Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 23(4): 11 – 21 (2019)
www.ejabf.journals.ekb.eg

Relationships between fish and otolith dimensions of *Epinephelus summana* (Forsskål, 1775) and *Cephalopholis argus* (Schneider, 1801) from the Egyptian Red Sea coast

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ARTICLE INFO

Article History:
Received: Sep.17, 2019
Accepted: Oct. 5, 2019
Online: Oct. 8, 2019

Keywords:
Otolith morphology
Epinephelus summana
Cephalopholis argus
Egyptian Red Sea

ABSTRACT

Otolith morphology analysis is one of the main tools used for fish or stock identification. Moreover, it is used in the stomach content studies for the identification of prey fish and their size according to the relationship between fish and otolith sizes. In the present study, the relationships between fish length and otolith morphological dimensions were investigated for *Epinephelus summana* (Forsskål, 1775) and *Cephalopholis argus* (Schneider, 1801) (family: Serranidae). A total of 170 *E. summana* and 154 *E. argus* (i.e 340 and 308 sagittal otoliths for *E. summana* and *E. argus* respectively) were sampled from the coast of the Egyptian Red Sea off Shalateen fishing ground. The statistical analysis was done by generalized linear models for the relationship between body length and weight and otolith morphology descriptors (length, width, area and perimeter) and shape indices (Aspect ratio, Compactness, rectangularity, Sulcus and Ostium). The results revealed that there is significantly correlation between the TL of fish and the eleven morphology descriptors and shape indices, where the side effect was $p<0.05$. Also, this study added new information for the region because of lack of data for the relationships between otolith morphometric and fish length.

INTRODUCTION

Serranid fishes consider as one of the most commercially important fishes in the Red Sea. Family Serranidae comprises a large number of species and at least 31 of them are found in the Red Sea (Randall and Ben Tauvia, 1983).

Epinephelus summana (Forsskål, 1775), distribute at a shallow protected coral-reefs area, especially, in both The Red Sea and the Gulf of Aden and is more closely to the allopatric *E. ongus* of the Indo-west Pacific, (Heemstra and Randall, 1993). There are very few studies on its biology and dynamics are available.

Cephalopholis argus (Schneider, 1801) is a common tropical species found in a different habitat of coral reef from 1 m to least 40 m, and the most widely distributed of the groupers This species is important to artisanal fisheries, throughout the Indo-West Pacific region (Heemstra and Randall, 1993).

Among fisheries management requirements is the age determination which carried out by hard parts like scales, otolith, vertebra, etc. The fisheries researchers have used the otolith to estimate the age and growth of fishes because of the clear and

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distinct growth rings of sagittal (Chilton and Beamish, 1982; Summerfelt and Hall, 1987). The otoliths are located in the head of teleost fishes and found in paierd calcareous structures; it is may be useful in the study of biological fish, ecological and fisheries science. Age and growth, movement and varied habitates, popoulation stock and level of trophic ecology were estimated by otolith (Tuset *et al.,* 2003a; Parisi-Baradad *et al.*, 2005; Short *et al.* 2006; Duarte-Neto *et al.*, 2008; Morat *et al.*, 2012; Radhakrishnan *et al.*, 2012; Sadighzadeh *et al.*, 2012; Lord *et al.*, 2012; Bani *et al.*, 2013; Bostanci *et al.*, 2015; Mehanna *et al.*, 2016; Osman *et al.*, 2018).

The otoliths are widely used tools in the identification and comparative taxonomy of fishes because it is large and inter-specific variability of fish otolith (Battaglia *et al.,* 2010). The morphometric measurements of sagittal otolith has been used in many studies to compare between the closely vareid species (Tuset *et al.*, 2003a; Ponton 2006; Short *et al.,* 2006; Skeljo and Ferri, 2012; Wakefield *et al.*, 2014; Zhuang *et al.,* 2015; Mehanna *et al.,* 2016) and between populations of a single species in marine and freshwater environments (Duarte-Neto *et al.,* 2008; Shepard *et al.,* 2010; Zorica *et al.,* 2010; Zhang *et al.,* 2013; Zischke *et al.,* 2016).

There is rare available information concerning the differentiations of grouper species from the Egyptian Red Sea using otolith morphometric. Furthermore, the otolith outline shape indices and measurements of grouper from the Red Sea have never previously been estimated. Thus, this study may be the first to distinguish grouper species using otolith dimensions and their relationships with fish size and otolith size. The main objectives are to determine the otolith dimensions and indices of two serranid species and their relation with the fish length as well as to distinguish these two species based on the otolith shape and dimensions off the Egyptian coast of the Red Sea.

MATERIALS AND METHODS

Fish samples were randomly collected from the commercial catch of the artisanal fishery landed in the southern Red Sea at Shalateen fishing port, which is located 520 km south of Hurghada (Fig. 1). Sampling procedure was done twice each month during the period from March 2018 to February 2019. The fishing method that catch these species at Shalateen fishing ground was the hook and line fishery. The total fish length was measured to the nearest mm, and fish weight (W) was recorded to the nearest 0.01 g. Then, the sex was recorded. Sagittal otoliths (340 and 308 left and right otoliths for *E. summana* and *C. argus*, respectively; Fig. 2) were extracted from the inner ear of 170 and 154 specimens of *E. summana* and *C. argus*, respectively, then the otolith cleaned and dried until investigation. Otolith weight (OW) for each head side was measured using a digital balance AS220 k/1 to the nearest 0.0001 g. Otolith morphologies were analysed by using a stereomicroscopic (Carl ZIESS v20) with camera Zeiss axiocam ERC 5s (5 mega pexils). Otolith measurements (Fig. 2); Otolith length (OL, mm), otolith area (OA, mm^2), otolith perimeter (OP, mm), sulcus (SU), ostuim (OS), Aspect ratio (AR), Compactness (C) and rectangularity (RE)) the otolith outline (Fig. 3) were extracted by using ImageJ 1.46r analysis software (Tuset *et al.* 2003b; Lombarte *et al.* 2006; Rohlf, 2006; Short *et al*. 2006; Bilge and Gülşahin, 2014; Yilmaz *et al*. 2014; Mehanna *et al*. 2016; Zischke *et al*. 2016; Osman *et al.* 2018; Mahé *et al.* 2018). The statistical analysis was investigated by different ways such the statistical description for minimum, maximum, and means, the linear regression between otolith outline and fish size. Finally, the generalized linear models (GLM; McCullough and Nelder, 1999) were modelled the relationship of body length with the otolith outline indices of according to the side (S):

Model "Side*Wt + Side*OL +Side*OH+ Side*OS+ Side*OO+ Side*OCA +Side*OA+ Side*Per+ Side*AS+ Side*CO+ Side*ER"

Statistical analyses were performed in the statistical environment SPSS18.

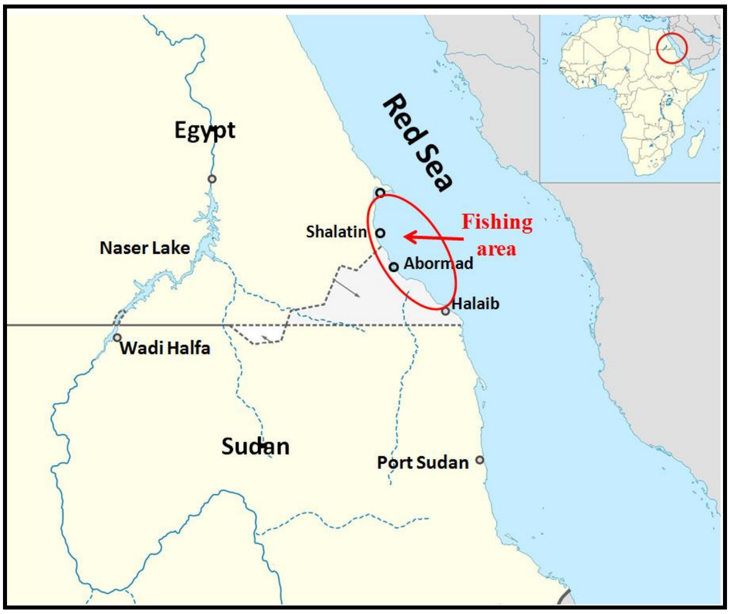

Fig. 1: Red Sea sector of Egypt showing the study area

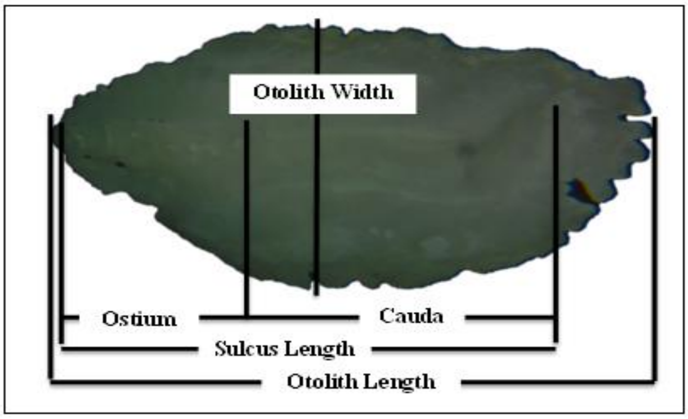

Fig. 2: Otolith morphometrics of *Epinephelus summana* and *Cephalopholis argus* from the Egyptian Red Sea, Egypt.

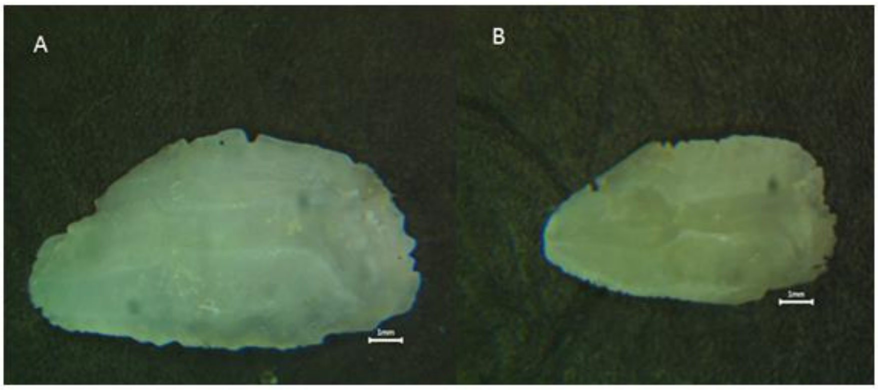

Fig. 3: Otolith shapes of the two grouper species investigated; (A) *E. summana* (Left otlith TL= 30.3cm, OWt= 0.1014g, OL= 9.63mm, OH= 5.06mm) and (B) *C. argus* (Left otlith TL= 35.7cm, OWt= 0.0473g, OL= 8.51, OH= 3.91mm)

RESULTS

The total length (TL) and body weight of the two investigated species varied between 20.6 to 60.2 and from 22.4 to 48.5 cm for *Epinephelus summana* and *Cephalopholis argus*, respectively. While the weight of the fish ranged between 167 and 3875 g and between 171 and 1894.8 g for *E. summana* and *C. argus*, respectively. *E. summana* was presented by higher number of specimens than *C. argus* during the study period. Table 1 provides the overall basic statistics on the size and weight ranges, the otolith lengths, weights and heights for two grouper species.

The statistical description for both left and right otolith measurements (minimum, maximum, mean, standard error and standard deviation). The otoliths of *C. argus* were smaller than those of *E. summana*, where the otoliths mean lengths were varied from 10.84±1.61 and 10.82±1.65 for left and right of *E. summana*, respectively, and from 8.23±0.91 and 8.20±0.90 for left and right of *C. argus* respectively. The otolith area for *E. summana* (ranging from 22.75 to 68.36 mm for both left and right otolith) was greater than that of *C. argus* (ranging from 20.07 to 39.99 mm for both left and right otolith). Aslo, the otolith widths were varied with values 5.19±0.77, 5.19±0.77, 4.01±0.57 and 4.01±0.58 for both left and right otolith of *E. summana* and *C. argus* respectively. The overall otolith measurements of *E. summana* were greater than those of *C. argus* in all sampled fish.

Table 1: Mean and standard deviation and range (minimum- maximum) of the otolith dimension of *Epinephelus summana* and *Cephalopholis argus* from the Egyptian Red Sea, Egypt.

	Left			**Right**		
Species	**Min. - Max.**	**Mean ±SD**	**St. E**	**Min. - Max.**	**Mean ±SD**	**St. E**
E. summana						
N. = 170						
BW	167.00- 3875.20	842.08±852.38	74.76			
TL	20.60- 60.20	34.62±9.37	0.82			
OW	0.0324- 0.1811	0.0834±0.0410	0.0036	0.0307±0.1811	0.0842±0.0410	0.0036
OL	8.05- 13.71	10.84±1.61	0.14	7.92±13.71	10.82±1.65	0.14
OH	3.78- 6.86	5.19±0.77	0.07	3.86±6.87	5.19±0.77	0.07
OS	7.22- 12.47	9.67±1.64	0.14	7.12±12.47	9.68±1.68	0.15
OO	2.08- 4.98	3.95±0.73	0.06	2.14±5.87	3.84±0.93	0.08
OC	4.07- 7.88	5.72±1.10	0.1	3.96±8.26	5.84±1.04	0.09
OA	22.75- 68.36	38.71±10.47	0.92	22.71±68.36	38.69±10.47	0.92
OP	20.62- 38.89	27.56±4.51	0.40	20.62±38.89	27.56±4.51	0.40
AS	0.42- 0.53	0.48± 0.19	0.017	0.42- 0.59	0.481± 0.24	0.021
CO	16.19- 23.41	19.86± 1.82	0.16	16.19- 3.45	19.87± 0.183	0.16
RE	0.51- 0.94	0.69± 0.086	0.008	0.51- 0.94	0.69± 0.90	0.008
C. argus						
No.= 154						
BW	171.00-1894.80	620.49±347.64	30.61			
TL	22.40-46.50	32.16±5.27	0.46			
OW	.0187-0.860300	.0562±0.104600	0.011	.0187-0.996500	.0651±0.138100	0.0146
OL	6.26-10.63	8.23±0.91	0.1	6.26-10.67	8.20±0.90	0.09
OH	3.02-5.53	4.01±0.57	0.06	3.02-5.45	4.01±0.58	0.06
OS	5.35-9.38	7.10±0.89	0.09	5.35-9.34	7.09±0.89	0.09
OO	1.98-4.57	3.12±0.61	0.06	1.98-4.57	3.12±0.63	0.07
OC	3.04-5.10	3.99±0.46	0.05	2.93-5.09	3.97±0.45	0.05
OA	20.07-39.99	25.42±5.62	0.59	20.07-39.97	25.42±5.62	0.59
OP	16.04-26.94	20.76±2.79	0.29	16.04-26.93	20.74±2.79	0.29
AS	.38- 0.690	0.488±0.045	0.005	0.39- 0.70	0.489±0.046	0.005
CO	12.81- 20.61	17.149±1.900	0.200	12.81- 20.59	17.122±1.905	0.201
RE	0.59- 1.03	0.772±0.093	0.010	0.59- 1.03	0.775±0.096	0.010

The correlation between otolith morphometric and fish total length of the two grouper species was found to be linear (otolith variables = a + b*TL) with high correlation (Table 2). All regressions were highly significant, and the analysis of otolith morphometric parameters versus TL indicated that the regression models explained nearly all of the variance that best fit TL. The correlations of two species were fluctuated through the different otolith morphology. The correlation coefficient (r^2) varied between 0.012 and 0.919 for left aspect ratio and right otolith width of *E. summana*, respectively, and from 0.017 to 0.953 for left aspect ratio and otolith perimeter of *C. argus*. The otolith perimeter of *C. argus* was highly correlated with fish length (r^2=0.953). The results indicated that the relationship between fish size and otolith morphological measurements for both left and right otolith were showed a good linear regression.

Table 2: The relationship between fish length and TL and each otolith descriptor for *Epinephelus summana* and *Cephalopholis argus* from the Red Sea, Egypt

Otolith descriptors	Relationship between TL and otolith descriptor	R^2
	E. summana	
OWt	Left side TL = 2.0874 + 0.5W	0.8126
	Right side TL = 2.0737+ 0.4896W	0.7889
OL	Left side TL=- 0.108 + 1.5855OL	0.8889
	Right side TL = - 0.0234+ 1.505OL	0.8588
OH	Left side TL= 0.3598+ 1.6401OH	0.9189
	Right side TL = 0.3763+ 1.6173OH	0.9097
Sulcus	Left side TL = 0.1915+ 1.3621OS	0.8474
	Right side TL = 0.2501+ 1.3022OS	0.8232
Ostium	Left side TL = 0.9228+ 1.0235OO	0.6478
	Right side TL = 1.0652+ 0.8051OO	0.6298
Cauda	Left side TL = 0.7286+ 1.0633OC	0.6703
	Right side TL = 0.7411+ 1.0328OC	0.5649
OA	Left side TL = 0.1013+ 0.9051OA	0.8504
	Right side TL = 0.1035 + 0.9037OA	0.8492
OP	Left side TL = - 0.5801+ 1.4674OP	0.8808
	Right side TL = - 0.5803+ 1.4676OP	0.8808
AS	Left side TL = -0.5902AS + 1.3249	0.0119
	Right side TL = -0.5705AS + 1.3317	0.0174
CO	Left side TL = - 0.6929+1.7046CO	0.519
	Right side TL = - 0.6822+ 1.696CO	0.5172
RE	Left side TL = 1.3786 - 0.8022RE	0.2204
	Right side TL = 1.3836 - 0.7787RE	0.2242
	C. argus	
W	Left side TL = 2.101+ 0.412W	0.8924
	Right side TL = 2.098+ 0.409W	0.8343
OL	Left side TL= 0.181+ 1.451OL	0.8628
	Right side TL = 0.181+ 1.453OL	0.8343
OH	Left side TL= 0.859+ 1.079OH	0.7119
	Right side TL = 0.871+ 1.058OH	0.7098
Sulcus	Left side TL = 0.570+ 1.102OS	0.6037
	Right side TL = 0.59+ 1.0767OS	0.5784
Ostium	Left side TL = 1.239+ 0.547OO	0.3616
	Right side TL = 1.241+ 0.545OO	0.3877
Cauda	Left side TL = 0.8300+ 1.1300OC	0.5164
	Right side TL = 0.917+ 0.986OC	0.3943
OA	Left side TL = 0.395+ 0.795OA	0.8454
	Right side TL = 0.395+ 0.795OA	0.8457
OP	Left side TL = - 0.182+ 1.282OP	0.953
	Right side TL = - 0.180+ 1.282OP	0.953
AS	Left side TL = 1.5848 + 0.2545AS	0.017
	Right side TL = 1.621+ 0.3723AS	0.0358
CO	Left side TL = 0.2916+ 0.9853CO	0.4148

	Right side TL = 0.2953+ 0.9828CO	0.4148
RE	Left side TL = 1.4543- 0.4395RE	0.0841
	Right side TL = 1.4602- 0.392RE	0.0708

OWt , otolith weight; OL, otolith length; OH, otolith width; OSU, *sulcus*; OS, *ostuim*; OA, otolith area; OP, otolith perimeter, AR, Aspect ratio; C, compactness; RE, rectangularity.

The regression analysis between fish length and fourteen otolith shape descriptors from generalized linear model was cleared that there is a significant relationship between the total length of fish and eight otolith parameters (ostium, cauda, otolith area, otolith perimeter, compactness, the otolith weight, length and aspect ratio) ($P<0.05$) for both *E. summana* and *C. argus* (Table 3).

Table 3 Generalized linear models for the relationship between TL and each otolith descriptor and the side effect for each relationship between TL and each otolith descriptor (Side effect). OWt , otolith weight; OL, otolith length; OH, otolith width; OSU, *sulcus*; OS, *ostuim*; OA, otolith area; OP, otolith perimeter, AR, Aspect ratio; C, compactness; RE, rectangularity. Bold lines showed the significant effect ($P<0.05$).

Otolith descriptor	Side effect	
	E. summana	*C. argus*
side * OWt	**0.001**	**0.000**
side * OL	**0.009**	0.099
side * OH	0.964	0.252
side * OSU	0.079	0.858
side * OO	0.075	0.789
side * OCA	0.211	0.857
side * OA	0.810	0.125
side * OP	0.957	**0.021**
side * AS	**0.044**	0.812
side * CO	0.620	0.968
side * RE	0.776	0.053

DISCUSSION

The morphological measurements of the otolith of fish are the most widely used tool to identify and compare the taxonomic characteristics of fishes due to the large size and interspecific variability in fish otoliths (Nolf, 1985; Battaglia *et al.*, 2010; Lord *et al.,* 2012; Bostanci *et al.*, 2015). Paleontologists, oceanographers and marine biologists have used the species specific distinctive morphology of the sagittae and their dense structure that can resist certain degree of disintegration to determine the identity of fish species found in middens, sediments and stomach content of marine birds and mammals (Fitch 1964, 1969, Tripple and Beamish 1987, Ainley *et al.* 1981, Treacy and Crawford 1981).

Researches in fish biology and population dynamics get huge usage of the otolith length-total length relationship (Echeverria, 1987). Furthermore, the identity of the eaten fish species and their size can be estimated from their otolith retrieved from the digestive tract of the piscivorous fishes (Aydin *et al.*, 2004). The estimated relationship between fish length and otolith biometry can be also used to determine fish length during development based on otolith morphometry. The otoliths can remain undigested for long periods in carnivore fish stomach and is possible to estimate prey fish size based on otoliths found in the stomach (Bostanci, 2009).

The otolith dimensions – fish size relationship in the Egyptian fisheries is rarely studied. So the present study is the first to interest with the estimated the different parameters of the otoliths of the grouper species in the Egyptian Red Sea. The estimation of the specific equations provided in the present study can be useful for studies on food and feeding as well as for paleontological.

There is little data available on otolith morphology of the two grouper species under study *E. summana* and *C. argus* from the Red Sea. The size range of the two grouper species in the present study was higher than that recorded in the previous studies (Osman, 2000; Mohamed, 2007). The study of relationship between otolith size and fish size varied according to the distribution region, the stock and sexes (Sparre *et al.*, 1989; Campana and Casselman, 1993; Reichenbacher *et al.*, 2009; Aneesh *et al.*, 2017), also the change of ontogenetic in the life span or history (Hare and Cowen, 1995). The present work was confirmed with other studies that investigated the correlation between fish length and otolith size (Mahé *et al.*, 2014; Mahé *et al.*, 2016; Mehanna *et al.*, 2016; Jawad, *et al.*, 2017; Mapp 2017; Mahé *et al.*, 2018; Osman *et al.*, 2018).

The investigation of fish length and otolith and the essential role of otolith morphometric measurements in fish identification stock were recently heavily studied (Harvey *et al.*, 2000; Tuset *et al.*, 2003b; Lychakov *et al.*, 2006; Sadighzadeh *et al.*, 2014; Gündoğdu and Baylan, 2016; Mehanna *et al.*, 2016; Mahé *et al.*, 2018b). The strong correlation between the somatic length and otolith size suggests that somatic growth has a significant influence on the otolith growth (Jockusch, 1997; Cardinale *et al.*, 2004). According to the current results, the correlation between TL and AR and CO was determined as a linear relationship, despite the relationship between TL and RE being determined as a nonlinear relationship. The results of generalized linear model GLM described the correlation between otolith measurements may be affected by the choice of the otolith (significant asymmetry between right and left otoliths). Generalized linear models for the relationship between TL and each otolith descriptor and the side effect on each relationship were investigated. There are no significant between the TL and some of otolith measurements while there is a significant difference for other otolith measurements such as otlith length, weight, perimeter and aspect ratio for both grouper species. The present study agreed with other studies, which reported the significant for the side effect on the select of the left and right otolith (Mahé *et al.*, 2017; Osman *et al.*, 2018). Considering the findings in this study, the fish length and otolith measurements parameters are useful for most verifying the role of otoliths in the identification, discrimination and taxonomic classification of fish. Also, the present results showed that the otolith shape indices significantly differed from species to species, although the indices indicate a similar pattern for both otoliths. Consequently, there are reliable with that otoliths are used for distinguish between fish species because of their form, diet, weight and growth (Tuset *et al.*, 2008; Battaglia *et al.*, 2010; Bacha *et al.*, 2010).

CONCLUSION

The reported of GLM investigated in the present study may be best way to study the relationship between fish length and otolith morphometric features used to ecological study, paleontological composition, fish population dynamics, yield estimates and stomach contents of piscivorous predators. These relationships provide a reliable tool in feeding studies and also provide support to palaeontologists in their research on fish fossils.

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