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Research article

A comparative assessment of the Black Sea anchovy stock using holistic production and analytical age structure models

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Abstract: The Black Sea anchovy (*Engraulis encrasicolus*) is economically and ecologically the most important commercial fish species in the Black Sea. Therefore, a management plan targeting the maximum sustainable yield has gained importance in recent years. The present study aims to provide a comprehensive assessment by using only Turkish data to evaluate the status of the Black Sea anchovy stock and compare the different approaches outcomes. For this, ASPIC (1968-2014) as a holistic production model and XSA (2005-2014) as an age-structured model are used. ASPIC estimates that the Black Sea's carrying capacity (K) is 1.2 million tons of anchovy, and to achieve the MSY of 244kton fish, 610kton (BMSY) fish must be present in the sea. It is estimated B2015 is 399ktons; this shows, now, there are 35% fewer fish present in the sea. Hence, the Black Sea anchovy is exposed to low overfishing. In XSA, the stock-recruitment relationship could not be established. Therefore, the current status of anchovy stock is estimated by Patterson's (1992) precautionary exploitation rate of Etarget=0.4 as a reference point. Accordingly, the current exploitation rate is calculated as Ecurrent=0.5, which is 25% higher than the Etarget. Hence, XSA results also suggest that the Black Sea anchovy is exposed to low overfishing. This result and the comparable parameter of F of the two models show the concordance and comparability of holistic (ASPIC) and analytic (XSA) models.

Keywords: Black Sea anchovy, stock assessment; analytical age structure model, XSA, holistic production model, ASPIC.

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Introduction

The Black Sea anchovy (*Engraulis encrasicolus*) is ecologically and economically one of the most important small pelagic, short-lived fish species for the Black Sea. Especially in Turkey, where anchovy fishing constitutes a significant part of its total fisheries, it is a commercial stock needed to be exploited sustainably. However, this precious resource had been used recklessly, disregarding the consequences. The cascading effects of the anthropogenic and environmental factors led to a low-catch period during the mid-1980s to early 1990s. In this time interval, the loss of Turkey alone was $309 million (Campbell, 1993; Caddy, 1992). In addition, the annual economic loss for the same period was estimated by Knowler (2005) to be 16.7 million US Dollars, mainly belonging to Turkey. For all Black Sea, it reached $1 billion when it is added the scrapping of redundant fishing vessels and losses in income and profits (Caddy, 1992). Considering these ecological and economic losses, which are very difficult to compensate, Turkey has recently made an effort for a management plan that targets maximum sustainable yield for anchovy in the Black Sea.

Fishery managers keep the responsibility to maintain the fish populations' sustainability by playing an executive role in the fishery and the industrial activities that affect the situation of the fish stocks.

One of the manager's direct control measures for catch and effort to manage the fishery is quotas (total allowable catch-TAC) (Shepherd, 2003). The other indirect control rules are minimum landing size limitations, gear restrictions, area, seasonal closures, etc. (Shepherd, 2003; Cooper, 2006). They need a good management plan containing specific stock information to determine the applicability of these parameters. Scientific stock assessments are the instruments that give management advice to the managers by answering the questions of "Current situation of the stock," "How big or how small is it?", "Is it increase or going to collapse?", "How will be the future of the stock with present regulations and/or future precautions?", "How fishing pressure affects the stock?", "Fishing pressure should be increased or decreased to make the stock sustainable?". For this purpose, several stock assessment models have been used to evaluate the stock condition. The scientific management advice is given concerning these model outputs. According to this advice provided by scientific stock assessment, the stock would be managed sustainably by getting the optimum product.

Thus, anchovy stock has been scientifically assessed since the last decade under the supervision of the Scientific, Technical, and Economic Committee for Fisheries (STECF) and General Fisheries Commission for the Mediterranean (GFCM), covering the entire basin with all riparian countries' contributions. The most commonly used stock assessment models for the Black Sea anchovy are eXtended Survivor Analysis (XSA) and A Stock-Production Model Incorporating Covariates (ASPIC). Both are different approaches with their pros and cons. The former is an analytical age-structured model; the latter is a holistic surplus production model. XSA (Darby and Flatman 1994; Shepherd 1999) is an age-structured model that considers the stock's demographic structure and Recruitment. It was derived from the virtual population analysis (VPA) by its novelty of tuning property. It has been used effectively in the Black Sea anchovy assessment since 2011 (STECF-14-14). On the other hand, ASPIC (Prager, 2014) does not take the length of fish or the stock's demographic structure and Recruitment into account. It assumes fish stock as indiscrete biomass and makes estimations over it. Thus, it is mainly preferred in data-poor situations. After 2013 (STECF 13-20), it was used as a second method to assess the Black Sea anchovy.

Since both models were used separate statistical approaches and different parameters for estimating the similar biological reference points, their outcomes' consistency is essential while giving advice. Therefore, this study aims to provide anchovy stock status via both surplus production and age-structured models, whether they are complementary models to each other.

Material and Methods

Although all Black Sea countries catch anchovy, Turkey and Georgia are the two countries that take up approximately 90% of the total anchovy catch of the whole Black Sea. Moreover, the Georgian anchovy catch quota is rented by the Turkish fleet (Castilla-Espino et al., 2014). Therefore, only Turkish and Georgian catch and effort data were used in this study. Since anchovy used the Turkish and Georgian coasts for their overwintering period (Chashchin, 1996; Gücü et al., 2017), it is mainly exposed fishery in this region. It is believed that the fishery-dependent data from this region can represent the Black Sea anchovy stock. Furthermore, it was assumed that all Black Sea anchovy catch belongs to a single stock unit (Ivanov and Beverton, 1985; Prodanov et al., 1997).

The needed data for fitting the ASPIC are catch, effort, and biomass index estimates (hydroacoustics). Whereas for running the XSA, catch-at-age (CN), catch-weight-at-age (CW), stock-weight-at-age (SW), the natural mortality rate (M), maturity schedule, % of fishing mortality before spawning (PF), % of natural mortality before spawning (PM) and tunings (TUN) are needed.

ASPIC

The model fitted between the years 1968-2014. The catch (landings in tons) and effort (vessel number) data were taken from the former State Institute of Statistics, SIS (1968-2004) and the Turkish Statistical Institute, TUIK (2005-2014). Landing data is used as catch data by assuming there is no discard. It is also assumed that the catchability is the same in every operation. Under the scope of the TUBITAK KAMAG Black Sea anchovy project, the relation between length and engine power of a vessel with its daily catch is analyzed. The length and engine power of a vessel has no effect on the daily catch (Gücü et al., 2017). Since no relation has been found between the catch, length, and engine power of a vessel, the vessel number is used as an effort in the current study. The fishery-independent biomass estimations for the entire basin were taken from the Former Soviet Union for 1980-1991 and Turkey, TUBITAK-KAMAG 110G124 project for 2011-2014.

ASPIC has two interface files; one is ASPIC7 Suite Programs, including "AGraph" for drawing graphs and "ASPIC 7" for running the data file.

XSA

The model was run from 2005-to 2014. The year interval is shorter than ASPIC because there is no continuous age data until 2005. The continuity of the data set is essential in XSA, especially in the age groups of the stock.

As the age of the fish increases, their frequency decreases in the catch. It creates mathematical gaps in the continuity of calculation. Therefore, XSA uses an approach called "plus-group" to deal with this problem. According to this approach, after a certain age, all fishes are gathered and come up as a single class. In anchovy, "age 4+" can be described as a plus-group.

CN, CW, and *SW* among the years were calculated by using the age-length-key (ALK) was taken from SUMAE between 2005-2010 and the TUBITAK-KAMAG 110G124 project for 2011-2014. Both combined and new Age-length key (ALK) were prepared. a and b values were taken from the TUBITAK-KAMAG 110G124 project for 2011-2014. These four years' average *a* and *b* values have been used for the rest of the years. Moreover, in this study, CW is assumed to be equal to SW.

Natural Mortality at age was estimated using two different approaches; Pauly (1980) and Gislason (2010). In Pauly's method, W_∞, k, L_∞, and annual water temperature parameters are needed. Natural mortality was calculated by Pauly with the parameters of W_∞ (Weight-infinity value from a von Bertalanffy growth curve), K (is the growth coefficient), L_∞ (Length-infinity value from a von Bertalanffy growth curve), and annual water temperature that was taken from the official website of NASA -http://gdata1.sci.gsfc.nasa.gov/daac-bin/G3/gui.cgi?instance%20_id=MODIS_DAILY_L3 - from 2005 to 2014). For the Gislason, L_∞, K, and BL (body length in cm) were used.

Maturity-at-age: The percentage of sexually mature individuals per age class. All anchovy after age one were considered mature, while the percentage of mature fish aged zero was used as 0% (STECF 13-20).

Tuning: CPUE of Georgia (2005–2014), Hydro-acoustic survey over Turkish EZZ (2011–2014), and CPUE of Turkish purse seine fleet (2005–2014) were used as tuning indexes.

The stock status results concerning fishing mortality and biomass indicators were evaluated with the help of the guiding chart in stock assessment forms of GFCM.

All required input data were prepared in Lowestoft format. XSA was run under R version 3.6.2 (R Core Team, 2019) with the *FLXSA*, *FLCore*, *FLEDA*, *FLAssess*, *FLash*, and *FLBRP* packages from FLR Project (https://flr-project.org/#packages) and *lattice*, iterators, and *ggplot2* packages from CRAN Repository(https://CRAN.R-project.org/package).

Results

ASPIC

Black Sea anchovy stock was assessed applying a non-equilibrium stock production model-ASPIC for 1963-2014. The approach used in the ASPIC is based on the optimization of seed parameters to minimize differences between estimated and observed data. It is called as estimated contrast index (good=0.5, best=1.0) which is 0.70 for this run. Moreover, even though the log-residual distribution in Figure 1 shows some trends in the early time series, it distributes randomly in recent years.

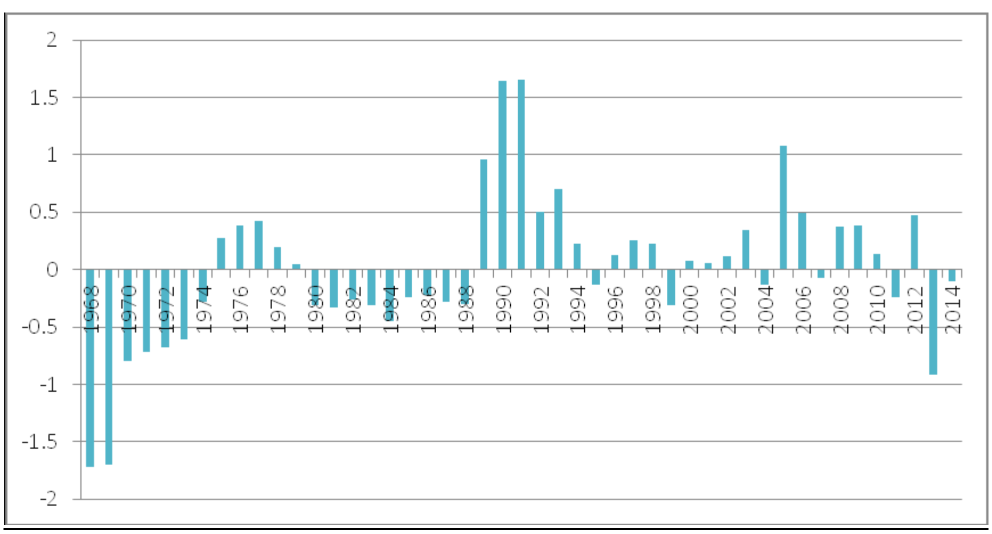

Figure 1. Log- residual distribution between observed and estimated values of ASPIC to the years.

In Figure 2, observed and calculated CPUE index results of the ASPIC are demonstrated. The fit between two values shows how the model accurately estimates the catch change with the fishing effort. The correlation between them is significant (Pearson's product-moment correlation: p-value = 0.005579). There are two periods; till the mid-1970s, and between the late 1980s and early 1990s, the estimated and the observed CPUE are not fit.

According to the model results, management parameter estimates of ASPIC in Table 1, the carrying capacity of the Black Sea for anchovy is 1.2 million tons. The maximum sustainable yield (MSY) that could be achieved from the stock is 244 thousand tons. The model also estimates that the stock biomass to get MSY from the anchovy stock (BMSY) is 610 thousand tons. The current biomass estimated in the final year (B2015) is 399,100 tones (65% of BMSY) which are 35% below the BMSY.

At MSY condition, which is the target for the stock assessment, B/BMSY should be 1. Figure 3 shows the ratio B/BMSY and F/FMSY. The sharp fluctuations in biomass are the main observed output for the Black Sea anchovy stock among the assessment years. According to the ASPIC results (Table 1), this ratio is 0.6. The model suggested that 35% less anchovy is present in the Black Sea than it should be; in other words, the anchovy stock is exposed to low overfishing at a 35% level.

Table 1. Parameters predicted by the ASPIC model

Parameter	Estimate	Logistic formula	General formula
MSY_Maximum sustainable yield	2.44E+05	----	----
Bmsy_Stock biomass giving MSY	6.10E+05	K/2	K*n**(1/(1n))
K_Carrying capacity	1.22E+06	2*Bmsy	Bmsy/phi
B./Bmsy Ratio: B(2015)/Bmsy	6.54E-01	----	----
F./Fmsy Ratio: F(2014)/Fmsy	5.32E-01	----	----
Fmsy/F. Ratio: Fmsy/F(2014)	1.88E+00	----	----
Y.(Fmsy) Approx. yield available at Fmsy in 2015	1.70E+05	MSY*B./Bmsy	MSY*B./Bmsy
...as proportion of MSY	6.98E-01	----	----
Ye. Equilibrium yield available in 2015	2.15E+05	4*MSY*(B/K -(B/K)**2)	g*MSY*(B/K -(B/K)**n)
...as proportion of MSY	8.81E-01	----	----

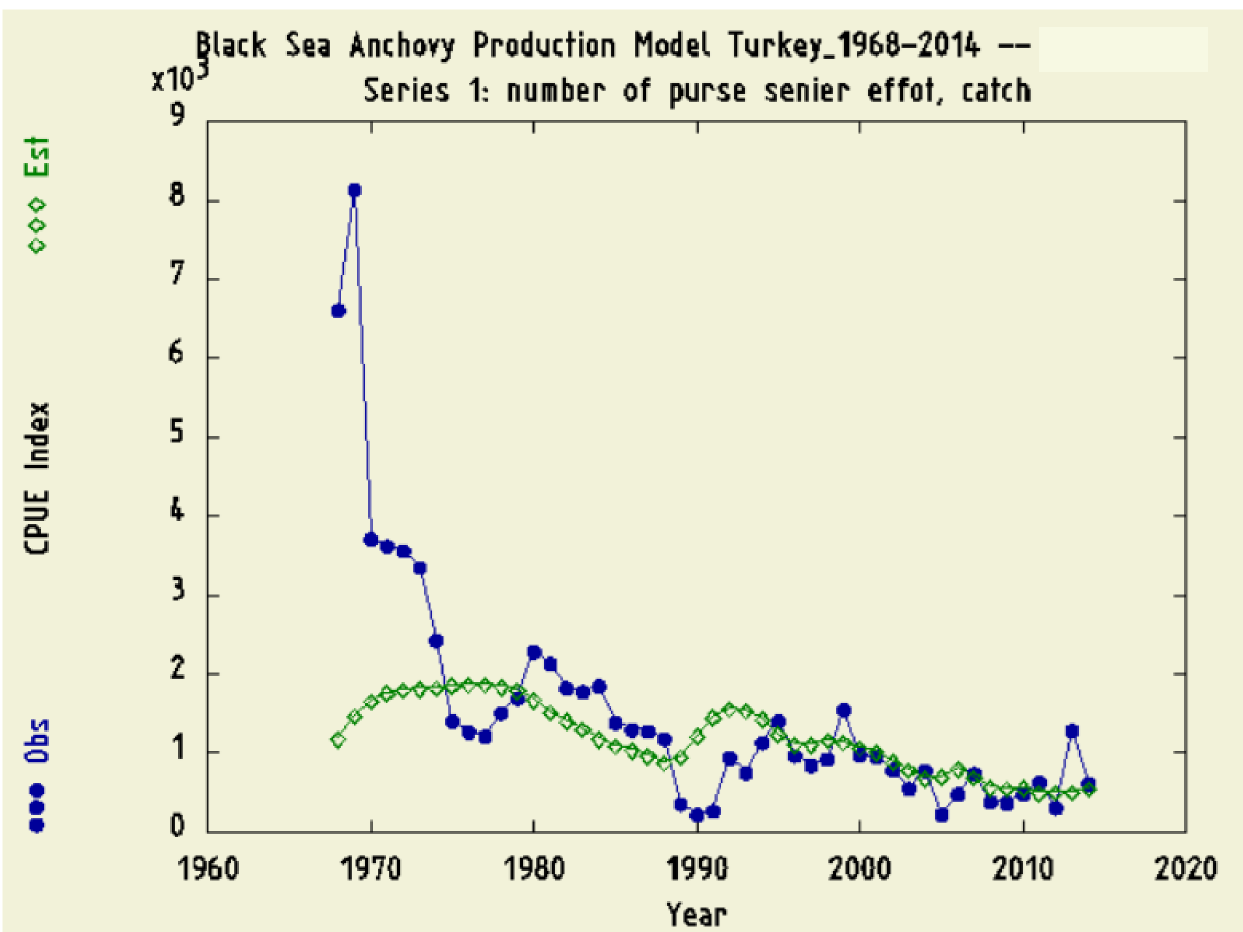

Figure 2. Observed and calculated CPUE Index values in ASPIC.

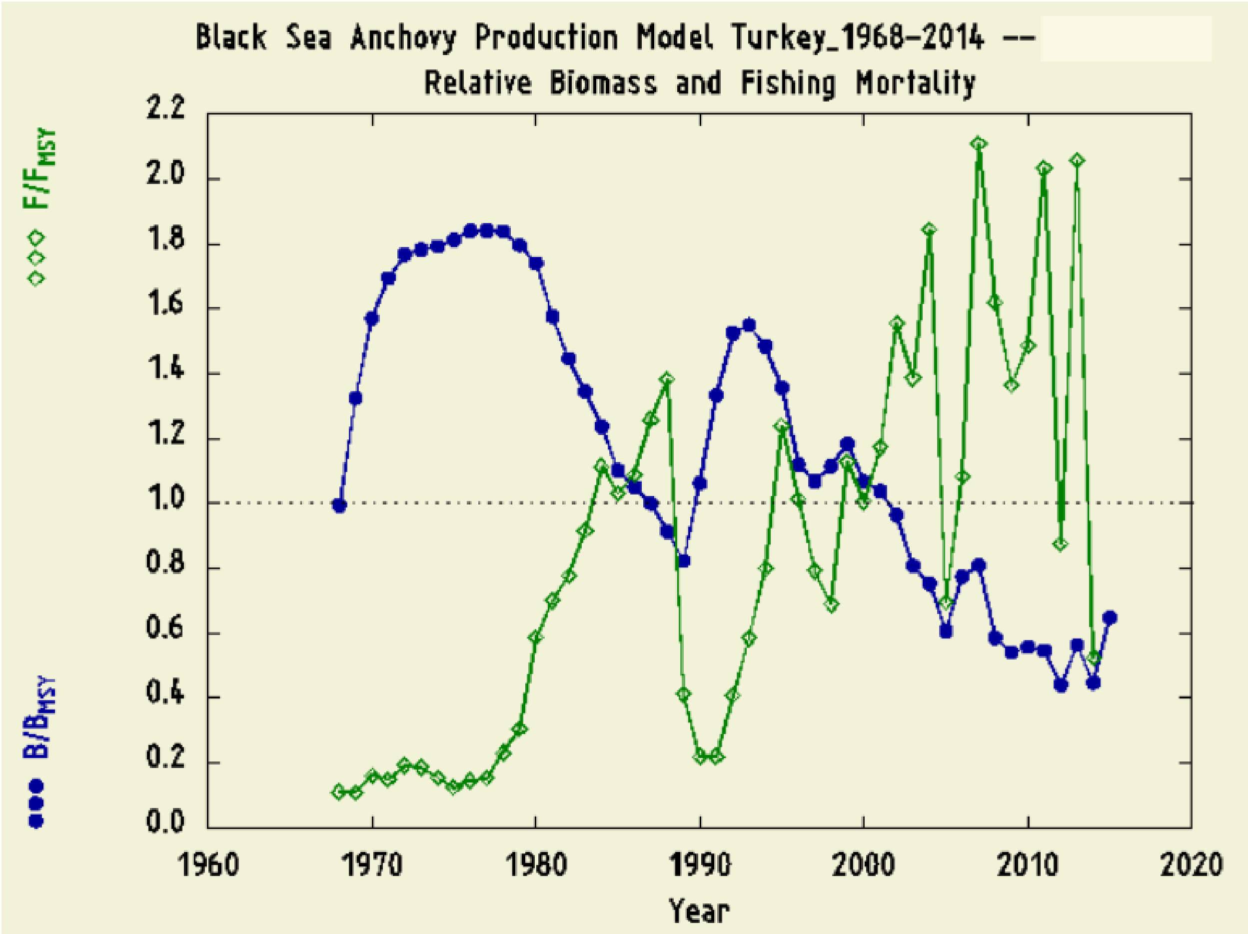

Figure 3. The biological reference point indicators targeting the MSY.

In the case of the forward short-term predictions, it is expected that if the fishing mortality rate in 2015 were at the targeted FMSY value, then the yield would be 170 thousand tons. This amount is 70% of the MSY. Moreover, if the catch amount in 2015 were 214 thousand tons, the yield would be equilibrium as the 88% proportion of MSY (Table 1).

XSA

As an analytical model application, Black Sea anchovy stock was assessed with an age-structured model of XSA for 2005-2014. As a feature of the XSA, different shrinkage factors (fse) have been tried while estimating the parameters. The different fse from 0.5 to 2.0 has been tested. The lowest residuals calculated within the model by the least-square technique were observed at fse=1.5 (Figure 4). Although there are some year effects in the early period of the Georgian CPUE, there are no unexpected trends among the year and ages for all tuning indexes.

The overall results for XSA for fishing mortality rate, Spawning Stock Biomass, Recruitment, and Catch have been demonstrated in Figure 5 and Table 2. Accordingly, fishing mortality rate, Recruitment, and Catch has shown a decreasing and SSB shows an increasing trend in recent years. However, although SSB displays a rising trend, Recruitment has reduced in recent years. This may be a sign of another factor that affects Recruitment rather than the fishery itself.

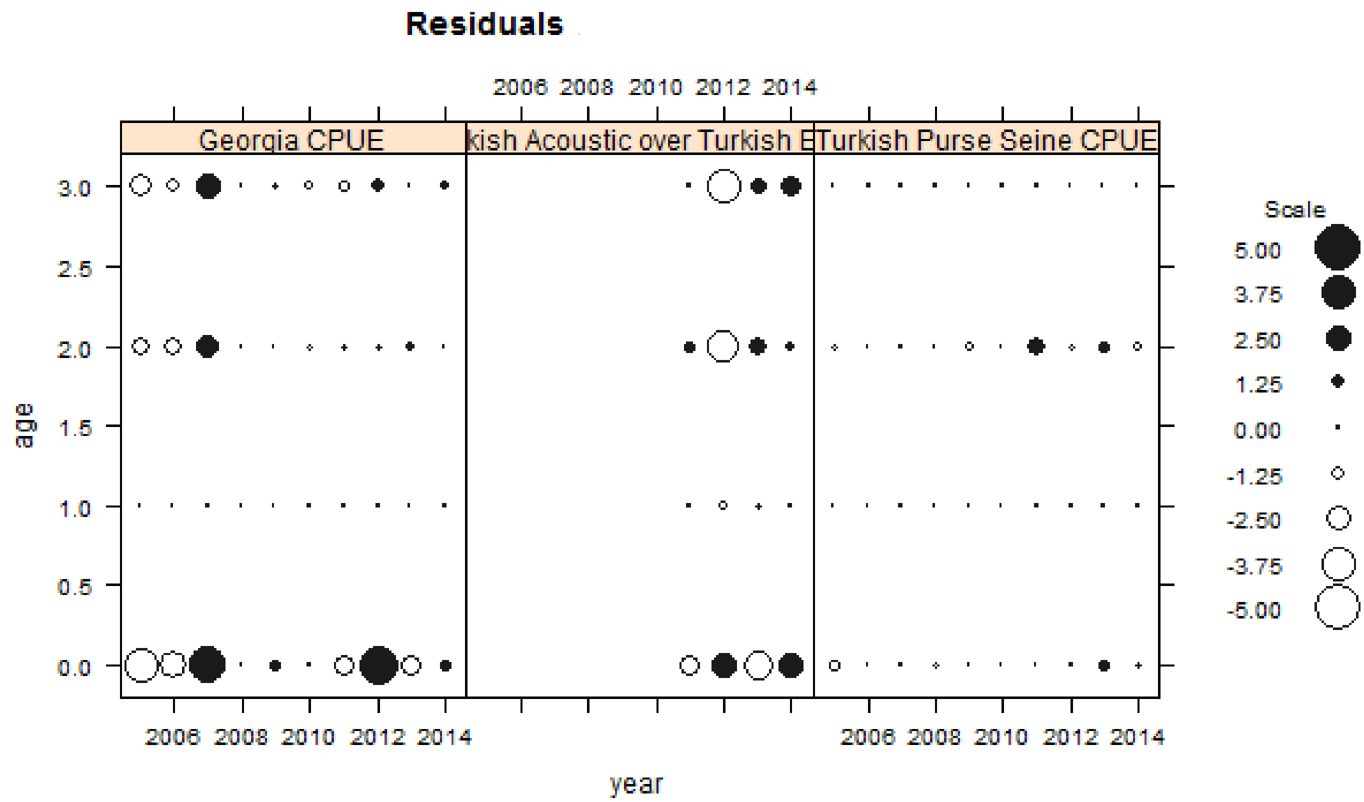

Figure 4. Residuals of the Tunings of Georgian CPUE, Turkish Acoustic over Turkish EEZ, and Turkish Purse Seine CPUE with fse=1.5.

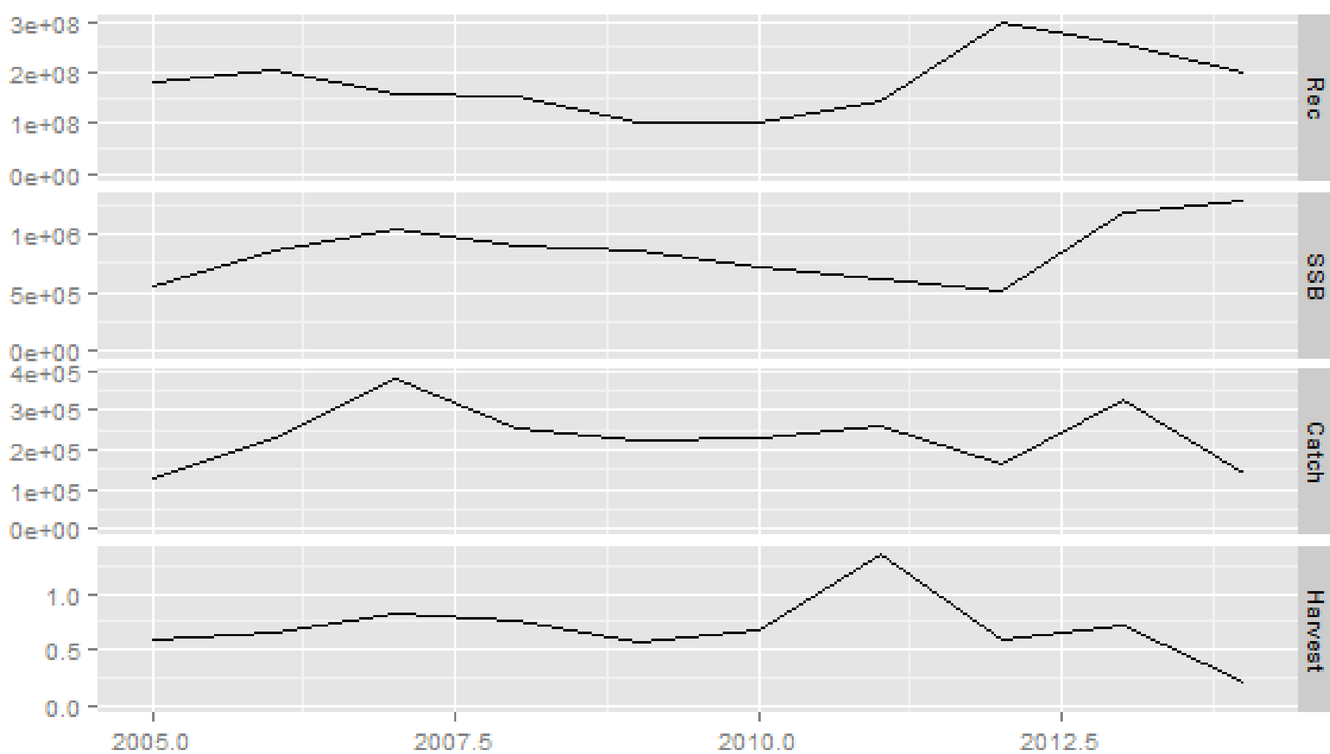

Figure 5. XSA results of Recruitment (rec), spawning stock biomass (SSB), catch and fishing mortality (harvest).

Table 2. XSA outcomes for SSB, Fbar, Rec, Catch, and Landings to the years from 2005 to 2014

Years	SSB	fbar	Rec	Catch
2005	562890	0.5838	178577148	128477
2006	851419	0.6596	205425040	229527
2207	1048113	0.82308	156309628	383061
2008	889906	0.76783	154702960	256682
2009	857361	0.56872	101528471	225463
2010	714427	0.66648	100734559	228944
2011	606447	1.34049	143673307	257396
2012	508329	0.59022	298632655	165964
2013	1187786	0.716	255475557	326104
2014	1289349	0.20552	198127939	137530

The robustness of the model has been tested by performing the retrospective analysis for the most recent four years. As the year was removed from the model, it was expected to get parameter estimation as close as possible. However, the retrospective results are not good enough to trust its future projections. Moreover, SSB and Rec estimation of the model is unexpectedly high. This higher rate and the unfollowed Recruitment and SSB trends mean the model's stock-recruitment relationship has not been established. Therefore, the biological reference points as MSY, BMSY, etc., can not be estimated with this assessment results. Yet, another approach, which is most common for the small pelagic fish, of Patterson's (1992) precautionary exploitation rate of E=0.4 (the target exploitation rate) is used for assessing the stock status.

$$E = \frac{F}{Z} = \frac{F}{F + M}$$

where, F is fishing mortality rate, M is the natural mortality rate, Z is the total mortality rate (Z=F+M) and E is the exploitation rate.

Since the XSA is the backward model, the terminal years have less reliable estimates. Therefore, the last three years' average F estimates are used to calculate the current fishing mortality anchovy stock exposed; $\mathbf{F_{[1:4;2011:2014]} = 0.71}$

For $\mathbf{E_{current}}$: $F_{current} = 0.71$, M = 0.73 (average of all ages)

$$\mathbf{Ecurrent = \frac{Fcurrent}{Fcurrent+M} = \frac{0.71}{0.71+0.73} = 0.5}$$

According to these results, the current exploitation rate is 25% higher than the targeted exploitation rate. This indicates that the Black Sea anchovy was exposed to low overfishing.

Table 3. Biological reference points of $F_{current}$, $E_{current}$, E_{target}, and $F_{0.1}$ (F_{MEY}) from Patterson's (1992) precautionary exploitation rate of E=0.4

$F_{current}$	$E_{current}$	E_{target}	F_{target}
0.71	**0.5**	**0.4**	**0.49**

Comparative Results of ASPIC and XSA

Both models indicate that Black Sea anchovy is exposed to overfishing at a low level. However, because of the nature of the models, some outputs cannot be comparable. ASPIC is the surplus production model, the simplest model used in stock assessment, used mainly in data-poor conditions (Gabriel and Mace, 1999). The results of ASPIC do not demonstrate the age structure in the population, natural mortality, maturity, fish growth, recruitment, and spawning stock biomass estimation. These are the outputs of the age-based models, such as XSA. Yet, ASPIC provides biomass estimation, which is quantified by fishing mortality (Gabriel and Mace, 1999).

The common parameter estimated by these two models is the fishing mortality rate which is the target reference point to evaluate the fishing pressure. Thus it has been used to test the consistency of these two model results. Hereunder, the differences between these two fishing mortality rates of ASPIC and XSA are statistically not significant (p value=0.26; t-test), and there is a strong correlation between them (Cor: 74%; p-value=0.01; Pearson's Cor. Test). As a result, it can be said that the ASPIC and XSA's fishing mortality estimations are consistent (Figure 6). This outcome shows that the ASPIC is model could be an option to use in data-poor conditions, with its consistent fishing mortality rate estimation with analytical models.

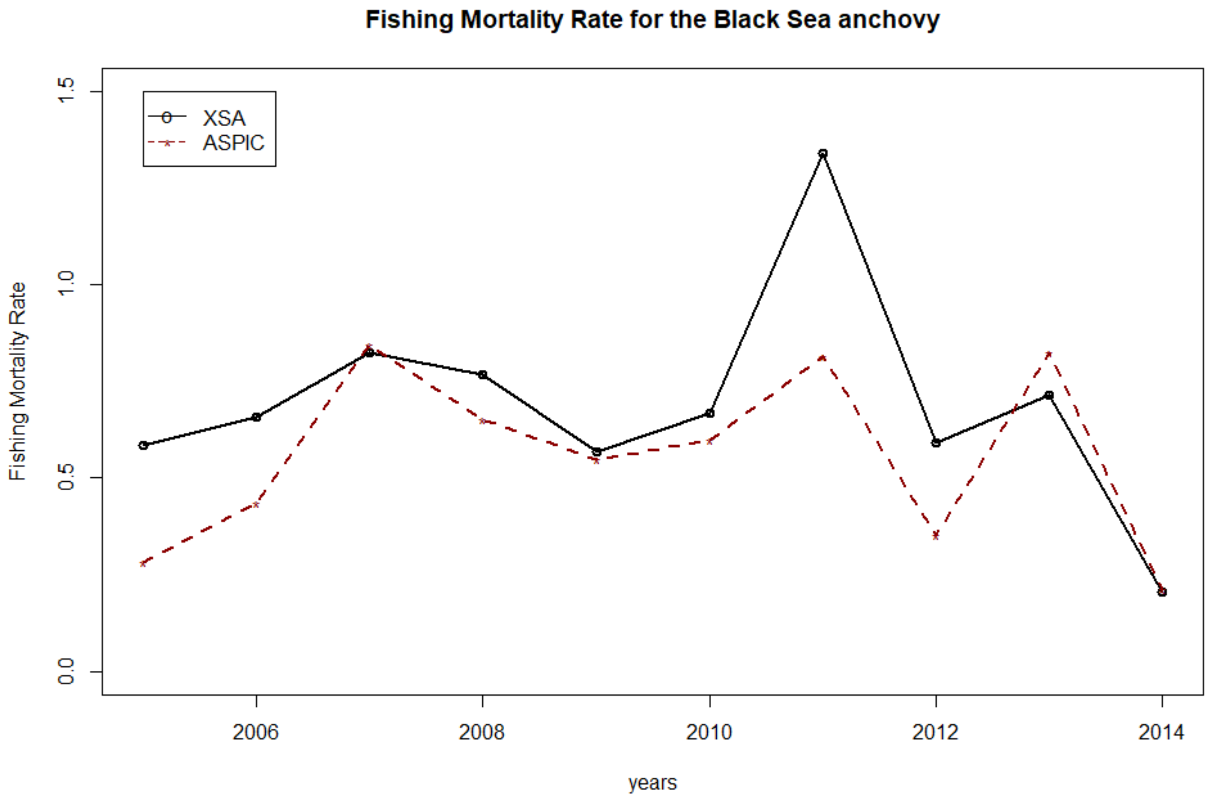

Figure 6. Fishing Mortality Rate for the Black Sea anchovy estimated through XSA and ASPIC.

Discussion

Black Sea anchovy is not only an ecologically and economically important fish species but also an irreplaceable food source for the Black Sea riparian countries. Therefore, scientific stock assessment has been performed for years for this precious stock to ensure its sustainability: Ivanov and Beverton (1985), Bingel et al. (1993), Chashchin (1996), Prodanov (1997), Prodanov and Stoyanova (2001), Chashchin et al. (2015) and recently by the regional fisheries management commissions such as; STECF (2011; 2012; 2013; 2014) and GFCM (since 2012). In Turkey, anchovy stock studies started with Pektaş Expedition in 1956 (AcARA, 1960). After Bingel et al. had conducted the assessment study in 1993, no comprehensive investigation for anchovy was done until 2011. The latest study was held from 2011 to 2015 by METU-IMS and SUMAE with the support of TUBITAK-KAMAG.

Turkey and Georgia are the two countries that fish the overwintering anchovies and keep more than 90% of the total anchovy catch, particularly after the collapse of the Soviet Union. Moreover, it is generally agreed that Russia exploits only Azov anchovy, which can safely be considered another stock (Sampson et al., 2013). Furthermore, Castilla-Espino et al. (2014) state that the Georgian national fleet's contribution is negligible compared with the fishing capacity of the Turkish purse seines. Therefore, the scientific studies performed by Turkey are very noteworthy for the sustainable exploitation of the Black Sea anchovy stock, and using Turkish data can represent the whole stock in the Black Sea. In the present study, to reduce the uncertainty, only the data from the Turkish fleet, which essentially exploits the fish in the Turkish and Georgian waters through a bilateral agreement between the countries, is used for the assessment of the stock status.

ASPIC

Although the estimated and observed CPUEs are sufficiently fit, there are two specific periods where the model estimates and the observed CPUE are considerably different (Figure 2). One is the early period of the data years; the other is the late 1980s and early 1990s. ASPIC is a forward model. Prager (1994) underlined that it is possible to observe incompatibilities in the beginning years due to the optimizations. On the other hand, the mismatch between the late 1980s and early 1990s fits the time intervals of the *Mnemiopsis leidyi* crisis that arose

(Kideys, 1994). In this period, the total catch dropped the level of 60 thousand tons (Gucu, 2002). It is an unexpected environmental effect that the model cannot predict.

According to ASPIC calculation results, between 1968 and 2014, the total biomass of the Black Sea anchovy reached its maximum value in 1977 as the initial stock biomass is estimated at a maximum level of "1,154 thousand tons". This value is lower than the estimation done by Ivanov and Beverton (1985), "1,500 thousand tons". Moreover, the gradual biomass increase observed from 1968 to 1977 (Figure 3) looks unrealistic at first sight. However, according to Gucu (1997), the same period characterizes the Turkish fishery's transition phase: Advanced fisheries technologies, such as acoustic devices, power blocks, etc., and the purse seines first came into the scene. This, in the short run, has increased the fishing pressure on the economically most valuable large pelagic fishes, such as *Sarda sarda* and *Pomatomus saltatrix*. Since large pelagic fish in the Black Sea preys upon anchovy, a decline in the upper trophic level biomass might have reduced the anchovy's predation pressure (Daskalov et al. 2020). Moreover, the higher eutrophication at that period (Mee et al., 2005) could positively affect the increase of anchovy biomass (Zaitsev, 1992).

After the collapse, the stock recovered, but the total catch could not keep up with its 1970s-80s level. As a small pelagic fish, anchovy is a short-lived species, and the stock responds to any environmental or fishing pressure change in a short time (Prodanov et al., 1997). For instance, according to ASPIC results, after 1994, stock biomass started to decrease again with the increasing fishing mortality rate. The response of the stocks under different fishing pressure conditions can be observed for different years. Reference points for biomass and fishing pressure (B/Bmsy and F/Fmsy) which are represented by the line at 1 in the plot (Figure 3), are the indicators to achieve MSY. If B/BMSY stays above the line, too many fish are left in the sea, implying surplus production. If B/BMSY stays below the line, it means the stock is exposed to overfishing. Similarly, if the F/FMSY ratio stays above 1, which is the line showing that the current stock indicator has reached the target, the fishing pressure is higher than it should be for the sustainability of the stock. On the other hand, if the F/FMSY ratio stays below 1, then fishing power falls such that maximum yield cannot be taken from the stock, and surplus production would occur again. Moreover, in the stock assessment study conducted by Demirel et al. (2020) for the assessment year of 2017, the B/BMSY (0.54) is still lower than the targeted level (1). On the other hand, the increase in F/FMSY (F_{2014}= 0.5; $F_{2017 \text{ estimated by Demirel et al. (2020)}}$=1.06) is noteworthy. Accordingly, overfishing may be a significant problem for the Black Sea anchovy stock for the upcoming years.

Only in the late 1980s and 1990s, the model cannot predict the sharp catch decrease since the cause is not only due to the fishery-dependent factors but also some environmental factors that affect the anchovy stock, such as higher eutrophication rate and the *Mnemiopsis leidyi* crisis (Kideys, 1994; Gucu, 2002).

To summarize, ASPIC results show that the state of the Black Sea anchovy stock is not at MSY level; it exposed overfishing. In the biomass aspect, initial stock biomass should be increased to the level of BMSY to get the maximum sustainable yield.

XSA

Comparatively, XSA is more complicated and requires more diverse data sets. As a derivation of the VPA analysis, XSA is more improved in terms of its tuning property. These advancements make XSA commonly used and one of the ICES' standard procedures (Shepherd, 1999). Most importantly, like all other age-based analytical models applied to a short-lived species, i.e., anchovy, this model has considerable drawbacks like an unestablished stock-recruitment relationship. In the current assessment, primarily due to the short time series and the life span of the Black Sea anchovy, the stock-recruitment relationships could not be established to make future projections. The same situation happened in the 2013 and 2014 assessments of STECF (Sampson et al., 2013; Damalas and Osio, 2014).

It is known that the Recruitment affects the following years' SSB amounts since this year's Recruitment will be the spawning stock of the following year. In Figure 5, the recruitment peaks as 2006 and 2012 caused an increase of the next year's spawning stock biomass. However, in the reverse condition, not every increase in SSB gives rise to the following years' recruitment amount. As in Figure 5, the increase of SSB in 2007 did not result in the recruitment amount in the following years. It is also the same in 2013 and 2014; although the SSB is at their higher level, a gradual decline in Recruitment was observed. SSB rise may not always affect the next year's recruitment amount. Since not all eggs can survive to the larval stage, and not every larvae survives to recruit to the parent stock due to any environmental conditions: temperature, salinity, currents, etc., competition for a food source, predation pressure, and operating natural mortality on them (Daskalov, 1998). However, the pulse in recruitment is a sign of a possible increase in the SSB amount of next year. For example, the increase in Recruitment in 2006 ensured the increase in SSB in 2007. However, although F decreased and the SSB increased in recent years, Recruitment shows a decreasing trend (Figure 5). This situation reflects that another factor like climatic changes must play a significant role in the Recruitment rather than the fishery. It is a source of uncertainty about the future of the stock.

Before this study, the same Black Sea anchovy stock assessment had been done by the STECF using all the Black Sea countries' data. The SSB results of 2011, 2012, and 2013 are 800 thousand tons, 700 thousand tons, and 669 thousand tons. The current assessment estimates 606 thousand tons, 508 thousand tons, 1.188 thousand tons, and 1.289 thousand tons for 2011, 2012, 2013, and 2014, respectively. Therefore, the current study results strongly disagree with those estimated previously except for the decrease from 2011 to 2012. The current assessment's SSB result follows a reverse trend from 2013 STECF outputs and increases gradually.

SSB in recent years (2013 and 2014) has been unrealistically high. Therefore, Patterson's (1992) precautionary exploitation rate of E=0.4 is used to evaluate the status of the stock. According to these results, the current exploitation rate is higher than the target exploitation rate. This indicates that the Black Sea anchovy is exposed to low overfishing as it is the same within the ASPIC result. Hence this similarity proves the unity between ASPIC and XSA. Moreover, the FMSY estimate from ASPIC is 0.4 and XSA is 0.49, which is the other sign of consistency between surplus-production and age-structured models. Finally, the comparable estimated parameter for both models for 2005-2014 is the fishing mortality rate. Accordingly, the differences between these two fishing mortality rates of ASPIC and XSA are not significant ($p<0.05$). So, it can be concluded that in a data-poor situation, ASPIC can be a valuable and reliable candidate to assess the fish stock.

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Conflicts of Interest
No potential conflict of interest was reported by the authors.

Ethical approval
All applicable national guidelines for the care and use of animals were followed.

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References
AcARA, A. (1960). Preliminary Report on" Pektas Expedition. *Inter. Comm. for the Scien. Exp. of the Mediterranean*, 16(3), 647-648.

Bingel, F., Kideys, A. E., Ozsoy, E., Tugrul, S., Basturk, O., & Oguz T. (1993). *Stock assessment studies for the Turkish Black Sea coast*. NATO-TU Fisheries Final Report. Institute of Marine Sciences. METU Içel Turkey 108p.

Caddy, J.F. (1992). *Rehabilitation of natural resources*. Environmental management and protection of the Black Sea Technical Experts Meeting, 20–21 May, Constanta, Romania, 1992.

Campbell, D. (1993). *Socio-economic study of the Black Sea fisheries*. Report of the Second Technical Consultation on Stock Assessment in the Black Sea, Ankara, Turkey, 15–19 February. FAO Fisheries Report, (495).

Castilla-Espino, D., García-del-Hoyo, J. J., Metreveli, M., & Bilashvili, K. (2014). Fishing capacity of the southeastern Black Sea anchovy fishery. *Journal of Marine Systems*, 135, 160-169.

Chashchin, A. K. (1996). The Black Sea populations of anchovy. *Scientia Marina*, 60(2), 219-255.

Chashchin, A., Shlyakhov, V. A., Dubovik, V. E., & Negoda, S. (2015). *Stock as-sessment of anchovy (Engraulis encrasicolus L.) in Northern Black Sea and Sea of Azov. Progressive Engineering Practices in Marine Resource Man-agement Stock Assessment of Anchovy (Engraulis encrasicolus L.) in Northern Black Sea and Sea of Azov*. I. Zlateva, V. Raykov & N. Nikolov (eds) USA: IGI Global, 209-243.

Cooper, A. B. (2006). *A guide to fisheries stock assessment: from data to recommen-dations*. University of New Hampshire, Sea Grant College Program.

Damalas, D., & Osio, G. C. (2014). *Scientific, Technical and Economic Committee for Fisheries (STECF) Black Sea assessments*. http://doi.org/10.2788/19168

Darby, C. D., & Flatman, S. (1994). *Virtual Population Analysis*: Version 3.1 (Windows/DOS), User Guide. Inf. Techn. Ser., MAFF Direct. Fish. Res., Lowestoft (1): 85 p.

Daskalov, G. (1998). Using abundance indices and fishing effort data to tune catch- at-age analyses of *Sprattus sprattus* L., *Merlangius merlangus* and *Squalus acanthías* L. in the Black Sea. *Cahiers Options Mediterraneennes (CIHEAM)*, 35, 215–228.

Daskalov, G. M., Demirel, N., Ulman, A., Georgieva, Y., & Zengin, M. (2020). Stock dynamics and predator–prey effects of Atlantic bonito and bluefish as top predators in the Black Sea. *ICES Journal of Marine Science*, 77(7-8), 2995-3005.

Demirel, N., Zengin, M., & Ulman, A. (2020). First Large-Scale Eastern Mediterranean and Black Sea Stock Assessment Reveals a Dramatic Decline. *Frontiers in Marine Science*, 7, 103, 1-13. doi: 10.3389/fmars.2020.00103

Gabriel, W. L., & Mace, P. M. (1999). *A review of biological reference points in the context of the precautionary approach*. In Proceedings of the fifth national NMFS stock assessment workshop: providing scientific advice to implement the precautionary approach under the Magnuson-Stevens fishery conservation and management act. NOAA Tech Memo NMFS-F/SPO-40 (pp. 34-45).

Gislason, H., Daan, N., Rice, J. C., & Pope, J. G. (2010). Size, growth, temperature and the natural mortality of marine fish. *Fish and Fisheries*, 11(2), 149-158.

Gücü, A. C., Genç, Y., Dağtekin, M., Sakınan, S., Ak, O., Ok, M., & Aydın, İ. (2017). On Black Sea anchovy and its fishery. *Reviews in Fisheries Science & Aquaculture*, 25(3), 230-244.

Gucu, A.C. (1997). *Role of fishing in the Black Sea ecosystem*. In: Sensitivity to Change: Black Sea, Baltic Sea and North Sea (Ozsoy, E., Mikaelyan, A., eds.), Kluwer Academic Publishers, The Netherlands, 149-162.

Gucu, A.C. (2002). Can overfishing be responsible for the successful establishment of in the Black Sea? *Estuarine, Coastal and Shelf Science*, 54, 439-451.

Ivanov, L. & Beverton, R. J. H. (1985) *The fisheries resources of the Mediterranean*. Part two: The Black Sea. Studies and Reviews, GFCM, FAO No. 60:135.

Kideys, A.E. (1994). Recent dramatic changes in the Black Sea ecosystem: The rea-son for the sharp decrease in Turkish anchovy fisheries. *Journal of Marine Systems*, 5, 171- 181.

Knowler, D. (2005). Reassessing the costs of biological invasion: *Mnemiopsis leidyi* in the Black Sea. *Ecological Economics*, 52(2), 187-199.

Mee, L. D., Friedrich, J., & Gomoiu, M. T. (2005). Restoring the Black Sea in times of uncertainty. *Oceanography*, 18(2), 32-43.

Patterson, K. (1992). Fisheries for small pelagic species: an empirical approach to management targets. *Reviews in Fish Biology and Fisheries*, 2(4), 321-338.

Pauly, D. (1980). On the interrelationships between natural mortality, growth parame-ters, and mean environmental temperature in 175 fish stocks. *Journal du Conseil*, 39(2), 175-192.

Prager, M. H., & Consulting, P. (2014). *User's Guide for ASPIC Suite, version 7: A Stock–Production Model Incorporating Covariates and auxiliary programs*.

Prodanov, K. (1997). Environmental management of fish resources in the Black Sea and their rational exploitation (Vol. 68). Food & Agriculture Org.

Prodanov, K. B., & Stoyanova, M. D. (2001). Stock assessments of the Black Sea anchovy during the period 1979-1993. *Mediterranean Marine Science*, 2(2), 7-15.

Sampson, D., Charef, A., & Osio, C. (2013). *Report 2013 Assessment of Black Sea stocks (STECF 13-20)*. http://doi.org/10.2788/34535

Scientific, Technical and Economic Committee for Fisheries (STECF) – Black Sea Assessments (STECF-14-14). 2014. Publications Office of the European Union, Luxembourg, EUR 26896 EN, JRC 92436, 421 pp.

Scientific, Technical, and Economic Committee for Fisheries (STECF)- 2011. Opinion by written procedure: assessment of Black Sea stocks (STECF-OWP-11-06) [G. Daskalov, H.-J. Rat zeds]:216p.

Scientific, Technical, and Economic Committee for Fisheries (STECF)- 2012. Assessment of Black Sea Stocks (STECF-12-15).2012. Publications Office of the European Union, Luxembourg, EUR 25580 EN, JRC 76532,279p.

Scientific, Technical, and Economic Committee for Fisheries (STECF) – 2013 Assessment of Black Sea stocks (STECF 13-20). 2013. Publications Office of the European Union, Luxembourg, EUR 25309 EN, JRC 85367, 429 pp.

Shepherd, J. G. (1999). Extended survivors analysis: An improved method for the analysis of catch-at-age data and abundance indices. *ICES Journal of Marine Science*, 56(5), 584-591.

Shepherd, J. G. (2003). Fishing effort control: could it work under the common fisheries policy?. *Fisheries Research*, 63(2), 149-153.

Zaitsev, Y. P. (1992). Recent changes in the trophic structure of the Black Sea. *Fisheries Oceanography*, 1(2), 180-189.