Use of morphological differences for the identification of two picarel species *Spicara flexuosa* and *Spicara maena* (Pisces: Centracanthidae)

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Abstract

The recognition and identification of the two species of *Spicara* genus (*Spicara flexuosa*, picarel and *Spicara maena*, blotched picarel) is difficult, due to a systematic confusion until now. In this work a number of external morphometric features (ten body ratios) are evaluated for their diagnostic possibilities. According to Principal Component Analysis results, the body ratios head length to standard length, head height to head length and the ratios of two body heights, indicated that these characters were not related to the maturity stage of the species. The discriminant analysis based on the above body ratios, indicated a rather high level of discrimination (83.2%) of the examined samples for two species. The results are discussed, and possibilities for improvement of the identification methodology for the two species are proposed.

Keywords: Centracanthidae, spicara, multivariate analysis, morphometric.

Introduction

Species that belong to the genus *Spicara* occur in shallow rocky and muddy bottoms throughout the Mediterranean and the Black Sea, in the Atlantic from Portugal to Morocco and around the Canary Islands (Froese & Pauly, 2013). These species contribute to fisheries in inshore areas of the Greek seas (Mytilineou & Papaconstantinou, 1991; Stergiou et al., 2011), and represent a major proportion of the total catch for coastal fisheries in Croatia (Dulcic et al., 2000). On the other hand, they are the common by-catch of coastal fisheries in the Mediterranean (especially those operating bottom trawlers) with low commercial value (Ragonese et al., 2004).

The genus *Spicara* has posed numerous identification problems and consequently many different species have been described, leading to a variety of synonyms. This fact was attributed to marked variations in coloration related to the effects of sexual dimorphism (reinforced by the protogynous hermaphroditism sex inversion) and colour changes due to the state of sexual maturity (Pollard & Pichot, 1971).

According to the review of Pollard & Pichot (1971), the old classification distinguished two genera, *Maena* and *Smaris* that subsequently were distinguished into two genera *Maena* and *Spicara* and finally were fused into a single genus *Spicara*, which comprises three species: *Spicara maena* (Linnaeus, 1758), *Spicara smaris* (Linnaeus, 1758) and *Spicara chrysalis* Valenciennes, 1830, which is a synonym of *Spicara flexuosa* Rafinesque, 1810 (Tortonese, 1975).

In literature, there was a systematic confusion about whether *S. maena* and *S. flexuosa* are the same (Tortonese, 1975; Eschmeyer, 2013; Froese & Pauly, 2013) or different species (Vasiliev, 1980; Papaconstantinou, 1988; Golani et al., 2006; Vasil’eva, 2007; Imsiridou et al., 2011). The above conflict is maintained till today; although karyological studies (Vasiliev, 1980) as well as genetic studies (Chiba et al., 2009; Imsiridou et al., 2011; Turan, 2011) undoubtedly prove that *S. maena* and *S. flexuosa* are two different species. Assuming that *S. maena* and *S. flexuosa* are two different species, identification is possible using meristic and morphometric characteristics (Tortonese, 1986; Fischer et al., 1987; Rizkalla, 1996).

Multivariate analysis, on a set of phenotypic characteristics, is regarded as a powerful technique for the determination of morphological relationships among different populations of a species (Claytor & MacCrimmon, 1988; Corti & Crosetti, 1996; Vidalis et al., 1997) and for investigating taxonomic problems among species (Spain et al., 1980; Karakousis et al., 1991; Iliadou et al., 1996; Katselis et al., 2006). It also creates the mathematical foundation for the development and support of new tools. The development of specialized software tools such as...
TPS-dig software, version 1.37 (Rohlf, 2003) offers the possibility of taking measurements of an item, on a digital photo. These tools are predominantly used in ichthyology nowadays. Despite the benefits, they have limitations associated with the quality of the extracted information. If a fish photo is to be used for determining the species, the recognition characters should be clearly identifiable and measurable.

The aim of this study is to evaluate the similarity/dissimilarity of *S. flexuosa* and *S. maena* species, using easily distinguishable morphometric characters. A second aim is to develop a mathematical background for the diagnosis of the two species, using the multivariate analysis of morphometric characters.

**Materials and Methods**

**Fish Samples**

Specimens were collected by professional fishermen in the Thermaikos Gulf (40° 23’ N; 22° 50’ E), Northern Aegean Sea. Individuals of *S. maena* were collected with purse seine nets (20 mm mesh-size stretched), in 25-35 m depth on sandy bottom with *Posidonia oceanica* beds, while those of *S. flexuosa* were collected with pots (metal frame lined with a wire mesh, box shaped 80x60x30 cm, mesh size 20 mm). Pilchards were used as bait and the pots were set at 25-35 m depth, on sandy or muddy bottoms, with parts covered with hard substrate. The advantages of these fishing gears (purse seines and traps) are that they capture a wide range of fish length from a specific fish population and area, either encircling shoals of fish or baiting individuals that are seeking shelter or food. In contrast, other fishing gears such as static gill nets and bottom trawls are selective on the range of fish length caught, and sweep a broader area. Individuals of *S. maena* and *S. flexuosa* were randomly collected from March to August 2008, a period which coincides with their spawning season (Tortonese, 1986; Karidas et al., 2009, 2011). Specimens were identified according to the characters of the identification keys (Tortonese, 1986; Fischer et al., 1987).

**Morphometric Analysis**

A series of measurements was recorded on each specimen, for six (6) distance characters (Fig. 1). Specifically, Total Length (TL) is defined as the distance from the tip of the nose to the longest caudal fin ray, Standard Length (SL) as the distance from the tip of the nose to the end of the vertebral column, Head Length (HL) as the distance from the tip of the nose to the posterior margin of the opercula, Head Height (HH) as the distance from the lower end to the upper end of the head, Maximum Body Height 1 (MBH1) as the vertical distance from the anterior part of the dorsal fin and ventral part of the body and Maximum Body Height 2 (MBH2) as the vertical distance from the dorsal fin and ventral part of the body.

These characters are easily distinguishable and visible on a fish photo, and some of these have been used to identify the two species (Fischer et al., 1987; Lythgoe & Lythgoe, 1992; Golani et al., 2006). All measurements were made to the nearest 0.1 cm with electronic vernier caliper; for paired structures only the left structure value was taken.

After measuring, fish were dissected and the gonads were removed and observed for sex identification. Sex and maturity stage of gonads were determined macroscopically according to the scale of Nikolsky (1963), slightly modified to fit the characteristics of the gonad stages of maturity of the picarels (Vidalis, 1994). Total weight of body (W) and weight of gonads (Wg) were measured to the nearest 0.1 g, and the Gonadosomatic Index (GSI=100*Wg/W) was calculated.

To minimize any variation resulting from allometric growth, all morphometric measurements were standardized according to Reist (1985): 

$$X'_{ij} = \log X_j - b \cdot (\log TL_j - \log TL_i)$$

where $X'_{ij}$ is the standardized measurement of the i morphometric character; $\log X_j$ is the mean logarithm of i morphometric character measurement; TL is the total length of the individual; $\log TL_j$ is the logarithm of the mean total length of pooled individuals and $b$ is the slope of the $\log X$ against $\log TL$ plot. Also, the anti-logarithms of standardized measurements and their ratios were estimated. Finally, the t-test was used (Zar, 1999) to identify whether there were any statistically significant differences between the species for each character ratio.

Principal component analysis (PCA) was used to test the contribution of the morphometric characters ratios and logarithm of GSI, to the configuration of fish shape variance (Hair et al., 1998). To elucidate the differentiation of the species, forward stepwise discriminant analysis (DA), on the characters based on the generalized Mahalanobis distance, was used, to determine the similarity between groups and the ability of these variables to identify the specimens correctly (Hair et al., 1998).

In order to identify any significant differences among the sex per species groups (immature, males and females) on the scores of each extracted canonical vari-
ables (CaV), analysis of variance (ANOVA) was applied. Furthermore, the Tukey HSD test was applied, to check which sex per species differs from each other. Also, to minimize any variation resulting from the maturity stage of individuals, the morphometric ratios that related with the GSI were excluded from the discriminant analysis. All statistical analyses were performed with the SPSS PC ver. 10 software package.

Results

Eight hundred and eighty eight (888) individuals were examined for morphometric analysis (9.9-84.3 g total body weight; 9.6-18.1 cm total length). From the above, two hundred and ninety nine (299) individuals of S. maena (11.6-18.1 cm total length) and five hundred and eighty nine (589) individuals of S. flexuosa (9.6-18.1 cm total length). Summary statistics and t-test results are shown in Table 1. Significant differences for all examined ratios of morphometric characters among the species, were shown (t-test<5; df= 887; P<0.05).

The PCA analysis extracted four factors with eigenvalues>1, explaining 96% of the variance (Table 2). Using a cut-off value of 0.6 for the factor loadings, factor 1 (F1) expressed characters associated with the maximum body height to length ratios and gonadosomatic index, factor 2 (F2) expressed variables associated with the head height to head length and to standard length ratios (HH/HL and HH/SL, respectively). Finally, factor 3 (F3) expressed variables associated with the head height to standard length ratio (HL/SL), while factor 4 (F4) expressed variables associated with the maximum body height ratio (MBH/MBH).

The discriminant analysis (DA) on the HL/SL, HH/SL, HH/HL and MBH/MBH presented one canonical variable (CaV) which contributed overall to the variance (the expressed characters by factor 1 were excluded, due to their relation to the maturity stage of each fish). The characters of primary importance in distinguishing species were HL/SL and HH/HL. The discriminant function (DF) was:

$$DF = -134.03 - 539.8 \cdot (HH/SL) + 384.4 \cdot (HL/SL) + 175.2 \cdot (HH/HL) + 6.96 \cdot (MBH/MBH)$$

### Table 1. Summary statistics for total length (TL), Gonadosomatic index (GSI) and ratios among the morphometric characters, estimated after the Reist (1985) standardization. X: mean value (cm); SD: standard deviation; Min-max: minimum and maximum value (cm); N: number of individuals; IM: immature individuals; M: males and F: females.

| Character | N=299 (IM=0; M=78; F=221) | N=589 (IM=174; M=269; F=146) |
|-----------|-----------------------------|-----------------------------|
| TL        | 15.37 ± 1.09               | 14.10 ± 1.80                |
| GSI       | 0.08 ± 0.05                | 0.01 ± 0.02                 |
| HL/SL     | 0.28 ± 0.01                | 0.29 ± 0.01                 |
| HH/SL     | 0.24 ± 0.01                | 0.24 ± 0.01                 |
| MBH/SL    | 0.30 ± 0.02                | 0.27 ± 0.01                 |
| MBH/SL    | 0.30 ± 0.02                | 0.27 ± 0.01                 |
| HH/HL     | 0.86 ± 0.04                | 0.81 ± 0.04                 |
| MBH/HL    | 1.05 ± 0.06                | 0.93 ± 0.04                 |
| MBH/HL    | 1.06 ± 0.06                | 0.93 ± 0.04                 |
| MBH/HH    | 1.22 ± 0.07                | 1.15 ± 0.05                 |
| MBH/HH    | 1.24 ± 0.07                | 1.15 ± 0.06                 |
| MBH/MBH   | 1.01 ± 0.04                | 1.01 ± 0.04                 |

### Table 2. Results of principal components analysis (PCA) and factor loadings for each morphometric variable on the four extracted PCA factors (Fi), after varimax normalized rotation.

| Character | Factors |
|-----------|---------|
| GSI       | F1      |
| HL/SL     | F2      |
| HH/SL     | F3      |
| MBH/SL    | F4      |
| MBH/HL    | F5      |

### Table 3. Results of the discriminant analysis (DA) and t-test results (df=887; P<0.05).
The discriminant function identified the membership (classification) of individual fish in the data to one of the two species, with a success rate of 83.19%. The percentage of correctly identified *S. maena* and *S. flexuosa* individuals was 64.5% and 92.7%, respectively (Table 3). The frequency distribution of discriminant function scores for two species is shown in Figure 2. The 77% of *S. flexuosa* individuals were given DF<0, while the 83% of *S. maena* were given DF>0 (Fig. 2). The DF scores differ significantly between sexes per species (ANOVA; df=4.804; F=162; P<0.05). On the other hand, no significant differences appeared among sexes on the same species (Tukey HSD test; P>0.05) (Fig. 3).

**Discussion**

The morphometric characters (phenetic characters) derive from the composite effect of genotype and environmental factors, and they are under the influence of natural selection (Dobzansky, 1970). It is certain that parameters related to the allometric growth of fish and the timing of the sampling (feeding activity and maturation), could pose some major limitations for the study of morphological relationships between species. This study attempted to minimize variances caused by these parameters through the common sampling period, as well as the transformation of the original measurements (Reist, 1970).

**Table 3.** Results of discriminant analysis classification showing the percentage of specimens classified in each species.

| Predicted species | Spicara maena | Spicara flexuosa | Total individuals |
|-------------------|---------------|------------------|-------------------|
| *Spicara maena*   | 64.5          | 35.5             | 299               |
| *Spicara flexuosa*| 7.3           | 92.7             | 589               |

*Fig. 2:* Frequency distribution of discriminant function scores of the first extracted canonical variable for *S. flexuosa* and *S. maena.*

*Fig. 3:* Box and Whisker plot (min-max, 95% values. Mean, SD) of the discriminant function scores of the first extracted canonical variable for male, female and immature individuals of *S. flexuosa* and *S. maena.* Groups that they do not differ statistically (Tukey HSD test; P>0.05) are indicated with the same letter, a or b.
It also attempted to remove the characters which are related to the maturity stage of fish, from the analysis.

The analysis of the morphological variability presented here, indicated significant differences in external shape between the two species (Table 1). The ratios of body measurements indicated that the individuals of *S. maena* are characterized by shorter/higher head and deeper body than those of *S. flexuosa*. These findings are in agreement with those of other authors (Pollard & Pichot, 1971; Tortonese, 1986; Fischer et al., 1987; Lythgoe & Lythgoe, 1992; Miller & Loates, 1997; Golani et al., 2006). Some authors have used the relation between head length and maximum body height, to identify the two species. The head length is equal or greater than the body height in *S. flexuosa*, while the head length is shorter than the body height in *S. maena* (Fischer et al., 1987; Lythgoe & Lythgoe, 1992; Golani et al., 2006). Although our results are confirmed by the above findings, the fact that the ratios of the body height (*MBH*/*HL*, *MBH*/*HH*, *MBH*/*HL*, *MBH*/*HH*, *MBH*/*SL*, *MBH*/*SL*) apart from the ratio of *MBH*/*MBH*, are related to the maturity stage of species (Table 2), decreases the discrimination ability of these characters.

In substitution of these recognizing characters, our results proposed that the ratios of a) head length to standard length (*HL*/*SL*) as F3, b) head height to head length (*HH*/*HL*) as F2, c) head height to standard length (*HH*/*SL*) as F2 and d) the ratio of the two body heights (*MBH*/*MBH*) as F4, show low association (<0.35) to the species maturity stage (*GSI*), since the factor loadings of F2, F3 & F4 are 0.22, 0.35 and 0.07 respectively (Table 2). The discriminant analysis based on these characters indicated a rather high level of species identification. Indeed, 83.2% of the examined specimens could be distinguished and classified correctly in the two species. Moreover, the loadings of discriminant function (linear results of these characters) were not related to the sexual dimorphism of the species (Fig. 3) and could thus constitute a more reliable tool for identification of the two species than the ones used today. Consequently, they can be a reliable tool for the identification of the two species. The sharpness of the characters as well as the high discriminative values (>83%), provide a great possibility to be used for identification of the two species from the new technologies.

The relatively small percentage of non-discrimination (16.8%) of the above characters, can be overcome by more general information about the species such as differences in certain biological aspects i.e. spawning period and sexual behaviour (Tortonese, 1986; Fischer et al., 1987; Lythgoe & Lythgoe, 1992; Dulčić et al., 2000; length of sex reversal: Lepori, 1960; Relini et al., 1999; Dulčić et al., 2000; Karakulak et al., 2007; Karidas et al., 2009, 2011), body colour pattern (Lythgoe & Lythgoe, 1992; Louisy, 2002; Karidas et al., 2009), and external morphology (Fischer et al., 1987; Lythgoe & Lythgoe, 1992; Louisy, 2002; Golani et al., 2006). Also, the fact that *S. maena* and *S. flexuosa* are two different species is reinforced by an anatomical character, which is present in *S. maena*: well-developed teeth on the vomer (Tortonese, 1986; Lythgoe & Lythgoe, 1992). Additionally, each species prefers different habitats, with *S. maena* inhabiting sandy - muddy Posidonia beds down to about 100 m, while *S. flexuosa* appears on sand or muddy bottoms, with rocky particles down to about 130 m (Tortonese, 1986).

In conclusion, the results from the morphometric analysis revealed discrimination between *S. maena* and *S. flexuosa*, based on four body proportions that derive from five easily identifiable morphological characters (*HH*, *HL*, *SL*, *MBH*, and *MBH*). The above characters could be used by information technology for developing new species recognition tools. In any case, these findings contribute to the improvement of the identification methods for the two species, based on external features.

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References

Chiba, S.N., Iwatsuki, Y., Yoshino, T., Hanzawa, N., 2009. Comprehensive phylogeny of the family Sparidae (Perciformes: Teleostei) inferred from mitochondrial gene analyses. *Genes Genetics and Systematics*, 84, 153-170.

Claytor, R.R., MacCrimmon, H., 1988. Morphometric and meristic variability among North American Atlantic salmon (*Salmo salar*). *Canadian Journal of Zoology*, 66, 310-317.

Corti, M., Crosetti, D., 1996. Geographical variation in the grey mullets: a geometric morphometric analysis using partial wrap scores. *Journal of Fish Biology*, 48 (2), 255-269.

Dobzansky, T., 1970. Genetic of evolutionary process. Columbia University Press, New York, 505 pp.

Dulčić, J., Kraljević, M., Grbec, B. Cetinić, P., 2000. Age, growth and mortality of blotched picarel *Sparus aurata* L. (Pisces: Centracanthidae) in the eastern central Adriatic. *Fisheries Research*, 48, 69-78.

Eschmeyer, W.N., (2013). Catalog of Fishes. *California Academy of Sciences* (http://research.calacademy.org/research/ichthyology/catalog/fishcatmain.asp). Electronic version 25 March 2013 (Accessed 2 April 2013).

Fischer, W., Bauchot, M.-L., Schneider, M., 1987. *Fiches FAO* d’identification des espèces pour les besoins de la pêche. (Révision 1). Méditerranée et mer Noire. Zone de pêche 37. *Volume II. Vertébrés*, FAO, Rome, pp. 1031-1036.

Froese, R., Pauly, D., 2013. *FishBase*. World Wide Web Electronic Publication. http://www.fishbase.org (version 02/2013)
(Accessed 2 April 2013).

Golani, D., Öztürk, B., Başusta, N., 2006. Centracanthidae. p. 168-169. In: Fishes of the Eastern Mediterranean. Golani, D., Öztürk, B., Başusta, N. (Eds). Turkish Marine Research Foundation, Istanbul.

Hair, J.F., Anderson, R.E., Tatham, R.L., Black, W.C., 1998. Multivariate data analysis. 4th edition. Prentice Hall, Englewood Cliffs, NJ, 730 pp.

Iliadou, K., Sourdis, J., Economidis, P.S., Wheeler, A., 1996. Morphological differentiation among species of genus Scardinius (Pisces: Cyprinidae) in Greece. Journal of Natural History, 30 (3), 459-473.

Imsiridou, A., Minos, G., Gakopoulou, A., Katsares, V., Karidas, T., et al., 2011. Discrimination of two picarel species Spicara flexuosa and Spicara maena (Pisces: Centracanthidae) based on mitochondrial DNA sequences. Journal of Fish Biology, 78 (1), 373-377.

Karakouis, Y., Triandafyllidis, C., Economidis, P.S., 1991. Morphological variability among seven Greek populations of brown trout (Salmo trutta). Journal of Fish Biology, 38 (6), 807-817.

Karakulak, F.S., Bilgin, B., Zengin, M., Erk, H., 2007. Blotched picarel, Spicara maena L. 1758, in the trammel and gill net catches in the Aegean Sea (Turkey). Rapports de la Commission Internationale pour l’Exploration Scientifique de la Mer Méditerranée, 38, 511.

Karidas, Th., Argiridis, N., Minos, G., 2009. Sex identification on hemaphroditic picarel Spicara flexuosa (Rafinesque, 1810) based on external characteristics and length frequency analysis. p. 128-129. In: Proceedings of the 31st Scientific Conference of Hellenic Association for Biological Sciences, Patra, 14-16 May 2009. (In Greek and English).

Karidas, Th., Argiridis, N., Minos, G., 2011. Size at sex reversal in blotched picarel Spicara maena (Linnaeus, 1758) in Theraimkos Gulf. p. 122-123. In: Proceedings of the 33th Scientific Conference of Hellenic Association for Biological Sciences, Edessa, 19-21 May 2011. (In Greek and English).

Katselis, G., Hotos, G., Minos, G., Vidalis, K., 2006. Phenotypic affinities on fry of four Mediterranean grey mullet species. Turkish Journal of Fisheries and Aquatic Sciences, 6(1), 49-55.

Lepori, N.G., 1960. Ermafroditismo protorogenico in Mono maena (L.) ed in Maena chrysalis (Cuv. e Val.) (Perciformes, Centracanthidae). Bolletino di Pesca, Piscicultura e Idrobiologia, 14, 155-165.

Louisy, P., 2002. Guide d’identifications des Poissons Marins. Europe de l’ouest et Mediterranée. ULMER, Paris, 430 pp.

Lythgoe, J., Lythgoe, G., 1992. Fishes of the sea. The North Atlantic and Mediterranean. The MIT Press, pp. 123-124.

Miller, P.J., Loates, M.J., 1997. Fish of Britain and Europe. Collins pocket guide. Harper Collins Publishers, London, pp. 200-201.

Mytilineou, C., Papakonstantinou, C., 1991. Age and growth of Spicara flexuosa (Rafinesque, 1810) (Pisces, Centracanthidae) in the Patraiakos gulf (Greece). Scientia Marina, 55 (3), 483-490.

Nikolsky, G.V., 1963. The Ecology of Fishes. Academic Press, London/New York, 352 pp.

Papakonstantinou, C., 1988. Check-list of marine fishes of Greece. National Centre for Marine Research, Hellenic Zoological Society, Athens, 257 pp.

Pollard, D.A., Pichot, P., 1971. The systematic status of the Mediterranean Centracanthidae fishes of the genus Spicara, and in particular S. chryselis (Val.) as indicated by electrophoresis studies of their eye-lens proteins. Journal of Fish Biology, 3, 59-72.

Ragonese, S., Fiorentino, F., Garofalo, G., Cristina, M., Levi, D., et al., 2004. Distribution, abundance and biological features of picarel (Spicara flexuosa), Mediterranean (Trachurus mediterraneus) and Atlantic (T. trachurus) horse mackerel based on experimental bottom-trawl data (MEDITS, 1994-2002) in the Strait of Sicily. p. 100-114. In: Report of the MedSudMed Expert Consultation on Small Pelagic Fishes: Stock Identification and Oceanographic Processes Influencing their Abundance and Distribution. MedSudMed (Eds). GCP/RER/010/ITA/MSM-TD-05. MedSudMed Technical Documents 5.

Reist, J.D., 1985. An empirical evaluation of several univariate methods that adjust for size variation in morphometrics data. Canadian Journal of Zoology, 63 (6), 1429-1439.

Relini, G., Bertrand, J., Zamboni, A., 1999. Synthesis of knowledge of the bottom fishery resources in the central Mediterranean (Italy and Corsica). Biologia Marina Mediterranea, 6 (1), 868 pp.

Rizkalla, S.I., 1996. A comparative study on the morphometric characters of fishes belonging to family: Centracanthidae in the Egyptian Mediterranean waters. Journal of King Abdul Aziz University: Marine Sciences, 7 (1), 255-261.

Rohlf, F.J., 2003. TPS-dig. Computer Programme version 1.37. Department of Ecology and Evolution, State University of New York at Stony Brook.

Spain, V.A., Grant, J.C., Sinclair, F.D., 1980. Phenotypic affinities of 11 species of Australian mullet (Pisces: Mugilidae). Australian Journal of Marine and Freshwater Research, 31, 69-83.

Stergiou, K.I., Karachle, P.K., Tsikliras, A.C., Mamalakis E., 2011. Shouting Fishes: Fishes from the Greek Seas – Biology, Fisheries and Management. Patakis Publishers, Athens, Greece, 358 pp.

Tortonez, E., 1975. Fauna d’Italia “Osteichthyes”. Pesci Ossei. Edizioni Calderini, Bologna XI. 636 pp.

Tortonez, E., 1986. Centracanthidae. p. 908-911. In: Fishes of the north-eastern Atlantic and the Mediterranean. Whitehead, P.J.P., Bauchot, M.-L., Hureau, J.-C., Nielsen, J., Tortonez, E. (Eds). UNESCO, Paris.

Turan, C., 2011. The systematic status of the Mediterranean Spicara species (Centracanthidae) inferred from mitochondrial 16S rDNA sequence and morphological data. Journal of the Black Sea/Mediterranean Environment, 17 (1), 14-31.

Vasiliev, V.P., 1980. The selective mortality of different chromosome morphs in Spicara flexuosa Raf. Genetica, 52/53 (1), 327-331.

Vasil’eva, E.D., 2007. Fish of the Black Sea. Key to marine, Brackish-water, Euryhaline, and Anadromous Species With Color Illustrations, Collected by S. V. Bogorodsky. VNIRO Publishing, Moscow, 237 pp.

Vidalis, K., 1994. Biology and population dynamics of the picarel (Spicara smaris, L. 1758) on the Cretan Continental Shelf. PhD Thesis, Department of Biology, University of Crete, Greece. 257 pp. (in Greek with English abstract).

Vidalis, K., Markakis, G., Tsimenides, N., 1997. Discrimination between populations of picarel (Spicara smaris L., 1758) in the Aegean Sea, using multivariate analysis of phenetic characters. Fisheries Research, 30(3), 191-197.

Zar, J.H., 1999. Biostatistical Analyses, 4th ed. Prentice Hall, New Jersey, 663 pp.