Linnaean Society*, 58: 237-254.

LIN S. J., CHAI,T. J., JENG S. S. & HWANG D.F., 1998 - Toxicity of the puffer *Takifugu rubripes* cultured in northern Taiwan. *Fisheries Science*, 64: 766-770.

LINDSEY C.C., 1978 - *Form, function and locomotory habits in fish*. In: Hoar W.S., Randall, D.J. (eds.). Fish Physiology, Academic Press, New York, p1-100.

NOGUCHI T., DIAGO K., ARAKAWA O. & HASHIMOTO K., 1985 - Release of paralytic shellfish poison from the exoskeleton of a xanthid crab, *Zosimus aeneus*. In: Toxic dinoflaggellates. (ANDERSON D., WHITE A.W. & BADEN D.G., eds.) Elsevier science, New York, 293-298.

PIETSCH T.W., 1978 - Evolutionary relationships of the sea moths (Teleostei: Pegassidae) with a classification of gasterosteiform families. *Copeia*, 517-529.

RANDALL J.E., 1995 - *Coastal fishes of Oman*. Bathurst, Australia: Crawford House Publishing Pty Ltd, 439 pp.

RAMZU M., 1994 - Étude de la régionalization de la colonnevertebrale en function des modes de nage chez les téléostéens, Morphologie, histolohieetcroissance. Thèse de doctorat, University of Paris-7, Fasc. 1(texte): 145p; fasc. 2 (illustrations), 158 Fig., 121p.

RAMZU M. & MEUNIER F.J., 1999 - Descripteursmorphologique de la zonation de la colome vertébrale chez la truite are-en-ciel *Oncorhynchusmykiss* (Walbaum, 1792) (Teleostei, Salmonidae). *Annals des Sciences Naturalles*, 3: 87-97.

RAMZU M., MEUNIER F.J. & SCHOVAER D., 1992 - Morphological and histological characteristics of the vertebral axis zonation in the trout (*Salmo trutta* L.) (Teleostei, Salmonidae): possible functional implications. *Oceanis*, 18: 85-91.

SMITH M.M. & HEEMSTRA P., 1986 - *Tetraodontidae*. P.894-903. In: M.M. Smith & P.C. Heemstra (eds.) *Smith's Sea Fishes*. Springer-Verlag, Berlin.

TRODA T.A., SINCLAIR E. & ULYATT D.B., 1973 - Pufferfish (tetrodotoxin) poisoning: clinical record and suggested management. *Medical Journal of Austalia*, 1(12): 599-602.

TSUNENARI S., UCHIMURA Y. & KANDA M., 1980 - Puffer poisoning in Japan – a case report. *Journal of Forensic Science*, 25: 240-245.

TYLER J.C., 1965 - Poisonous and worthless fishes? Frontiers. *Academy of Natural Sciences of Philadelphia*, 30: 36-45.

TYLER J.C., 1980 - Osteology, phylogeny and higher classification of the fishes of the order Plectognathi (Tetraodontiformes). NOAA Technical Report NMFS, Circular 434, U.S. Department of Commerce, National Oceanographic and Atmospheric Administration, National Marine Service, p. 422.

VIDELER J.J., 1993 - *Fish swimming*. Chapman & Hall, London, 260p.

VRONSKII A.A. & NIKOLAITCHOUK L.A., 1989 - *Morphologie fonctionnelle de la musculature locomotrice du corps des poisons*. Live; La Pensée Scientifique, 184p. (In Russian).

WARD A.B. & BRAINERD E.L., 2007 - Evolution of axial patterning in elongate fishes. *Biological Journal of the Linnaean Society*, 90: 97-116.

WEBB P.W., 1978 - Hydrodynamique et énergétique de la propulsion des poisons. In: Bulletin de L'Office des recherché sur les pêcheries du Canada, 160p.

WEIHS D., 1989 - Design features and mechanics of axial locomotion in fish. *American Zoologist*, 24: 151-160.