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RESEARCH PAPER

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Life-History Traits of the Black Scorpionfish (*Scorpaena porcus*) in Southeastern Black Sea

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Abstract

Scorpaena porcus is one of the most important members of rock and reef community in the Black Sea. The present study aimed to investigate the bio-ecological properties of *S. porcus* in the Eastern Black Sea. The growth, age, and sex compositions, feeding and reproduction biology of 1061 individuals were examined. The total length of the individuals ranged between 6.7 and 25.5 cm. The observed age ranged up to 8 years in both the sexes; the oldest individual both in males and females was 8 years of age. The von Bertalanffy growth function parameters in the samples were L_∞=22.15 cm, k=0.287, t_0= -1.577 (year) and W_∞=238.14 g. The sex ratio (male/female) was 1/1.13. *S. porcus* fed most frequently on fish and decapods in all seasons. The reproduction period was identified to be between June and October, as evident by GSI values and macroscopic and histological analysis of gonads. Hydrated oocytes first appeared in June on the histological examinations; however, the atresia was highest in October. In conclusion, the study identified *S. porcus* as a new target species and the studied bio-ecological characteristics are expected to be important in developing an optimal strategy for fishery stock management.

Introduction

Family Scorpaenidae comprises of 219 species, only 17 species of them were recognized/detected in the last decade (Mahe, Goascoz, Dufour, Iglesias, & Tetard., 2014). The benthic species *Scorpaena porcus* (Linnaeus, 1758) is widely distributed from the English islands to the Azores and the Canary Islands (Eastern Atlantic), the Mediterranean, and the Black Sea coasts (Hureau & Litvinankov, 1986; Pallaoro & Jardas, 1991; Bilgin & Çelik, 2009; Stewat & Hughes, 2010; Ferri, Petrić, & Matić-Skoko., 2010). A coastal benthic species *S. porcus* is observed up to 800 m of depth (Pallaoro & Jardas, 1991). *S. porcus* generally inhabit shallow rocky areas and bottom of the seagrass meadows and are found between 5–15 m in the Adriatic Sea, 10–30 m in Mediterranean, and 10–30 m in the Black Sea (Bilgin & Çelik, 2009, 2009; Ferri *et al*., 2010). Black scorpion fish, a carnivorous species feeds on small fish including gobies, blennies, crustacean, and other invertebrates (Hureau & Litvinankov, 1986; Başçınar & Sağlam, 2009; Roşca & Arteni, 2010). Reproductive strategies in the Scorpaenidae have evolved from basic oviparity to matrotrophic viviparity. However, oviparity is more common in the genus Scorpaena. Fertilization in the Scorpaena occurs externally and development is oviparous. Nevertheless, the reproductive strategy of *S. porcus* is oviparus, where eggs are pelagic and embedded in a gelatinous matrix (Munoz, Casadevall, & Bonet., 2002; Munoz, Sàbat, Vila, & Casadevall, 2005; Koyo & Munoz, 2007; Stevart & Hughes, 2010).

S. porcus are slow-growing and short-lived fish; individuals may live a maximum of 11 years (Mesa, 2010). Although scorpion fish is a non-target species in

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Turkey (The Black Sea, Sea of Marmara, Aegean Sea, and Mediterranean), recently are being caught as target species. The total production of scorpion fish is 192 tons in Turkey, and Black Sea has been reported to have the highest production of 39 tons (Anonymous, 2013).

The present study was aimed to investigate the bio-ecological characteristics including the age, growth, feeding composition, and the reproductive characteristics of black scorpion fish, which are of primary importance in developing an optimal strategy for fishery stock management.

Materials and Methods

A total of 1061 individuals of the black scorpion fish were collected during monthly sampling from Southeastern Black Sea (coast of Trabzon and Rize), between January 2011 and December 2011, at a depth of 15–25 m using a bottom trammel net with a mesh size of 32 mm (Figure 1).

For each sampled individual, the total length was measured to the nearest millimeter (0.1 mm). The total body weight, gonad, liver, and stomach contents were weighted with accuracy 0.01 g and the sex of specimen was also determined.

The sagittal otoliths from all samples were removed, dried, and kept for further analysis on age and growth. They were immersed in 70% alcohol in a black founded Petri plate and were read using a binocular microscope (Leica LZ 75) (12.5 X) by epi-illumination (Chilton & Beamish 1982). Opaque and hyaline zones on the otolith samples were clearly visible that were enumerated under reflected light without grinding or cutting. Slow hyaline zones appeared as dark rings through the dark transparent background, whereas fast or opaque zones appeared as light rings under reflected light. The areas of complete growth as annual ring were represented by the combination of one opaque zone and a subsequent hyaline zone, as other Scorpaenids (Massuti, Morales-Nin, & Moranta, 2000; La Mesa, La Mesa, & Micalizzi, 2005; La Mesa, Scarcella, Grati, & Fabi 2010).

The length-weight relationship was calculated by using the exponential regression equation W=a*L^b where W is the total weight of a fish, a and b are parameters derived from the least square method (Ricker, 1973). The Von Bertalanffy growth parameters ($L_\infty = \frac{a}{(1-b)}$; $K = -lnb$ and $t_0 = t_1 + \frac{1}{K} * \ln(\frac{L_\infty - L_t}{L_\infty})$) were determined using at age-length data and the growth according to sexes were estimated by using the Von Bertalanffy function $L_t = L_\infty(1 - e^{-K(t-t_0)})$. where L_∞ is asymptotic fish length (cm), L_t is length at age t (cm), K is the Brody growth coefficient, and t_0 is the theoretical age when the length equals zero. The growth performance was determined using the growth index (Ø); $Ø = \mathrm{Log\,K} + 2\,\mathrm{Log\,L_\infty}$ (Sparre & Venema, 1987, King, 1995). Instantaneous rate of total mortality (Z) was derived from survival rate (S); $S_{(t)}$=$N_{(t+1)}/N_{(t)}$; where, $N_{(t)}$: frequency at t age, $N_{(t+1)}$: frequency at t+1 age. When S rate was calculated, frequency of following ages that frequencies started to decrease were used. $Z = -LnS$, natural mortality rate (M) was determined by LnM = (–0,0152–0,279 Ln L_∞+0,6543 Ln k+0,463 Ln T) and fishing mortality rate (F) was estimated using $Z = F + M$ (Sparre & Venema., 1987; Pauly, 1980). Reproductive period was determined by gonadosomatic index (GSI); $GSI = \left(\frac{GW}{TW-GW}\right) * 100$; (GW: gonad weight, TW: total weight) and

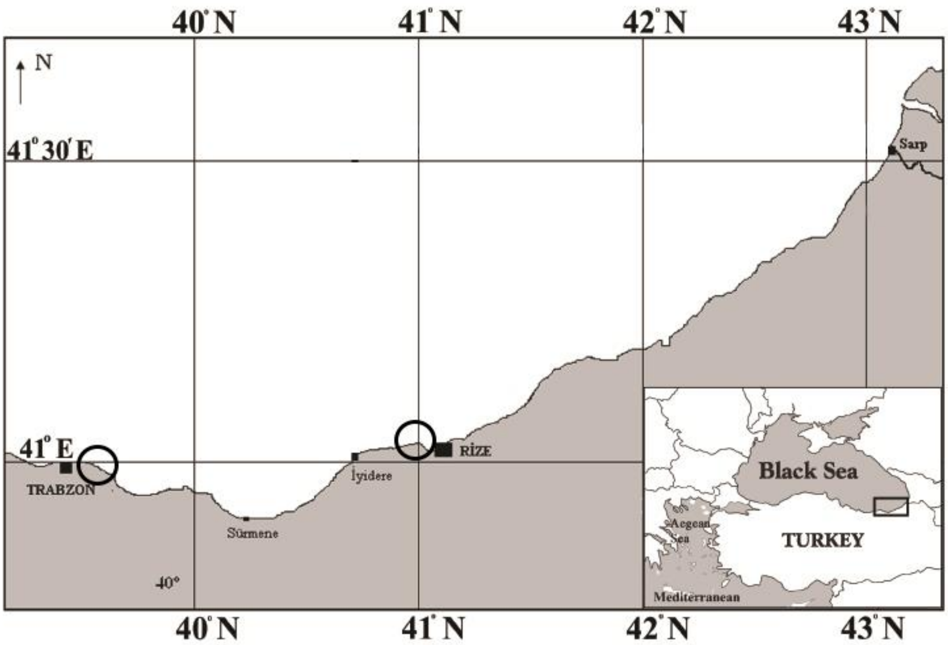

Figure 1. Study area.

hepatosomatic index; $\mathrm{HSI} = (\mathrm{LW/TW}) * 100$; (LW: liver weight) (King, 1995; Nunes, Silva, Soares, & Ganias, 2011). Stomachs were dissected and all prey items were identified to the lowest possible taxonomic level, counted. Percentage of prey groups occurrence frequency (*F%*), percentage of prey groups numerical frequency (*N%*) (Hyslops, 1980) were determined as:

$$F(\%) = \frac{n}{N_s} * 100$$

$$N(\%) = \frac{n^{\prime}}{N_p} * 100$$

Where, n is number of fish in which a prey group, N_s is total fish number in which at least one of the food groups, n^1 is total number of food group, N_p is total number of all prey groups.

Egg fertility was calculated by total fecundity. At the beginning of the ovulation period, the eggs were taken from the mature gonads of the individuals, the numbers of eggs in the ovaries were estimated and the fecundity was calculated by using the gravimetric method (Hunter, Lo,

& Leong, 1985; Murua, Kraus, Saborido-Rey, Witthames, Thorsen, & Junquera, 2003; Macchi *et al.,* 2005). Individual fecundity-length and fecundity-weight were correlated. For preparing the ovaries for histological analysis, each stage of maturation phases of gonads was determined based on both the macro and microscopic characteristics of the gonads. The maturity phases of gonads were determined considering the differences in oocytes microscopically in histological sections. Several studies have been conducted to reveal the maturity phases of the gonads. However, in these studies, differences were observed both in terms of definition of maturity phases of the gonads and in numbers of maturity phases (Selman & Wallace, 1989; Murua, *et al*., 2003; Munoz, *Sàbat, Vila, & Casadevall,* 2005; Koya & Munoz, 2007; McMillan, 2007; Nunez & Dupochelle, 2008; Stahl & Kruse, 2008, Brown-Peterson, Wyanski, Saborido-Rey, Macewicz, & Lowerre-Barbieri, 2011). Macroscopic and microscopic maturity stage were defined as; immature, developing, spawning, regressing and resting stages according to Brown-Peterson *et al*. (2011). For the microscopic analysis of the development stages, sampling was performed monthly. Firstly, the ovaries were kept in Bouin's fluid. The samples were dehydrated in graded alcohol (25%, 50%, and 75%) for 15 min. The samples were cleared in xylene (75%) and embedded in paraffin at 65°C in an incubator for 12 h. The histological sections of 5–10 µm were cut using microtome (Leica RM 2135) and tissues were stained with Hematoxylin-eosin in order to determine oocyte and gonad development under a microscope (Nikon e400). The deviations from the expected 1:1 sex ratio were determined using chi-square (χ^2) test. Student's *t*-test was applied to determine the significant differences among growth, GSI, and HSI. One-way Analysis of Variance (ANOVA) was performed to determine the differences among monthly egg diameters. All statistical analyses were performed using the SigmaPlot 12. *p*-values less than 0.05 were considered as statistically significant.

Results

Length- Frequency Distribution

The analysis was performed for 1061 samples. Out of 1061 individuals, 409 were female and 465 were male, 150 remained sexually undetermined and 37 individuals were immature. The length of sampled individuals ranged between 6.7 and 25.5 cm and the weight ranged between 5.96 and 470.76 g. The mean length and weight of the sampled individuals were 15.47±2.86 cm and 83.60±52.19 g, respectively. The length of the females ranged between 9.4 and 25.5 cm (mean 15.96±3.19 cm) and their weight ranged between 16.73 and 470,76 g (mean 95.76±61.55 g), respectively. The length of males ranged between 8.5 and 22.8 cm (mean 14.88±2.28 cm) and weights ranged between 5.64 and 208.03 g (mean 62.10±28.95 g). The overall sex ratio between male and female was not 1:1.13 differing significantly from the expected 1:1 value ($\chi^{2\ (df=1)}=3.588$; $p>0.05$) as determined using χ^2 test. The length and sex distribution are presented in Figure 2, but the sex ratio according to length classes was differing significantly from expected ($\chi^{2\ (df=16)}=96.481$; $p<0.01$).

Age

The age was determined by interpreting growth rings of otoliths of 471 individuals of which 13 of them immature, 207 males and 251 females (Table 1). Neither sectioning nor grinding was required because of the clear image of the age rings. Age composition of the sample population ranged between 0 and 8 years. The oldest individual was aged 8 years among both male and female groups (Figure 3). The age frequency distributions of males (n: 207) and females (n: 251) were not significantly different (Kolmogorov-Smirnov test) (p>0.05). Age compositions, length (mean±standard deviation) according to groups are represented in Table 1. L_∞, k, t_0 and W_∞ growth parameters were computed by considering the mean length data of specific age group.

Growth and Mortality

The length-weight relationship among female, male and other individuals are shown in Table 2. Positive allometric growth was observed when considering coefficient b in length-weight relationship

Table 1. Mean length and weight data belong to each sexing age class

TL	Male								Female								Overall									
	Age groups								Age groups								Age groups									
	b	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	0	1	2	3	4	5	6	7	8	Total
6																	2									2
7																	3									3
8	1																3	1								4
9	-									1							4	-	1							5
10	2	2							2	1							1	4	3							8
11	11	11							9	10	1							20	21	1						42
12	9	21							7	20	-							16	41	-						57
13	2	23	7						6	28	5							8	51	12						71
14		16	20	1					1	20	8							1	36	28	1					66
15		2	21	1						2	19	1							4	40	2					46
16		1	14	3	1					1	25	3	1						2	39	6	2				49
17			3	5	4	2					13	2	2	1						16	7	6	3			32
18			3	3	4	3	1				9	2	2	1						12	5	6	4	1		28
19			1	1	4	1	-				4	4	5	1						5	5	9	2			21
20					1		1	1			3	1	3	1						3	1	4	1	1	1	11
21											2	5	3	1	1					2	5	3	1	1	-	12
22											1	2	4	2						1	2	4	2	-	-	9
23												2		2							2		2	-	-	4
24																									-	0
25																1									1	1
n	25	76	69	14	14	6	2	1	25	83	90	22	20	9	1	1	13	50	159	159	36	34	15	3	2	471
L	11.92	14.19	15.32	17.3	18.27	18.73	19.65	-	12.04	14.26	16.77	19.76	20.07	21.6	-	-	8.71	11.98	14.23	16.1	18.64	19.36	20.16	20.42	22.57	
Sd	0.661	1.142	1.256	1.16	0.949	0.847	1.484	-	1.297	1.121	1.898	2.333	1.805	1.841	-	-	0.983	1.033	1.127	1.781	2.288	1.751	2.027	1.379	4.136	

TL: Total Length, n: number of fish, Sd: Standard deviation

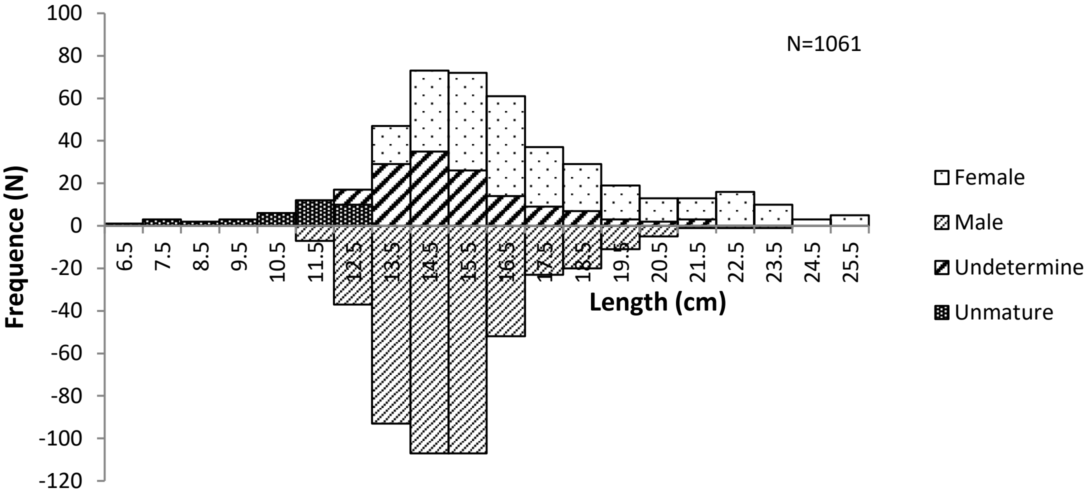

Figure 2. Length frequency distribution of *S. porcus* sampled in the study area.

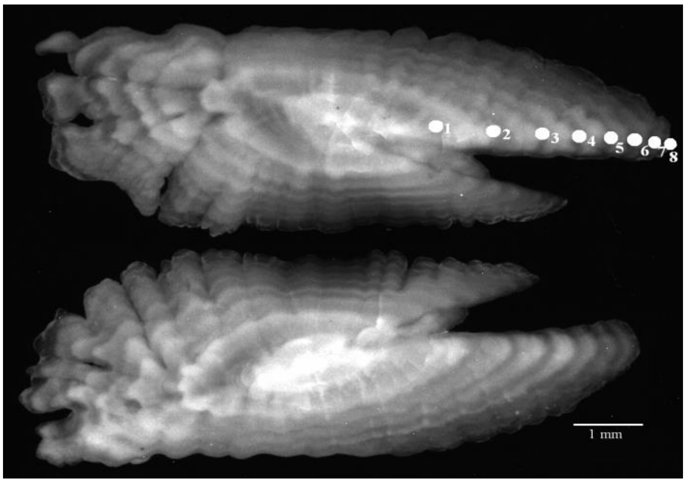

Figure 3. Showing the annulation pattern in an eight-year-old *S. porcus*. (X12,5).

Table 2. Length- weight relationship functions of female, male and all samples of *S. porcus*

Female	Male	All sample
$W=0{,}0123L^{3{,}1983}$	$W=0{,}0105L^{3{,}2352}$	$W=0{,}0101L^{3{,}2491}$
n=409	n=465	n=1061
r= 0,981	r= 0,979	r=0,982

function.

The age groups 7 and 8 in females and age group 8 in general samples were not considered for the analysis of growth coefficient as they were represented by only one sample. According to age composition, maximum numbers of females were represented among the older classes. Statistically significant differences were observed between the mean length of male and female ($t_{(df.5)}$=3.065) $p<0.05$. The growth coefficients are shown in Table 3 and the age-length relationships are illustrated in Figure 4. Statistically differences were not observed between the growth parameters of male and female as a result of the *t*-test ($p>0.05$).

The most important parameter that exhibits the reduction in stocks is the mortality. In this study, instantaneous rate of mortality (Z) was determined as Z=0.503 and S=0.605. The natural rate of mortality (M) was calculated using growth parameters and mean annual temperatures (15.38±5.89°C) at a depth where scorpion fish can live and was found to be M=0.371 and F one of the components of Z was F=0.132.

Table 3. Growth coefficients and performances according to the sexes

Parameters	Male	Female	Overall
L_∞	21,91	29,67	22,15
K	0,243	0,184	0,287
t_0	−2,279	−1,543	−1,577
W_∞	224,65	612,35	238,14
Ø	2,068	2,211	2,149
n	207	251	471

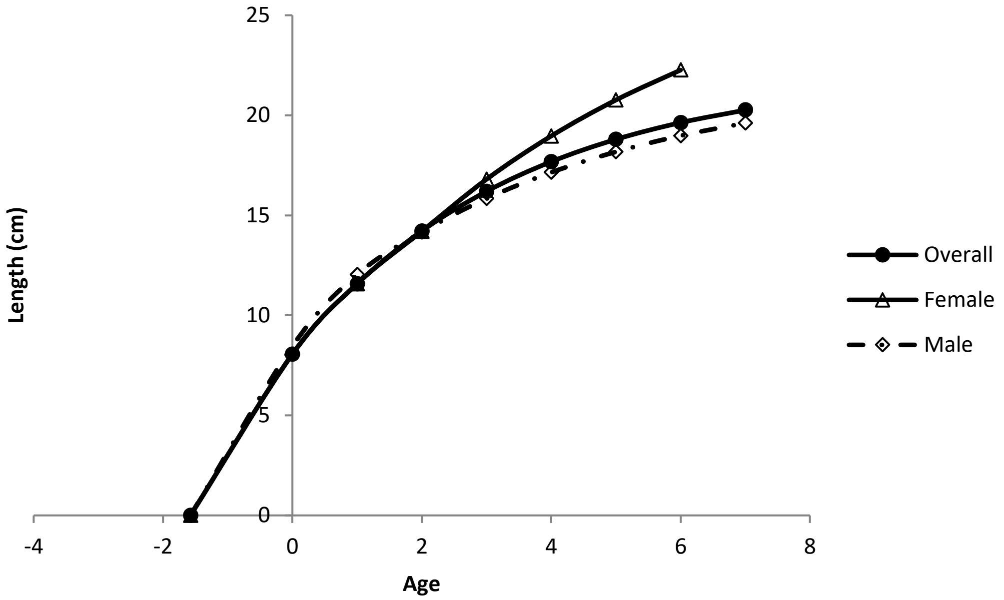

Figure 4. Growth curve of *S. porcus* according to the sexes.

Table 4. The seasonal distribution of percentage of prey groups, occurrence frequency (*F%*), percentage of prey groups numerical frequency (*N%*) for the preys that were observed in the stomach of *Scorpaena porcus*

	Seasons							
	Winter		Spring		Summer		Autumn	
Prey groups	N%	F%	N%	F%	N%	F%	N%	F%
Fish	33.33	37.50	37.84	20	27.27	33.33	20	28.57
Crab	26.67	25	32.43	30	56.82	33.33	50	42.86
Sea horse	0	0	13.51	20	6.82	11.11	10	14.29
Mussel	0	0	2.70	10	6.82	11.11	0	0
Isopoda	20	25	8.11	10	0	0	0	0
Shrimp	20	12.50	5.41	10	2.27	11.11	20	14.29

Feeding

Stomach contents were analyzed (Table 4) in order to reveal the influence of seasonal variations on the feeding behavior of the *S. porcus.*

Significant differences between seasonal feeding compositions were determined using χ^2 test ($\chi^2_{(df=15)}$=25.648; $p<0.05$). The scorpion fish mainly fed on fish in winter (33%) and spring (38%), whereas crabs were the main diet component in summer (57%) and fall (50%). Harbor crab (*Liocarcinus depurator*) ranks first in feeding components of scorpion fish whereas fish comes later. The fish species identified for the quantities consumed were whiting (*Merlangius merlangus euxinus*), red mullet (*Mullus barbatus*) and goby fish (*Gobius* sp.). Seahorses (*Hippocampus* sp.) and shrimp (*Crangon crangon*) were the other species that were observed. The small quantities of mussel (*Mytilus galloprovincialis*) and isopods (*Idotea* sp.) were also encountered. The feeding behavior of scorpion fish is shown in Figure 5.

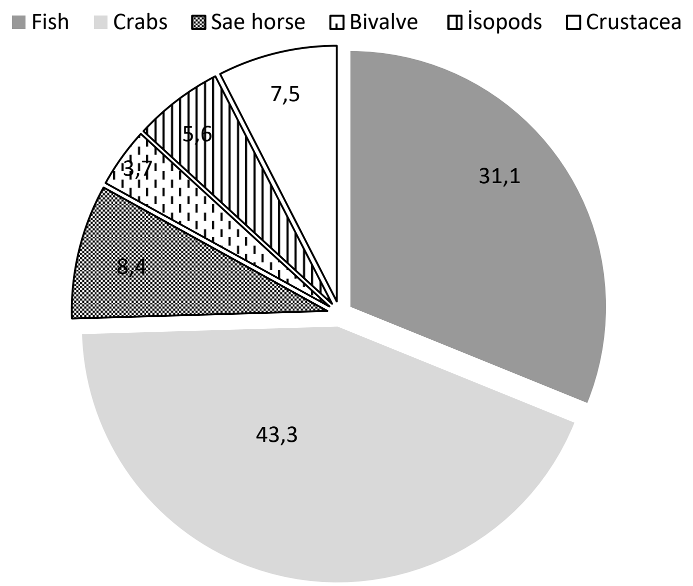

Figure 5. Feeding composition of scorpion fish.

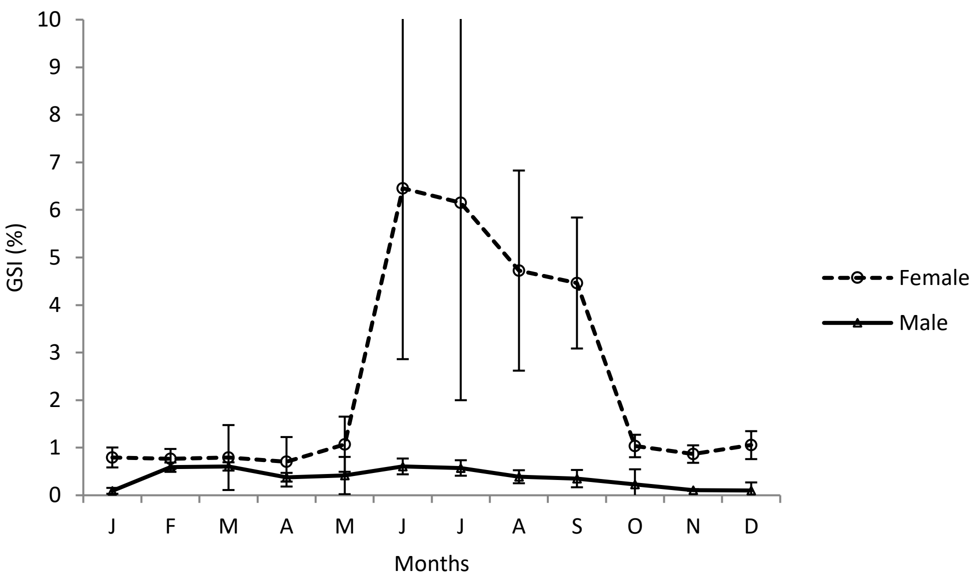

Figure 6. Monthly GSI distribution of *S. pocus.*

Reproduction

Gonadosomatic index (GSI) and Hepatosomatic index (HSI) were recorded monthly to determine the reproductive period of scorpion fish. The distribution of GSI according to sexes is represented in Figure 6. The GSI values for males were observed to be higher from February to October; however, higher GSI values for females were observed between June and October.

The females exhibited the highest GSI value (6.455±3.593) in June, while the lowest GSI value was recorded in April (0.704±0.520). The mean GSI value was determined as (2.406±1.178). However, a continuous decrease in GSI values was observed after June till October, and some stability was observed from October to April. The male exhibited the highest GSI value (0.606±0.166) in June while the lowest GSI value (0.072±0.062) was observed in January. The mean GSI value of 0.363±0.149 was recorded in males. The monthly variations of GSI values were highly significant in both the sexes.

HSI values for both the sexes were recorded on monthly basis. A highest HSI value was recorded in the month of April for both the sexes (Figure 7). The highest HSI value of 4.290±1.028 in females was observed in the month of April. However, the lowest HSI value of 1.596±0.927 was recorded in the month of January, with the mean annual HSI value of 2.785±0.961. The highest HSI value in males was recorded to be 3.166±1.005 in the month of April whereas, the lowest HSI value of 1.730±0.878 was observed in the month of September with the mean HSI value of 2.449±1.110. No significant difference in the monthly variation of HSI values was observed for both the sexes.

Total fecundity of samples during the spawning period was determined using the gravimetric method. The relationships between total length and fecundity, and total weight and fecundity are illustrated in Figure 8.

The fecundity analyses were performed on 30 samples, the smallest individual had a length of 14.3 cm and a weight of 70.29 g, whereas the largest individual was 23.8 cm in length and 308.11 g in weight. The number of eggs in individuals with minimum and maximum length was 91.800 and 353.160, respectively. The mean fecundity was recorded as 153.500±95.708.

Gonad maturity phases in females were determined macroscopically (Figure 9). According to the observed maturity phases, the reproductive period of *S. porcus* was determined to be between June and October.

According to the histological analyses of the ovaries, the organs were categorized into five developmental stages (Table 5). A significant difference in monthly variation in egg diameters (F (df=6;223)=82.886: *p*≤0.01) was observed in ANOVA test.

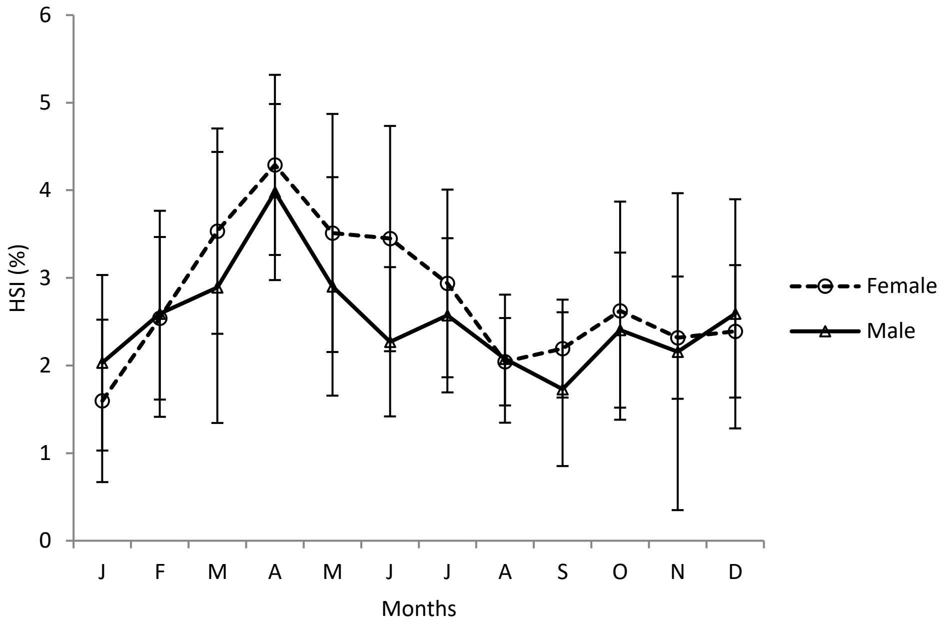

Figure 7. Monthly HSI distribution of *S. porcus.*

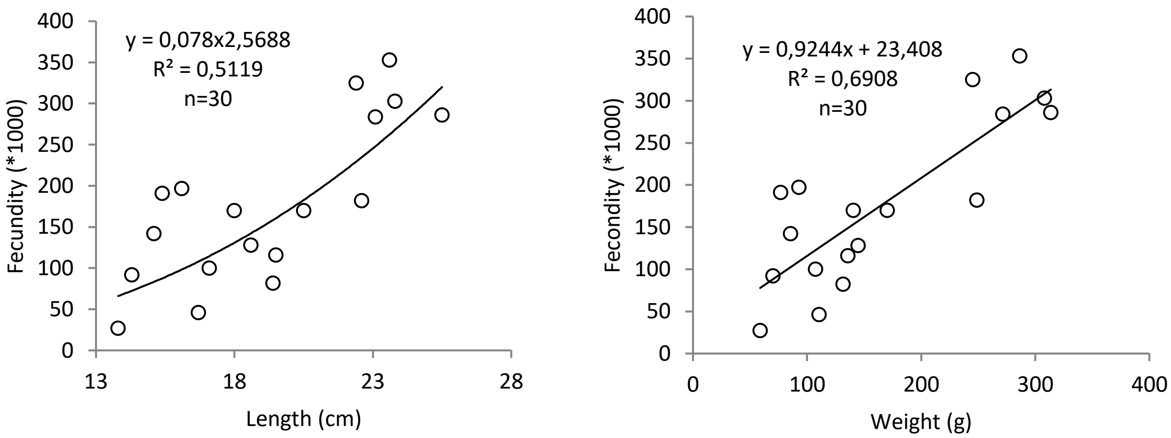

Figure 8. The relation of total length-fecundity and total weight-fecundity in *S. porcus.*

Discussion

In the present study, the length of *S. porcus* was found to be between 6.7 and 25.5 cm with the mean value of 15.47±2.868; however, Demirhan and Can (2009) recorded the length between 4.6 and 22.9 cm in the samples obtained from the same region. Bilgin and Çelik (2009) reported the length ranging between 5.7 and 23.6 cm, with the mean value of 11.77±0.20, in the samples collected from Sinop shore in Central Black Sea. Furthermore, Akalın, Ilhan, Ünlüoglu, Tosunoglu and Özaydin (2011) found the length ranging from 7.5 to 27.2 cm with the mean of 18.6±3.79 in the Aegean Sea. Pallaroro and Jardas (1991) and Scarcella *et al*. (2011) reported the length of the scorpion fish as 8.2−30.0 cm and 8.0−27.0 cm, respectively in the Adriatic Sea. The differences among the findings may be attributed to the different origin of the samples from the different regions and fishing gears. In this study, the males were smaller than the females and were dominant among the small fish. The lengths between the sexes exhibited significant differences ($p<0.01$), which is in accordance with other studies from different regions (Koca, 2002a; Demirhan & Can, 2008; Bilgin & Çelik, 2009; Ferri, *et al*., 2010).

S. porcus is a slow growing and short-lived species with a maximum lifespan of 11 years (Jardas & Pallaoro, 1992; Scarcella *et al*., 2011). The maximum age of *S. porcus* was found to be 8 years (age classes 0–8) in this study, although the oldest individual reported has been reported to be 18 years in some studies (Aksıray, 1987). The age of 0–7 years (Demirhan & Can, 2009), 0–8 years (Bilgin & Çelik, 2009) and 1–6 years (Koca, 2002a) were reported in the studies in the Black Sea, however, 1-11 years (Jardas & Pallaoro, 1992), 0-8 years (La Mesa *et al.,* 2010; Scarcella *et al.,* 2011) were

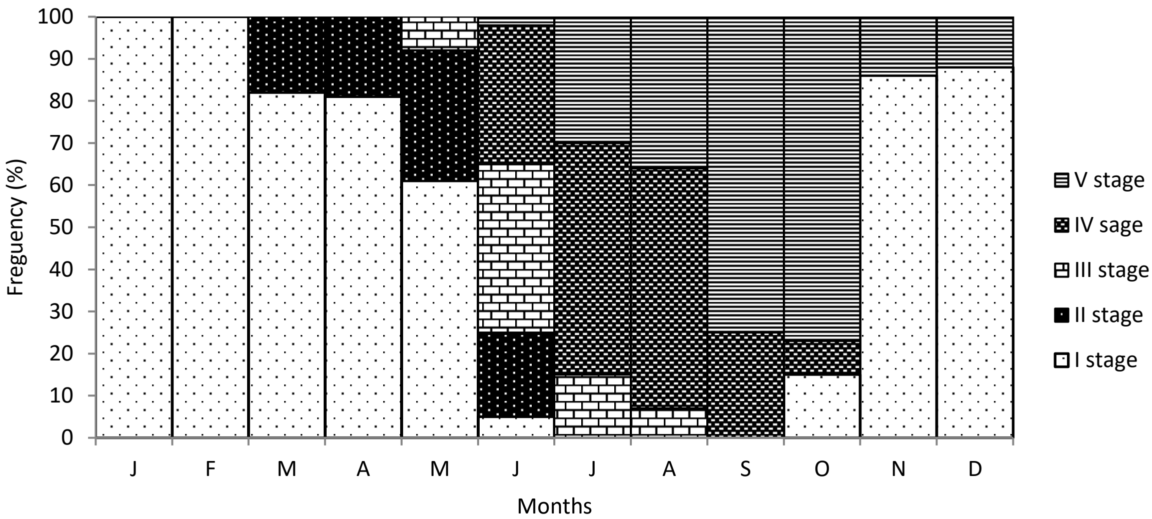

Figure 9. Macroscopic gonad development stages of *S. porcus*; I Immature, II Developing, III Spawning capable, IV Regressing, V Regenerating.

Table 5. Description of microscopic characteristics of each maturity stage

Maturity stage	Microscopic characteristics
Immature Stage	The gonads appeared to be rich in connective tissues, The oogonia were small and polygonal. The size of the nucleus was approximately half of the oocyte. The oocytes had chromatin nucleus with peri-nucleus stage and there was no gonadal development in this stage (Figure 10A). The mean diameter of oocyte is 40.66±7.73 µm in November to February.
Developing Stage	Connective tissue in gonads began to decrease, Enlargement in the cytoplasm of oocytes and decrement of diameters of nucleus occurred (Figure 10B). The mean diameter of oocyte 57.82±19.37 µm March to May.
Spawning Stage	Vitellogenesis stage and yolk granulation with nucleus immigration were observed while immigration of nucleus in some oocytes ended. The hydration of oocytes began and diameters reached to the maximum in this stage (Figure 10C). The mean diameter of oocyte 313.04±77.36 µm in June.
Regressing Stage	Nucleus immigration ended, vitellogenesis was in progress with hydrated oocytes and follicular atresia were observed after spawning (Figure 10D). The reabsorption and follicular atresia were also observed. The mean diameter of oocyte value is 57.82±19.37 µm in March to May.
Resting Stage:	A few follicular atresia and rarely hydrated oocytes were observed after spawning. The reabsorption of the oocytes in ovary was preceded and the reconstruction was also observed (Figure 10E). The mean diameter of oocytes of 62.50 ±19.83 µm in September

reported in the Adriatic Sea, 2–7 years (Passalaqua, Canta, Bono, & Beltrano, 2005) was reported in Sicilian shores, and 9 years was reported by Mahe *et al.* (2014) in English Channel of French Shores. The maximum lifespan in the most of the studies was similar; however, some differences were also found in a few studies. These differences may be attributed to the catching of the larger individuals from the populations, which are exposed to fishing pressure, different environmental factors (Scarcella *et al.,* 2011), populations in different geographical regions, and using different fishing gears.

A positive allometric growth was observed in length-weight relationship functions for females, males, and all individuals. However, Koca (2002a) reported a negative allometric growth in Sinop, Black Sea, and Bilgin and Çelik (2009), determined a positive allometric growth in the same region. Karakulak (2006) reported a negative allometric growth in the Aegean Sea and Jardas and Pallaoro (1992) reported a positive allometric growth in the Adriatic Sea. These differences may arise due to variations in nutrition, temperature, and other environmental factors, season, sex, genetic, regions, the number of samples, and the length range of the samples (Saborido-Rey & Kjesbu, 2005; Karakulak, Erk, & Bilgin, 2006; Magnussen, 2007). The growth parameters observed in the present study and those in other studies are presented in Table 6. When these values are taken into account, there are differences in the growth parameters of *S. porcus* in different geographical regions. Saborido-Rey and Kjesbu (2005) and Magnussen (2007) expressed that the environmental factors, nutrient abundance, and temperature changes effect on performance of growth of organisms.

While considering fishing and mortality rate obtained by the empirical methods (F=0.137), *S. porcus* seems to be insufficient exploitation in terms of fishing. This was a non-target species but has now become a target species for catching in the Black Sea. To exploit the stocks of *S. porcus*, an indicator species in benthic sea sources (Munoz *et al*., 2013), its bio-ecological properties must be well known.

The feeding regime of *S. porcus* exhibited seasonal variations. They fed mainly on crabs in spring, summer, and fall, while fed on fish in winter. Feeding groups are generally composed of crustacea, fish, isopods, and bivalves. The feeding strategies reported in other studies carried out in the Black Sea and other seas show that the *S. porcus* exhibits feeding adaptation with benthic organisms where live the same habitats (Table 7). Scorpaenids are recognized as macrophage carnivorous due to the large size of prey compared to their body sizes. Scorpaenids have developed the technique to catch moving preys like fish and crustacea (Harmelin-Vivien, Kaim-Malka, Ledoyer, & Jacob-Abraham, 1989; La Mesa *et al*., 2007; Başçınar & Sağlam, 2009). The nutrition diet of this species may vary due to the coastal ecosystems with high diversity. The studies in Adriatic and the Mediterranean Sea, which possesses high coastal ecosystems compared to the Black Sea confirm this claim. The results of the present study and other studies from the same region, at the different period in the Black Sea exhibit similar results. However, a study by Roşca and Arteni (2010) in the different region of Black Sea demonstrated a different diet for *S. porcus*. Furthermore, similar reports on seasonal variation in the diet of Scorpaenids have also been reported (La Mesa *et al*., 2007; Başçınar & Sağlam, 2009; Roşca & Arteni, 2010). The seasonal variations in the diet are related to the distribution and abundance of prey and dynamics of the water mass in the region (Başçınar & Sağlam, 2009).

Table 6. The von Bertalanffy Growth parameters and growth performance obtained from different regions (Ø)

L_∞	K	t_0	Ø	Area	Source
40.81	0.107	−2.227	−	Black Sea (Sinop)	Koca (2002a)
23.5	0.28	−0.03	−	Sicilia	Passalacqua *et al.* (2005)
28.20	0.182	−0.80	−	Adriatic	Jardas and Pallaoro (1992)
22.30	0.23	−3.43	2.07	Adriatic	La Mesa *et al*. (2010)
21.80	0.29	−2.51	2.14	Adriatic	Scarcella *et al*.(2011)
22.15	0.287	−1.577	2.149	Southern Black Sea	This research

Table 7. Feeding regime of *S. porcus* according to other studies

Feeding Groups	Region	Reference
Brachyurans, fish, molluscs, isopoda, other	Adatic Sea	Pallaora and Jardas (1991)
Brachyurans, fish, decapods, other	Mediterranean Sea (Gulf of Lion)	Harmelin-Vivien *et al*. (1989)
Fish, crustaceans, molluscs, algae	Black Sea	Başçınar & Sağlam (2009)
Crustacea, fish, Gastropoda	Black Sea	Demirhan & Can (2009)
Bivalves, gastropods, amphipods, isopods, decapods, fishes and algae	Black Sea (Coast of Romania)	Roşca and Arten (2010)
Crustacea, fish, isopoda and bivalve	Southern Black Sea	The present study

GSI is one of the important biological indexes in the fish biology which is used to determine the reproductive status of a species (King, 1995; Stahl & Kruse, 2008). The highest value of the GSI in June and the decrease to normal levels in October exhibit that the stocks of *S. porcus* in Southeast Black Sea spawn between June and October, similar findings were observed in the studies conducted by Bilgin and Çelik (2009); Koca (2002b) in Sinop region (Black Sea) (Figure 6). However, Çelik and Bircan (2004) reported that the reproduction period of *S. porcus* stocks in Dardanelles Strait that interconnect the Sea of Marmara and the Aegean Sea is between July and September.

HSI is one of the important biological indicators used for the determination of fish population conditions and status of energy reserve (Bolger & Connolly, 1989; Nunes *et al,* 2011). HSI had the highest value in April and then declined from April to

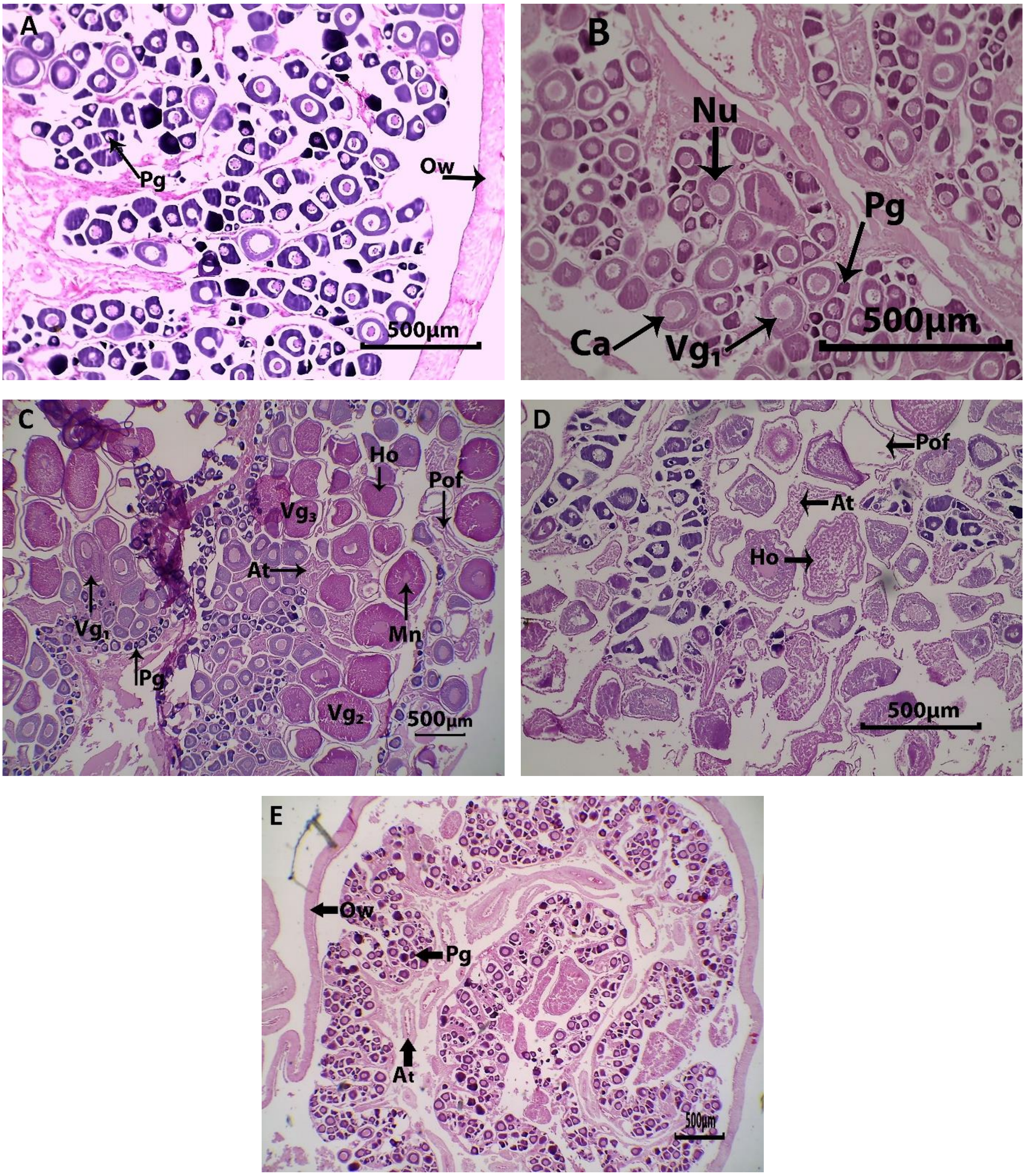

Figure 10. Different developmental stages of ovary: A) Immature (Pg: primary growth, Ow: ovarian wall), B) Developing (Nu: nucleus, Ca: cortical alveoli, Vg_1: early vitellogenic oocyte), C) Spawning capable (Mn: migration nucleus, Vg_2: mid-vitellogenic oocyte, Vg_3: late vitellogenic oocyte, Ho: hydrated oocyte, At: atretic oocyte, Pof: post ovulate follicle), D) Regressing, and E) Resting.

September (Figure 7). The highest values of HSI and its tendency to decrease, just before the reproductive period, demonstrate that energy transfer in the form of lipid occurs from the liver to ovaries. GSI and HSI have an inverse relationship (Munoz *et al.,* 2005; Nunes *et al.,* 2011).

Total fecundity of *S. porcus* was also estimated in the present study. There was a significant difference between the smallest individual with 91800 eggs and the largest individual with 353160 eggs. The increment in fecundity was observed with the increased length, age, and weight, respectively. To the best of our knowledge, there are far too low studies that reported fecundity with the mean value of 153.500±95.708, as observed in the present and 324071±20220.48 as estimated in a study performed in Dardanelles Strait by Çelik and Bircan (2004). Different populations inhabiting in different geographic regions and environmental conditions show different sex ratio and reproductive behaviors.

Maturity stages were classified macroscopically into five stages (Figure 9). According to these stages, it was determined that first spawning period of *S. porcus* stocks in Eastern Black Sea begins in June and proceeds until October. There are a few studies on the reproductive biology of this species. Similar results were observed by Bilgin and Çelik (2009), who studied the same species in Central Black Sea.

It is important to analyze the changes in the fish ovaries to specify the maturity status and to generate annual fishing quota which may be used in fisheries strategic management depending on spawning stock biomass prediction (Stahl & Kruse, 2008). Although it is expensive and requires substantial time, histological methods are used to classify ovaries correctly (Lowerre -Barbieri, *et al*. 2011). In this regard, the ovaries of *S. porcus* were classified by both macroscopically and microscopically to determine maturity (Figure 10). When Table 5 is examined, it is observed that the histological examination of the ovaries showed that the first hydrated oocytes with the maximum diameters in gonads and the first stage of the spawning were observed in the month of the June. Atretic oocytes were frequently observed and hydrated eggs were rarely observed in September that later discharged and ended up. The reproductive period was identified between June and October, according to GSI and macroscopic results; however, the histological findings showed it to be between June and September. Thus, it can be interpreted that the reproductive period of *S. porcus* is between June and September according to histological analysis, which is highly appropriate. There were no oil globules in the oocytes in histological sections, nevertheless, they are pelagic similar to other species of this genus (Munoz, Casadevall, & Bonet, 2002).

Recently, it has been noted that this species, being caught by many fishing gears as discard, has now begun to be evaluated commercially. As Davies, Cripps, Nickson, and Porter (2009) reported "Yesterday's bycatch may be tomorrow's target catch''. The decrease in the commercially important species stocks in the Black Sea made *S. porcus* as a new target species. The TUIK (Turkish Statistical Institute) took *S. porcus* into the scope of capture production species and conducted studies on the effects of fishing gears with special reference to this species (Aydın, Karadurmuş & Kontaş, 2015). Thus, it is of primary importance to consider the bioecological and reproductive characteristics of *S. porcus* for developing an optimal strategy for efficient management of the stocks.

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