International Journal of Fisheries and Aquatic Studies 2016; 4(6): 512-517

ISSN: 2347-5129
(ICV-Poland) Impact Value: 5.62
(GIF) Impact Factor: 0.549
IJFAS 2016; 4(6): 512-517

www.fisheriesjournal.com
Received: 07-09-2016
Accepted: 08-10-2016

Ahmed MS Omar
Department of Anatomy and Embryology, Faculty of Veterinary Medicine, Zagazig University, Zagazig, Egypt

Sherif Kh AMohamed
Department of Anatomy and Embryology, Faculty of Veterinary Medicine, Zagazig University, Zagazig, Egypt

Correspondence
Sherif Kh AMohamed
Department of Anatomy and Embryology, Faculty of Veterinary Medicine, Zagazig University, Zagazig, Egypt

Comparative morphological studies on the otoliths (Ear stones or crystals) in some marine and fresh water fishes

Ahmed MS Omar and Sherif Kh AMohamed

Abstract
To overview this study, the otoliths (ear-stones or crystals) of four fish species were obtained to complete this comparative morphological study. Thirty Narrow-barred Spanish mackerel (*Scomberomorus commerson*), thirty Hard tail jack or blue runner fishes (*Caranx crysos*), twenty Round sardinella fishes (*Sardinella aurita*) and twenty Common carp (*Cyprinus carpio*) fish species were used, where the ear-stones were extracted from the head of the fishes, prepared and examined anatomically. The results revealed that, the topographic characters of four fish otoliths were nearly similar, that all of them were rested on deep fossae on the floor of the cranial cavity just in front of foramen magnum. Significant differences were observed in this work regarding the morphological characters among these stones in fish species under investigation. We conclude that, size and shape of fish otolith might positively relate to its size, weight and age and also, surprisingly, we noted that otolith shape nearly adapted to the external outlines of each fish head. The figures were plotted and the obtained results were discussed with the available literature.

Keywords: Otoliths (ear-stones or crystals), narrow-barred Spanish mackerel, hard tail jack or blue runner, round sardinella, common carp

1. Introduction
The otolith (ear-stone or crystal) is one of the main structures of the internal ear in fishes, as well as, these ear crystals play an important role as stato-acoustic organs which were related to numerous sensory hair cells that connected with the semicircular canals of internal ear and they were concerned with the processes of hearing, balance and equilibrium [1, 2]. The otoliths were relatively heavy stones, lodged inside right and left deep fossae in the floor of cranial cavity just lower to the brain in front the foramen magnum [1, 3]. The otoliths were not bony structures while they were consisted of calcium carbonate crystals (CaCo3) [1-6]. During the movement of the fish head, the otolith touch the cilia of the sensory hair cells which detect the changes in balance and receive information to the semicircular canals to go to brain that send a response regulate the balance of the fish body inside the water [2,7]. Also, regarding the importance of the otolith for fisheries; [8, 9] mentioned that, there was a strong relationship between fish-age and otolith mass, length and width. The aim of our work is to clarify the morphological variations of the otoliths (Ear stones or crystals) in some marine and fresh water fishes and their relations to fish size, weight and age.

2. Materials and Methods
2.1 Animals
Thirty adult fishes of Narrow-barred Spanish mackerel (*Scomberomorus commerson*), thirty Hard tail jack or blue runner (*Caranx crysos*), twenty Round sardinella (*Sardinella aurita*) and twenty Common carp (*Cyprinus carpio*) fish species. Fishes were collected from different culture ponds and fishes sales areas in Zagazig and Abo-hamad cities, Sharkia, Egypt, Africa. Fishes were kept in deep freezing temperatures for further examinations.

2.2 Otolith and skull preparations
Step 1 (skull separation): Fish heads of every species were separated from the fish bodies after weighting the entire fish of every species.

The latter aimed to obtain skull of each one to describe the bony boundaries of the species otoliths. Manual removal of skin, gills and surrounding structures of fish skull by using dissecting equipments: scalpel, forceps, toothed forceps, scissors and plastic gloves. After that, fish skulls were separated of for special cleaning.

Step 2 (Otolith and skull cleaning): All soft tissues as brain were removed from the skull by filling the cranial cavity with water through foramen magnum then shaking and refilling until the cranial cavity was completely washed. Skulls were soaked in hydrogen peroxide (H_20_2) with a concentration of 2%-3% until bleaching process was occurred, then thoroughly washed [10]. The bony roof of every skull was cut by using a manual scissor to demonstrate the otoliths in its deep fossae of right and left otoliths that situated on the bony floor of the cranial cavity.

2.3 Topographic and morphologic examination

Otoliths, skulls and their adult fishes were photographed using digital camera 10 mega pixels then were edited and labeled on Adobe Photoshop Cs4 version 9. The latter aimed to declare the topographic and morphological characterizes of each otolith and its location inside the bony floor of fish skulls of differed species.

2.4 Magnification process

A magnification lens (X-4) was used to clarify the structure and outer lines of these minute crystals.

2.5 Stereomicroscope examination

As well as, the light stereomicroscope (X-10) was used for obtaining more details and clear figures. The results were registered and discussed with those of the available literature.

3. Results

3.1 Hard tail jack or blue runner adult fishes (*Caranx crysos*)

The otolithic crystal of this fish had an oval shape with sharply pointed anterior end (needle shape). It had two surfaces, two borders and two extremities; the lateral surface appeared smooth except at the crystal line appearance at its dorsal border. The medial surface characterized by the presence of a vascular furrow or groove which extends from the posterior end till the base of the pointed anterior end. The dorsal border was convex and serrated while the ventral one appeared gently convex and smooth where it extended with the needle shape anterior end. The anterior end was markedly pointed having a needle projection while the posterior one appeared rounded and convex. Fossa of each otolith appeared as an elongated oval like depression on the floor of the cranial cavity in front of foramen magnum representing the shape of otolith (Figs; 1,2,3,4 and 5).

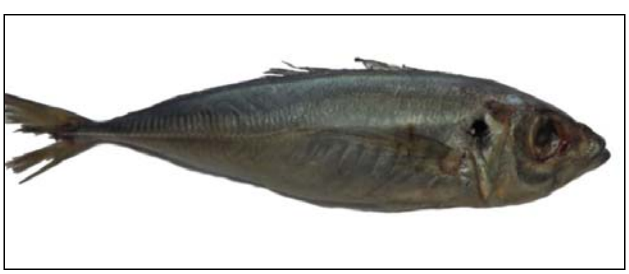

Fig 1: A photomicrograph of hard tail jack fish

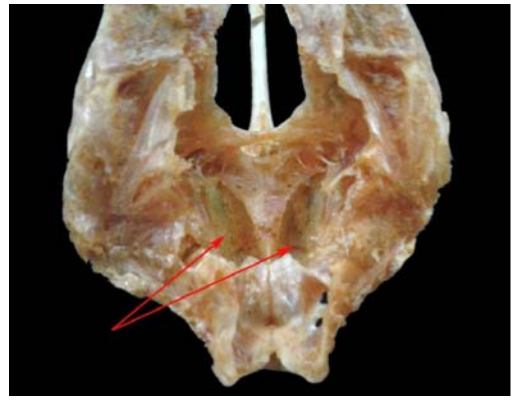

Fig 2: A photomicrograph of the skull of hard tail jack (red arrows refers to the otolithic fossae)

Fig 3: A photomicrograph of the left otolith of hard tail jack (medial view)

Fig 4: A photomicrograph of the left otolith of hard tail jack magnified by x15 stereomicroscope (medial view)

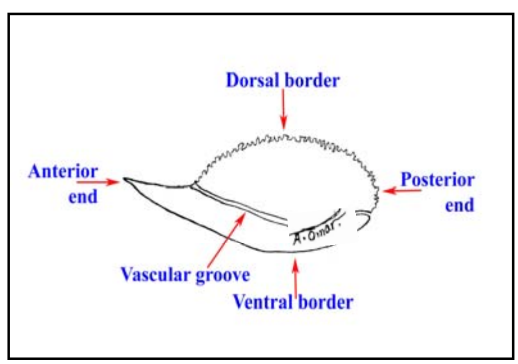

Fig 5: A schematic diagram of the right otolith of hard tail jack (medial view)

3.2 Narrow-barred Spanish mackerel (*Scomberomorus commerson*)

The otolithic crystal of these fishes appeared as an elongated quadrilateral thin plate with a wide posterior end and narrower anterior end with three pointed projections, moreover the middle one of them appeared longer and had a needle shape. The dorsal border was concave while the ventral one appeared straight. The medial surface was convex and carried a vascular groove; in addition the lateral surface was concave. Fossa of each otolith appeared as an elongated slit like depression on the floor of the cranial cavity in front of foramen magnum (Figs; 6,7,8,9 and 10).

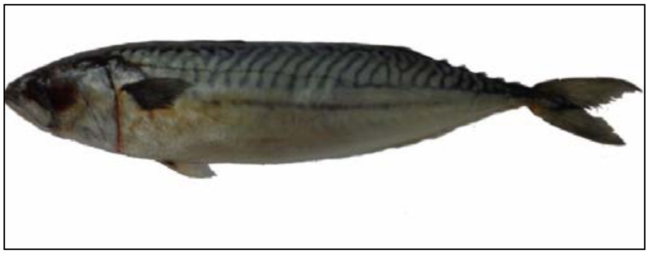

Fig 6: A photomicrograph of Narrow-barred Spanish mackerel fish

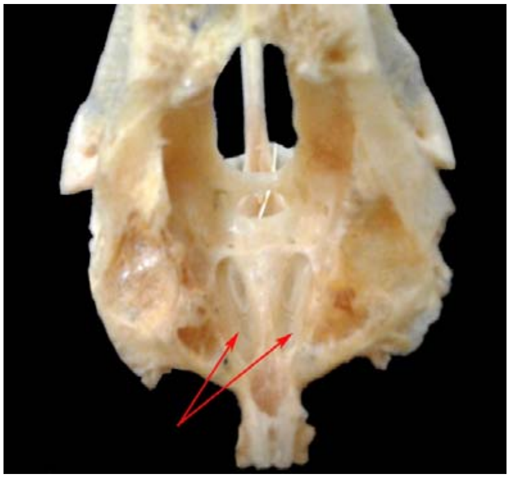

Fig 7: A photomicrograph of the skull of Narrow-barred Spanish mackerel (red arrows refers to the otolithic fossae)

Fig 8: A photomicrograph of the left otolith of Narrow-barred Spanish mackerel (medial view)

Fig 9: A photomicrograph of the left otolith of Narrow-barred Spanish mackerel magnified by x15 stereomicroscope (medial view)

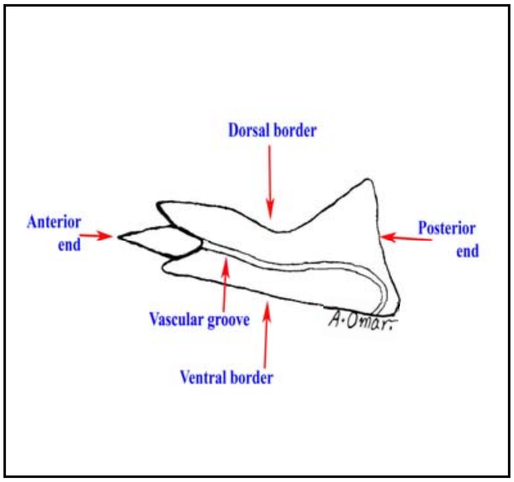

Fig 10: A schematic diagram of the right otolith of Narrow-barred Spanish mackerel (medial view)

3.3 Round sardinella (*Sardinella aurita*)

The ear stone of Round sardinella fish was small in size in relation to the small size of this species. In general it had a bifid shape where it was formed of two unequal parts (completely fused), where the dorsal part appeared smaller than the ventral one. The two surfaces were smooth; the dorsal border was gently convex and smooth while the ventral one was straight except for presence of a serrated middle portion. The anterior end appeared pointed while the posterior one was rounded. Fossa of each otolith appeared as a small slit like depression at the floor of the cranial cavity (Figs; 11,12,13,14 and 15).

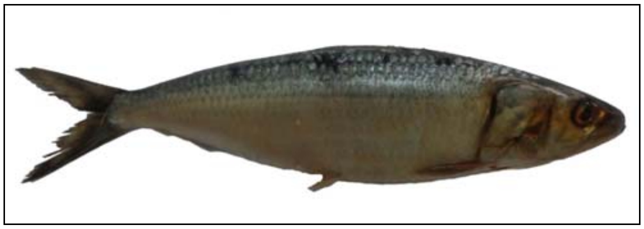

Fig 11: A photomicrograph of Round sardinella

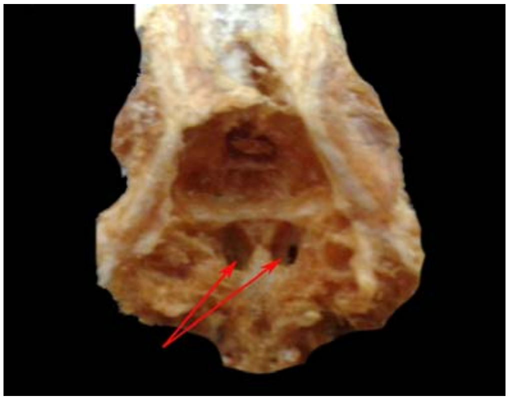

Fig 12: A photomicrograph of the skull of Round sardinella (red arrows refers to the otolithic fossae)

Fig 13: A photomicrograph of the left otolith of Round sardinella (medial view)

Fig 14: A photomicrograph of the left otolith of Round sardinella magnified by x15 stereomicroscope (medial view)

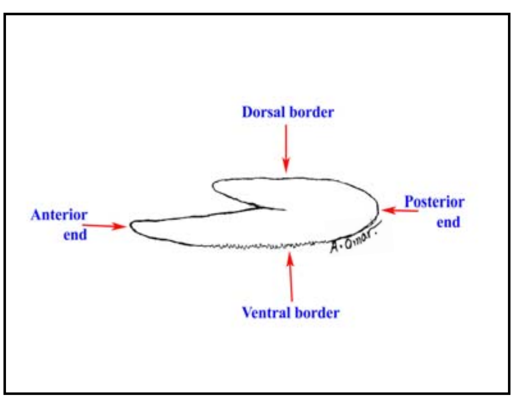

Fig 15: A schematic diagram of the right otolith of Round sardinella (medial view)

3.4 Common carp (*Cyprinus carpio*)

The otoliths in Common carp formed of two pairs; anterior large one in addition to smaller posterior one. The anterior pair (right and left otoliths) was lodged in the corresponding fossae; each otolith had a quadrilateral or nearly circular shape except for the wide right-angled notch which present anteriorly. At the angle of this notch there was a very sharp minute spinous process. The outer line of this otolith was clearly serrated, the lateral surface appeared smooth while the medial one was convex and carried a faint vascular groove. The smaller otolith (posterior pair) of this species had a very small or minute size in relation to the size and weight of the individual, where it measured about 2mm length in a fish of 300 gm weight and located in a fossa at the posterior part of cranial cavity on both sides of the exit of Foramen magnum. It had a kidney (bean) shape with a clear notch on its ventral border, while the dorsal border is smooth and convex. As well as, the caudal border appeared rounded while the anterior one was pointed. Also, its lateral surface was smooth; while the medial one was smooth except for its posterior elevated end. Fossa of anterior otolith appeared nearly rounded shallow depression while the posterior fossa looked as small slit like depression at the floor of the cranial cavity near foramen magnum representing the shape of each otolith (Figs; 16,17,18,19,20,21,22 and 23).

Fig 16: A photomicrograph of Common carp fish

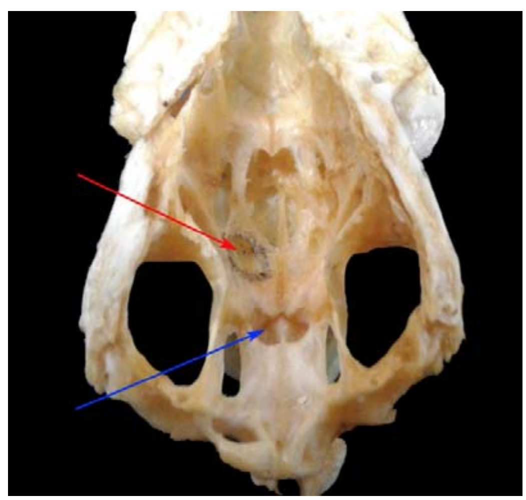

Fig 17: A photomicrograph of the skull of Common carp (red arrows refers to the anterior otolithic fossa, blue arrow refers to the caudal one)

Fig 18: A photomicrograph of the right anterior otolith of Common carp (medial view)

Fig 19: A photomicrograph of the right posterior otolith of Common carp (medial view)

Fig 20: A photomicrograph of the right anterior otolith of Common carp magnified by x15 stereomicroscope (medial view)

Fig 21: A photomicrograph of the left posterior otolith of Common carp magnified by x15 stereomicroscope (medial view)

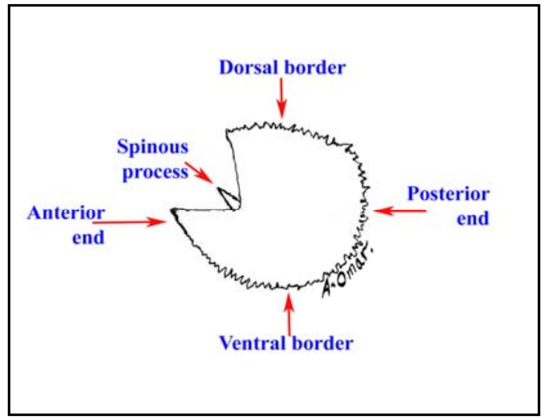

Fig 22: A schematic diagram of the right anterior otolith of Common carp (medial view)

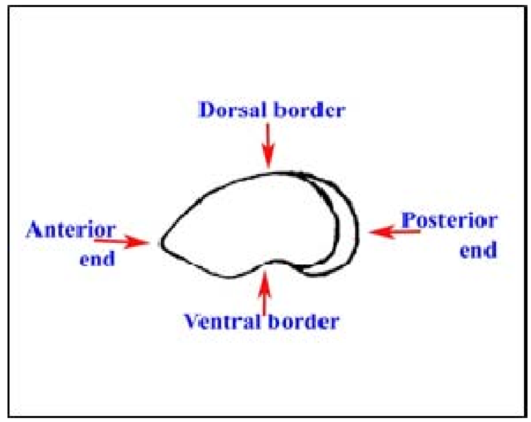

Fig 23: A schematic diagram of the right posterior otolith of Common carp (medial view)

4. Discussion

Our findings about the marked differentiation in the shape of the otoliths of the studied species were highly variable among fish species; where their shapes ranging from a relatively simple disc in some flat-fishes to irregular shape in the red-fishes [11]. Indeed, we noted in this study that the lateral surface of otoliths in four fishes was smooth. A vascular groove or furrow (Sulcus acousticus) on the medial surface of the otoliths has been observed [4].

The blue fin tuna had otoliths of elongated form in larger fishes and squared in small ones [12], a result which was completely differed from the present findings where the otolithic shape was fixed in both small and larger individual in the same species.

With regard to some fresh-water fishes, an oval, leaf-like shape (oblong or flat shape) in addition to the serrated edge in eel otolith, a result which came in a line with the present research about the clear difference in the shape of otoliths in the fish species under investigation. The latter author added that, the shape and size of otoliths vary between fish species and might be used as a good marker for fish identification [13]. In the same line, [14] explained that, the otolith shape may aid in the identification of the species, the findings which could be supported by the present study where each species under investigation had a characteristic otolithic shape. Moreover, the growth, shape and size of otoliths were strongly affected by the environmental factors such as temperature, pressure, as well as, the saturation of the carbonates, a result which not employed here [15, 16].

Notably, The otoliths of all fishes under investigation were observed inside deep fossae in the cranial cavity just lower to the brain where they were considered as a part of the main compartments of the internal ear which was concerned with the balance, hearing and equilibrium [1-6, 13, 17].

Concerning the determination of fish-age, the otoliths may be used in this respect [13, 14]. Furthermore, [18] pointed out that, this method could be used in marine fishes only but it was rarely employed in fresh-water species, where the annual rings could be counted on their scales. These statements not used in the present study but the size of the otolith may give a good indication about the weight and size of the examined fish.

Surprisingly, one pair of the otoliths (right and left ones) in all studied species was observed in the present study except for two pairs were seen in the common carp fish, arranged in an anterior and posterior position. A similar result was reported by [1,5,6,12,19], while three otoliths (3 pairs) on each side of the head inside the cranial cavity arranged in an anterior, middle and posterior positions were recorded [4, 13, 20]. In addition, two pairs of the otoliths were first observed in Salmon embryos, while the third pair developed latter anterior to the first pairs [20].

It is also interesting to note that the structure of these otoliths not bony in their tecture, but they consist of precipitation of calcium carbonate crystals (Caco3), this was in correlation with [1, 4, 6, 17]. Moreover, the otoliths of Tilapia nilotica were formed of calcium carbonate or calcareous crystals which became more solid and relatively heavy structures. In particular, the calcium carbonate crystals of teleost fishes were solidified into a single mass to give the otoliths [5].

Generally, the four fish otoliths were lodged on deep fossae on the floor of the cranial cavity just in front of foramen magnum that indicated the similarity in their topographic characters. We can note that all otoliths take the same shape of its fossae in skull and also, right and left otoliths in the same species are typically similar in its shape.

It is of great importance to know that the lateral surface of all otoliths in four fishes was smooth while the medial one is grooved, that may indicate the connection of the medial surface with semicircular canals of internal ear.

The variations in the size and shape of otoliths in different species might be used as an excellent mark for fish identification (their age, weight and size).

5. Acknowledgment

We thank God and our stuff for completing this work.

6. Disclosure

The authors declare no conflicts of interest, financial or otherwise.

7. References

1. Harder A. Anatomy of fishes Schweizerbart' sche Verlagsbushhandlung (Nagele U. obermiller) Stuttgart. 2nd Ed. E. 1975, 326-332.
2. Rodríguez Mendoza RP. Otoliths and their applications in fishery science. Ribarstvo. 2006; 64(3):89-102.
3. Kontas S, Bostanci D. Morphological and Biometrical Characteristics on Otolith of *Barbus tauricus* Kessler, 1877 on Light and Scanning Electron Microscope. Int. J Morphol. 2015; 33(4):1380-1385.
4. Lombarte A, Lleonart J. Otolith size changes related with body growth, habitat depth and temperature. Environ. Biol. Fishes. 1993; 37:297-306.
5. Popper AN, Ramcharitar J, Campana SE. Why otoliths? Insights from inner ear physiology and fisheries biology. Mar. Freshwater Res. 2005; 56:497-504.
6. Omar A, Mervat M, Konsowa, Helal A. Anatomical and biochemical studies on the otolith of tilapia nilotica. African Association of Veterinary Anatomist. March 1st scientific conference. Cairo. Egypt, 2010.
7. Zorica B, Sinovcic G, Čikes kec V. Preliminary data on the study of otolith morphology of five pelagic fish species from the Adriatic Sea (Croatia). ACTA ADRIATICA. 2010; 51(1):85-92.
8. Cardinale M, Arrhenius F, Johnsson B. Potentiale use of otolith weight for the determination of age structure of Baltic cod (*Gadus morhua*) and Plaice (*Pleuronectes platessa*). Fish. Res. 2000; 45:239-252.
9. Araya M, Cubillos L, Guzman M, Penailillo J, Spulveda A. Evidence of a relationship between age and otolith weight in the Chilean jack mackerel, Trachurus Symmetricus murphyi. Fish. Res. 2001; 54:17-26.
10. Lee Post D. The bone building books step by step guides for the preparation and articulation of animal skeletons. 1st Ed, 2005, 25-36.
11. Hunt JJ. Morphological characteristics of otoliths for selected fish in the Northwest Atlantic. J Northw. Atl. Fish. Sci. 1992; 13:63-75.
12. Megalofonou P. Comparison of otolith growth and morphology with somatic growth and age in young-of-the-year bluefin tuna. J Fish Biol. 2006; 68:1867-1878.
13. Artzi Y, Gisis G, Goldstein H. Manual for freshwater fish otoliths-Israel. INP A. 2009, 1-20.
14. Akin T, Gulnur M, Hasan T. The use of otolith length and weight measurements in age estimations of three Gobiidae species (*Deltentosteus quadrimaculatus, Gobius niger, and Lesueurigobius friesii*). Turk. J Zool. 2011; 35(6):819-827.
15. Wilson Tr, Depth-related RR. changes in sagitta morphology in six macrourid fishes of the Pacific and Atlantic Oceans. Copeia. 1985, 1011-1017.
16. Aldrich JC. The world beyond the species, an argument for greater definition in experimental work. In: J.C. 1989, 3-8.
17. Parmentier E, Cloots R, Warin R, Henrist C. Otolith crystals (in Carapidae): Growth and habit. J Struct. Biol. 2007; 159:462-473.
18. Iikyaz AT, Metin G, Kinacigil HT. The use of otolith length and weight measurements in age estimations of three Gobiidae species (*Deltentosteus quadrimaculatus, Gobius niger, and Lesueurigobius friesii)*. Turk. J Zool. 2011; 35(6):819-827.
19. Juma Al-Mamry, Jawad L, Al-Busaidi H, Al-Habsi S, Al-Rasbi S. Relationships between fish size and otolith size and weight in the bathypelagic species, Beryx splendens Lowe, 1834 collected from the Arabian Sea coasts of Oman. Quad. Mus. St. Nat. Livorno. 2010; 23:79-84.
20. Geffen AJ. The deposition of otolith rings in Atlantic salmon (*Salmo salar* L., embryos). J Fish Biol. 1983; 23:467-474.