

Distinctive features of species of *Spicara* genus in Sevastopol coastal area

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Abstract: Based on the results of long-term observations of the species composition of the ichthyofauna in the coastal waters near the city of Sevastopol (Black Sea), we noted the occurrence of Mediterranean species *Spicara maena* from 2010, mainly in the Balaklavskaya bay. The frequency of blotched picarel, *Spicara maena* L. 1758 in catches of Sevastopol fishermen made it possible to carry out a detailed analysis of two species of the *Spicara* genus to identify differences in values of morphophysiological and morphometric parameters for *Spicara flexuosa* and *Spicara maena* in the period 2016 – 2018. The findings can be regarded as sound evidence of the existence of two species of the genus *Spicara* - *S. flexuosa* and *S. maena* - in Sevastopol coastal waters since such characteristics as the maximum body height and body height at the end of gill cover, the length of the segment between lower jaw apex and starting point of the base of the first pectoral and first dorsal fins, the length of the anal and dorsal fins, the number of rays in the dorsal fin differ significantly for these two species. The ratio of the height of fish head to its length, which is one of diagnostic signs used to differentiate species, also differs significantly for *S. flexuosa* and *S. maena*. In addition, during periods of rest, hepatosomatic and gonadosomatic indexes for the high body pickerel are noticeably higher than those for the blotched picarel.

Keywords: *Spicara flexuosa*, *Spicara maena*, Black Sea, Sevastopol

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1. Introduction

Invasive alien species are animals or plants that have been introduced naturally or as a result of artificial acclimatization to new environments, outside their previous habitats. A suitable food source base for their thriving in Black Sea coastal waters together with another factor – global warming – leads to “mediterrization”, including a new formation of ichthyofauna.

Centracanthidae fish are an essential Black Sea bioresource as they are an important link of the trophic chain. They have a wide feeding habits spectrum (from zooplankton organisms to benthic animal forms), in addition to being themselves a food source for large species of carnivorous fish and currently one of the main parts of dolphin diet (Krivokhizhin and Birkun, 2009; Gladilina and Goldin, 2014).

There are three species of the *Spicara* genus in the Black Sea, among which *S. flexuosa* (Rafinesque, 1810) is the most widespread in the waters along all the coasts of the sea.

(Svetovidov, 1964; Salekhova, 1979; Vasilieva and Salekhova, 1983; www.fish.base). According to S. Stoyanov (cit. according to Svetovidov, 1964), Mediterranean blotched picarel and the picarel *Spicara alcedo* (Risso, 1810) were earlier found in single specimens only near Bulgaria. However, already in 2012, Ph.D. Boltachev A.R. indicated that two species of the genus *Spicara* — the high body pickerel and blotched picarel live near Crimea, the latter is reported to be periodically seen in fishermen catches along the southern coast of Crimea from Balaklavskaya bay to Ayudag (Boltachev and Karpova, 2012).

According to some fishermen reports and my observations, the blotched picarel has been seen regularly in catches in the area of the Balaklavskaya bay and Vasileva Balka since about 2010, mainly in summer and periods when water temperature drops due to wind-driven effects, upwelling. At the present time, *S. maena* is found in the samples from other Sevastopol bays all the year round, and in the Balaklavskaya bay this species practically has displaced the *S. flexuosa*.

Based on observations and analysis of these two species in 2018, it can be said some representatives of the high body pickarel and the blotched picarel are not clearly distinguishable from each other, which suggests that the *S. maena* not only confidently acclimatized in the entire marine area of Sevastopol, but, possibly, hybridized with the *S. flexuosa*. According to Salekhova L.P. (1979), hybridization of these two species took place in the Mediterranean basin. This study aims to confirm the existence of two species *S. flexuosa* and *S. maena* in the coastal waters of Sevastopol at present on the basis of comparative complex analysis of morphophysiological and morphometric of fish as well as to identify key biological parameters that can characterize these two species accurately.

2. Materials and Methods

The biological analysis of characteristics of the typical specimens of *S. flexuosa* Rafinesque, 1810 and *S. maena* L. 1758 (Pisces, Centranchidae) was carried out on fish caught in the bays of Sevastopol (Karantinnaya, Aleksandrovskaya, Balaklavskaya, Strelezkaya) using bottom snares in the period 2016-2018. Initially, the basis we used to distinguish the blotched picarel from high body pickarel was the sign that the length of head is less than body height (Tortonese, 1975, 1986; Fisher et al., 1987).

Next, biological analysis was carried out in accordance with approved techniques (Pravdin, 1966; Schwartz et al. 1968). Their age was determined by reading the scale. Three morphophysiological indices of these species – gonadosomatic index (GSI), hepatosomatic index (HSI), condition factor (CF) – were calculated in accordance with approved methods (Schwartz et al., 1968) for fish caught in cold spells of the year (gonads were on II maturity stages).

Morphometric analysis of plastic and meristic characteristics were made. The plastic parameters of fish included such measurements (in mm):

- the distance from the top of the lower jaw to the starting point of the base of the first pectoral fin (aB);
- the distance between the lower jaw apex and the vertical of the starting point of the base of the first dorsal fin (aD);
- the distance between the lower jaw apex and the vertical of the starting point of the bases of the ventral fins (aV);
- the distance from the top of the lower jaw to the vertical of the beginning of the base of the first anal fin (aA);
- the maximum body height (on the vertical of the base of the first ray of the dorsal fin) (H);
- body height at the end of gill cover (head height) (h);
- the length of the head (from the lower jaw apex to the most protruding back point of gill cover) (c);
- horizontal eye diameter (0);

- pectoral fin length (B);
- ventral fin length (V);
- dorsal fin length (D);
- anal fin length (A);
- the distance between eyes (f).

Among meristic indices we determined were: the number of rays in the dorsal (n_1), anal (n_2) fins and the number of vertebrae in two species (n_3).

All research results were statistically processed according to G.F. Lakin (1973); the parameters studied were calculated using the standard program «EXCEL» and presented as $M \pm SEM$.

3. Results and Discussion

As we earlier reported (Kuzminova et al., 2016a), the *S. flexuosa* can be seen almost constantly in Sevastopol territorial waters. There is quite a logical explanation for the fact that *S. maena* is confidently establishing itself in the waters all of Sevastopol coast. Firstly, the southernmost point of the Crimean peninsula (cape Sarych) is located near the Anatolian peninsula, where seasonal surface meridional current arises, that directed from the Turkish coast to the Crimea. Near Foros it bends west, then flows along the peninsula southwestern coast (Hydrometeorology..., 1991). It is with this current that Mediterranean species may get into our waters (Boltachev and Karpova, 2012).

Ph.D. Boltachev A.R. noted that earlier (data given before 2011), the blotched picarel was seen in the Balaklavskaya bay and on the open sea from cape Aya to cape Tolstyak; not a single fact of catching them in the Sevastopolskaya, Karantinnaya, Streletskaaya, Kruglyaya and Kazachaya bays was reported (Boltachev and Karpova, 2012).

We point out that the blotched picarel has been found in catches since 2017, not only in the Balaklavskaya bay, but also in Karantinnaya, Aleksandrovskaya ones and near cape Tolstyak. In the period 2016 – 2018, we analysed the Spicara specimen caught mainly in the following bays: Alexandrovskaya (147 specimens), Matyushenko (128 specimens), Karantinnaya (61 specimens); we could only analyze 14 and 4 specimens of fish from the Streletskaaya bay and cape Tolstyak area respectively.

The idea of a genetical similarity between these two species has been already supported by a number of experts (Tortonese, 1975; Arculeo et al., 1996; Turan, 2011; Imsiridou A. et al., 2011; Bektas et al., 2018; Parrinello et al., 1999). However, some researchers continue discovering additional signs (areas of distribution, color and fluorescence of the body and fins, but most importantly - morphometric differences) characterizing *S. flexuosa* and *S. maena*

(Tortonese, 1986; Karidas et al. 2009; Minos et al., 2013), that suggests that the problem of their identification still exists.

As can be seen from Table 1, the hepatosomatic index for both females and males of the Black Sea *S. flexuosa* is higher than that for the blotched picarel. The difference between the values of GSI for the two species is less, even though this index is usually higher for the high body pickerel. In addition, for both species spawning season began in early April, with the process of maturation to have begun, apparently, in March. No significant differences in condition factor were found for *S. flexuosa* and *S. maena*.

Interestingly, the same differences in the HSI values between the two species were found earlier for fish caught in the Mediterranean Sea (area of the island of Lampedusa): despite insignificant differences between representatives of the genus *Spicara*, this index was higher in females and males of *S. flexuosa*, compared to those of the *S. maena* (Lipskaya and Salekhova, 1980). The most likely explanation for this (and that is in agreement with our data) is that *S. flexuosa* has a wider feeding habits spectrum

compared to other representatives of the genus (Lipskaya and Salekhova, 1980).

The study revealed there were no significant differences in parameters of the number of rays in the anal fin and the number of vertebrae (Table 2).

In males, significant differences between the two species were found in the following parameters: the distance between the lower jaw apex and starting point of the base of the first pectoral fin (aB), the distance between the lower jaw apex and the vertical of the starting point of the base of the first dorsal fin (aD); the length of the dorsal and anal fins (Table 3). Moreover, the Mediterranean invader has one ray more (Table 4). The study revealed that in females and males of the blotched picarel the distance between the snout and starting point of ventral fin is greater than that for the *S. flexuosa*, but these differences are insignificant. *S. maena* has a much higher body height than *S. flexuosa* but the head height, on the contrary, is less ($p \leq 0.05$). The eye diameter for high body pickerel is greater than that for the blotched picarel, which is confirmed by data in the earlier studies of Mediterranean species (Salekhova, 1979), but these differences are significant only in males.

Table 1 Morphophysiological parameters of individuals of the genus *Spicara* in the coastal area of the Sevastopol in 2016-2018

parameters	age, y.o.	high body pickerel		blotched picarel	
		female	male	female	male
HSI, ‰	0+	10,89±0,95	–	7,69±1,76	–
	1+	10,81±0,41	–	8,44±0,71	–
	2+	12,69±1,35	–	8,23±0,31	–
	3+	16,04±2,61	17,81±3,36	10,25±2,59	12,76±0,57
	4+	–	13,09±1,16	–	11,75±2,45
GSI, %	0+	1,09±0,17	–	0,44±0,13	–
	1+	0,92±0,04	–	0,98±0,08	–
	2+	1,11±0,14	–	0,68±0,11	–
	3+	1,01±0,16	0,46±0,13	0,71±0,05	0,16±0,009
	4+	–	0,24±0,04	–	0,24±0,02
CF, %	0+	1,55±0,09	–	1,58±0,03	–
	1+	1,66±0,02	–	1,67±0,05	–
	2+	1,57±0,03	–	1,65±0,04	–
	3+	1,87±0,14	1,79±0,06	1,88±0,27	1,64±0,02
	4+	–	1,78±0,09	–	1,76±0,08

Note: values in bold mean significant differences between two species of the same sex and age

Table 2 Meristic characteristics of high body pickerel and blotched picarel in the coastal area of Sevastopol

species	high body pickerel	blotched picarel
index		
the number of rays in the dorsal fin, n ₁	21,35 ± 0,09	22,3 ± 0,08
the number of rays in the anal fin, n ₂	12,23 ± 0,06	12,44 ± 0,1
number of vertebrae, n ₃	23,32 ± 0,09	23,05 ± 0,09

Note: values in bold mean significant differences between two species

In the earlier study, George Minos and co-authors evaluated the information content of some plastic characteristics and calculation indices of *Spicara*, and come to the conclusion that many of them depend not only on species, but also on the stage of fish maturation. The key characteristics used to distinguish *S. maena* from *S. flexuosa* were the ratio of head length (s) to standard length (Sl), head height (h) to Sl and h/c (Minos et al., 2013). Our study revealed that the height of the head and the ratio of height to length of the head for both species differ significantly ($p \leq 0.05$), which confirms the presence of two species of the genus *Spicara* in Sevastopol coastal waters.

There is some evidence that the presence of teeth on the vomer and the number of canines on the dentale are also used as diagnostic signs for *Spicara* genus. Teeth on the vomer of *S. flexuosa* (if any) are in a small area at the front of the head, there are at least two pairs of canines on the dentale. The teeth on the vomer of *S. maena* are arranged in a long row along the midline of the bone, continuing on the handle, and the dentale has no more than one pair of canines (Vasilieva and Salekhova, 1983). In addition, based on both the exterior of fish and osteological analysis of the skull, some authors say about a high skull of *S. maena* compared to *S. flexuosa* (Vasilieva and Salekhova, 1983).

When comparing analytically the high body pickerel and the supposed blotched picarel, we discovered no teeth on the vomer in any individuals of the two species (from Balaklavskaya bay and other catching locations). However, significant differences found between the values of morphophysiological indices and eight morphometric characteristics suggest the existence of two species.

We have supplemented our research with mathematical treatment of some plastic characteristics of all of the specimens of fish (the data base) and calculated the mode in a discrete sequence of those characteristics.

As can be seen in Figure 1, the distribution of such parameters as the height of head, the height of body, the length of the dorsal fin (converted to the standard length) is very close to two-modal one.

As can be seen in Figure 1, the distribution of such parameters as the height of head, the height of body, the length of the dorsal fin (converted to the standard length) is very close to two-modal one.

Table 3 Plastic characteristics of high body pickerel and blotched picarel in the coastal area of Sevastopol (in % of SL)

index	species		blotched picarel	
	high body pickerel			
	female	male	female	male
aB	28,56±0,14	28,85±0,17	–	28±0,16
aD	30,47±0,32	30,16±0,23	30,83±0,63	29,1±0,24
aV	33,09±0,19	33,60±0,20	38,91±3,07	33,9±0,53
aA	59,99±0,37	60,55±0,25	58,64±0,68	60,56±0,29
H	19,72±0,36	19,47±0,49	24,66±0,63	27,18±0,64
h	22,47±0,29	23,42±0,40	19,37±0,37	21,7±0,18
c	26,97±0,13	26,70±0,12	27,09±0,45	26,63±0,13
0	10,89±0,30	9,87±0,13	10,39±0,26	9,39±0,1
f	7,56±0,11	7,55±0,27	7,54±0,25	8,06±0,14
B	22,51±0,31	23,38±0,55	22,83±0,82	24,22±0,35
D	51,21±0,26	51,41±0,37	50,37±0,87	52,62±0,32
V	21,49±0,32	21,65±0,53	21,52±0,56	22,76±0,22
A	21,16±0,31	20,09±0,53	20,88±0,43	21,46±0,13
h/c	0,84±0,01	0,88±0,02	0,71±0,01	0,82±0,01

Note: values in bold mean significant differences between two species of the same sex

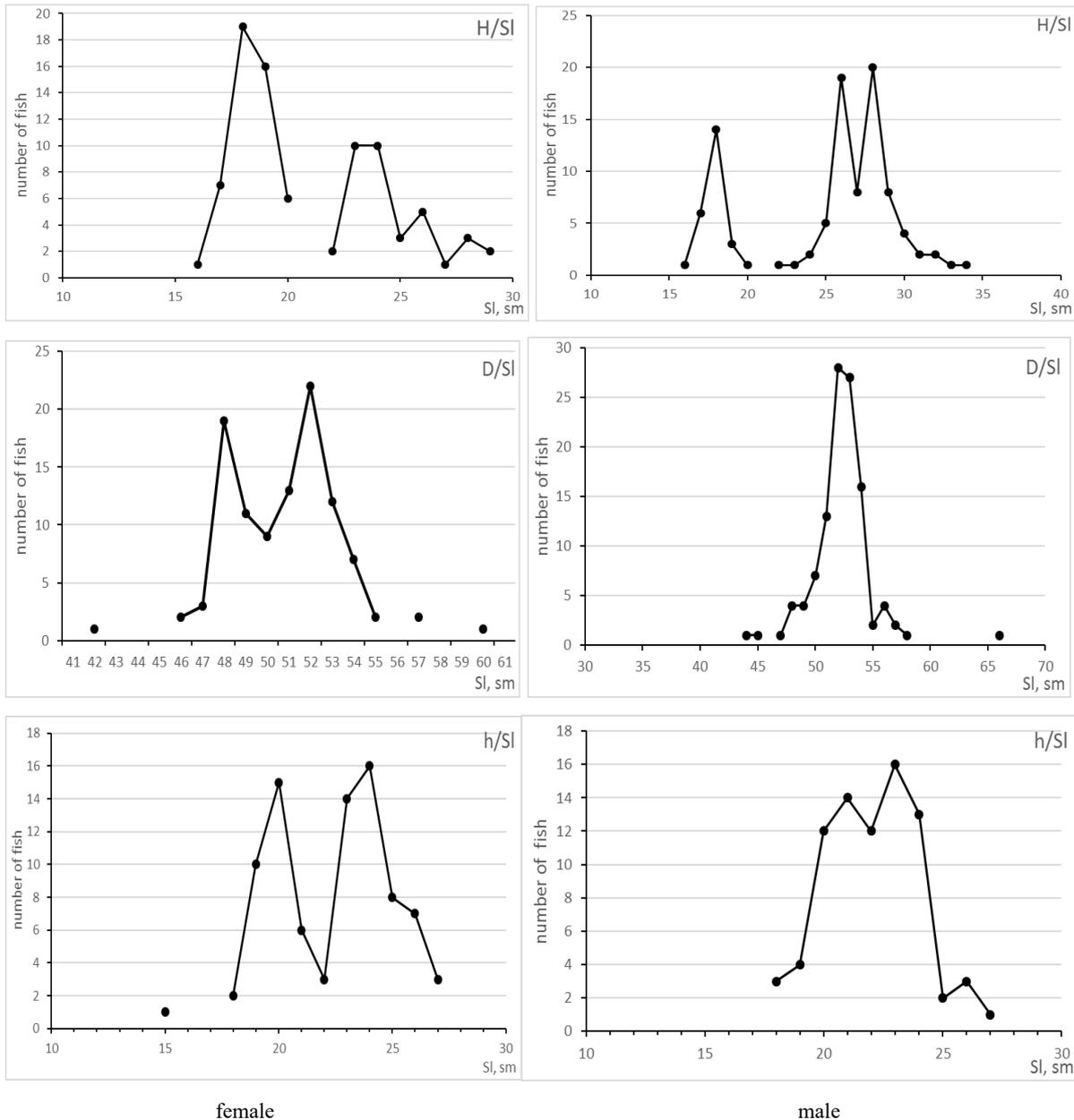


Fig. 1. Distribution of some plastic characteristics of *Spicara* genus in the coastal area of Sevastopol in 2016 - 2018: H - body height, h - head height, D - dorsal fin length, Sl - standard length

The fact that the values of head length of both species in our bays differ insignificantly, and the lack of teeth on the vomer in the *S. maena* jaw suggest that the blotched picarel and the *S. flexuosa* may have been hybridizing freely in our waters, which was described in the earlier studies of these species living in the Mediterranean Sea (Salekhova, 1979). In addition, it is known that the relative values of some plastic characteristics (as well as morphophysiological indicators) for the *S. flexuosa* caught in the Balaklavskaya bay, South coast, Karadag, Batumi, Novorossiysk differed from those for the fish caught near Sevastopol, which suggest that biological parameters of this bottom-pelagic species are dependent on habitat factors. That link is confirmed by data from other authors (Minos et al., 2013): in North Aegean Sea the height of the body of the *S. flexuosa* is higher than that of Black Sea individuals from Sevastopol waters. It is also

known, that Black Sea population of Centranchidae in Crimean waters differs from the Mediterranean one in having higher body length variability, higher body weight variability, high condition factor and a high hepatosomatic index (Lipskaya and Salekhova, 1980). Consequently, originating from the Mediterranean Sea and now inhabiting mainly the Balaklavskaya bay, which is far from other Sevastopol bays, the *S. maena* may have experienced changes in its growth rate. Hence changes in plastic parameters of the fish. Moreover, the blotched picarel and the native *S. flexuosa* may have been hybridizing with each other for years, which has led to blurry biological characteristics of these two different species and, among other things, affected the structure of the graphs obtained – in some cases we can see three rather than two peaks of the

feature frequency (Fig. 1), which can serve as evidence of the existence of hybrids in the schools of picarels.

4. Conclusion Thus, the study convincingly demonstrates the existence of two species of the genus *Spicara* – *Spicara flexuosa* and *Spicara maena* – since such characteristics as the maximum body height and body height at the end of gill cover, the length of the segment between lower jaw apex and starting point of the base of the first pectoral and first dorsal fins, the length of the anal and dorsal fins, the number of the rays in the dorsal fin differ significantly for the two species. Also, for *Spicara flexuosa* and *Spicara maena*, there is a clear difference between the values of the ratio of height of the fish head to its length, another diagnostic sign used to differentiate species. During periods of rest, hepatosomatic index and gonadosomatic index for Black Sea *S. flexuosa* are noticeably higher than those for *S. maena*.

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