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Descriptive key to the otoliths of three *Sardinella* species (Pisces, Clupeidae) from the northern Oman Sea

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Abstract. The Sagitta otolith characteristics in 3 species viz. *Sardinella gibbosa*, *S. longiceps* and *S. sindensis*, of various standard lengths were compared. The results showed that these species have acquired peculiar characteristics which separate them from the other species. Likewise presence of two groups of characteristics: (1) characteristics that are consistent in the sagitta otoliths of *S. gibbosa*, *S. longiceps* and *S. sindensis* which are useful to separate these species from the rest of clupeids species, however these otolith characteristics in 3 species of *Sardinella* genus are more closely related to one another, (2) characteristics that vary due to genetically guided mechanism and biological factors but that may be useful to define species and are species-specific.
Key Words: otolith, morphology, SEM, *Sardinella*, Oman Sea.

Introduction. The inner ear in all of teleosts (Osteichthyes) contains a left and right membranous labyrinth enclosed in bony otic capsules at the rear of the neurocranium. The labyrinth includes three semicircular canals oriented in different planes and three compartments: the utriculus, sacculus and lagena. Each compartment contains otoliths (earbones or earstones), the lapillus, sagittae and asteriscus, respectively (Berra & Aday 2004). Otoliths have an important biological function because they enable the inner ear to mediate the senses of hearing and balance (Popper et al 2005). These otoliths are composed of calcium carbonate in the form of aragonite, in a protein matrix. The present study focuses on the saccular otolith, which is the largest and/or most massive of the three types of otoliths in most groups of teleost fishes (Nolf 1985; Assis 2005), however, in otophysan fishes (Cypriniformes, Siluriformes, Characiformes and Gymnotiformes) the asteriscus is the largest (Harvey et al 2000; Berra & Aday 2004). Otoliths commonly are used to determine the taxon, age, and size of fishes (Harvey et al 2000).

Aristotle, in the third century BC, was the first to observe the uniqueness of fish otoliths (Stinton 1975), whereas their taxonomic utility was recognised by Cuvier (Cuvier & Valenciennes 1836) and their value to palaeoichthyology was first acknowledged by Koken (1884). Since then, the use of the saccular otolith as a taxonomic characteristic has proliferated, as demonstrated by the number of publications on otoliths of extant species (e.g. Nolf 1985; Hecht 1987; Smale et al 1995). The species-specific shape properties of the otolith have been used in stomach content studied of marine ichtiophagous species (Fitch & Brownell 1968). Ontogenetic otolith shape change during fish growth have been described and used to identify age in commercial species (Cardinale et al 2004) and sex and maturing stage (Piera et al 2005). Characteristics of populations can also be detected by the morphology of the saccular otolith (Reichenbacher & Sienknecht 2001; Schulz-Mirbach & Reichenbacher 2006).

Studies on otolith morphology of the family Clupeidae are few. The aim of the present work is to give a comprehensive description of the otolith of 3 species of *Sardinella* genus collected from the Oman Sea to facilitate these species identification

and the characterization of three size classes of fish standard length. This work is regarded as a contribution to ichthyology since it will help resolve future taxonomic problems that might arise among the members of the genus *Sardinella*.

Material and Method. In total, one hundred ten sagitta otoliths pairs of *Sardinella* genus belonging to different standard lengths collected from the Oman Sea (Figure 1), in November 2008, were analyzed. The specimens, which ranged from 108 to 138 mm in standard length for *Sardinella gibbosa*, 120 to 156 mm for *S. longiceps* and 85 to 115 mm for *S. sindensis*, were placed in 3 groups (according to their standard length in each species). Only sagittal otoliths were extracted from the specimens.

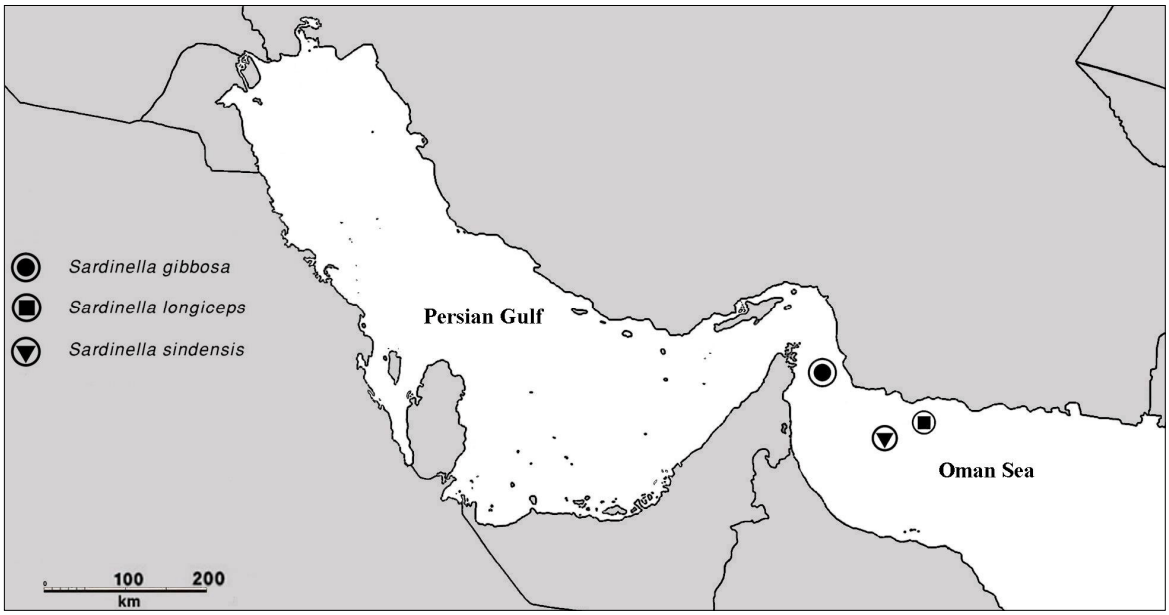

Figure 1. Map of southern Iranian coastal zone, the Persian Gulf and Oman Sea, the sampling areas of *Sardinella gibbosa, S. longiceps* and *S. sindensis*.

The otoliths were removed by turning the ventral side of the fish upward to allow removal of the lower jaw, the gills and the hypobranchial apparatus and to expose the base of the skull. With a sharp scalpel, the otic capsules were separated and the otoliths gently removed with a pair of fine tweezers (Figure 2).

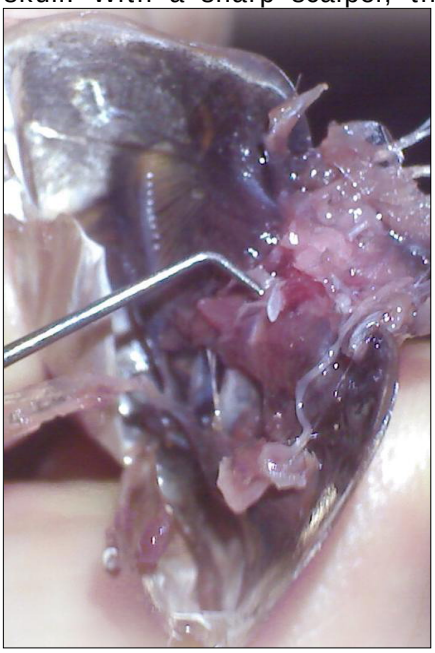

Figure 2. Sagittal otolith extracting in *Sardinella* sp.

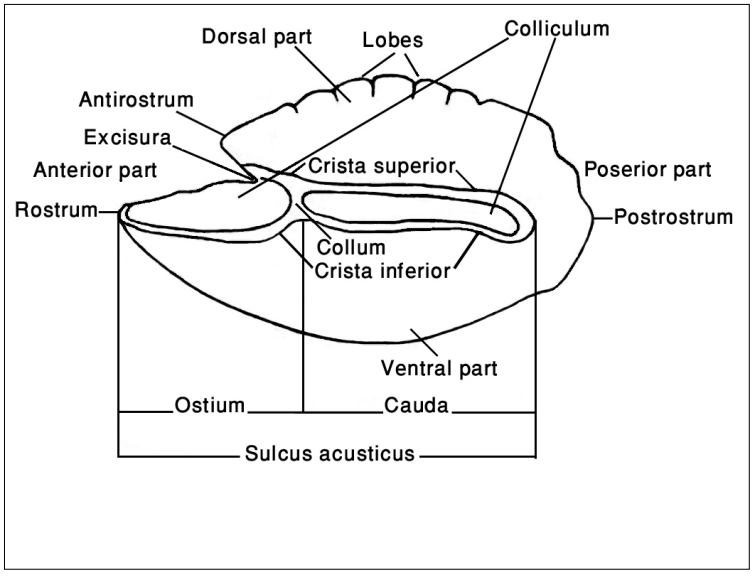

Figure 3. Morphological nomenclature of the inner face of otolith (Schwarzhans 1978).

Then, the otoliths were cleaned with 70% ethanol and stored dry in a glass vials. Scanning electron microscopy (SEM) was used to record the morphological characteristics on the medial faces (proximal surface) of the saccular otolith (sagitta). The terminology of otolith morphology follows in Figure 3. The otoliths to be used for SEM were air dried and mounted on an aluminium stub using double-sided carbon tape. Stubs were sputter coated with gold in a vacuum of about 4061023 torr. Otoliths were viewed in a Philips XL 45 FEG at 5.0 KV.

Results. Based on the morphological changes of sagitta otolith and fish standard length can be assigned 3 groups and description of the otolith morphological characteristics were carried out in these groups. SEM images of otoliths from each species were prepared for comparative investigation of the morphology.

Morphological characteristics of sagitta otolith in S. gibbosa. The sagitta otolith of *S. gibbosa* is ovate and otolith size is small, averagely 2.4% of standard length, otolith width in this species is 43% of otolith length. Distal surface concave that increased by otolith growth. Sagitta otolith was not thick (Figure 4).

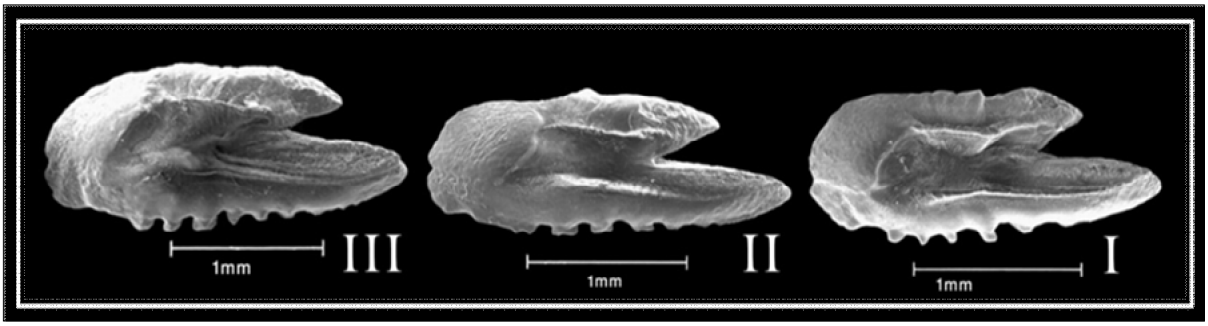

Figure 4. Diagram of the mesial face of the sagitta otoliths of *S. gibbosa.*
Group I (standard length 108-113 mm), Group II (standard length 123-128 mm), and Group III (standard length 133-138 mm).

Dorsal margin in groups I, II and III are irregular. In groups I and II dorsal depression are exist but gradually in group III if present, it is shallow groove. Ventral margin lobate in groups II and III are slightly irregular anteriorly and posteriorly. Rostrum in groups I, II and III are long and broad and in groups I and II are pointed tip and in group III is rounded tip, sometimes constricted. Rostrum length is 29% of otolith length. Antirostrum in groups I, II and III are moderate to well developed with pointed tip. Antirostrum length is 55% of rostrum length and 10% of otolith length. Width antirostrum is 56% of rostrum width. Sulcus acusticus in groups I, II and III are heterosulcoid, opening ostial and approximately deep. Cauda in groups I, II and III are straight and horizontal, not flared posteriorly, tip well-defined. Ostium in groups I, II and III are elongate, dorsally flared, ventral margin horizontal. Collum in groups I and III are developed but in group II slightly defined. Crista superior in group I is approximately developed rim-like over cauda and ostium and in groups II and III are developed ridge-like over cauda and ostium. Crista inferior in group I is developed, rim-like along cauda and ostium in groups II and III are developed ridge-like along cauda and ostium. Excisura major in groups I, II and III are well developed and in group I excisura angle is 50^{o}, in group II is 44^{o} and in group III excisura angle is 34^{o}. Excisura minor in groups I, II and III are developed therefore postrostrum and pararostrum are exist (Table 1).

Table 1

Sagitta otolith characteristics of three size classes of the *S. gibbosa*

Otolith characteristics	*Group I (108-113 mm)*	*Group II (123-128 mm)*	*Group III (133-138 mm)*
Otolith shape	ovate	ovate	ovate
Otolith width	moderately thin	moderately thin	moderately thin
Depth	shallow	shallow	shallow
Mesial surface	convex	convex	convex
Lateral surface	concave	concave	concave
Dorsal margin	irregular to lobed, rounded over cauda and over ostium	irregular, sculpture smooth, rounded over cauda and over ostium	mainly flattened; sometimes flattened over cauda and curves over ostium,
Ventral margin	lobate, horizontal, smooth at anteriorly	lobate, horizontal, irregular anteriorly and posteriorly	lobate, horizontal, irregular anteriorly and curved, irregular posteriorly
Posterior margin	rounded, irregular with excisura minor, developed, postrostrum, pararostrum	rounded, irregular with excisura minor, developed, postrostrum, pararostrum	rounded, irregular with excisura minor, developed postrostrum, pararostrum
Sulcus acusticus	heterosulcoid, opening ostial and approximately deep.	heterosulcoid, opening ostial and approximately deep.	heterosulcoid, opening ostial and approximately deep.
Ostium	elongate, dorsally flared, ventral margin horizontal	elongate, dorsally flared, ventral margin horizontal	elongate, dorsally flared, ventral margin horizontal
Cauda	straight and horizontal, not flared posteriorly, tip well-defined	straight and horizontal, not flared posteriorly, tip well-defined	straight and horizontal, not flared posteriorly, tip well-defined
Collum	developed	slightly defined	developed
Crista superior	developed, rim –like over cauda and ostium	developed ridge-like over cauda and ostium	developed ridge-like over cauda and ostium
Crista inferior	developed rim along cauda and ostium	developed ridge-like along cauda and ostium	developed, ridge-like along cauda and ostium
Dorsal depression	elongateand empty	shallow, empty	if present,it is shallow groove
Ventral depression	absent, if present shallow groove and empty	absent, if present shallow groove and empty	absent, if present shallow groove and empty
Rostrum size	long	long	long
Rostrum shape	pointed tip	pointed tip	rounded tip and sometimes constricted
Rostrum thickness	broad	broad	broad
Antirostrum	moderate to well developed with pointed tip	moderate to well developed with pointed tip	moderate to well developed, with pointed tip
Excisura major	well developed and excisura angle 50°	well developed and excisura angle 44°	well developed and excisura angle 34°

Morphological characteristics of sagitta otolith in S. longiceps. The sagitta otolith of *S. longiceps* is ovate and otolith size is small, average 2.1% of standard length, otolith width in this species is 42% of otolith length. Distal surface concave that increased by otolith growth. Sagitta otolith was not thick (Figure 5).

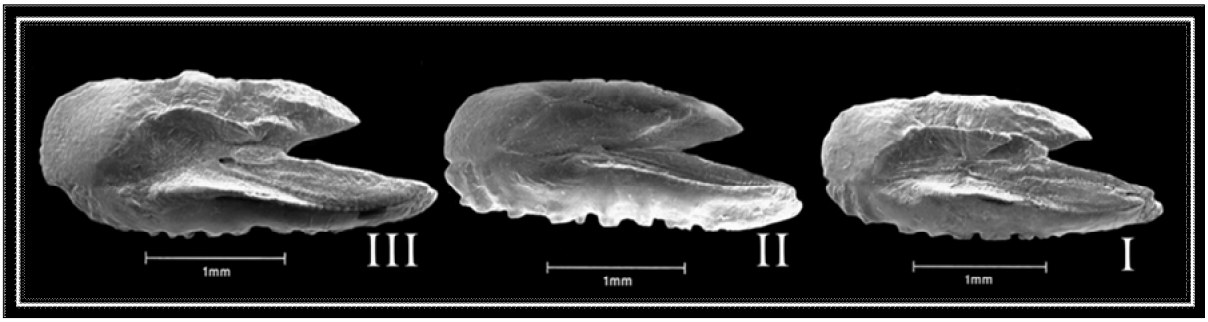

Figure 5. Diagram of the mesial face of the sagitta otoliths of *S. longiceps*. Group I (standard length 120-126 mm), Group II (standard length 132-138 mm), and Group III (standard length 150-156 mm).

Dorsal margin in groups I, II and III are irregular. Dorsal depression if present, is shallow groove. Ventral margin lobate in groups I, II and III are slightly irregular at anteriorly. Rostrum in groups I, II and III are long and broad and pointed. Rostrum length is 40-47% of otolith length. Antirostrum in groups I, II and III are well developed with pointed tip. Antirostrum length is 48% of rostrum length and 22% of otolith length. Width antirostrum is 90-95% rostrum width. Sulcus acusticus in groups I, II and III are heterosulcoid, opening ostial and approximately are deepen, and increased by otolith growth. Cauda in groups I, II and III are straight and horizontal, not flared posteriorly and in tip slightly defined. Ostium in groups I, II and III are elongate, dorsally flared, ventral margin horizontal. Collum in groups I, II and III are defined and developed. Crista superior in groups I, II and III are developed ridge-like over cauda and ostium. Crista inferior in groups I and II are developed ridge-like along cauda and ostium, but in groups III is developed rim-like along cauda and ostium. Excisura major in groups I, II and III are well developed. In group I excisura angle is 35°, in group II is 42° and in group III excisura angle is 42°. Excisura minor is not developed, therefore postrostrum and pararostrum are absent (Table 2).

Table 2

Sagitta otolith characteristics of three size classes of the *S. longiceps*

Otolith characteristics	*Group I (120-126 mm)*	*Group II (132-138 mm)*	*Group III (150-156 mm)*
Otolith shape	ovate	ovate	ovate
Otolith width	moderately thin	moderately thin	moderately thin
Depth	shallow	shallow	shallow
Mesial surface	convex	convex	convex
Lateral surface	concave	concave	concave
Dorsal margin	irregular, sculpture smooth, rounded over cauda and over ostium	irregular, sculpture smooth, rounded over cauda and over ostium	irregular to lobed, rounded over cauda and over ostium,
Ventral margin	lobate, horizontal, slightly irregular anteriorly, sculpture posteriorly	lobate, horizontal, slightly irregular anteriorly, sculpture posteriorly	lobate, horizontal, irregular anteriorly and curved, irregular posteriorly
Posterior margin	rounded, irregular with or without excisura minor, postrostrum and pararostrum	rounded, irregular with or without excisura minor, postrostrum and pararostrum	rounded, irregular without excisura minor, postrostrum and pararostrum
Sulcus acusticus	heterosulcoid, opening ostial and approximately deep	heterosulcoid, opening ostial and approximately deep	heterosulcoid, opening ostial and approximately deep
Ostium	elongate, dorsally flared, ventral margin horizontal	elongate, dorsally flared, ventral margin horizontal	elongate, dorsally flared, ventral margin horizontal
Cauda	straight and horizontal, not flared posteriorly, tip slightly defined	straight and horizontal, not flared posteriorly, tip slightly defined	straight and horizontal, not flared posteriorly, tip slightly defined
Collum	developed	developed	developed
Crista superior	developed ridge-like over cauda and ostium	developed ridge-like over cauda and ostium	developed ridge-like over cauda and ostium
Crista inferior	developed ridge-like along cauda and ostium	developed ridge-like along cauda and ostium	developed, rim-like along cauda and ostium
Dorsal depression	if present,it is shallow groove, empty	if present,it is shallow groove, empty	if present,it is shallow groove, empty
Ventral depression	absent	absent	absent, if present shallow groove and empty
Rostrum size	long	long	long
Rostrum shape	pointed tip	pointed tip	pointed tip
Rostrum thickness	broad	broad	broad
Antirostrum	moderate to well developed, with pointed tip	moderate to well developed, with pointed tip	moderate to well developed, with pointed tip
Excisura major	well developed and excisura angle 35°	well developed and excisura angle 42°	well developed and excisura angle 42°

Morphological characteristics of sagitta otolith in S. sindensis. The sagitta otolith of *S. sindensis* is ovate and otolith size is small, average 2.2% of standard length, otolith width in this species is 45% of otolith length. Distal surface concave that increased by otolith growth. Sagitta otolith was not thick (Figure 6).

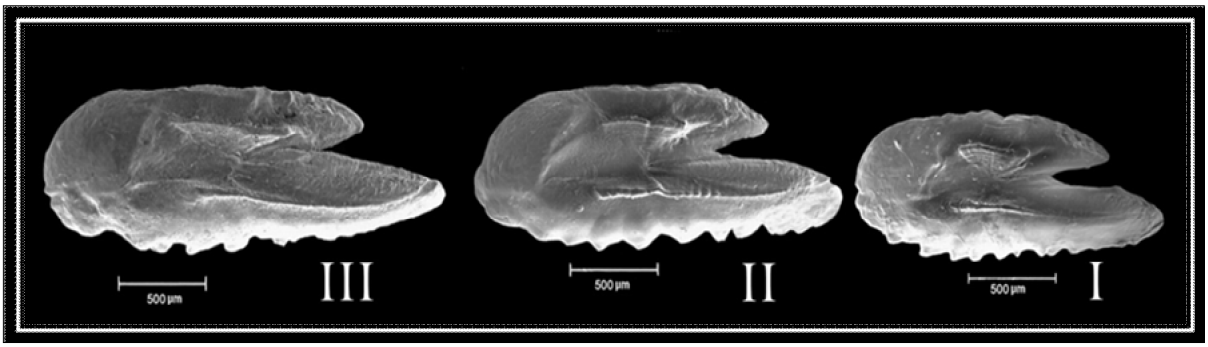

Figure 6. Diagram of the mesial face of the sagitta otoliths of *S. sindensis*. Group I (standard length 85-90 mm), Group II (standard length 95-100 mm), and Group III (standard length 110-115 mm).

Dorsal margin in groups I, II and III are irregular. In group I and II dorsal depression are exist but gradually in group III is shallow groove, if it is presented. Ventral margin lobate along cauda and ostium, and rostrum in groups I, II and III are long and broad and in groups I and II are rounded tip and in group III is pointed tip. Rostrum length is 38% of otolith length. Antirostrum in groups I, II and III are moderate to well developed with pointed tip. Antirostrum length is 44% of rostrum length and 17% of otolith length. Width antirostrum is 70% of rostrum width. Sulcus acusticus in groups I, II and III are heterosulcoid, opening ostial and approximately deep. Cauda in groups I, II and III are straight and horizontal, not flared posteriorly and tip well-defined. Ostium in groups I, II and III are elongate, dorsally flared, and the ventral margin is horizontal. Collum in groups I and II are developed but in group III is slightly defined. Crista superior in group I, II and III are developed ridge-like over cauda and ostium. Crista inferior in group I is developed, ridge-like along cauda and ostium and in groups II and III are developed rim-like along cauda and ostium. Excisura major in groups I, II and III are well developed, and the excisura angle in group I is 35^{o}, in group II is 40^{o} and in group III is 42^{o}. Excisura minor is not developed therefore postrostrum and pararostrum are absent (Table 3).

Some characters such as oblong shape of otolith, otolith width, depth, convex mesial surface (proximal face), concave lateral face, ostial and heterosulcoid sulcus acusticus, ostium, straight and horizontal cauda and antirostrum share are not varied among the 3 species of *Sardinella* genus. Varied characters among the 3 species of *Sardinella* genus are the rostrum shape which are mostly large and broad, shape of the tip which were not consistent in each species and in *S. gibbosa* almost is rounded tip and in *S. longiceps* and *S. sindensis* are almost pointed tip, the well-developed and ridge-like crista superior in *S. sindensis* and *S. longiceps* and rime-like in group I and developed ridge-like in *S. gibbosa*, the well-developed and ridge-like for crista inferior in *S. gibbosa*, developed and ridge-like in groups I and II and rime like in group III in *S. longiceps*, and developed ridge-like in group I and rime like in groups II and III in *S. sindensis*, the shape of the dorsal margin showed a trend of change in irregularity in these species and rarely includes lobes, the ventral margin is lobate in these species and can be different in place and numbers, the posterior margin is usually not uniform and can be rounded and irregular in these species, in *S. gibbosa* excisura minor, postrostrum and pararostrum are exist, in *S. longiceps* few specimens have excisura minor and in *S. sindensis* excisura minor is absent. Depressions in the dorsal and ventral areas have a distinctive shape and contain certain structures that make them morphologically different from the rest of the neighbouring area. Dorsal depression is empty in these species but ventral depression not showed (Figures 4, 5 and 6). Collum is developed in *Sardinella* genus and cauda has slightly difference in tip among these species, in *S. gibbosa* and *S. sindensis* tip are well-

defined and in *S. longiceps* tip is slightly defined. Excisura angle gradually decrease in *S. gibbosa* therefore rostrum and antirostrum are closed to each other and in *S. longiceps* and *S. sindensis* excisura angle gradually increase.

Table 3

Sagitta otolith characteristics of three size classes of the *S. sindensis*

Otolith characteristics	*Group I (85-90 mm)*	*Group II (95-100 mm)*	*Group III (110-115 mm)*
Otolith shape	ovate	ovate	ovate
Otolith width	moderately thin	moderately thin	moderately thin
Depth	shallow	shallow	shallow
Mesial surface	convex	convex	convex
Lateral surface	concave	concave	concave
Dorsal margin	irregular, sculpture smooth, rounded over cauda and over ostium	irregular, emarginated, rounded over cauda and over ostium	mainly flattened; sometimes flattened over cauda and over ostium,
Ventral margin	lobate, horizontal, slightly irregular anteriorly, sculpture posteriorly	lobate, horizontal, sculpture anteriorly and posteriorly	lobate, horizontal, irregular anteriorly and curved posteriorly
Posterior margin	rounded, irregular without excisura minor, postrostrum and pararostrum	rounded, irregular, sculpture smooth, without excisura minor, postrostrum and pararostrum	rounded, irregular, emarginated, without excisura minor, postrostrum and pararostrum
Sulcus acusticus	heterosulcoid, opening ostial and approximately deep	heterosulcoid, opening ostial and approximately deep	heterosulcoid, opening ostial and approximately deep
Ostium	elongate, dorsally flared, ventral margin horizontal	elongate, dorsally flared, ventral margin horizontal	elongate, dorsally flared, ventral margin horizontal
Cauda	straight and horizontal, not flared posteriorly, tip well-defined	straight and horizontal, not flared posteriorly, tip well-defined	straight and horizontal, not flared posteriorly, tip well-defined
Collum	developed	developed	slightly defined
Crista superior	developed ridge-like over cauda and ostium	developed ridge-like over cauda and ostium	developed ridge-like over cauda and ostium
Crista inferior	developed, ridge-like along cauda and ostium	developed, rim-like along cauda and ostium	developed, rim-like along cauda and ostium
Dorsal depression	shallow groove, empty	shallow groove, empty	if present, it is shallow groove, empty
Ventral depression	absent	absent	absent
Rostrum size	long	long	long
Rostrum shape	rounded tip	rounded tip	pointed tip
Rostrum thickness	broad	broad	broad
Antirostrum	moderate to well developed with pointed tip	moderate to well developed with pointed tip	moderate to well developed, with pointed tip
Excisura major	well developed and excisura angle 35°	well developed and excisura angle 40°	well developed and excisura angle 42°

Discussion. Morphological characteristics of fish otoliths are highly variable between species, ranging from the relatively simple disc shape of some flatfish (Pleuronectidae) to the irregular shape of others, such as redfish *Sebastes* sp. (Hunt 1992). The growth of the otolith continues throughout a fish's lifetime and is based on a genetically guided mechanism (Gauldie & Nelson 1988). However, otolith growth is influenced by many factors, such as seasonal variations, temperature, habitat and diet (Campana 2001). Investigations of morphological characteristic of otolith shapes are useful to identify

species and specific guides or keys to fish otoliths also have been published (Morrow 1979; Harkonen 1986; Hecht 1987; Smale et al 1995; Furlani et al 2007).

There are some landmark morphological features of the saccular otolith that assist in taxonomic studies (Figure 3). Because of their large size and degree of inter-specific variation, the teleost saccular otolith (sagitta) is the most widely used tool in comparative taxonomic studies. Study on otolith morphology in the *Sardinella* genus, deals with a wide range of otolith characteristics. However, there are only a few characteristics that are taxonomically important for *Sardinella* genus and these will be useful in future taxonomic studies.

In generalized otolith models, the sagitta otoliths are described as medially convex and distally concave bodies (Parmentier et al 2002; Parmentier et al 2007). Shape and nucleus location result from the release of soluble Ca^{2+} on the proximal side (Ibsch et al 2004), which in turn precipitates as $CaCO_3$ crystals due to an increasing alkaline gradient, from the sulcal area towards the otolith edge (Gauldie & Nelson 1990). As a result, the growth of the crista superior and crista inferior is privileged and there is a more important development of the sulcal side. The macula is elongated and narrow in teleosts, and the crista superior and inferior are proportionally more important than the colliculum (Popper & Hoxter 1981; Lombarte & Fortuno 1992; Ladich & Popper 2001). The macula faces the colliculum, and prevents otolith growth at this level (Pannella 1980; Popper & Hoxter 1981; Lombarte & Fortuno 1992).

Lombarte et al (2003) have showed in *Merluccius* the sagitta otolith shape variability has been related to genetic, ontogenetic and environmental factors. Many previous studies on fossil and extant otoliths have demonstrated that the sulcus morphology usually is consistent among the species of a single genus (Nolf 1985), and thus this feature is likely controlled genetically (Gauldie 1988). Interspecific variation in sulcus morphology has previously been recorded for only a few other genera. For example, in *Merluccius* (Merlucciidae), interspecific sulcus variation separates the American from the Euro–African species, and hence sulcus variation parallels zoogeography and phylogeny (Torres et al 2000). However, sulcus variation has been shown to concur with specialization in hearing abilities, and thus interspecific sulcus variation may also result from ecomorphological adaptations (Ramcharitar et al 2004; Popper et al 2005). For example, an ecomorphological influence on sulcus morphology is reflected in the ratio of the sulcus area to the total otolith area; the ratio increases in species from deeper water environments (Lombarte 1992; Tuset et al 2003).

Apart from sulcus morphology, a correlation between particular otolith features (e.g., rostrum, antirostrum proportions) and biological functions such as swimming ability, feeding, or other activities has not yet been established (Popper et al 2005). Considering the whole variety of teleost fishes there might be some correlation between the otolith rostrum length and swimming ability (Nolf 1985; Volpedo & Echeverria 2003), but this feature has not been shown to be significant in the discrimination of closely related species (Reichenbacher et al 2007).

The results of the present study showed that the overall morphology and generally oblong shape of the otolith remains consistent of the *Sardinella* genus. According to Volpedo & Echeverria (1999), the absence of changes in the shape of the otolith may be related to the organic matrix and the way in which $CaCO_3$ is deposited during sagittal development. Two groups of characteristics can be distinguished from the results at hand: (1) characteristics that are consistent in the sagitta otoliths of *S. gibbosa*, *S. longiceps* and *S. sindensis* which are useful to separate these species from the rest of clupeids species, however these otolith characteristics in 3 species of *Sardinella* genus are more closely related to each other, (2) characteristics that vary due to genetically guided mechanism and biological factors but that may be useful to define species and are species-specific. Reasons for these differences are not yet clear. It is assumed that the structural variability of otoliths follows some evolutionary trends (Fermin et al 1998; Lychakov 1988, 1995a, b). On the other hand, it seems that the structural variability of the otoliths is correlated to the interspecific variation of life styles, motor activities and hearing capabilities of the animals (Gauldie 1988; Lychakov 1990, 1992; Lychakov & Rebane 1993; Platt & Popper 1981; Popper & Coombs 1982). Thus, the structural

variability of the otoliths may reflect phylogenetic and ecomorphological patterns. Also Tuset et al (2003) relates the shape of the otolith to the biological and ecological behaviour of the species.

The consistency of the characteristics presented through different standard lengths can be used as a tool to separate these species from each other and other members of genus *Sardinella*, but before such a decision is made regarding their usefulness in the identification of *Sardinella* genus, they need to be shown to be unique to these species.

Conclusions. It is clear that *Sardinella* genus shares the following characteristics, width, otolith shape, proximal surface (mesial face shape), distal surface (lateral face shape), shape of the sulcus acusticus, ostium and straight and horizontal canda. The second group of characteristics (shape of the dorsal, ventral, and posterior margins; dorsal and ventral depressions; and shape of the rostrum and antirostrum), despite showing inconsistencies among fishes, provides a good taxonomic tool to separate *Sardinella* genus from each other (interspecies) and the rest of the clupeids species already described by other authors, providing that adult otoliths are used in such comparison. Moreover, such differences in otolith characteristics might be considered important for fisheries, biologists, archaeologists and geologists who can use them as a way to separate *S. gibbosa*, *S. longiceps* and *S. sindensis.*

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