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COMPARATIVE MORPHOMETRIC ANALYSIS OF THE SMALL-SCALED SCORPIONFISH, *SCORPAENA PORCUS* (SCORPAENIDAE, SCORPAENIFORMES), FROM THE SOUTHERN COAST OF THE CRIMEA AND EASTERN PART OF THE ADRIATIC SEA

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Comparative Morphometric Analysis of Small-Scaled Scorpionfish, *Scorpaena porcus* (Scorpaenidae, Scorpaeniformes), from the Southern Coast of the Crimea and Eastern Part of the Adriatic Sea. Manilo, L. G., Peskov, V. N. — Comparative analysis of morphometric characters of small-scaled scorpionfish from the Black Sea (near the southern coast of the Crimea) and from the eastern part of the Adriatic Sea showed significant differences in males and females on thirteen plastic and three meristic characters. These differences may be due to unequal abiotic and biotic habitat conditions, and refer about the geographical variability of the species, indicating the presence of two different populations in the study area.

K e y w o r d s: plastic characters, meristic characters, small-scaled scorpionfish, *Scorpaena porcus*, Black Sea, Adriatic Sea.

Introduction

Family Scorpaenidae comprises 216 species of 26 genera, widely distributed from the coastal waters to depths of over 2000 m in tropical, subtropical and temperate zones of the Pacific, Indian and Atlantic Oceans (Froese, Pauly, 2012). The area of a typical representative of the family — small-scaled scorpionfish, *S. porcus* (Linnaeus, 1758) covers waters of the East Atlantic from Britain to Morocco (up to Senegal, according to some researchers), including the Azores and the Canary Islands, the Mediterranean, the Black Sea and partially the Sea of Azov (Diripasko, 2011; Vasil'eva, Luzhnyak, 2013, Bat et al., 2005; Fricke et al., 2007; Mahé et al., 2014).

Small-scaled scorpionfish is a demersal species found on rocky soils, accumulations of boulders or limestone, covered with thickets of *Cystoseira*. It is mainly nocturnal fish, which feeds on crustaceans and small fish (Carpentieri et al., 2001; Morte et al., 2001). This species is characterized by its "molting": on average every 28 days, the upper layer of its skin with scales clears and replaced by a new one (Vasil'eva, 2007, etc.). In the Black Sea, particularly near the Turkish coast, *S. porcus* is well represented in the local fishery. Near the coast of the Crimea, this fish is an object of amateur fishing and spearfishing within the depths of 5–20 m. In *S. porcus*, sex differences in the rate of growth, maturation and life span, as well as in linear dimensions and proportions of the body are well expressed (Smirnov, 1986; Bilgin, Çelik, 2009; Ferri et al., 2010; Peskov, Manilo, 2016). According to the literature, females grow faster than males and usually are larger in the same age. Females on average live longer than males (Smirnov, 1986; Bilgin, Çelik, 2009; Ferri et al., 2010). Sex differences in the linear dimensions and proportions of the body begin to appear from the age of three years (Smirnov, 1986).

Despite the relatively well-studied biology of the small-scaled scorpionfish in various parts of the Mediterranean Sea and the Black Sea (Pashkov et al., 1999; Bilgin, Çelik, 2009; Turan et al., 2009; La Mesa et al., 2010; Scarcella et al., 2011, etc.), as well as the often quoted descriptions and information on the main meristic characters in many special sources (Svetovidov, 1964; Karapetkova, Zhivkov, 2006; Vasil'eva, 2007; Boltachev, Karpova, 2012; Vasil'eva, Luzhnyak, 2013; Golani et al., 2006, etc.), in-depth and comparative morphological data on this species are quite rare.

The aim of this study is a comparative morphometric analysis of *S. porcus* from the coastal waters of the Black Sea near the southern coast of the Crimea and in the eastern part of the Adriatic Sea.

Material and methods

The basis of our work is the data on morphology of *S. porcus*, obtained in the processing of ichthyological collection in the National Museum of Natural History (NMNH) NAS of Ukraine. The material is represented by samples from the coastal waters of the Crimea: No 1163, Ukraine, Crimea, Sudak District, Karadag Nature Reserve, the Black Sea, 1–23.06.1978; No 2848, Ukraine, Crimea, near Sevastopol, the Black Sea, 09.1985; No 2852, Ukraine, Crimea, near Sevastopol, the Black Sea, 20.06.1981; No 2853, Ukraine, Crimea, Sudak district, Karadag Nature Reserve, the Black Sea, 27.01.1986; No 5663, Ukraine, Crimea, near Yalta, Mishor, the Black Sea, 15–16.08.1996; No 5681, Ukraine, Crimea, near Sevastopol, Quarantine bay, the Black Sea, 15–30.06.1981; No 6577, Ukraine, Crimea, Sevastopol, Aleksandrovskaya bay, the Black Sea, 9.10.2002; No. 6589, Ukraine, Crimea, near Sevastopol, Balaklava District, Balaklava bay, the Black Sea, 10.10.2002; No 7206, Ukraine, Crimea, near Sevastopol, Quarantine bay, the Black Sea, 7–15.05.2008; No 7652, Ukraine, Crimea, near Sevastopol, Sevastopol bay, the Black Sea, 21.06.2008; No 7905, Ukraine, Crimea, Sudak District, Karadag Nature Reserve, the Black Sea, 12–14.09.2010; No 7914, Ukraine, Crimea, near Yalta, "Cape Martyan" Reserve, the Black Sea, 9.09.2010; No 9531, Ukraine, Crimea, Sudak District, Karadag Nature Reserve, the Black Sea, 1–5.06.2013, No 9543, Ukraine, Crimea, near Yalta, "Cape Martyan" Reserve, the Black Sea, 6–9.06.2013. Total of 73 specimens were processed, including 21 female, 40 males and 12 individuals without sex determination.

Fish were caught by gillnets in the coastal waters depths ranging from 10 to 15 m, and fixed in 4 % formaldehyde solution for further processing in laboratory conditions. Morphological analysis was performed according to the methodic adopted for members of the family Scorpaenidae (Pravdin, 1966) under the scheme with minor changes: TL — the total length of the body; SL — standard body length; LD — the length of dorsal fin base; LA — the length of anal fin base; LP — the length of pectoral fin; LV — the length of pelvic fin; LC — the length of caudal fin; PD — predorsal (antedorsal) length; pD — postdorsal length (from the end of dorsal fin base to the beginning of the base of caudal fin rays); l_{caud} — the length of caudal peduncle (from the end of anal fin base before the base of caudal fin rays); PA — preanal (anteanal) length; PV — preventral (anteventral) length; PP — prepectoral (antepectoral) length; H — maximum height of the body (on vertical of the third rigid dorsal fin); h — height of caudal peduncle; CL — length of the head from the start of upper lip to the top edge of the gill cover; O — diameter of the eye; PO — preorbital length; IO — interorbital length; OLO — postorbital length (from the posterior edge of the eye to the end of horizontal spine on the gill cover); mx — the length of the upper lip. The following meristic characters were also counted: D — the number of spiny rays in dorsal fin; d — number of soft rays in dorsal fin; A — number of spiny rays in anal fin; a — number of soft rays in anal fin; P — number of rays in pectoral fin; V — number of spiny rays in ventral fin; v — number of soft rays in ventral fin; sp. br. — number of gill rakers on the first gill arch; squ — number of bored scales in the lateral line; l.l. — number of scales along the lateral side of the body.

In the study of body proportions were calculated relative values for 20 plastic characters: relative to the standard body length — 14 (for all measurements except those for head), relative to the head length — 5 (for measurements of the head) and 1 — the ratio of caudal peduncle height to the maximum height of the body. The sex of the small-scaled scorpionfish was determined on the absolute values of plastic characters using a linear discriminant analysis (Peskov, Manilo, 2016). For each sample, standard statistical parameters in a number of variations were calculated: minimum (min), maximum (max) and the arithmetic mean (M) of character value, the error of the arithmetic mean (m), standard deviation (SD) and the coefficient of variation (CV, %). The size variability of body proportions in the scorpionfish was studied using linear correlation coefficient (r), which is calculated between the value of the standard body length of the fish (SL) and the corresponding values of morphometric indices. Student's t-test (Lakin, 1990) was used to compare the variability of the studied characters (CV). Differences at the 5 % significance level were considered as statistically significant. All calculations were performed on PC using the STATISTICA, v. 6.

Results and discussion

Plastic characters. Dimensional variability of body proportions in *S. porcus* in the sample from the coastal waters of the Black Sea near the southern coast of the Crimea is practically absent. A slight negative correlation with the standard body length (SL) is observed for the three indices (LC/SL, O/CL, mx/CL) of the 20 studied (r = –0.36, –0.30, –0.26, respectively). A low positive correlation with SL is obtained for two indices (PA/SL and OLO/CL) (r = 0.26 and 0.34, respectively). On this basis, further analysis of the variability of body proportions in the scorpionfish were carried out without taking into account body size and age of the fish.

Within the area, the total body length (TL) in adult scorpionfish sufficiently varies strongly depending on the age, sex and locality. For example, in the Black Sea the small-scaled scorpionfish at the age of 7–8 years reaches a body length of 28–30 cm (Smirnov, 1986). To the south-eastern part of the Black Sea, Bilgin and Çelik (2009) provide the maximum values of the total body length 23.6 cm for scorpionfish males, and 31.7 cm — for females. Near the

southern coast of the Crimea, the total body length varies from 13.1 to 20.5 cm in males, and from 13.1 to 26.1 cm in females (our data). According to Ferri et al. (2010), in the eastern Adriatic, the total length of the body (TL) in adult males varies from 10.3 to 23.4 cm, and from 10.2 to 25.8 cm in females. Differences between adult individuals of the Black Sea and the Adriatic populations in the TL is not statistically significant (tables 1 and 2).

Results of comparison of the small-scaled scorpionfish from two remote localities on body proportions suggest that the relative values of nine characters (CL/SL, LD/SL, LA/SL, PD/SL, PP/SL, h/SL, IO/CL, PO/CL and h/H) are on average significantly higher in individuals of both sexes from the Black Sea population as compared to those from the Adriatic. The mean relative values of the two characters (LP/SL, LV/SL), on the contrary, are higher in males and females of scorpionfish from the Adriatic Sea as compared to those from the Black Sea (tables 1 and 2).

There are statistically significant differences between females in the relative value of the standard length of the body (the mean value of SL/TL index is higher in females of the Black Sea population) and the postorbital length (the mean value of OLO/CL index is greater in females from the eastern Adriatic). In males, the differences on these characters are not expressed. The relative length of the caudal fin (LC/SL) and the relative diameter of the eye (O/CL) was significantly greater in males of the Black Sea population as compared with males of the Adriatic Sea. The differences between the females on these two characters are not statistically significant.

Unfortunately, we were not able to carry out an interpopulation-based comparison of the three plastic characters (pD/SL, l_{caud}/SL and mx/CL), which we consider essential for this species due to lack of such data for fish from the Adriatic Sea.

Table 1. Comparison of females of *S. porcus* from the Adriatic and the Black Seas on mean values of plastic characters using the Student's t-test

Characters	Adriatic Sea (Ferri et al., 2010) ♀ (n = 226)		Black Sea, Crimea (our data) ♀ (n = 21)		t
	min–max	M ± SD	min–max	M ± SD	
TL, mm	102.0–258.0	164.1 ± 3.40	131.0–261.0	171.0 ± 3.53	0.86
SL/TL	72.94–88.48	77.50 ± 1.981	76.2–84.0	78.46 ± 1.955	–2.15*
CL/SL	34.01–45.74	40.37 ± 2.259	40.7–45.2	43.20 ± 1.314	–8.74***
LD/SL	43.97–66.91	58.89 ± 3.445	58.2–66.8	62.77 ± 2.287	–7.07***
LA/SL	10.48–20.00	14.53 ± 1.637	14.4–20.2	17.29 ± 1.387	–8.57***
LP/SL	23.85–35.11	30.02 ± 2.468	24.8–29.3	27.42 ± 1.400	7.49***
LV/SL	21.26–32.46	26.59 ± 2.263	20.9–28.1	25.25 ± 1.776	3.22**
LC/SL	19.51–33.61	26.96 ± 2.211	19.1–30.6	27.41 ± 2.935	–0.68
PD/SL	26.05–37.65	32.13 ± 2.197	31.4–38.6	34.66 ± 2.136	–5.18***
pD/SL	–	–	6.1–10.7	8.77 ± 1.281	–
l_{caud}/SL	–	–	12.1–16.6	14.39 ± 1.529	–
PA/SL	57.82–80.00	68.45 ± 2.884	63.1–74.1	68.43 ± 2.787	0.03
PP/SL	30.61–48.03	37.75 ± 2.307	36.2–42.9	39.46 ± 1.977	–3.74***
PV/SL	25.00–47.76	40.12 ± 2.981	36.7–45.8	40.24 ± 2.351	–0.22
H/SL	30.49–47.37	37.11 ± 2.573	33.6–42.0	37.27 ± 2.200	–0.31
h/SL	7.19–13.47	9.69 ± 0.824	9.8–11.2	10.51 ± 0.347	–8.75***
O/CL	13.64–31.25	21.78 ± 3.099	18.5–26.3	22.13 ± 2.111	–0.69
IO/CL	4.17–23.08	12.51 ± 2.246	11.1–14.9	13.12 ± 1.162	–2.07*
PO/CL	10.42–36.36	25.03 ± 3.275	24.2–29.5	25.95 ± 1.546	–2.29*
OLO/CL	21.85–57.69	47.51 ± 4.343	43.6–48.9	46.03 ± 1.608	3.26**
mx/CL	–	–	46.5–50.9	48.46 ± 1.253	–
h/H	21.21–36.17	26.19 ± 2.260	26.4–30.3	28.30 ± 1.214	–6.93***

Note. In tables 1–3: min–max — minimum and maximum values of the character; M — its mean value; SD — standard deviation; t — Student's t-test; ** $P < 0{,}01$; *** $P < 0{,}001$.

Table 2. Comparison of males of *S. porcus* from the Adriatic and the Black Seas on mean values of plastic characters using the Student's t-test

Characters	Adriatic Sea (Ferri et al., 2010) ♂ (n = 179)		Black Sea, Crimea (our data) ♂ (n = 40)		t
	min–max	M ± SD	min–max	M ± SD	
TL, cm	103.0–234.0	151.0 ± 2.48	131.0–205.0	154.0 ± 1.68	0.93
SL/TL	66.91–82.93	76.53 ± 1.980	75.2–78.5	76.80 ± 0.840	–1.36
CL/SL	34.56–46.49	40.42 ± 2.238	40.7–46.8	43.47 ± 1.203	–12.04***
LD/SL	50.49–69.77	59.07 ± 3.358	58.7–66.8	63.03 ± 0.268	–15.56***
LA/SL	11.18–21.87	15.01 ± 1.598	16.4–20.8	18.61 ± 1.068	–17.41***
LP/SL	24.80–38.38	31.31 ± 2.711	25.7–32.9	28.70 ± 1.588	8.09***
LV/SL	21.31–34.41	28.06 ± 2.558	23.3–30.8	26.72 ± 1.627	4.18***
LC/SL	23.35–34.75	28.17 ± 2.067	27.4–33.0	30.23 ± 1.425	–7.54***
PD/SL	26.59–41.44	32.38 ± 2.390	32.2–37.1	34.36 ± 1.095	–7.96***
pD/SL	–	–	6.1–10.8	8.55 ± 1.024	–
l_{caud}/SL	–	–	12.2–17.3	14.78 ± 1.170	–
PA/SL	60.19–74.60	67.69 ± 2.385	64.0–73.4	67.79 ± 1.911	–0.29
PP/SL	32.74–50.69	38.11 ± 2.474	37.7–43.3	39.90 ± 1.205	–6.74***
PV/SL	23.40–47.66	39.87 ± 3.710	37.7–49.1	40.56 ± 2.021	–1.63
H/SL	26.40–45.76	36.89 ± 2.761	34.5–40.3	37.38 ± 1.375	–1.63
h/SL	6.76–13.79	9.59 ± 0.909	9.9–11.0	10.55 ± 0.287	–11.75***
O/CL	14.28–32.61	22.21 ± 3.191	19.3–26.5	23.30 ± 1.785	–2.95**
IO/CL	7.69–22.73	12.47 ± 2.087	11.0–16.0	13.25 ± 1.073	–3.38***
PO/CL	15.38–36.73	24.49 ± 3.684	23.1–28.4	25.68 ± 1.286	–3.48***
OLO/CL	20.51–65.45	46.16 ± 5.057	40.9–49.9	45.53 ± 1.960	1.29
mx/CL	–	–	46.1–55.0	49.35 ± 1.836	–
h/H	16.67–38.09	26.08 ± 2.730	26.3–30.8	28.27 ± 1.025	–8.40***

Thus, adult mature specimens of the small-scaled scorpionfish from the waters of the Black Sea and the eastern Adriatic were not significantly different in total body size (TL). Body proportions in individuals of both populations are practically independent of their total body size. According to the results of the comparative analysis, scorpionfish from the Adriatic population is characterized a significantly greater length of pectoral and pelvic fins, taken with respect to the standard body length. The relative sizes of most other plastic characters on average is significantly higher in scorpionfish from the Black Sea population (tables 1, 2).

Meristic characters. There are no statistically significant differences in three from seven analyzed meristic characters between fish from the Adriatic and Black seas. The number of spiny and soft rays in the ventral fin was the same in all processed specimens — one spiny ray and five soft. According to Ferri et al. (2010), the number of rays in dorsal fin of the fish from the Adriatic is constant: twelve spiny and ten soft. According to our data, in individual scorpionfish specimens from the Black Sea there are 11 or 13 (usually 12) spiny rays in the dorsal fin, and the number of soft rays varies from 9 to 11, but these differences were not statistically significant and are not presented in table 3.

Data on one of the meristic characters (the number of perforated scales in the lateral line) in scorpionfish from the Adriatic Sea are absent in Ferri et al. (2010). This character is generally not observed in the known literature, however, we believe it is essential. Despite the minor differences in the number of rays in the anal fin of the small-scaled scorpionfish of two different localities, they were statistically significant ($t = 4,7$ at $P < 0,001$). The coefficient of variation on this character amounted 4.40 in the Adriatic Sea, and 4.78 in the Black Sea (table 3.).

The most significant differences between fish from the Adriatic and the Black Sea was obtained by the following characters. The number of gill rakers in fish from the Adriatic Sea

Table 3. Comparison of meristic characters of *S. porcus* from the Adriatic and the Black Seas

Characters	Adriatic Sea (Ferri et al., 2010) ♂, ♀ (n = 450)			Black Sea, Crimea (our data) ♂, ♀ (n = 73)			t
	min–max	M±SD	CV (%)	min–max	M±SD	CV (%)	
A+a	III+5–6	8.82 ± 0.388	4.40	III+5–7	9.00 ± 0,287	4.78	4.7***
sp. br.	14–17	15.56 ± 0.456	2.93	11–15	13.23 ± 0.731	5.53	26.4***
squ	–	–	–	23–28	25.56 ± 1.182	4.62	–
l.l.	52–55	53.5 ± 0.625	1.17	58–64	61.23 ± 1.898	3.10	34.5***

Note. CV — coefficient of variation.

varies from 14 to 17 with a mean of 15.6. In the Black Sea their number is much smaller — from 11 to 15 (M = 13.2), while the Student's t-test was 26.4 (P < 0,001). Comparing the data on the number of scales along the lateral sides of the fish body from the Adriatic and the Black Seas, we found significant differences. This value is significantly higher in fish from the Black Sea, the mean of 61.23 (53.5 in the Adriatic) and the Student's t-test (t) was the highest among all the plastic and meristic characters.

Table 3, presented by Ferri et al. (2010, p. 49), contains the meristic characters of *S. porcus* from different localities. Comparison of such data from these areas is not permitted, with the exception of their own observations and materials of Eschmeyer (1969) from East Atlantic. For example, it is not correct to compare the data from the Adriatic Sea with compilated one from the Mediterranean Sea and the Atlantic or those from the Mediterranean and Black Seas. Investigating the variability of characters of the species from western to eastern borders of the area, it is necessary to compare them from the limited and more specific water areas, which may be the subject of further studies on this species.

It is known that the biological characteristics of species are depending on the temperature of sea water (Wootton, 1990). Distance and geographical location of areas can also affect on the specifics of organisms from different parts of the area (Munch, Salinas, 2009; Pauly, 2010).

Comparing the hydrological conditions of matched water bodies, we can note the following. The salinity of the Adriatic Sea waters is 38–38.5 ‰, and 38.3 ‰ in the eastern part of the media. Its surface waters in the coastal area have a pronounced annual change-set temperature. In winter, temperature of the water surface is about 7 °C, rarely dropping below, and rising 18 °C in the spring. It reaches a maximum of 22–24 (25) °C in the summer; mean annual water temperature is 11 °C (Russo, Artegiani, 1996; Lipizer et al., 2014). The Mediterranean Sea, including the Adriatic, is characterized by very low levels of biological productivity, which is the result of a small influx of river waters and weak vertical circulation for most of the year.

In contrast to the Adriatic Sea, the salinity in the coastal waters of the Black Sea is less than half, in particular, salinity values in the surface layers on the southern coast of Crimea are close to 17.5 ‰ only in June, in the rest of year they increase to 18.0–18.3 ‰ (Chekmenyova, Subbotin, 2009). The local water circulations with anticyclonic pattern are permanently fixed in coastal parts of the sea. The temperature of the surface water layers, depending on the time of year, is ranged from 6 to 25 °C on average in open sea, but sometimes reaching 30–32 °C in shallow waters near the coast in summer and freezing in winter. In the Black Sea, the phenomenon of biological productivity is expressed much stronger than in those in the Adriatic. It is provided mainly due the large influx of nutrient salts with river waters and partly from the Sea of Azov.

Significant differences in the plastic and meristic characters between the samples of small-scaled scorpionfish from the Adriatic and the Black Seas, in our opinion, are connected with geographical variability and are the result of adaptation of this species to the exist in specific environmental conditions. These differences indicate the existence of two geographically isolated populations of *S. porcus* in the study area.

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