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OTOLITH ECO-MORPHOLOGICAL PATTERNS OF BENTHIC FISHES FROM THE COAST OF VALENCIA (SPAIN)

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ABSTRACT

Benthic fishes exhibit different adaptive strategies and different degrees of association with the substrate. The aim of this study is to describe the morphologic and morphometric characteristic of otolith of four species of benthonic fish off the coast of Valencia and study the relationship between these otolith´s characteristics witch the substrate. The *sagittae* analysed belonged to the following species: *Scorpaena scrofa* Linnaeus, 1758 (N=40), *Mullus surmuletus* Linnaeus, 1758 (N=29), *Uranoscopus scaber* Linnaeus, 1758 (N=24) and *Synaptura lusitanica* Capello, 1868 (N=121). The fishes were sexed, the total length (TL) was measured in mm, and the *sagittae* were removed to examine their morphology and morphometry. The E (=maximum width of the otolith (OW)/ maximum length of the otolith (OL)%) and S (sulcus area (SS)/otolith area (OS) %) index were calculated. The E morphometric index showed a tendency towards an elongated or circular shape and the S index showed a tendency of macula nervous to have a greater surface area of information uptake to transmit to the fish brain. The analysis of otolith morphology and morphometry revealed the existence of different eco-morphological patterns associated with habitat use and the type of substrate where the fish is most frequently found. The E and S index have proven to be useful for discriminating between the *sagittae* of fishes from different water column uses and are associated a different substrates type.

Key words: Otoliths; Ecomorphology; Morphometry; Benthic environment.

RESUMEN

Palabras clave:

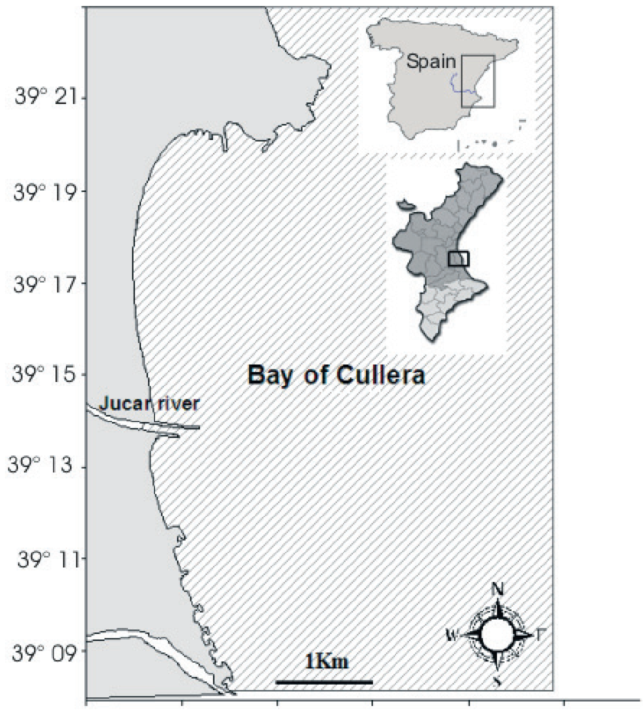

Figure 1: *Study area.*

INTRODUCTION

Benthic fishes exhibit different adaptive strategies and different degree of association with the substrate. This association mainly depends on the type of substrate and on the morphology, physiology and behaviour of the fish (Lindsey 1978; Menni 1983).

In general, fishes living on soft substrate (slimy and sandy substrates) burrow partially in the bottom while stalking prey. Most of these predators, such as the Pleuronectiformes, are characterised by rapid and short-distance movements. Fishes found on hard substrate (rocky substrate) hide in holes or stand motionless, waiting for the prey to approach. These are represented by the Scorpaeniformes and Serranids, and other fish families.

The differences in habitat use and the different communication strategies of fishes may also affect different structures as the otolith *sagittae* (Cruz and Lombarte 2004; Lombarte and Cruz 2007; Lombarte *et al*. 2010). Otoliths are three paired of calcified structures (*sagittae, lapilli* and *asterici*) found in the inner ear, used for balance and/or hearing in all teleost fishes. The otolith shape is species-specific. Environmental factors (Aguirre and Lombarte 1999; Torres *et al*. 2000; Gauldie and Crampton 2002; Volpedo and Echeverría 2003; Volpedo *et al*. 200; Volpedo and Fuchs 2010), ontogeny (Tombari *et al*. 2005; Gonzalez Naya *et al*. 2012), physiology as the hearing capabilities associated with specialization in acoustic communication (Popper and Fay 1993; Paxton 2000; Lombarte and Cruz 2007) and the phylogeny (Nolf and Tyler 2006), could affect the morphology, the morphometry and the microstructure of sagittae (Volpedo and Fernández Cirelli 2006; Volpedo *et al*. 2007). The literature studying the morphometric variation of the otoliths of benthic fish are limited (Volpedo and Echeverría 2003).

The aim of this study is to describe the morphologic and morphometric characteristic of otolith of four species of benthonic fish off the coast of Valencia (*Scorpaena scrofa* Linnaeus, 1758, *Mullus surmuletus* Linnaeus, 1758*, Uranoscopus scaber* Linnaeus, 1758, and *Synaptura lusitanica* Brito Capello, 1868*),* and study the relationship between these otolith´s characteristics witch the substrate.

MATERIALS AND METHODS

The analysis was based on the *sagittae* of four fish species: *Scorpaena scrofa* (N=40), *Mullus surmuletus* (N=29), *Uranoscopus scaber* (N=24) and *Synaptura lusitanica* (N=121). Fish samples were mature specimens and present the typical morphological pattern of their otoliths. Between July 2004 and March 2005, fishes were caught in Bay of Cullera (39º 12'- 38º 59' N and 0º 09'- 0º 15'W) (Fig. 1) with gillnets operated by commercial, and artisanal fishermen.

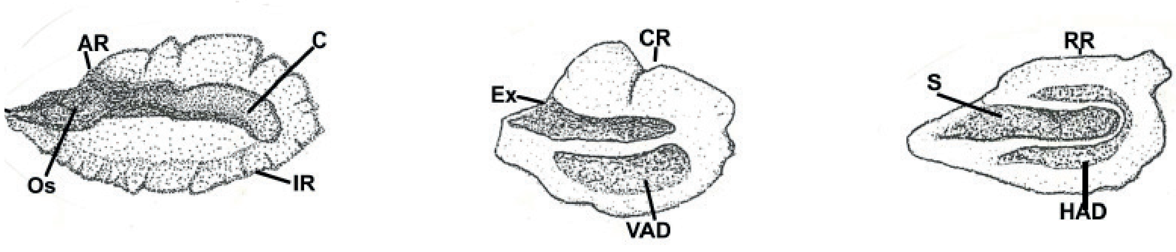

Figure 2:
Otolith morphology of sagittae. Antirostrum (AR), cauda (C), crenulated rim (CR), excisura (Ex), horseshoe-shaped area depression (HAD), irregular rim (IR), ostium (Os), rostrum (R), regular rim (RR), sulcus (S) and ventral area depresion (VAD).

Samples were kept at -18ºC until processing in the laboratory. The specimens were identified using appropriate keys (Corbera *et al*. 2000; Whitehead *et al*. 2001; Froese and Pauly 2008).

Fishes were sexed, their total length (TL) was measured to the nearest mm, and the *sagittae* were removed from the otic capsules. They were prepared for examination and drawing, and measured under stereoscopic microscope to the nearest 0.1 mm.

Otolith morphological description is based on the terminology proposed by Volpedo and Echeverría (2000) and Tused *et al*. (2008). The following morphological characters were considered in medial face: geometrical shape, type of rim, presence of *rostrum*, *antirostrum* and *excisura*, type of *sulcus*, presence of *ostium* and *cauda* and presence de area depression. In addition, the topography of the lateral face (side opposite the sulcus) was described (Fig. 2).

The maximum width of the otolith (OW) and maximum length of the otolith (OL) were measured in the medial face of each right *sagitta* (Fig. 3).

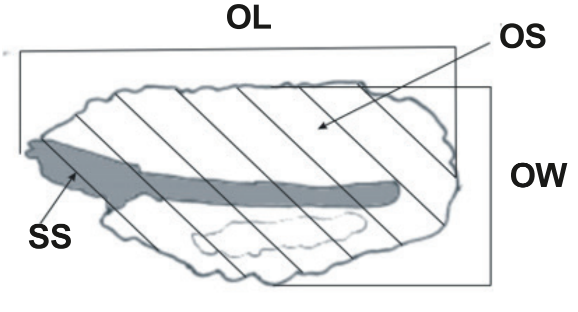

Figure 3:
Morphometry of otoliths. Maximum length of the otolith (OL), maximum width of the otolith (OW).

The E and S index were calculated. The E index (E = OW/OL%) was calculated to assess if the otoliths showed a tendency towards an elongated or circular shape. The S index is (SS)/(OS) %). The otolith and sulcus areas were measured using a digital image processing system. The OL*100/fish size was calculated, total length (TL, mm) was the reference for fish size. The E index and OL*100/TL were calculated from 45 species from otolith images provided AFORO data base (http://aforo.cmima.csic.es) purposes comparatives.

The statistical analysis was based on the mean values of the different parameters. The Student's t-test (Sokal and Rolf 1987; Zar 2004) was used to compare between the length and width of the right and left *sagittae* and between the *sagittae* of males and females.

A ANCOVA was used to test for significant differences in the E and S index among species, followed by the *Tukey's multiple comparison test*. Linear regression analysis was performed to determine the relationship between each morphometric character (OW and OL) and fish total length (TL), and the regression parameters and the coefficient of determination (R^2) were calculated. Statistical analysis was performed using SPSS Inc., 16.0 for Windows and StatGraphics Centurion XV, version 15.2.06.

RESULTS

Morphological features of *sagittae*

The *sagitta* of *Scorpaena scrofa* is elongated, with a regular dorsal rim and an irregular ventral rim. The rostrum is conspicuous and represents 28% approximately of otolith length. The *excisura* and *antirostrum* are conspicuous. The *sulcus* is divided into a funnel-shaped *ostium* and a *cauda* slightly directed to the ventral rim distally. A ventral area depression is parallel to the *sulcus*. The medial face is convex and the lateral face is concave with radiating grooves (Fig. 4 A).

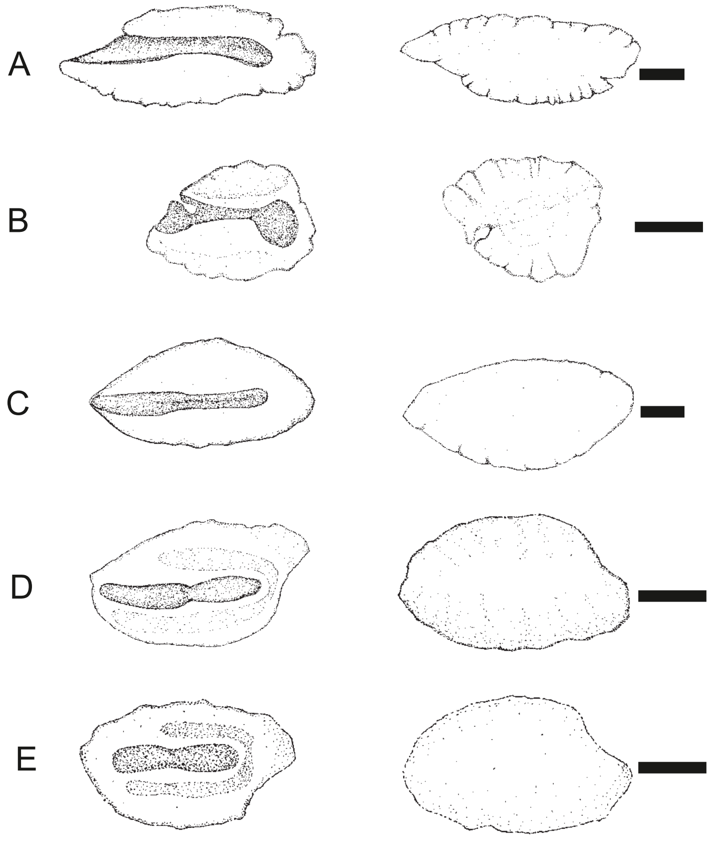

Figure 4:
Morphology of sagittae. A: Scorpaena scrofa. B: Mullus surmuletus, C: Uranoscopus scaber, D: left sagitta of Synaptura lusitanica, E: right sagitta of Synaptura lusitanica. Scale: 2 mm

In *Mullus surmuletus* the *sagitta* is oval, with scalloped or crenulated ventral and dorsal rims; the rostrum represents 30% approximately of otolith length and the excisura has a notch. The *ostium* is perforated. The *sulcus* is open anteriorly and posteriorly, is surrounded by ventral and dorsal ridges, and divided into *ostium* and *cauda*. The *ostium* is funnel-shaped and the *cauda* is initially straight and then curves distally towards the ventral rim. It has dorsal and ventral area depressions, oriented parallel to the *sulcus*. The medial face is convex and the lateral face is concave and shows radiating grooves. (Fig. 4 B)

The *sagitta* of *Uranoscopus scaber* is oval, with regular rims. It lacks *rostrum, antirostrum* or *excisura*. The *sulcus* is closed anteriorly and posteriorly and not divided into *ostium* and *cauda*. The area depression is absent. The medial and lateral faces are slightly flat, with the latter showing radiating grooves (Fig. 4 C).

The left and right *sagittae* of *Synaptura lusitanica* show morphological differences. The left *sagitta* is oblong, with regular rims. There is a quadrangular-shaped process at the postero-dorsal tip. The rostrum is poorly developed and the excisura and antirostrum are short. The *sulcus* is open anteriorly, *ostium* and *cauda are* differentiated. The *cauda* is small and almost circular in the posterior part of the sulcus, and is surrounded by a horseshoe-shaped area depression. The medial face is convex and the lateral face is undulated (Fig. 4 D). The right *sagitta* is oblong, with irregular rims and a projection at the postero-dorsal tip. The *ostium* and *cauda* are differentiated. The *collum* is present between the *ostium* and the *cauda*. The horseshoe-shaped area depression is present. The medial face is convex and the lateral face is undulated (Fig. 4 E).

Morphometrical features of otoliths

Table 1 shows the significance of the differences in length and width between the right and left *sagittae*, as determined by the Student's t-test.

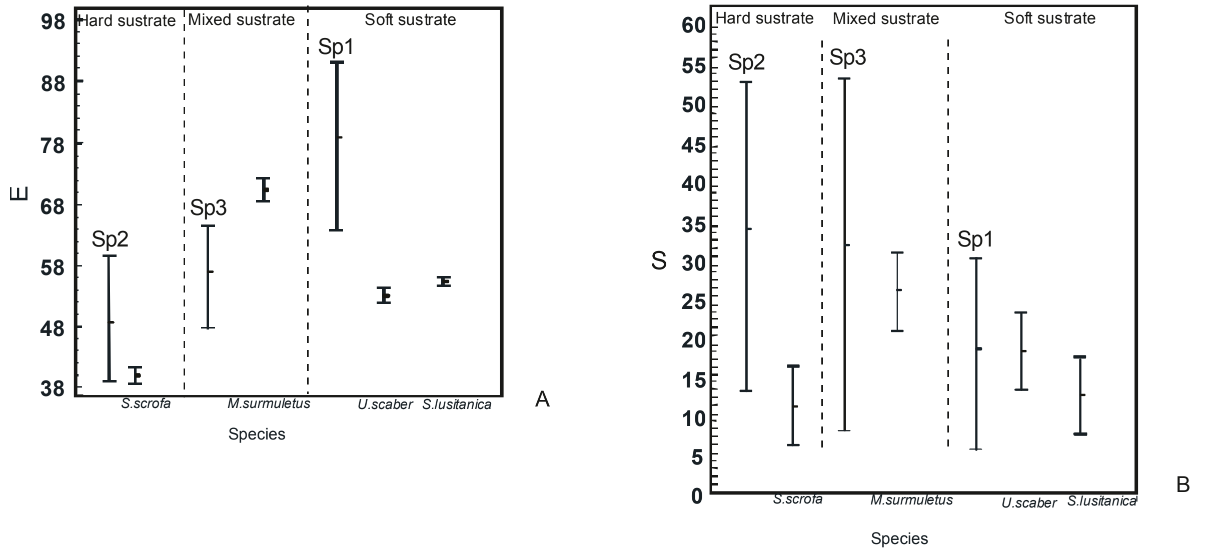

Figure 5:

Mean values and standard deviation. A) E index (E= OW/OL%). B) S index (S= SS/ OS %). sp1: species associated to soft substrate (Table 4), sp2: species associated to hard substrate (Table 4), sp3: species associated to mixed substrate (Table 4).

In relation to fish relative size (OL*100/TL), the otoliths of *S. scrofa* and *U. scaber* were the largest (4.11-4.64 and 3.03-4.83, respectively), while those of *M. surmuletus* and *S. lusitanica* were the smallest (2.70-3.48 and 2.26-3.11, respectively).

The right and left *sagittae* of *M. surmuletus*, *S. scrofa* and *U. scaber* no showed morphological differences in the topography of the inner and outer face of the otolith. S. lusitanica present differences between the right and left sagitta (Fig. 4).

The results of the comparison between the *sagittae* of males and females are shown in Table 2. The otoliths of females of *M. surmuletus*, *S. lusitanica* and *U. scaber* were significantly larger than those of males of a similar length, while the otoliths of *S. scrofa* did not differ significantly between sexes.

The regression parameters (a and b) and coefficient of determination (R^2) for the relationships between the morphometric characters of the *sagittae* and fish total length are presented in Table 3. The regressions were significant for all species (Table 3) and data from symmetric fishes fitted well to the linear regression model (R^2>0.80). The lowest values of R^2 were obtained for *S. lusitanica*, particularly for the relationship between otolith width and fish total length. In this species showing morphologically different right and left *sagittae*, the values of R^2 calculated from the right *sagittae* were higher than those from the left *sagittae*.

The lowest and highest values of the E morphometric index were obtained for *S. scrofa* (40.3%) and *M. surmuletus* (70.54%), respectively, while *S. lusitanica* and *U. scaber* showed similar values (55.63 % and 53.12 %, respectively) (Fig. 5 A). ANCOVA showed significant differences in the E morphometric index among the studied species ($F_{(3;216)}$ = 117.2; $P < 0.05$), and the *Tukey's multiple comparison test* revealed significant differences between *M. surmuletus, S. scrofa* and the other species. There were no significant differences in the E morphometric index between *S. lusitanica* and *U. scaber*.

The mean value of S indexes for *M. surmuletus* are highest (26.12 % ± 4.57) and lowest for *S. scrofa* (11.58% ± 3.73). *S. lusitanica* and *U. scaber* showed intermediate values (12.94% ± 3.55 % and 18.74% ± 8.32%, respectively) (Figure 5 B).

ANCOVA showed significant differences in the S index among studies species ($F_{(3;216)}$ = 107.3; $P < 0.05$) and the *Tukey's multiple comparison test* revealed significant differences between *M. surmuletus, S. scrofa* and the other species. There were no significant differences in the S morphometric index between *S. lusitanica* and *S. scrofa*.

DISCUSSION

The otoliths of benthic fishes from the coast of Valencia showed different eco-morphological patterns, which could be associated with the type of substrate where the fish is most frequently found and habitat use.

In order to relate our results with those of the Otolith AFORO Database and have a reference in the interpretation of these, we have obtained the E index and

Table 1:

*Morphometric features (mean ± SD) of sagitta in the studied species and t-student results for comparison between right and left otolith. N. sample number, TL= fish total legth; OL = maximum length of the otolith; OW= maximum width of the otolith. *P>0.05 significative*

Species	TL (mm)	Morphometric features	Right Otolith (mm)	Left Otolith (mm)	t-value	N	P
S. scrofa	224 ± 7	OL	9.8 ± 1.6	9.1 ± 2.1	0.87	24	0.4
		OW	3.8 ± 0.6	3.6 ± 0.8	0.34		0.7
M. surmuletus	205 ± 4	OL	6.3 ± 0.8	6.3 ± 0.8	0.054	20	0.9
		OW	4.5 ± 0.5	4.4 ± 0.5	0.705		0.5
U. scaber	234 ± 5	OL	9.2 ± 2.1	9.2 ± 2.1	0.087	24	0.9
		OW	4.9 ± 0.9	4.8 ± 0.9	0.097		0.9
S. lusitanica	235 ± 4	OL	6.3 ± 1.0	5.9 ± 1.1	2.56	121	**< 0.05***
		OW	3.4 ± 0.5	3.7 ± 0.8	2.91		**< 0.05***

the relative sizes of the otoliths in relation to the TL, from 45 species of western Mediterranean, north and central eastern Atlantic fishes (Tuset *et al*. 2008; Otolith AFORO Database 2012). The data are shown in table 4.

In table 4, of the 45 species, 18 species inhabit soft substrates, 17 hard substrates and 10 species are associated to mixed substrates (hard and soft) (Fischer *et al*. 2007). The average of the E index of species associated with soft substrates is 79.09% ±8.37 and S 20.13 ± 12.7 %. In the case of species associated with hard substrates have an average of E index of 48.47% ±5.23 and S 35.43±20.11 %., while the 10 species associated both to mixed substrates have an average of 56.20% ±5.81 and S 34.63±23.6 %.

The species of *Bothidae, Cynoglossidae, Gobiidae* and *Soleidae* families generally present otolith with the E index values >60% and are associated to soft substrates

Table 2:

*Comparison between morphometric features (mean ± SD) of sagitta of both sex and t-student results. OL = maximum length of the otolith; OW= maximum width of the otolith. *P>0.05 significative.*

Species	Morphometric features	Female (mm)	Male (mm)	t-values	g.l.	P
S. scrofa	OL	9.8 ± 1.7	9.7 ± 1.6	0.17	24	0.87
	OW	3.8 ± 0.6	4.0 ± 0.8	0.98		0.33
M. surmuletus	OL	6.7 ± 0.6	5.8 ± 0.5	3.1	20	**< 0.05***
	OW	4.7 ± 0.5	4.2 ± 0.5	2.23		**< 0.05***
U. scaber	OL	9.9 ± 2.2	9.1 ± 1.2	3.01	40	**< 0.05***
	OW	5.2 ± 1.0	4.4 ± 0.6	2.9		**< 0.05***
S. lusitanica	OL	6.3 ± 1.1	5.7 ± 0.7	3.4	121	**< 0.05***
	OW	3.7 ± 0.7	3.3 ± 0.5	4.03		**< 0.05***

Table 3:

Regression lineal parameters pf morphometrical features of sagitta in relation to total length of fish. a: intercept, b: slope, R2: determination coefficient. LOL. left otolith length, LOW left otolith width, OL: right length otolith, OW: right otolith width, TL. Total length of fish.

Specie	Morphometrical features	a	b	R^2
S. scrofa	TL vs OL	3.40	0.26	0.87
	TL vs OW	1.17	0.11	0.88
M. surmuletus	TL vs OL	2.76	0.17	0.81
	TL vs OW	1.17	0.13	0.84
U. scaber	TL vs OL	-0.43	0.41	0.87
	TL vs OW	0.30	0.19	0.88
S. lusitanica	TL vs OL	0.36	0.25	0.85
	TL vs LOL	-0.02	0.25	0.62
	TL vs OW	1.15	0.09	0.40
	TL vs LOW	0.83	0.12	0.25

and S index values between 10.38-53.16 %. The species of *Muraenidae, Scorpaenidae, Serranidae, Trachinidae* and *Tripterygiidae* families present otolith with the E index values <60% and S index values between 13.25-32.91 and are associated to hard substrates. The labrids, mullids and sparids present species associated to soft substrates and hard substrates (Table 4). *Xyrichthys novacula* (labrids) present an E index value of 89.41% inhabiting soft substrate, while the labrids associated to hard substrate (Table 4) present E index values between 50.00-55.11%. *Mullus barbatus barbatus* present an E index value of 75.96% inhabinting sof substrates (Fischer *et al*. 2007). The sparid species of soft bottom (*Dentex macrophthalmus*) present E index values of 80.46 %, and sparid species of hard bottom (*Dentex dentex*) E index values of 57.44% (Table 4).

The fishes burrowing into soft bottom substrates (*U. scaber* and *S. lusitanica*), have oblong otoliths of variable size in relation to fish total length and an E morphometric index with 53.12% and 55.63%. This species *inhabit* sandy or muddy bottoms between 10 to 90 m deep, feeding off small fish, crustaceans, molluscs and polychaetes (Calvin 2000, Jaramillo 2009). *U. scaber* and *S lusitanica* shared similar habitat, however the latter is a trophic specialist, predating predominantly on polychaetes (Jaramillo 2009). As the E and the S indexes are similar it can be suggested that otolith morphology and morphometry reflected the similarities between *U. scaber and S lusitanica* habitat characteristics and behavior. These relationships established for other species of different habitats (Volpedo and Echeverria 2003; Volpedo *et al*. 2008; Cruz and Lombarte 2004; Lombarte and Cruz 2007).

The otolith of *S. lusitanica* shows a horseshoe-shaped area depression, which results from cranial remodelling and eye migration during larval metamorphosis. This feature is shared by other flatfishes such as *Achiropsetta tricholpis* Norman, 1930, *Etropus longimanus* Norman, 1933, *Paralichthys orbynianus* (Valenciennes, 1839), *P.isosceles* Jordan, 1891, *P. brasiliencies* (Ranzani, 1842), *P. patagonicus* Jordan, 1889 and *Xystreuris rasile* Jordan, 1891 (Volpedo and Echeverría 1997).

S. scrofa is present on hard bottoms, and *M. surmuletus* is found on mixed bottoms (soft and hard substrates), both species showed a different morphological pattern in their otoliths and water column used. *S. scrofa* is a solitary fish common on hard substrate and in caves, and it may move to sandy bottom sediments despite its sedentary behaviour (Corbera *et al*. 2000). The otolith of this species is 4.5% of fish total length, with an E index of 40.3%, and the S index (11.58%) is the lowest value of studied species in this paper. The otolith of *S. scrofa* is elongated shape and well-developed rostrum are also present in other species of the genus such as *S. elongata, S. maderensis, S. notata* and *S. porcus* (Tuset *et al*. 2008), and in hard-bottom serranid and notothenid fishes (Volpedo and Echeverría 2003).

Table 4:

E index and OL/TL relation in species of literature.1-soft substrate, 2: hard substrate,3: mixed bottoms (soft and hard substrates).

Family	Specie	E %	(OL*100)/TL	SS/OS%	Subst
Bothidae	*Arnoglossus imperialis* (Rafinesque, 1810)	69.70	1.886	30.493	1
	Arnoglossus laterna (Walbaum, 1792)	66.67	2.371	24.691	1
	Arnoglossus rueppelii (Cocco, 1844)	67.77	2.305	24.585	1
	Arnoglossus thori Kyle, 1913	64.94	3.138	53.165	1
	Bothus podas (Delaroche, 1809)	66.93	1.434	28.097	1
Callionymidae	*Callionymus maculatus* Rafinesque, 1810	47.80	2.661	54.762	3
	Callionymus risso Lesueur, 1814	49.86	2.823	53.126	3
	Synchiropus phaeton (Günther, 1861)	47.81	2.314	20.408	3
Cepolidae	*Cepola macrophthalma* (Linnaeus, 1758)	55.10	2.305	20.719	3
Citharidae	*Citharus linguatula* (Linnaeus, 1758)	61.60	3.035	17.580	3
Cynoglossidae	*Symphurus ligulatus* (Cocco, 1844)	80.72	3.557	12.032	1
	Symphurus nigrescens Rafinesque, 1810	87.17	1.965	15.741	1
Gobiidae	*Deltentosteus quadrimaculatus* (Valenciennes, 1837)	84.22	4.444	10.578	1
	Gobius niger Linnaeus, 1758	78.04	4.549	10.384	1
	Lesueurigobius friesii (Malm, 1874)	87.27	4.650	10.601	1
Mullidae	*Mullus barbatus barbatus* Linnaeus, 1758	75.96	2.176	18.636	1
Soleidae	*Bathysolea profundicola* (Vaillant, 1888)	85.51	2.070	14.38	1
	Monochirus hispidus Rafinesque, 1814	85.51	2.070	24.27	1
	Pegusa lascaris (Risso, 1810)	91.47	2.413	13.62	1
	Solea senegalensis Kaup, 1858	82.66	2.464	19.72	1
	Solea solea (Linnaeus, 1758)	79.19	1.700	13.61	1
Sparidae	*Lithognathus mormyrus* (Linnaeus, 1758)	59.91	3.531	20.303	3
	Dentex macrophthalmus (Bloch, 1791)	80.46	4.894	14.090	1
Trachinidae	*Trachinus draco* Linnaeus, 1758	47.58	4.935	17.045	2
	Trachinus radiatus Cuvier, 1829	48.62	3.828	19.153	2
Labridae.	*Coris julis* (Linnaeus, 1758)	55.11	1.957	18.135	2
	Labrus merula Linnaeus, 1758	50.00	1.726	14.250	2
	Labrus viridis Linnaeus, 1758	51.35	1.930	14.620	2
	Symphodus cinereus (Bonnaterre, 1788)	62.79	1.911	7.210	3
	Symphodus doderleini Jordan, 1890	55.02	2.544	16.080	3
	Symphodus mediterraneus (Linnaeus, 1758)	56.60	2.136	9.434	3
	Symphodus ocellatus (Linnaeus, 1758)	65.58	1.925	7.339	3
	Symphodus rostratus (Bloch, 1791)	60.09	2.027	6.874	2
	Symphodus tinca (Linnaeus, 1758)	56.13	1.843	5.893	2
	Xyrichthys novacula (Linnaeus, 1758)	89.41	2.040	18.750	1
Muraenidae	*Muraena helena* Linnaeus, 1758	44.25	0.718	32.915	2
Scorpaenidae	*Helicolenus dactylopterus* (Delaroche, 1809)	50.64	4.542	23.552	2
	Scorpaena elongata Cadenat, 1943	40.30	5.448	16.071	2
	Scorpaena notata Rafinesque, 1810	43.12	5.508	21.278	2
	Scorpaena porcus Linnaeus, 1758	42.96	4.656	13.252	2
Serranidae	*Epinephelus marginatus* (Lowe, 1834)	48.57	2.714	28.820	2
	Serranus cabrilla (Linnaeus, 1758)	42.31	4.160	23.909	2

M. surmuletus mainly inhabits mixed bottoms (rocky bottoms and soft substrates), and undergoes vertical movements between 5 and 100 m in depth (Froese and Pauly 2008). This species showed the highest value of E and S indexes (70.54% and 26.13%, respectively), which may be explained by a differential use of the water column. The indexes values obtained for *M. surmuletus* are similar at de values determinate by Volpedo *et al*. (2008) in mesopelagic Antarctic fishes that make extensive vertical migrations and other Mediterranean fishes species that using soft and hard substrates (table 4).

The high value of S index could be associated with water column uses, this could be a support for adaptive physiological features as specialization in acoustic communication in deep waters in order to compensate the reduction of light with depth (Lombarte and Cruz 2007), among other factors. The otolith morphology of this species (geometric shape, type of rims, presence of rostrum, and type of *sulcus*) is similar to that of other species of the same genus such as *M. barbatus, M. mullus* and *M. argentinae* Hubbs, Marini & Hubbs, 1933 (Volpedo and Echeverría 2000; Tuset *et al.* 2008). The differences in otolith morphometry observed between males and females of *M. surmuletus,* S. *lusitanica* and *U. scaber* were also found for *Prionotus nudigula* Ginsburg, 1950 (Volpedo and Thompson 1998). This result may be due to the fact that these species are sexually dimorphic in size, with females growing at a lower rate and being larger than males (Reñones *et al.* 1995; Jaramillo 2009).

According to Volpedo and Echeverría (2003), the differences in the E and S index among fish species may be due not only to phylogenetic factors but also to environmental and bioecological factors. In this work, the E and S index have proven to be useful for discriminating between the *sagittae* of fishes from different substrate. On this basis, it can be seen as a valuable tool for studies of trophic ecology in the coast of Valencia.

This work contributed to the knowledge of the bioecology of commercially important benthic fishes and provided key information for studying the trophic ecology of fish-eating species and fishery management.

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