BETWEEN LUMPERS AND SPLITTERS, WHICH TAXONOMICAL APPROACH TO MEDITERRANEAN SMALL TUNA OF GENUS *AUXIS*?

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SUMMARY

Systematic studies (Collette e Aadland, 1996) have assigned the Mediterranean tuna of genus Auxis to the subspecies Auxis rochei rochei, but the diagnostic characters proposed for this taxon fit only in part Mediterranean material. A research, supported by MIUR (Ministero dell'Università e della Ricerca), was carried out both on morphological characteristics and genetic diversity of samples of Auxis obtained both in the Mediterranean and in the adjacent Atlantic. From Atlantic Morocco to the Central Mediterranean only one species was found; its main morphological characteristics are illustrated, taking into account, for sake of comparison, those of A. thazard. The peculiarities of Mediterranean Auxis deserve appreciation on a taxonomical basis.

KEYWORDS

Auxis rochei, *Mediterranean*, *morphometry*, *meristics*, *taxonomy*

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Introduction

The bullet tuna, *Auxis rochei* (Risso, 1810), is an epipelagic neritic as well as oceanic species, cosmopolitan in warm waters (Collette and Nauen, 1983). Its oceanic distrbution in the Indo Pacific and in South and Central Atlantic, is shared with a very similar species, *Auxis thazard* (Lacepede, 1800). Albeit the two species entered in the scientific literature about two centuries ago, only in a relatively recent time detailed morphological studies were carried out to compare them (Uchida, 1981) and to verify the possible separations at species level (Collette and Aadland, 1996). According to the latter Authors, the genus *Auxis* includes two species divisible in four subspecies; in the Mediterranean, after a reexamination of collections from France, Italy (Ligurian, Tyrrhenian, Ionian and Adriatic Seas) Austria, Lebanon, Israel, all studied specimens were assigned to A. *rochei rochei* Risso 1810 (Collette and Aadland, 1996); in fact, in the same time, a new subspecies, *A. rochei eudorax* Collette and Aadland, was described in the Eastern Pacific, on the basis of a larger corselet and a higher number of gillrakers on first arch.

In Japanese waters the two species of *Auxis* were described and figured in nice tables since the beginning of 1900, under the names *A. hira* and *A. maru* and the fish also distinguished by taste and commercial characteristics (Kishinouye, 1923). Mediterranean ichthyologists on the contrary, thinking that there were only one species of *Auxis*, used for a long time the name *A. thazard*, the first appeared in the literature, for the Mediterranean fishes. Such use leaves a trail in fishery statistics of small tunas, both in the ICCAT and the FAO approach: in fact ICCAT produces data about the Atlantic and Mediterranean annual catch of "frigate tuna" (a term which in different contexts is equal to *A. thazard* or to both species) and FAO utilizes the mixed category *A. thazard - A. rochei*, given the impossibility to distinguish species.

The present note is aimed to verify at which extent the morphological characteristics of *A. rochei* studied in the above mentioned systematic studies (Uchida, 1981; Collette and Aadland, 1996) are present in the Mediterranean fish on the basis of consistent samples. These were collected in the Central and West Mediterranean and adjacent Atlantic coast (Ionian Sea, Sicily strait, Ligurian Sea, Atlantic Morocco). More than 200 specimens were analyzed in their genetic and morphological characteristics to verify: 1) if in the Mediterranean there are one or two species of Auxis; 2) which are the main morphological and meristic patterns of Mediterranean fish; 3) what the genetic study can show in terms of stock units identification. The present note presents the morphological characteristics regarding point 2), while the genetics results will be detailed in a following paper.

Materials and methods

Studied material consists of four samples (Table 1) collected in the Mediterranean and adjacent Atlantic near Larache (Morocco).

The length/frequency distributions of sampled fish with the exclusion of larvae are shown in fig. 1.

Morphometric characters examined in this study were: fork length (FL); head length (HL); body depth at five antero-posterior levels: at eye (AO); at opercular margin (AOP); at origin of first dorsal fin (A1D); at interdorsal space (ASI); at origin of second dorsal fin (A2D); round weight (RW).

Meristic characters examined were:

- number of rows of scales in the lateral corselet at second dorsal fin origin
- number of gillrakers on first arch
- number of vertebra in which the first free parapophysis occurs
- number of vertebra in which the first foramen occurs (figures of these vertebral charactyeristics in Uchida, 1981).

Genetic study was based both on mythocondrial DNA and microsatellite DNA technics; the four samples resulted formed by only one species (Orsi Relini *et al*., 2008 in preparation)

Results and discussion

A) Length/weight relationships and condition index

The length/weight relationships (fig. 2A) shows heavier fish in the Ionian Sea, where the sampling occurred at the beginning of reproductive season. The condition index K (Fulton, 1911) gives a clearer pattern of the seasonal variation of weight: K is higher in Moroccan fish, sampled in November, and Ionian fish sampled in June-July than in the Ligurian sample, which included the cold half of the year, December to May (fig. 2B).

B) Body depths

According to Collette and Aadland (1996) body depth, measured at different levels, is useful to differentiate the two species of *Auxis*, being *A. rochei* a slender species in respect of *A. thazard*, which is more fusiform or tuna shaped in its lateral profile. However the measures of these set of data in the two species and their ranges were

only in part published by the cited authors. We figure the data collected in the three samples from Ligurian Sea, Ionian Sea and Atlantic Morocco in form of regressions in respect of fork length (fig. 3 and 5). Such measures, transformed in % fork length were used to compare the samples; their means are shown in table 2.
The first three body depth, at eye (fig. 3A), at opercular margin (fig. 3B) and at the first dorsal fin (fig. 3C) grows regularly with the size of fish with significant differences in the geographical samples of Morocco versus Ligurian and Ionian Sea (Mann Whithney Text). Morocco fish are distinguished for their juvenile age and the diversity of these diameters can be explained by allometric growth. As an example of the latter, we have figured the growth of head length as percent of FL, in relation to the size of fish: pooling the samples, the resulting trend has a significant R (α=0.001) (fig. 4).
The remaining two body depths give differents results, with significant differences among all the three samples: body depth at central interdorsal space (fig. 5A) and at second dorsal fin origin (fig. 5B) separate Ionian, Ligurian and Moroccan fish (Mann Whithney Text). These measures are influenced by the mass of visceral organs (stomach, gonads etc.) As previously indicated, Ionian sample is distinguished for its "fat condition" and the Morocco one for juvenile age.

C) Corselet width
Both the Ligurian and Ionian are formed by large corseleted fish, i.e., under the second dorsal fin origin, the number of rows of scales is, in the majority of cases, 6 or more (fig. 6). However this characteristics is influenced by size (age) of fish (fig. 6; R significant per α=0.001). The Moroccan sample, formed by young fishes, gives a less clear pattern; in fact the scale rows are often in course of development and a reading is possible only under a dissecting microscope. Given that we have obtained different lectures of this characteristic according to the modalities of the inspection (i.e. naked eye or stereomicroscope) we considered these numbers and more in general the corselet structure not suitable for a diagnosis of species in young fish.

D) Number of gillrakers on first arch
In a worlwide approach, the number of gillrakers on first arch is 39-49 in *A. rochei rochei* and 36-44, in *A. thazard thazard* (Collette and Aadland, 1996). The number of gillrakers counted in the present three samples of fishes are shown in table 3 and in fig. 7. Pooling the three samples the mean is 41.82 (N=341; st. dev. 1.51) the lowest found in a population of A. rochei and therefore the closest to *A. thazard* populations. In fact Collette and Aadland (1996) found $\overline{x}$ = 42.6 in the Mediterranean (N=37), $\overline{x}$ = 42.17 in the West Atlantic and $\overline{x}$ = 43.5 in the East Atlantic.

E) Number of vertebra bearing the first free parapophysis.
The first free parapophysis was found in the range 20th-23th vertebra, with the modal value at 21th vertebra in the Morocco sample and at 22th vertebra in both Ligurian and Ionian samples (fig. 8). Such positions are typical of *A. rochei* (Uchida, 1981).

F) Number of vertebra bearing the first inferior foramen
The first foramen was found in the range 26th to 30th vertebra, with the modal value at 27th vertebra in the Morocco and Ionian samples and at 28th vertebra in the Ligurian sample (fig. 9). According to Uchida (1981) such positions are typical of *A. thazard*. According to Kishinouye (1923) the sole presence of an inferior vertebral foramen is indicative of *A. thazard*; in fact he studied mainly young fish, indicating a growth to about 0.6 kg in *A. rochei* and 1.5 kg in *A. thazard*.

G) Colour patterns
Dorsal surfaces bear marks of various forms : vertical, oblique and curve lines and spots (fig. 10). The combination of these produces a large variety of patterns, which includes spots surrounded by emicircles or circles, forming a sort of jaguar pattern (fig. 10). Sometimes spots are present also under the lateral line (Rodriguez Roda, 1980). The variability of colour patterns was described since a long time in the Mediterranean (Tortonese, 1963; Cefali and Cavallaro, 1983) and is in contrast with the fact that FAO and ICCAT guides describe a colour pattern typical of *A. rochei*, with vertical bars, and another one typical of *A. thazard*, with oblique to horyzontal bars or lines.

Conclusions
In samples of *Auxis* collected in the Central and Western Mediterranean (Ionian Sea, Ligurian Sea amd Sicily Strait) including its natural extension beyond the Gibraltar Strait (Atlantic Morocco, i.e. in the Mauritanian waters of the Mediterranean sub province, acccording to Ekman), we have recorded and figured some morphological and biometric characteristics, which in previous work were used to separate the two species *A. thazard* and *A. rochei*. The same samples were analyzed by genetic techniques to verify if one or two species were present and results indicated only one species.

Morphometric characteristics, such as several body heights, resulted homogeneous, as far as minor differences can be explained in terms of size/age; similarly, different length/weight relationships can be related to sampling season. Four meristic characters gave contradictory results: in fact 1) the majority of specimens in their adult ages had the large corselet typical of *A. rochei*; 2) the number of gillrakers on first arch was in the range 38-46, which largely corresponds to the worldwide total range of *A. rochei* (39-49) but, averaging in total 41.82, is the closest to be *A. thazard thazard* range (36-44); 3) the number of vertebra bearing the first free parapophysis was 21-22, like in *A. rochei*; 4) the number of vertebra bearing the first inferior foramen was 27-28-29 like in *A. thazard*.

In conclusion we have observed mixed characteristics in the same fish. This point is very interesting, because the old idea of Mediterranean ichthyologists about the existence of only one species of *Auxis* can be resurrected. Their apparent "lumper" attitude had a real basis in the local *Auxis* which, at least in the Central-Western Mediterranean, belongs to only one species and shares characteristics of two. These aspects also suggest different steps of evolution inside the Scombridae of this genus. The fossil bed of Monte Bolca, in Italy near Verona, shows different genera (at least 4) of this family in tropical waters during the middle Eocene (Monsch, 2006). So this group of fish is probably very ancient and go back to a time in which the Atlantic did not exist. When and where *Auxis* appeared and when more than one species occurred, it is not known. Today the Atlantic is inhabited by the two species of *Auxis* (fig. 11, by Collette and Aadland, 1996), but not in its complete extent. The Northern section, as well as the Mediterranean is inhabited only by *A. rochei*. This fish (fig. 11, dotted rectangle), in our opinion need to be distinguished by the *A. rochei* that was studied and described in the Indopacific.

If we consider the problem of the names used for *Auxis* species, the Mediterranean *Auxis* is represented by the type of Risso, fished in the Ligurian Sea (Nice) (Collette and Aadland, 1996). So, if the results of the present study will be accepted by the scientific community, a possible new name will regard the Indopacific populations, not the present one (Collette, in litteris).

Acknowledgements

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Table 1. Main characteristics of examined samples.

Area	Sampling period	Total number	FL (cm)	Male	FL (cm)	Female	FL (cm)	Unsexed	FL (cm)
Ligurian Sea	02/05/06-13/08/07	83	27-46.5	31	30.5-46.5	45	28-45.5	7	27-34.5
Ionian Sea	June-July 2007	43	34-44.5	9	35.5-43.5	8	34-43.5	26 gutted	36-44.5
Atlantic Morocco	21/11/2007	50	23.5-29.5	18	24.5-28.5	24	23.5-29.5	8	23.5-28
Sicilian Channel	-	50	Larvae	-	-	-	-	-	-

Table 2. Mean values of body depths, as percentage of FL, in three geographical samples of *A. rochei*.

	% AO/LF	% AOP/LF	% A1D/LF	% ASI/LF	% A2D/LF
Ligurian Sea (LF = 27 - 46.5 cm)	***10.48***	***19.64***	***21.85***	***22.16***	***19.04***
Stand. dev.	0.52	1.26	1.55	1.89	1.32
N	83	83	81	78	78
Ionian Sea (LF = 34-44.5 cm)	***10.40***	***20.11***	***22.22***	***24.11***	***20.61***
Stand. dev.	0.36	0.80	1.03	0.98	0.87
N	43	42	35	17	19
Atlantic Morocco (LF = 23.5-29.5 cm)	***9.58***	***15.53***	***17.35***	***17.59***	***15.09***
Stand. dev.	0.40	0.76	0.89	1.06	1.11
N	50	50	48	49	50

Table 3. Number of gillrakers present in three geographical samples.

	38	39	40	41	42	43	44	45	46	Tot num.	Mean	Stand. Dev.
Atlantic Morocco	-	4	19	23	19	20	6	5	1	97	41.77	1.56
Ligurian Sea	-	7	18	44	44	34	10	2	1	160	41.77	1.32
Ionian Sea	2	6	11	11	20	20	8	4	2	84	41.96	1.77
Total	**2**	**17**	**48**	**78**	**83**	**74**	**24**	**11**	**4**	**341**	**41.82**	**1.51**

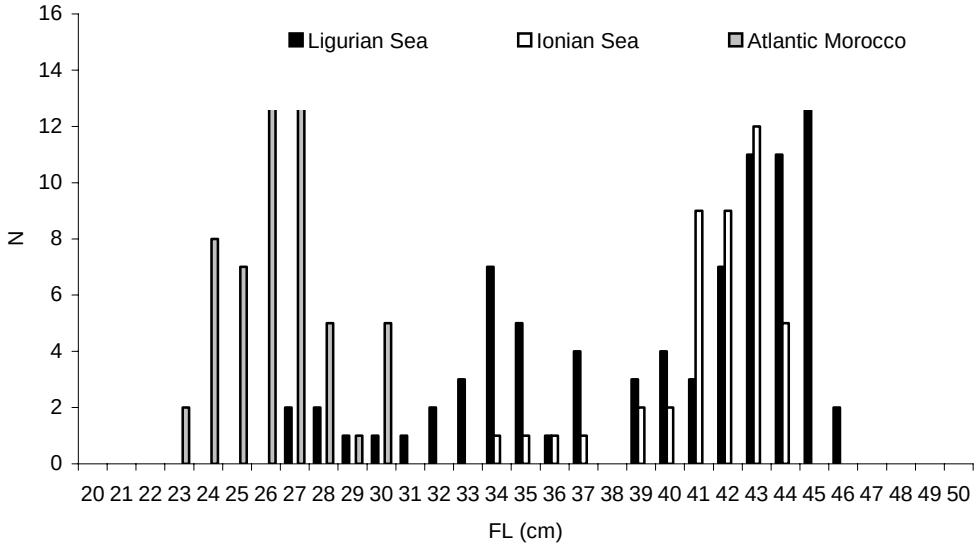

Figure 1. Length/frequency distributions of the three geographical sample of *A. rochei*.

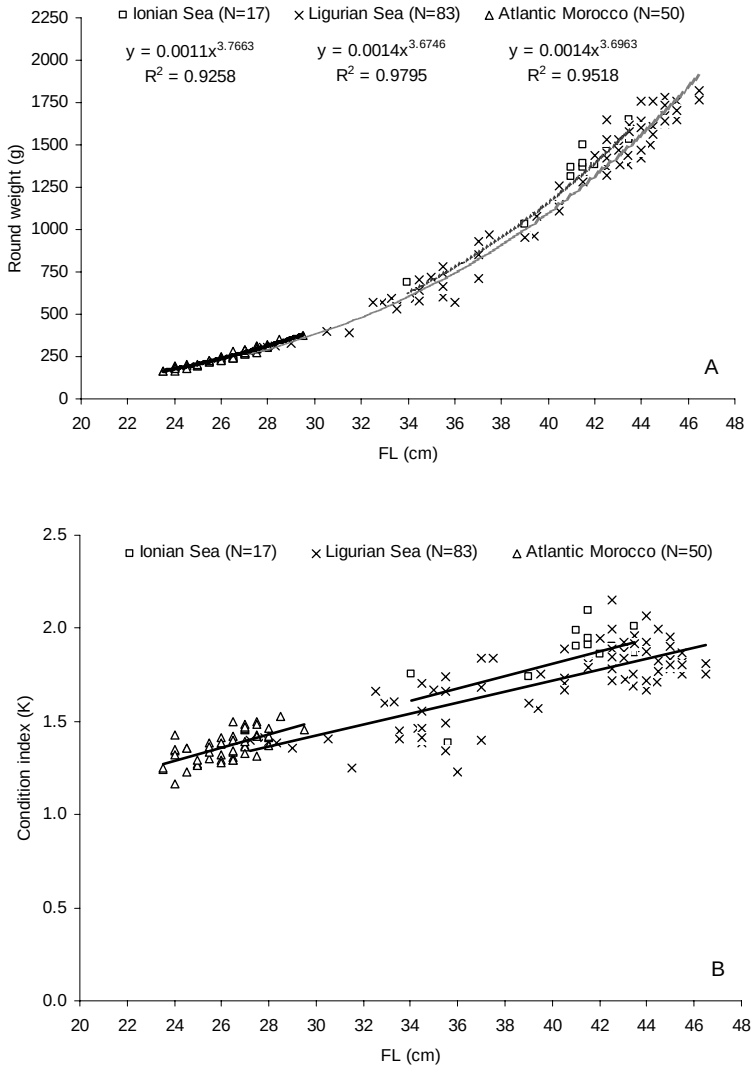

Figure 2. Length weight relationships (A) and condition index (B) of the three geographical sample of *A. rochei*.

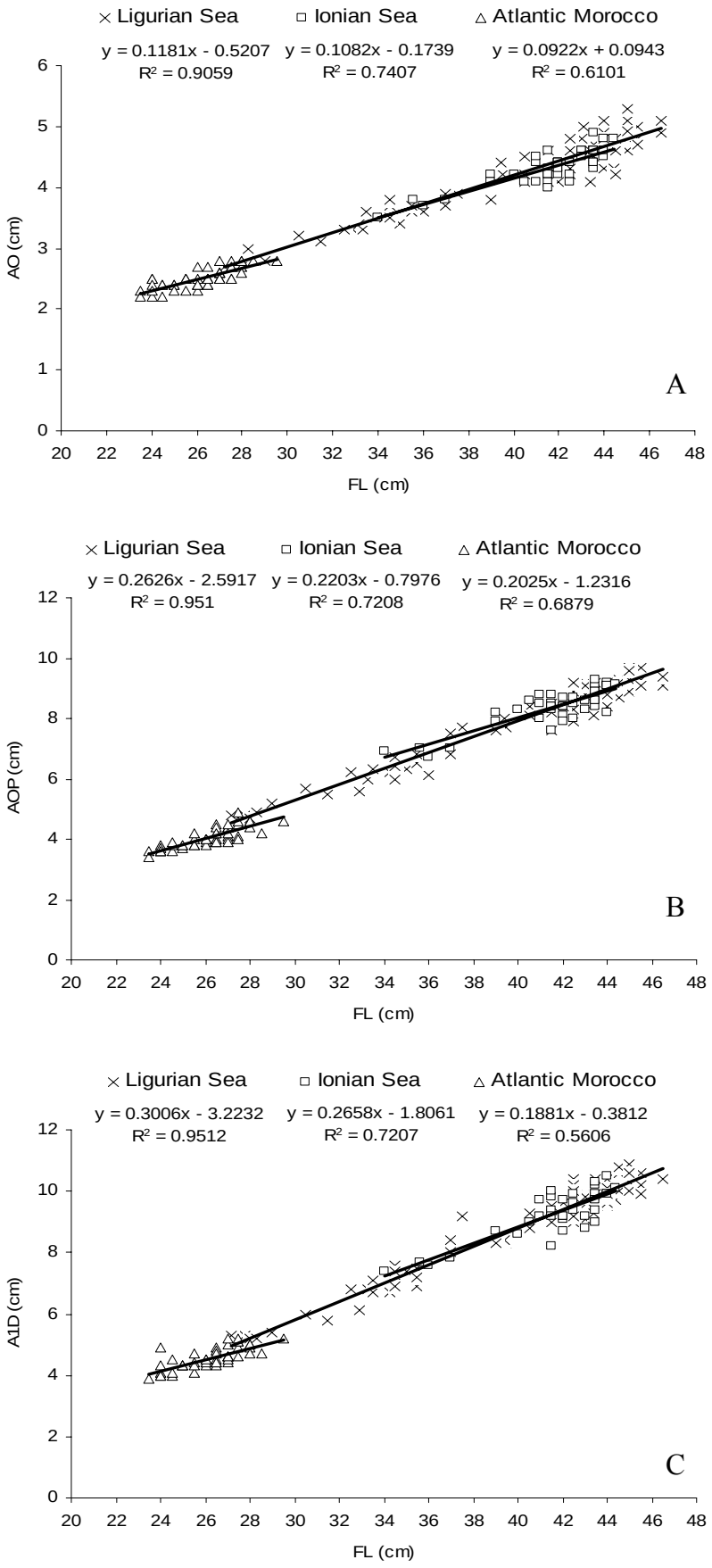

Figure 3. Body depths: A) at the centre of eye (AO); B) at the opercular margin (AOP); C) at first dorsal fin origin (A1D) related to the fork length in three geographical sample of *A. rochei*.

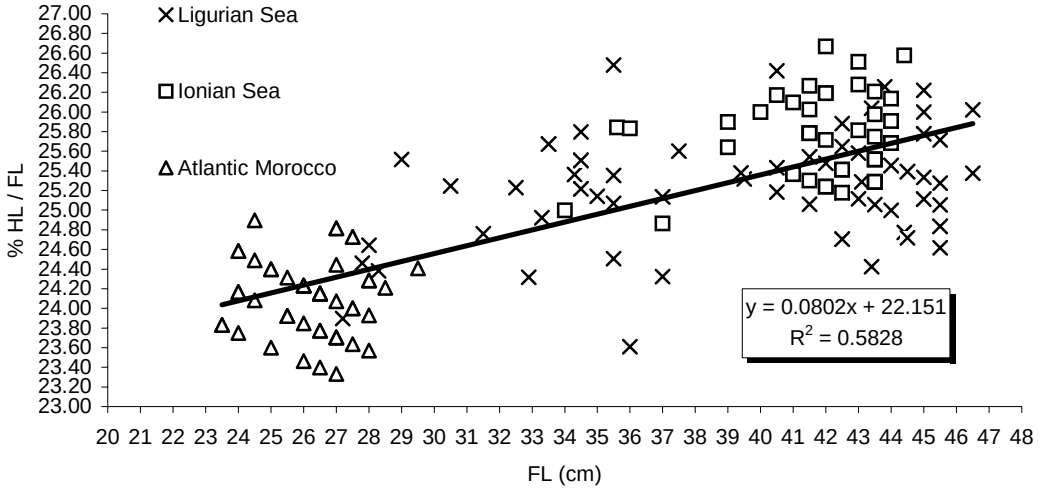

Figure 4. Head length, as %FL, in relation to FL: the growth of the head during the life is clear.

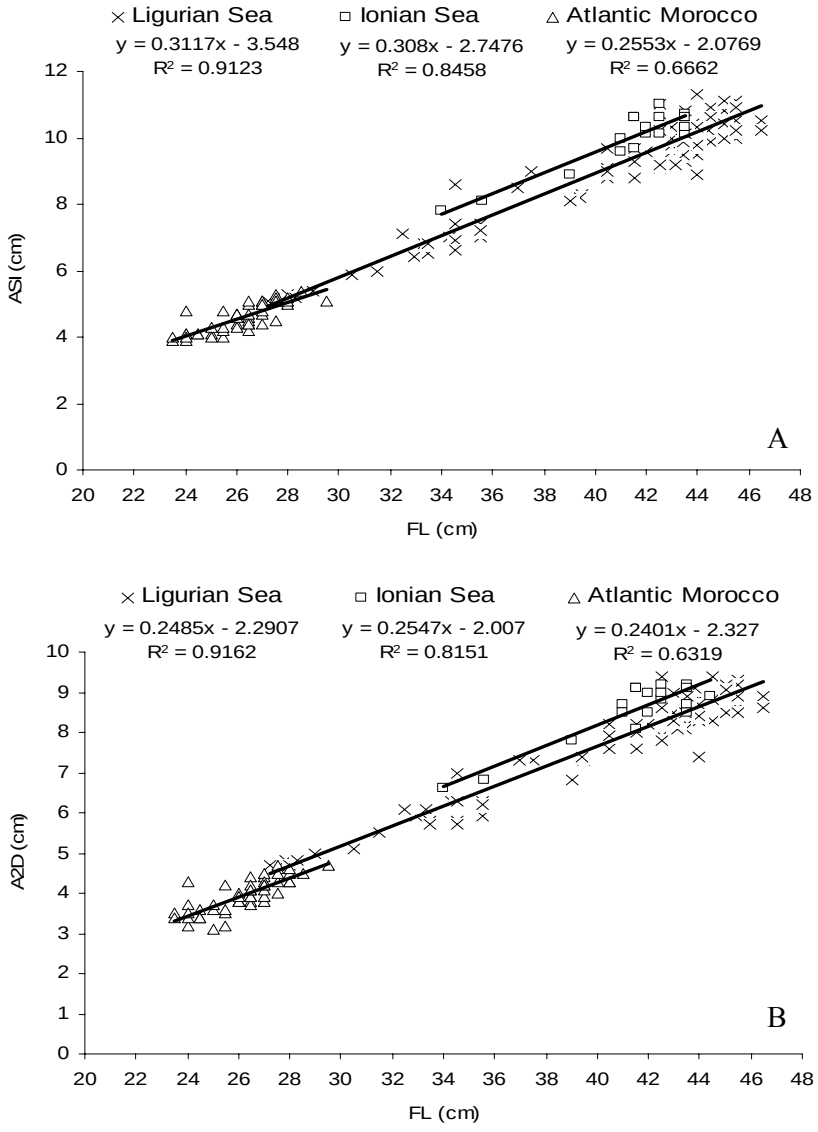

Figure 5. Body depths: A) at the interdorsal space (ASI); B) at second dorsal fin origin (A2D) related to the fork length in three geographical sample of *A. rochei*.

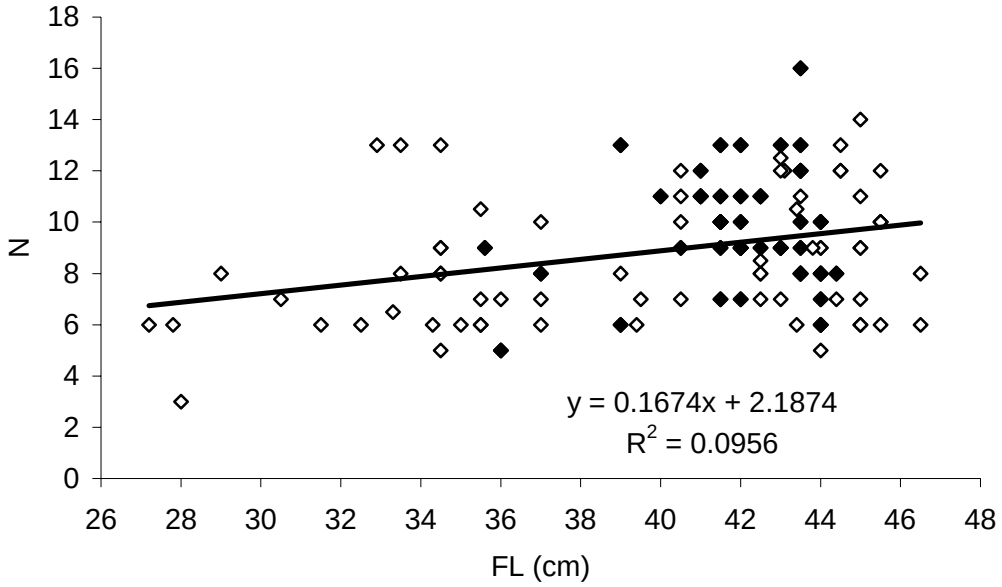

Figure 6. Number of scale rows forming the corselet in the Ligurian (white dots) and Ionian (black dots) *A. rochei*.

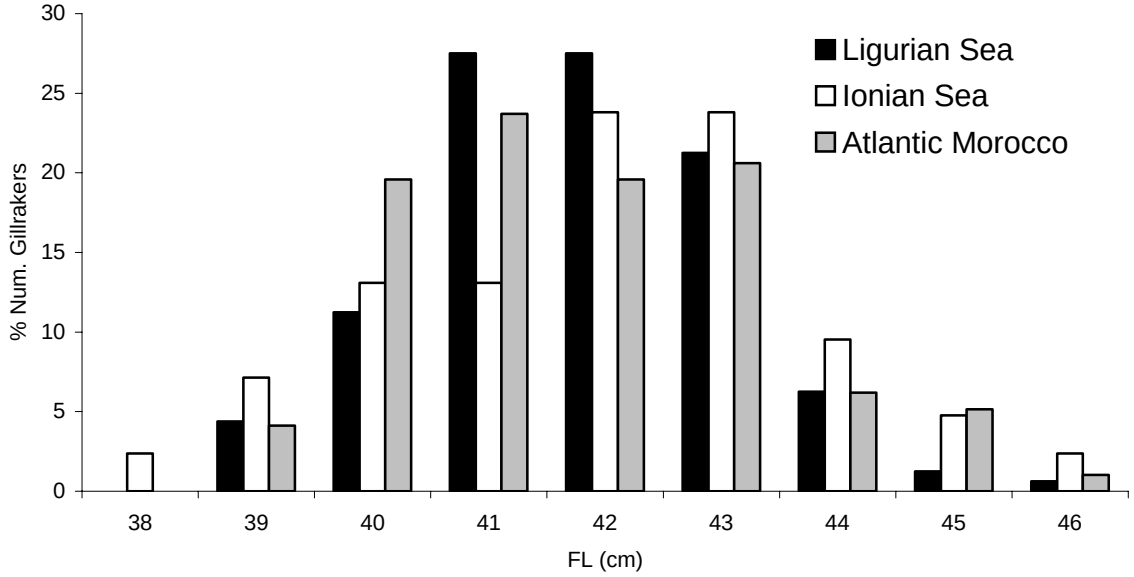

Figure 7. Frequency distributions of number of gillrakers in three geographic samples of *A. rochei*.

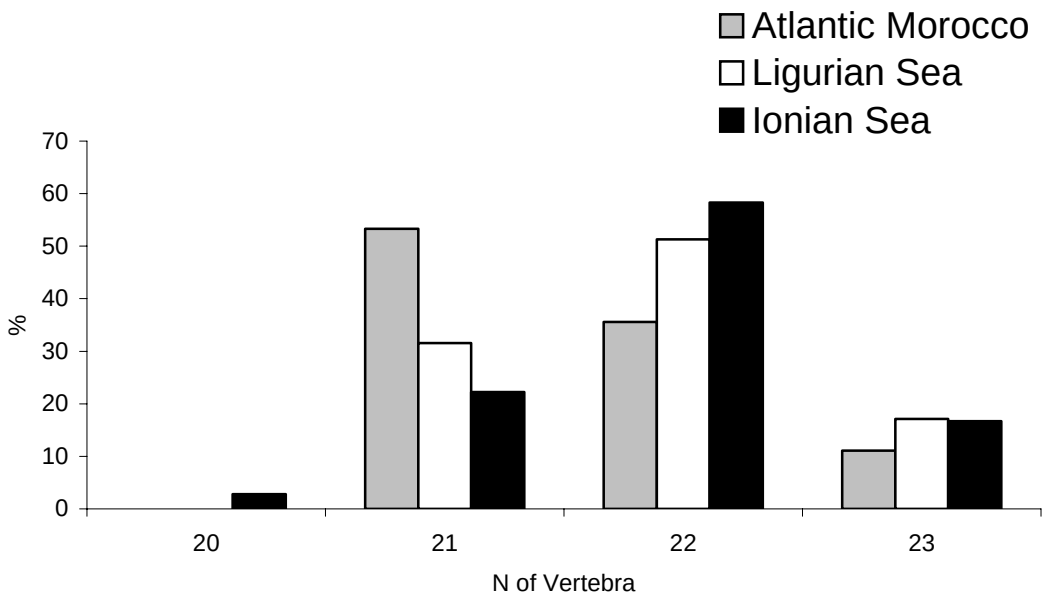

Figure 8. Occurrence of the first free parapophysis on the vertebrae 20th to 23th in the three geographical samples of *A. rochei*.

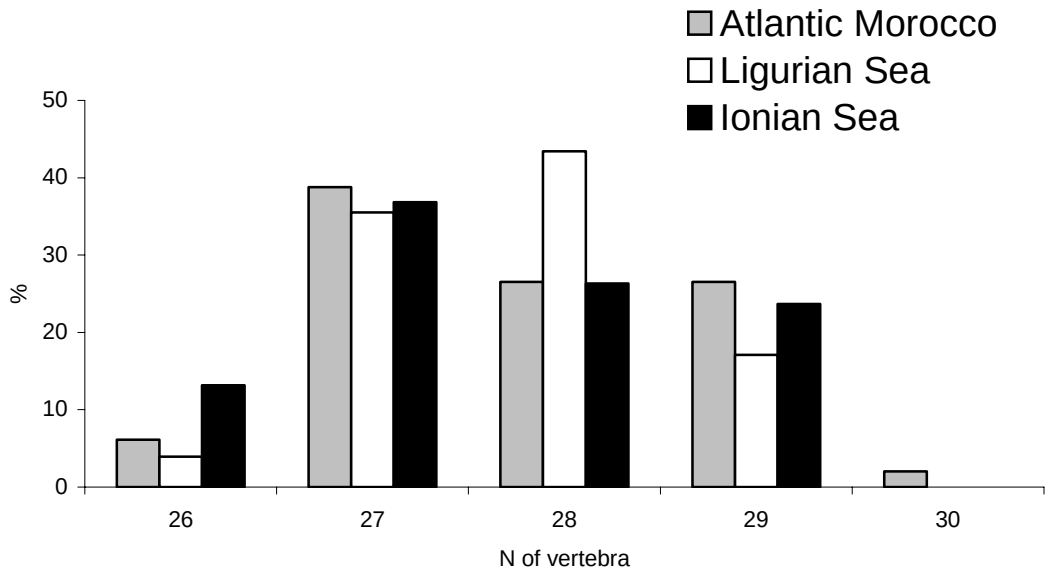

Figure 9. Occurrence of the first inferior foramen on the vertebrae 26th to 30th in the three geographical samples of *A. rochei*.

Figure 10. Spots and rings, or jaguar patterns, of Mediterranean *Auxis*.

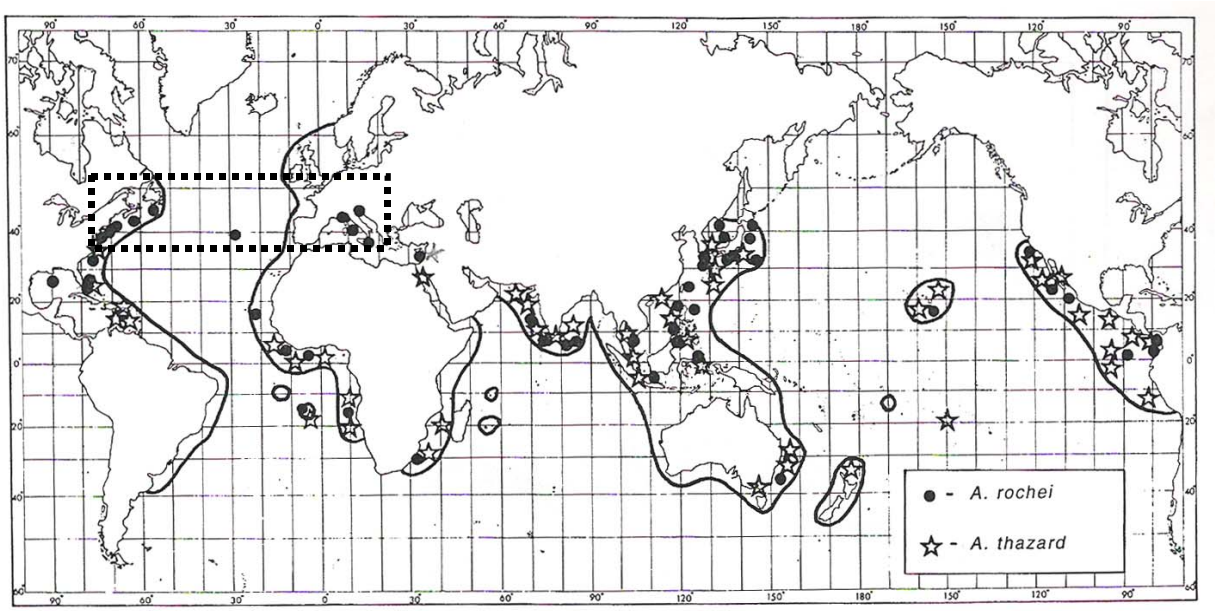

Figure 11. Distribution of *Auxis rochei* and *A. thazard* studied by Collette and Aadland (1996) and area (dotted rectangle) of North Atlantic and Mediterranean in which the presence of a peculiar taxon of *Auxis* is hypothesized.