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RESEARCH ARTICLE ARAŞTIRMA MAKALESİ

Population parameters of the pontic shad, *Alosa immaculata* Bennett, 1835 in the Fatsa coast of the south-eastern Black Sea

Güney-doğu Karadeniz'in Fatsa kıyılarında tirsi balığının, *Alosa immaculata* Bennett, 1835 populasyon parametreleri

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Abstract: The aim of this study is to estimate population parameters of pontic shad, *Alosa immaculata* Bennett, 1835 in the Fatsa coast of the south-eastern Black Sea. A total of 314 pontic shad specimens were collected from study area using artisanal fishing gears from March 2013 to February 2014. In the study, parameters of the von Bertalanffy growth equation were found as L_∞=43.05 cm; k=0.430 per year and t_0=-0.451 year. The growth performance index (Φ') was estimated as 2.90. The total mortality (Z), natural mortality (M), fishing mortality rates (F) were calculated as 1.33 year^{-1}, 0.75 year^{-1} and 0.58 year^{-1}, respectively. The annual instantaneous fishing mortality rate was greater than both the target (F_{opt}=0.375 year^{-1}) and limit (F_{limit}=0.50 year^{-1}) biological reference points. Similarly, the present level of exploitation rate (E=0.43) was higher than the exploitation ratio for maximum yield per recruit (E_{max}=0.375) suggesting that overexploitation occurred. These results showed that this species has been over-exploited in the Fatsa coast of the south-eastern Black Sea. Measures should be taken to reduce the current exploitation rate for sustainable fishing of pontic shad in the Fatsa coast of the south-eastern Black Sea.

Keywords: Black Sea, pontic shad, *Alosa immaculata*, growth, mortality, exploitation

Öz: Bu çalışmanın amacı, Güney-doğu Karadeniz'in Fatsa kıyılarında tirsi balığı *Alosa immaculata* Bennett, 1835'nın popülasyon parametrelerini belirlemektir. Geleneksel uzatma ağları kullanılarak, Mart 2013 ile Şubat 2013 tarihleri arasında yapılan örnekleme avcılığı çalışmalarında toplam 314 tirsi balığı yakalanmıştır. Çalışmada, von Bertalanffy büyüme denkleminin parametreleri L_∞=43,05 cm, k=0,430 yıl^{-1} ve t_0=-0,451 yıl olarak bulunmuştur. Büyüme performans indeksi ise (Φ') 2,90 olarak hesaplanmıştır. Toplam ölüm (Z), doğal ölüm (M) ve balıkçılık ölümü (F) oranları sırasıyla 1,33 yıl^{-1}, 0,75 yıl^{-1} ve 0,58 yıl^{-1} olarak tahmin edilmiştir. Yıllık anlık balıkçılık ölümü oranı, hem optimum balıkçılık ölümü oranı (F_{opt}=0,375 yıl^{-1}) hem de limit (F_{limit}=0,50 yıl^{-1}) biyolojik referans noktalarından daha yüksek bulunmuştur. Mevcut sömürülme oranı (E=0,43), stoka katılım başına düşen maksimum verim için hesaplanan maksimum sömürülme oranından (E_{max}=0,375) daha yüksektir. Bu sonuçlar, tirsi balığının Güney-doğu Karadeniz'in Fatsa kıyılarında aşırı av baskısı altında olduğunu göstermektedir. Tirsi balığının sürdürülebilir avcılığı için mevcut sömürü oranını azaltacak önlemler alınmalıdır.

Anahtar kelimeler: Karadeniz, tirsi, *Alosa immaculata*, büyüme, ölüm oranı, sömürülme

INTRODUCTION

In Black Sea including the Sea of Azov, three shad species of the genus *Alosa* are known: Pontic shad, *Alosa immaculata* Bennett, 1835; Caspian shad, *Alosa tanaica* Grimm, 1901 and Black Sea shad *Alosa maeotica* Grimm, 1901 (Tiganov et al., 2013). The Pontic shad, *Alosa immaculata* Bennet, 1835 is the largest species of the family Clupeidae in the Black Sea. It is an anadromous fish species which inhabits Black Sea and Azov Sea, and for spawning enters the big rivers (Navodaru, 2001; Višnjić-Jeftić et al., 2013; Raikova-Petrova, 2013; Rozdina et al., 2015; Lenhardt et al., 2016). Pontic shad is an endemic fish species for the Black Sea (Turan et al., 2015) and it is found off the coasts of the Black Sea and the Marmara Sea in Turkey (Turan et al., 2007). According to TUIK data, the total catches of *Alosa* species caught from Turkish waters between 2009 and 2018 are seen in Figure 1.

Pontic shad is a fish species that lives scattered in mid-August until December, Turkey's Black Sea waters. They are

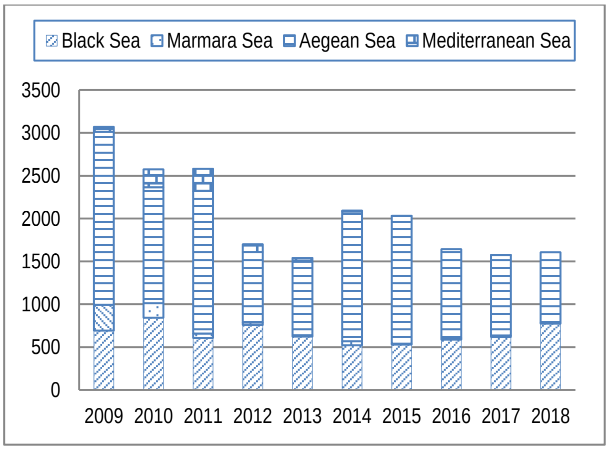

Figure 1. Total catches of *Alosa* species caught from Turkish seas between 2009 and 2018 (Ton)

usually fished with midwater trawl, purse seine and gillnets (Erguden, 2007; Özdemir et al., 2010; Tiganov et al., 2016). The meat has a high fat content and is a good source of nutrients. Therefore, consumption is particularly recommended. Although the meat of this species is excessively bony, it is a very tasty (Polat and Ergun, 2008).

This species migrates upriver to spawn at 3 years, rarely earlier and only a few individuals spawn two seasons. It appears along coast in March-April, enters rivers when temperatures reach about 6-9°C, between late March and late April. Migration usually peaks in May. Spawning starts when temperature rises above 15°C, in April-August. Spent individuals migrate back to sea to feed. Juveniles inhabit floodplain and shallow riverine habitats, migrate to the sea or estuarine habitats during first summer; in autumn, they move to the sea, remaining there until they mature. At sea, feeds on a wide variety of zooplankton (especially crustaceans) and small fish. Impoundment of main rivers (all happened more than 10 years ago) has significantly reduced available spawning sites and migration routes. The current threat to the species is overfishing, at sea and in the rivers during the migration runs, which is causing a population decline of unknown levels (Freyhof and Kottelat, 2008).

In IUCN (2018) reported that pontic shad is a vulnerable fish species. Overfishing is the major current threat to the species. It is caught both at sea and in the lower courses of rivers during the migration. Dam construction in the Black Sea basin (over 10 years ago) has led to the loss of large areas of spawning grounds.

The sustainable exploitation of this commercial fish species requires detailed study of the population and mortality parameters of populations. The species has been regularly studied on the Turkish coast of the Black Sea (Samsun, 1995; Özdamar, 1995; Kalaycı et al., 2007; Ergüden et al., 2007; Yılmaz and Polat, 2011; Samsun et al., 2017). In this study, population parameters such as the growth, mortality and exploitation rate for pontic shad caught from the Fatsa coasts of the south-eastern Black Sea were investigated.

MATERIALS AND METHODS

Study area

The study was carried out in Fatsa (Ordu) coast of Black Sea (Figure 2). Pontic shad specimens were monthly collected by using multifilament gillnets with mesh sizes of 32, 34, 36 and 38 mm, from March 2013 to February 2014. The fishing experiments were conducted three times for each month except for July and August. In July and August, fishing experiments could not be conducted due to in maintenance of fishing boat. During the sampling, the total length (L) of each specimen collected was measured.

Data analysis

For data analysis was used software package FiSAT II (FAO - ICLARM Stock Assessment Tool) based on length frequency distribution (Gayanilo et al., 2003).

The estimation of the growth parameters

The growth parameters (L_∞, k) were estimated by the length frequency analysis using the ELEFAN model implemented by the FiSAT II program (Gayanilo et al., 2005). The theoretical age at birth (t_0) was calculated using the empirical formula (Pauly, 1979):

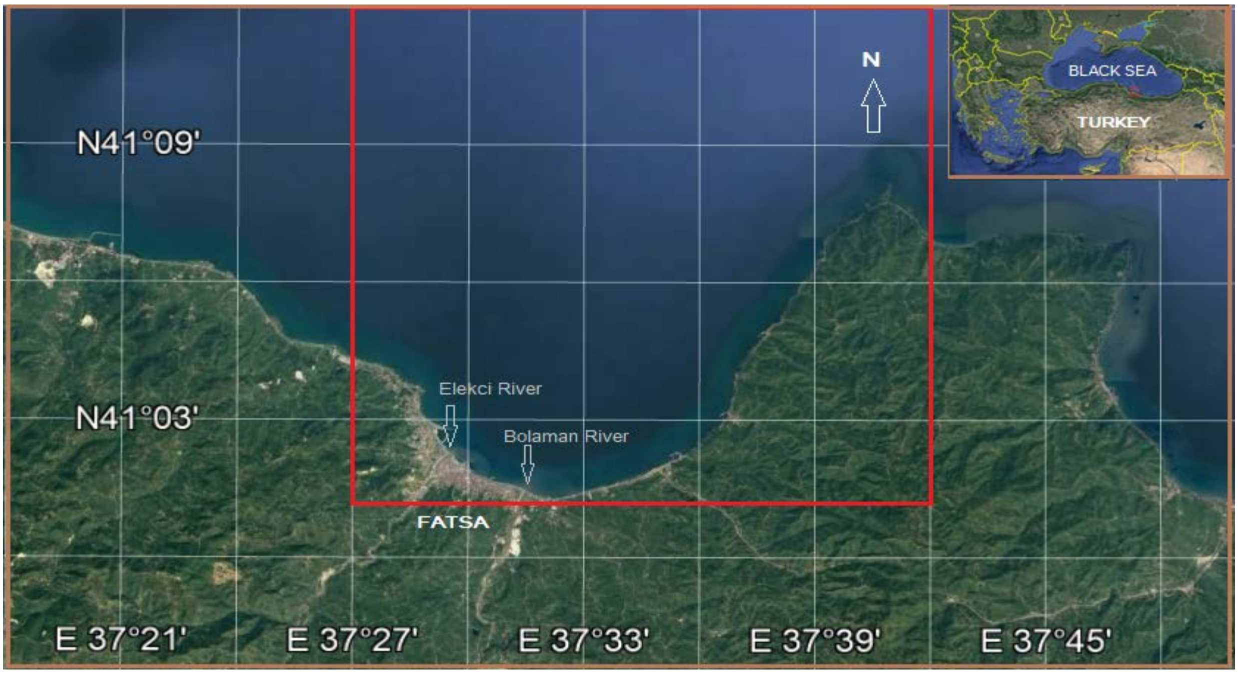

Figure 2. Study area

$Log(-t_0)=-0.3922 - 0.275*Log_{10}(L_\infty) - 1.038*Log_{10}(k)$. The general equation of the increase in length as a function of age (Von Bertalanffy) is: $L_t=L_\infty*[1-e^{-k*(t-t_0)}]$.

Where; L_t = length at age t, L_∞ = the asymptotic length of fish; k = curvature parameter that determines how fast the fish approaching to L_∞; t_0= the theoretical age at which the fish length is 0.

The growth performance index was calculated from the below expressed equation:

$(\Phi') = 2*Log(L_\infty) + Log(k)$ (Munro and Pauly, 1983).

The mortality

The estimation of mortality rates represent an important component of fisheries management. Total mortality (Z) was computed using the length converted catch curve analysis method in FiSAT II computer software package. The natural mortality (M) was estimated by the Pauly's empirical formula, using a mean surface temperature (T). Water temperature was monthly measured using thermometer and determine as 17.7 °C. $Log\ M = -0.0066 - 0.279*Log(L_\infty) + 0.6543*Log(k) + 0.4634*Log(T)$ (Pauly, 1980). Where; *M* is the natural mortality, L_∞ is the asymptotic length, *T* is the mean surface temperature and k refers to the growth rate coefficient of the VBGF. Fishing mortality (F) was calculated using the relationship: F=Z-M (Gulland, 1971), where; *Z* is the total mortality, *F* is the fishing mortality and *M* is the natural mortality. The exploitation level (E) was obtained using the relationship: E=F/Z (Gulland, 1971). Fishing mortality rate with target (F_{opt}) and limit (F_{limit}) biological reference points were estimated by formula of Patterson (1992): $F_{opt}=0.5M$ and $F_{limit}=2/3M$.

Probabilty of capture

The ascending left arm of the length converted catch curve incorporated in FİSAT II tool was used to estimate the probability of length at first capture (L_c) in addition to the length at both 25 and 75 captures which corresponded to the cumulative probability at 25% and 75% respectively. The probability of capture gives clear idea about the estimate of the real size of the fish in the fishing area that is being caught by specific gear. It is an important tool for fisheries managers in sustainably managing a target fishery, because it helps would be managers determining the minimum mesh size of a fishing fleet.

Length at recruitment (Lr) and Length at first capture (Lc)

Length at recruitment (Lr) was estimated also in the same manner by applying the growth equation of Von Bertalanffy: $Lr = = \bar{L}-k*(L_\infty-L')/Z$. Where; *L'* is the length for which all fish of that length and longer are under full exploitation, $\bar{L}$ is the mean length and *Z* is the instantaneous total mortality coefficient. Length at first capture (Lc) was investigated from the equation of Beverton and Holt (1956) which applies the growth constants of Von Bertalanffy: $Lc = \bar{L} - k(L_\infty - \bar{L}) / Z$. Where; $\bar{L}$ is the mean length of the catch, *k* and L_∞ are the constants of Von Bertalanffy equation and Z is the instantaneous total mortality coefficient.

Relative yield per recruit (Y/R) and relative biomass per recruit (B'/R)

Relative yield per recruit (Y/R) was based on the Beverton and Holt model (1966). The relative biomass per recruit (B'/R) was estimated as B'/ R=(Y'/R)/F. E_{max} depicts exploitation rate producing maximum yield. $E_{0.1}$ highlighting exploitation rate at which the marginal increase of *Y'/R* is 10% of its virgin stock with $E_{0.5}$ implying exploitation rate under which the stock is reduced to half its virgin biomass were computed using the procedure incorporated using the Knife-edge option fitted in the FiSAT II Tool. The length frequency data were pooled into groups with 1cm length intervals. Then the data was analyzed using the FiSAT II (FAO-ICLARM Stock Assessment Tools) software (Gayanilo et al., 1993).

RESULTS

Growth parameters

A total of 314 pontic shad were collected during the sampling studies. The total lengths of the fish studied were between 13 and 41 cm, with an average value of 30.5 cm.

Table 1. Mean, minimum and maximum total lengths (L) of pontic shads collected from study area (N: Fish number, SD: Standard Deviation)

Month	N	L	SD	min.	max.
March 2013	68	29.5	5.7	13.0	37.0
April	30	34.0	2.7	28.0	38.0
May	8	30.1	2.9	27.0	35.0
January	8	32.1	3.0	29.0	38.0
September	20	29.5	3.8	26.0	39.0
October	82	31.2	4.1	19.0	41.0
November	30	30.7	2.8	26.0	36.0
December	17	29.8	3.0	26.0	34.0
January 2014	27	28.6	3.0	23.5	33.5
February	24	29.6	5.5	21.0	41.0
Total	314	30.5	4.4	13.0	41.0

The L_∞ and k were estimated as 43.05 cm and 0.430 $year^{-1}$ from length frequency data using ELEFAN I by FiSAT II software (Figure 3). Since very few pontic shads were caught in some sampling periods, the data were seasonally evaluated. Then, the t_0 was calculated as -0.451 year using the empirical formula.

The von Bertalanffy growth function fitted to size-at age relationship for pontic shad in the Fatsa coast of the south-eastern Black Sea was shown in Figure 4. The growth performance was calculated as Φ'=2.90 from L_∞, k and mean annual water temperature (17.7 ºC).

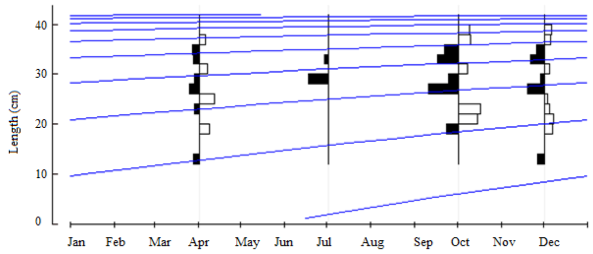

Figure 3. Restructured Length frequency distribution output from FiSAT II with superimposed growth curves (Dark bars= actual frequency bars & White bars=reconstructed bars)

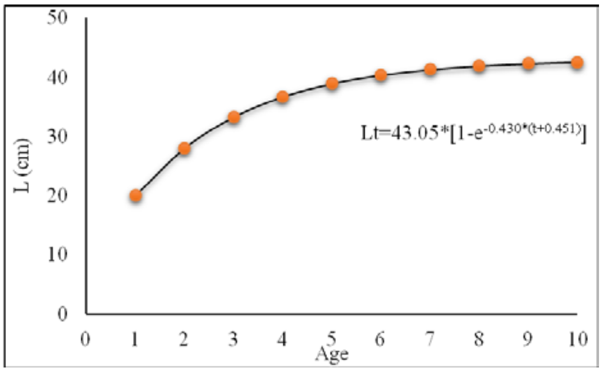

Figure 4. The von Bertalanffy growth function fitted to size-at age relationship for pontic shad in the Fatsa coasts of the south-eastern Black Sea

Mortality coefficients and current exploitation rate

The instantaneous rate of natural mortality (M) was estimated to be 0.75 year^{-1} by using Pauly (1980)'s empirical formula, with an average temperature of 17.7 °C. A length-converted catch curve (Figure 5) was utilized for the calculation of the instantaneous total mortality at Z=1.33 (0.88-1.79) year^{-1}. The fishing mortality (F) was estimated to be 0.58 year^{-1} which was much greater than both the target (F_{opt}=0.375 year^{-1}) and limit (F_{limit}=0.50 year^{-1}) biological reference points. The exploitation rate (E) was estimated to be 0.43 year^{-1}.

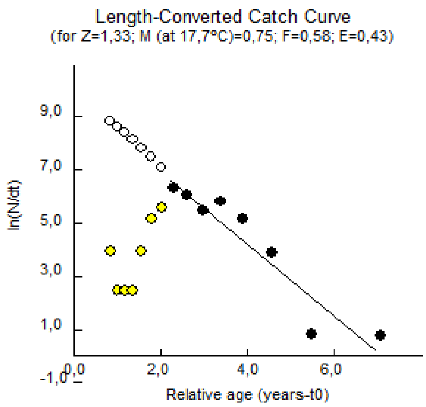

Figure 5. FiSAT II output of linearized length-converted catch curve for pontic shad in Fatsa coast of the south-eastern Black Sea (Yellow and white dots were not used in calculations)

Length at first capture (Lc)

The typical selectivity for pontic shad caught in the Fatsa coast of the south-eastern Black Sea showed that at least 25% of fish of 26.93 cm, 50% of the fish of 29.53 cm and 75% of all fish of 32.13 cm total length were caught by gillnets (Figure 6). The midpoint of lower length classes in the sampled data was used as a length at recruitment which is 20.8 cm. The length at first capture (Lc) was adopted as 26.4 cm.

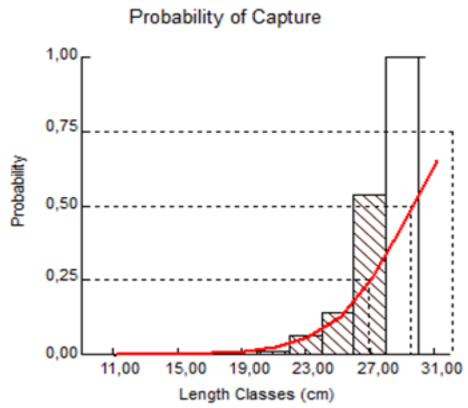

Figure 6. Estimated probability of capture by length of pontic shad caught from the Fatsa coast of the south-eastern Black Sea

FiSAT II output of the probability of capture for pontic shad in the fisheries waters of Fatsa coast of the south-eastern Black Sea (0.25, 0.50 and 0.75 relates to 25%, 50% and 75% respectively)

Relative yield per recruit (Y'/R)

The Beverton and Holt relative yield per recruit model in Figure 7 showed that the indices for sustainable yield were 0.244 for optimum sustainable yield ($E_{0.5}$), 0.375 for the maximum sustainable yield (E_{max}) and 0.307 for economic yield target ($E_{0.1}$). The current exploitation rate was estimated 0.43 from the analysis of mortality rates, which was already above the maximum, optimum and economic yield indices.

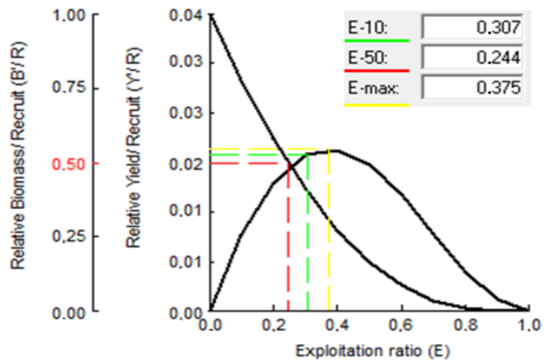

Figure 7. Beverton and Holt's relative yield per recruit and average biomass per recruit models, showing levels of yield indices for pontic shad in the Fatsa coast of the south-eastern Black Sea (Red dashes=$E_{0.1}$, Green dashes=$E_{0.5}$ and Yellow dashes=E_{max})

DISCUSSION

Maximum length of pontic shad was determined as 41 cm in the south-eastern coast of the Black Sea which was slightly larger than the values reported by Yılmaz and Polat (2011), Samsun (1995), Özdamar (1995), Kalaycı et al. (2007), Özdemir et al. (2010), Yankova et al. (2011), Özdemir and Duyar (2013) in the Black Sea and by Ibănescu et al. (2017) in the Romanian section of the Danube river and Rozdina et al. (2013) in the Bulgarian sector of the Danube.

The growth parameters L_∞, k and t_0 are constants in an equation we can predict the fish body size when it reaches a certain age. The asymptotic length (L_∞=43.05 cm) and the growth coefficient k (0.430 year^{-1}) of the pontic shad were close to the values reported in the some studies. For example, the L_∞ and k were found to be L_∞=40.06 cm, k=0.32 year^{-1} in the Turkish coast of the Black sea (Özdemir et al., 2018), L_∞=40.43 cm, k=0.380 year^{-1} in the Romanian section of the Danube river (Ibănescu et al., 2017), L_∞=35.7 cm, k=0.493 year^{-1} in the Bulgarian sector of the Danube river (Rozdina et al., 2013), L_∞=57.38 cm, k=0.1067 year^{-1} in the Danube river (Kolarov, 1980), L_∞=40.43 cm, k=0.27 year^{-1} in the Black Sea (Kolarov, 1983). In the present study, the phi-prime index (Φ') of Munro was calculated as 2.90. This value is higher than values reported in the Romanian section of the Danube river (Ibănescu et al., 2017), Bulgarian sector of the Danube river (Rozdina et al., 2013), the Danube river (Kolarov, 1980) and Black Sea (Kolarov, 1983). These comparisons show that the pontic shad grow faster in the Fatsa coast than in some other regions of the Black sea and the Danube river.

The growth difference among different populations of the same species may be due to environmental conditions, gonad development and reproduction period (Bagenal and Tesch, 1978), as well as sampling site, sampling time, characteristics of sampling nets and sampling methods (Tiraşin, 1993). For example, our research area and Samsun coasts are very close each other. However, the results show significant differences. Probably, this difference may be due to the sampling method. While the samples of our study were collected with gillnets, Özdemir et al. (2018) investigated samples collected by midwater trawl from the Samsun coastal areas in 2011-2012.

Morphometric and meristic structure of Black Sea Shad populations sampled from Marmara Sea (Adalar) and Black Sea (Şile, Sinop, Samsun, Trabzon) were investigated by Turan et al. (2010). According to the results of that study, Trabzon and Sinop populations were different morphologically from other populations and from each other. It is thought that these differences may be due to the geographical location of the rivers preferred by the populations. In this study, it is stated that populations move away from each other with geographical distance increase. These results show that, apart from reproductive migration, pontic shads in the Black Sea do not migrate long-distance. In the Fatsa coast, this species enter into the Bolaman and Elekçi rivers for breeding. Many rivers flow into the Black Sea coastal area of Turkey. Each of these rivers has different characteristics. This may also affect the growth of fish. Because, the migration from the sea to the river the fish cease the feeding, spend a lot of energy to reach the spawning sites and lose weight. This inevitably reduces the fish condition (Rozdina et al., 2015).

Contrary to the values (M=0.51 year^{-1} and F=0.69 year^{-1}) reported by Özdemir et al. (2018) in Samsun coast of the Black Sea, the natural mortality (M=0.75 year^{-1}) was greater than the fishing mortality (F=0.58 year^{-1}). In the Black Sea coast of Turkey, the pontic shad is usually fished with gillnets and midwater trawl. In the Black Sea coast of Turkey, the pontic shad is usually caught with gillnets and midwater trawl. However, while fishing with midwater trawl is free on the shores of Samsun, it is prohibited on the shores of Fatsa. Therefore, the fishing mortality rate of pontic shad was higher in Samsun region than Fatsa region.

Patterson (1992) reported that fishing mortality rates above 2/3 M are often associated with stock declines, whereas fishing mortality rates below this level have resulted in stock recovery. Therefore, we consider that fishing mortality rates above 2/3 M to represent an undesirable state for the resource, and a situation which management action should avoid, in essence a limit reference point (F_{limit}) for fishery managers. Exploitation rates above F_{limit} have been associated with stock declines whilst below this level the tendency has been towards stock recovery. Exploitation below F_{opt} allows stock to increase in size. In our study the fishing mortality (F=0.58 year^{-1}) was considerably greater than both the target (F_{opt}=0.375 year^{-1}) and limit (F_{limit}=0.50 year^{-1}) biological reference points, suggesting that this species is being over-exploited in the Fatsa coast of the south-eastern Black Sea. Pontic shad, like all other alosines species, are highly sensitive to multiple stresses, both natural and anthropogenic (Smederevac-Lalić et. al., 2018). Therefore, changes in the population structure and stock size of the pontic shad in the Black Sea must be monitored continuously. Estimating mortality rates are important for maintaining fish stocks at the desired level, so to avoid the over-exploitation of fishery resources. In present study, the analysis showed an E_{max} to be 0.375 against the present exploitation rate (E) of 0.43 thus indicating that the stock of this species is under fishing pressure in the Fatsa coast of the south-eastern Black Sea. It could be concluded that the pontic shad stock in the Fatsa coast of the south-eastern Black Sea is in a situation of overexploitation and for the management purpose the current exploitation rate should be reduced to the level of 0.375.

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