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RESEARCH PAPER

Biological Characteristics of Azov Anchovy (*Engraulis encrasicolus maeoticus* A.) in 2016-2017 and 2017-2018 Fishing Seasons

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Abstract

Biological parameters of Azov anchovy from commercial catches in 2016/2017 and 2017/2018 fishing seasons were studied. During the first season, fishery was mainly based on fish of the 1st age group with an average length of 10.9 cm TL, while in 2017/2018 on 2-year-old fish with length of 11.4 cm. Parameters of the length-weight relationship were not different between sexes: for fish < 9.5 cm TL a = 0.00126, b = 3.719, and for fish ≥ 9.5 cm a = 0.0207, b = 2.475. The sex ratio in overall was close to 1:1. The relative condition factor Kn and total lipids content were higher in October-November 2017/2018 than in 2016/2017 and gradually decreased to February-March in both seasons. The growth rate was also slightly higher in 2017/2018. For both seasons, growth parameters in the von Bertalanffy equation were estimated as L_∞ = 13.0 cm, W_∞ = 12.6 g, K = 0.73 yr^{-1}, t_o = -0.86 yr. Azov anchovy is lighter in weight than the Black Sea anchovy at the same length. The growth rate of Azov anchovy seems to be similar to the Black Sea anchovy for age groups 0 and 1, but declined as fish getting older.

Introduction

The European anchovy, *Engraulis encrasicolus* (Linnaeus, 1758) is represented by two subspecies or populations in the Azov-Black Sea basin: Azov anchovy (*E. encrasicolus maeticus* Alexandrov, 1927) and the Black Sea anchovy (*E. encrasicolus ponticus,* Puzanov, 1926). The taxonomic status of the Azov and Black Sea anchovies is still an ongoing dispute (Gücü *et al.*, 2017). However, these anchovies considered as separate stocks, and their assessment, as well as recording to fisheries statistics and regulations were carried out separately (STECF, 2015; GFCM, 2014).

Unlike the Black Sea anchovy, which spends entire lifecycle in the Black Sea, Azov anchovy spawns and feeds in the Sea of Azov in summer, then migrates through the Kerch Strait to the Black Sea in October-November. The main overwintering area of Azov anchovy is located along the northern Caucasian coast to Georgia, sometimes even reaching the Turkish border (Chashchin, 1996). Düzgüneş *et al*. (2018) reported that Azov anchovy approaches the Turkey-Georgia border, and can move southwards along the coastline down to Turkish waters in summer. The results of the recent work (Gursalan *et al.*, 2017) show the possibility that overwintering anchovy fished along the Turkish Eastern Anatolian coast may not exclusively originate from the northwestern shelf, but mainly from the eastern Black Sea basin and the Sea of Azov.

Anchovy biomass is characterized by very high spatial-temporal variability, as these fast-growing and short-lived fish respond very rapidly to environmental changes by recruitment success (Guraslan *et al.*, 2014; Gücü *et al.*, 2016). The biomass of the Azov Sea anchovy varied in range of 10-650 thousand tons during 1991-2016 (mean level was about 170 thousand tons), while

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Russian-Ukrainian landings were from 140 tons to 54.5 thousand tons (mean about 20 thousand tons) (Chashchin *et al*., 2015; Shlyakhov *et al*., 2018) (Figure 1). Thus, the average catch-to-stock ratio in 1991-2012 was approximately 11%, but it sharply increased and reached 42-44% in 2015-2016. These data do not include catches of Azov anchovy of Turkish and Georgian fleets. The Russian-Ukrainian Commission on Fisheries in the Sea of Azov recommended an annual exploitation rate for Azov anchovy at the level 20-30% of its initial stock (Shlyakhov, 2015). The Commission annually approved total allowable catch (TAC) for Russia and Ukraine in 15-30 thousand tons until 2010, but in 2010-2018 the TAC was increased to 60-80 thousand tons. The total catch of Azov anchovy in 2016 by Russia, Ukraine and Abkhazia was more than 75 thousand tons and for the first time in 25 years exceeded the TAC of 65 thousand tons. Therefore, one of the aims of the present study was to assess the condition of Azov anchovy population, including size and age structures, sexual composition, fatness, growth and other parameters after the intensive fishing pressure.

Moreover, there are numerous publications on biological and population parameters of the Black Sea anchovy, while the data on the Azov anchovy are very scarce and were published in the past century (Popova, 1954; Dement'eva, 1958; Kornilova, 1960; Volovik & Kozlitina, 1983). Some data on the size-age composition of anchovies overwintering along the Crimean coast were reported by Zuyev with co-authors (Zuyev, 2014; Zuyev *et al*., 2014; and references therein), however, these data mainly related to mixed schools of the Azov and Black Sea anchovies.

Materials and Methods

Anchovy samples of approximately 1.5 kg (150-200 individuals) were randomly taken from commercial landings of fishing boats once a week (if possible) for two fishing seasons, lasting from October 2016 to March 2017 and from October 2017 to February 2018. The first catches were from the Sea of Azov and the Kerch Strait during the anchovy migration to the Black Sea, and then from a traditional wintering ground of Azov anchovy off the North Caucasus coast between Anapa and Sochi. The belonging of the anchovies to the Azov subspecies was checked and confirmed using the otolith length to width aspect ratio and the angle between rostrum and anti-rostrum as proposed by Vodyasova and Soldatov (2017). Overall, 3626 anchovies in 2016/2017 fishing season and 1705 fish in 2017/2018 were sampled from different catches (Table 1). Fish were measured and grouped in 0.5 cm intervals of fork length (FL), counted and weighed to assess the size-weight composition and length-frequency distribution of the catches.

For detailed biological analysis, at least ten specimens were randomly taken from each 0.5 cm size class. A total of 1745 anchovies were measured in the total (TL), fork (FL) and standard (SL) length to the nearest 0.1 cm and weighed for the total wet body weight (W) to the nearest 0.01 g, and also their sex and age were determined.

To calculate the conversion factors between TL, FL, and SL, the linear equations $L_2 = c\ L_1$ were used. The length-weight relationship (LWR) was estimated following the equation $W = a\ L^b$ transformed into $\log W = \log a + b \log TL$. Two different relationships were

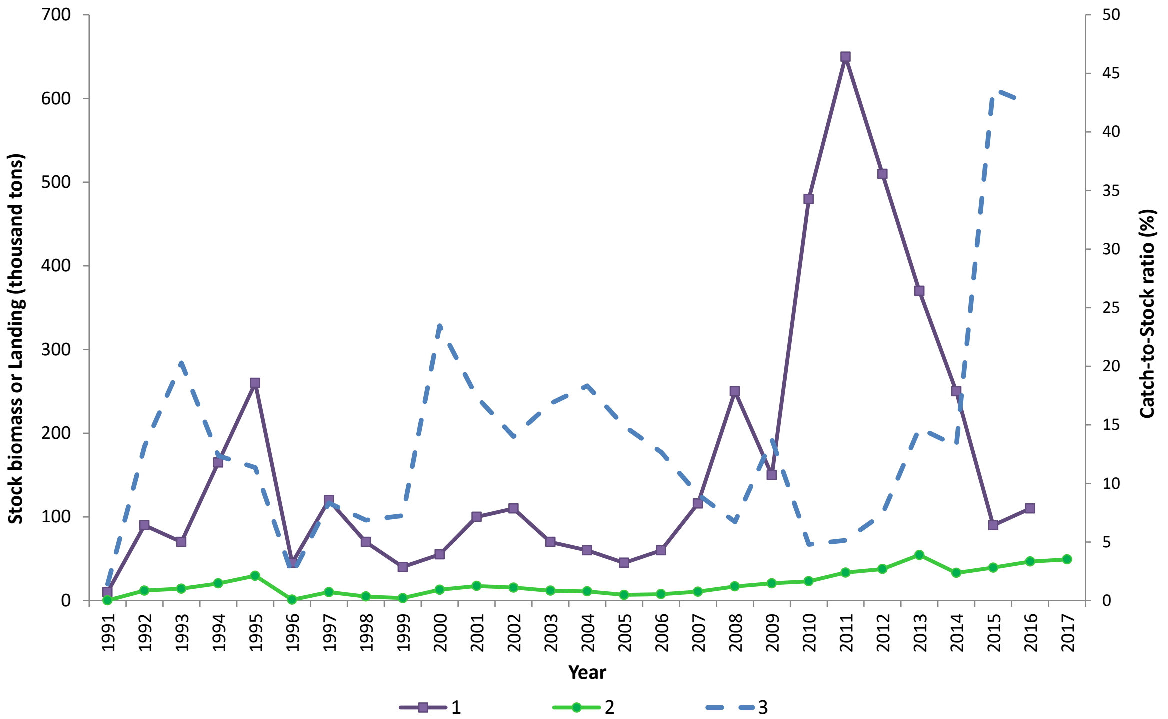

Figure 1. Stock biomass (1), Russian-Ukrainian landings (2) (from Chashchin *et al*., 2015; Shlyakhov *et al*., 2018) and catch-to-stock ratio (3) of Azov anchovy in 1991-2017.

proposed for small (TL < 9.5 cm) and larger fish separately. The "segmented" package for R-software allowed us to calculate the relationships and define a breakpoint between them (Muggeo, 2008).
The fish condition was assessed based on the relative condition factor Kn and content of total lipids in fish body. The Kn was estimated using the equation $Kn = W/\hat{W}$ (Le Cren, 1951) where the expected fish weight $\hat{W}$ was calculated by one of the formulas depending on fish size to make the Kn consistent across lengths. Then a logarithmic transformation was applied to Kn to eliminate the abnormality of the Kn distribution. To determine the lipid content (% of wet weight), whole fish of each size group were minced in a blender, and the lipids were extracted with a chloroform-methanol mixture (2 : 1, vol/vol) as previously described (Yuneva *et al*., 2019).

For age determination, whole otoliths were placed in glycerin and inspected under a stereomicroscope, counting annual rings. Age was recorded as group 0, 1, 2 and 3+ years old. The birth date of anchovies was assumed to be 1st July. Age-length keys (ALK) were calculated for the two seasons separately based on length-at-age data and number of fish in 0.5 cm fork length classes using R-software with the "alk" function from "fishmethods" package (Nelson, 2017; available at https://cran.r-project.org). The age compositions of anchovy for both seasons were calculated using the lenght-frequency distributions and corresponding ALKs. Length-at-age data also were used to estimate growth parameters in von Bertalanffy growth function $L_t = L_\infty [1 - e^{-K(t-t_o)}]$ and $W_t = W_\infty [1 - e^{-K(t-t_o)}]^b$, where L_t and W_t are the length and weight of fish at age t; L_∞ and W_∞ are the asymptotic length and weight, *K* is the instantaneous growth coefficient, and t_o is the hypothetical age at which fish length is equal to 0, and b is the exponent of the length-weight relationship. The parameters L_∞, K and t_o were calculated using R-software with the "growth" function in the "fishmethods" package (Nelson, 2017).

Standard statistical methods (summary statistics, normality tests, two-sample tests, etc.) were applied using the PAST ver. 3.25 software (Hammer, 2019; available at https://folk.uio.no/ohammer/past/). The Shapiro-Wilk test was performed to check the normality of the data. The Student t-test for equal means was used when the data followed a normal distribution. The Kolmogorov-Smirnov test was used to compare anchovy size distributions and the χ^2 test was used to check the sex composition (Zar, 1999).

Results

Length-Length Relationships

Scientists use various measurements of fish body length as a basis for their research. Turkish scientists traditionally use the total length in anchovy studies while most Russian authors use the fork length or standard length. We calculated linear relationships between TL, FL, and SL for Azov anchovy to find conversion coefficients:

$TL = 1.096\ FL \quad FL = 0.913\ TL \quad SL = 0.858\ TL$

$TL = 1.166\ SL \quad FL = 1.064\ SL \quad SL = 0.940\ FL$

The coefficients of determination (R^2) were higher than 0.99 in all cases. Thus, for the Azov anchovy, FL is 91.3% of TL, and SL is 85.8% of TL or 94% of FL.

Length-Weight Relationships

The average values of fish weight in different size classes was higher in the second fishing season 2017/2018 compared to the first one, with some exceptions (Table 2). These differences were statistically significant ($P < 0.001$) for size classes where the number of measured fish exceeded 100 individuals.
The length-weight relationship for all fish within the size range from 5.1 to 14.4 cm TL, for two seasons combined can be calculated as $W = 0.0033\ TL^{3.206}$ (Figure 2a). However, an examination of residuals showed strong nonlinearity (Figure 2b), that related to differences in body shape between juveniles and adult fish. Therefore, with the "segmented" package, we calculated two

Table 1. Data on anchovy samples, number of measured and analyzed specimens.

Fishing season	Month	N of samples	N measured	N bioanalysis
2016/2017	October	6	643	182
	November	6	772	142
	December	7	874	165
	January	3	522	123
	February	2	287	140
	March	3	528	168
2017/2018	October	3	291	127
	November	5	517	329
	January	4	669	287
	February	1	228	82
Total		40	5331	1745

Table 2. Mean weight (± SD) of Azov anchovy in different size classes in 2016/2017 and 2017/2018 fishing seasons.

Size class (TL, cm)	Fishing season				*t*-test (P)
	2016/2017		2017/2018		
	N	Mean weight (g)	N	Mean weight (g)	
5.1–5.5	5	0.61 ± 0.08	0	–	–
5.6–6.0	4	0.81 ± 0.06	0	–	–
6.1–6.5	3	1.15 ± 0.15	0	–	–
6.6–7.0	13	1.57 ± 0.28	5	1.72 ± 0.19	0.31
7.1–7.5	16	2.25 ± 0.34	2	2.26 ± 0.26	0.78
7.6–8.0	25	2.69 ± 0.39	5	2.52 ± 0.27	0.98
8.1–8.5	12	3.48 ± 0.66	16	3.41 ± 0.40	0.98
8.6–9.0	16	3.90 ± 0.53	21	4.36 ± 0.55	0.72
9.1–9.5	19	5.30 ± 0.87	25	5.20 ± 0.56	0.54
9.6–10.0	54	5.98 ± 0.78	48	6.05 ± 0.72	0.60
10.1–10.5	102	6.62 ± 0.70	105	6.98 ± 0.69	<0.001
10.6–11.0	148	7.27 ± 0.95	122	7.89 ± 0.85	<0.001
11.1–11.5	203	8.04 ± 1.12	144	8.89 ± 1.03	<0.001
11.6–12.0	143	8.99 ± 1.34	127	10.03 ± 1.21	<0.001
12.1–12.5	71	9.83 ± 1.15	110	10.80 ± 1.23	<0.001
12.6–13.0	22	11.02 ± 1.07	99	11.54 ± 1.32	0.17
13.1–13.5	5	12.25 ± 0.70	40	12.73 ± 1.28	0.43
13.6–14.0	0	–	11	13.98 ± 2.50	–
14.1–14.5	1	16.85	2	16.02 ± 2.80	–

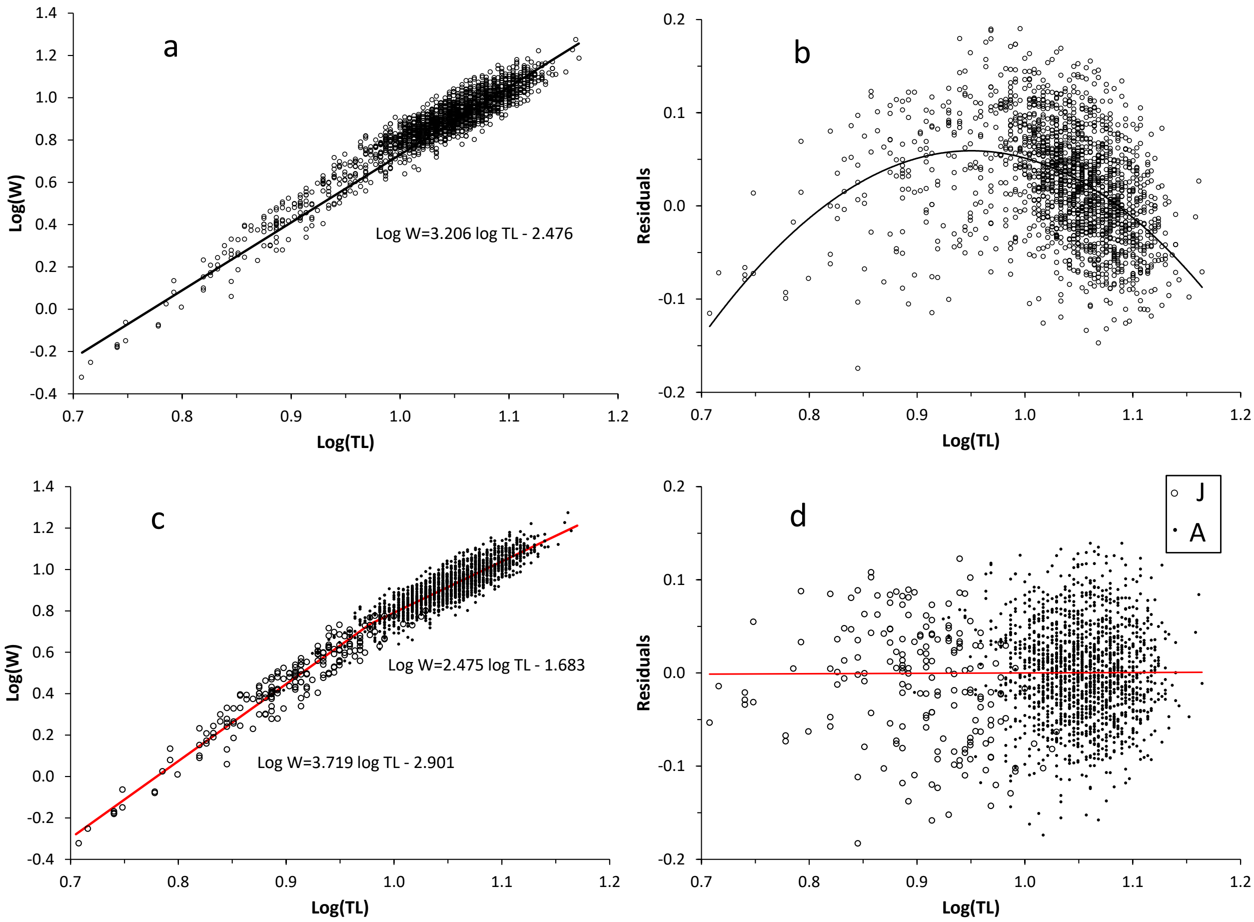

Figure 2. Double-logarithmic plot of anchovy weight vs total length based on all data (a) and absolute residuals (b), plot segmented on two lines for small and large fish (c) and absolute residuals (d). A break-point between two lines corresponds to TL = 9.5 cm. The symbols on plots below mean juveniles (J) and adult (A) fish.

different regression lines that described the log-transformed data more accurately (Figure 2c). The calculated breakpoint between the lines corresponds to 9.5 cm TL. Thus, the LWR for fish < 9.5 cm TL was found as:

$$W = 0.00126\ TL^{3.719}, \qquad (1)$$

and for larger fish

$$W = 0.0207\ TL^{2.475}. \qquad (2)$$

There was no statistically significant trend of residuals for such a segmented line (Figure 2d).

Thus, calculating Kn for small fish according to equation (1) and for large fish by equation (2), we obtained values that were independent of fish length.

No statistically significant differences were found between LWRs for either male or female. Thus, the generalized formula $W = 0.022\ TL^{2.45}$ can be used for mature fish longer than 8.5 cm TL.

Size Composition

The comparison of length-frequency distributions of Azov anchovy was conducted based on the fork length. The size distributions were significantly different for the two seasons (KS-test, $P < 0.001$) (Figure 3). The modal size class in 2016/2017 was 9.5-10.0 cm FL, while in 2017/2018 it increased to 10.5-11.0 cm FL. The relative abundance of fish larger 11.0 cm FL doubled in the second season (21% vs. 10%). Mean length of the anchovy was 9.88±0.41 cm FL (or 10.82±0.45 cm TL) and weight was 7.60±1.10 g in 2016/2017 while in the next season they increased to 10.37±0.35 cm FL (11.36±0.38 cm TL) and 8.91±0.92 g. The differences between the means were significant according to *t*-test ($P < 0.001$). Mean anchovy lengths ranged monthly between 9.0 and 10.6 cm FL during 2016/2017 and 9.7-10.9 cm FL during 2017/2018 and did not differ significantly within the studied seasons (ANOVA, P = 0.13 and P = 0.63 respectively).

Females were usually slightly larger than males (KS-test, $P < 0.05$). The mean length of females in 2016/2017 was 11.19±0.99 cm TL and males 11.08±0.82 cm TL, whereas in 2017/2018 it was 11.44±1.26 cm TL and 11.22±1.14 cm TL respectively. Both females and males were significantly larger in 2017/2018 than in the previous season (KS-test, P < 0.001).

The largest specimens of the Azov anchovy were found in 2017, they were 3-years old fish: female of 14.4 cm TL and 16.85 g and a male of 14.5 cm TL and 18.82 g.

Age, Age Composition and Age-Length Keys

According to the data of age determination using otoliths, the anchovy population consisted of four age groups (0, 1, 2, 3+).

The average length and weight of different age groups during various months are presented in Table 3. The results showed a small growth of the anchovy generations during the winter periods. Fingerlings born in 2016 increased their length from 7.6 to 8.15 cm, while the generation of 2017 grew from 8.0 to 8.9 cm. Older age groups grew less intensively, their increments were approximately 2-4 mm for the winters. At the same time, a decrease of mean body weight was observed in most cases in adult fish during wintering.

Overall, the average length and weight of each age group were notably larger in the fishing season

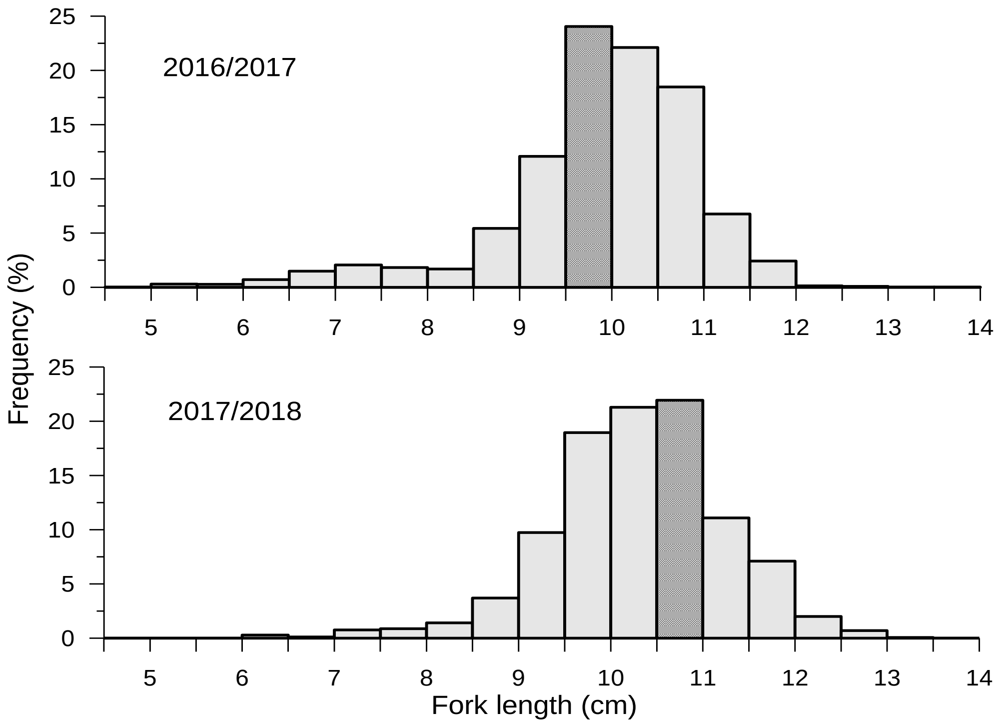

Figure 3. The length-frequency distribution of Azov anchovy in 2016/2017 and 2017/2018 fishing seasons.

2017/2018 in comparison with previous season, except the average length of fish in the age group 1.

The age composition of Azov anchovy for each fishing season which was calculated using ALKs, is shown in Figure 4. In 2016/2017, age group 1 was dominated in catches (59.2%), while age group 2 was less numerous (30.7%). Fingerlings (age group 0) and the oldest age group 3+ accounted for only a small portion of the catches (8.0% and 1.9%, respectively). In the next season, age group 2 was the most numerous (45.1%), the share of age group 3 increased to 14.0%, while the portion of 1-year's old fish decreased to 36.6%.

Sex Composition

Out of 1529 specimens of Azov anchovy sexed for the two seasons, we recorded 733 males, 756 females, and 40 immature fingerlings. So, for both seasons combined, the sex ratio was very close to 1:1. However,

Table 3. Mean values of TL (cm) and weight (g) (underline) with standard errors of Azov anchovy by age groups in various months of 2016/2017 and 2017/2018 fishing seasons.

Month	Age group			
	0	1	2	3+
		Fishing season 2016/2017		
October	7.60±0.23 2.77±0.24	10.55±0.14 7.39±0.25	11.26±0.11 8.53±0.18	–
November	7.29±0.13 2.36±0.14	10.62±0.08 7.02±0.12	11.60±0.07 8.93±0.23	–
December	–	10.56±0.07 7.00±0.12	11.61±0.08 9.07±0.16	–
January	–	11.04±0.06 7.54±0.12	11.73±0.06 9.09±0.15	12.30±0.18 10.19±0.69
February	–	11.08±0.07 7.42±0.17	11.55±0.07 8.66±0.15	12.42±0.30 10.91±0.61
March	8.15±0.21 2.75±0.25	10.59±0.06 6.65±0.12	11.86±0.06 9.04±0.14	12.71±0.15 10.86±0.51
		Fishing season 2017/2018		
October	8.00±0.14 3.03±0.30	10.45±0.08 7.73±0.19	11.65±0.07 10.53±0.18	12.50±0.12 11.96±0.31
November	8.69±0.15 4.15±0.23	10.38±0.06 7.28±0.12	11.60±0.06 9.44±0.13	12.52±0.09 11.51±0.22
January	8.36±0.17 3.67±0.23	10.59±0.07 7.28±0.13	11.95±0.07 9.67±0.14	12.58±0.09 10.85±0.21
February	8.91±0.21 3.77±0.27	10.62±0.09 6.92±0.18	11.93±0.10 9.13±0.22	12.76±0.10 10.95±0.24

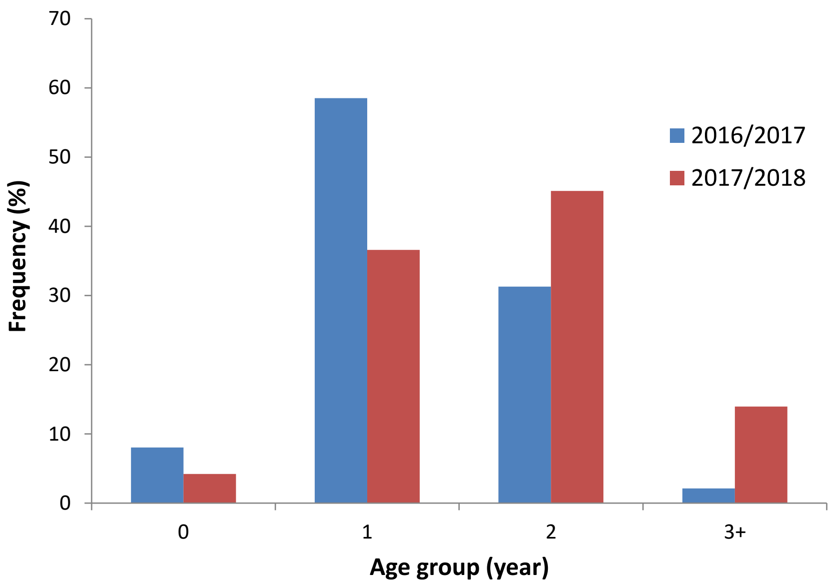

Figure 4. Age-frequency distribution of Azov anchovy in the two seasons.

significant differences were observed between the two seasons (χ^2-test, P < 0.01). Males prevailed each month from October 2016 to March 2017 (52-58%), while in 2017/2018 the sex ratio shifted towards females, which dominated at 50-56% for the studied months.

Fish Condition

Mean values of Kn at the beginning of the fishing seasons (October-November), were 1.02 in 2016/2017 and 1.08 in 2017/2018 (Table 4). The Student's t-test showed that these means were statistically different (P < 0.0001).

The lipid content in the anchovy body in October-November 2016 was 15.1%, and in the same months of 2017, it was much higher, reaching 16.6%.

Mean values of Kn, as well as lipids, were decreasing in February-March to 0.94-0.95 and 13.7-13.8% respectively. The comparison of average values of Kn and lipids in the middle and end of 2016/2017 and 2017/2018 wintering seasons did not show the significant difference due to the large variability.

It is worth to note that the lipid content related to fish size. Overall, the small fish 5.0- 7.0 cm TL in October-November had the lowest values of lipids (on average < 9.0%), fish of 8.0-12.0 cm TL had maximal values (14.5%), and fish larger than 12 cm contained 12.0%.

Growth

As was shown in Table 3, the average length and weight of the same age groups were greater in the second fishing season in most cases than in the first ones. Based on length-at-age data and using "growth" function in the "fishmethods" package of R, the von Bertalanffy growth equations for different fishing seasons were estimated as follow:

2016/2017 $TL = 12.2\,[1 - e^{-1.22\,(t + 0.38)}]$,

2017/2018 $TL = 14.0\,[1 - e^{-0.44\,(t + 1.67)}]$,

Combined $TL = 13.0\,[1 - e^{-0.73\,(t + 0.86)}]$

Despite the VBG parameters notably differed between seasons, the fitted growth curves were similar for fish older than 1 year (Figure 5). Therefore, the differences in values of VBG parameters were mainly related to differences in sizes of the age group 0 in various years.

Table 4. Mean relative condition factor (Kn) and lipid content of Azov anchovy in selected months during the two fishing seasons.

	Condition factor Kn			Lipids (% wet weight)		
Season	2016/2017	2017/2018	*t*-test	2016/2017	2017/2018	*t*-test
Oct – Nov	1.020 ± 0.016	1.080 ± 0.010	P < 0.0001	15.1 ± 3.0	16.6 ± 2.9	P = 0.08
Dec – Jan	0.980 ± 0.012	1.007 ± 0.011	P = 0.0014	15.4 ± 2.1	15.1 ± 1.1	P = 0.75
Feb – Mar	0.938 ± 0.011	0.949 ± 0.017	P = 0.33	13.8 ± 1.1	13.7 ± 1.4	P = 0.75

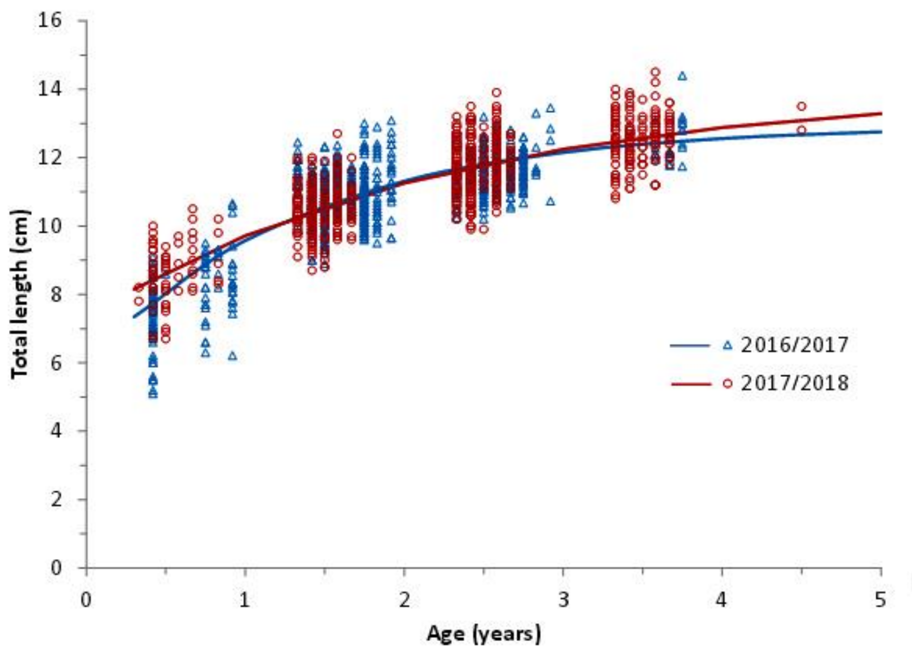

Figure 5. Length-at-age of Azov anchovy in 2016/2017 and 2017/2018 fishing seasons and fitted growth curves.

In fact, these curves do not describe the growth rate of a single cohort or individual fish, but allow you to compare the length of the age of the Azov anchovy with other subspecies of anchovies.

Actually, these curves do not describe the growth rate of a single cohort or an individual fish but allow us to compare the length-at-age of Azov anchovy with other anchovy subspecies.

Discussion

The Azov Sea ecosystem has recently undergone changes due to an increase in the water salinity from 9.4 ppm in 2006 to 13.8 ppm in 2017 (Kosenko *et al*., 2017). Initially, the salinization of the Sea of Azov had a positive impact on the population of Azov anchovy. Its spawning and feeding grounds have expanded, the quality and quantity of food have improved due to the increase in the penetration of the Black Sea plankton into the Sea of Azov and the reduction of trophic competition with ctenophore-invader *Mnemiopsis leidyi* and fish *Clupeonella cultriventris* (Yuneva *et al*., 2019). These changes in the Azov ecosystem initially promoted an unprecedented increase in the stock biomass of Azov anchovy in 2010-2012, but have since declined dramatically in 2015-2016 (see Figure 1). Obviously, the water salinity in the Sea of Azov also plays an important role in the distribution of spawning and feeding grounds of the anchovy, the survival of fish larvae and the recruitment yield.

Environmental factors, especially the sea surface temperature, play a major role in the dynamics of anchovy stocks (Gursalan *et al*., 2014). Recent data indicate that climate changes affect the location of spawning and overwintering grounds, as well as the timing and migration pathways of the anchovies, and ultimately the fishing success (Gücü *et al*., 2016; Gursalan *et al*., 2017).

In addition to environmental factors, fishing can have a significant impact on fish populations. The results of this work showed that despite very large landings of the anchovy in 2015 and 2016, the average length and weight of the fish in catches were significantly greater than in 2010-2012 when the stock biomass was maximal and the catch to stock ratio was the lowest. The average size of anchovies in 2010-2012 was 9.1 cm FL (Yuneva et al., 2019), while in 2016/2017 it was 9.9 cm and even increased to 10.4 cm in 2017/2018. Also, the average weight of fish in catches increased from 6.6 g to 7.6 and 8.9 g, respectively. Besides, the maximum size of Azov anchovy recorded in the present study was 14.5 cm TL and 18.82 g that is greater than the maximum reported length of the Azov anchovy in the literature as 14 cm (Svetovidov, 1964).

Azov anchovy is a fish with a short lifespan, and fish in our study were represented by individuals aged 0 to 4 year's old, as expected. Anchovy fisheries were based on 1-year's old fish (59.2%) in 2016/2017 and 2-year's old fish (45.1%) in 2017/2018. So, the recruitment to the stock in 2015 was quite strong and supported fisheries in the next two seasons, comprising 56% of the catch biomass in 2016/2017 and 50% in 2017/2018. However, there was no successful recruitment in 2016 and 2017.

The size composition of anchovy did not show any significant differences between months within the studied seasons. A slight increase in length for all anchovy generations was observed during wintering, especially in age group 0, but the mean body weight was decreased in most cases at the same time. Generally, the average length and weight of each age group were significantly larger in the fishing season 2017/2018 in comparison with the previous season.

There are numerous studies on length-weight relationship for the Black Sea anchovy, while published data for Azov anchovy are practically absent. We found only one paper (Volovik & Kozlitina, 1983), which reported the value of coefficient b for Azov anchovy in the range of 2.56-2.89. So, we compared our results with literature data on the Black Sea anchovy (Table 5). According to our calculations, adult specimens of Azov anchovy were lighter in weight than the Black Sea anchovy at the same length (Figure 6). This may be related by a higher content of lipids in Azov anchovy than in the Black Sea anchovy (Yuneva *et al*., 2013), because its specific body weight is lower, as fat is lighter than other tissues.

The present study indicates that young anchovies up to 9.5 cm TL had a positive allometric growth (b = 3.719), while adult fish > 9.5 cm had the negative allometric growth (b = 2.475). This can be explained by different growth strategies of immature young and mature adult fish. Somatic growth in body length prevails in young individuals to grow faster and avoid predators, and 9.5 cm is approximately the largest length of fingerlings (age group 0). The strategy of adults is focused on the fat accumulation, production of gonads and reproduction. So, in this case, is better to use different LWR equations and calculate the relative condition factor (Kn) instead of Fulton condition factor. Overall, the body condition of Azov anchovy estimated by Kn and content of total lipids was higher in the beginning (October-November) of second fishing season 2017/2018 and gradually decreased to February-March in both seasons due to the low feeding intensity, weight and lipid losses. According to Shul'man (1974), this pattern is common for warm-water fishes and the lipid content in the anchovy body is reached its maximum values in October-November, therefore this parameter is used as an indicator of the feeding success before wintering. From Yuneva *et al*. (2019), the lipid content reached more than 18% in 2010-2012, when the stock biomass of Azov anchovy were at the maximum level. The current decrease of lipid content to about 15-16% indicated the deterioration in the food supply of the anchovy in 2016 and 2017.

As well as LWR parameters, published data on the growth of Azov anchovy are very rare. For the first time, parameters of von Bertalanffy equation were calculated

Table 5. Parameters of the length-weight relationship (LWR) and the von Bertalanffy growth equation (VBG) for Azov anchovy and the Black Sea anchovy.

Period	LWR parameters *a*	LWR parameters *b*	VBG parameters L_∞ (cm)	VBG parameters W_∞ (cm)	VBG parameters *K* (yr^{-1})	VBG parameters t_o (yr)	Source
			Azov Sea anchovy				
–	–	–	11.70	–	1.16	-0.17	Bayliff (1967), on data from Berg *et al.* (1949)
–	–	–	9.40	–	1.21	-0.37	Bayliff (1967), on data from Svetovidov, 1964
	–	2.89	–	9.0	0.31	-1.82	
1932-77	–	2.87	–	13.3	0.57	-1.42	Volovik & Kozlitina (1983)
	–	2.56	–	26.2	0.78	-1.11	
1967-77	–	–	13.26	22.6	0.61	-1.80	
2016-18	0.022	2.45	13.00	12.6	0.73	-0.86	Present study
			Black Sea anchovy				
1977-85	–	–	13.90	20.0	0.99	-0.74	Shlyakhov *et al*. (1990)
1985/86	0.0023	3.416	16.77	–	0.32	-2.07	Erkoyuncu & Özdamar (1989)
1986/87	0.0025	3.383	16.85	34.48	0.32	-1.99	Karaçam & Düzgüneş (1990)
1987/88	0.0025	3.387	14.14	20.04	0.92	-0.32	Düzgüneş & Karaçam (1989)
1988/89	0.0064	2.974	15.73	23.32	0.32	-2.19	Ünsal (1989)
1993/94	0.0051	3.048	15.82	23.07	0.34	-2.14	Düzgüneş *et al*. (1995)
1994/95	0.0047	3.098	16.83	29.47	0.31	-2.21	Özdamar *et al*. (1995)
1998/99	0.0083	2.872	15.66	–	0.34	-2.53	Samsun *et al*. (2004)
1999/00	0.0076	2.919	17.07	–	0.28	-2.10	
2000/01	0.0118	2.710	16.84	–	0.23	-3.08	
2001/02	0.0051	3.057	18.46	–	0.22	-2.86	Samsun *et al*. (2006)
2002/03	0.0075	2.895	18.73	–	0.16	-3.97	
2004/05	0.0101	2.790	21.17	–	0.20	-2.31	Bilgin *et al*. (2006)
2004/05	0.0101	2.794	16.11	23.88	0.29	-2.56	Şahin *et al*. (2008)
2005/06	0.0055	3.0425	15.27	21.99	0.28	-3.53	
2006/10	0.024	2.507	14.60	–	0.48	-1.55	Yankova (2014), Yankova *et al*. (2011)
2010/11	0.011	2.742	16.37	23.52	0.43	-1.35	Sağlam & Sağlam (2013)
2005-16	0.0046	3.122	–	–	–	–	Gücü *et al.* (2018)
2008-11	0.0124	2.711	16.52	–	0.36	-2.02	Kasapoğlu (2018)

by Bailiff (1967) on the basis of length-at-age data reported by Berg *et al*. (1949) and Svetovidov (1964) (see Table 5). These data were later compiled by Pauly (1978) and included in FishBase (Froese & Pauly, 2019). Later, the growth data for Azov anchovy were reported by Volovik and Kozlitina (1983). They found significant differences in growth rates between different cohorts and showed characteristic values for "accelerated", "moderate" and "weak" growth. According to our results, anchovy growth in 2016/2017 and 2017/2018 seasons appeared similar to “moderate” growth following Volovik and Kozlitina (1983). To compare growth rates between Azov and the Black Sea anchovies, we also included in Table 5 some literature data on VBG parameters of the Black Sea anchovy. The major differences between the subspecies were observed in the values of asymptotic length which in Azov anchovy were ranged between 9.4-14.0 cm, while for the Black Sea anchovy were notably higher ranging from 13.9 to 21.2 cm. The recent overview of the Black Sea anchovy (Bilgin *et al.*, 2016) demonstrated changes in the mean length at age of anchovy caught in waters of Turkey from 1985 to 2011. Our data on mean length of Azov anchovy are within the ranges pointed by these authors for age groups 0 and 1, but smaller than in older age groups. Based on data from Table 5, we plotted a comparative picture showing the growth curves of Azov anchovy on the background of the range of growth curves for the Black Sea anchovy (Figure 7). The growth rate of Azov anchovy seems to be similar to the Black Sea anchovy for the age groups 0 and 1, but declined for fish of the oldest age groups.

Observed changes in the Azov anchovy population structure and the fluctuation of the stock biomass are likely related to environmental conditions rather than to fishing pressure. However, we believe that the continuation of fishing of Azov anchovy at the current level would adversely affect the size-age structure, reduce biological growth rate and inevitably lead to overfishing and depletion of the stock.

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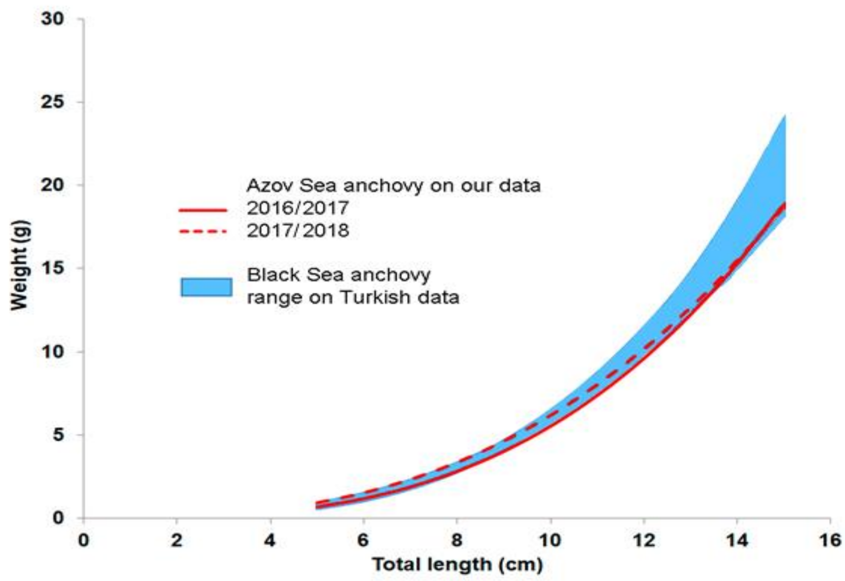

Figure 6. The length-weight relationships of the Azov anchovy in comparison with the range of combined LWR data for the Black Sea anchovy (drawn according to data from Table 5).

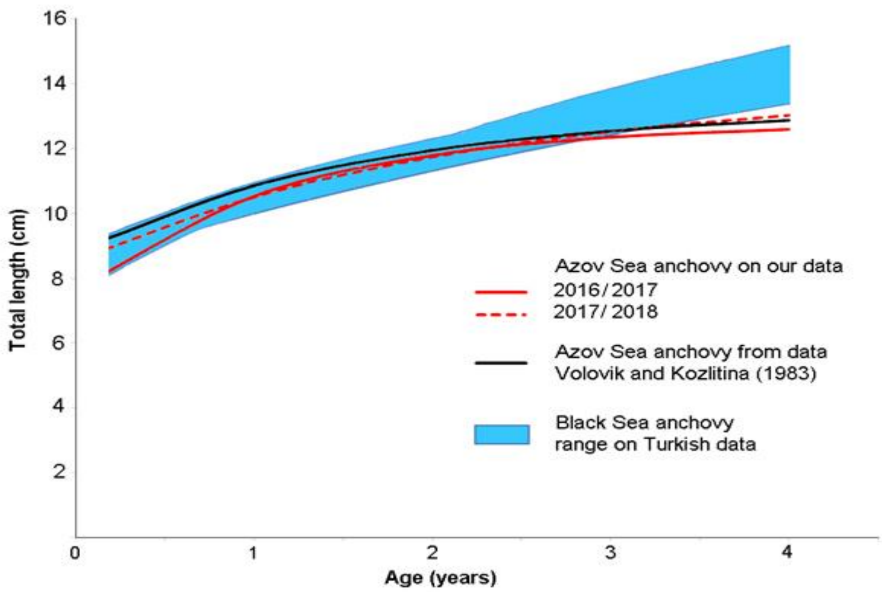

Figure 7. Growth curves of Azov anchovy in comparison with the range of growth curves of the Black Sea anchovy (drawn according to data from Table 5).

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