Intra- and interspecific discrimination of *Scorpaena* species from the Aegean, Black, Mediterranean and Marmara seas

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**Summary:** This study was conducted to discriminate five *Scorpaena* species and populations of each species according to morphometric characters. A total of 1865 fish specimens were collected from the eight locations in the four Turkish seas: Antalya, Balıkesir, Çanakkale, Hatay, İzmir, Marmara Ereğlisi, Ordu and Şile. In the study, 26 morphometric traits were measured for intra- and interspecific discrimination of five *Scorpaena* species. The data were subjected to analysis of variance, principal components analysis (PCA) and canonical discriminant analysis. As results of the PCA, 10 traits for *S. maderensis* and *S. scrofa*, 12 traits for *S. elongata* and 13 traits for *S. notata* and *S. porcus* were found to be important for intraspecific discrimination. The overall classification scores of intraspecific discrimination were determined as 94.6% for *S. elongata*, 90.5% for *S. maderensis*, 96.7% for *S. notata*, 96.5% for *S. porcus* and 92.2% for *S. scrofa*. The PCA indicated that 13 morphometric measurements among the 26 traits are important in the interspecific discrimination of five *Scorpaena* species. The cross-validated canonical discriminant analysis was correctly classified as 97.4% at the *Scorpaena* species level. The discrimination of correctly classified species ranged from 94.8% to 100%. Finally, we demonstrated that the morphometric characters examined in the present study can be used successfully in the intra- and interspecific discrimination of *Scorpaena* species from different habitats.

**Keywords:** *Scorpaena*; morphometric; intra- and interspecific; discriminant analysis; four seas.

**Discriminaciones intra e interspecíficas: especies de *Scorpaena* del mar Negro, el mar Egeo, el mar de Mármaras y Mediterráneo**

**Resumen:** Este estudio se realizó para discriminar cinco especies de *Scorpaena* y poblaciones de cada especie en función de los caracteres morfométricos. Se recolectaron un total de 1865 especímenes de peces de los ocho lugares como Antalya, Balikesir, Çanakkale, Hatay, İzmir, Marmara Ereğlisi, Ordu y Şile en los cuatro mares turcos. En el estudio, se midieron 26 rasgos morfométricos para discriminaciones intra e interspecíficas de cinco especies de *Scorpaena*. Los datos se sometieron a ANOVA, análisis de componentes principales (PCA) y análisis discriminante canónico (CDA). Como resultado del PCA, 10 rasgos para *S. maderensis* y *S. scrofa*, 12 rasgos para *S. elongata*, 13 rasgos para *S. notata* y *S. porcus* son importantes para la discriminación intraspecífica. Las puntuaciones generales de clasificación de discriminación intraspecífica se determinaron como 94.6% para *S. elongata*, 90.5% para *S. maderensis*, 96.7% para *S. notata*, 96.5% para *S. porcus* y 92.2% para *S. scrofa*. La PCA indicó que 13 medidas morfométricas entre los 26 rasgos son importantes en la discriminación interspecífica de cinco especies de *Scorpaena*. El análisis discriminante canónico con validación cruzada clasificó correctamente como 97.4% a nivel de la especie *Scorpaena*. La discriminación de especies correctamente clasificadas osciló entre 94.8 y 100%. Finalmente, demostramos que los caracteres morfométricos examinados en el presente estudio se pueden utilizar con éxito en las discriminaciones intra e interspecíficas de especies de *Scorpaena* de diferentes hábitats.

**Palabras clave:** *Scorpaena*; morfométrico; intra e interspecíficas; análisis discriminante; cuatro mares.

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INTRODUCTION

There are more than 32000 species of fish, accounting for over half of all vertebrate animals (Nelson et al. 2016). They are dispersed over wide geographic areas, and the environmental conditions can affect traits such as reproduction, fertility and longevity (Rawat et al. 2017). The situations experienced by fish species in their life cycle may also affect their morphometric characteristics. Variations in growth, development and maturation of fish caused by environmental factors cause differences in body shape even within the same genus and species (Cadrin 2000).

Information on stock structure, species identification and differentiation is useful for developing management strategies that will help conserve biodiversity associated with species, subspecies, and stocks (Turan et al. 2005, Cadrin et al. 2014). Furthermore, identifying the intra- and interspecific differences/similarities of fish with variable life history characteristics is quite important for understanding population dynamics and evaluating sustainable harvests (Turan et al. 2005, Cadrin et al. 2014). There is also a need to determine how many stocks are managed in a given area and clarify how different stocks are susceptible to fishing pressure and unfavourable environmental conditions (Baldwin et al. 2012). Since genotypic and phenotypic differentiation between fish populations that occur due to isolation may lead to speciation or the formation of a different population, it is important to examine the degree of differentiation at both the intra- and interspecific levels. Morphometric analyses have been used for inter- and intraspecific identification/distinction of many freshwater and marine fish species, such as Rastrelliger kanagurta from peninsular India (Jayasankar et al. 2004), Clarias gariepinus from Turkey (Turan et al. 2005), Pomatomus saltatrix from the Aegean, Black, and Mediterranean seas (Turan et al. 2006), the genus Puntius from Assam, India (Choudhury et al. 2011), Catanichthys from India (Ujainia and Kohli 2011), rattail fish from New Zealand (Ibáñez and Jawad 2018), Barbonymus spp. from Aceh, Indonesia (Batubara et al. 2018) and Macrophthalmus panguicales from Bangladesh (Mahfuj et al. 2019a).

The family Scorpaenidae includes approximately 23 genera (from 210 to 223 species) distributed both in marine and freshwater waters at medium and great (more than 700 m) depths in a variety of aquatic habitats (Froese and Pauly 2020). Scorpaenid systematic are complicated and unsettled (Froese and Pauly 2020). Arculeo and Lo Brutto (2014) and Akalin et al. (2011) indicated that many species of the Scorpaenidae families are quite difficult to define morphologically because small individuals especially are very similar and the characters for describing species are not easy to use. The family includes many fish species that are mostly found in marine waters but rarely spread to freshwater. One of the popular genera in the family Scorpaenidae is the Scorpaena genus. Currently, six valid species are recognized in this genus from the Turkish coasts; the black scorpionfish (S. porcus Linnaeus, 1758) and the small red scorpionfish (S. notata Rafinesque, 1810) in the Aegean, Black, Mediterranean and Marmara seas; the slender rockfish (S. elongata Cadenat, 1943), the Madeira rockfish (S. maderensis Valenciennes, 1833) and Cadenat’s rockfish (S. loppei Cadenat, 1943) from the Mediterranean Aegean seas; and the red scorpionfish (S. scrofa Linnaeus, 1758) from the Aegean, Mediterranean and Marmara seas. Five species belonging to the Scorpaena genus are reported in large numbers in Turkish waters, but S. loppei is reported in very few numbers (Keskin and Eryilmaz 2009).

Many studies have provided detailed information with diagnostic features on the distribution and biology of Scorpaena species (Hureau and Litvinenko 1986, Fischer et al. 1987, Morato et al. 2001). However, no detailed study has been made on the discrimination of Scorpaena species in Turkish marine waters, and only a few studies have been made on Scorpaeniformes species in the Mediterranean Sea. These studies were addressed using cytogenetics (Caputo et al. 1998), meristic characters and genetic analysis of the mitochondrial 16S rDNA gene (Turan et al. 2009). The literature includes a limited number of morphometric studies of the genus Scorpaena, but no morphological study in which intra- and interspecific comparisons were made together. The present study was therefore undertaken to investigate the intra- and interspecific discrimination of five Scorpaena species (S. elongata, S. maderensis, S. notata, S. porcus and S. scrofa) inhabiting the Aegean, Black, Mediterranean and Marmara seas on the basis of morphometric characters.

MATERIALS AND METHODS

Ethical statement

All protocols for fish capture were approved by the Turkish Agricultural Research and Policy General Directorate. The care and use of experimental animals complied with Ordu University Animal Experiments Local Ethics Committee animal welfare laws, guidelines and policies, as approved by the Ordu University Animal Experiments Local Ethics Committee (No:82678388/08).

Sampling

Fish samples were collected during the 2019-2020 fishing season from the eight locations along the coastline of Turkey’s four seas (Fig. 1); İzmir (Aegean Sea), Antalya and Hatay (Mediterranean Sea) for S. elongata; Antalya (Mediterranean Sea), Balıkesir and İzmir (Aegean Sea) for S. maderensis; İzmir (Aegean Sea), Hatay (Mediterranean Sea), Marmara Ereğlıisi (Sea of Marmara) and Şile (Black Sea) for S. notata; İzmir (Aegean Sea), Hatay (Mediterranean Sea), Marmara Ereğlıisi (Sea of Marmara) and Ordu (Black Sea) for S. porcus; and Çanakkale (Sea of Marmara), İzmir (Aegean Sea) and Hatay (Mediterranean Sea) for S. scrofa. All samples were preserved and fixed in 70% ethanol and deposited at Ordu University.
Intra- and interspecific discrimination of *Scorpaena* species

Morphometric analysis

A total of 26 metric measurements were used: total length (TL) (1), standard length (SL) (2), head length (HL) (3), body height (BL) (4), caudal peduncle height (CPH) (5), caudal peduncle length (CPL) (6), caudal fin length (CL) (7), dorsal fin base length (DBL) (8), shortest dorsal fin spine length (SDL) (9), longest dorsal fin spine length (SDL) (9), dorsal fin spine length (SDL) (9), predorsal length (PDL) (11), preventral length (PVL) (12), preanal length (PAL) (13), preorbital height (POH) (14), snout length (NL) (15), maxilla length (ML) (16), eye diameter (ED) (17), interorbital distance (IOD) (18), pectoral fin base length (PBL) (19), prepectoral length (PPL) (20), ventral fin base length (VBL) (21), ventral fin spine length (VSL) (22), anal fin base length (ABL) (23), shortest anal fin spine length (SAL) (24), longest anal fin spine length (LAL) (25) and supraocular tentacle length (STL) (26) (Fig 2). These metric measurements from each individual were taken on the left side of the fish body by the same researcher using a digital caliper (±0.01 mm) and a millimetre ruler (±0.1 cm). The sex of each fish sample was determined by internal inspections after the morphometric measurements had been obtained.

Statistical analysis

The data were tested for normality and homogeneity of variances using the Kolmogorov-Smirnov (K-S) test and the Levene test, respectively. In addition, we investigated whether there was a difference between the data of male and female individuals. An analysis of variance (ANOVA) with Tukey comparisons of morphometric characters was conducted to test for variation among populations and species. Moreover, before running further analysis, the size effects of all morphometric variables were eliminated, as described by Elliott et al. (1995). The equation is as follows: $M_{adj} = M (L_s/L_o)^b$, where $M$ is the original value of the morphometric measure, $M_{adj}$ is the adjusted size of the measure, $L_o$ is the standard length of the fish and $L_s$ is the mean of the standard length of all fish. The parameter $b$ was estimated for each character from the observed data of slope of the regression of log$M$ in log$L_o$, using all fishes. Size-adjusted data were subjected to principal component analysis (PCA) and canonical discriminant analysis (CDA) to identify intra- and interspecific differences of the five *Scorpaena* species. Large factor loadings (positive or negative) of PCA indicate that a particular variable has a strong relationship to a particular principal component. Loadings of at least 0.3 magnitude were taken into account when making intra- and interspecific distinctions. The UPGMA clustering method was used to generate a dendrogram for intra- and interspecific discrimination of the genus *Scorpaena* by computing the Euclidian distance values of morphometric measurements. Wilks’ lambda ($\lambda$) was used.
Table 1. – Descriptive statistics (Mean±SD) and ANOVA results of morphometric measurements of S. elongata populations.

| Morphometric Measurements | Antalya (n=109) | Hatay (n=113) | Izmir (n=110) | F values | ANOVA P values |
|---------------------------|-----------------|---------------|---------------|----------|----------------|
| TL (cm)                   | 15.8±1.4 ±11b   | 14.10±2.72c   | 17.26±3.05c   | 24.98    | 0.001          |
| SL (cm)                   | 12.68±3.43b     | 11.23±2.25c   | 13.94±2.54c   | 26.64    | 0.001          |
| HL (cm)                   | 5.14±1.25c      | 4.71±0.94c    | 5.76±1.05c    | 26.22    | 0.001          |
| BL (mm)                   | 41.69±12.80b    | 36.30±8.06c   | 46.18±8.10c   | 27.93    | 0.001          |
| CPH (mm)                  | 12.18±3.65b     | 10.55±2.04c   | 12.21±2.21c   | 13.68    | 0.001          |
| CPL (mm)                  | 11.72±4.57b     | 9.73±1.59c    | 10.13±2.00c   | 13.52    | 0.001          |
| CL (cm)                   | 3.13±0.70b      | 2.89±0.54c    | 3.38±0.37c    | 17.86    | 0.001          |
| DBL (cm)                  | 7.64±2.05b      | 6.80±1.40c    | 8.39±1.52c    | 25.07    | 0.001          |
| SDL (mm)                  | 10.78±1.96b     | 10.79±1.82c   | 11.79±1.36c   | 12.31    | 0.001          |
| LDL (mm)                  | 21.34±5.11b     | 19.22±3.40c   | 23.18±3.79c   | 25.48    | 0.001          |
| PDL (cm)                  | 3.88±1.34b      | 3.70±0.62c    | 4.25±0.73c    | 9.56     | 0.001          |
| PVL (cm)                  | 5.21±1.33b      | 4.64±0.91c    | 5.66±1.01c    | 24.38    | 0.001          |
| PAL (cm)                  | 9.05±2.64b      | 8.39±1.61c    | 10.22±1.87c   | 21.96    | 0.001          |
| POH (mm)                  | 11.30±2.74b     | 10.30±1.99c   | 12.50±2.30c   | 24.26    | 0.001          |
| NL (mm)                   | 12.42±3.25b     | 11.37±2.15c   | 13.66±2.31c   | 21.54    | 0.001          |
| ML (mm)                   | 27.13±6.92b     | 24.29±4.47c   | 29.81±5.21c   | 27.04    | 0.001          |
| ED (mm)                   | 17.84±3.25b     | 17.11±2.41c   | 11.28±2.15c   | 203.03   | 0.001          |
| IOD (mm)                  | 6.26±1.14b      | 5.34±1.04c    | 6.50±1.12c    | 34.75    | 0.001          |
| PBL (mm)                  | 15.85±3.78b     | 14.60±2.51c   | 17.34±2.76c   | 22.31    | 0.001          |
| PPL (cm)                  | 5.02±1.64b      | 4.68±0.93c    | 5.69±1.04c    | 19.08    | 0.001          |
| VBL (mm)                  | 4.67±1.77b      | 3.95±1.25c    | 6.38±1.71c    | 68.56    | 0.001          |
| VSL (mm)                  | 18.77±3.50b     | 18.12±2.81c   | 19.97±2.69c   | 10.64    | 0.001          |
| ABL (mm)                  | 17.75±4.15b     | 16.37±2.79c   | 19.77±3.05c   | 28.62    | 0.001          |
| SAL (mm)                  | 8.04±1.48b      | 7.44±1.10c    | 8.74±1.18c    | 29.48    | 0.001          |
| LAL (mm)                  | 18.82±3.95b     | 17.60±2.69c   | 20.49±2.96c   | 22.34    | 0.001          |
| STL (mm)                  | 2.23±0.04b      | 2.14±0.03c    | 2.22±0.06c    | 1.16     | 0.314          |

Table 2. – Jackknife classification matrix of the discriminant canonical analysis applied to the three S. elongata populations from the coastline of Turkey’s two seas.

| Population | Antalya (100) | Izmir (110) | Hatay (9) |
|------------|---------------|-------------|-----------|
| Predicted Group Membership | 91.7 | 8.3 | 92.0 |

The correct classification percentages and numbers are in bold; the number of individuals is given in parentheses.

Variables showed normality (P>0.05; K-S test) and homogenous variance (P>0.05; Levene test). There was no statistically significant difference in terms of morphometric data between female and male individuals (P>0.05; t-test). For this reason, intra- and interspecific comparison analyses were carried out by comparing the data of male and female individuals together.

Scorpaena elongata

A total of 332 S. elongata individuals were sampled from the Antalya, Izmir and Hatay stations in the Aegean and Mediterranean seas. The descriptive analysis of morphometric measurements of S. elongata is presented in Table 1. The one-way ANOVA shows significant (P<0.05) differences in all the morphometric measurements (except for STL) among the S. elongata populations (Table 1). As a result of the PCA, it was determined that 12 morphometric measurements taken from the samples (body height, longest dorsal fin spine length, preanal length, preorbital height, snout length, maxilla length, eye diameter, pectoral fin base length, ventral fin base length, ventral fin spine length, anal fin base length and longest anal fin spine length) are quite important in the intraspecific distinction of the S. elongata. Morphometric ratios were calculated between these important morphometric characters and standard length for each S. elongata population (Supplementary Table S1). These morphometric measurements were selected for the CDA. It was determined that the first two functions are important for the CDA performance for the S. elongata populations (F1[97.4%], λ=0.008, P<0.001; F2[2.6%], λ=0.420, 203.03).

RESULTS

Intraspecific discrimination

A total of 1865 fish individuals belonging to five species (S. elongata, S. notata, S. maderensis, S. porcus and S. scrofa) from the eight locations of the Aegean, Black, Mediterranean and Marmara seas were studied for morphometric analysis. The morphometric variables showed normality (P>0.05; K-S test) and homogenous variance (P>0.05; Levene test). There was no statistically significant difference in terms of morphometric data between female and male individuals (P>0.05; t-test). For this reason, intra- and interspecific comparison analyses were carried out by evaluating the data of male and female individuals together.
Intra- and interspecific discrimination of *Scorpaena* species

Intra- and interspecific discrimination of *Scorpaena* species (F1 [92.7%], λ=0.420; F2 [7.3%], λ=0.703, P<0.001) (Fig 5). The CDA results showed that these 10 characters taken from the fish samples were quite effective for discriminating two *S. maderensis* populations from each other and that they achieved 94.6% success in the intraspecific distinction of *S. maderensis* (Table 4). *S. maderensis* populations were clustered by hierarchical cluster analyses of meristic data. Antalya and Hatay were the closest *S. elongata* populations and Izmir the most divergent one (Fig. 4).

Scorpaena maderensis

A total of 326 *S. maderensis* individuals were sampled from the Antalya, Balıkesir and Izmir stations in the Aegean and Mediterranean seas. The descriptive analysis of morphometric measurements of *S. maderensis* is presented in Table 3. ANOVA revealed that there were significant (P<0.05) differences in the TL, SL, HL, BL, CPL, CL, SDL, LDL, PAL, POH, NL, VBL, ABL and LAL measurements among *S. maderensis* populations, and there was no statistically significant (P>0.05) difference in the CPH, DBL, PDL, PVL, ML, ED, IOD, PBL, PPL, VSL, SAL and STL measurements (Table 3). The PCA analysis indicated that ten morphometric measurements taken from the samples (body height, longest dorsal fin spine length, preanal length, preorbital height, maxilla length, caudal peduncle height, caudal peduncle length, pectoral fin base length, anal fin base length and longest anal fin spine length) are quite important in the intraspecific distinction of *S. maderensis*. Morphometric ratios were calculated between these important morphometric characters and standard length for each *S. maderensis* population (Supplementary Table S2). These morphometric measurements were selected for the CDA. It was determined that the first two functions were important for the CDA analysis performed for the *S. maderensis* populations (F1 [92.7%], λ=0.110, P<0.001; F2 [7.3%], λ=0.703, P<0.001) (Fig 5). The CDA results showed that these 10 characters taken from the fish samples were quite effective for discriminating three *S. maderensis* populations from each other and that they achieved 90.5% success in the intraspecific distinction of *S. maderensis* (Table 4). *S. maderensis* populations were clustered by hierarchical cluster analyses of meristic data. Balıkesir and Izmir were the closest *S. maderensis* populations and Antalya the most divergent one (Fig. 4).

Scorpaena notata

A total of 428 *S. notata* individuals were sampled from the Izmir, Hatay, Marmara Ereğlisi and Şile stations in the Aegean, Black, Mediterranean and Mar-
Table 3. – Descriptive statistics (Mean±SD) and ANOVA results of morphometric measurements of S. maderensis populations.

| Morphometric Measurements | Antalya        | Balıkesir    | İzmir        | ANOVA       |
|---------------------------|----------------|--------------|--------------|-------------|
| SL (cm)                   | 9.55±1.44a     | 10.03±1.20a  | 10.13±1.44a  | 3.82        |
| H (cm)                    | 3.98±0.62a     | 4.17±0.50a   | 9.81±1.23a   | 3.18        |
| VBL (mm)                  | 34.08±5.11b    | 36.27±4.34a  | 34.57±4.79a  | 6.32        |
| CPH (mm)                  | 10.13±1.44a    | 9.81±1.23a   | 10.18±1.28a  | 2.42        |
| CPL (mm)                  | 8.13±0.97a     | 6.48±0.57a   | 7.23±0.92a   | 104.23      |
| CL (cm)                   | 2.91±0.38a     | 3.03±0.32a   | 2.94±0.34a   | 3.61        |
| DBL (cm)                  | 6.12±0.95a     | 6.38±0.80a   | 6.16±0.77a   | 2.91        |
| SDL (mm)                  | 9.68±1.42b     | 9.34±1.42a   | 8.73±1.11a   | 14.29       |
| LDL (mm)                  | 16.15±2.29b    | 17.12±1.78a  | 15.66±1.79a  | 15.66       |
| STL (mm)                  | 2.87±0.45a     | 3.00±0.37a   | 2.93±0.39a   | 2.99        |
| PVL (cm)                  | 3.82±0.53a     | 3.88±0.41a   | 3.86±0.47a   | 0.43        |
| PDL (cm)                  | 6.67±1.04a     | 7.07±0.90a   | 6.77±0.91a   | 5.16        |
| POH (mm)                  | 8.41±1.31a     | 8.84±1.19a   | 8.54±1.24a   | 3.43        |
| NL (mm)                   | 10.79±1.49a    | 10.82±1.45a  | 10.38±1.19a  | 3.36        |
| ML (mm)                   | 20.32±3.03a    | 21.01±2.36a  | 20.56±2.64a  | 1.87        |
| ED (mm)                   | 9.23±1.00a     | 9.13±0.84a   | 9.29±0.84a   | 0.87        |
| IOD (mm)                  | 5.55±0.65a     | 5.56±0.57a   | 5.54±0.85a   | 0.01        |
| PBL (mm)                  | 13.60±2.13a    | 14.14±1.77a  | 13.68±1.86a  | 2.50        |
| PPL (cm)                  | 3.64±0.50a     | 3.68±0.43a   | 3.69±0.45a   | 0.47        |
| VBL (mm)                  | 4.56±0.57a     | 4.44±0.48a   | 4.38±0.51a   | 3.27        |
| VSL (mm)                  | 14.85±1.47b    | 14.51±1.39a  | 14.42±1.25a  | 2.87        |
| ABL (mm)                  | 16.56±1.96a    | 17.31±1.77a  | 16.63±1.75a  | 5.49        |
| SAL (mm)                  | 9.55±1.06a     | 9.46±0.99a   | 9.35±0.80a   | 1.11        |
| LAL (mm)                  | 17.24±1.81b    | 17.68±1.41a  | 17.19±1.51b  | 3.07        |
| STM (mm)                  | 4.40±0.61a     | 4.21±0.42a   | 4.29±0.49a   | 0.02        |

Table 4. – Jackknife classification matrix of the discriminant canonical analysis applied to the three S. maderensis populations from the coastline of Turkey’s two seas.

| Population | Antalya | Balıkesir | İzmir |
|------------|---------|-----------|-------|
| Antalya    | 90.8 (99) | -         | 9.2 (10) |
| Balıkesir  | 94.5 (103) | 5.5 (6) |         |
| İzmir      | 9.3 (10) | 4.6 (5) | 86.1 (93) |

Overall: 90.5% of original grouped cases correctly classified.

The correct classification percentages and numbers are in bold; the number of individuals is given in parentheses.

The descriptive analysis of morphometric measurements of S. notata is presented in Table 5. ANOVA revealed significant (P<0.05) differences in all the morphometric measurements among the S. notata populations (Table 5). As a result of the PCA, it was determined that 13 morphometric measurements taken from the samples (body height, caudal peduncle height, caudal peduncle length, longest dorsal fin spine length, preorbital height, snout length, maxilla length, eye diameter, pectoral fin base length, anal fin base length, longest anal fin spine length, supraocular tentacle length and ventral fin spine length) are quite important for the intraspecific distinction of S. notata. Morphometric ratios were calculated between these important morphometric characters and standard length for each S. notata population (Supplementary Table S3). These morphometric measurements were selected for the CDA. It was determined that the first three functions were important for the CDA analysis performed for the S. notata populations (F1[94.7%], λ=0.003, P<0.001; F2[5.2%], λ=0.200, P<0.001; F3[0.1%], λ=0.947, P<0.019) (Fig. 6). It was determined from the CDA results that these 13 characters taken from the fish samples were quite effective for discriminating four S. notata populations from each other and that they achieved 96.7% success in the intraspecific distinction of S. notata (Table 6). S. notata populations were clustered by hierarchical cluster analyses of meristic data. Marmara Ergelisi and Şile are the closest populations that were sister populations to the Hatay population. İzmir was the most divergent S. notata population (Fig. 4).

Scorpaena porcus

A total of 459 S. porcus individuals were sampled from the İzmir, Hatay, Marmara Ergelisi and Ordu stations in the Aegean, Black, Mediterranean and Marmara seas. The descriptive analysis of morphometric measurements of S. porcus is presented in Table 7. The one-way ANOVA showed significant (P<0.05) differences in all the morphometric measurements among the S. porcus populations (Table 7). The PCA analysis indicated that 13 morphometric measurements taken from the samples (body height, caudal peduncle height, caudal peduncle length, shortest dorsal fin spine length, longest dorsal fin spine length, snout length, maxilla length, eye diameter, pectoral fin base length, anal fin base length, longest anal fin spine length, supraocular tentacle length and ventral fin spine length) are quite important for the inraspe-
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Table 5. – Descriptive statistics (Mean±SD) and ANOVA results of morphometric measurements of *S. notata* populations.

| Morphometric Measurements | Hatay (n=106) | İzmir (n=106) | Marmara Ereğlisi (n=107) | Şile (n=109) | ANOVA |
|---------------------------|--------------|--------------|--------------------------|--------------|-------|
| VSL (mm)                  | 15.5±3.58b   | 14.73±3.63a  | 13.52±2.59b              | 13.57±2.73c  | 63.86 0.001 |
| SL (cm)                   | 12.0±2.84b   | 14.46±2.85a  | 10.41±2.06a              | 10.43±2.19c  | 61.54 0.001 |
| HL (cm)                   | 5.10±1.38b   | 6.33±1.33a   | 4.31±0.92                | 4.36±0.92    | 71.49 0.001 |
| BL (mm)                   | 42.08±8.31b  | 48.09±8.44a  | 37.94±7.68b              | 37.77±7.44c  | 39.37 0.001 |
| CPH (mm)                  | 11.80±2.98b  | 14.66±3.19a  | 10.25±2.04a              | 10.41±2.28c  | 62.60 0.001 |
| CPL (mm)                  | 8.12±2.59b   | 10.40±2.63a  | 6.73±1.18                | 6.86±1.75c   | 77.39 0.001 |
| CL (cm)                   | 3.56±0.77b   | 4.28±0.79b   | 3.11±0.55                | 3.15±0.56c   | 69.31 0.001 |
| DBL (cm)                  | 7.38±1.45b   | 8.51±1.47a   | 6.65±1.34                | 6.65±1.35c   | 40.68 0.001 |
| SDL (mm)                  | 10.65±2.53b  | 12.67±2.50a  | 9.60±2.14                | 9.21±1.55c   | 52.43 0.001 |
| LTL (mm)                  | 21.08±5.98b  | 27.28±6.18a  | 17.47±2.96b              | 17.47±2.78c  | 101.60 0.001 |
| PDL (cm)                  | 3.53±0.80b   | 4.05±0.73a   | 3.04±0.59                | 3.11±0.68c   | 46.82 0.001 |
| PVL (cm)                  | 4.81±1.33b   | 6.11±1.39a   | 4.01±0.73                | 4.04±0.76c   | 85.66 0.001 |
| PAL (cm)                  | 8.53±2.15b   | 10.27±2.09a  | 7.28±1.53                | 7.31±1.65c   | 60.23 0.001 |
| POH (mm)                  | 8.72±2.41b   | 11.65±3.13a  | 7.36±1.51                | 7.29±1.57c   | 87.37 0.001 |
| NL (mm)                   | 13.84±4.20b  | 17.66±4.41a  | 11.46±2.42                | 11.42±2.60c  | 74.53 0.001 |
| ML (mm)                   | 25.78±6.98b  | 32.05±7.05a  | 21.71±3.89                | 21.97±4.32c  | 75.39 0.001 |
| ED (mm)                   | 11.17±3.17b  | 14.21±3.18a  | 9.31±1.36                | 9.32±1.45c   | 94.87 0.001 |
| IDO (mm)                  | 6.38±1.96b   | 8.78±1.92a   | 5.80±1.10                | 5.91±1.22c   | 81.98 0.001 |
| PBL (mm)                  | 16.84±4.13b  | 20.69±4.36a  | 14.50±2.86                | 14.58±3.20c  | 66.14 0.001 |
| PPL (cm)                  | 4.49±1.12b   | 5.43±1.13a   | 3.81±0.71                | 3.84±0.76c   | 67.79 0.001 |
| VBL (mm)                  | 5.30±1.17b   | 6.04±1.12a   | 4.61±0.85                | 4.62±0.93c   | 47.36 0.001 |
| VSL (mm)                  | 17.71±4.41b  | 21.63±4.35a  | 14.62±2.17                | 14.78±2.17c  | 97.08 0.001 |
| ABL (mm)                  | 19.29±2.99b  | 21.11±2.88a  | 17.61±2.67                | 17.63±2.86c  | 36.40 0.001 |
| SAL (mm)                  | 10.64±1.94c  | 11.69±1.72a  | 9.59±1.61                | 9.77±1.67c   | 32.81 0.001 |
| LAL (mm)                  | 20.17±3.78b  | 22.59±3.16a  | 17.97±2.31                | 18.21±2.52c  | 54.70 0.001 |
| STL (mm)                  | 3.15±0.99b   | 6.67±1.64a   | 4.27±0.69                | 2.69±0.58c   | 51.56 0.001 |

Table 6. – Jackknife classification matrix of the discriminant canonical analysis applied to the four *S. notata* populations from the coastline of Turkey’s four seas.

| Population | İzmir (106) | Hatay (106) | Marmara Ereğlisi (107) | Şile (109) |
|------------|-------------|-------------|------------------------|------------|
| İzmir      | 100.0 (106) | -           | -                      | 96.5% (105) |
| Hatay      | 100.0 (106) | -           | -                      | 96.5% (105) |
| Marmara    | -           | 93.5 (100)  | 6.5 (7)                | 96.7% (104) |
| Ereğlisi   | -           | -           | 3.5 (4)                | 96.7% (104) |
| Şile       | -           | -           | 3.5 (4)                | 96.7% (104) |

The correct classification percentages and numbers are in bold; the number of individuals is given in parentheses.

specific distinction of the *S. porcus*. Morphometric ratios were calculated between these important morphometric characters and standard length for each *S. porcus* population (Supplementary Table S4). These morphometric measurements were selected for the CDA. It was determined that the first three functions are important for the CDA analysis performed for the *S. porcus* populations (F1[F(2,99), λ=0.002, P<0.001; F2[F(5.6), λ=0.090, P<0.001; F3[F(4.2), λ=0.330, P<0.001] (Fig. 7). It was determined from the CDA results that these 13 characters taken from the fish samples were quite effective for discriminating four *S. porcus* populations from each other and that they achieved 96.5% success in the intraspecific distinction of *S. porcus* (Table 8). *S. porcus* populations were clustered by hierarchical cluster analyses of meristic data. Two branches were produced by UPGMA: the first was made up of İzmir and Hatay populations; the second was made up of Marmara Ereğlisi and Şile populations. These were the closest *S. porcus* populations (Fig. 4).

*Scorpaena scrofa*

A total of 320 *S. scrofa* individuals were sampled from the Çanakkale, İzmir and Hatay stations in the...
Table 7. – Descriptive statistics (Mean±SD) and ANOVA results of morphometric measurements of *S. porcus* populations.

| Morphometric Measurements | Hatay (n=114) | Izmir (n=115) | Marmara Ereğli (n=115) | Ordu (n=115) | ANOVA F values | P values |
|---------------------------|---------------|---------------|------------------------|--------------|----------------|----------|
| TL (cm)                   | 16.5±3.98b    | 18.56±4.27a   | 14.56±3.82a            | 13.94±4.15a  | 30.85          | 0.001    |
| SL (cm)                   | 12.8±3.28a    | 14.56±3.43a   | 11.81±3.12a            | 10.78±3.43a  | 27.42          | 0.001    |
| HL (cm)                   | 5.2±1.13b     | 6.31±1.53b    | 5.02±1.36b             | 4.52±1.52b   | 31.99          | 0.001    |
| BL (mm)                   | 48.48±12.33a  | 63.53±15.88a  | 45.04±12.55b           | 39.18±12.74a | 69.06          | 0.001    |
| CPH (mm)                  | 13.42±3.01b   | 14.92±3.72b   | 11.59±3.29b            | 10.76±3.47b  | 31.62          | 0.001    |
| CPL (mm)                  | 10.50±2.37b   | 13.94±3.71b   | 9.42±2.63b             | 8.80±2.63b   | 73.52          | 0.001    |
| CL (cm)                   | 3.70±0.73b    | 4.02±0.85b    | 2.74±0.73b             | 3.23±0.80b   | 58.89          | 0.001    |
| DBL (cm)                  | 8.1±2.04a     | 8.94±2.04a    | 6.98±1.83a             | 6.81±1.99a   | 30.12          | 0.001    |
| SDL (mm)                  | 12.3±3.43b    | 13.87±3.05b   | 10.36±2.80b            | 9.76±3.10b   | 42.46          | 0.001    |
| LDL (mm)                  | 19.5±3.85b    | 23.46±4.56b   | 17.58±4.81b            | 17.85±4.31b  | 44.02          | 0.001    |
| PDL (cm)                  | 3.94±1.07b    | 4.62±1.15b    | 3.68±1.01b             | 3.25±1.21b   | 30.94          | 0.001    |
| PVL (cm)                  | 5.16±1.34b    | 5.61±1.31b    | 4.45±1.23b             | 4.07±1.24b   | 33.92          | 0.001    |
| PAL (cm)                  | 9.24±2.38b    | 10.94±2.78b   | 8.67±2.33b             | 7.71±2.72b   | 32.35          | 0.001    |
| POH (mm)                  | 9.19±2.45b    | 10.07±2.41b   | 7.29±1.92b             | 6.97±1.94b   | 53.72          | 0.001    |
| NL (mm)                   | 13.8±3.28b    | 15.94±3.91b   | 12.45±3.32b            | 11.65±3.71b  | 32.19          | 0.001    |
| ML (mm)                   | 27.1±6.48b    | 31.13±7.42a   | 24.24±6.43b            | 23.02±7.17b  | 31.77          | 0.001    |
| ED (mm)                   | 11.0±1.91b    | 15.64±3.54b   | 8.86±2.44b             | 9.85±2.26b   | 148.49         | 0.001    |
| IOD (mm)                  | 6.61±1.69b    | 9.32±2.22b    | 6.10±1.64b             | 5.77±1.75b   | 89.70          | 0.001    |
| PBL (mm)                  | 17.6±4.27b    | 22.19±5.31a   | 18.65±5.06b            | 15.75±5.52b  | 33.14          | 0.001    |
| PPL (cm)                  | 4.88±1.33b    | 5.19±1.26b    | 4.07±1.11b             | 3.82±1.15b   | 33.00          | 0.001    |
| VBL (mm)                  | 5.63±1.21b    | 5.22±1.47b    | 5.50±1.63b             | 4.61±0.88b   | 13.59          | 0.001    |
| VSL (mm)                  | 17.92±3.92b   | 22.27±4.52b   | 17.56±4.71b            | 15.38±4.18b  | 51.32          | 0.001    |
| ABL (mm)                  | 20.4±4.49b    | 22.89±4.17b   | 17.58±4.63b            | 17.54±4.45b  | 39.06          | 0.001    |
| SAL (mm)                  | 11.3±2.49b    | 13.08±2.61a   | 9.81±2.62b             | 9.65±2.54b   | 45.15          | 0.001    |
| LAL (mm)                  | 20.02±3.47b   | 21.71±3.32a   | 16.71±4.74b            | 18.28±3.70b  | 36.44          | 0.001    |
| STL (mm)                  | 10.93±1.95b   | 15.46±3.62a   | 8.86±2.43b             | 9.81±2.33b   | 1380.04        | 0.001    |

Table 8. – Jackknife classification matrix of the discriminant canonical analysis applied to the four *S. porcus* populations from the coastline of Turkey’s four seas.

| Population | Predicted Group Membership |
|------------|---------------------------|
|            | Izmir                     |
| Hatay      | -                         |
| Marmara Ereğli | -     |
| Ordu       | -                         |

Overall: 96.5% of original grouped cases correctly classified.

The correct classifications percentages and numbers are in bold; the number of individuals is given in parentheses.

Aegean, Mediterranean and Marmara seas. The descriptive analysis of morphometric measurements of *S. scrofa* is presented in Table 9. ANOVA revealed significant (P<0.05) differences in all the morphometric measurements (except for PPL and STL) among the *S. scrofa* populations (Table 9). As a result of the PCA, it was determined that ten morphometric measurements taken from the samples (body height, caudal peduncle height, shortest dorsal fin spine length, longest dorsal fin spine length, preorbital height, snout length, maxilla length, pectoral fin base length, ventral fin spine length and anal fin base length) are quite important in the intraspecific distinction of *S. scrofa*. Morphometric ratios were calculated between these important morphometric characters and standard length for each *S. porcus* population (Supplementary Table S5). These morphometric measurements were selected for the CDA. It was determined that the first two functions were important for the CDA analysis performed for the *S. scrofa* populations (F1[93.7%], λ = 0.055, P < 0.001; F2[6.3%], λ = 0.600, P < 0.001) (Fig. 8). It was determined from the CDA results that these 10 characters taken from the fish samples were quite effective for discriminating four *S. scrofa* populations from each other and that they achieved 92.2% success in the intraspecific distinction of *S. scrofa*.
Table 9. – Descriptive statistics (Mean±SD) and ANOVA results of morphometric measurements of *S. scrofa* populations.

| Morphometric Measurements | Çanakkale (n=107) | Hatay (n=107) | İzmir (n=106) | ANOVA |
|---------------------------|-------------------|----------------|----------------|-------|
| TL (cm)                   | 22.88±5.03×       | 19.90±5.63×    | 21.57±3.91×    | F=9.90 | P<0.001 |
| SL (cm)                   | 17.71±3.77×       | 15.59±4.29×    | 16.71±3.01×    | 8.60   | P<0.001 |
| HL (cm)                   | 7.74±1.79×        | 6.65±1.98×     | 7.51±1.43×     | 11.63  | P<0.001 |
| BL (mm)                   | 57.99±12.96×      | 50.75±14.27×   | 56.04±10.77×   | 9.22   | P<0.001 |
| CPH (mm)                  | 18.22±4.46×       | 15.42±4.73×    | 17.47±3.34×    | 12.59  | P<0.001 |
| CPL (mm)                  | 14.28±3.06×       | 12.64±3.45×    | 13.16±2.59×    | 8.14   | P<0.001 |
| CL (cm)                   | 5.18±1.31×        | 4.31±1.38×     | 4.86±0.95×     | 13.62  | P<0.001 |
| DBL (cm)                  | 10.33±2.06×       | 9.39±2.62×     | 9.87±1.71×     | 5.10   | P<0.007 |
| SDL (mm)                  | 16.10±3.35×       | 12.98±2.68×    | 14.78±2.60×    | 31.43  | P<0.001 |
| LVL (cm)                  | 33.28±8.33×       | 27.04±7.67×    | 30.66±5.87×    | 19.36  | P<0.001 |
| DVL (cm)                  | 5.86±1.37×        | 5.19±1.59×     | 5.83±1.09×     | 8.11   | P<0.001 |
| PVL (cm)                  | 7.32±1.65×        | 6.42±1.86×     | 6.97±1.32×     | 8.21   | P<0.001 |
| PAL (cm)                  | 13.58±3.06×       | 11.78±3.36×    | 12.85±2.39×    | 9.91   | P<0.001 |
| POH (mm)                  | 22.97±5.26×       | 19.68±5.83×    | 22.41±4.21×    | 12.44  | P<0.001 |
| NL (mm)                   | 21.80±6.04×       | 17.58±6.44×    | 21.42±3.98×    | 18.59  | P<0.001 |
| ML (mm)                   | 39.55±8.75×       | 34.12±9.56×    | 37.42±7.03a    | 11.08  | P<0.001 |
| ED (mm)                   | 17.57±2.14×       | 16.75±1.99×    | 17.13±1.84ab   | 4.55   | P<0.011 |
|IOD (mm)                   | 10.42±2.79×       | 8.33±2.91×     | 10.34±2.01×    | 22.32  | P<0.001 |
| PBL (mm)                  | 25.09±6.08×       | 20.56±6.21×    | 24.69±4.12×    | 21.60  | P<0.001 |
| PPL (cm)                  | 6.60±1.47×        | 6.59±1.91×     | 6.26±1.19×     | 1.67   | 0.191 |
| VBL (mm)                  | 7.80±1.88×        | 6.14±2.13×     | 7.30±1.73×     | 20.94  | P<0.001 |
| VSL (mm)                  | 25.52±4.60×       | 22.44±5.09×    | 25.35±3.25×    | 16.70  | P<0.001 |
| ABL (mm)                  | 24.50±5.10×       | 21.76±5.55×    | 23.31±3.41×    | 8.84   | P<0.001 |
| SAL (mm)                  | 13.01±3.11×       | 10.94±3.43×    | 12.44±1.38×    | 15.67  | P<0.001 |
| LAL (mm)                  | 24.39±4.40×       | 22.34±5.30×    | 23.81±2.53×    | 6.52   | P=0.002 |
| STl (mm)                  | 1.72±0.32×        | 1.68±0.20×     | 1.71±0.18×     | 0.99   | 0.374 |

Table 10. – Jackknife classification matrix of the discriminant canonical analysis applied to the four *S. scrofa* populations from the coastline of Turkey’s three seas.

| Population | Çanakkale | İzmir | Hatay |
|------------|-----------|-------|-------|
| Çanakkale  | 87.9 (94) | 12.1 (13) | - |
| İzmir      | 10.4 (11) | - | 89.6 (95) |
| Hatay      | 0.9 (1) | 99.1 (106) | - |

Overall: 92.2% of original grouped cases correctly classified.

(From Table 10). *S. scrofa* populations were clustered by hierarchical cluster analyses of meristic data. Çanakkale and İzmir were the closest *S. scrofa* populations and Hatay was the most divergent (Fig. 4).

### Interspecific discrimination

A total of 1865 individuals belonging to five *Scorpaena* species were sampled from the Antalya, Bahkeşir, Çanakkale, İzmir, Hatay, Marmara Ereğlisi, Ordu and Şile stations in the Aegean, Black, Mediterranean and Marmara seas. The descriptive analysis of morphometric measurements of five *Scorpaena* species is presented in Table 11. The one-way ANOVA showed significant (P<0.05) differences in all the morphometric measurements among the *Scorpaena* species (Table 11). The PCA analysis indicated that 13 morphometric measurements taken from the samples (body height, caudal peduncle height, caudal peduncle length, longest dorsal fin spine length, preorbital height, snout length, maxilla length, eye diameter, pectoral fin base length, anal fin base length, longest anal fin spine length, supraocular tentacle length and ventral fin spine length) were quite important for the interspecific discrimination of five *Scorpaena* species. These morphometric measurements were selected for the CDA. It was determined that the first four functions were important for the CDA analysis performed for the...
Table 11. – Descriptive statistics (Mean±SD and range) and ANOVA results of morphometric measurements of five *Scorpaena* species.

| Morphometric Measurements | *S. elongata* (n=326) | *S. maderensis* (n=320) | *S. notata* (n=459) | *S. porcus* (n=459) | *S. scrofa* (n=320) | ANOVA | F values | P values |
|---------------------------|-----------------------|--------------------------|---------------------|--------------------|--------------------|-------|----------|----------|
| TL (cm)                   | 15.71±3.57a           | 12.74±1.64a              | 15.33±3.80a         | 15.90±4.44a        | 21.45±5.05a        | 214.96 | 0.001    |          |
| SL (cm)                   | 9.2-23.6              | 9.8±0.23a                | 11.81±1.66a         | 12.50±1.43a        | 16.68±0.92a        | 1347.22| 0.001    |          |
| HL (cm)                   | 7.1-18.9              | 4.08±0.17b              | 7.2-17.7 (7.2-17.7)  | 4.95±0.35b         | 7.29±0.55b         | 1621.65| 0.001    |          |
| BL (mm)                   | 41.6±3.48             | 35.07±1.64d             | 41.53±4.55d         | 45.41±4.79d        | 54.93±4.04d        | 1010.49| 0.001    |          |
| CPH (mm)                  | 11.61±0.97c           | 10.05±0.43a             | 11.75±1.84a         | 12.60±1.81b        | 16.99±1.45b        | 1041.54| 0.001    |          |
| CPL (mm)                  | 10.48±1.20            | 7.27±0.75b              | 7.99±1.57f          | 10.82±1.70g        | 13.38±1.19h        | 663.97 | 0.001    |          |
| CL (cm)                   | 3.14±0.27c            | 2.97±0.13c              | 3.53±0.50c          | 3.45±0.51c         | 4.74±0.47c         | 916.02 | 0.001    |          |
| DBL (cm)                  | 7.60±0.71c            | 6.23±0.23c              | 7.32±0.80c          | 7.73±0.93c         | 9.88±0.53c         | 1127.34| 0.001    |          |
| SDL (mm)                  | 11.17±0.80c           | 9.29±0.64f              | 10.51±1.51d         | 11.58±1.70f        | 14.68±1.51h        | 687.89 | 0.001    |          |
| LDM (mm)                  | 21.27±1.95c           | 16.31±0.95e             | 20.79±1.42c         | 19.75±2.55d        | 30.29±3.06e        | 1105.23| 0.001    |          |
| PDL (cm)                  | 3.93±0.29c            | 2.94±0.14d              | 3.43±0.44e          | 3.85±0.55e         | 5.61±0.39f         | 2035.03| 0.001    |          |
| PVL (cm)                  | 5.16±0.48c            | 3.87±0.13e              | 4.73±0.85d          | 4.82±0.65e         | 6.90±0.45f         | 1157.40| 0.001    |          |
| PAL (cm)                  | 9.20±0.84e            | 8.64±0.25d              | 8.33±1.24c          | 9.12±1.26c         | 12.74±0.86d        | 1522.82| 0.001    |          |
| POH (mm)                  | 11.40±1.03c           | 8.85±0.41c              | 8.69±1.77c          | 8.37±1.39c         | 21.66±1.69c        | 5742.23| 0.001    |          |
| NL (mm)                   | 12.53±1.17c           | 10.66±0.46c             | 13.51±2.59b         | 13.46±2.37c        | 20.10±2.29c        | 1027.10| 0.001    |          |
| ML (mm)                   | 27.10±2.41c           | 20.64±0.71c             | 25.31±4.21c         | 26.47±3.40c        | 37.04±2.55c        | 1270.19| 0.001    |          |
| ED (mm)                   | 15.48±3.04c           | 9.2±0.39e               | 10.98±2.04c         | 11.37±2.68c        | 17.27±0.84c        | 843.05 | 0.001    |          |
| IOD (mm)                  | 6.05±0.60             | 5.56±0.06a              | 6.81±1.27a          | 6.94±1.47a         | 9.65±1.25a         | 646.45 | 0.001    |          |
| PBL (mm)                  | 16.01±1.33a           | 13.78±0.61a             | 16.61±2.60a         | 18.58±2.54a        | 23.46±2.69a        | 973.11 | 0.001    |          |
| PPL (cm)                  | 5.11±0.50a            | 3.68±0.14f              | 4.39±0.67f          | 4.48±0.60f         | 6.49±0.32a         | 1419.14| 0.001    |          |
| VBL (mm)                  | 4.90±1.11a            | 4.46±0.23f              | 5.15±0.66a          | 5.24±0.46a         | 7.04±0.85a         | 619.24 | 0.001    |          |
| VSL (mm)                  | 19.01±1.24a           | 14.64±0.54a             | 17.18±2.94a         | 18.34±2.66a        | 24.57±1.92a        | 931.15 | 0.001    |          |
| ABL (mm)                  | 18.03±1.08a           | 16.84±0.78a             | 18.97±1.72a         | 19.68±2.42a        | 23.27±1.69a        | 593.89 | 0.001    |          |
| SAL (mm)                  | 8.12±0.67             | 9.46±0.38a              | 10.46±1.04a         | 10.99±1.56c        | 12.13±1.23c        | 644.06 | 0.001    |          |
| LAL (mm)                  | 19.09±1.58a           | 17.41±0.65a             | 19.80±1.20a         | 19.26±2.17c        | 23.63±1.38a        | 568.49 | 0.001    |          |
| STL (mm)                  | 2.19±0.49d            | 4.32±0.33d              | 4.17±1.57e          | 11.34±2.63a        | 1.70±0.24a         | 2656.61| 0.001    |          |

Table 12. – Jackknife classification matrix of the discriminant canonical analysis applied to the five *Scorpaena* species from the coastline of Turkey’s four seas.

| Species     | *S. elongata* | *S. maderensis* | *S. notata* | *S. porcus* | *S. scrofa* | Predicted Group Membership |
|-------------|---------------|-----------------|-------------|-------------|-------------|-----------------------------|
| *S. elongata* | 98.5 (327)   | -               | -           | -           | -           | 100.0 (320)                  |
| *S. maderensis* | 1.8 (6)   | 98.2 (320) | -           | -           | -           | 94.8 (435)                  |

Overall: 97.4% of original grouped cases correctly classified.

The correct classifications percentages and numbers are in bold; the number of individuals is given in parentheses.

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**Fig. 9.** Interspecific discrimination of the five *Scorpaena* species using morphometric characters.

five *Scorpaena* species (F1 [88.4%], $\lambda = 0.001, P<0.001$; F2 [8.2%], $\lambda = 0.027, P<0.001$; F3 [2.0%], $\lambda = 0.194, P<0.001$; F4 [1.4%], $\lambda = 0.493, P<0.001$) (Fig. 9). It is determined from the CDA results that these 13 characters taken from the fish samples were quite effective for discriminating five *Scorpaena* species from each other and that they achieved 97.4% success in interspecific discrimination of these *Scorpaena* species (Table 12).

Hierarchical cluster analyses of meristic data clustered *Scorpaena* species. Three main branches were produced by UPGMA. In the first branch, *S. scrofa* was seen to be morphometrically most divergent from the other species. In the second branch, *S. notata* and *S. porcus* were the closest taxa forming the sister group to *S. elongata*. The neighbouring branch made up of *S. maderensis* was seen to be morphometrically most divergent from the other species and was branched as a third group. The third group, the neighbouring branch, included only *S. maderensis* (Fig. 4).

DISCUSSION

The genus *Scorpaena* is distributed throughout temperate and tropical seas of the world (Hureau and Livtinenko 1986, Gomon et al. 1994, Froese and Pauly 2020). It is known that *Scorpaena* species are difficult to identify at the species level using visual observation alone due to coloration similarities and overlapping morphological features in different habitats (Hureau and Livtinenko 1986, Golani et al. 2006, Akalin et al. 2011). Morphometric characters of the fish species are a strong means to measure and distinguish species and stock relations (Turan et al. 2005, Cadrin et al. 2014). In this study, the intra- and interspecific discriminations of five *Scorpaena* species inhabiting the Aegean, Black, Mediterranean and Marmara seas were successfully performed using CDA based on morphometric characters. It was determined that data obtained from *Scorpaena* species showed some differences among the species but were generally compatible with the data of Froese and Pauly (2020). The most significant measurements of five *Scorpaena* species taken into account for discrimination through the traditional analysis were body height, caudal peduncle height, caudal peduncle length, longest dorsal fin spine length, preorbital height, snout length, maxilla length, eye diameter, pectoral fin base length, anal fin base length, longest anal fin spine length, supracaudal tentacle length and ventral fin spine length. As a result of CDA analysis, it was determined that morphometric characters are also effective for intraspecific discrimination of five *Scorpaena* species. For example, the highest intraspecific discrimination was determined for *S. notata* populations (96.7%), followed by *S. porcus* (96.5%), *S. elongata* (94.6%), *S. scrofa* (92.2%) and *S. maderensis* (90.5%).

The intraspecific morphological variations of five *Scorpaena* species may be due to variation in body shape but not to the total length effect because it was normalized successfully using the Elliott et al. (1995) method. Cadrin (2000) indicated that is difficult to explain the causes of morphological differences between fish populations. However, it is assumed that these differences may be related to genetic factors or may also be related to environmental factors such as feeding, habitat, pH, turbidity and temperature (Winberger 1992).

Pothen et al. (2006) indicated that the Wilks’ lambda ($\lambda$) value varies between 0 and 1. The discriminating power of CDA is best when Wilks’ lambda ($\lambda$) is close to 0. In the current study, the Wilks’ lambda ($\lambda$) values for intraspecific discriminations were 0.008 for *S. elongata*, 0.110 for *S. maderensis*, 0.003 for *S. notata*, 0.002 for *S. porcus* and 0.055 for *S. scrofa*. The Wilks’ lambda ($\lambda$) value was determined as 0.001 for interspecific discrimination of the five *Scorpaena* species. CDA results show that morphological measurements of the five *Scorpaena* species produce good discrimination within each species and among the species. These lambda values also support the high accuracy of CDA for morphometric measurements in the present study. Using the morphometric measurements of *Scorpaena* species, the actual separation rate in CDA was determined to be high (Table 12). Body morphometric traits were reported to provide a moderate level of discrimination in many species and genera from marine and freshwater habitats such as *Trachurus mediterraneus* in the Aegean, Black, and Mediterranean seas (Turan 2004), *Eugenes spp.* in the eastern Pacific (González-Acosta et al. 2005), *Megalops cordyla* from the Indian coast (Sajina et al. 2011), the genus *Laboe* in Assam, India (Choudhury and Dutta 2012), *Channa punctatus* from Indian rivers (Khan et al. 2013), the genus *Nemipterus* in Malaysia and its surrounding seas (Imtiaz and Naim 2018), *Ompok pabo* from Bangladesh freshwater (Mahfuj et al. 2019b) and mullet species in Aceh, Indonesia (Yulianto et al. 2020).

La Mesa (2005) revised the description of *S. maderensis* sampled from the southeastern coasts of Sicily using the metric and meristic characteristics and reported that most of the morphometric characters of *S. maderensis* evaluated in this study overlap with the
S. porcus data, causing some problems in species distinction. The same author reported that supraocular tentacle length and anal fin spine length were the most effective characters for distinguishing S. maderensis and S. porcus species. Similarly, in the present study, it was determined that the supraocular tentacle length, shortest anal fin spine length and longest anal fin spine length were the most effective characters for distinguishing between S. maderensis and S. porcus species. Turan et al. (2009) compared S. elongata, S. maderensis, S. notata, S. porcus, and S. scrofa from Iskenderun Bay (Mediterranean Sea) based on the number of spines and soft rays on anal, ventral and dorsal fins, the number of soft scales on the pectoral and caudal fins, the number of scales on the lateral line, and the number of gill spines and vertebrae. They concluded that caudal fin rays, pectoral fin rays, vertebrae numbers and lateral scale numbers are important for species differentiation.

Ferri et al. (2010) evaluated 18 morphometric characteristics of S. porcus sampled from the eastern Adriatic Sea. They reported that these characters did not differ statistically between male and female individuals (P>0.05). Similarly, in the present study, 26 morphometric characters were evaluated for S. porcus from the Aegean, Black, Mediterranean seas and Mar-Mara seas, and it was determined that metric characters showed no statistical difference between female and male individuals (P>0.05). Thus, this study contributes to the literature by supporting the data of previous studies over new samples obtained from different stations in different habitats. Akalin et al. (2011) compared 19 metric and 7 meristic characteristics in S. porcus and S. notata sampled from the Aegean Sea. Although they stated that the black spot on the dorsal fin and supraocular tentacle are effective characters for differentiating these two species, there were problems in distinguishing juvenile individuals. Therefore, they stated that a detailed morphometric comparison was needed for Scorpaena species. They found statistical differences between the two species in supraocular tentacle length, upper jaw length, pectoral fin length, caudal peduncle height, eye diameter, longest dorsal fin spine length, pelvic fin spine length, shortest anal fin spine length and longest anal fin spine length. Our study also revealed that morphometric characters may differ statistically among fish species (Table 11). Manilo and Peskov (2016) evaluated 20 morphometric characteristics of S. porcus sampled from the south coast of Crimea and the eastern part of the Adriatic Sea. They compared the male and female individuals in both regions separately. As a result of this comparison, they reported that the 13 morphometric characteristics were statistically different between these two regions. Similar results were obtained in the present study, and the PCA indicated that 13 morphometric measurements were important for the intraspecific discrimination of five S. porcus from four seas. We also achieved a success rate of 96.5% in the intraspecific separation of S. porcus sampled from different seas using these morphometric data (Table 8). As explained above in the literature review, although there are some intra- and interspecific morphometric-based studies for the genus Scorpaena, no studies based on morphometric measurements of these five Scorpaena species had been carried out in such wide geographic areas. Therefore, this is the first study based on morphometric data to perform intra- and interspecific discrimination of the five Scorpaena species sampled from eight stations in four seas.

In many studies, the characters are considered one of the simplest, most cost-effective and most commonly used tools to distinguish between fish populations (Khan et al., 2013, Siddik et al., 2015), to determine the structure of fish assemblages (Cheng et al., 2005) and to identify fish stocks (Cadrin et al. 2014, Siddik et al., 2016). However, in some cases these morphometric characters may not be suitable for identifying or discriminating every fish species and population. Therefore, the determination of these characters is important for fish biology and fisheries management.

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REFERENCES

Akalın S., İlnan D., Ünlüoğlu A., et al. 2011. Length-weight relationship and metric-meristic characteristics of two scorpi- on fishes (Scorpaena notata and Scorpaena porcus) in İzmir Bay. J. Fish. Sci. 5: 291-299. https://doi.org/10.3153/jfscsm.2011033
Arcoleo M., Lo Brutto S. 2014. New contribution to the systematic status of various Mediterranean Scorpionfish, as inferred from a mitochondrial DNA sequence. Rev. Biol. Mar. Oceanogr. 49: 367-371. https://doi.org/10.4067/S0718-19572014000200015
Baldwin R.E., Banks M.A., Jacobson K.C. 2012. Integrating fish and parasite data as a holistic solution for identifying the elusive stock structure of Pacific sardines (Sardinops sagax). Rev. Fish. Biol. Fisher. 22: 137-156. https://doi.org/10.1007/s11160-011-9227-5
Batubara A.S., Muchlisin Z.A., Efizion D., et al. 2018. Morpho- metric variations of the genus Barbonymus (Pisces, Cyprinidae) harvested from Aceh Waters, Indonesia. Fish Aquatic. Sci. 26: 231-237. https://doi.org/10.2478/aofp-2018-0026
Cadrin S.X. 2000. Advances in morphometric identification of fishery stocks. Rev. Fish. Biol. Fisher. 10: 91-112. https://doi.org/10.1023/A:1008939104413
Cadrin S.X., Kerr L.A., Mariani S. (eds), Stock Identification Methods. San Diego: Elsevier, pp. 1-5. https://doi.org/10.1016/B978-0-12-397003-9.00001-1
Caputo V., Sorice M., Vitturi R., et al. 1998. Cytogenetic studies in some species of Scorpaeniformes (Teleostei: Percomorpha). Chromosome Res. 6: 255-262. https://doi.org/10.1023/A:1009210605487
Cheng Q., Lu D., Ma L. 2005. Morphological differences be- tween close populations discernible by multivariate analy- sis: a case study of genus Coilia (Teleostei: Clupeiformes). Aquat. Living Resour. 18: 187-192. https://doi.org/10.1051/alr:2005020
Choudhury S., Dutta K. 2012. Interrelationships of five spe- cies of the genus Labeo by morphometric analysis. IOSR J. Pharm. Biol. Sci. 2: 35-39. https://doi.org/10.9790/0308-0263337

SCI. MAR. 85(3), September 2021, 197-209. ISSN-L 0214-8358 https://doi.org/10.3989/scimar.05185.018
Choudhury S., Saikia P., Sougrakpam N., et al. 2011. Assessment of morphometric variation and establishing taxonomic relationships among six species under Puntius genus. Int. J. Environ. Res. 1: 233-237.

Elliott N.G., Haskard K., Koslow J.A. 1995. Morphometric analysis of orange roughy (Hoplostethus atlanticus) off the continental slope of southern Australia. J. Fish Biol. 46: 202-220.

https://doi.org/10.1111/j.1095-8649.1995.tb05962.x

Ferri J., Petrič M., Matić-Škoko S. 2010. Biometry analysis of the black scorpionfish, Scorpaena porcus (Linnaeus, 1758) from the eastern Adriatic Sea. Acta Adriat. 51: 45-53.

Fischer W., Schneider M., Bauchot M.L. 1987. Fiches FAO d’identification des espèces pour les besoins de la pêche. Méditerranée et mer Noire. Zone de Pêche 37. Vol. II. Vertébrés. FAO, Rome, 1070 pp.

http://www.fao.org/3/x10700en.htm

Froese R., Pauly D. 2020. FishBase. World Wide Web electronic publication. Accessed: 12.12.2020.

http://www.fishbase.org/

Golani D., Öztürk B., Bağusta N. 2006. Fishes of the eastern Mediterranean. Turkish Marine Research Foundation, Istanbul, 260 pp.

Gomon M.F., Glover J.C.M., Kuiter R.H. 1994. The fishes of Australia’s south coast. State Print, Adelaide, 992 pp.

González-Acosta A.F., De La Cruz-Agüero J., Castro-Aguirre J.L. 2005. A review of eastern Pacific species of the genus Eugerres (Perciformes: Girelidae). Bull. Mar. Sci. 76: 661-673.

Hureau J.C., Litvinenko N.I. 1986. Scorpaenidae. In: Whitehead P.J.P., Bauchot M.L., et al. (eds), Fishes of the North-eastern Atlantic and the Mediterranean. Paris: Unesco, pp. 121-1229.

Ibáñez A.L., Jawad L.A. 2018. Morphometric variation of fish scales among some species of rafail fish from New Zealand waters. J. Mar. Biol. Assoc. U.K. 98: 1911-1998.

https://doi.org/10.1017/S0025315418000224

Imtiaz A., Naim D.M.D. 2018. Geometric morphometrics species discrimination within the genus Nemipterus from Malaysia and its surrounding seas. Biodiversitas 19: 2316-2322.

https://doi.org/10.13057/biodiv/d190640

Jayasankar P., Thomas P.C., Paulton M.P., et al. 2004. Morphometric and genetic analyses of Indian mackerel (Rastrelliger kanagurta) from peninsular India. Asian Fish. Sci. 17: 201-215.

https://doi.org/10.13057/biodiv/d210802

Keskin Ç., Eryilmaz L. 2009. The presence of Scorpaena lappeii (Osteichthyes, Scorpaenidae), in the Turkish seas. Mar. Biodivers. Rec. 2: 1-2.

https://doi.org/10.1017/S1755267208000341

Khan M.A., Miyan K., Khan S. 2013. Morphometric variation of snakehead fish, Channa punctatus, populations from three Indian rivers. J. Appl. Ichthyol. 29: 637-642.

https://doi.org/10.1111/j.1439-0426.2012.02058.x

La Mesa G. 2005. A revised description of Scorpaena maderensis (Scorpidae) by means of meristic and morphometric analysis. J. Mar. Biol. Assoc. U.K. 85: 1263-1270.

https://doi.org/10.1017/S0025315405012415

Mahfuj M.S., Khatun A., Boidya P., et al. 2019a. Meristic and morphometric variations of barred spiny eel, Macrognathus p坎calus populations from Bangladesh freshwater; an insight into landmass-based truss network system. Ribarstvo 77: 7-18.

https://doi.org/10.2478/rib-2019-0002

Mahfuj M.S., Hossain M.F., Jinia S.S., et al. 2019b. Meristic and morphometric variations of critically endangered butter catfish, Ompok pabilu inhabiting three natural sources. Int. J. Biosci. 14: 518-527.

Manilo L.G., Peskov V.N. 2016. Comparative morphometric analysis of the small-sized scorpionfish, Scorpaena porcus (Scorpidae, Scorpaeniformes), from the southern coast of the Crimea and eastern part of the Adriatic Sea. Vestn. Zool. 50: 533-538.

https://doi.org/10.1515/vzoo-2016-0060

Morato T., Afonso P., Lourinho F., et al. 2001. Length-weight relationships for 21 coastal fish species of the Azores, North-Eastern Atlantic. Fish. Res. 50: 297-302.

https://doi.org/10.1016/S0165-7836(00)00215-0

Nelson J.S., Grande T.C., Wilson M.V.H. 2016. Fishes of the world. 4th ed. Wiley-Blackwell, Inc, New Jersey, 707 pp.

https://doi.org/10.1002/9781119174844

Pothis K., Gonzales-Salas C., Chabanet P., et al. 2006. Distinction between Mulloidichthys flavolineatus juveniles from Reunion Island and Mauritius Island (south-west Indian Ocean) based on otolith morphometrics. J. Fish Biol. 69: 38-53.

https://doi.org/10.1111/j.1095-8649.2006.01047.x

Rawat S., Benakappa S., Jitendra Kumar A.S., et al. 2017. Identification of fish stocks based on truss morphometric: A review. J. Fish. Life Sci. 2: 9-14.

Sajina A.M., Chakraborty S.K., Jaiswar A.K., et al. 2011. Stock structure analysis of Megalaspis cordyla (Linnaeus, 1758) along the Indian coast based on truss network analysis. Fish. Res. 108: 100-105.

https://doi.org/10.1016/j.fishres.2010.12.006

Siddik M.A.B., Hanif M.A., Chaklader M.R., et al. 2015. Fishery biology of gangetic whiting Sililagnopsis panijas (Hamilton, 1822) endemic to Ganges delta, Bangladesh. Egypt. J. Aquat. Res. 41: 307-313.

https://doi.org/10.1016/j.ejar.2015.11.001

Siddik M.A.B., Chaklader M.R., Hanif M.A., et al. 2016, Stock identification of critically endangered olive barb, Puntius sarana (Hamilton, 1822) with emphasis on management implications. J. Aquac. Res. Dev. 7: 1-6.

https://doi.org/10.4172/2155-9546.1000411

Turan C. 2004. Stock identification of Mediterranean horse mackerel (Trachurus mediterraneus) using morphometric and meristic characters. ICES J. Mar. Sci. 61: 774-781.

https://doi.org/10.1016/j.icesjms.2004.05.001

Turan C., Yalcın S., Turan F., et al. 2005. Morphometric comparisons of African catfish, Clarias gariepinus, populations in Turkey. Folia Zool. 54: 165-172.

Turan C., Oral M., Öztürk B., et al. 2006. Morphometric and meristic variation between stocks of Bluefish (Pomatomus saltatrix) in the Black, Marmara, Aegean and northeastern Mediterranean Seas. Fish. Res. 79: 139-147.

https://doi.org/10.1016/j.fishres.2006.01.015

Turan C., Gündüz I., Gurlek M., et al. 2009. Systematics of Scorpaeniformes species in the Mediterranean Sea inferred from mitochondrial 16s rDNA sequence and morphological data. Folia Biol. 57: 219-226.

https://doi.org/10.3409/fb57-1-2-219-226

Ujjainia N.C., Kohli M.P.S. 2011. Landmark-based morphometric analysis for selected species of Indian major carp (Catla catla, Ham. 1822). Int. J. Food Agric. Vet. Sci. i: 64-74.

Wimberger P.H. 1992. Plasticity of fish body shape. The effects of diet, development, family and age in two species of Geophagus (Pisces: Cichlidae). Biol. J. Linn. Soc. 45: 197-218.

https://doi.org/10.1111/j.1095-8312.1992.tb00640.x

Yulianto D., Indra I., Batubara A.S., et al. 2020. Morphometrics and genetics variations of mullets (Pisces: Mugilidae) from Aceh waters, Indonesia. Biodiversitas 21: 3422-3430.

https://doi.org/10.13057/biodiv/d120802

SUPPLEMENTARY MATERIAL

The following supplementary material is available through the online version of this article and at the following link: http://scimar.icm.csic.es/scimar/supplm/sm05185esm.pdf

Table S1. – Ranges of selected morphometric variables of S. elongata populations.

Table S2. – Ranges of selected morphometric variables of S. maderensis populations.

Table S3. – Ranges of selected morphometric variables of S. notata populations.

Table S4. - Ranges of selected morphometric variables of S. porcus populations.

Table S5. – Ranges of selected morphometric variables of S. scrofa populations.
Intra- and interspecific discrimination of *Scorpaena* species from the Aegean, Black, Mediterranean and Marmara seas

Serdar Yedier, Derya Bostanci

Supplementary material
Table S1. – Ranges of selected morphometric variables of *S. elongata* populations.

| Morphometric Variables | Antalya       | Hatay        | İzmir       |
|------------------------|---------------|--------------|--------------|
| BL/SL                  | 0.293-0.365   | 0.296-0.325  | 0.324-0.346  |
| LDL/SL                 | 0.170-0.194   | 0.164-0.171  | 0.162-0.168  |
| PAL/SL                 | 0.667-0.735   | 0.732-0.746  | 0.730-0.733  |
| POH/SL                 | 0.088-0.091   | 0.089-0.092  | 0.092-0.096  |
| NL/SL                  | 0.098-0.103   | 0.098-0.099  | 0.097-0.101  |
| ML/SL                  | 0.209-0.215   | 0.213-0.228  | 0.211-0.230  |
| ED/SL                  | 0.131-0.161   | 0.136-0.175  | 0.081-0.083  |
| PBL/SL                 | 0.124-0.130   | 0.122-0.133  | 0.121-0.147  |
| VBL/SL                 | 0.022-0.044   | 0.028-0.046  | 0.023-0.051  |
| VSL/SL                 | 0.137-0.172   | 0.146-0.180  | 0.136-0.167  |
| ABL/SL                 | 0.138-0.155   | 0.136-0.155  | 0.137-0.156  |
| LAL/SL                 | 0.147-0.167   | 0.136-0.168  | 0.145-0.180  |

Standard length (SL), body height (BL), longest dorsal fin spine length (LDL), preanal length (PAL), preorbital height (POH), snout length (NL), maxilla length (ML), eye diameter (ED), pectoral fin base length (PBL), ventral fin base length (VBL), ventral fin spine length (VSL), anal fin base length (ABL) and longest anal fin spine length (LAL).

Table S2. – Ranges of selected morphometric variables of *S. maderensis* populations.

| Morphometric Variables | Antalya       | Balıkesir    | İzmir       |
|------------------------|---------------|--------------|--------------|
| BL/SL                  | 0.362-0.370   | 0.361-0.375  | 0.336-0.347  |
| LDL/SL                 | 0.165-0.169   | 0.172-0.181  | 0.155-0.165  |
| PAL/SL                 | 0.697-0.724   | 0.701-0.703  | 0.667-0.676  |
| POH/SL                 | 0.088-0.091   | 0.088-0.091  | 0.078-0.088  |
| ML/SL                  | 0.207-0.210   | 0.214-0.227  | 0.204-0.210  |
| CPH/SL                 | 0.107-0.110   | 0.096-0.103  | 0.10-0.106   |
| CPL/SL                 | 0.082-0.089   | 0.062-0.073  | 0.070-0.073  |
| PBL/SL                 | 0.142-0.146   | 0.140-0.147  | 0.128-0.138  |
| ABL/SL                 | 0.164-0.180   | 0.166-0.189  | 0.165-0.180  |
| LAL/SL                 | 0.169-0.196   | 0.169-0.202  | 0.158-0.196  |

Standard length (SL), body height (BL), caudal peduncle height (CPH), caudal peduncle length (CPL), longest dorsal fin spine length (LDL), preanal length (PAL), preorbital height (POH), maxilla length (ML), pectoral fin base length (PBL), anal fin base length (ABL) and longest anal fin spine length (LAL).

Table S3. – Ranges of selected morphometric variables of *S. notata* populations.

| Morphometric Variables | Hatay        | İzmir       | Marmara Ereğlisi | Şile          |
|------------------------|--------------|--------------|------------------|---------------|
| BL/SL                  | 0.337-0.362  | 0.356-0.362  | 0.357-0.361      | 0.349-0.356   |
| LDL/SL                 | 0.175-0.193  | 0.159-0.203  | 0.160-0.174      | 0.150-0.170   |
| POH/SL                 | 0.069-0.078  | 0.054-0.088  | 0.063-0.071      | 0.070-0.077   |
| NL/SL                  | 0.109-0.130  | 0.106-0.136  | 0.109-0.116      | 0.106-0.117   |
| ML/SL                  | 0.221-0.236  | 0.204-0.236  | 0.201-0.225      | 0.208-0.217   |
| ED/SL                  | 0.089-0.104  | 0.089-0.107  | 0.080-0.098      | 0.082-0.094   |
| PBL/SL                 | 0.136-0.155  | 0.140-0.154  | 0.134-0.137      | 0.137-0.141   |
| CPH/SL                 | 0.102-0.110  | 0.096-0.109  | 0.096-0.099      | 0.093-0.101   |
| CPL/SL                 | 0.064-0.081  | 0.059-0.083  | 0.062-0.069      | 0.059-0.071   |
| ABL/SL                 | 0.145-0.183  | 0.147-0.176  | 0.147-0.179      | 0.152-0.175   |
| VSL/SL                 | 0.147-0.154  | 0.154-0.156  | 0.128-0.144      | 0.127-0.150   |
| STL/SL                 | 0.025-0.032  | 0.037-0.052  | 0.039-0.042      | 0.025-0.027   |

Standard length (SL), body height (BL), caudal peduncle height (CPH), caudal peduncle length (CPL), longest dorsal fin spine length (LDL), preorbital height (POH), snout length (NL), maxilla length (ML), eye diameter (ED), pectoral fin base length (PBL), ventral fin spine length (VSL), anal fin base length (ABL), longest anal fin spine length (LAL) and supraocular tentacle length (STL).
Intra- and interspecific discrimination of *Scorpaena* species

Table S4. - Ranges of selected morphometric variables of *S. porcus* populations.

| Morphometric Variables | Hatay     | İzmir     | Marmara  | Ereğlisi |
|------------------------|-----------|-----------|----------|----------|
| BL/SL                  | 0.352-0.394 | 0.357-0.456 | 0.347-0.403 | 0.354-0.385 |
| SDL/SL                 | 0.082-0.101 | 0.089-0.092 | 0.085-0.089 | 0.085-0.095 |
| LDL/SL                 | 0.149-0.179 | 0.153-0.179 | 0.141-0.157 | 0.150-0.185 |
| NL/SL                  | 0.104-0.110 | 0.100-0.110 | 0.102-0.109 | 0.107-0.113 |
| ML/SL                  | 0.212-0.216 | 0.196-0.220 | 0.208-0.212 | 0.219-0.227 |
| ED/SL                  | 0.077-0.105 | 0.088-0.104 | 0.066-0.077 | 0.082-0.110 |
| PBL/SL                 | 0.139-0.142 | 0.141-0.155 | 0.149-0.163 | 0.145-0.155 |
| CPH/SL                 | 0.095-0.117 | 0.081-0.108 | 0.087-0.107 | 0.097-0.108 |
| CPL/SL                 | 0.080-0.086 | 0.078-0.098 | 0.066-0.083 | 0.080-0.082 |
| ABL/SL                 | 0.150-0.176 | 0.149-0.176 | 0.143-0.152 | 0.149-0.182 |
| VSL/SL                 | 0.137-0.153 | 0.146-0.160 | 0.144-0.149 | 0.135-0.157 |
| STL/SL                 | 0.078-0.099 | 0.088-0.104 | 0.066-0.077 | 0.085-0.102 |

Standard length (SL), body height (BL), caudal peduncle height (CPH), caudal peduncle length (CPL), shortest dorsal fin spine length (SDL), longest dorsal fin spine length (LDL), snout length (NL), maxilla length (ML), eye diameter (ED), pectoral fin base length (PBL), ventral fin spine length (VSL), anal fin base length (ABL), longest anal fin spine length (LAL) and supraocular tentacle length (STL).

Table S5. – Ranges of selected morphometric variables of *S. scrofa* populations.

| Morphometric Variables | Çanakkale | Hatay     | İzmir     |
|------------------------|-----------|-----------|-----------|
| BL/SL                  | 0.310-0.329 | 0.292-0.324 | 0.312-0.338 |
| SDL/SL                 | 0.092-0.094 | 0.075-0.098 | 0.089-0.091 |
| LDL/SL                 | 0.178-0.204 | 0.171-0.185 | 0.170-0.187 |
| POH/SL                 | 0.126-0.136 | 0.123-0.125 | 0.132-0.140 |
| NL/SL                  | 0.092-0.131 | 0.091-0.126 | 0.127-0.129 |
| ML/SL                  | 0.226-0.228 | 0.212-0.219 | 0.210-0.234 |
| PBL/SL                 | 0.130-0.149 | 0.133-0.137 | 0.149-0.166 |
| CPH/SL                 | 0.088-0.109 | 0.092-0.097 | 0.102-0.109 |
| ABL/SL                 | 0.148-0.156 | 0.145-0.153 | 0.138-0.177 |
| VSL/SL                 | 0.145-0.171 | 0.127-0.163 | 0.144-0.215 |

Standard length (SL), body height (BL), caudal peduncle height (CPH), shortest dorsal fin spine length (SDL), longest dorsal fin spine length (LDL), preorbital height (POH), snout length (NL), maxilla length (ML), pectoral fin base length (PBL), ventral fin spine length (VSL) and anal fin base length (ABL).