Variability of Otolith Morphology in Major Fish Species in Coastal Waters of Cape Coast-Elmina, Ghana

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Abstract

The fish sagittae otoliths have unique structures for various fish species. These otoliths are very important hard parts in fish for growth and age studies. In this study, sagittae otoliths of major marine finfishes were analysed and compared using descriptive morphological characters. Information obtained was a first step that would lead to future age and growth studies on these fishes for stock assessment in fisheries management. The study was conducted in 2017, and 38 fish species belonging to 21 families were encountered in the beach seine landings (Cape Coast) and artisanal canoe and semi-industrial landings (Elmina), all in the Central Region of Ghana. The fish species and their respective sagittae otoliths were extracted using standard methods and all were digitally photographed. The observed differences among the otoliths were in their overall shape, margins and anterior region that were described to be oblong, obovate, discoid, oval, rhomboidal, anvil-shaped, ovate, circular, triangular, elliptic, spindle-shaped, tear-drop and rectangular. The margins were observed to be irregular, crenate and sinuate for various otoliths. Ranges of fish total lengths and sagittae otolith lengths were presented for various fish species encountered during the study. The largest otolith lengths were recorded in *Pseudotolithus senegalensis* (82 – 230 mm TL; 4.7 – 8.0 mm OL) and the smallest otolith lengths were observed in *Sardinella aurita* (76 – 209 mm TL, 1.4 – 3.5 mm OL). The results of these sagittae otoliths descriptions in this study would be a useful information towards ageing of finfishes which is lacking in Ghanaian waters.

Introduction

Marine fishes of commercial importance landed in Ghana are the sardines, chub mackerel, cassava fish, anchovy, moonfish, red snapper, skipjack, yellowfin tunas and shellfishes such as cuttlefish, squid, shrimps and lobsters (Nunoo et al., 2007; Addison et al., 2008). These fisheries resources are exploited by the artisanal, semi-industrial and industrial fisheries in Ghana. In Ghanaian waters, only a few fish hard parts (i.e. sagittae otoliths, dorsal spines and scales) of marine fish species of ecological and commercial importance had been described and studied (Aggrey-Fynn, 2009). These hard parts are useful in fish age determination that are applied in growth and mortality analyses, and fish population dynamic studies.

In tropical waters, generally otolith for ageing fish had proven to be very difficult simply because of the similarity in seasons throughout the year. On the other hand, the sagittae otoliths have been useful in fish age studies (Campana & Jones, 1992; Gettel et al., 1997; Mendoza, 2006), ontogenetic processes (Capoccioni et al., 2011) and spatial and temporal migrations of fishes (Smith and Kwak, 2014). Nonetheless, the sagittae otoliths had proven to show high specific inter- and intravariability in shape and size. This affords their use as efficient tool for the identification of fish species (Tuset et al., 2008; Bani et al., 2013; Jawad et al., 2017), populations (Bose et al., 2017) and stocks (Mendoza, 2006; Pothin et al., 2006; Duarte-Neto et al., 2008). Again, genetic and exogenous factors such as water temperature, salinity, depth and food supply had been reported to have some influence on otolith morphological variability (Hussey, 2008; Vignon and Morat, 2010; Capoccioni et al., 2011; Bremm and Shulz, 2014).

Therefore, given the importance and scientific relevance of otoliths, the present study aimed at describing the otolith morphology in various fishes of ecological and commercial importance in Ghanaian waters. These objectives will go a long way to promote and facilitate identification and ageing of finfishes in Ghanaian waters.

Materials and methods

Study area

The study area comprised of OLA-Duakor beaches at Cape Coast and fish landing quay at Elmina. Cape Coast and Elmina are in the Central Region of Ghana located on latitudes (5°4'01"N and 5°6'01"N) and longitudes (1°19'51"W and 1°21'26"W) for Elmina, and latitudes (5°5'59"N and 5°6'01"N) and longitudes (1°16'41"W and 1°18'26"W) for Cape Coast. In Elmina, the main occupation is fishing whereas in Cape Coast the inhabitants engage in tourism and fishing. Elmina fish landing quay allows various dugout canoe sizes for artisanal fisheries and wooden boats for semi-industrial fisheries. The OLA-Duakor beaches in Cape Coast are sandy beaches ideal for beach seine operations. Coconut trees, which form the strand vegetation along the beaches provide support for the beach seine gear when they are deployed up to 200 m into the sea. The canoes for the artisanal fisheries operate at the inshore waters of Ghana, whereas the semi-industrial boats trawl and purse seine further offshore in Ghanaian waters.

Methods

Marine fish specimens were collected from January to April 2017 from beach seine operators in OLA-Duakor in Cape Coast as well as canoe and semi-industrial landings at Elmina fish landing quay. The fish samples were transported to the Fisheries and Coastal Research Laboratory of the University of Cape Coast, Ghana for analyses. Fish species were identified based on the morphological and meristic characteristics (Schneider, 1990; Froese and Pauly, 2017). Each fish specimen, total length (TL) was measured to the nearest 0.1 cm.

Sagittae otoliths for various finfishes were removed using the methods by Zorica et al. (2010) and Jawad & Al-Mamry (2012) to expose otoliths through opening the otic bulla and cutting the cranium respectively. Gill method was also used for the finfishes

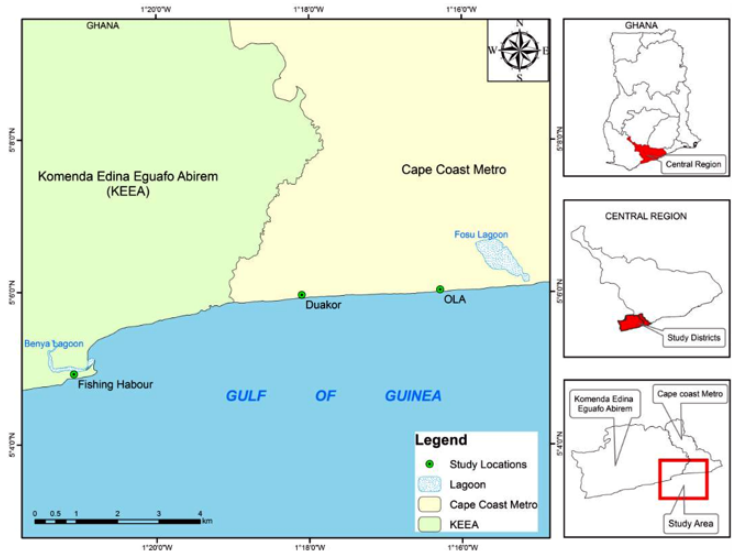


Fig. 1. Map of study area showing Fishing Harbour at Elmina and OLA-Duakor Beach in Cape Coast

by cutting off the isthmus, removal of gills and breaking of otolith capsule to expose otoliths. Sagittae otoliths of the flounders were removed by making a diagonal incision between the eyes using a dissection blade. From the incision, the first and visible sagitta otolith was removed with forceps followed by a further cut to expose and remove the other otolith. The sagittae otolith pairs removed were cleaned with distilled water and stored dry for later examination. Otoliths were photographed using a digital camera attached to a stereo microscope. The images were taken on a dark background in order to achieve good light contrast. Sagittae otoliths lengths were measured to the nearest 0.1 mm using calibrated eyepiece of stereomicroscope.

Results

The sagittae otolith specimens collected during the study period were 2,112 in number. The specimens were taken from 38 species of finfishes belonging to 21 families that were identified (Table 1). The most common fish species by numbers during the study period include: *Chloroscombrus chrysurus (*Carangidae*), Sardinella maderensis (*Clupeidae*), Brachydeuterus auritus (*Haemulidae*), Galeoides decadactylus (*Polynemidae*)* and *Dentex congoensis (*Sparidae*)*. There were other fish species

TABLE 1
Fish species obtained from OLA-Duakor and Elmina fish landing sites

Family	Species	Numbers recorded			Total
		BF	CF	SF	
Aulopidae	*Aulopus cadenati*	-	-	4	4
Bothidae	*Bothus africanus*	2	-	24	26
Carangidae	*Alectis alexandrinus*	22	-	2	24
	Caranx crysos	28	3	-	31
	Caranx hippos	27	-	-	27
	Chloroscombrus chrysurus	196	288	38	522
	Decapterus punctatus	-	32	1	33
	Selene dorsalis	37	8	1	46
	Trachinotus ovatus	18	27	-	45
	Trachurus trecae	-	9	-	9
Clupeidae	*Ethmalosa fimbriata*	23	24	-	47
	Ilisha africana	-	24	11	35
	Sardinella aurita	29	-	5	34
	Sardinella maderensis	105	11	1	117
Cynoglossidae	*Cynoglossus senegalensis*	12	-	28	40
Drepaneidae	*Drepane africana*	1	-	-	1
Elopidae	*Elops lacerta*	1	-	-	1
Gerreidae	*Eucinostomos melanopterus*	-	-	16	16
Haemulidae	*Brachydeuterus auritus*	45	231	99	375
	Pomadasys incisus	-	-	67	67
Hemiramphidae	*Hemiramphus brasilliensis*	18	-	-	18
	Oxyporhamphus micropterus	1	-	-	1
Labridae	*Xyrichthys novacula*	-	-	16	16
Lobotidae	*Lobotes surinamensis*	1	-	-	1
Mullidae	*Pseudopeneus prayensis*	-	-	33	33

TABLE 1 cont
Fish species obtained from OLA-Duakor and Elmina fish landing sites

Family	Species	Numbers recorded			Total
		BF	CF	SF	
Polynemidae	*Galeoides decadactylus*	18	16	85	119
	Pentanemus quinquarius	5	-	12	17
Priacanthidae	*Priacanthus arenatus*	-	-	1	1
Sciaenidae	*Miracorvina angolensis*	-	-	1	1
	Pseudotolithus elongatus	5	10	7	22
	Pseudotolithus senegalensis	35	-	18	53
Scombridae	*Orcynopsis unipolar*	5	-	-	5
	Scomberomorus tritor	1	-	-	1
Sparidae	*Dentex congoensis*	-	-	220	220
	Dentex gibbosus	1	-	64	65
Sphyraenidae	*Sphyraena sphyraena*	22	3	10	35
Synodontidae	*Trachinocephalus myops*	-	-	1	1
Trichiuridae	*Trichiurus lepturus*	-	2	1	3

BF=Beach seine fishery; CF=Canoe fishery; SF=Semi-industrial fishery; -=Absent.

that appeared just once in the samples from beach seine, canoe and inshore landings during the study period. These include: *Drepane africana (*Drepaneidae*), Elops lacerta (*Elopidae*), Oxyporhamphus micropterus (*Hemiramphidae*), Lobotes surinamensis (*Lobotidae*), Priacanthus arenatus (*Priacanthidae*), Miracorvina angolensis (*Sciaenidae*), Scomberomorus tritor (*Scombridae*) and Trachinocephalus myops* (Synodontidae) (Table 1).

The morphologic variability in sagittae otoliths presented ranged from elliptic in *Aulopus cadenati, Elops lacerta* and *Trachinocephalus myops*; rhomboidal in *Bothus africanus*, *Chloroscombrus chrysurus*, *Trachurus trecae*, *Dentex gibbosus* and *Dentex congoensis*; ovate in *Alectis alexandrinus, Caranx hippos*, *Ilisha africana* and *Orcynopsis unipolar*; anvil-shaped in *Caranx crysos, Trachinotus ovatus* and *Pseudotolithus senegalensis*; spindle-shaped in *Decapterus punctatus* and *Scomberomorus tritor*; discoid in *Selene dorsalis*, *Drepane africana*, *Xyrichtys novacula* and *Priacanthus arenatus*; tear-drop in *Ethmalosa fimbriata*, *Sardinella aurita* and *Sardinella maderensis*; rectangular in *Cynoglossus senegalensis*; oblong in *Eucinostomus melanopterus*, *Brachydeuterus auritus*, *Pomadasys incisus*, *Hemiramphus brasilliensis*, *Lobotes surinamensis*, *Pentanemus quinquarius* and *Sphyraena sphyraena*; circular in *Oxyporhamphus micropterus*; oval in *Galeoides decadactylus* and *Miracovina angolensis*; triangular in *Pseudotolithus elongatus*; to obovate in *Trichiurus lepturus*. Margins and anterior region were very variable in the otoliths of species encountered and might help to differentiate these fishes. Margins varied between regular in otoliths of *Cynoglossus senegalensis* to irregular in otoliths of *Caranx hippos* and many other species (Table 2).

Discussion

From the results of 21 families constituting 38 species (Tables 1 and 2) indicate that otolith morphology presents a useful and informative character for identification and

TABLE 2
Fish otolith variability, length ranges and descriptions of sagittae otoliths of marine fish species in Ghanaian Waters

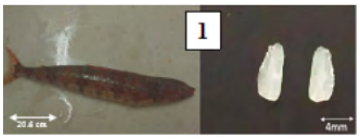
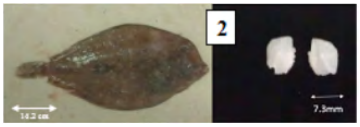
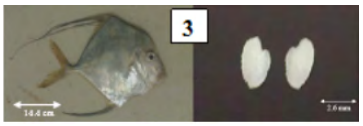
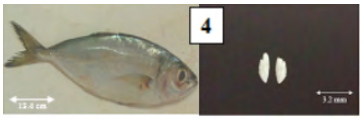
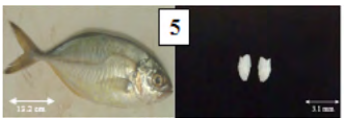
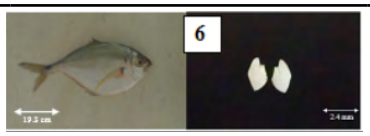
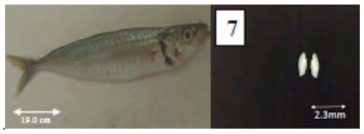
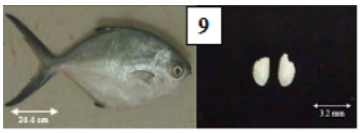
Species	Fish-Otolith Image	Length Ranges Observed		Sagittae Otolith Description
		TL (mm)	Sagittae Otolith (mm)	
Aulopus cadenati		117 – 230	3.1 – 7.7	Elliptic shape with dentate margins at both the dorsal and ventral sides, anterior end is pointed and posterior end is curvy
Bothus africanus		128 - 165	4.3 – 8.0	Rhomboidal shape with crenate margins at both the dorsal and ventral sides, both the anterior and posterior ends are bluntly pointed
Alectis alexandrinus		78 - 156	1.5 – 3.6	Fragile, ovate in shape with serrate margins at dorsal and ventral sides, the anterior end is bluntly pointed and posterior end is curvy
Caranx crysos		112 – 160	1.5 – 4.5	Anvil-shaped with crenate dorsal and ventral margins, curvy at the anterior end and bluntly pointed at the posterior end
Caranx hippos		115 - 175	2.3 – 5.7	Ovate shape with irregular margins at the dorsal and ventral sides, anterior end bluntly pointed and posterior end curvy
Chloroscombrus chrysurus		90 – 202	1.7 – 3.3	Rhomboidal shape with serrate margins, pointed at the anterior end and slightly pointed at the posterior end
Decapterus punctatus		140 - 195	1.9 – 2.4	Fragile, spindle-shaped with crenate margins at dorsal and ventral sides, pointed at the anterior and posterior ends
Selene dorsalis		75 – 158	1.5 – 3.2	Discoid shape, crenate at the dorsal and ventral margins, curvy anterior and posterior ends
Trachinotus ovatus		110 - 265	2.2 – 4.0	Anvil-shaped with crenate dorsal and ventral margins, slightly curvy anterior end and bluntly protruding at the posterior end
Trachurus trecae		140 - 148	5.2 – 5.4	Rhomboidal shaped with serrate dorsal and crenate ventral margins, bluntly pointed at the anterior end and pointed at the posterior end.

TABLE 2 cont.
Fish otolith variability, length ranges and descriptions of sagittae otoliths of marine fish species in Ghanaian Waters

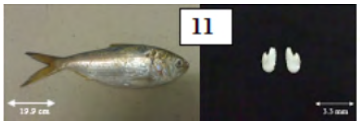
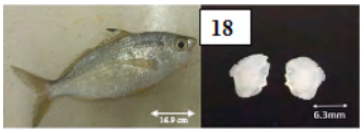
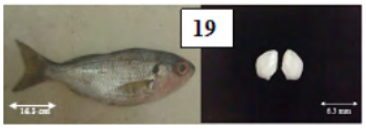
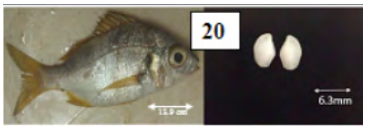
Ethmalosa fimbriata		145 – 202	3.1 – 3.6	Fragile, small tear-drop shape with irregular dorsal and serrate ventral margins, pointed anterior end and curvy posterior end
Ilisha africana		116 – 201	3.0 – 4.3	Fragile, ovate in shape with entire dorsal and sinuate ventral margins, protruding anterior and curvy posterior ends
Sardinella aurita		79 – 209	1.4 – 3.5	Fragile, small, tear-drop shape with serrate ventral and entire dorsal margins, pointed anterior and curvy posterior ends
Sardinella maderensis		76 – 190	1.8 – 3.1	Fragile, small, tear-drop shape with serrate ventral and entire dorsal margins, pointed anterior and curvy posterior ends
Cynoglossus senegalensis		190 – 250	2.2 – 4.9	Rectangular shape with entire margins at both the dorsal and ventral sides
Drepane africana		115	3.2	Discoid shape with irregular margin at the dorsal side and crenate margin at the ventral side, anterior and posterior ends are curvy.
Elops lacerta		260	3.6	Elliptic shape with crenate margins at both the dorsal and ventral sides, anterior end is pointed and posterior end is curvy
Eucinostomus melanopterus		116 – 169	3.4 – 6.3	Oblong shape with dentate dorsal and serrate ventral margins, slightly pointed anterior end and curvy at the posterior end
Brachydeuterus auritus		59 – 175	3.0 – 8.8	Oblong shape with lobed dorsal and crenate ventral margins, curvy anterior and posterior ends
Pomadasys incisus		118 - 165	5.5 – 7.4	Oblong shape with crenate margin at the ventral side and entire margin at the dorsal side, slightly pointed anterior and curvy posterior ends
Hemiramphus brasilliensis		151 - 270	2.8 – 3.7	Oblong shape with crenate margin at the dorsal side and entire margin at the ventral side, bluntly pointed anterior and curvy posterior ends

TABLE 2 cont.
Fish otolith variability, length ranges and descriptions of sagittae otoliths of marine fish species in Ghanaian Waters

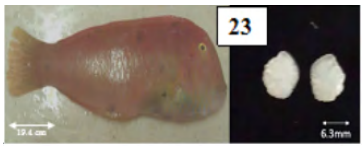
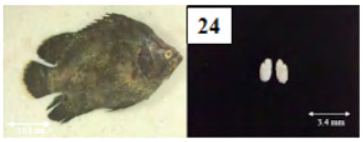
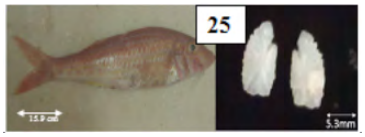
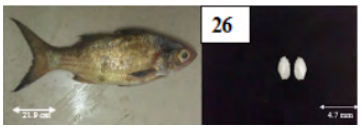
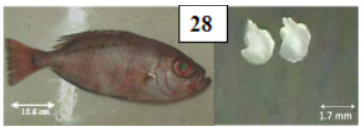
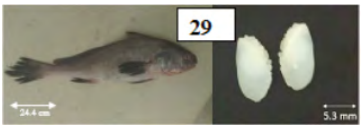
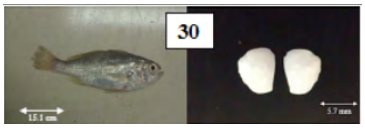
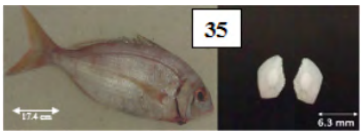
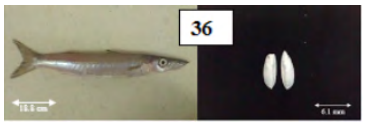
Oxyporhamphus micropterus		115	4.1	Circular shape with crenate margins at both dorsal and ventral sides, anterior and posterior ends are curvy
Xyrichtys novacula		129 – 194	3.0 – 6.3	Discoid shape with crenate margins at both dorsal and ventral sides, both the anterior and posterior ends are curvy
Lobotes surinamensis		123	3.4	Oblong shape with entire margin at the dorsal side and serrate margin at the ventral side, anterior end is bluntly pointed and posterior end is curvy
Pseudopeneus prayensis		118 -168	4.8 – 5.5	Fragile, ovate shape with dentate margins, anterior end is bluntly pointed and posterior end is curvy.
Galeoides decadactylus		113 – 228	3.7 – 4.9	Oval shape with crenate dorsal and dentate ventral margins, anterior and posterior ends are slightly curvy
Pentanemus quinquarius		130 - 161	5.0 – 5.4	Oblong shape with sinuate margins at the dorsal and ventral sides, anterior end is bluntly pointed and posterior end is curvy.
Priacanthus arenatus		156	1.7	Small discoid shape with crenate margins throughout, anterior and posterior ends are curvy
Miracovina angolensis		244	5.3	Oval shape with dentate margin at the dorsal side and entire margin at the ventral side, both anterior and posterior ends are curvy
Pseudotolithus elongatus		69 – 151	4.4 – 5.7	Triangular shape with entire dorsal and lobed ventral margins, curvy anterior and posterior ends
Pseudotolithus senegalensis		82 – 230	4.7 – 8.0	Anvil-shaped with irregular dorsal and dentate ventral margins, anterior end is deep grooved and posterior end is curvy

TABLE 2 cont.
Fish otolith variability, length ranges and descriptions of sagittae otoliths of marine fish species in Ghanaian Waters

Orcynopsis unipolar		250 - 253	2.5 – 2.6	Very small, ovate shape with serrate margins on both the dorsal and ventral sides, anterior end is pointed and posterior end is slightly curvy
Scomberomorus tritor		351	3.3	Fragile, spindle-shaped with crenate margins on both the dorsal and ventral sides, both anterior and posterior ends are pointed
Dentex gibbosus		70 – 187	3.0 – 6.4	Rhomboidal shape with dentate margins throughout the dorsal and ventral sides, pointed anterior and bluntly pointed posterior ends
Dentex congoensis		80 – 184	3.7 – 7.5	Rhomboidal shape with dentate margins throughout the dorsal and ventral sides, pointed anterior and bluntly pointed posterior ends
Sphyraena sphyraena		132 – 331	3.8 – 6.8	Fragile, oblong shaped sagittal otolith with crenate margin at the dorsal end and entire at the ventral end
Trachinocephalus myops		135	2.2	Elliptic shape with sinuate margins at the dorsal and ventral sides, anterior end pointed and posterior end curvy
Trichiurus lepturus		485 – 630	3.8 – 4.1	Obovate shape with crenate margins at the dorsal and ventral sides, slightly protruding at the anterior end and slightly curvy at the posterior end

discrimination of the fish species that were analysed. The observed variations in sagittae shape, margins and anterior region among the studied fishes (Table 2) demonstrate that otoliths are species-specific. Overall morphology varied from rhomboidal to ovate in carangids, elliptic to tear-drop with a notch between rostrum and antirostrum in clupeids, and oblong with curvy posterior zone in gerreids, haemulids and hemiramphids. These variations in otoliths are corroborated by numerous studies in other geographical areas. The observed variations in the sagittae otoliths may be due to the differences in the habitat, preferred depth, availability of food, hearing ability (variability of the sensorial macula) and behaviour of the species (Lombarte, 1992; Paxton, 2000; Volpedo and Echevarría, 2003; Cruz and Lombarte, 2004; Montanini et al., 2015; Jawad et al., 2017). Further

investigations of the ecology of studied fishes are needed to prove and explain possible effects of diverse environmental factors on their otolith morphology. In comparison with available published morphologic descriptions of sagittae otoliths of other fish species, the differences in otolith shape, outline, margins, anterior and posterior regions were analysed. Comparison with Tuset et al. (2008) revealed that these characteristics of the otoliths in the carangids, such as irregular margins of the dorsal and ventral sides in *Caranx hippos*, and curvy ends in the anterior and posterior otolith zones of haemulids, and the notch between rostrum and antirostrum in clupeids, are distinctive features in the adult finfishes for specific groups.

In addition, fragile otoliths were observed in some carangids such as *Alectis alexandrinus*, *Decapterus punctatus*, and *clupeids* such as *Ethmalosa fimbriata, Ilisha africana, Sardinella aurita* and *Sardinella maderensis*. Strongly pointed posterior ends were observed in otoliths of some carangids and scombrids, while the anterior dorsal area was strongly protruding and pointed in some clupeids as compared to adult finfishes in Tuset et al. (2008). Again, the wide variations in otoliths of these fishes could be due to the changes in physical and chemical parameters in different niches occupied by these species in the marine space (Bartulović et al., 2007; Tuset et al., 2008).

Conclusion

In conclusion, fish otolith which is a calcium carbonate deposits that are laid down periodically in fish is a useful hard part for fish identification, growth and age studies. The growth and ageing of fish would also be useful in fish stock assessment and therefore, fisheries management. Hence, this study had provided the morphological descriptions of sagittae otoliths in common fish species that are landed by artisanal and semi-industrial fishers in Ghana. This would go a long way to enhance fish ageing and growth studies of marine finfishes for stock assessments in Ghanaian waters.

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