A COMPARATIVE ASSESSMENT OF THE BLACK SEA ANCHOVY STOCK BY USING HOLISTIC PRODUCTION AND ANALYTICAL AGE STRUCTURE MODELS

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A COMPERATIVE ASSESSMENT OF THE BLACK SEA ANCHOVY STOCK BY USING HOLISTIC PRODUCTION AND ANALYTICAL AGE STRUCTURE MODELS

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ABSTRACT

A COMPERATIVE ASSESSMENT OF THE BLACK SEA ANCHOVY STOCK BY USING HOLISTIC PRODUCTION AND ANALYTICAL AGE STRUCTURE MODELS

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Economically the most important fish species in Turkey is the Black Sea anchovy (*Engraulis encrasicolus*). It provides 60% of the total fish catch amongst all Turkish fisheries. However this precious resource has, so far, been exploited recklessly disregarding the consequences. Moreover, the reasons for the dramatic fluctuations in the quantity of anchovy landings over the years are poorly known. A sound management plan targeting maximum sustainable yield therefore necessitates scientifically proven stock assessment. In general, there are two methodological approaches currently used in stock assessment, each with pros and cons. The analytical model, namely eXtended Survivor Analysis (XSA), takes the recruitment compartment into consideration explicitly and requires age structure of the stock being known. On the contrary, holistic production model, entitled A Stock-Production Model Incorporating Covariates (ASPIC), disregards the demographic structure of the stock and does not account for recruitment.

The aim of this study is to carry out an assessment with only Turkish data to evaluate the current Black Sea anchovy stock condition. To achieve this goal two different models of ASPIC (1968-2014) and XSA (2005-2014) were used to assess

the same stock using two different approaches and examine the conformity of these holistic and analytical models, respectively. These models have been chosen since they are the most widely used in stock assessment and for easy comparison of results from previous studies by ensuring the continuity.

ASPIC estimates the carrying capacity (K) of Black Sea anchovy as 1.2 m tons and indicates that there should be 610 k tons (B_{MSY}) of fish present in the sea to achieve the maximum sustainable yield of 244 k tons (MSY) fish from the system with the fishing mortality rate of 0.4 (F_{MSY}) that targeted the MSY. According to the estimated biomass of 399 k tons (B_{2015}) in 2015, there are now 35% less fish present in the sea. Hence, it can be said that the Black Sea anchovy is exposed to low overfishing. On the other hand; in XSA, the fishing mortality rate is calculated as $F_{current}$=0.71, yet the stock- recruitment relationship of Black Sea anchovy cannot be established. Therefore; the current status of stock has been estimated from the Patterson's (1992) precautionary exploitation rate of E_{target}=0.4 as a reference point. Accordingly, the current exploitation rate is calculated as $E_{current}$=0.5 which is 25% higher than the E_{target}. Hence, XSA results also suggest that the Black Sea anchovy is exposed to low overfishing. This result and the other comparable parameters of fishing mortality rates for the two models show the concordance and comparability of holistic (ASPIC) and analytic (XSA) models with respect to each other.

Key words: Black Sea anchovy, Stock Assessment, Analytical Age Structure Model; XSA, Holistic Production Model; ASPIC.

ÖZ

KARADENİZ HAMSİ STOKUNUN BÜTÜNSEL ÜRETİM VE ANALİTİK YAŞ YAPISI MODELLERİ KULLANILARAK KARŞILAŞTIRMALI STOCK DEĞERLENDİRMESİ

Akkuş, Gizem
Yüksek Lisans, Deniz Biyolojisi ve Balıkçılığı Bölümü
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Karadeniz Hamsi'si (*Engraulis encrasicolus*), ekonomik anlamda Türkiye'nin en önemli balık türüdür. Tek başına tüm Türk balıkçılığının %60'ını oluşturur. Ne yazık ki; bugüne kadar bu değerli kaynak, stokun durumu göz ardı edilerek dikkatsizce sömürüldü. Dahası yıllardır avlanan balık miktarında yaşanan belirgin dalgalanmanın nedeni neredeyse bilinmiyor. Bu nedenle maksimum sürdürülebilir ürün hedefleyen bir yönetim planı, bilimsel kapsamlı, bir stok değerlendirmesi gerektirmektedir. Genel itibariyle; her birinin artıları ve eksileriyle beraber, stok tahmininde iki metodolojik yaklaşım vardır. Analitik modeller, Genişletilmiş Hayatta Kalma Analizi (XSA), stoka katılımı göz önünde bulundurur, bununla birlikte stokun yaş yapısını da gerektirir. Öte yandan; üretim modelleri, bütünsel olanlar, Zamana Bağlı Değişkenlerle Birleştirilmiş Stok-Üretim Modeli (ASPIC) stoka katılmayı ve stokun yaş yapısını göz önünde bulundurmaz.

Bu çalışmanın amacı Karadeniz hamsisinin stok değerlendirmesini sadece Türkiye datasını kullanarak yapmaktır. Bunu gerçekleştirebilmek için ise hem stoku iki ayrı yaklaşımla değerlendirmek hem de analitik ve bütünsel modeller arasındaki

olası uyumu analiz etmek için bütünsel, ASPIC (1968-2014), ve analitik, XSA (2005-2014), iki ayrı model kullanılmıştır. Bu modeller son zamanlarda sıkça kullanılması ve bu yüzden de sonuçların geçmiş çalışmalarla kıyaslanabilmesi için seçilmiştir.

ASPIC, hamsi taşıma kapasitesini (K) 1.2 m ton olarak önerdiği Karadeniz'de, maksimum sürdürülebilir ürünün (MSY), 244 k ton, avlanabilmesi için denizde olaması gereken balık miktarını (B_{MSY}) 610 k ton olarak, maksimum sürdürülebilir ürün hedefleyen balıkçılık baskısı oranını (F_{MSY}) ise 0.4 olarak önermektedir. B_{2015} (2015 yılındaki tahmini biyokütle), 399 k ton, tahminine göre denizde olması gerekenden (B_{MSY}) %35 daha az balık bulunmaktadır. Bu tahminlere göre Karadeniz hamsisi düşük oranda aşırı avcılığa maruz kalmaktadır. XSA sonuçlarına göre ise, $F_{güncel}$=0.71 olarak hesaplanmış fakat, stok ve stoka katılım arasında bir ilişki bulunamamıştır. Bu nedenle stoğun güncel durumu Patterson'nun (1992) ithiyati sömürü olan E= 0.4 referans alınarak tahmin edilmiştir. Bu sonuca göre ise güncel sömürü oranı, $E_{güncel}$ =0.5 olarak hesaplanmıştır ki bu değer hedeflenen sömürü oranından (E_{hedef}=0.4) %25 daha fazladır. Bu nedenle, XSA sonuçları da Karadeniz hamsisinin düşük miktarda aşırı avcılığa maruz kaldığını göstermektedir. Bu ve diğer karşılaştırılabilir parametreler ele alındığında sonuçlar, iki ayrı model olan bütünsel (ASPIC) ve analitik (XSA) modellerin birbiriyle uyumlu ve karşılaştırılabilir olduğunu gözler önüne sermiştir.

Anahtar Kelimeler: Karadeniz hamsisi, Stok Yönetimi , Analitik Yaş Yapısı Modeli; XSA, Bütünsel Üretim Modeli; ASPIC

To my love..

&

To the people in my life who make me smile…

☺

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List of Abbreviations

K……….........Carrying Capacity

MSY…….........Maximum Sustainable Yield

B……………...Biomass

B_{MSY}…………..Biomass that can produce MSY

SSB…………...Spawning Stock Biomass

F……………...Fishing Mortality Rate

F_{MSY}…………..…Fishing Mortality Rate at the level that maintains the MSY

M……………..Natural Mortality Rate

Z……………...Total Mortality Rate (Z=M+F)

E…………..….Exploitation Rate

Rec…………...Recruitment

CPUE……..….Catch per Unit Effort

EZZ………..…Exclusive Economic Zone

TUBITAK…...The Scientific and Technological Research Council of Turkey

TUIK………...Turkey Statistics Corporation

FAO……........Food and Agriculture Organization of the United Nations

STECF………Scientific, Technical and Economic Committee for Fisheries

GFCM………..General Fisheries Council for the Mediterranean

1. INTRODUCTION

The Black Sea anchovy (*Engraulis encrasicolus*) is ecologically and economically most important species for the Black Sea and Black Sea riparian countries, particularly for Turkey. Since it has taken up almost 90% of the total anchovy catch of the whole Black Sea alone especially after collapse of the Soviet Union. Moreover; anchovy catch constitutes alone the 60% of the whole fishery of Turkey. Therefore; this adds substantially more value to have anchovy stock. To protect and to be able to exploit this precious stock sustainably, it is either needed to know the current status of the stock and the future of it with respect to the management strategies based to the scientific stock assessment. To achieve these goals two different models (with their pros and cons) of ASPIC (A Stock-Production Model Incorporating Covariates), this is the holistic one that assumes the fish stock as a homogenous biomass. Recruitment, age and length structure of stock and natural mortality are not required for doing estimations, and XSA (eXtended Survivors Analysis), which is the analytical one that takes recruitment, demographic structure of stock and natural mortality into consideration, are used to assess the same stock with two different approaches and to examine the conformity of these holistic and analytical models, respectively.

1.1. Characteristic Features of the Black Sea

The Black Sea is an inland sea and it is located between South-eastern Europe and the western edges of Asia and the North of the Anatolia with the coordinate between latitudes 40°55'N - 46°37'N and longitudes 27°27'E - 41°47'E. Its maximum length is at 42°29'N latitude - 620 miles - and maximum width at 31°27'E longitude - 332 miles (Prodanov et al., 1997). The Black Sea, with a surface area of 423,000 km2, is approximately one-fifth of the surface area of the Mediterranean (Zaitsev & Mamaev, 1997). It has a total volume of 547,000 km3, and a maximum depth of around 2200 m (Oguz et al., 2004). It is bordered by the countries of Turkey, Romania, Ukraine, Russia and Georgia (Figure 1).

Figure 1: Border countries of the Black Sea (www.ceoe.udel.edu)

The Black Sea is a semi-closed basin which means it has small connection with the ocean. It binds to the Azov Sea through the Kerch Strait and to the Mediterranean Sea through first the Bosporus Strait, then through the Sea of Marmara and the Dardanelles Strait, then through the Aegean Sea and the Sea of Crete (Oguz et al., 2004).

The salinity of surface layer of the Black Sea is very low (brackish) when compared to World Ocean. The reason is mostly the characteristics of large catchment area of this sea. It has so many big rivers which are discharging though it, like the Danube, Dniester, Dnieper, South Bug etc. They determine the lower surface salinity of Black Sea waters when compared to those of the Marmara and Aegean and Mediterranean Seas. These river inputs not only effect salinity but also cause the eutrophication by carrying the nutrients to the basin. High nutrient input bring about the high productivity and high productivity supports the life of small pelagic fishes such as anchovy (Chashchin, 1998). A uniquely high river discharge into the Black Sea has at least two major consequences for the Black Sea marine life: first is the rivers carry high amount of nutrients and it creates an eutrophic environment which cause the regime shift (Oguz et al., 2008) and consequently effect the food web of the Black Sea by reducing the pelagic large fishes, and it increases the importance of the small pelagic fishes in Black Sea environment. In other word the marine life in the Black Sea is already not diverse and these kinds of food web misbalances affect the whole system in a short time (Vershinin, 2007). The second is the high river input creates less saline surface water and this causes density gradient which supports the strong stratification of the Black Sea. This stratification blocks the vertical mixing (Oguz et al., 1998). The situation leads to oxygen limitation in deep basin and consequently permanent anoxic conditions in almost 87% of the basin (Oguz et al., 1998). There is very stable condition in the deep water of Black Sea. Below 200 m within the range of values of approximately 8.9-9.1^{o}C in temperature, 22-22.5 σt in salinity and 17.0-17.3 kg m^{-3} in density (Oguz et al., 1998). The deepest part of the water column approximately below 1700 m involves homogeneous water mass formed by convective mixing due to the bottom geothermal heat flux during the last several thousands of years (Murray et al., 1991).

Algae and marine organisms cannot live in this anoxic zone of the Black Sea. Instead there are anaerobic bacteria which disintegrate sinking remains of the upper layer marine life. These are the saprophytic bacteria, and they produce hydrogen sulfide (H_2S). Therefore, the anoxic zone of the Black Sea is also called as “sulfuric anoxic layer”.

Although the Black Sea has permanent stable deep layer, it has also very dynamic upper layer (0-200m) with the presence of turbulent eddies in its two-gyre system surrounded by a seasonally modified cyclonic Rim Current structure around them. The formation of intense Rim Current takes place after the permanent thermocline breaks up at the beginning of winter. However, the intermediate and deep layer of the Black Sea displays strong density stratification. The brackish waters introduced by the Danube River keeps the surface layers less saline. Therefore, the wind-induced mixing effect is only limited to the upper layers causing poor ventilation conditions over the basin (Murray et al., 2007), (Figure 2).

In addition; the surface currents and the deep layer of the Black Sea separation from each other (H_2S in the deep sea never mix the surface layer) prevents the H_2S from mixing to the upper layer. In the case it happens, marine organisms would be poisoned.

Characteristic surface water current is illustrated in Figure 2, is also important in terms of the migration of the organisms such as anchovy.

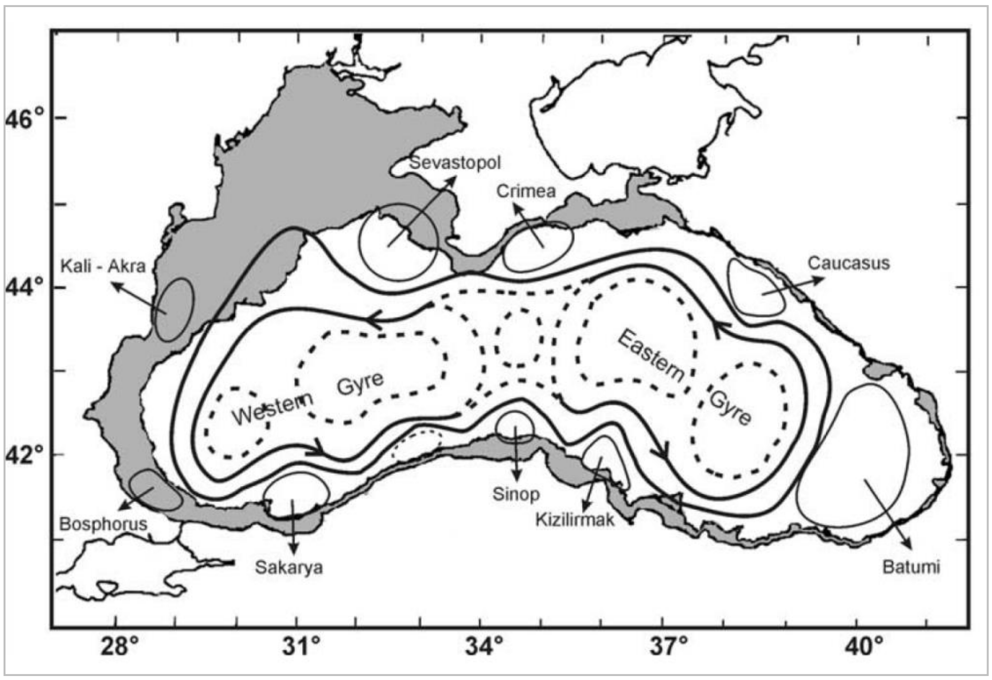


Figure 2: The schematic diagram for the main features of the upper layer circulation of Black Sea (Oguz et al., 1993)

All these physical, chemical and environmental characteristics of the Black Sea are very important to know for investigation, clarification and the explanation of the primary production, growth, migration and the lifecycle of the whole sea organisms of the Black Sea. Among the whole specific diversity, the greatest economic value, however, is not more than two dozens of species. The rest included commercially less important fishes, mollusks, crustaceans and other aquatic organisms. The main portion of catches falls into three groups; anadromous, pelagic, and demersal fishes. In each of these groups, more than 90% of capture volume fall on several leading species (Shlyakhov, 2001). One of them is the anchovy.

1.2. Anchovy (*Engraulis encrasicolus*)

Anchovy (*Engraulis encrasicolus*) is a species which belongs to the Kingdom; Animalia, Phylum; Chordata, Class; Actinopterygii, Order; Clupeiformes, Family; Engraulidae, Genus; Engraulis, and Species; Engraulis encrasicolus.

It is a small foraging fish and it has distribution worldwide. In the Black Sea it has two different subspecies. These are Azov Sea anchovies (*Engraulis encrasicolus maeticus*) and Black Sea anchovies (*Engraulis encrasicolus ponticus*) (Aleksandrov, 1927; Mayorova, 1934; Pusanov, 1936). The former feeds and reproduces in the Azov Sea and overwinters across the northern Caucasian and Crimean coasts. The later one which is the Black Sea anchovy feeds and reproduces in Black Sea. On the other hand; some researches advance work concern the discovery of hybridization between the Black Sea and Azov anchovy populations (Chashchin, 1985; Mikhailov and Dobrovolov, 1990). Moreover to these; it is thought that there is another stock which feeds and reproduces and also hibernates on the Anatolian coast within the Turkish Exclusive Economic Zone (Gucu et al., 2016).

The Black Sea anchovy is a fast growing, short-living (3 to 4 years), and migratory, small pelagic fish species. It can be easily distinguished according to its physical appearance (Figure 3). It has deeply cleft mouth, the pointed snout and the angle of the gape behind the eyes extends beyond the lower jaw. It also can be confused with sprat with its forked tail and its single dorsal fin, however the body of the anchovy is more rounded and slenderer that of the sprat.

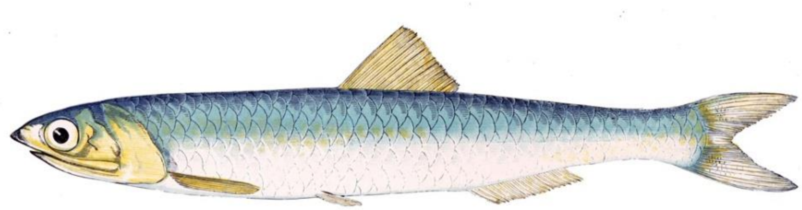


Figure 3: Illustration of a Black Sea anchovy (*Engraulis encrasicolus ponticus*) (suurunleri.ibb.gov.tr)

Anchovy is an oceanodromous marine, pelagic-neritic fish. According to Arkhipov (1993) and Fashchuk et al. (1995) anchovy reaches its maturity several months after the spawning which takes place from middle of the May to the middle of the August, mainly the summer time June and July. They spawn is mostly in the surface warm stratified layer of coastal and shelf waters. Therefore anchovy is known as pelagic spawner fish. The only restriction in spawning season of the anchovy is the temperature. Therefore, the area where it spawns is important. Due to the thermohaline fronts, eggs and larvae stay in the coastal regions. Eggs float around the upper 50m of the sea. The shape of the egg of the Black Sea anchovy is oval (Chashchin et al., 2015). Furthermore, it spawns in batches. During a spawning season an average female anchovy can lay between 13.000 - 40.000 eggs (Bat et al., 2007). Spawning takes place in the optimum temperature of 23-25°C (Niermann et al., 1994; Adrianov et al.,1996; Sorokin, 2002), in the optimum salinity of 12-18 ‰, in the optimum pH of 8.3-8.4 (Demir, 1959) and in the optimum spawning depth of 5-10m in coastal regions (Slastenenko,1956).

They prefer estuaries to live, where plenty of nutrient discharged by the rivers. So this inputs encourage the primary production and consequently the zooplankton, that the anchovy feed on (anchovy feeds mainly on zooplankton), abundance become higher. The Danube River which falls into the northwestern shelf of the Black Sea where is the major spawning and feeding area for anchovy (Niermann et al, 1994). These productive conditions create very favorable environment to live for small pelagic fish species (Chashchin et al., 2015). Although anchovy's salinity tolerance range is large, temperature tolerance range is low; that's why only handicap in this region is temperature for anchovy. Anchovy cannot exist at the water which has the temperature below 6°C for a long time (Mayorova, 1951). According to Chashchin et al. under the influence of temperature decline the anchovy initiates migration to the southern Black Sea by creating schools. The migration usually takes place along the Romanian and Bulgarian coast, followed by the approach of the wintering schools to Turkish Anatolia and even Georgian coastal waters (Pusanov, 1936). According to

Danilevsky (1964), the anchovy migration occurs from the northwestern Black Sea to the Southern Crimea. Black Sea anchovy in the eastern Black Sea spend the winter near the Georgian coast and can also form schools in Turkish waters. From October-November to March anchovy stay in its overwintering ground of South-east of the Black Sea. After March they again migrate to their usual feeding and spawning habitats for the rest of the year (Figure 4). During this October- March time of the year, anchovy face with the high commercial fishery where they hibernate.

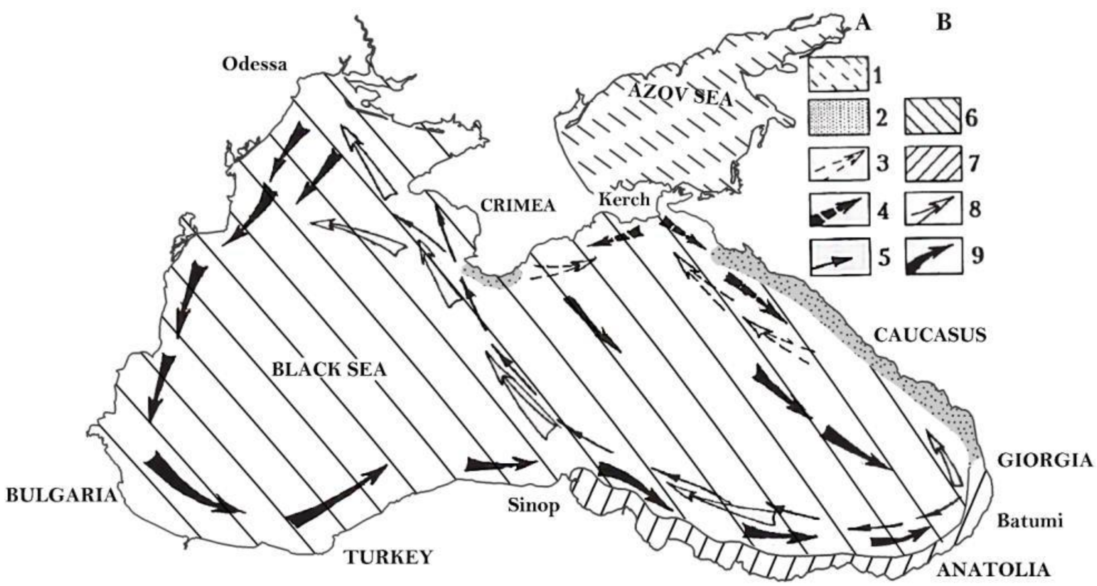


Figure 4: Spawning and overwintering grounds and the migration routes of the anchovies in the Black Sea (the Azov anchovy: 1 = spawning and foraging region; 2 = wintering region; 3 = spring migrations; 4 = autumn migrations; 5 = periodic migrations of a mixed population. The Black Sea anchovy: 6 = spawning and foraging region; 7 = wintering region; 8 = spring migrations; 9 = autumnal migrations taken from Chashchin (1996)).

Anchovy mostly prefer continental shelf to live as it is mentioned above. Especially their overwintering time, they come closer to the coast. In general they are seen at surface night and 30-40 m depth during the day. This is mostly due to the effect of the location of the zooplanktons that the anchovy feed on and also the effect of the temperature preference of them.

Black Sea adult anchovies can be in length between 12 and 15cm. Generally, the length range in anchovy stock changes about 4-15 cm. This means that when a larva reaches to approximately 4 cm length it recruits to the main stock and start to reproduce in the spawning season.

Anchovy is a small pelagic fish. It plays a crucial role in pelagic food web of the Black Sea (Figure 5) , since it is prey of the other important species like *Sarda sarda*, *Pomatomus saltatrix*, *Trachurus trachu*rus and many others economically important fish species. But its importance in pelagic food web does come not only for being prey but also for being the predator of the zooplankton. Moreover it is a competitor of other planktivore species. Thus, it is an organism that considerably affecting the Black Sea ecosystem as a whole (Kideys, 1994)

Anchovy is economically very important in the Black Sea, since it occupies 50% (Gucu, 1997) of the total catch pay of this sea's fishery. Especially after the overfishing of the large pelagic fishes. Prior to this, small pelagic fish was not as important target for the fisheries as large pelagic.

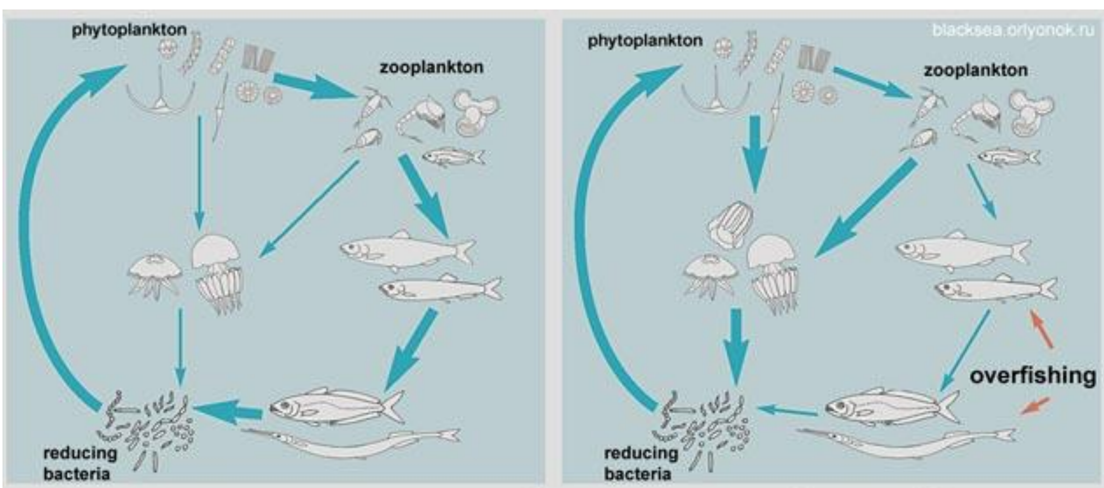


Figure 5: Schematic diagram of the pelagic food web of the Black Sea. (Blacksea-education.ru)

1.3. The Anchovy Fisheries Regulations in Turkey

The fisheries policy of Turkey can be summarized as, the fishing power has been struggled to develop until 1989. On the other hand, after 1990 it has been struggled to restrict. The important steps in fishery was established in 1950s in Turkey with the foundation of the fisheries cooperatives and the biggest development in fisheries happened in between the years of 1975-80 with the encouragements in development of vessels and the equipments (Duzgunes and Erdogan, 2008). According to Ustundag (2010) fishing effort increased dramatically due to these developments until 1988. He also suggests that the amount of anchovy catch increased 4.4 times in 28 years until 1989 when the collapse occurred mostly due to the *Mnemiopsis leidy*. After this crisis minimum landing size (9cm) was applied to be able to prevent the overfishing of anchovy. In 1991, some restrictions was applied the fishing licenses, however, in 1994, 1997 and 2001 limited additional licenses was given. Moreover, since 2002 new licenses have not been granted by the government. Thus, the entrance of a new vessel to the fishing fleet has been blocked. It has been only permitted that the right to 20% increase the size (to be used only once) (Ustundag, 2010). And in recent years there are several regulations that come into force. Such as, anchovy fishing to night hours only (16:00 to 08:00) and to winter months (15 September-March) since 2007, setting a depth limit (0-24 m) for purse seining in 2011 and a vessel buy-back program launched in 2012. These are some of the regulations that were implemented by Turkey.

If it is considered that there are no proper laws for fishery in Georgia, it can be said that the regulations in Georgia is not sufficient (Duzgunes and Erdogan, 2008). The minimum landing size in Georgia is 7 cm and the quota is applied to the rented fishing licenses (60k tons then it was increased 80k tons and finally it reached 85k tons). However, although Turkey and Georgia apply some regulations on the Black Sea anchovy fishery, the Illegal, Unreported and Unregulated (IUU) fishing problem still cannot be solved (Ozturk, 2013).

Illegal, Unreported and Unregulated (IUU) Fishing

Illegal, unreported and unregulated fishing is a very big problem for a fishery management. It is unpredictable lost from the system. It leads to over-exploitation of the stock and also create an unfair competition between fishermen who fishing legally (Ozturk, 2013). IUU simply means: (i) Illegal fishing: it is a fishing activities which done by vessels in the water under the boundaries of authority of a country without permission or by breaking the laws. (ii) Unreported fishing: it is a fishing activity

Which is misreported or even not reported to the authority of a country? (iii) Unregulated fishing: it is a fishing activities which is conducted without any applicable conservation or management measures taken by the authority (Duzgunes and Erdogan, 2008).

1.4. What is Stock Assessment?

In every system, fishery managers have responsibilities to maintain sustainable fish populations that they have, and they are also responsible to the fishery and the industrial activities that affect the situation of the fish stocks. They deal with all these responsibilities by using some tools such as quotas, size limits, gear restrictions, area and seasonal closures (Cooper, 2006). To determine all these parameters, managers need a good management plan that contains the all information about the specific stock. In this point a stock assessment will be better choice for the decision makers, which is prepared in scientific manner. A scientific stock assessment gives information about the “Current situation of the stock”, “How big or how small is it?”, “Is it getting bigger 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?”. Moreover to that scientific stock assessment makes some future projections also. In terms of short, medium and long term projections. After all these knowledge and projections, decision makers interpret and determine the precautions that makes fish stock and the fishery sustainable (Cooper, 2006).

A proper stock assessment should contain information both fishery and the fish stock that has been assessed. Before going one step further, it will be good to remind that the differences between the fish population and the fish stock. Because it can be used interchangeably in many source and also in this study. “Fish population” is defined by the Cooper in 2006 from Department of Natural Resources University of New Hampshire as groups of individual fish of a single species which can be interbreed each other and located in a specific area which can be either as small as a river or as large as the ocean. On the other hand; “fish stock” is mostly defined by management point of view. It is defined as self-regenerating individuals of the same species or of the same race living in a certain geographical area and spawning at a certain time of a year in a certain region and fished independently from other stock (Bingel et al., 1993). For instance in the Black Sea there is an anchovy population which has two known stock as Black Sea and Azov Sea anchovy. Moreover, nowadays it is also known that there is a third stock which feed, spawns and hibernate in the same place of the shelf of the Turkish EEZ (Gucu et al., 2016). In this study whole three stocks are assumed as one. Therefore, it can be used as stock or population, interchangeably.

The main parameters that affect a stock are; growth, recruitment, natural mortality and fishing mortality. Increase of stock weight through growth, Increase of stock weight through recruitment, Decrease of stock weight through natural mortality and Decrease of stock weight through fishery, respectively (Bingel, n.d.) (Figure 6). The balance between these parameters shows the equilibrium of the system with its lost and gains. The main objective is to keep the stock in this balance with a scientific assessment and operable precautions.

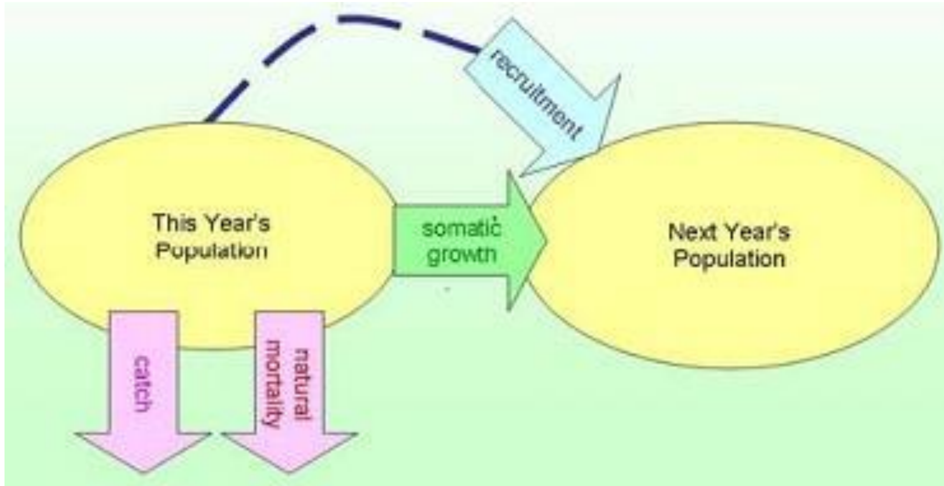


Figure 6: The main parameters that influence a fish stock. (ICES course materials, 2013)

After making this clarification we can continue to the features of proper stock assessment. An assessment uses the data of age, growth, natural mortality, sexual maturity, fisheries mortality, recruitment, etc. To get these entire knowledge scientists should well define the geographical boundaries of the population and the stock; critical environmental factors affecting the stock; feeding habits; and habitat preferences. After having this knowledge and collecting proper data, scientist needs mathematical and statistical techniques to assess the stock. There are dozens of the stock assessment models with different assumptions and data needs. They have been written to analyze and assess the data and consequently the stock.

1.5. Biological Reference Points

A biological reference point is a value that gives idea about the stock size, fishing mortality or any other parameters that help estimation of the stock situation over time. In other words, biological reference points are guides for decision makers in determining whether the population is getting smaller or bigger, fishing pressure is in a critical level or not. It also gives idea about in what direction the precautions should be taken (Cooper, 2006).

The basic biological reference point that has been used this assessment are;

- Fishing Mortality rate (*F*): It is the rate which represent the removed fish from the stock via harvesting. It should be in balance with the growth rate of the stock. And F_{MSY} is the target for getting maximum fishing rate by preserve the sustainability of the stock that exposed to the fishing. For example, according to Bingel (2002) F =0.1 is the value of F where Y/R (yield per recruit graph) is equal to 10 percent of Y/R maximum.
- Maximum Sustainable Yield (*MSY*): It is the largest catch which would be taken from the stock continuously under the lasting environmental condition by preserving the sustainability of the stock. According to Cooper (2006) "maximum sustainable yield is the greatest number of fish that can be caught each year without impacting the long-term productivity of the stock."
- Biomass (*B*): It is the total weight of fish in a specific stock (FAO, 1998). B_{MSY} is the stock size which can give the maximum sustainable yield (Cooper, 2006). To keep the stock at B_{MSY} level, F_{MSY} should be at the level which would maintain the maximum sustainable yield.
- Spawning Stock Biomass (*SSB*): The total weight of the mature individuals which are reproductively active (Cadima, 2003). SSB_{MSY} is the size of the reproductively mature part of the stock that produces enough to keep the stock sustainable level and produce the maximum sustainable yield (Cooper, 2006). It is calculated by using stock in numbers, a maturity and mean weights per individual by age. It is the most important reference point since it gives idea about the stock biomass since it is a biomass-based reference point (Lassen and Medley, 2001).

These are the basic biological reference points which help the precise estimations of the stock situation and gives information for the decision makers. After getting idea about the stock size then we can analyze whether the stock is overfished or not.

1.6. What is overfishing?

Overfishing is an important concept in stock assessment. Because if it hauls fish more than it should be (*MSY* level), then the stock size will get lower. Similarly, if it is left too much fish in sea, hauled less than *MSY*, then stock would reach the carrying capacity of the system and environment could not support such a big population then, again, the stock size get decrease. (Figure 7) The concept is called as "Surplus production". According to Fishery Manager's Guidebook of FAO (2002) "Surplus production depends of a model which suggests that the annual net growth in abundance and biomass of a stock increases as the biomass of the stock increases, until a certain biomass is reached, or surplus production, reaches the *MSY*. This biomass is referred to as B_{MSY}, and the fishing mortality rate referred to as F_{MSY}. As the biomass increases above B_{MSY}, density dependent factors such as competition for food, diseases and cannibalism on smaller individuals start to reduce the net population growth which therefore decreases until the average carrying capacity of the stock then net population growth reaches zero. In reality, an unexploited stock will tend to fluctuate about this biomass because of environmental variability." (Cochrane, 2002).

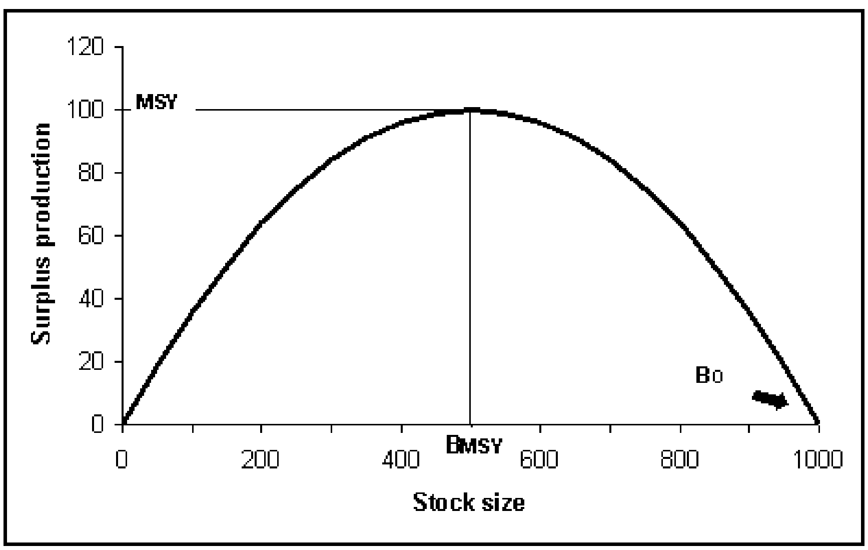


Figure 7: Surplus production with the relation of *MSY* and carrying capacity of the system (Cochrane, 2002)

All in all; overfishing indicates bankruptcy of fish stocks due to the excess amount of exploitations (Figure 8) (Pauly, 1994). There are five types of overfishing as;

1. Growth overfishing: Catch of the young fish before they reach appropriate size to become mature and reproduce efficiently. It is beginning of the overfishing that was first identified and resolved theoretically by Baranov (1918); Beverton and Holt (1957). It causes the concept of sub-optimal yield (Pauly, 1994). It means, for instance, in anchovy minimum landing length is determined as 9cm are fished that gives the optimum yield from the stock. If the fish which has length smaller than 9cm then the yield will drop gradually since stock is exposed to growth overfishing.

2. Recruitment overfishing: It is the excess catch of the parent fish before they recruited a new generation to sustain population. The second step of the overfishing which is recognized by Ricker (1954). It shows that the stock exploitation level is exceeded. And finally population cannot be kept at constant, sustainable level by the adult fish because their number is getting lower (Pauly, 1994).
3. Biological overfishing: The combination of growth and recruitment overfishing. It exceeds maximum sustainable yield (*MSY*). This means that the stock is exploited so much that produced recruits are not enough for sustainable level of stock and biomass decrease in other words catch declines on the right in the graph which is shown in Figure 8, (Schaefer, 1954; Fox, 1970; Ricker, 1975).
4. Ecosystem overfishing: Excess catch of a certain species lead to emptiness in niche that creates an advantage for another species which would alter the current ecosystem by occupying this niche (Pauly, 1979).
5. Economic overfishing: Fishing exceeds maximum economic yield (*MEY*), where catch/effort becomes lower (Figure 8). It is originally defined economic theory by Gordon (1953), after that it combined with parabolic surplus production models to yield Gordon-Schaefer model (Figure 8) (Pauly, 1994).

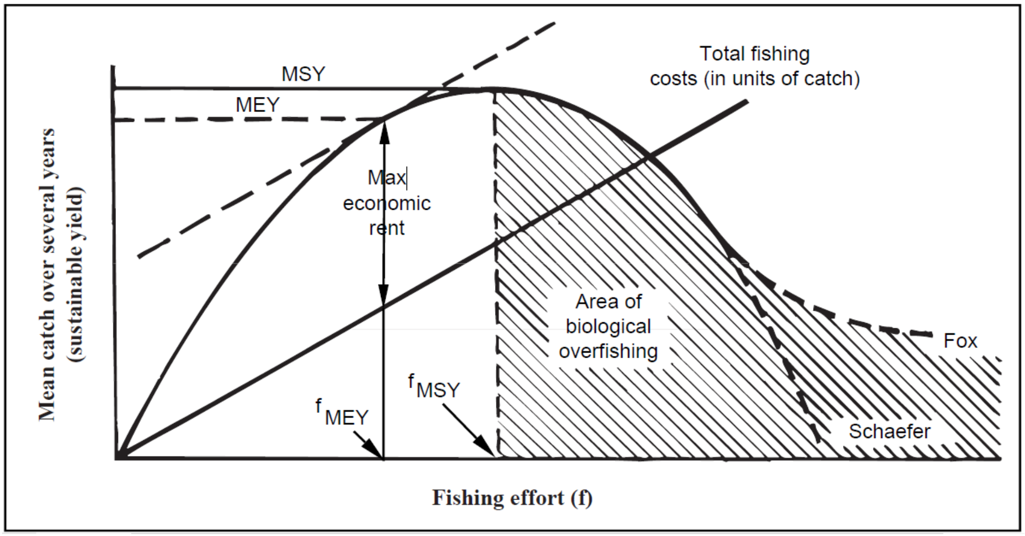


Figure 8:Schematic representations of biological overfishing, due to both growth and recruitment overfishing (shaded, right area of a Schaefer- or Fox-type production model), and of economic overfishing, occurring when fishing effort exceeds the level (f_{MEY}) required to maximize economic rent, i.e. to produce MEY. Note that MEY is always (slightly) below MSY, the stated or implicit goal of many management schemes; and that beyond MSY, subsidies will reduce catches (by reducing total costs). (Pauly, 1994)

In this assessment, while determining the anchovy stock's current situation, whether stock is overfished or not, "the Range of Overfishing levels based on fishery reference points" scale which accept by the General Fisheries Council for the Mediterranean (GFCM) in 2014 is used as reference. That has been shown in the Table *1* below.

Table 1: The scale that used in order to assess the level of overfishing status by F0.1 from a Y/R and Fc (current level of F) (This figure has been taken from the Stock Assessment Template of GFCM, 2014).

- If the reference point is below or equal to 1.33 the stock is in **(O_L): Low overfishing**
- If the the reference point is between 1.33 and 1.66 the stock is in **(O_I): Intermediate overfishing**
- If the the reference point is equal or above to 1.66 the stock is in **(O_H): High overfishing**

A good scientific stock assessment not only defines the current situation of the stock but also can estimate the future of the stock with some projections.

1.7. Projections of Future Yields and Stock Situation

It is not sufficient to calculate the current stock situation for managing a stock like anchovy. An assessment should provide a management advice by doing some future projections which is based on yield (in weight) and other stock indicators such as recruitment trends, spawning stock biomass and fishing mortality rate. To do this time series regression analysis has done by the models by the mean of the last three years is used more often (Lassen and Medley, 2001).

Fishery management which based on fish stock assessment has two important components. One is projections of future yield with respect to the estimated fishing scenarios and the other is the interpretation of these scenarios via the reference points with respect to the criteria that desired to establish the stock status with respect to the biological reference points. The decisions are often not the direct reflection of the biological advice because fish stock management also cares socioeconomic and political issues. Therefore; it is important to calculate the fishing mortality and exploitation pattern, since it makes management more close to biological implications. To be able to provide advice for management; these scenarios created by the projections with short, medium and long term time intervals should be done (Lassen and Medley, 2001).

- <u>Short-term Projections:</u> It is the 2-3 years time period in which terminal year's estimated stock composition effect mostly the future yields. For instance, more than 50% of the yield belongs to the terminal year's cohort (Lassen and Medley, 2001).
- <u>Medium-term Projections:</u> It is the 5-10 years time period in which terminal year's estimated stock composition still slightly effect the future yields. For instance, more than 10% of the yield belongs to the terminal year's cohort (Lassen and Medley, 2001).
- <u>Long-term Projections:</u> It is more than 10 years time period in which state of the stock is considered in relation to reference points. It considers not short-term fluctuations, but long-term situation of the stock with different exploitation rate (Lassen and Medley, 2001).

Under shade of all these information, in this study both fisheries related data and independent information have been used in order to get a proper stock assessment. Commercial catch-per-unit-effort (CPUE) and acoustic survey abundance indices have been used to tune assessment models (Daskalov, 1998).

A stock assessment model estimates the parameters such that the absolute or relative abundance of species and also the exploitation rate of a stock of this species by using the available information like effort using by fishing, total catch, natural and fishing mortality, growth, etc. Stock assessment models do not give the exact results for the parameters which one looks for. According to the Kilduff et al. (2009) "Stock assessment models often seem like a 'black box' that scientists plug numbers into and get answers stakeholders have to live with, regardless of stakeholders' understanding of the science or the answer it provides. The truth is, fisheries scientists have been working to develop rigorous stock assessment models capable of hand the inherent difficulties of fisheries data while representing the complexities of fish population dynamics." The aim of this study is to compare the estimation of both the surplus production and age structured models and to interpret the results whether or not they verify each others. Since all these models use different parameters and give estimations about the similar biological reference points. In this point of view, this study aims to shed light on the comparability of the holistic and analytical models together for the same species which is the Black Sea anchovy in our case.

As no single model can provide best answer to estimate the current and future situation of a stock, in this study anchovy stock will be analyzed by two different models. To stay close to the safe side while estimating the situation of stock each surplus production and age structured models are analyzed in terms of advantages, disadvantages, data requirements, and statistical assumptions. Then, according to these backgrounds knowledge it is decided that it will be better if it is used ASPIC (A Stock-Production Model Incorporating Covariates) as a surplus production model and XSA (eXtended Survivors Analysis) as an age structured model. All information and working principle of these models have been explained in "material-method" part of this thesis.

Scope of the Study

The main aims of this study to get idea about the current situation of the stock and to propose some predictions for the Black Sea anchovy stock under different harvest scenarios. To be more clear the determination process can be divided into different steps as; (i) determination of the exploitation rate and any other biological reference points to make assessment results more clear for estimations, (ii) determination of stock situation, whether it is overfished or not and (iii) determination of the projection levels as short, medium and long term.

2. MATERIALS AND METHODS

In a very generic sense the living marine resources are being assessed by two methodological approaches. One is holistic and considers the stock as a single unit and the other is analytical model. Production models (ASPIC), being holistic, disregards the demographic structure of the stock and do not take recruitment into consideration. In the contrary, the analytical models (XSA) take the recruitment compartment into consideration explicitly; and they require age structure of the stock being known. Both models have advantage and disadvantage over the other and in this work the strategy is to utilize both approaches, to compare the results of these two alternative models and so that to assess the Black Sea anchovy stock.

2.1. Data Source

The time series data, which will be explained below in detail, have been taken from the TUIK- Turkey Statistics Corporation. The rest of the data (last 4 years) has been collected during- TUBITAK-KAMAG 110G124 project - *Assessment of Black Sea Anchovy Using Acoustic Method and Establishing a Monitoring Model for*

National Fisheries Data Collection Program. This project conducted cooperatively by METU Institute of Marine Sciences and Trabzon Central Fisheries Research Institute (SUMAE).

The catch data is the anchovy landings of Turkey published by the former State Institute of Statistics, SIS (1968-2005) for 38 years and Turkish Statistical Institute, Turk Stat (2005-2011) for six years. The data are available for eastern (Hopa – Sinop) and western (İnebolu – İğneada) Black Sea coast of Turkey. In this study the catch data from these two parts were combined.

The XSA model is run for the period between the years 2005-2014. The landing data is of TUIK; however length compositions of the landings were available only after 2005. On the other hand, ASPIC data set is in between the years of 1968-2014 as the model requires a wide time range to capture the contrast in data, i.e. then response of the stock under very low and very high fishing. Also ASPIC do not need too much data set, such as age structure and this makes it easy to reach successive proper data in wide range of years. To sum up; although there are differences, the years are comparable and these differences are due to the availability of proper data.

2.2. Stock Assessment Models

2.2.1. ASPIC (A Stock Production Model Incorporating Covariates)

The model has been reviewed and tested properly in terms of various applications to tuna stocks via the International Commission for the Conservation of Atlantic Tunas (ICCAT) by Prager (1992). It has been also used as an assessment tool for *Xiphias gladius* (ICCAT), *Thunnus thynnus* (ICCAT), *Pleuronectes ferruginea* (NEFSC, NAFO), and *Paralichthys dentatus* (NEFSC) among others. Moreover; this model has been used in many assessments of small pelagic species in not only U.S.A. but also international fish conservation and management bodies like STECF (Scientific, Technical and Economic Committee for Fisheries), ICES, NAFO, and ICCAT.

2.2.1.1. General definition of the method

A Stock Production Model Incorporating Covariates (ASPIC) is a suite computer program and a non-equilibrium surplus production model which fits the surplus-production models to catch and effort data. It is written by Dr. Michael Prager. It has several version but in this study ASPIC version 7 (v.7 on August 6, 2014) has been chosen to use analyse the data. This last version was revised by the author to diminish the possible errors in the calculation and in the algorithm. These differences make ASPIC v.7 more trustable than the previous versions. Moreover, it is a program which is free to use, and it can be downloaded from http://www.mhprager.com. ASPIC software is a suite of programs. It contains ASPIC, ASPICP and AGRAPH for running the model, making projections and drawing graphics, respectively. ASPIC v.7 can work on 32-bit and 64-bit versions of Windows (it needs the operating system). It does not need any other software to run. It is a holistic model, means that this model does not consider about the length of fish or demographic structure of the stock and also does not take the recruitment into account. It assumes fish stock as an indiscrete biomass and makes calculation over it. It fits logistic (Schaefer, 1954) and generalized (Pella and Tomlinson, 1969) surplus production models to catch and effort data and sometimes abundance indices as an index (Prager, 2014). While doing this it puts to use forward-projecting and observation-error estimator with weighted least-squares and does not make an equilibrium approximation.

2.2.1.1. Model Assumptions

ASPIC runs on some critical assumptions (Prager, 2014);

- ✓ It assumes that the population is not at equilibrium condition and also assumes that yield do not have to be equal to the surplus production.
- ✓ Being a holistic model, it assumes stock being an integral single unit, do not divide it demographically, and also do not take the recruitment into consideration. The model provides estimates of some biological reference

points over the total biomass. It uses only catch, effort and index of relative abundance data.

- ✓ ASPIC, in a sense, is based on estimated observation errors and it is assumed that observation errors (residuals) are distributed normally.
- ✓ ASPIC gives weight to landing (catch) data rather than the index data while doing calculations in terms of the statistic.
- ✓ ASPIC uses logistic production growth of the Schaefer while doing calculation (Figure 9). It means if the population size (stock size) is close to zero, the growth of the population will be low. Since there will be few fish in the stock and this means there will be little production; in fact little yield. Moreover, if the population size is close to the carrying capacity (K) where it is the maximum stock size, again the yield is very low since production of the stock decrease due to the limited resources. However if it is at half of the carrying capacity (K/2) , when the biomass at B_{MSY}, then the growth of the population will be maximum so that the highest surplus production is seen at this level. In other words maximum sustainable yield (MSY) occurs in this point, in theory. This theory is the basic assumption of ASPIC. And straightforwardness of this theory is the reason of why it is used very often in the area of stock assessment.

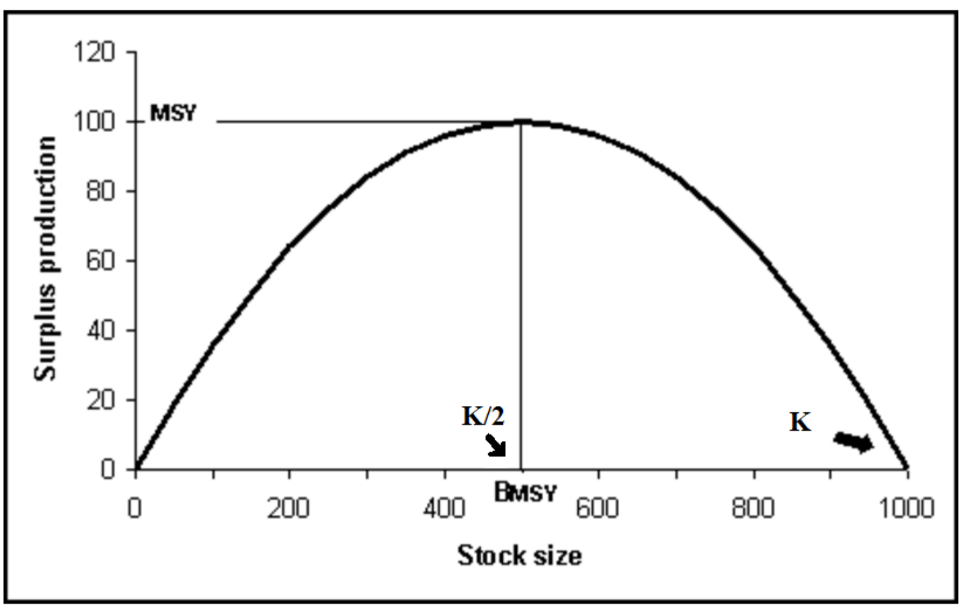


Figure 9: Logistic population growth curve in terms of biomass. (Have been taken from FAO; A fishery manager's guidebook Management Measures and Their Application.)

- ✓ While doing estimation, ASPIC assumes that catchability (*q*) is equal for all age classes in the population.
- ✓ ASPIC used in this study does not take environmental conditions into account. It assumes that there were no changes in environmental conditions during the years which are included in the model. The deviations from the model results may therefore, to some extent, be indicators of environmental variability.
- ✓ ASPIC can assume that yield is exactly known and residuals are accumulated in effort or relative abundance (sometimes vice versa). In this study conditioning on yield was preferred since; yield usually is known more precisely than effort or relative abundance, although conditioning on yield makes calculation slower than the conditioning on fishing effort.

In the light of these assumptions the algorithm of ASPIC can be summarized as follows;

2.2.1.2. Needed Data

The ASPIC needs series of catch, effort and index of biomass data (Table 2) to run the model. The catch and effort data were taken from TUIK (Turkey Statistics Corporation). Acoustic data are taken from Russia between the years of 1980-1991, until the collapse of USSR. After that there is no acoustic data between the years of 1992 and 2010 up until the TUBITAK-KAMAG 110G124 project - *Assessment Of Black Sea Anchovy Using Acoustic Method And Establishing A Monitoring Model For National Fisheries Data Collection Program*- which was conducted by METU and SUMAE between the years of 2011-2015. Moreover, the ASPIC needs some starting guesses about some parameters. These estimated parameters are *MSY* (maximum sustainable yield), F_{MSY} (fishing mortality rate at *MSY*), *B1/K* (ratio of the biomass at the beginning of the analysis over carrying capacity (*K*=unfished biomass)) and *q* (catchability coefficient) for each data series. The starting guesses of these parameters should also contain bounds (minimum and maximum values).

Table 2: The data which is used in ASPIC v.7 (-1 means no available data in ASPIC)

Year	Catch (tons)	Effort (number of Vessels)	Biomass index of Russia	Biomass index of Turkey
1968	33135	5	-1	-1
1969	40787	5	-1	-1
1970	67109	18	-1	-1
1971	65353	18	-1	-1
1972	85906	24	-1	-1
1973	84216	25	-1	-1
1974	70802	29	-1	-1
1975	58216	41	-1	-1
1976	67992	53	-1	-1
1977	71366	58	-1	-1
1978	105183	69	-1	-1
1979	133678	78	-1	-1
1980	239289	104	270000	-1
1981	259767	121	320000	-1
1982	266523	145	150000	-1
1983	289860	162	300000	-1
1984	318917	171	190000	-1
1985	273274	195	150000	-1
1986	274740	210	50000	-1
1987	295902	229	100000	-1
1988	295000	247	235000	-1
1989	96806	262	32000	-1
1990	66409	280	48000	-1
1991	79225	284	92000	-1
1992	155417	163	-1	-1
1993	218866	287	-1	-1
1994	278667	243	-1	-1
1995	373782	262	-1	-1
1996	273239	278	-1	-1
1997	213780	248	-1	-1
1998	195996	209	-1	-1
1999	310801	199	-1	-1
2000	260670	262	-1	-1

2001	288616	299	-1	-1
2002	336419	419	-1	-1
2003	266069	473	-1	-1
2004	306656	388	-1	-1
2005	119255	497	-1	-1
2006	212081	428	-1	-1
2007	357089	473	-1	-1
2008	225344	566	-1	-1
2009	185606	483	-1	-1
2010	203026	409	-1	-1
2011	246390	384	-1	306000
2012	109187	339	-1	261000
2013	255309	197	-1	292000
2014	71530	115	-1	315000

It is used wide range of data set in ASPIC (1968-2014), when it is compared to XSA (2005-2014). The main reason is that ASPIC needs more years in data to establish a contrast among the data set. It means if it is used several years data, they will accumulate in the close place in graph and it creates a lot of lines to pass this place and that prevent making proper estimations since it increases the possibilities. However in large year data set it is possible to get an exact line for analysis and for making some straight estimation. The situation is almost the same with XSA, but due to the lack of proper (XSA needs sequential data series for analysis) data it is used ten years of successive data for assessing the stock.

Modeling Flow

The basic modeling flow of ASPIC is illustrated in Figure 10. This model reads inputs from the text files and also outputs of the model are given also as a text file, therefore ASPIC is called as a text-mode program (Prager, 2014). While running the program the possible informational or error massage is printed in the screen, this is an advantage of the model since any mistake can be corrected while processing.

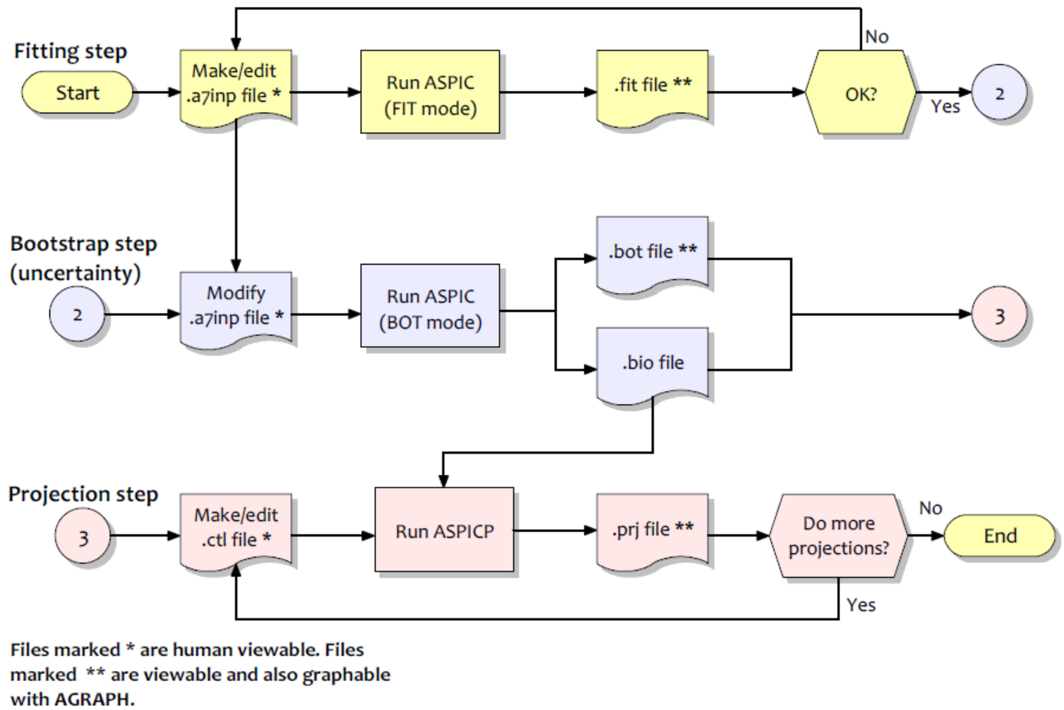


Figure 10: ASPIC Suite modeling flow. (Prager, 2014)

ASPIC has two interface files; one is ASPIC7 Suite Programs which include “AGraph” for drawing graph, “ASPIC 7” for running the data file, “ASPICP 5” for making short, medium and long term projections and the shortcut of the Notepad to create a data file. The other is ASPIC7 Suite Sample Files which consists of some sample files with the extensions of .a7inp, .fit, .bot, .bio, .ctl, .prj, etc. on Table 3.

Table 3: Input (I) and Output (O) files of ASPIC and related programs

File extension	Input or output?	Used by	File contents and description
.a7inp	I	ASPIC	Input file with data, starting guesses, and run settings
.fit‡	O	ASPIC	Main output file from FIT program mode
.bot‡	O	ASPIC	Main output file from BOT program mode
.bio†	O, I	ASPIC, ASPICP	Estimated *B* and *F* trajectory for each bootstrap trial (BOT program mode); used by ASPICP.
.det†	O	ASPIC	Estimates from each bootstrap trial (BOT program mode).
.sum	O	ASPIC	Optional file with summary of all runs made in a directory
.prn	O	ASPIC	Estimated trajectories in a table easily read by a spreadsheet or statistics program
.rdat†	O	ASPIC	Detailed output file formatted for reading by the dget() function of S-Plus or R. Includes inputs and estimates.
.rdatb†	O	ASPIC	As above, but from bootstrap runs
.gen	O	ASPIC	Summary results from GENGRID mode
.ctl	I	ASPICP	Control file with projection parameters
.prj‡	O	ASPICP	Projection results
.prb	O	ASPICP	Supplement of .bio file with projection results

‡ File types readable by AGRAPH .

† File types intended for reading mainly by other computer programs.

In fact, ASPIC has two program modes; one is FIT mode and the other is BOT mode. In former mode, ASPIC fits the model and computes estimated parameters. Also calculations about the quantities of management interest are done in FIT mode. In the latter mode, ASPIC fits the model and computes bootstrapped confidence intervals according to the estimated values. The bootstrapping procedure of ASPIC is used for bias correction and also holding the approximate non-parametric confidence intervals. In other words; bootstrapping in the ASPIC provides estimates of precision. A standard analysis starts with FIT mode and to find out different model structures model makes several runs. After the model and data source established, BOT mode should be created to estimate uncertainty of the results. Then the projections can be made with respect to different scenarios to reach the MSY in stock exploitation.

Whole model can be divided into three parts as fitting, bootstrapping and projection steps (Figure 10).

Fitting Step

As it is explained above, the first step is creating an .a7inp extension file. That includes the estimated parameters, some other values and the data sets. ASPIC can fit up to 12 serial data set (observed data, estimated data or biomass index series). Moreover data series can be of several types (Table 4) (Prager, 2014). The .a7inp file, which created as a text file, should be saved as a sample file. From there .a7inp file is dragged and dropped to the ASPIC7 to run the model. If all values is calculated properly with the given estimates and within bounds, model gives "NOTE: ASPIC v.7 ended normally" message. If not, it should be checked and change values on .a7inp file up until see this message and this message also gives the place where the output text file with .fit extension is saved as " Output file: C:/ Users/x/ Desktop/ASPIC/Black Sea Anchovy.fit" (same file with .a7inp). Thereafter the output .fit file will be used an input file for AGraph that draws the graphs of F/F_{MSY}, B/B_{MSY} and CPUE index for demonstrating the results.

Table 4: Codes for the types of data series allowed in ASPIC.

Code	Data type	When measured
CE	Fishing effort rate and yield	Effort rate: annual average Catch: annual total
CC	CPUE and catch	CPUE: annual average Catch: annual total
B0	Estimate of biomass	Start of year
B1	Estimate of biomass	Annual average
B2	Estimate of biomass	End of year
I0	Index of biomass	Start of year
I1	Index of biomass	Annual average
I2	Index of biomass	End of year

Table 5: Input data format for preparing the .a7inp file in ASPIC.

```
ASPIC-V7
# File generated by aspic5to7 v.0.59, at 2014-05-14 16:52:50
"Black Sea Anchovy Production Model Turkey+Georgia_1968-2014 -- MSc thesis _ Gizem"
# Program mode (FIT/BOT), verbosity, N bootstraps, [opt] user percentile:
```

```
FIT  222
# Model shape, conditioning (YLD/EFT), obj. fn. (SSE/LAV/MLE/MAP):
LOGISTIC  YLD  SSE
# N years, N series:
47  3
# Monte Carlo mode (0/1/2), N trials:
0  30000
# Convergence criteria (3 values):
1.0d-08  3.0d-8  1.0d-04
# Maximum F, N restarts, [gen. model] N steps/yr:
8.0d0  8  24
# Random seed (large integer):
6745249
# 9 Initial guesses and bounds follow:
B1K    0.5  0
MSY    1.91E+05   1  150000  500000
Fmsy   4.0d-01  0    1.0d-02  1.5d0
q      0.001  1  1.00E+00  5.0e-06  5.0e-02
q      0.001  1  1.00E+00  5.0e-06  5.0e-02
q      0.001  1  1.00E+00  5.0e-06  5.0e-02
DATA
"number of purse seiner effort, catch"
CE
"SSB-Hydroacoustic"
B0
"Turkey-Hydroacoustic"
B2
```

Bootstrap Step (Uncertainty)

The main idea of this step is to digitize the uncertainties by bootstrapping to create an estimated data file to be able to make forward projections. To do this .a7inp file was modified from .a7inp to .bot extension by changing the line 3 in the input file (Table 5) as writing the BOT instead of FIT and also decide the number of bootstrapping according to the recommendation of the Prager,2014 as “at least 500 bootstrap trials to calculate the ASPIC’s default 80% confidence intervals” or according to any other personal decision. The rest of the input file is preserved than new file was saved as “Black Sea anchovy-BOOT.a7inp” in the same sample file which contains all the data files. Then, again with the same drag and drop method, input was run in the ASPIC 7 that is in the ASPIC7 Suite Programs file. After running model, it gives an output as "Black Sea anchovy-BOOT.bot" with .bot extension which is viewable and also graphable with AGRAPH. And after bootstrap runs model gives two more additional files with the extensions of ".bio" and ".det". The .bio file is used by ASPICP for making some projections in the projection step following a bootstrap run. The .det file provides information on the individual bootstrap trials. It is not used directly by any supplied program, but it can be useful in further analysis (Prager, 2014).

Projection Step

After bootstrap run, the outputs are used in projection step to make short, medium and long term projections, since anchovy is a short live species it is not recommended a long term projection, about the stock that will be assessed. The main interface in this step is ASPICP which is another text-mode program that reads the projection commands of the users from a control file that have an extension of .ctl. To establish a projection one should create a .ctl file (Table 6). "The most important point one must be careful is that the control file (among other things) gives the name of .bio file from an ASPIC bootstrap run, from which bootstrap estimates of F_{MSY}, B_{MSY}, annual *B* and annual *F* are read." (Prager,2014) Also projection commends are built in terms of year, yield and effort with the basis of *MSY* values. For instance in the table.., it has been shown a representative projection. One can create many different scenarios for different time intervals. This is one of the five-year scenario that has been used in this assessment that could be interpreted as one (x1) year 20% of the *MSY*, that suggested by the model, would be applied to the stock, for two (x2) years, it would be fished 50% of F_{MSY} and for two (x2) years it would be fished at 90% of F_{MSY}. In this assessment F=0, $F_{current}$ and F_{MSY} are the basic projection parameters in terms of fishing mortality management. *MSY* catch and continue to current catch amount is the parameters in terms of catching amount that projected in short, medium and long term.

Table 6: Input data format for preparing the .ctl file in ASPIC.

This EXACT STRING indicates v4 file format
ASPICP-V4
Projection title

```
"Black Sea Anchovy Production Model Turkey+Georgia_1968-2014 -- MSc thesis"
## BIO file to read
"Black Sea Anchovy-BOOT.bio"
## CV of MSY for projections (0.0 <= CV <= 1.0)
0.25
## Confidence interval type (BC | PC), smoothing (1 | 0)
PC  0
## Years to drop at start of plots
1
 ## Options (1|0): run agraph, write prb file, write rdat file
0  1  1
## Random number seed
6745249
# Projection specs follow here:
x1   0.2       MSY
x2   0.5     FMSY
x2   0.9     FMSY
%% END
==================================================================
NOTES ON PROJECTION SPECIFICATIONS
A line may begin with
xN : Repeat the spec for N years
#  : Ignore this line. It is a comment.
%  : End of specs.  REQUIRED to mark end.
None of the above, and just contain the spec itself.
-----------------------------------------------------------------------------------------------
Each spec has two values:
(1) A real number, the projected yield or effort.
(2) A character string that indicates what the number means. Options:
       YABS = yield in same units as assessment
       YREL = yield, relative to yield in last year of assessment
       MSY  = yield, relative to MSY as estimated by the assessment
       FREL = fishing mortality rate, relative to the last year of the assessment
       FMSY = fishing mortality rate, relative to Fmsy as estimated by the assessment
```

Afterwards .ctl file is run in ASPICP shortcut by the same drag and drop method. If it is run properly model gives the output report file of “Black Sea Anchovya7.prj”. It is viewable and also graphable with AGRAPH and demonstrates the projection results with graphics of B/B_{MSY}, F/F_{MSY} and relative biomass and fishing mortality in same graph according to the MSY line. ASPICP gives another output file with the extension of .prb which is an extension of the .bio file that has the projection years. It contains more detailed results from the projection trials. Prager, 2014 suggest that .prb file is meant for analysis with a statistics program or spreadsheet. Finally, after all projections are done, the model end and ready for the interpretation.

ASPIC was simplified in many manners. Such that it does not taken into account how environmental conditions and climate changes affect the biomass of the fish stock. Moreover; interaction between species and regime shifts of the Black Sea are disregarded by this model. It is only give some estimation about biological reference points to manage and assess the stock. Just gives idea, it does not explain the exact results. That's why in this study it is used two different approaches in stock assessment to verify and compare the results of each method. One of the approaches is ASPIC and the other one is XSA, as fallows, which is more complex than ASPIC because it takes recruitment and the age structure of the stock into account.

2.2.2. XSA (eXtended Survival Analysis)

This model has been used by ICES for about 20 years and it is accepted as standard application in stock assessment. Also it has been used successfully in the assessment of not only small pelagic like anchovy but also many different stocks (Darby and Flatman, 1994 and Shepherd, 1999). Such as in the assessment of; Beaked Redfish by Northwest Atlantic Fisheries Organization (Melo et al., 2009), *Merluccius merluccius* by STECF (assessment report2012), *Sardina pilchardus* by STECF (STECF Report, 2012), *Sprattus sprattus*, *Merlangius merlangus* and *Squalus acanthias* in the Black Sea (Daskalov, 1998), *Trachurus trachurus*, by FAO and *Engraulis encrasicolus* in Mauritania and Morocco again by the FAO (FAO, Working Group on the Assessment of Small Pelagic fish of Northwest Africa,2015). Moreover, there are too much works done by XSA for the Black Sea anchovy makes the XSA important model to be used, due to the consistency with the past works. Moreover to that, in this study XSA has been used not only for concordance with past works but also to analyze whether analytic and holistic models' results are compatible or not.

2.2.2.1. General definition of the method

The Extended Survivors Analysis (XSA) (Darby and Flatman 1994; Shepherd 1999) is an age-structured model which derived from the virtual population analysis (VPA) (Darby and Flatman 1994; Shepherd 1999). It differs from VPA by its ability to utilizing the full information year-class strength from the catch-at-age data, by its sensitivity to observation errors in the final year, also by its tuning procedure which approximate the value of observed index data and calculated results of the model and by the estimation of the fishing mortality rate (F) from the most recent years. Moreover, this model works in R languages and it can be called as ready-made package. It contains some FLR Libraries to run the model. Also data should be prepared in the Lowestoft format (Gucu and Ok, 2011).

According to Shepherd (1992), XSA has a working principle basically depends on the relationship between catch per unit effort (CPUE) and population abundance. It is also constructed on the basis of iteration-reweighting technique for search a least- squares solutions, means iteration is a successive estimates of fishing mortality, it continues until the difference between observed and calculated values getting minimum (Patterson et al., 1999). This procedure includes an iterative weighting of CPUE indices (Lassen & Medley, 2001). The most important property of XSA is to its capability of calibrating “tuning” the data set with the acoustic (in this study case) and CPUE indices while estimating the parameters such as F.

XSA iterates backward down a cohort and create a virtual population (N) . To be clearer it can be said that XSA re-creates the historical population structure of a stock by using total catch-at-age data that is given a specific level of natural mortality. The starting point is estimation at the terminal population size to start the backward calculation. In XSA this population size number is established by using the relationship between CPUE, abundance and year class strength.

Moreover, in XSA, continuity of the data set is very important especially in the age groups of the stock. As the age of the fish increases, their frequency decreases in catch. This leads to some missing ages in the sample due to the skipping in some older ages. It creates mathematical gaps in the continuity of calculation. To deal with this problem XSA uses an approach which is called as "plus-group". 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. Since the observed frequency of the older ages is interrupted after age 4.

2.2.2.2. Model Assumptions

- ✓ XSA assumes catch-age data is exactly correct, therefore this model do not take into account errors in catch-at-age
- ✓ XSA assumes that in the final year there is no observational error.
- ✓ The other most strict assumptions of XSA is the fishing mortality rate being higher than natural mortality (i.e. F > M).
- ✓ XSA has a constraint that fleet catchabilities-at-age (sampling efficiency) is assumed to be constant with respect to time (ages that considered as "recruits") or with respect to year-class abundance (ages that treated as "recruits").
- ✓ XSA assumes that catchability is independent from age, above a specific age (means, the catchability of the oldest true age is fixed and used for all preceding age). It reduces the estimated number of parameters. And this age is user-defined.
- ✓ XSA assumes all the data is in the proper format (Lowestoft) and order in the input file.

2.2.2.3. ANOVA

Before beginning the analysis it was tested the four alternative data sets of Turkish data with Turkish tuning, Turkish data with Turkish and Georgian tuning, Turkish and Georgian data with Turkish tuning and Turkish and Georgian data with Turkish and Georgian tuning between the years from 2005 to 2014. To achieve this it has been used "R Studio" for analysis of this statistical test for these four alternatives by using the input data of "fbar", "ssb", and "rec" XSA results of these options. According to the statistical results of ANOVA; there are no significant differences between these data options. That is why we decided to use and Georgian data with Turkish and Georgian tuning to increase the data set for getting more proper results.

2.2.2.4. Needed Data

To run the model the needed data set is shown in the Table 7. Whole data should be a text file and should be gathered in a file in desktop.

Table 7: Data set which is used in XSA.

LA	Catch in tones	2005 - 2014
CN	Catch-at-age in numbers	2005 - 2014
CW	Weight-at-age in the commercial catch	2005 - 2014
SW	Weight-at-age of the spawning stock	2005 - 2014
NM	Natural mortality	2005 - 2014
MO	Proportion mature-at-age	2005 - 2014
PF	**%** of fishing mortality before spawning	0.00 (assumed)
PM	**%** of natural mortality before spawning	0.00 (assumed)
TUN		
CPUE of Georgia		2005 - 2014
Hydro-acoustic survey over Turkish EZZ		2011 - 2014
CPUE of Turkish purse seine fleet		2005 – 2014

Before running the model data preparation has been done as follows. The input file should be as

Figure 11. To be clearer every step, while preparing this text files, are going to be explain in detail in below.

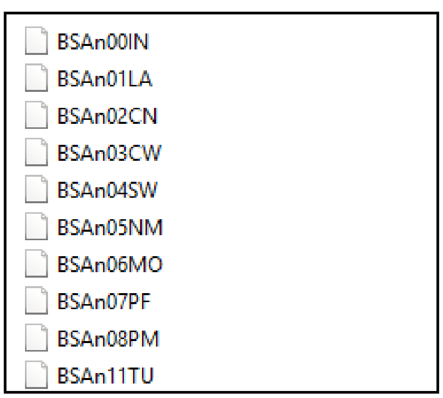


Figure 11: Text files that needed for running the model.

Index File

In this file, the order and the content of the input file has summarized for the model. It contains the name of the prepared data set. In Lowestoft format, every data which have been written in the Table 8, should also be prepared in same format. To be able to properly run the model.

Table 8: Index file for the assessment of Black Sea Anchovy by using XSA. (*** means unused data set in the assessment)

BLACK SEA ANCHOVY,2005-2014,stock assessment, master thesis
1
BSAn01LA
BSAn02CN
BSAn03CW
BSAn04SW
BSAn05NM
BSAn06MO
BSAn07PF
BSAn08PM
***
BSAn11TU

Landing Data (LA) File

In this study landing data is used as a catch that is assumed that this data also involves discards. The unit of the data is ton. Landing data is taken from TUIK. According to STECF ,2008, Assessment Report; landing data is optional, however it gives more precise results when it is used, since it facilitates the creation of the virtual stock and make it easy to establish backward stock estimations.

As a landing data; it is used Turkish and Georgian data. Although all Black Sea countries catch anchovy, in this study it is only used these two countries data. Because approximately 90% of total catch is belong to Turkey and moreover to that the Georgian's fishes are also caught by Turkish fleet. In the Table 9 below it has been demonstrated how a LA file should be.

Table 9: Total landing data of Turkey and Georgia between the years of 2005-2014. First line is the title of the study, second is sex determination; "1" means no sex discrimination in

assessment, third line shows first and the last year of the data set; from 2005 to 2014, fourth line demonstrates the demographic discrimination from age “0” to age “4+” and in the fifth row “5” means the five different age class from “0” to “4+” are used. The rest of the rows represent the every year’s landing data from 2005 to 2014.

```
Black Sea Anchovy Turkey+Georgia,2005-2014,COMBSEX,PLUSGROUP
1           1
 2005        2014
 0           4
 5
128477
229527
383061
256682
225463
228944
257396
165964
326104
137530
```

Catch-at-age (in number and weight) Data (CN,CW,SW)

It means number of fish caught per age class and year. The unit is number in other words it is expressed as thousand of individual fish. Division of stock into age classes is the most important part of the data preparation. To be able to divide the Black Sea Anchovy stock into age group, five age set has establishes as “0”, “1”, “2”, “3” and “4+”. Where “4+” represents both four and the elder than four years old fish in the stock. The needed data as it has demonstrated below are; length frequency data (each year has its own length frequency data) which has been taken from SUMAE between the years of 2005-2010 and from METU-TUBITAK-KAMAG 110G124 project between the years of 2011-2014, age length key; (Table 10) which is prepared by using the METU’s age reading data. It is done by the specimens that collect from the Black Sea throughout the cruise of the project. And also by using the SUMAE’s age-length key data. By combining these two data it has been created a new age-length key, total catch (Table 11) which is taken from TUIK, total effort (Table 11) which is taken from TUIK, a and b values that are taken from METU-TUBITAK-

KAMAG 110G124 project between the years of 2011-2014, these four year's average a and b values have been used for the rest of the years because for this year there is not proper data; for calculation of average weight which used in the calculation of age distribution of length frequencies and age distribution of total catch in terms of weight and number.

Table 10: Age-length key in percentage (SUMAE).

Age-Length Key

Length	(%)Age0	Age1	Age2	Age3	Age4	Age5	Age6
1	0	0	0	0	0	0	0
1.5	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
2.5	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
3.5	0	0	0	0	0	0	0
4	100	0	0	0	0	0	0
4.5	100	0	0	0	0	0	0
5	100	0	0	0	0	0	0
5.5	100	0	0	0	0	0	0
6	99.31034	0.689655	0	0	0	0	0
6.5	94.33962	5.660377	0	0	0	0	0
7	68.78613	31.21387	0	0	0	0	0
7.5	59.1954	40.8046	0	0	0	0	0
8	46.59686	52.87958	0.52356	0	0	0	0
8.5	34.09091	65	0.909091	0	0	0	0
9	15.50388	79.06977	5.426357	0	0	0	0
9.5	5.882353	89.41176	4.705882	0	0	0	0
10	2.118644	85.16949	12.71186	0	0	0	0
10.5	0	69.19643	30.35714	0.446429	0	0	0
11	0	57.62712	36.72316	3.954802	1.694915	0	0
11.5	0	26.57343	69.93007	2.097902	0.699301	0.699301	0
12	0	2.542373	88.13559	9.322034	0	0	0
12.5	0	0.961538	58.65385	40.38462	0	0	0
13	0	0	38.23529	61.76471	0	0	0
13.5	0	0	10	90	0	0	0
14	0	0	0	100	0	0	0

14.5	0	0	0	80	19	1	0
15	0	0	0	50	50	0	0

Table 11: Catch (tons) and Effort (number of vessels) data of Turkey and Georgia between the years of 2005-2014. Whole catch and effort data have been taken from TUIK.

	Turkey		**Georgia**	
Year	**Catch**	**Effort**	**Catch**	**Effort**
2005-2006	119255	497	9222	68
2006-2007	212081	428	17446	74
2007-2008	357089	473	25972	55
2008-2009	225344	566	31338	23
2009-2010	185606	483	39857	18
2010-2011	203026	409	25918	19
2011-2012	246390	384	11006	19
2012-2013	109187	339	56777	14
2013-2014	255309	197	70795	26
2014-2015	71530	115	66000	21

Table 12: a and b values of the years 2011-2014 and the average of them for other years.

	2011-2012	**2012-2013**	**2013-2014**	**2014-2015**	**Average**
a	0.0063	0.0038	0.0043	0.0039	0.0046
b	2.9984	3.176	3.1571	3.1893	3.1302

To arrange all these data Excel has been used not only for calculation but also for making all data visible. To summarize the Excel calculation;

- ❖ L_{freq} are used to get total weight of every age as

  $$W_{total/age} = a * L_{freq}^{b}$$

- ❖ To get age distribution of length by using L_{freq} in terms of number, total fish amount in every age has been multiplied by the fish percentage at every specific age (age-length key) then has been divided by 100 to get rid of percentage and get number of total fish in every age.

- ❖ To convert age distribution of length from number to weight, every age’s length distribution that calculated in terms of number has been multiplied with the every age’s own total weight. Then we get age distribution of length in terms of weight by the unit of gram.
- ❖ To get age distribution of total catch in terms of weight, total weight per unit age has been multiplied by the total catch. Weight per unit age has been calculated by the number of fish in every age, independently, has been summed and divided by the weight of fish in every age, independently. Then to get total weight per unit age whole age’s weight per unit age has been summed.
- ❖ Finally, to get age distribution of total catch in terms of number, age distribution of total catch in terms of weight for every specific age that has been calculated in previous step has been multiplied by the total weight, that has been calculated in first step by using L_{freq}, of this specific age.

After all these calculations which have been repeated for Turkey and Georgia data, results should be prepared as text file by using Notepad. It is not easy to move every year and every age’s CN,CW and SW data individually. For this reason and also to avoid the errors it has been written “Macro” in Excel. This Macro has been created each of the “BSAn02CN”, “BSAn03CW” and “BSAn04SW” text file in the data input file which has been already prepared in the desktop as it is shown in Figure 11. This process also has been repeated for Turkey and Georgia data.

To be clearer; “CN” represents age distribution of catch in number, “CW” represents age distribution of catch in weight and “SW” represents age distribution of stock in weight. And in this study, it is assumed that catch weight is equal to stock weight. All in all, after preparation of these data Turkey and Georgia data have been summed and input files have been become as the Table 13 and Table *14*.

Table 13: CN (age distribution of catch in number) data file. Every row represents year and every column stands for ages from 0 to 4+.

```
Black Sea Anchovy Turkey+Georgia,2005-2014,COMBSEX,PLUSGROUP
1          2
 2005        2014
 0          4
 1
1.37E+06     6.78E+06     4.86E+06     2.41E+06     3.02E+04
4.07E+06     1.70E+07     1.02E+07     1.26E+06     1.81E+05
4.71E+06     3.04E+07     1.63E+07     1.97E+06     2.26E+05
3.02E+06     1.12E+07     1.41E+07     2.35E+06     1.90E+05
2.96E+06     1.43E+07     1.03E+07     1.92E+06     1.47E+05
2.10E+06     8.20E+06     1.22E+07     3.11E+06     1.16E+05
2.61E+06     1.51E+07     1.24E+07     2.06E+06     2.05E+05
1.17E+07     1.97E+07     4.80E+06     2.29E+05     6.31E+04
4.89E+06     3.23E+07     1.17E+07     9.27E+05     1.71E+05
2.93E+06     1.13E+07     5.94E+06     5.75E+05     1.01E+05
```

Table 14: CW (age distribution of catch in weight) and SW (age distribution of stock in weight) data file. Every row represents year and every column stands for ages from 0 to 4+.

```
Black Sea Anchovy Turkey+Georgia,2005-2014,COMBSEX,PLUSGROUP

 1          3
 2005        2014
 0          4
 1
6.06E-03      1.23E-02     1.97E-02     2.54E-02     1.93E-02
5.39E-03      1.29E-02     1.82E-02     2.35E-02     1.94E-02
5.30E-03      1.32E-02     1.79E-02     2.34E-02     1.94E-02
4.78E-03      1.38E-02     1.90E-02     2.39E-02     1.94E-02
5.23E-03      1.31E-02     1.87E-02     2.42E-02     1.94E-02
5.07E-03      1.34E-02     1.95E-02     2.44E-02     1.94E-02
4.97E-03      1.42E-02     1.84E-02     2.39E-02     1.94E-02
3.84E-03      1.07E-02     1.47E-02     1.90E-02     1.94E-02
6.42E-03      1.27E-02     1.62E-02     2.08E-02     1.94E-02
4.82E-03      1.25E-02     1.78E-02     2.18E-02     1.94E-0
```

Natural Mortality (MO) File:

Natural mortality (M) is the death of the fishes due to the natural causes such as predation, illnesses, aging, etc. since it is not human dependent the calculation of natural mortality is very controversial. There are several ways to calculate M with different parameters (L_{inf}, W_{inf}., K(l), B(l) and even temperature (since it affects the growth rate and consequently the natural mortality). In this assessment it has been used a ready-made R code which is written by Gery A. Nelson from Massachusetts Division of Marine Fisheries. It can be reached by free from the website of http://finzi.psych.upenn. edu/library/fishmethods/html/M.empirical.html. The matrix can calculate natural mortality with nine different methods but we have only used Pauly (1980) and Gislason (2010).

Natural mortality which has been calculated by Pauly (1980) with the needed the parameters of W_{∞}, k, L_{∞} and water temperature. Water temperature data is taken from the official website of the NASA (http://gdata1.sci.gsfc.nasa.gov/daac-bin/G3/gui.cgi?instance _id=MODIS_DAILY_L3) while entering the coordinate of the Black Sea whole area of the sea is chosen. Then chosing the single water temperature in terms of time series between 2005-2015. Downloaded mountly temperature data, transferred to the Excel and finally it is calculated that the annual average sea water temperature of whole Black Sea from 2005 to 2015 as it is shown in the Table 15.

Table 15: Annual average sea temperature of Black Sea between the years of 2005-2014.

Year	Temperature (C^0)
2005	15.38
2006	15.28
2007	15.85
2008	15.37
2009	15.79
2010	16.50
2011	15.35

2012	16.24
2013	15.99
2014	16.03

Natural mortality which has been also calculated by Gislason (2010) with the needed parameters of Linf, K(l) and B(l).

Table 16: R code for calculation of natural mortality (M)

```
library(fishmethods)

temp<-read.table("C/Users/x/Desktop/temperature from 2005 to 2014",header=T)
attach(temp)
names(temp)
#Arguments
#Linf  Length-infinity value from a von Bertalanffy growth curve (total length-cm).
#Winf  Weight-infinity value from a von Bertalanffy growth curve (wet weight-grams).
#Kl    Kl is the growth coefficient (per year) from a von Bertalanffy growth curve for length.
#Kw    Kw is the growth coefficient (per year) from a von Bertalanffy growth curve for weight.
#T     the mean water temperature (Celsius) experienced by the stock.
#tmax  the oldest age observed for the species.
#tm    the age at maturity.
#GSI   gonadosomatic index (wet ovary weight over wet body weight).
#Wdry  total dry weight in grams.
#Wwet  total wet weight at mean length in grams.
#Bl    body length in cm.
#method      vector of method code(s). Any combination of methods can employ.
#1= Pauly (1980) length equation - requires Linf, Kl, and T;
#9= Gislason et al. (2010) - requires Linf, K and Bl.

for (i in 1:10)  {
  print(Year[i])
  print(M.empirical(Linf =13.408 , Winf = 15.259, Kl = 0.618, Kw = NULL,
              T = SST[i], tmax = NULL, tm = NULL, GSI =NULL,
              Wdry = NULL,Wwet = NULL, Bl =7.747 , method = c(1, 9)))}
```

The code which is in the package has been shown in Table 16 to run this natural mortality calculation program in the R environment; firstly library(fishmethods) should be installed in the R. Then the direction of the Black Sea temperature file must be read to the program. After all these, the needed data have been written to the code. If the data which we do not need for calculation is present, it should be written “null” in data place. It means it does not need for the calculation that we have chosen. After in all the output of these calculations about natural mortality which will be used in model has been shown in

.

Table 17: Annual values of natural mortality (M) which is change over age classes, but has been fixed between years.

```
Black Sea Anchovy Turkey+Georgia,2005-2014,COMBSEX,PLUSGROUP
1 5
2005 2014
0 4
1
1.32    0.81    0.56    0.48    0.48
1.32    0.81    0.56    0.48    0.48
1.32    0.81    0.56    0.48    0.48
1.32    0.81    0.56    0.48    0.48
1.32    0.81    0.56    0.48    0.48
1.32    0.81    0.56    0.48    0.48
1.32    0.81    0.56    0.48    0.48
1.32    0.81    0.56    0.48    0.48
1.32    0.81    0.56    0.48    0.48
1.32    0.81    0.56    0.48    0.48
```

Proportion mature-at-age (MO)

It is a proportion of sexually mature individuals per age class. In this assessment it has been fixed over years (Table *18*).

Table 18: Sexual maturity indices for per age class of Black Sea Anchovy.

```
Black Sea Anchovy Turkey+Georgia,2005-2014,COMBSEX,PLUSGROUP
1 6
2005 2014
0 4
2
0 1 1 1 1
```

Tuning Data

It is very important for XSA, since this is the most important feature of XSA that distinguishes it from classical VPA analysis. It does a validation between the results of the model and supportive biomass data (acoustic and CPUE values). And it tunes the results until get the proper and most reliable results. The biomass data that has been used as tuning index are Turkish acoustic results, which belong to the Black Sea Anchovy project between the years of 2011-2014, and CPUE index that calculated for Turkish and Georgian catch and effort data for every age classes.

CPUE data, which has been used for tuning, is assumed as biomass data. In fact; if it is considered that fish are homogeneously distributed in the sea, the amount of fish which caught by a vessel in every individual operation will be an indicator the total amount of the fish in the sea. And it is known that fish does not disperse homogeneously in the sea, however if the sample size gets bigger, the importance of this assumption will decrease gradually then. The most important point is that for the proper estimation of the CPUE, it is needed the correct definition of effort. Therefore it is assumed that catchability of every operation is same. It is accepted that the amount of fish which have been caught from a specific school by a bigger purse seine in a single operation is same with that caught by a smaller purse seine in one operation. It is not incorrect because according to the Black Sea Anchovy Project results which have holt in 2011-2015, there is no correlation has been found between the characteristics of vessel and the amount of fish that is caught in one single operation (Gucu at al., 2014).

The Turkish Acoustic data over the Turkish Exclusive Economic Zone (EEZ) is a one tuning data and it has been taken from the TUBITAK-KAMAG 110G124 Black Sea Anchovy project between the years of 2011-2014. Turkish catch and effort data, which has been used for calculation of CPUE, have been taken from TUIK. Georgian catch and effort data (again for calculation of CPUE) have been taken from Assessment of Black Sea Stock (Gucu, 2014). All these CPUE values should be separated into age classes as 0, 1, 2, 3 and 4+. The procedure is same with the calculation of age distributions of total catch in terms of number and weight. However in this time instead of “catch” data it has been used “CPUE” data. Then it has been calculated age distributions of total CPUE in terms of number and weight. All process took place in Excel, again. Then the input text file of the tuning data has been obtained by using a Macro in Excel. It has been shown in Table 19 below.

Table 19: Tuning input file of Georgia CPUE and Turkish Purse Seine CPUE in years 2005-2014 with respect to age groups. Turkish Acoustic over Turkish EEZ in years 2011-2014.

Black Sea Anchovy Tuning - Georgian CPUE, Acoustic, Turkish CPUE

103

Georgia CPUE

2005	2014				
1	1	0.7	0.9		
0	4				
1	1.13E+03	9.54E+03	7.45E+03	9.17E+02	3.06E+02
1	1.96E+03	1.66E+04	1.29E+04	1.59E+03	5.32E+02
1	2.16E+05	1.83E+06	1.43E+06	1.76E+05	5.86E+04
1	1.13E+04	9.59E+04	7.48E+04	9.22E+03	3.07E+03
1	1.84E+04	1.56E+05	1.22E+05	1.50E+04	5.00E+03
1	1.13E+04	9.60E+04	7.49E+04	9.23E+03	3.08E+03
1	2.61E+03	3.44E+04	3.35E+04	4.59E+03	1.46E+03
1	3.37E+05	5.76E+05	1.29E+05	5.76E+03	2.72E+03
1	2.95E+03	2.55E+05	1.37E+05	8.57E+03	3.83E+03
1	2.75E+04	2.62E+05	1.60E+05	2.00E+04	7.91E+03

Turkish Acoustic over Turkish EEZ

2011 2014

1	1	0.75	1		
0	4				
1	1.78E+07	9.74E+06	5.46E+05	6.61E+04	6.36E+03
1	1.48E+08	6.02E+06	1.90E+04	9.20E+01	3.54E+01
1	1.24E+07	3.10E+07	5.95E+06	2.89E+05	6.66E+04
1	1.06E+08	2.34E+07	5.24E+06	3.66E+05	8.84E+04
Turkish Purse Seine CPUE					
2005	2014				
1	1	0.67	1		
0	4				
1	2.43E+03	1.22E+04	8.97E+03	4.74E+03	5.89E+01
1	8.84E+03	3.68E+04	2.21E+04	2.74E+03	3.97E+02
1	9.03E+03	6.01E+04	3.22E+04	3.88E+03	4.36E+02
1	4.41E+03	1.55E+04	2.25E+04	3.87E+03	2.94E+02
1	4.75E+03	2.35E+04	1.78E+04	3.57E+03	2.44E+02
1	4.07E+03	1.52E+04	2.71E+04	7.27E+03	2.38E+02
1	6.48E+03	3.74E+04	3.11E+04	5.19E+03	5.11E+02
1	1.43E+04	3.86E+04	1.07E+04	5.25E+02	1.49E+02
1	2.24E+04	1.26E+05	4.71E+04	4.10E+03	6.83E+02
1	1.22E+04	5.13E+04	2.71E+04	2.91E+03	4.33E+02

After all text file has been prepared, the model was ready to run. The codes of the XSA model are in Appendix. And the results of ASPIC and XSA are shown in the next section of “Results”.

3. RESULTS

3.1. ASPIC (A Stock-Production Model Incorporating Covariates)

In the following section Black Sea anchovy stock was assessed applying a non-equilibrium stock production model with ASPIC disregarding the internal stock dynamics such as recruitment.

The Results of the Fitting and Bootstrap Step of the Model

The first step in the analysis was to ensure consistency of the data set and positive correlation is targeted among the data pairs (Table 20).

Table 20: CPUE and degrees of freedom for the correlation in input data series.

CORRELATION AMONG INPUT SERIES EXPRESSED AS CPUE (NUMBER OF PAIRWISE OBSERVATIONS BELOW)

		1	2	3
1	number of purse seiner efforts, ca..	1.000		
		47		
2	SSB-Hydroacoustic	0.782	1.000	
		12	12	
3	Turkey-Hydroacoustic	0.308	0.000	1.000
		4	0	4

Approach used in the ASPIC is based on the optimization of seed parameters in a way to minimize differences between estimated and observed data. Therefore it is not suitable to use parametric statistical testes to analyze the reliability of the model. But still, the goodness is tested, internally, by replacing the sum of squares of ANOVA (by the optimization outcome). As it is demonstrated in Table 21, the results are quite satisfactory where a score between 0.5-1.0. It can safely be rated “good”. since it is “0.70” which in between the values of 0.5-1.0 (Prager, 2014).

Table 21:Goodness of Fit and Weighting of the ASPIC

GOODNESS-OF-FIT AND WEIGHTING

Objective function component: label and source of variance	Weighted SSE	N	Weighted MSE	Current weight	Inv. var. weight	R-squared in CPUE
Loss(-1) Unmatched yield	0.000E+00					
Loss(0) Penalty on B1 > K	0.000E+00	1	N/A	0.000E+00	N/A	
Loss(1) number of purse seiner effort, catch	1.968E+01	47	4.374E-01	1.000E+00	8.884E-01	0.117
Loss(2) SSB-Hydroacoustic	4.122E+01	12	4.122E+00	1.000E+00	9.426E-02	-36.954
Loss(3) Turkey-Hydroacoustic	1.545E-01	4	7.727E-02	1.000E+00	5.028E+00	-8.500
TOTAL OBJECTIVE FUNCTION, MSE, RMSE:	6.10571903E+01		1.035E+00	1.017E+00		

Estimated contrast index (good=0.5, best=1.0): **0.7007** ..... Mean of B coverage proportions > and < Bmsy
Estimated nearness index (best=1.0): 1.0000 ..... Proportional closeness of any B to Bmsy

The outcomes were also inspected by checking the distribution of the log residuals (observed-estimated) which, in an undesired fit, tend to give systematically higher and lower values at the tails of the distribution.

When the distribution of the residuals obtained in the assessment is consider (Figure 12) no such trend was between the years and they were distributed randomly at the last part of the graphic.

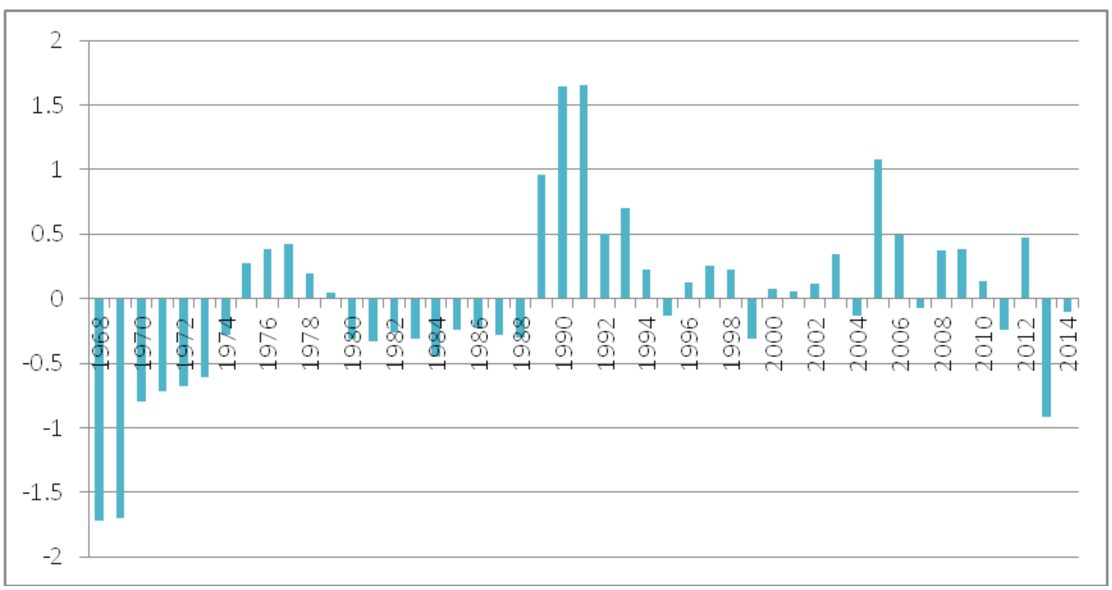


Figure 12: Log- residual distribution of the ASPIC with respect to the years.

Table 22:Model parameter estimates of ASPIC.

MODEL PARAMETER ESTIMATES

Parameter		Estimate	User guess	2nd guess	Min bound	Max bound	Estimate
B1/K	Starting relative biomass (in 1968)	5.000E-01	5.000E-01	5.000E-01	5.000E-01	5.000E-01	0
MSY	**Maximum sustainable yield**	**2.440E+05**	2.500E+05	1.646E+05	1.500E+03	5.000E+05	1
Fmsy	**Fishing mortality rate at MSY**	**4.000E-01**	4.000E-01	4.000E-01	4.000E-01	4.000E-01	0
phi	Shape of production curve (Bmsy/K)		0.5000	0.5000	-----	----- -----	0
q(1)	number of purse senier effot, catch	1.667E-03	1.000E-03	2.698E-04	5.000E-06	5.000E-02	1
q(2)	SSB-Hydroacoustic	1.000E+00	1.000E+00	3.756E-02	5.000E-06	5.000E-02	0
q(3)	Turkey-Hydroacoustic	1.000E+00	1.000E+00	3.881E-02	5.000E-06	5.000E-02	0

According to the results of model, management and derived parameter estimates of ASPIC in Table 22 and Table 23, under the current situation with sharp fluctuations experienced in past is the carrying capacity of the Black Sea for anchovy is 1.2 millions tones. The maximum sustainable yield (*MSY*) that could be achieved from the stock is “244 thousands tones”. The model also suggests that in order to achieve *MSY* the biomass of the stock (*BMSY*) should be “610 thousands tones”. Currently, the biomass estimated in the final year (B_{2015}) is 399,100 tones (65% of B_{MSY}) which are 35% below the B_{MSY}. In other words, at *MSY* condition this ratio (B/B_{MSY}) should ideally be around “1”. Therefore the model suggested that 35% less anchovy is present in the Black Sea than it should be, in other words the anchovy stock is overfished at 35% level.

In the case of the forward short term predictions, it is expected that, if the fishing mortality rate in 2015 have been the targeted (F_{MSY}) value, then the yield will be 170 thousand tons. This amount is the 70% of the *MSY*. Again according to the estimates of the model, if the amount of anchovy, that will catch 2015, is 214 thousands tones then the yield will be equilibrium as the 88% proportion of *MSY* (Table 23).

Table 23:Management and derived parameter estimates of ASPIC

MANAGEMENT and DERIVED PARAMETER ESTIMATES

	Parameter	Estimate	Logistic formula	General formula
MSY	**Maximum sustainable yield**	**2.440E+05**	----	----
Bmsy	**Stock biomass giving MSY**	**6.100E+05**	K/2	K*n**(1/(1n))
K	Carrying capacity	1.220E+06	2*Bmsy	Bmsy/phi
n	Exponent in production function	2.0000	----	----
g	Fletcher's gamma	4.000E+00	----	[n**(n/(n-1))]/[n-1]
B./Bmsy	**Ratio: B(2015)/Bmsy**	**6.543E-01**	----	----
F./Fmsy	Ratio: F(2014)/Fmsy	5.316E-01	----	----
Fmsy/F.	Ratio: Fmsy/F(2014)	1.881E+00	----	----
Y.(Fmsy)	**Approx. yield available at Fmsy in 2015**	**1.702E+05**	MSY*B./Bmsy	MSY*B./Bmsy
	...as proportion of MSY	6.975E-01	----	----
Ye.	**Equilibrium yield available in 2015**	**2.148E+05**	4*MSY*(B/K-(B/K)**2)	g*MSY*(B/K-(B/K)**n)
	...as proportion of MSY	8.805E-01	----	----
--------- Fishing effort rate at MSY in units of each CE or CC series ---------				
fmsy(1)	number of purse seiner effort, catch	2.400E+02	Fmsy/q(1)	Fmsy/q(1)

To see the results more visible, the graphs that has demonstrated in following figures below.

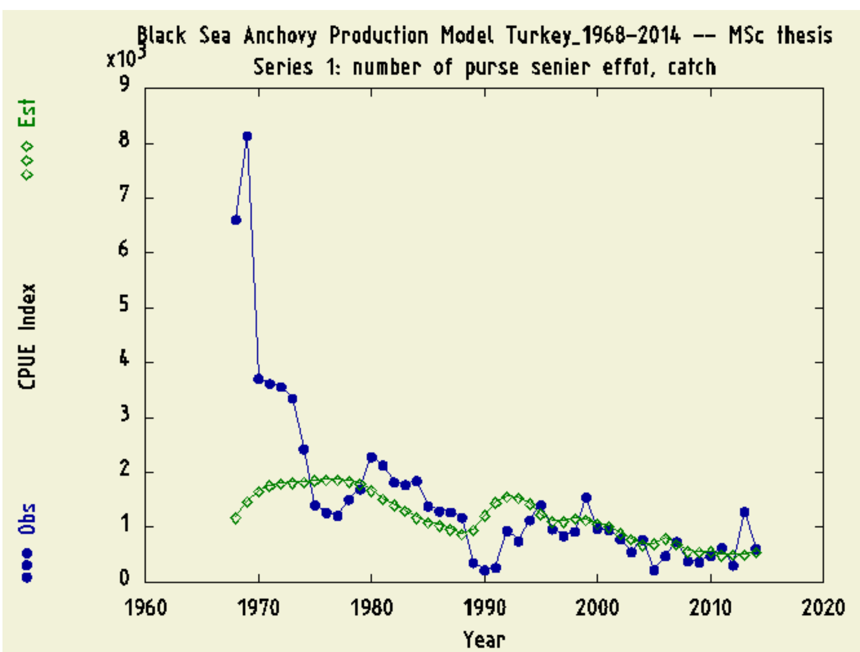


Figure 13: Observed and calculated CPUE Index values in ASPIC.

In Figure 13 observed and calculated CPUE index results of the ASPIC is demonstrated. The fit between two (calculated and observed) values shows how model estimates the change in catch with the fishing effort accurately while doing prediction. This concordance is very important and assumed as success in marine life models. There are some mismatches between observed and estimates CPUE values. One is the beginning years. According to the Prager (1994), who is the author of the model, it is expected to see incompatibilities in the beginning years of the model due to the optimizations that is used in the algorithm of the model. The other is the years 1990s, when the Mnemiopsis crisis had taken place and the total catch dropped the level of 60 thousand tons (Gucu, 2002). It is an unexpected environmental effect that the model cannot predict. Therefore, the mismatch can be seen normal.

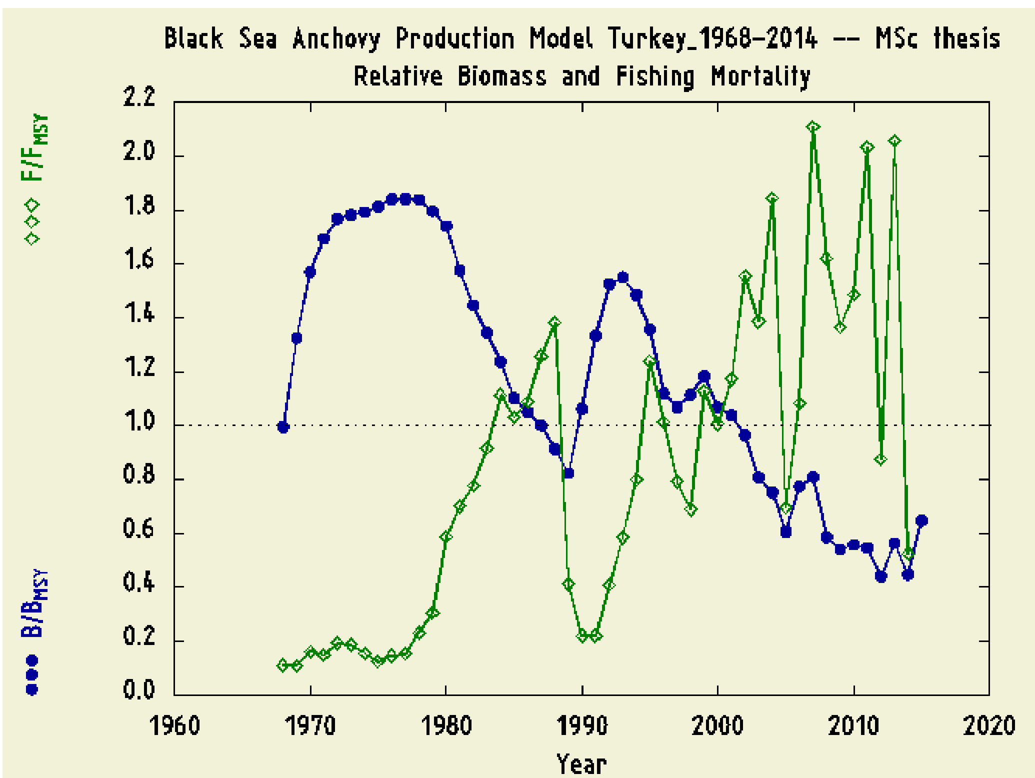


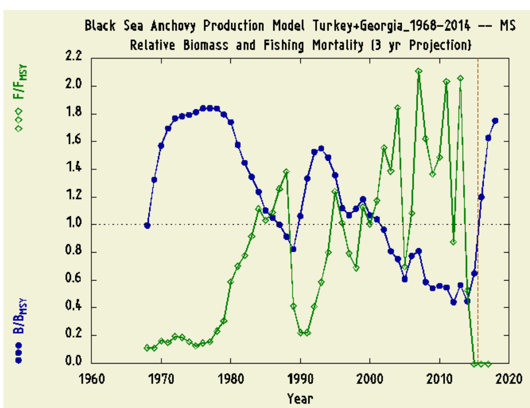
Figure 14: The relation between the ratios of fishery that observed over targeted to the MSY and biomass that observed over targeted to the MSY with respect to the fishing years.

The Figure 14 is one of the most important outputs of the ASPIC. It shows the ratio B/B_{MSY} *and* F/F_{MSY}, results can be interpreted more clearly when it is expressed as a ratio. From this graph it can be observed that response of the stocks under different conditions. Before interpretation the graph it would be the beneficial to explain the logic of the graph. According to it, the line "1.0", it is also called "*MSY* line" is the target of the model the ratio of ratio B/B_{MSY} *and* F/F_{MSY} should be on this line to ensure the sustainability of the stock. If B/B_{MSY} stays above this line it means there are too much fish left in the sea and this means Surplus Production. If B/B_{MSY} stays below this line it means that there are less fish left in the sea to sustain the stock and this means overfishing of the stock as it is explained in the introduction part of this thesis. Similarly; if F/F_{MSY} ratio stays above the *MSY* line then it can be concluded that the fishing power is higher than it should be for the sustainability of the stock. On the other hand; if F/F_{MSY} ratio stays below the *MSY* line then fishing power fall down the level which stock's sustainability threshold and fish biomass get bigger and again surplus production would take place. Beyond this knowledge, until beginning of the 1980s, fishing effort is quite below the *MSY* line that the stock can deal with. In other words, fisheries are not sufficient to be able to catch the surplus production of the stock. Through the end of the 1980s, the anchovy biomass that left in the sea started to approach the targeted *MSY* line and at 1987 it reach to the targeted level with the increasing of the intensity of fishing. However, the rapid rate of increase of the fishing effort passes critical level before reaching the target at 1984. This increase cause the decrease of the biomass level and most probably pave the way for the Mnemiopsis crisis that was claimed as this crisis also responsible to decrease of the anchovy biomass level (Kideys, 2003). The biomass drop that was observed in anchovy is not only due to increase of the fishing effort but also the other factors as 2005. Until 2005 with the decreasing of the fishing effort the biomass was continuing at surplus production level. It is claimed that the Atlantic bonito (*Sarda sarda*) was overbear in this year. Since bonito is one of the major predator of anchovy, the increase of the bonito level consequently decrease the anchovy biomass. The reason of the 2005 drop can be estimated as this (Gucu, 2014). In recent years with the increasing fishing power, the anchovy biomass remained below the targeted level until the years of 2012 and 2013. This is because the precautions (buy the ship back, daytime fishing ban, minimum catch length, etc) those have been taken by fishery managers. After that biomass level started to approach targeted level with the decreasing of fishing effort.

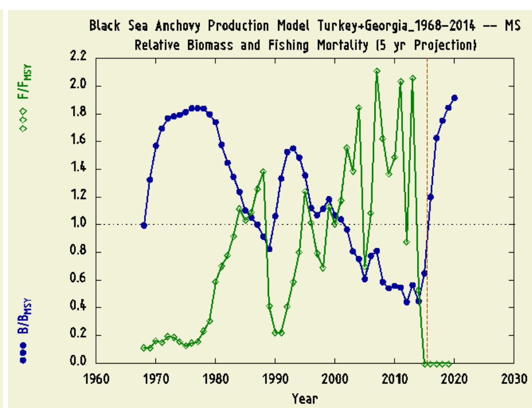
The Results of the Projection Step of the Model

In this assessment by using ASPIC 5 different scenarios have been tested in terms of short (3 years), medium (5 years) and long (10 years) term projections of the Black Sea anchovy stock with respect to $F_{CURRENT}$, F_{MSY}, current catch and catch at *MSY* as follows;

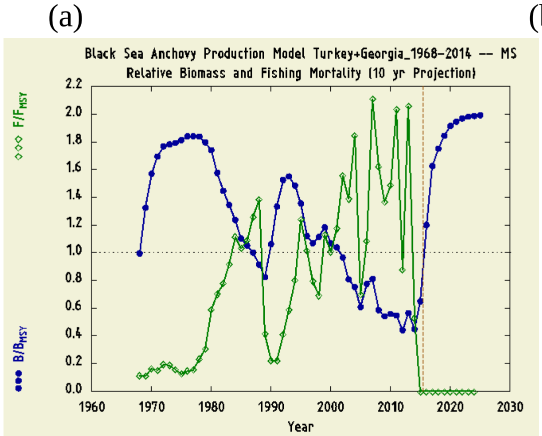
- <u>Short, medium and long term projections with no fishery and consequently no catch</u>



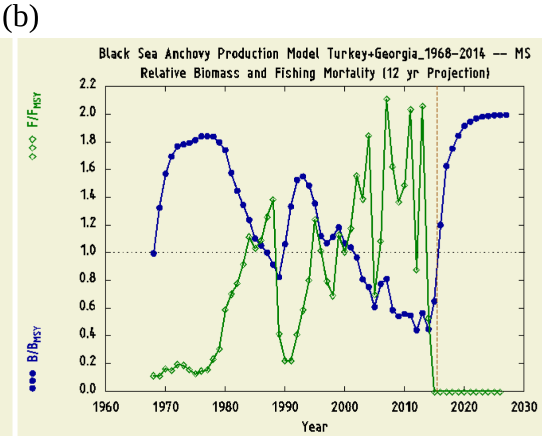
(a)



(b)



(c)



(d)

Figure 15: First scenario under the condition of no fishing activity. (a), (b) and (c, d) stand for short (3 years), medium (5 years) and long (10 and 12 years) term projections, respectively.

In Figure 15 it is demonstrated that the short, medium and long term projections of the stock under no fishing activity. In Figure 15 (a), it can be seen that if fishing activity is stopped the biomass of the stock goes over the targeted biomass level in 3 years. In Figure 15 (b), under no fishing activity B/B_{MSY} continues to increase in 5 years. Moreover, if it is continued no fishing conditions then the biomass rises, it almost reached the carrying capacity of the system. To be able to observe the carrying capacity of the system the projection years are increased until 12 and it can be said that rapid growth rate of the biomass arrives at the conclusion of S-shaped "logistic growth curve". From this interpretation it can be said that the carrying capacity of the Black Sea for anchovy stock is 1.220E+06 tones that is calculated by the ASPIC.

- <u>Short, medium and long term projections with F_{MSY}</u>

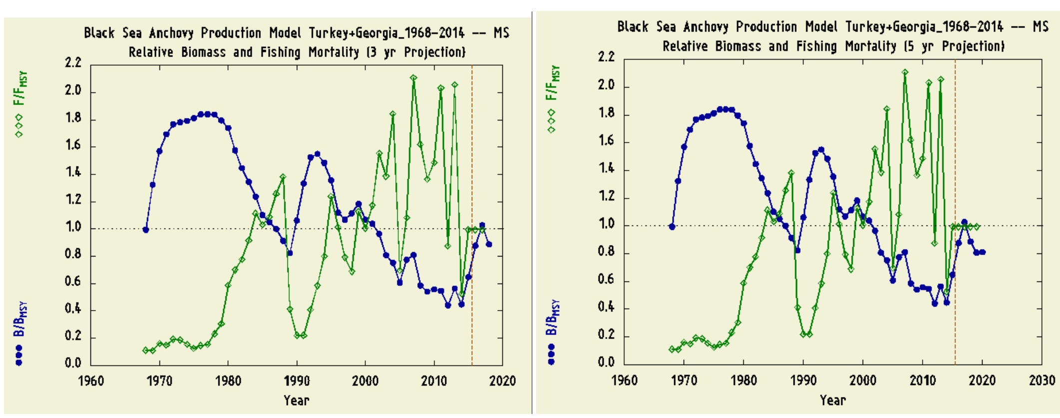
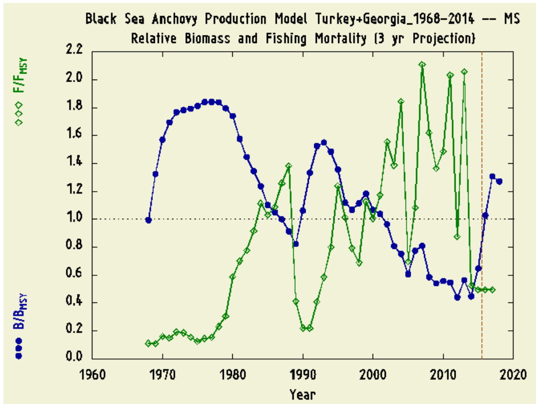


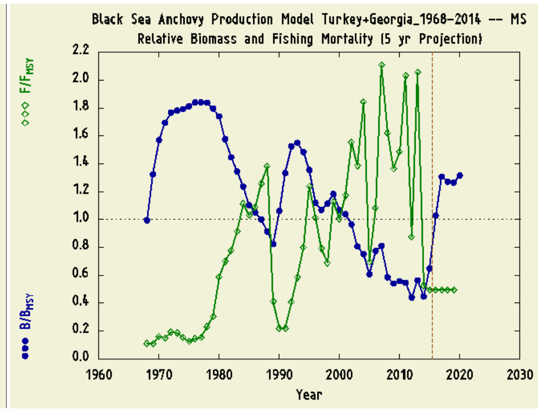
Figure 16: Short and medium term projections of the Black Sea anchovy stock under F_{MSY} condition that calculated by the ASPIC.

In Figure 16, it shown that the stock situation when it is exposed to F_{MSY} condition with 3 and 5 years time interval. According to the results it can be said that unless the stock is not at the B_{MSY} level and it is exposed the fisheries with the level of *MSY*, then the biomass of the stock decreases and stay below the target *MSY* line. This means overfishing takes place in the following years.

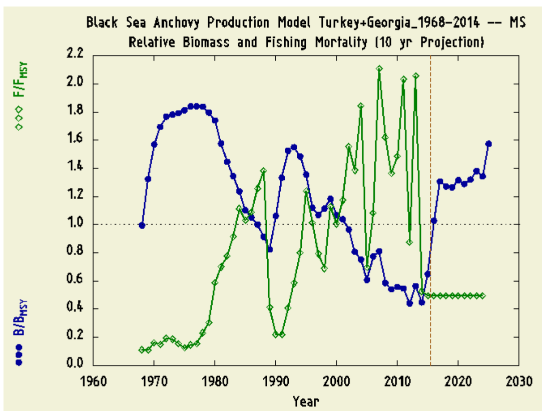
- Short, medium and long term projections with $F_{current}$



(a)



(b)



(c)

Figure 17: Black Sea anchovy stock B/B_{MSY} and F/F_{MSY} results under $F_{current}$ conditions.

In Figure 17 the stock has been exposed $F_{current}$ (0.2; F_{MSY} =0.4) for 3, 5 and 10 years. Since $F_{current}$ stays very below to the *MSY* line the B/B_{MSY} ratio increases dramatically with the following years and create surplus production in the Black Sea.

There are tens of projections have been done to predict the future of the Black Sea anchovy stock by controlling the fishery only. Since in Turkey there is no quota application on anchovy, it would be the good idea to assess fishery and establish a good fishery plan for sustainable management of the stock.

- Medium term projection by using F_{MSY} and $F_{current}$

From the results of the no fishery, F_{MSY} and $F_{current}$ (F_{REL}), it can be said that, only one management plan which depends on the one parameter is not sufficient to assess the stock. That's why the combinations of the alternative scenarios have been tried in hundreds times. Only tens of them give reasonable results. It will not be demonstrated all of them but the best one is chose as a result of the study that has been done only by using fishery parameter. The best projection among tens of them is medium term (5 years) for anchovy. Since it gives faster and more desirable results in terms of assessment (Figure 18).

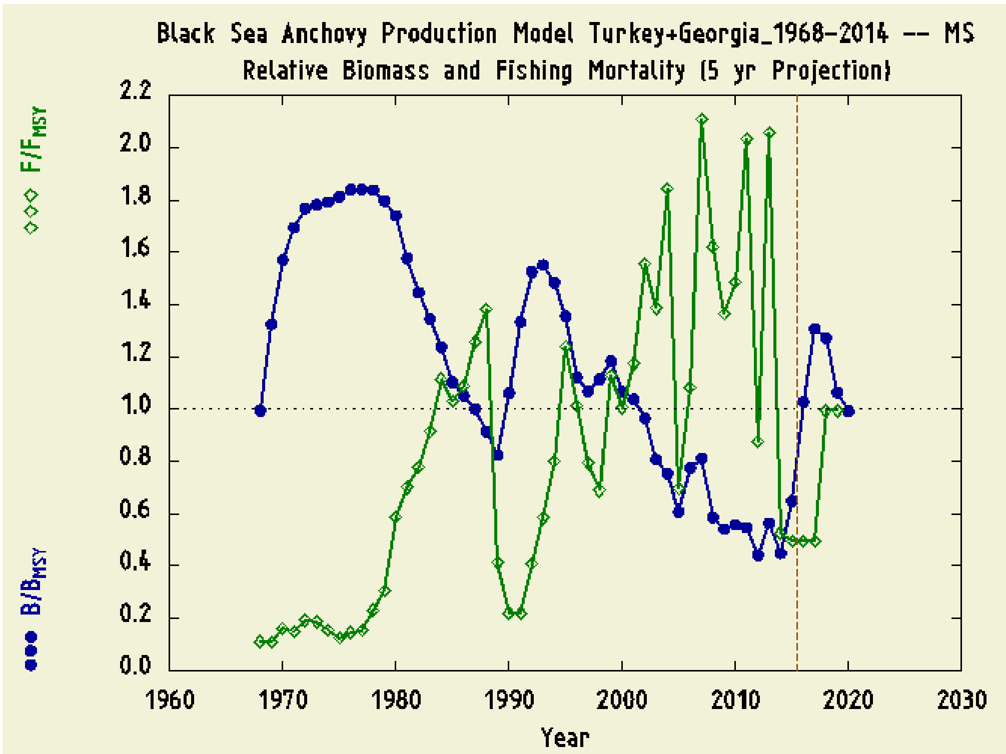
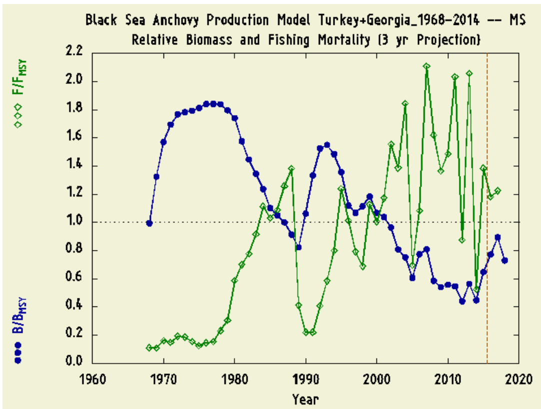


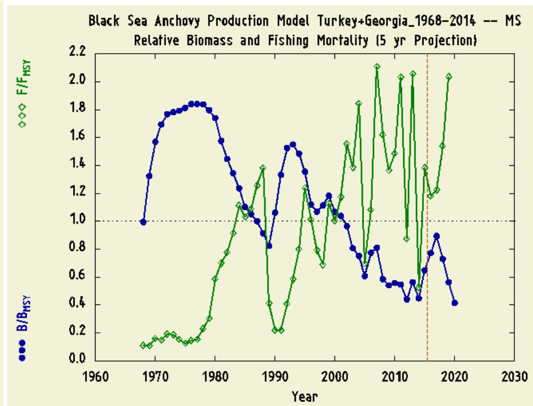
Figure 18: Medium term (5 years) scenario result with 3 years F_{REL} and 2 years F_{MSY}.

In Figure 18 the anchovy stock has been applied F_{REL} ($F_{current}$) for 3 years. It means effort that was applied to the stock in 2014 will have been applied for 3 more years and as it can be seen from the figure biomass rate of the stock will increase up to 30% higher than the targeted *MSY* value. But after that if the same stock will have been exposed F_{MSY}, which is two times of $F_{current}$, for 2 more years, biomass of the stock and the fishing mortality reach the *MSY* that is "244 thousand tons". This means *B* (biomass of the stock) will be equal to B_{MSY} (biomass of the stock that gives the maximum sustainable yield) that is "610 thousand tons" and *F* (fishing mortality that stock is exposed) will be equal to F_{MSY} (fishing mortality that stock should be exposed to give maximum sustainable yield) that is "0.4" means approximately "292 purse seine vessels".

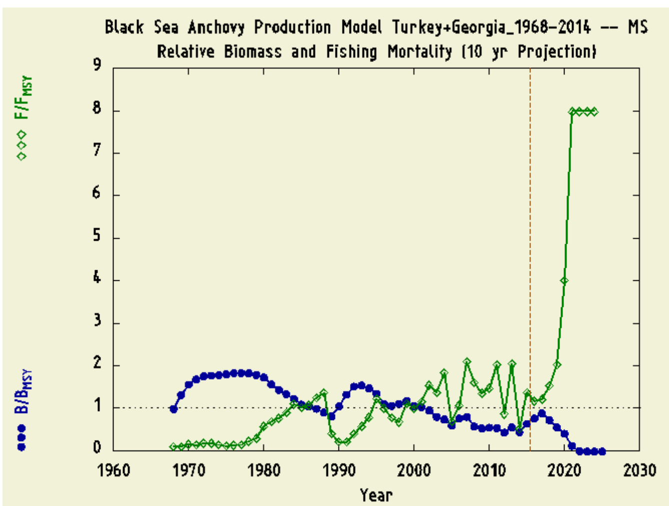
➢ <u>Short, medium and long term projections with the yield of *MSY*</u>



(a)



(b)

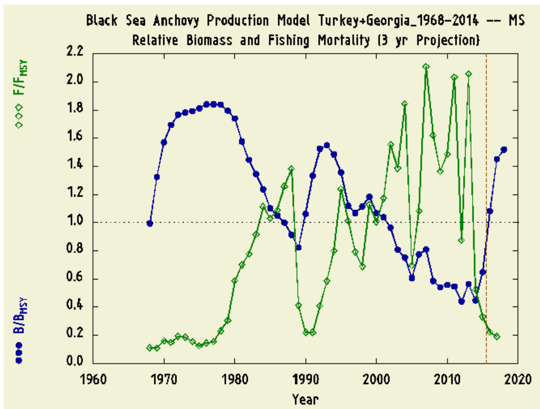


(c)

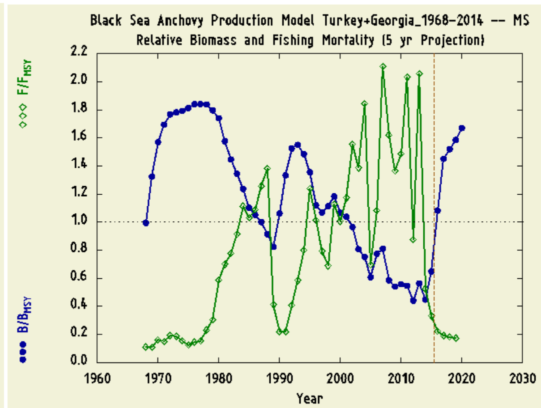
Figure 19: Short (a), medium (b) and long (c) term projections of the Black Sea anchovy stock that exposed catch at *MSY* level.

In Figure 19, it was projected that if stock is exploited at *MSY* level (244 thousand tons) in 3 following years, the biomass rate and fishing mortality rate of the stock will shift away from the target line. If it continues 2 more years than biomass rate and fishing mortality rate of the stock will shift away from the target line more dramatically. On tap of that if the *MSY* level catch continues 5 more years, after 10 years, the stock will inevitably collapse.

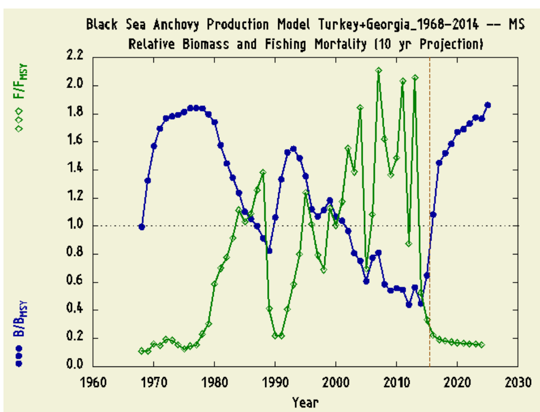
- <u>Short, medium and long term projections with the current yield of *YREL*</u>



(a)



(b)



(c)

Figure 20: Short (a), medium (b) and long (c) term projections of Black Sea anchovy stock that exposed catch at current level (*YREL*).

In Figure 20, it was projected that if stock is exploited at *YREL* level (71.5 thousand tons) in 3 following years, the biomass rate of the stock will increase a considerable extent and fishing mortality rate of the stock will decrease; both of them will shift away from the targeted *MSY* line. After 5 years, biomass rate will increase continuously and fishing mortality rate almost stabilized around 0.2 which is current fishing mortality. If the same catch amount continues up to 10 years, the biomass rate of the stock getting higher and higher and this means it will have been left too much fish in the stock, in other words surplus production situation will take place.

➢ <u>Projection with the quota application</u>

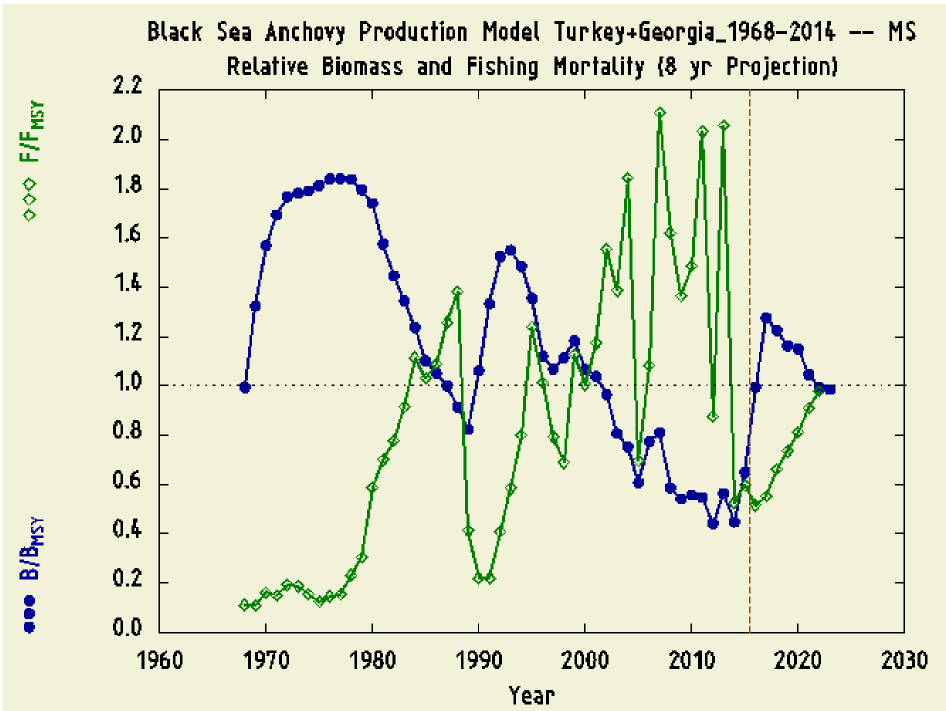


Figure 21: Projection of the stock with the quota of *MSY* by raising the catch gradually in 8 years.

If it is applied quota on the Black Sea anchovy catches of Turkey at calculated *MSY*; "240 thousand tons (to be in the safe side, quota has been determined 4 thousand tons less than real calculated *MSY* amount)" level of ASPIC, the result will be as Figure 21. To be reaching the quota, the biomass and fishing mortality rate of the stock should be in *MSY* level. That's why in this study, it is suggested that the catch should be raised gradually from current state to *MSY* and consequently quota level.

3.2. XSA (eXtended Survivor Analysis)

To be sure that whether we used Georgian data with Turkish data or not, may create any difference in the result while assessing the Turkish catch, it was applied ANOVA. It explained the statistical differences between the data set. According to ANOVA result there is no significant variance between the data sets of Turkish data with Turkish tuning, Turkish data with Turkish and Georgian tuning, Turkish and Georgian data with Turkish tuning and Turkish and Georgian data with Turkish and Georgian tuning that was shown in Table 24 and Figure 22.

Table 24: The results of the ANOVA

```
      year           fbar          test  
 Min.   :2005   Min.   :0.1280   F1:10  
 1st Qu.:2007   1st Qu.:0.5529   F2:10  
 Median :2010   Median :0.6449   F3:10  
 Mean   :2010   Mean   :0.6775   F4:10  
 3rd Qu.:2012   3rd Qu.:0.7532          
 Max.   :2014   Max.   :1.4099          

           Df Sum Sq Mean Sq F value Pr(>F)
year        1  0.093 0.09258   1.019  0.320
test        3  0.004 0.00137   0.015  0.997
Residuals  35  3.178 0.09081
```

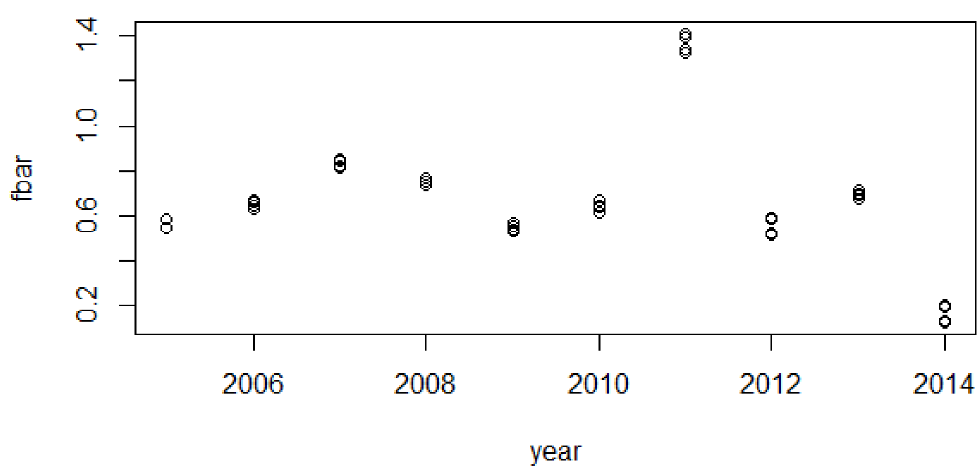


Figure 22: The fbar results of the four different possibilities of the Turkish data with Turkish tuning, Turkish data with Turkish and Georgian tuning, Turkish and Georgian data with Turkish tuning, Turkish and Georgian data with Turkish and Georgian tuning for the ANOVA test.

These results mean, it does not make any differences to use any of the possibilities. For this reason we decided to use Turkish and Georgian data with Turkish and Georgian tuning between the years of 2005 and 2014 to keep the data set larger. Since as the data set gets broader, XSA gives more reliable results.

Before beginning the analysis it can be a good idea to show the meaning some of the input data as in the Figure 23.

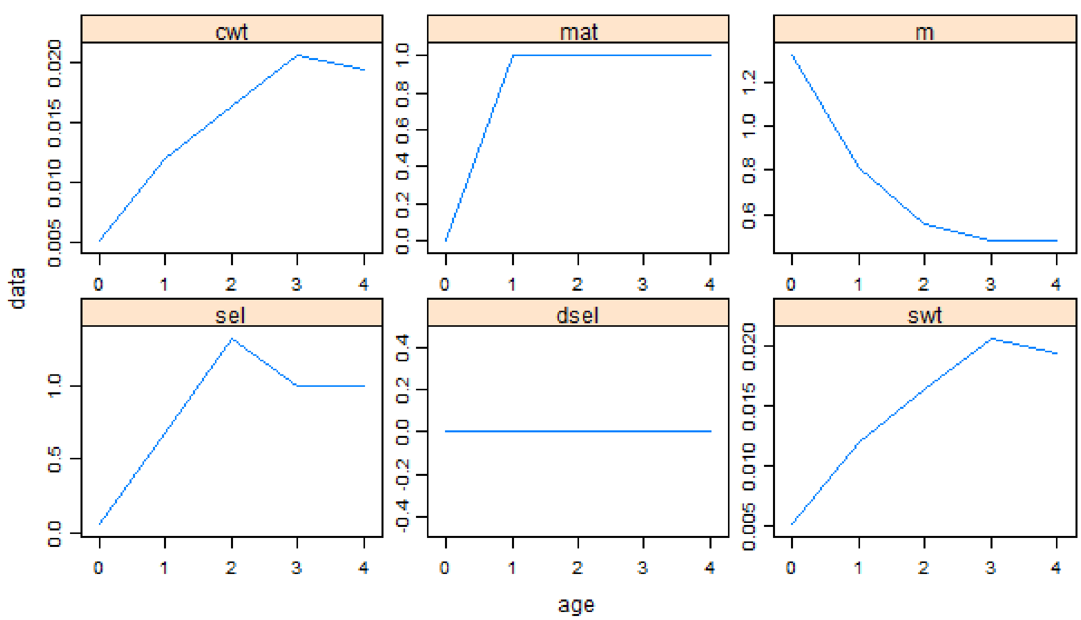
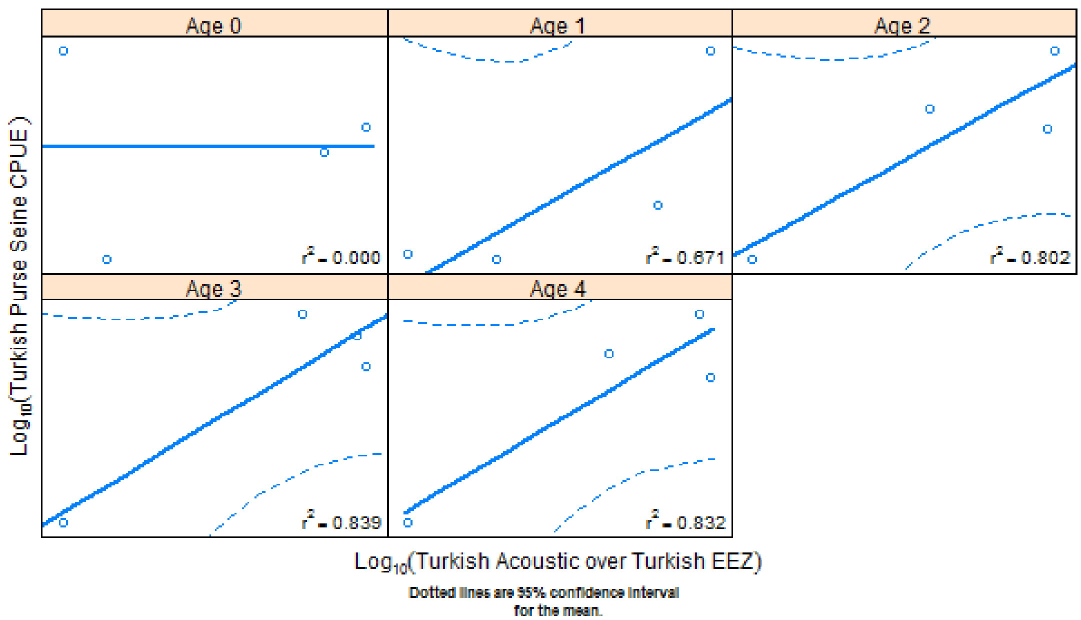


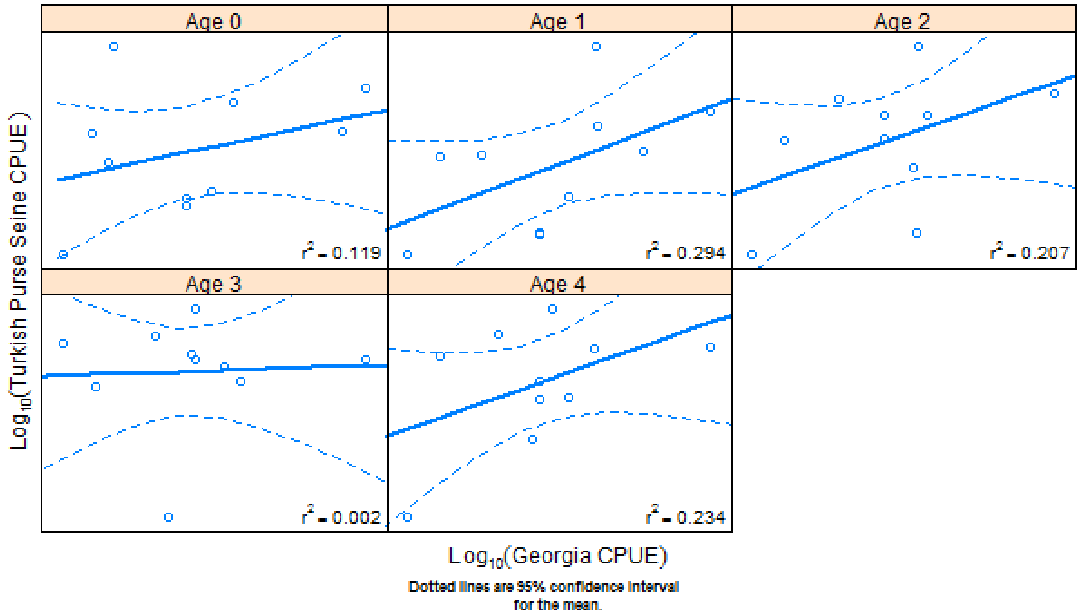
Figure 23: It is demonstrated average catch weight, maturity, natural mortality, selectivity in catch, selectivity in discards and average stock weight according to age.

According to Figure 23, the average catch and stock weight graphs increase like it is expected, because it is known that the weight of the catch increases as the age gets older, however after age 3 it is observed that the catch weight decreases. The sudden decrease can be explained as the age-4 group amount in the total catch is small and this effect the relative catch weight. On the sexual maturity graph it is observed that the value increases until anchovy reach the sexual maturity age which is “1”. After reaching sexual maturity the graph fixed. When we come to the natural mortality, it is higher at age-0 and decreases as the fish get older, as it is expected. On the other hand in the selectivity it is expected that the selectivity should be higher at age-1, since this age group is exposed higher fishing pressure, yet in XSA result age-2 has higher selectivity. Moreover; since in XSA it is assumed that there is no discards in catch, that's why catch and landing data are equal to each other in this assessment, the selectivity of discard is equal to zero.

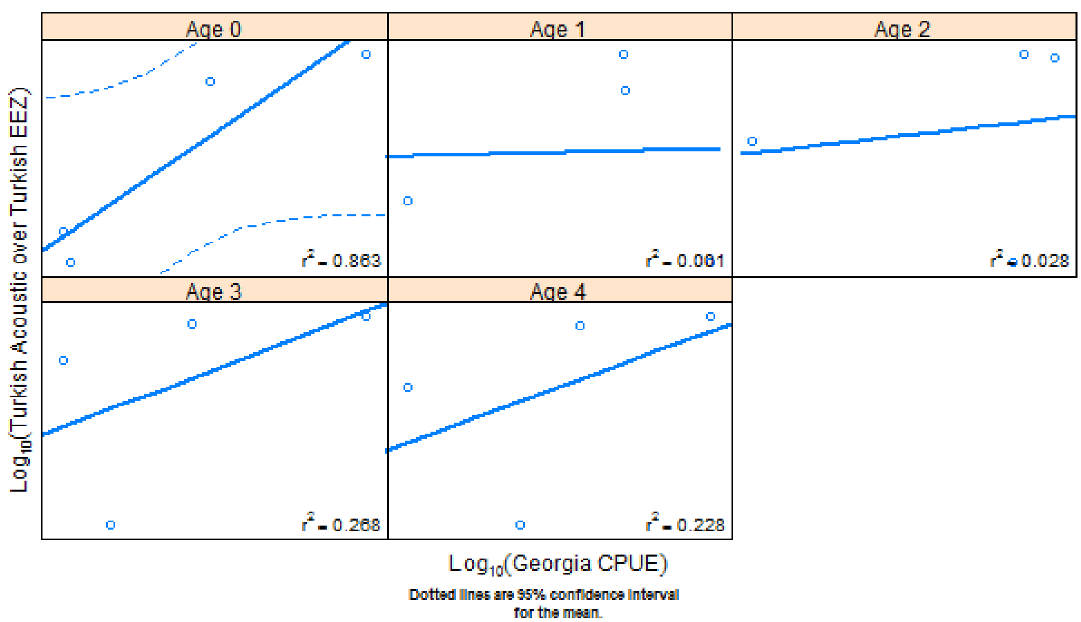
Comparison and internal consistencies between the estimated biomass over the Turkish and Georgian CPUE and acoustic survey over Turkish EZZ is demonstrated Figure 24 below.



(a)



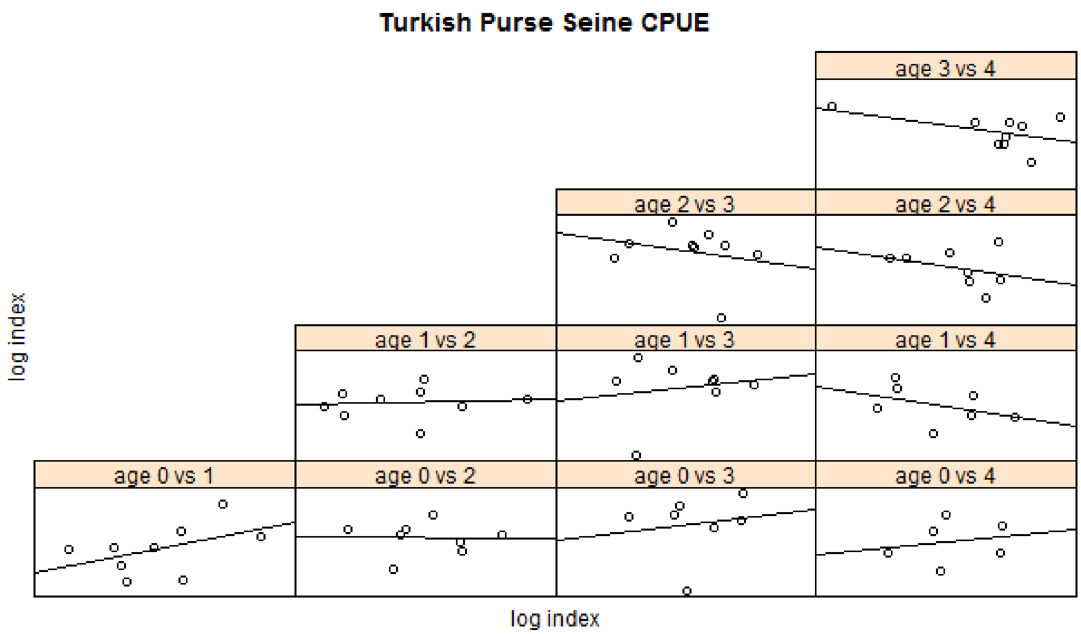
(b)



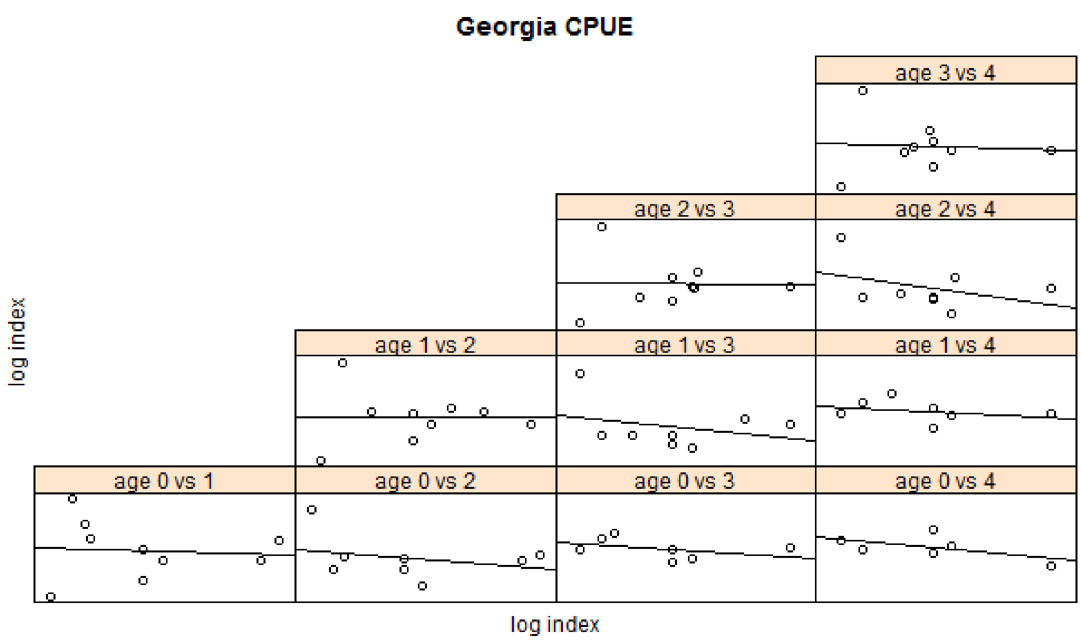
(c)

Figure 24: Results of the internal consistency between the tuning index in terms of age and with respect to each other; Turkish purse seine CPUE and Turkish acoustic over Turkish EZZ (a), Turkish purse seine CPUE and Georgian CPUE (b), Turkish acoustic over Turkish EZZ and Georgian CPUE (c)

The consistency results of CPUE and acoustic distributions are accepted as a normal between the groups according to age. Since, CPUE is used as an indicator of the total fish in the sea in most of the assessment models. That is why it is expected in XSA that if one slope of specific age in the consistency graph increases for one age, the other age should also increase, in terms of positive linear correlation between the age groups. Almost all graph in Figure 24 (a, b and c) has this positive linear correlation, so this gives confidence about the proper calculation of the fishing effort. But it is also known that variability and bias in the estimations can be seen in the results; because models can not include the environmental changes or con not estimate the errors while sampling. Therefore we can say that at least these types of consistency analysis can control the model itself and increase reliability of the estimation which done by the XSA.



(a)



(b)

Figure 25: Consistencies of survival rates by age with (a) Turkish purse seine CPUE, and (b) Georgian CPUE.

In Figure 25 (a, b) it is demonstrated that the consistency in survival rates by age. In it, each index is compared according to the calculated age of own. According to the results, the distributions between the groups were not normal. Since it is expected all distributions will show a positive linear correlation. However, in our results, most of the survival rate consistencies between ages showed negative correlation.

Residuals:

The residual analysis results have been shown in this section that is achieved by using different shrinkage factors as 0.5, 1.0, 1.5, and 2.0 (these factors are chosen by ICES, STECF and GFCM in XSA analysis after tested different values.) with fse=1.5 for testing the sensitivity of the model. Distribution of residuals, for each shrinkage, was calculated by least square technique.

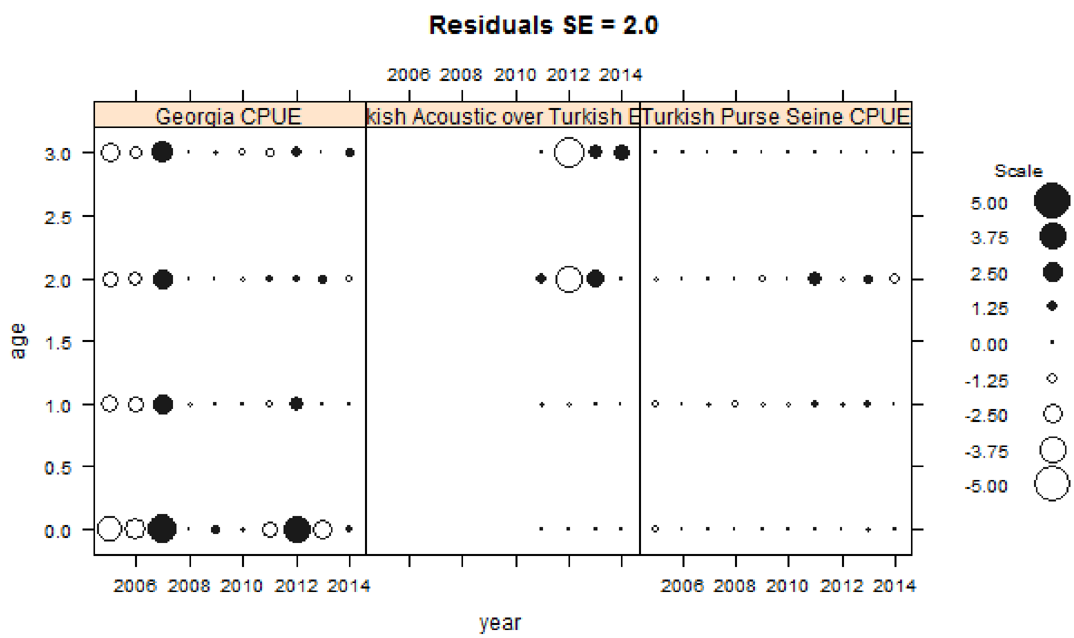


Figure 26: Residuals of the Tunings of Georgian CPUE, Turkish Acoustic over Turkish EEZ and Turkish Purse Seine CPUE with fse=1.5 and 2.0 shrinkage.

In Figure 26 it was shown the chosen residual results with fse=1.5 and 2.0 shrinkage. The residual shows the differences between observed biomass, calculated from CPUE, and calculated biomass, estimated by XSA. As the smaller the value of this differences, the model gives healthier results. According to our results the bigger scale of the value is 5.0 that has chosen among four different shrinkage factors and it shows the differences between observed and calculated values is small enough to give reliable results.

Retrospective Analysis:

In this assessment retrospective analysis was done for four different parameters as; recruitment, ssb (spawning stock biomass), catch (yield) 1and harvest (fishing effort) according to four different shrinkage factors by the removing of the data sequentially from the beginning of the most recent year to most previous year and this gap in the data was calculated by the model again. If the estimation of model is close to observed data then it can be said that the future estimation and the model itself is sensible enough to make estimation close to the real time. Although the best result was obtained in our retrospective analysis from the 2.0 shrinkage factor, the branching in the Figure 27 shows that the model cannot make estimations which close to the real values. Eventually, this result means, the future projections of the model will not be reliable.

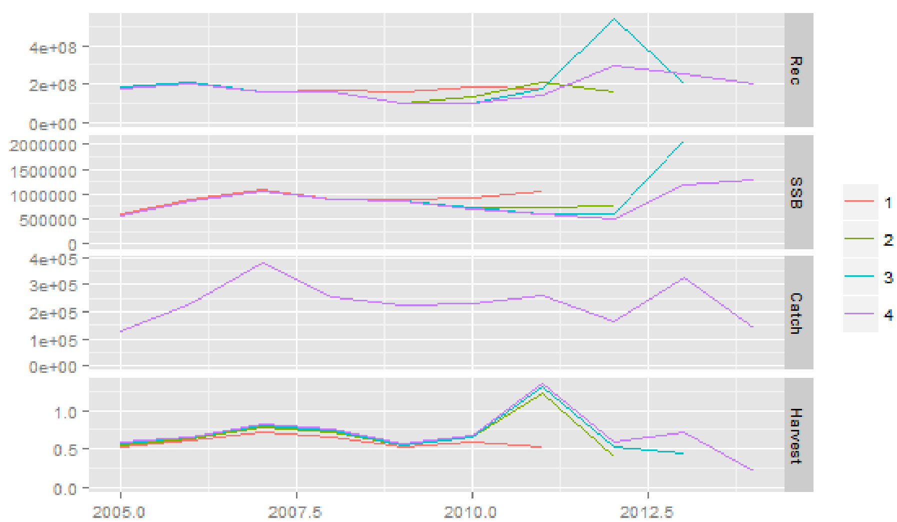
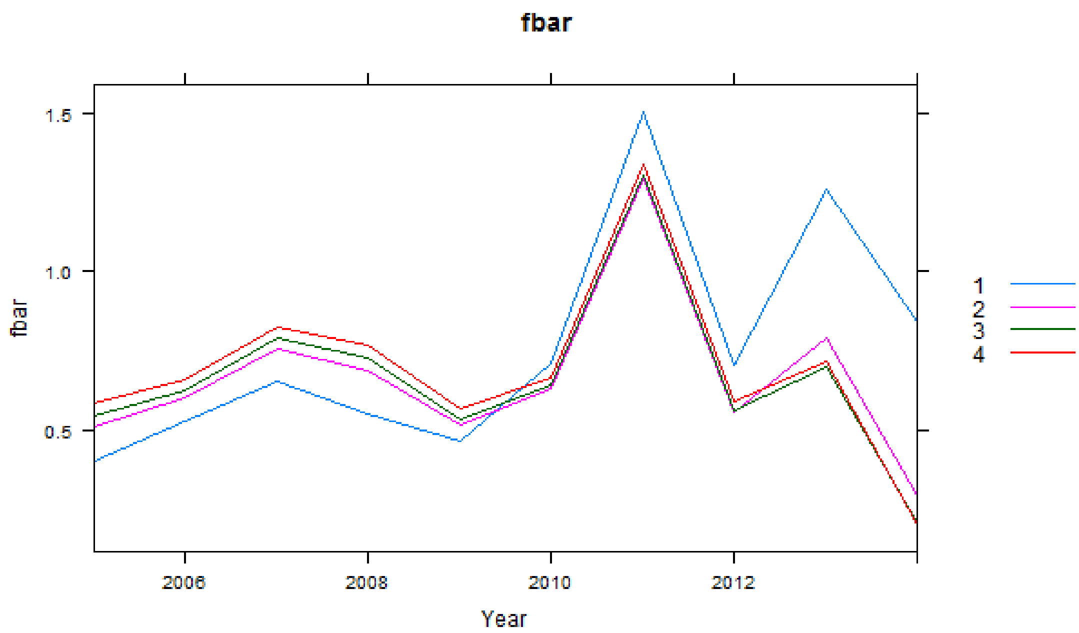
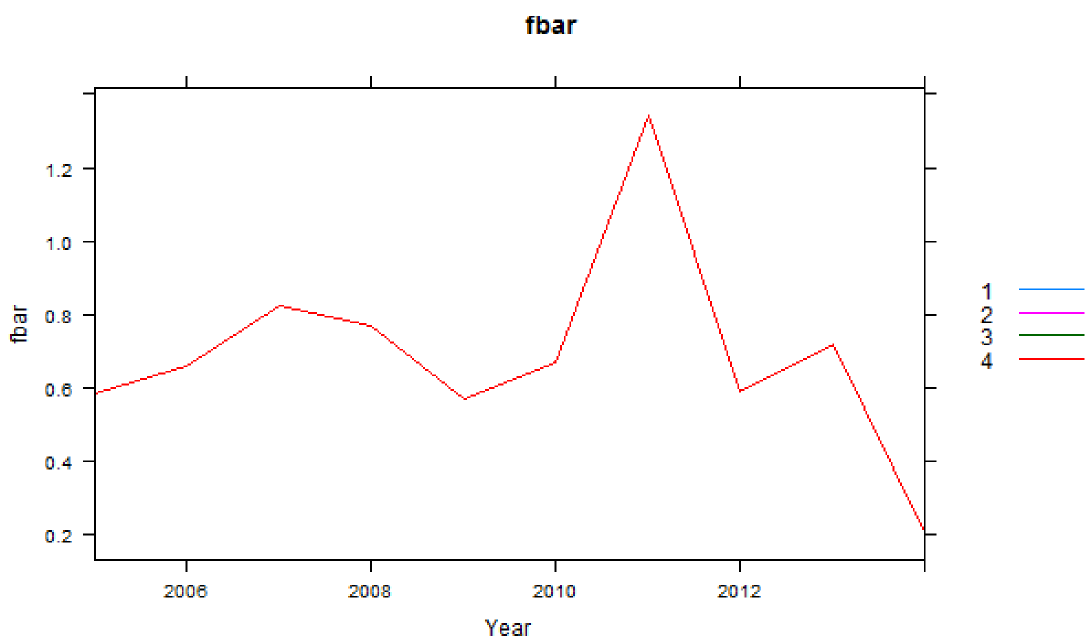


Figure 27: Retrospective analysis with four different shrinkage factors; 1, 2, 3 and 4 stands for 0.5, 1.0, 1.5 and 2.0 respectively.

The individual retrospective analysis results of “fbar”, “ssb” and “rec” were shown in Figure 28, Figure 29 and Figure 30.

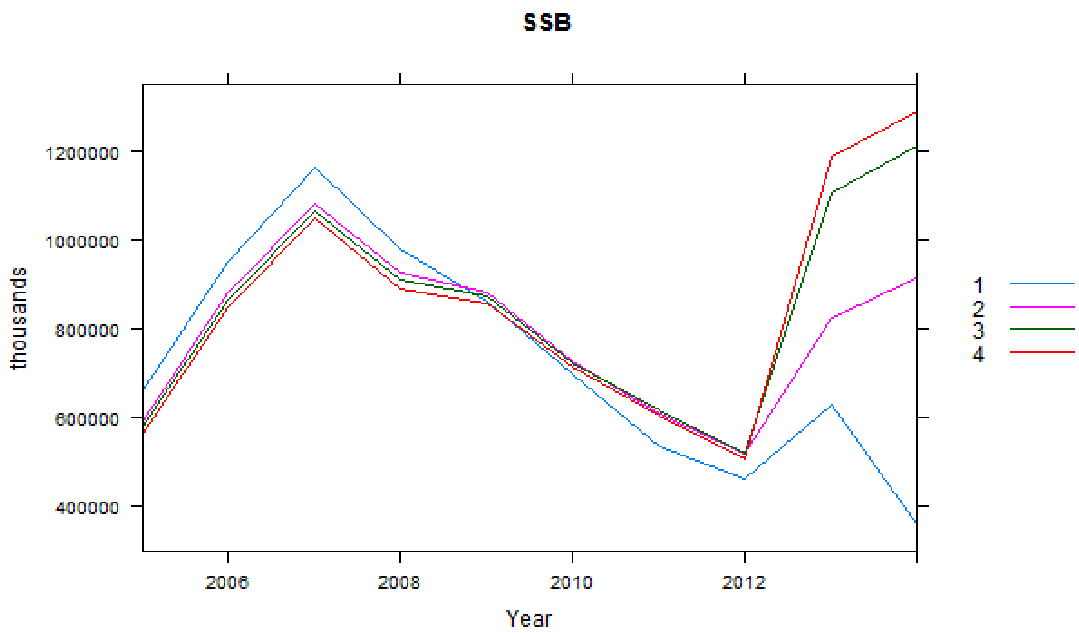


(a)

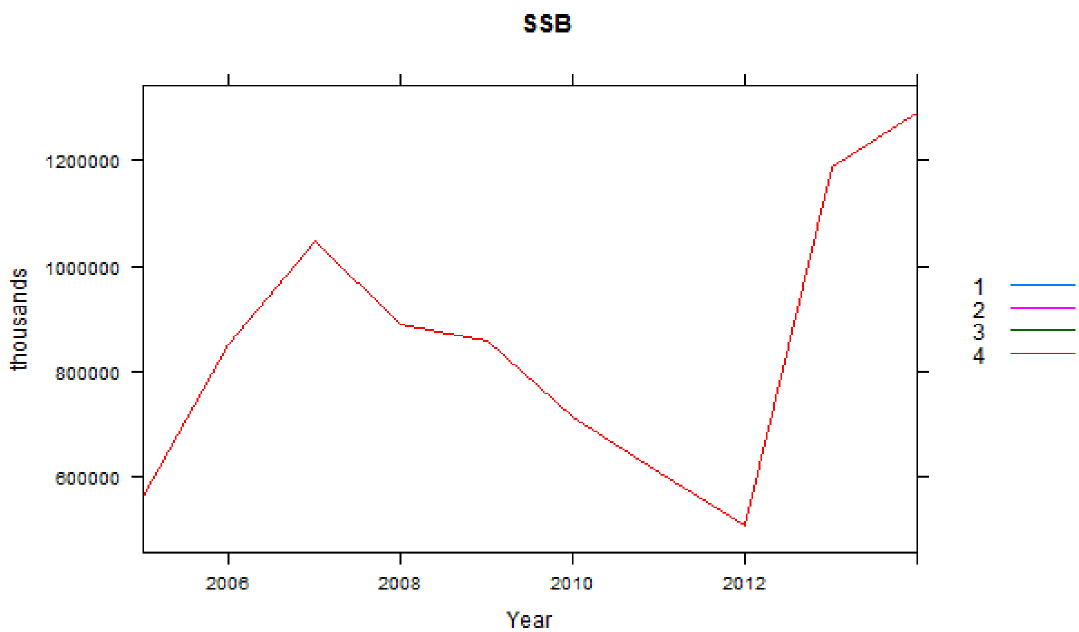


(b)

Figure 28: (a) XSA results: Fishing mortality (fbar) estimate by four different shrinkage of 0.5, 1.0, 1.5 and 2.0 with 1(blue), 2(pink), 3(green) and 4(red), respectively. (b)XSA results: Fishing mortality (fbar) estimate by 2.0 shrinkage factor with fse=1.5, between the years of 2005-2014.

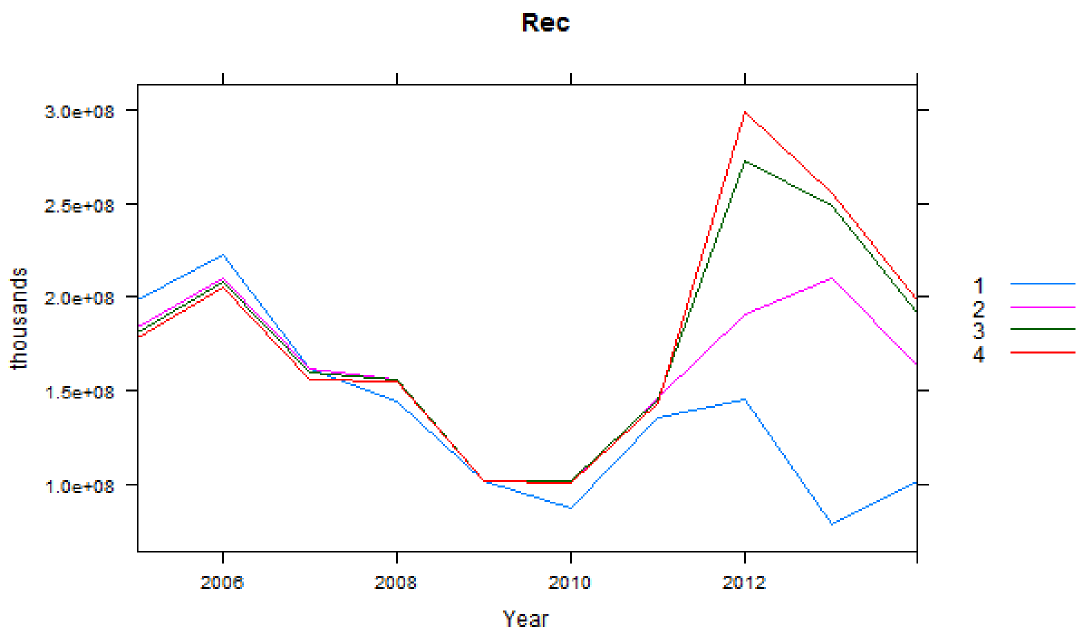


(a)

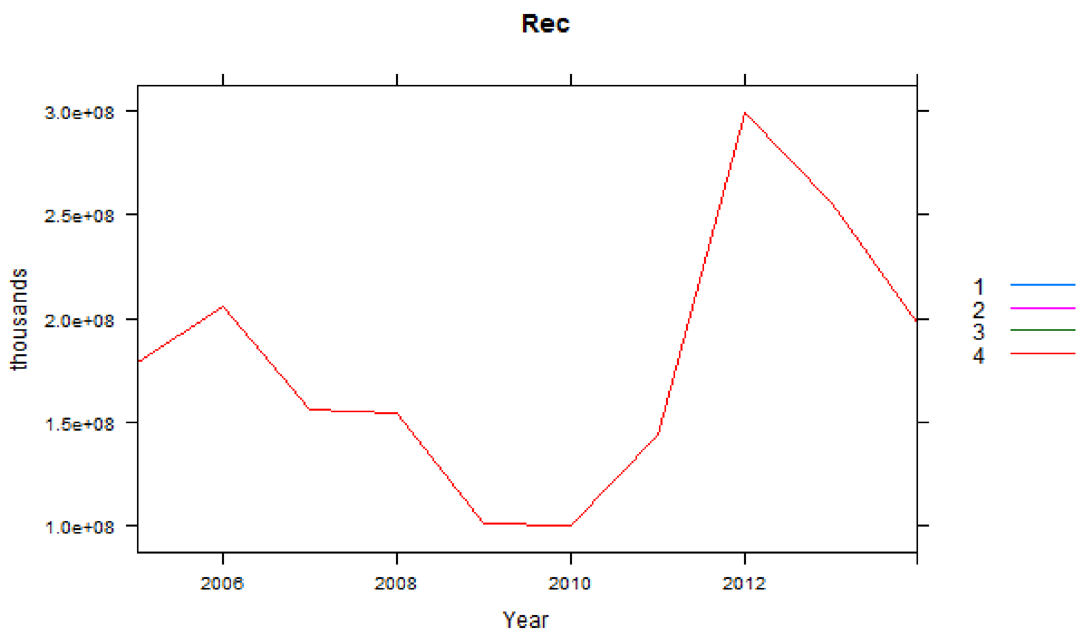


(b)

Figure 29: (a) XSA results: Spawning stock biomass (SSB) estimate by four different shrinkage of 0.5, 1.0, 1.5 and 2.0 with 1(blue), 2(pink), 3(green) and 4(red), respectively. (b) XSA result: Spawning stock biomass (SSB) estimate by 2.0 shrinkage factor with fse=1.5 between the years of 2005-2014.



(a)



(b)

Figure 30: (a) XSA results: Recruitment (rec) estimate by four different shrinkage of 0.5, 1.0, 1.5 and 2.0 with 1(blue), 2(pink), 3(green) and 4(red), respectively. (b) XSA result: Recruitment (rec) estimate by 2.0 shrinkage factor with fse=1.5 between the years of 2005-2014.

The overall results for XSA in terms of fbar, SSB, rec and harvest has demonstrated in Figure 31 and Table 25.

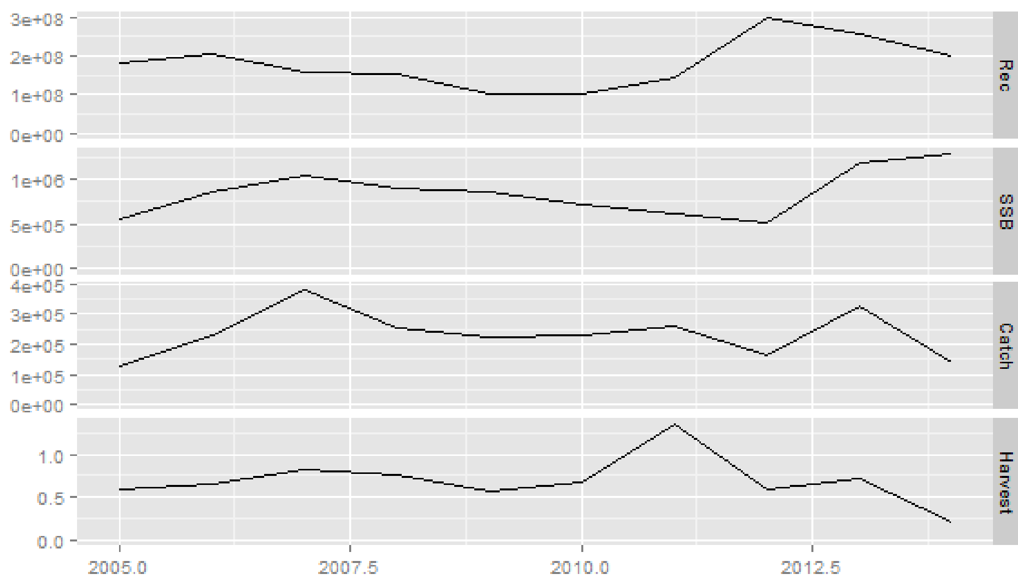


Figure 31: XSA results of Recruitment (rec), spawning stock biomass (SSB), Catch and fishing mortality (harvest).

Table 25: ssb, fbar, rec, catch and landings results of the XSA with respect to the years from 2005 to 2014

	ssb	fbar	rec	catch	landings
2005	562890	0.5838	178577148	128477	128477
2006	851419	0.6596	205425040	229527	229527
2007	1048113	0.82308	156309628	383061	383061
2008	889906	0.76783	154702960	256682	256682
2009	857361	0.56872	101528471	225463	225463
2010	714427	0.66648	100734559	228944	228944
2011	606447	1.34049	143673307	257396	257396
2012	508329	0.59022	298632655	165964	165964
2013	1187786	0.716	255475557	326104	326104
2014	1289349	0.20552	198127939	137530	137530

In Figure 28 (a) it shows the fishing mortality calculations with four different shrinkages. The best results were taken with shrinkage 2.0 that demonstrated in (b) in which the change in fishing mortality pressure on stock is seen. According to the results the peaks in fishing mortality is observed in the years of 2007, 2008, 2011 and 2013. Yet, the highest value is observed in 2011 where the f_{2011} was equal to 1.34.The fishing mortality rate shows an increasing trend up until the 2011. After this year the fishing mortality rates decrease visibly. The lowest values were observed in years of 2009, 2012 and 2014. It is a remarkable result that the lowest value of fishing mortality that observed in 2012 was recorded right after the 2011's highest value. Also, gradual decline of the fishing mortality pressure after 2011 on the Black Sea anchovy stock is a reflection of success of the precautions that taken by the fishery managers in Turkey in 2011.

According to Figure 29, spawning stock biomass (SSB) has three major picks in 2007, 2013 and 2014 among the 10 years of assessment. After the increasing period until 2007, gradual decline was observed until 2012. It is expected because in these years fishing mortality was relatively high. SSB also gives idea about the stock itself. Therefore it can be said that in 2005-2007 stock biomass was increased until 2007, after 2007 stock was getting smaller gradually until 2012 which is the lowest value that the Black Sea anchovy stock has among ten years of 2005-2014. After 2012 stock started to recover and biomass was getting increase and reaches its higher value among the last ten years in 2014 with the decreasing fishing mortality.

In Figure 30, recruitment (Rec) fluctuations can be observed with four different shrinkages in (a), the best results were taken in 2.0 shrinkage factor which is demonstrated in (b). According to these results recruitment amount of the Black Sea anchovy declined from 2005 to 2010. After 2010, it started to increase again until 2012 which is the year that the highest level of recruit enter to the stock with consequence of this increase the SSB is increase as a matter of course. The lowest level of the recruit of the Black Sea anchovy stock was observed in 2010 and as a result of this decrease, the SSB of the next years drop dramatically.

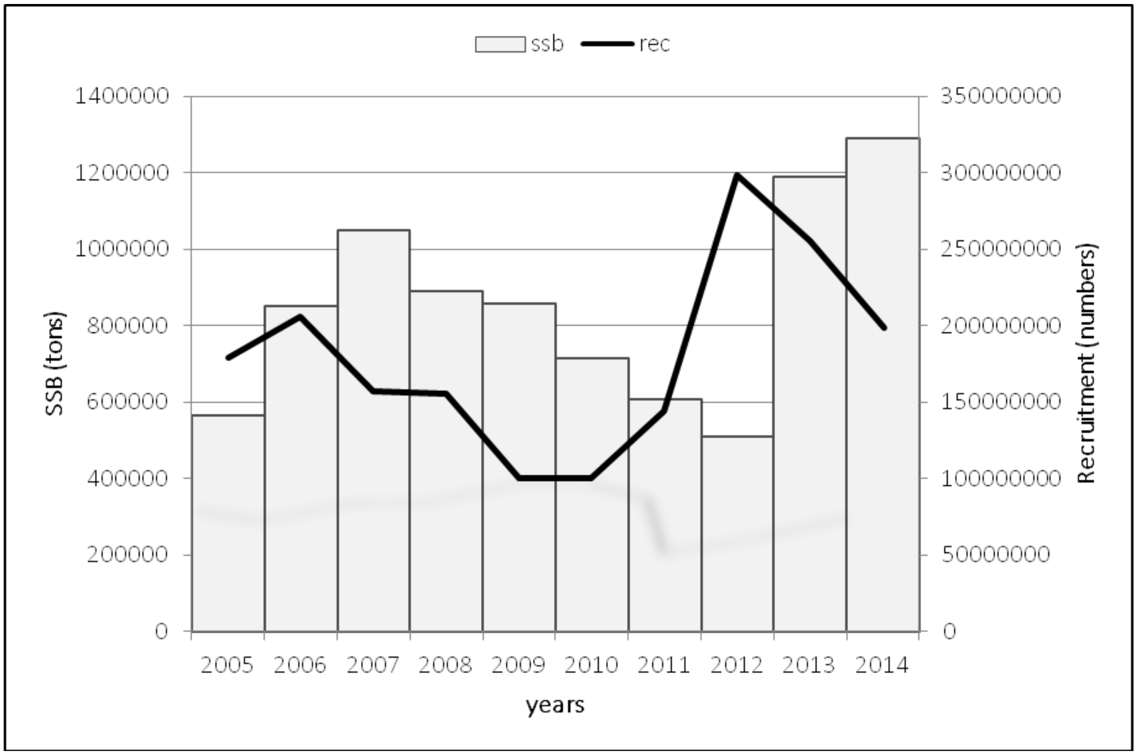


Figure 32: the recruitment (rec) and spawning stock biomass (ssb) results of XSA between the years of 2005 and 2014.

The recruitment effects the next years' SSB amounts since this year's recruitment will be the spawning stock of the next year. It can be observed from the Figure 32. In every peak of the recruitment as 2006 and 2012 caused increase of the next year's spawning stock biomass as the following years of the 2006 and 2012. However in the reverse condition it is not the case that means not every increase and/or peaks give rise in the recruitment amount of the next years. Like in the Figure 32, the increase of SSB in 2007 was not resulted the rise in recruitment level in the following years. It is also same in the years of 2013 and 2014, although the SSB is in their higher level, the gradual decline in recruitment was observed.

After XSA model analysis it is not found any relation between stock and recruitment that is why it cannot be taken proper results in biological reference points as *MSY*, B_{MSY}, etc. Therefore Patterson's (1992) precautionary exploitation rate of E=0.4 is used to evaluate the status of the stock. Model gives fishing mortality estimations. By using fishing mortality (f), natural mortality (M) and exploitation rate

(E) we can estimate the current situation of the stock whether it is overfished and in sustainable level or not. The biological reference points that calculated by XSA are not realistic and very high. Therefore we took the $F_{current}$ as the average of the terminal four years; $\mathbf{F_{[1:4;2011:2014]} = 0.71}$ and $\mathbf{E_{target}=0.4}$.

To calculate F and E values the formula of $E = \frac{F}{Z} = \frac{F}{F+M}$ was used.

For $\mathbf{E_{current}}$;

$\mathbf{F_{current} = 0.71}$ (average of terminal four years)

M = 0.73 (average of all ages)

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

From this $\mathbf{E_{current}= 0.5}$

Table 26: Biological reference points of $F_{current}$, $E_{current}$, E_{target} and $F_{0.1}$ (F_{MEY}) from the 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**

According to these results, current exploitation rate is higher than the target exploitation rate. This indicates that the Black Sea anchovy exposes to low overfishing.

Projections:

According to the model estimation $F_{0.1}$ =0.9. This value is higher than the reality. Although the branching in retrospective analysis prove that the future predictions of XSA, the three years projection results are shown in Figure 33 with fishing mortalities of "F_{target}, $F_{current}$ and $F_{no\text{-}fishing}$" . Since no relation has been found between stock and recruitment, model cannot make any prediction about the recruitment. However the SSB would decrease dramatically in there years with this fishing mortality levels. And consequently catch would decline in following three years.

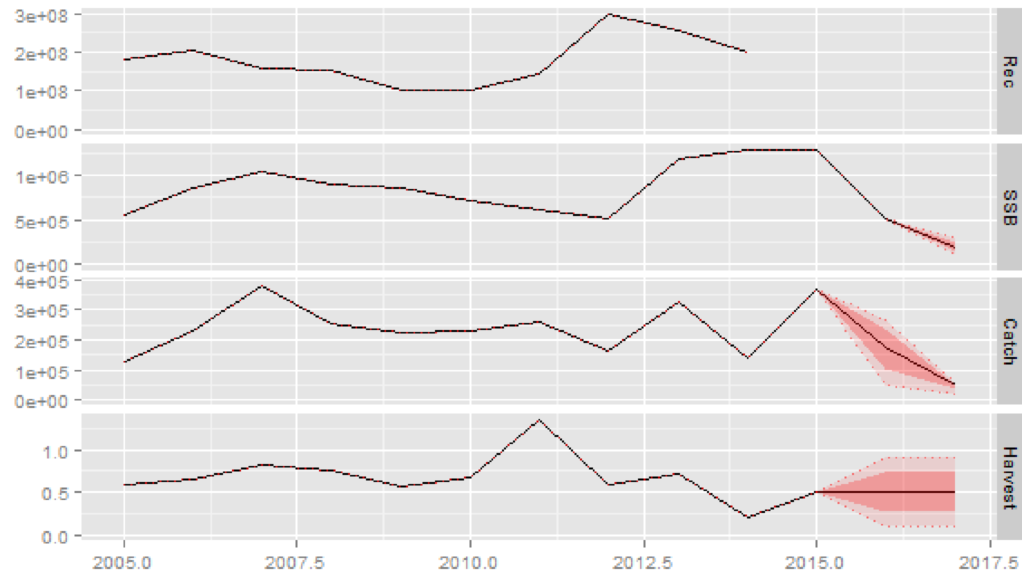


Figure 33: Three years (2015-2017) projections of the Black Sea anchovy stock with the F0.1 fishing mortality level.

3.3. Comparative Results of ASPIC and XSA

To compare the results of two models it was used fishing mortality rates in this study, since the common output for these two models is only "f". The other outputs are different in terms of unit patterns. For instance the estimated biomass output of ASPIC do not find any response in XSA, by reason of, in XSA the biomass output has been given in terms of spawning stock biomass. That is why these two parameters are not comparable. According to only comparable parameter of fishing mortality rate that shown in Figure 34, ASPIC and XSA has uniformity. To prove this concordance, t-test was applied to these two models' fishing mortality rate results. The p-value of t- test was equal to "0.26<0.5". From this it can be said that the differences between these two fishing mortality rates of ASPIC and XSA is not significant.

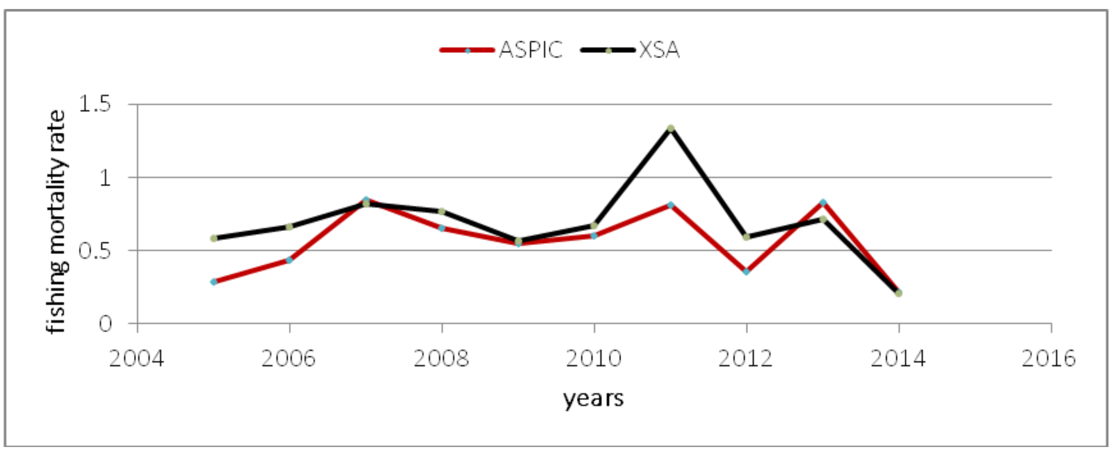


Figure 34: Distribution of fishing mortality rates of ASPIC and XSA.

4. DISCUSSION

4.1. The Past Catch and Effort Data of the Black Sea Anchovy

Black Sea anchovy is ecologically and economically the most important fish species and an irreplaceable food source for the Black Sea riparian countries. Therefore the studies about the anchovy, stock situation and the management of this precious source have very significant value. The stock assessment of the Black Sea anchovy have been done since very long time by some scientists; Ivanov and Beverton (1985), Prodanov (1997; 1998; 2001), Daskalov (1997; 1998; 2011), Bingel (1989), Chashchin (1996, 2015 and recently by the regional fisheries managements commissions such as; STECF (2011; 2012; 2013; 2014) and GFCM (2012; 2013; 2014).

The anchovy stock studies in Turkey started with Pektas (Expedition) in 1953, then in 1972 with the UNDP/FAO project. The following one is conducted in 1989 by Bingel from METU-IMS. The latest study was held from 2011 to 2015 by Gucu under the national project of "*Assessment of Black Sea Anchovy Using Acoustic Method and Establishing a Monitoring Model for National Fisheries Data Collection Program"*.

The observed data shows that the total biomass of anchovy changed remarkably between the years of 1968-2014 (Figure 14). Between 1968 and 1980s the total catch profile of Turkey increased dramatically with increasing number of vessels and fishing power (Figure 35). Therefore, within the time period between 1968 and 2014, the maximum catch is observed "318 917 tons in 1984". The number of vessels increased significantly until 1990s due to the fishery development strategy of Turkey (Duzgunes and Erdogan, 2008), the catch dropped dramatically before 1990s. There are many hypothesis suggested by scientist on this collapse. According to Kideys (1994), the sharp decrease of anchovy catch is due to the invasive species of *Mnemiopsis leidy* that compete with anchovy in terms of niche, food source and it is also a predator of the anchovy eggs. Yet, according to Gucu (1997) the reason of this collapse is due to overfishing of the anchovy stock with the increasing power of the individual vessels with their sonar system, engine power etc. On the other hands, Oguz et al. (2008) suggested that the reason of the decrease in anchovy catch not only excessive fishing, over-eutrophication and invasion by alien species events but also variability in the regional climate indices, i.e., North Atlantic Oscillation. However, the reason behind the anchovy collapse still remains unknown. Until 2004 the catch fluctuated between “373 782 tons” and “195 996 tons” with the fluctuated effort that decreased sharply after 1990. In 2005 the anchovy catch drop the lowest value (128 477tons) of the last years. In the same year bonito (*Sarda sarda*) gave its maximum catch “over 70 000 tons” (Ulman et al., 2013). This may be linked to that the high amount of bonito increase the predation pressure over the anchovy and decrease in catch was observed, indispensably. After 2005 stock started to recover itself, although effort increases dramatically and reached its maximum number of 589 vessels in 2008. However, this increase in effort seems to create overfishing on the anchovy stock. The results of the overfishing also showed itself by the decrease in the catch per unit effort in whole Black Sea countries catches.

Although Black Sea anchovy’s reproduction and feeding takes place at the North-western Shelf nursery area, then they exhibit an overwintering migration and hibernate at the southeastern coastal waters of the Black Sea (Ivanov and Beverton, 1985; Chashchin, 1996; Shulman, 2002). As they go from one end of the basin to the other, their aggregations are exposed to exploitation by all Black Sea countries at varying levels. Therefore, the stock assessment studies conducted in the area almost always rely on the data gathered from all Black Sea countries. This approach may be seen advantageous because the concept of stock unit is, so that, not violates; however the differences in the length and age composition of the catch are disregarded. However comparative studies clearly showed that these geographical differences may be critically important (Ozdamar et al., 1994) and therefore may have significant impact on the assessments.

In the present study to reduce the uncertainty only the data from Turkish fleet which essentially exploits the fish in the Turkish and Georgian waters through bilateral agreement between the countries, is used for the assessment of the stock status. The approach in essence relies of Gulland's (1969; 1983) "stock" definition stating that for operational purposes and for practicality a part of a population "can be managed as an independent unit if the results of assessment and the impact of management measures do not differ significantly from what they would be in the case of a truly independent stock". It may also worth to note that Turkey and Georgia are the two countries that fish the overwintering anchovies and taking up the more than 90% of the total anchovy catch of the whole Black Sea (Figure 35) (particularly after collapse of the Soviet Union). Also as stated by Castilla-Espino et al. (2014) the contribution on Georgian national fleet is negligible when compared with fishing capacity of the Turkish purse seines. Moreover, it is generally agreed that Russia exploits only Azov anchovy, which can safely be considered as another stock (Sampson et al., 2013).

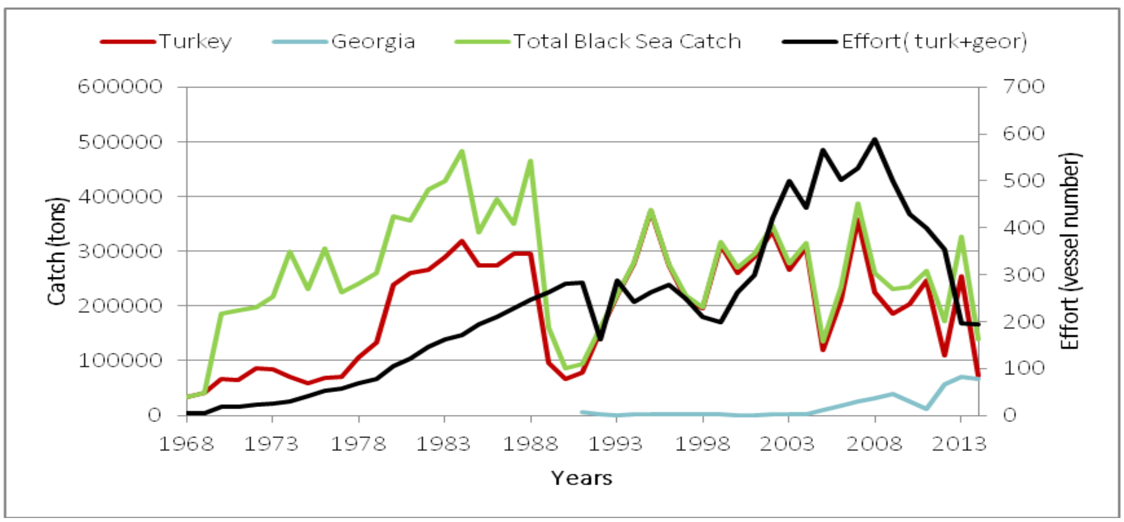


Figure 35: Total catch comparison of Turkey, Georgia and whole Black Sea countries with the effort of whole Black Sea countries.

The main aim of this study arises from this point of view. To achieve this goal two different models; ASPIC (A Stock-Production Model Incorporating Covariates) and XSA (eXtended Survivors Analysis) are used to assess the same stock with two different approaches and examine the conformity of these holistic and analytical models, respectively. These models have been chosen because they are most widely used models in stock assessment and to make easy the comparison of the results with previous studies by ensuring the continuity.

4.2. Holistic Approach

In holistic approach it is needed catch and effort data to run the model. It is used landing data as a catch data by assuming there is no discard. As an effort data it is used vessel number. Because it is assumed that in every operation the catchability is same. In other words, for every operation the amount of fish that is caught by a big purse seine is not different than the amount of fish that caught by the small purse seine from any particular fish school. In the Black Sea Anchovy TUBITAK KAMAG 110G124 Project report, it is analyzed the relation between length and engine power of a vessel with the daily catch of this vessel then it is found that as the length and engine power of a vessel increase, the daily catch does not change. Since there is no relation has been found between the catch and length and engine power of a vessel, in current study vessel number used as an effort.

The findings indicate that both the models, holistic one ASPIC and analytical one XSA, are confirming each other in terms of estimates of some biological reference points and the current situation of the stock. Although both need different parameters to analyze the stock, the comparable results show that the estimations are reliable and compatible with each other.

First model output is that Black Sea anchovy stock is exposed to “low overfishing” according to the stock status classification proposed by GFCM (Figure 5). Meaning that the stock condition is not critical. However, it needs to be improved if the management goal is to achieve maximum sustainable level in the harvest. On the other hand projections (Figure 18 and Figure 21) suggests that, if the current fishing effort can be kept as it was in 2015, the Black Sea anchovy stock can recover itself within 5-8 years time, unless climatic and/or any other environmental factors play exerts and adverse conditions.

According to calculation results of ASPIC between the years of 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 maximum level of “1,154,000 tons”. However, this value is conflicting with the estimations by Ivanov and Beverton (1985), “1,500,000 tons”. It is an expected result since the assessment done in this study uses only Turkish data and in the contrast in Ivanov and Beverton (1985) ‘s used the data from all Black Sea countries.

The reason of the gradual biomass increase observed from 1968 to 1977 look unrealistic at first sight as this would necessitate a gradual increase in the carrying capacity of the ecosystem for this species. However, according to Gucu (1997) the same period characterize the transition phase of the Turkish fishery at which use of advanced fisheries technologies, such acoustic devices, power-blocks etc., in the purse seines first came into the scene. This, in the short run, has increased the fishing pressure on the economically most sought large pelagic fishes, such as *Sarda sarda* and *Pomatomus saltatrix*. Given that large pelagic fish in the Black Sea preys upon anchovy, a decline in the biomass of upper trophic level might have possibly reduce the predation mortality on the anchovy and hence their carrying capacity has been leveled up to a higher level. It may also be postulated that eutrophication which has been first recognized in the Black Sea at the same period could have positive effect on the increase of anchovy biomass. Although eutrophication has adverse effects on the ecosystems, a proliferation at the lower trophic levels of an ecosystem may be advantageous for the planktivorous small pelagic fish like anchovy. Therefore both, decrease in the predator pressure and increase in the lower trophic levels through increased nutrient flow could possibly create a good environmental condition for the anchovy (Daskalov, 2003). Similarly according to Zaitsev (1992), the eutrophication of Black Sea is due to the land-based pollution with human effect, and this situation has triggered the evolution of the Black Sea fisheries by increasing the carrying capacity of the system. Small pelagic fishes have occupied the 35 % of the total catch of the system between the years of 1930s-1950s. After these years, small pelagic fish stock amount has increased dramatically and large pelagic stocks decrease in an opposite manner until 1980s. Towards the end of 1980s, 75-80% of the Black Sea catch composed of small pelagic fishes. This increase is essentially very identical to the one captured by ASPIC biomass rate presented in Figure 14.

Following the collapse, the stock surprisingly started to recover although the fishing effort kept its increasing trend. However, the catch could not keep up with its 1970s-80s level. With respect to the estimation of ASPIC; in 1994 the carrying capacity reached its maximum of "946 200 tons" within the last two decades. According to Prodanov et al. (1997) anchovy is a short-lived species, the stock gives response to any environmental or fishing pressure change in a short time. This may explain what might possibly happen in 1993-1994 when an increase of the biomass has been experienced. With the collapse of the USSR, and with the loss of one of the major fleets thereafter, fishing effort should have been decreased drastically. Also, following the period when Georgian regained their sovereignty, the USSR fishing fleet abandoned one of the main fishing grounds . That could be another factor possibly giving a chance for the anchovy stock to further recover. Although in 1993-1994 has also unfavorable environmental conditions, as the higher Mnemiopsis biomass, diminishing in fishing pressure is beneficial factor for the stock recovery in 1994 (Prodanov et al., 1997). After 1994 stock biomass started to decrease again. But this time, according to ASPIC results it was due to the overexploitation of the stock. During the same period increase in the effort both in number of vessels and use of fisheries technologies, mainly by sonars and fish pupms are noteworthy (Gucu, 2002). After 1994 increase, the stock biomass decreases gradually until 2011-2012 period. In 2002-2003 periods biomass rate fell below the estimated *MSY* level. After this time stock biomass has never reached to the targeted level. This is mostly due to the high fishing effort and consequently due to the over-exploitation of the stock.

The diagnostics of stock assessment made in 2011 and 2012 by STECF for all the Black Sea countries points to overexploitation and the quota (Total Allowable Catch -TAC)proposed was 200 000 tons in 2011 (Daskalov, 2011) and 141 616 tons (Osio, 2012) in 2012. On the contrary; in 2011-2012 fishing season the fishing mortality rate increase from 0.62 to 1.3. That is why the next season of 2012-2012 the TAC decreased to the level of 41% and it was suggested that TAC would be 141.616 tons. According to Gucu (2013), these quotas were not a useful strategic plan because in 2013 analysis the stock- recruitment relation was not correct as exceptionally high discard rate[1] to be not taken into consideration and consequently any future projections included quota and effort suggestion would have been unrealistic. Since STECF recommendations are not binding for the majority of the Black Sea states it has not been enforced (Sampson, 2013). Although TAC is not enforced some other effort based precautions have been taken by the Turkish government. These includes (i) restricting anchovy fishing to night hours only (16:00 to 08:00) and to winter months (15 September-March) since 2007; (ii) setting a depth limit (0-24 m) for purse seining in 2011; and (iii) a vessel buy-back program launched in 2012. The only country applying a catch quota to anchovy is Georgia (institutionally 60k tons, then it was increased to 80k tons and then to 85k tons) (Castilla-Espino et al., 2014). Also the minimum landing size is another precaution that have been taken by the Black Sea countries and it varies from country to country; with the largest in Bulgaria, Romania, and Turkey (9 cm total length) and the lowest in Georgia (7 cm, TL). The countries Turkey and Georgian assessment precautions are very important because anchovy hibernate in these countries' EEZs. After these measures are enforced s a slight increase in biomass of the Black Sea anchovy stock in recent years could be observed (Figure 14).

When fishing effort is considered, Black Sea fishing effort, ("0.07") was well below the targeted level until end of the 1970s. It was 83% lower than the estimated F_{MSY} rate of "0.4". From Figure 14, after 1978 number of vessels used in anchovy fishery has increased the high CPUE attracted more fishermen to invest on new boats and technologies and consequently the fishing effort has increased so much that very soon it leaped over with 25% higher of the targeted level. After that gradual increase in 1989 fishing effort decreased suddenly with the decrease of biomass rate of the anchovy due to *Mnemiopsis leidy* (Kıdeys, 1994), overfishing (Gucu, 1997) or climatic variability (Oguz, 2008), as it has been explained above. It can be concluded that, this increase in effort was exposed high fishing pressure and created weakness by decreasing the stock biomass which blocked the protection of the niche of

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[1] Due to dominance of 0-year class in the stock fleet extensively used grids to sort out undersized anchovies during 2012-13 fishing season.

anchovy from the *Mnemiopsis leidy* with the cascading effect of the regime shift. That's why one should not think about the only reason is *Mnemiopsis leidy* or overfishing or regime shift itself, they all seem to be interconnected events. Until 1991, fishing mortality rate continued to decrease and reached "0.08" which was 80% lower than the F_{MSY}. Moreover, the collapse of the Soviet Union in 1991 can be shown as the other important reason of sharp decline of the effort in 1990-1991 periods (Prodanov et al., 1997). However after 1991, fishing effort increased gradually and reached over the target in 1995 and started to decrease with the decreasing of CPUE until 1998 (Figure 14). In 1999 it increased and passed target again and increase gradually by making fluctuations until period when the above mentioned effort reduction measures were enforced in Turkey. Within these time interval only in 2005 the effort showed sharp decline due to the bonito increase (Castilla-Espino et al., 2014). It is thought that the increase in Bonito in this year take more attention of fishermen than the anchovy due to the higher economical value of bonito. Beside the economical reason bonito predation decreased the anchovy stock biomass. That is why the fishing pressure on anchovy might have been directed to the bonito. These results are mostly well fit to the previous work done on Black Sea anchovy stock assessment. According to Prodanov and Stoyanova (2001), the trends in fishing effort and biomass of the anchovy from 1979 to 1993 well agree with this assessment. The results are not exactly the same, for instance in 1991, 1992 fishing effort was 0.38 and 0.63 in Prodanov's results. However in this assessment it was 0.08 and 0.16, respectively. This is not surprising because in this assessment is used only Turkish and Georgian data on the other hand in Prodanov's assessment it was used whole Black Sea countries catch and effort data. Yet the trends are well fit with the fishing mortality rates of current assessment (Figure 14).

According to the results of model, management and derived parameter estimates of ASPIC in Table 22 and Table 23, under the current situation with sharp fluctuations experienced in past is the carrying capacity of the Black Sea for anchovy is 1.2 millions tones. The maximum sustainable yield (*MSY*) that could be achieved from the stock is "244 thousands tones". The model also suggests that in order to achieve *MSY* the biomass level of the stock (*BMSY*) should be "610 thousands tones".

Currently, the estimated biomass in the final year (B_{2015}) as 399,100 tones (65% of B_{MSY}) which is 35% less than B_{MSY}. In other words, at *MSY* condition this ratio (B/B_{MSY}) should ideally be around “1”. Therefore the model suggested that 35% less anchovy present in the Black Sea than it have to be, in other words the anchovy stock is overfished at 35% level. According to GFCM ‘s (2014) “the Range of Overfishing levels based on fishery reference points” scale and ASPIC results the Black Sea anchovy stock is exposed to low level overfishing.

According to model estimations, initial biomass of 2013, B_{2013} is equal to 422 000 tons with F_{2013}=0.9 and catch in 2013 was 326 104 tons which is 77% of the initial biomass. Moreover; B_{2014} is 298 000 tons with F_{2014}=0.4, which is equal to the F_{MSY}, and total catch in 2014 was 137 530 tons that is 45% of the initial biomass. The B_{2015} estimates is 353 000 tons. The suggested *MSY* by the ASPIC is 244 000 tons which is 69% of the initial biomass. However B_{MSY} should be 623 300 tons to give *MSY* amount of fish. This means that the initial biomass of the anchovy stock in the Black Sea is 50% lower than the amount that must be present in the sea to exploit the 244 000 tons of fish. Therefore, the catch in 2015 could not be as high as *MSY*. In case of forward short term predictions, it is expected that, if the fishing mortality rate in 2015 have been the targeted (F_{MSY}) value, then the yield would be 170 thousands tones. This amount is the 70% of the *MSY*. Again according to the estimates of the model, if the amount of anchovy, that will catch 2015, is 214 thousands tones then the yield will be in equilibrium as the 88% proportion of *MSY* (Table 23).

Projection results of ASPIC which are short (3 years), medium (5 years) and long (8-10 years) term with different combinations of F=0 (Figure 15) , F_{MSY} (Figure 16), F_{REL} (Figure 17), yield in *MSY* level (Figure 19) and Y_{REL} (Figure 20) are estimated the future of the stock. These are demonstrated end explained in the results section earlier. To be able to sustain *MSY* condition of stock the best and the shortest time approach for the projection is shown in Figure 18. According to this projection the anchovy stock is being applied F_{REL} ($F_{current}$) for 3 years. It means effort that was applied to the stock in 2014 is going to be applied for 3 more years. Moreover, as seen from the Figure 18 biomass rate of the stock will increase up to 30% higher than the targeted *MSY* value. But in case the same stock is being exposed to F_{MSY}, which is two times of $F_{current}$, for 2 more years, biomass of the stock and the fishing mortality reach the *MSY* that is “244 thousand tons”. This means *B* (biomass of the stock) will be equal to B_{MSY} (biomass of the stock that gives the maximum sustainable yield) that is “610 thousand tons” and *F* (fishing mortality that stock is exposed) will be equal to F_{MSY} (fishing mortality that stock should be exposed in order to supply maximum sustainable yield) that is “0.4” means approximately “292 purse seine vessels”. These are the projections with current management applications. If it is directly applied quota on Black Sea anchovy catches by Turkey at calculated *MSY*; “240 thousand tons (to be in the safe side, estimated quota has been determined 4 thousand tons less than real calculated *MSY* amount)” level of ASPIC, the result will be as Figure 21. To reach the quota, the biomass and fishing mortality rate of the stock should be in *MSY* level. In other words, before quota application stock biomass should be tried to increase to the B_{MSY} level. Accordingly if the 240 thousand tons quota has been applied with the $B_{current}$; not only high level of overfishing would be observed but also stock collapse is expected to take place (Figure 19). Moreover with current effort CPUE is seen decrease dramatically, meaning that the catch would never reach the quota. Hence, in this study, it is suggested that the catch should be raised gradually from current state to *MSY* state and consequently to the defined quota level. With this way in 8 years, stock should sustain *MSY* level via gradual increase that corresponds to *MSY* levels of 0.5,0.6, 0.7, 0.8, 0.86, 0.9, 0.95 and 1.0 of *MSY* in the following eight years.

To summarize, ASPIC results leads to the point that the state of the Black Sea anchovy stock is not at *MSY*, however it is not critically in danger as suggested by the STECF in 2011. To be able to deal with overfishing problem and raise the stock to the MSY level, the initial stock biomass should be increased to the level of B_{MSY} to get the maximum sustainable yield. To achieve this goal ASPIC suggested five years projection continuing with the current fishing effort, $F_{current}$, of 3 more years, then F_{MSY} will be applied 2 more years. As explained before these parameters and results are estimations. ASPIC does not provide sensitivity to environmental and climatic conditions and basically neglects them. Therefore the results and projections could be change over the years triggered by strong alterations in the environmental conditions. However, how the data set gets long and the data are reliable, the vraisemblance of the estimations will increase. ASPIC is generally seen as over simplistic method by the stock assessment scientists. Although this may seem as a weakness at the first glance, in fact, ASPIC's power lay in the necessity of less diverse data. Additionally, it is still assumed that the ASPIC type surplus production models perform better than many of the more detailed age-structured models (Prager, 1992). Besides, ASPIC can fit data from up to 10 different data series of fishery-dependent or fishery-independent indices, to construct approximate non-parametric confidence intervals and to correct for bias. Furthermore, it uses bootstrapping and it can fit the model by providing the relative importance on yield or effort or abundance indices (Prager, 2014). Moreover, ASPIC assumes the fish stock as a homogenous biomass and recruitment, age and length structure of stock and natural mortality does not required by doing estimations.

4.3. Analytical Approach

Comparatively, XSA (eXtended Survivor Analysis) takes the recruitment, demographic structure of the stock with the natural mortality and tuning indices. Therefore, XSA is more complicated than ASPIC, as it requires more diverse data sets. In mathematical sense, it is one step further than ASPIC as recruitment and SSB is taken into account and since such kind of stock assessment model cannot estimate the environmental and climatic effect on the stock. With XSA one can predict the environmental effect on in relation to recruitment and SSB indices. Being also a derivation of the VPA analysis, XSA is more improved in terms of terminal years of age structure of the stock and tuning property on data. Hence, the most distinctive feature of XSA that makes it different from the derivative models is to do correction on the data by further including acoustic and CPUE data. Moreover, it is known to use backward calculation method. These advancements makes XSA commonly used and therefore standard procedure that used by ICES (Shepherd, 1999). However, XSA cannot estimate uncertainty. It does not take errors in catch-at- age data into account. Most importantly this model, like all other age-based analytical models applied to a short-lived species i.e., anchovy has considerable drawbacks. Although comparative biological reference points are provided, the stock- recruitment relationships could not be established to make future projections. The same situation happened in 2013 and 2014 assessment of STECF (Sampson, 2013 and Damalas, 2014).

According to the outputs of XSA model; the internal consistency of the CPUE index were not as expected due to the negative correlation between the age groups was observed (Figure 24 and Figure 25). This situation might be arisen either from insufficient continued age-year data, or the likely error in second age groups. As it is observed in the selectivity graph (Figure 23). It was expected the selectivity that observed in one age group, since it is thought that the most of the catch contain one age class. However in the model results selectivity is seen in second age class. It means that the composition of the catch mainly include second age group. It can be thought as a cause of this situation is the arrival of the fish to hibernation place is in parts and usually first comers are the older fishes (older than age one). In case the samples that were taken from the first comers, it would create an error in determination of the age composition of the stock. The samples that are not representative of the fishing season not only create age composition error but also lead to creating a healthy age-length key for the current assessment. In order to make a good management plan, successful assessment results are needed. To achieve this goal the most important parameter is the good age-length key which represents the stock. However in the Black Sea anchovy it has not been successfully obtained due to several reasons. Firstly, the age reading of Black Sea anchovy still has not been attributed to certain standardization. It still deviates from scientist to scientist and consequently from country to country. Secondly, different subspecies of anchovy (Azov and Black Sea anchovy) has a mixed population structure in the overwintering grounds during the time interval of sampling (Chashchin, 2015). Moreover to that according to Gucu et al. (2016), there is a permanent local parental stock in Turkish coast that do not migrate; feed, reproduce, hibernate and remain stationary at the Southeastern Black Sea all year round. The mixing of these three stocks takes place at the same place, create a nonconcurrence in the age reading, inevitably, and they all have different condition factor and growth indices. Despite of this fact, commissions such as STECF, GFCM and ICES still use the XSA and other models that need age length key, due to lack of any alternative method (Eero, 2002).

Residual analysis (Figure 26) with the fse=1.5 and 2.0 shrinkage which shows the differences between observed biomass which is calculated from CPUE, and calculated biomass which is estimated by XSA that gives the smaller value to make reliable estimations. The retrospective analysis results are demonstrated in Figure 27 with different shrinkage factors. From this graph it can be observed “recruitment”, “ssb”, ”catch” and “harvest” results with respect to each other. And the calculation results in Table 25 are shown in Figure 28, Figure 29 and Figure 30. According to these results it is concluded that for the purpose of stock assessment the fishing with respect to the years gain importance. The fishing mortality rate (harvest) fluctuated between 0.56-0.82 in the years of 2005-2010. The model is able to catch the downfall in 2005, *Sarda sarda* maximum year. The peak in 2011 is showing signs of the overfishing, as it can be observed from the decrease in spawning stock biomass. In other words, until 2011 the fishing mortality rate has increased consistently, however the total catch has fluctuated around the 240-250 thousand tons. This means that the catch per unit effort decrease and to get the same yield from the stock the fishing pressure increase and consequently overfishing was observed by a decrease in the spawning stock and following that decrease in the recruitment took place in 2005-2011 periods. It is argued that in these years the recruitment overfishing was observed. Until 2011 stock condition went very bad. This proves the TAC application of STECF in 2011 and 2012 that explained above. Fortunately; vessel buy-back program and other precautions that have been taken by Turkey decrease the fishing pressure on the stock. The decrease in the fishing pressure after 2011 to 2014 can be explained with this reason.

Spawning stock biomass (*SSB*) results that shown in Figure 29, is a reflection of the fish amount. It shows the total of the potential fishing stock. However it cannot give detailed information individually except increase and decrease of the stock. Therefore other recruitment and fbar results should be evaluated together. On the other hand the recruitment results of XSA calculation is demonstrated in Figure 30. It is alone shows the variations of individual fish that participating to the stock with time and do not give information about the stock condition. According to the recruitment results; there is an increase in recruitment observed from 2005 to 2006. However after 2006 the recruitment amount decreases gradually until 2010. In 2010 lowest known stock recruitment was observed. When SSB is considered, the reflection of the decrease in recruitment can be observed in the following year's SSB amount. From here it can be concluded that this year's SSB rise may not affect the next year's recruitment amount, since not all egg can survive to the larval stage and not every larvae survive to recruit to the parent stock due to the environmental conditions, competition for food source, predation pressure and operating natural mortality on them (Daskalov, 1998). However, the pulse in recruitment in this year is a sign of a possible increase in the SSB amount of next year. All the same, the increase in recruitment in 2006 ensured the increase in SSB in 2007. In 2010-2012 period the increased recruitment was foreshadowed by the 2012 increase of SSB which had exposed to overfishing with the F_{2010}=0.66 and F_{2011}=1.34 in 2010-2011 time interval. However, in the recent years, although the decreasing F value provide the stock a fair crack of the whip to recover itself, and the response is observed immediately by the increase in SSB from 2012 to 2014 (Figure 32). However, the decrease in recruitment is seen to create a doubt about the future of the stock. Since the decrease in recruitment with the increasing SSB is a reflection of the other important factors (i.e., climatic changes) on the stock rather than fishing pressure. In the reproductive period and the climatic irregularities its immediate aftermath affects the recruitment negatively. Although XSA does not take environmental condition effects into consideration, it allows the interpretation and recommendation provision about the effect of climatic changes and environmental conditions. A final comment about the recruitment, even though the SSB seems as high level as "1.289.349 tons" of the last decade (this increase may still be the reflection of 2012 pulse in recruitment, since the decrease in effort may result in fish accumulation in the sea), in case the decrease in the recruitment continues within 2 years a dramatic decrease in SSB is expected according to the results of the XSA. The projection of XSA in Figure 33 supports this suggestion.

Before this study the same Black Sea anchovy stock assessment has been done by the STECF since four years. The SSB results of 2011, 2012 and 2013 are 800 thousand tons, 700 thousand tons and 669.281 thousand tons, respectively. In the current assessment 606.447, 508.329, 1.187.786 and 1.289.349 tons are estimated for the years of 2011, 2012, 2013 and 2014, respectively. Therefore the current study results are strongly disagreeing with those estimated previously except the decrease from 2011 to 2012. This confirms the downturn of the stock in 2011-2012 years. Although according to the 2013 report of STECF's SSB results that shows a decrease, according to current assessment it follows a reverse trend and increase gradually. It is known that 2014 catch in Turkey is too low when it is compared to the previous years (TUIK, 2014). According to Gucu et al (in press) the reason of this drop is due to the climate variability and hence anchovy did not accumulate and arrive to the coast of the Turkey and hibernated directly in the Georgian waters in 2014. Since Georgia has quota applications, not efficient fishing activity took place. Even though, not every vessel filled its individual quota. If it is accepted that all Turkish fleet were fishing within the Georgian EEZ in 2014 season, than the catch would be higher than 200 thousand tons. This is an extreme situation and it effects the all managements of the Black Sea anchovy stock assessment in terms of SSB amount, especially if it is not used extensive data sets.

After XSA model analysis, no relation between stock and recruitment is observed. That is why it cannot be accepted as proper results according to biological reference points; *MSY*, B_{MSY}, etc. Therefore Patterson's (1992) precautionary exploitation rate of E=0.4 is used to evaluate the status of the stock. The biological reference points that calculated by XSA are not realistic and remain very high. Therefore, we took the $F_{current}$ as the average of the terminal four years; $\mathbf{F_{[1:4;2011:2014]} = 0.71}$. The reason is that, in the models, performing retrospective analysis, and the calculated last year's F is not enough to represent the stock itself. Since model could not calculate the all age groups F, conventionally, the average of the last 3 or 5 years of F, taken as an $F_{current}$. Since anchovy is a short-lived species, it is taken the average of last four years in terms of representing the all age groups in the stock. From this $\mathbf{F_{MSY} = 0.49}$**,** $\mathbf{F_{current} = 0.71}$**,** $\mathbf{E_{target} = 0.4}$ **and** $\mathbf{E_{current} = 0.5}$ is found (Table 26).

According to these results, current exploitation rate is higher than the target exploitation rate. This indicates that the Black Sea anchovy exposed to low overfishing as it is same within the ASPIC result. Hence this similarity proves of the conformity between ASPIC and XSA. Moreover, with the close fishing mortality rates of F_{MSY}=0.49 of XSA and F_{MSY}=0.4 of ASPIC.

4.4. Comparison of ASPIC and XSA with Each Other and with Previous Studies

According to shown STECF and GFCM fishing mortality results from 2011 to 2014 in Table 27. $F_{[1:4;2011:2014]}$ of STECF and GFCM are estimated higher than current assessment results, it is not unexpected since they have used the whole Black Sea countries data. Although the same method has been used in three different assessments the age-length key (ALK) differences or the year that the data set include may have introduced variability in the results.

Table 27: Comparison of the f results of the assessments, our, STECF and GFCM

Years	Our Assessment	STECF	GFCM
2011	1.34	0.62	
2012	0.59	1.81	0.64
2013	0.71	1.23	0.91
2014	0.2	1.2	1.01
$F_{[1:4;2011:2014]}$	0.71	1.21	0.85

Finally, the comparable result of XSA and ASPIC includes only the fishing mortality rates, since the common outputs of these two models is only the “f” in terms of biological reference points. The other outputs are different in terms of unit patterns. For instance the estimated biomass output of ASPIC do not find any counterpart in XSA, due to this fact, in XSA the biomass output has been given in terms of spawning stock biomass. Therefore these two parameters are not comparable. For the only comparable parameter of fishing mortality rate (shown in Figure 34), ASPIC and XSA has a uniformity. To prove this concordance, t-test was applied to these two models’ fishing mortality rate results. The p-value of t- test was equal to “0.26<0.5”. Accordingly, it is suggested that the differences between these two fishing mortality rates of ASPIC and XSA are not significant. Moreover, not the exact value but instead the trends in SSB in XSA and biomass in ASPIC fit each other, it is the other punch line of this study after correlation of the fishing mortality values in terms of the conformity of the analytic (XSA) and the holistic (ASPIC) models.

5. CONCLUSION

The Black Sea anchovy (*Engraulis encrasicolus*) is ecologically and economically the most important species in the Black Sea and its riparian countries, Turkey in particular. It constitutes 90% of the total anchovy catch of the whole Black Sea alone especially after collapse of the Soviet Union. Moreover, anchovy catch contributes alone more than 60% of the total catch of Turkey. Therefore, this adds substantial value to scientific regulation of the anchovy stock. To protect and to be able to exploit this economically important stock sustainably, strategies based on the scientific stock assessment management strategies should be established. To achieve this goal, in the present study, two different models, (i) ASPIC (A Stock-Production Model Incorporating Covariates), the holistic one that assumes the fish stock as a homogenous biomass. Recruitment, age and length structure of stock and natural mortality does not required by doing estimations, and (ii) and an analytical one, the XSA (eXtended Survivors Analysis), which takes recruitment, demographic structure of stock and natural mortality into consideration, was used for either assess the same stock with two different methods. Moreover, this approach will render the evaluation of conformity between the two (holistic and analytical) models possible. Furthermore, in present stock assessment, it was used only Turkish data with the Georgian data, due to the fact that since 2006 the Georgian fishing quota has rented to Turkey for ten years. From this aspect current assessment differs from other studies which were done by the commissions of STECF and GFCM. This fact makes the present study more specific than the previous ones with not only diminished error sources with respect to the other data sources which was taken from the all Black Sea countries, but also the used methods (XSA and ASPIC) that was chosen for the assessment of the Black Sea anchovy. XSA has data tuning process and more reliable calculation of the terminal years fishing mortality and other parameters than the Virtual Population Analysis which was used in the previous assessment of the Black Sea anchovy.

According to results of ASPIC (in 1968-2014 period), despite the long-term report fluctuations, the current management and derived parameter estimates reveal that the carrying capacity of the Black Sea for anchovy as 1.2 m tons. The estimated maximum sustainable yield (*MSY*) is “244 k tons” with the fishing mortality rate of “F_{MSY}=0.4” from such a stock of the biomass at MSY (B_{MSY}) should be “610 k tons”. Currently, the estimate of biomass in the year 2015 (B_{2015}) is given as 399,1 k tones (65% of B_{MSY}) which is 35% below the B_{MSY}. In other words, the model suggests that the current biomass of the anchovy less in 35% level to get annually 244 thousand tons of anchovy from the Black Sea. This means the Black Sea anchovy stock is subjecting to overfished at 35% level. It is a low overfished with respect to the overfishing scale suggested by GFCM (2014). With regard to the forward short-term predictions, in case the fishing mortality rate in 2015 is accepted as the targeted (F_{MSY}) value, then the yield will be 170 k tons. This value corresponds the 70% of the *MSY*. Hence, if the level of allowable anchovy catch, set to 214 k tons in 2015, then the yield is shown to be in equilibrium with the 88% of *MSY*.

On the other hand, owing to the fact that the stock-recruitment relation of the Black Sea anchovy is not yet established, the results from XSA analysis (that run during the years of 2005-2014) is not suitable for estimation of some important biological reference points (i.e., *MSY*, B_{MSY}, F_{MSY}), interpretation of future projections and provision of quota advice. However, some useful parameters, “fbar”, “SSB” and “rec”, available from this model and the precautionary exploitation rate of E_{target}=0.4 calculated from Patterson’s (1992) made the estimation of the currents state of the stock possible. Accordingly, from the parameters of $F_{current}$=0.71 with the F_{target}=0.49

and $E_{current}$=0.5, it can be concluded that the current exploitation rate is higher than the target exploitation rate with the higher fishing mortality rate. This indicates that Black Sea anchovy is exposed to low overfishing as supporting the assessment results done with ASPIC similarly. Another comparable parameter, i.e., the fishing mortality rate calculated from both models reveals the concordance and comparableness of holistic (ASPIC) and analytic (XSA) models with each others.

The results of the current study are supported by the assessment results of the Prodanov in 1968-1994 periods. Even so, present assessment is more powerful than previous ones. Since in here, instead of VPA it was used XSA which is more reliable with its tuning property by using acoustic and CPUE data. On the other hand, current assessment disagrees with the STECF and GFCM results. It also is considered to be caused by the difference of data content that was used.

The Recommendations;

- From XSA results stock-recruitment relation cannot be established.

Due to the fact that there is no estimation could be done about the future projections of the Black Sea anchovy. Therefore it can only be recommended that exploitation rate of $E_{current}$= 0.5 should be withdrawn to the level of E_{target}=0.4 by decreasing the fishing effort in order to establish a sustainable stock and to prevent deficiency of the landing of anchovy. In the same manner, according to ASPIC results by regulation in fishing effort in 5 years stock could reach MSY level. To increase of initial stock biomass. As there is no regulation of quota application in Turkey that adapt its fishing strategy, and quota advice is not possible with the currently available data used in this study, top priority must be the reduction of effort. Moreover, although, ASPIC suggests that the quota application can be applied after gradual increase of the initial stock to MSY level, XSA cannot give any quota advice due to the lack of information about stock-recruitment relationships. Therefore no quota is advised in this study. Instead, decreasing the fishing effort, for the aim of increase CPUE, by continuing vessel buy-back program or reducing the hours and/or days for fishing until reaching the F_{MSY} level is confidently suggested.

- To be able to establish more reliable assessment, a healthy and standardized ALK and data sets which contains more years is needed. Hence, as a second advice length measurement applications and age reading studies should be enhanced to obtain an elaborated age-length key (ALK). Since ALK is the core of such type of assessment, it should be standardized and be representative of the entire stock of the Black Sea anchovy.
- Although the laws protect the Black Sea anchovy stock the IUU fishing only stands to reason for the over exploitation of the fish stock. It also creates unjust competition among fisherman. To be able to deal with IUU problem, IUU fishing never should not be tolerated in terms of implementation of the laws.
- Additionally, tracking data in the field and the control of the vessels should be improved quickly as fallows; bycatch and discard controls should be increased, the minimum landing size (9cm for Turkey, 7cm for Georgia) application should continues with increasing the frequency.
- To prevent illegal and unregistered fishing, not only legal ones but also all landing points should be controlled. If it is possible satellite tracking system for fishing vessels is suggested. Moreover, these measures should be taken seriously and followed acutely. Penalties about regulations should be more deterrent.
- In the Black Sea there is a big fishing fleet and fisherman manpower for not only anchovy but also other fish stocks. The most important point is to make these fish stocks and fishing fleets sustainable. Therefore the catch amount has to be regulated with respect to this fact. Since, the amount of catch affects the living standard of the fisherman (price of fish). Hence, a management plan targeting maximum sustainable yield and it necessitates scientifically proven stock assessment. To be able to do that the data from the field should be collected continuously and faithfully.
- In near future international agreements and some other commissions are going to force countries to prepare fishery management plans. Therefore Turkey should be ready already to these actions by preparing its own fishery management

plan. Hence, this kind of scientific stock assessments and other studies must go on constantly. All in all, the final suggestion is to increase the sampling period and establishment of continuity in fisheries surveys. The current study is the last outcome of the project of "Assessment Of Black Sea Anchovy Using Acoustic Method And Establishing A Monitoring Model For National Fisheries Data Collection Program" supported by the TUBITAK. In order to develop a national marine resources strategy such kind of national projects should be running as long-terms monitoring projects (as it is in this project) so that the model predictions and hence recommendations will be more closely in line with the observations.

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APPENDICES

Appendix A: Algorithm of ASPIC

Russell (1931) wrote an algebraic formula which provides a basis in the mathematical stock dynamic calculations used in the ASPIC. The main idea is gathered around the parameters that lead to gain or loss in a fish population which expose to the fishing activity.

According to this model stock stays at equilibrium with its losses (due to natural and fishing mortalities) and gains (due to recruitment and growth in weight).

$$B_{t+1}=B_t + R_t + G_t – M_t – C_t$$

Where; B_{t+1} stand for Biomass in the year of t+1,

B_t is the biomass in year t,

R_t is recruitment in year t,

G_t is the growth biomass individuals that have already been recruited to the stock in year t,

M_t is the die of fish due to the natural causes in year t and

C_t is for losses from the stock due to the fishery in year t.

Since not all parameters are known in every time step, Russell's formula needs to some simplifications with some assumptions. From holistic point of view; production (P) is determined by the recruitment and growth. Moreover; surplus production (SP) is defined as subtraction of natural mortality from production. Then the next year's fish biomass is estimated from the formula of,

$$B_{t+1}=B_t+ SP_t - C_t$$

By assuming the SP as a function of the biomass, the next year's biomass can also be calculated in any given time. For instance;

$$B_{t+1}=B_t+ f(B_t) - C_t$$

Where $f(B_t)$ is the definition of the stock production function of population in terms of biomass and it describes the gain (recruitment and increases in weight) and lost (natural mortality). In ASPIC (in this study) logistic model- Schaefer (1954) is used which is a form of the basic equation of the production model as;

$$f(\mathrm{Bt}) = \mathrm{r}\mathrm{B}_\mathrm{t}\left(\frac{\mathrm{K}-\mathrm{B}_\mathrm{t}}{\mathrm{K}}\right)$$

Where K (B_{max}) is the carrying capacity of ecosystem. In other words; it is the maximum amount of fish that the environment can support. r is the intrinsic growth rate of population ($0 \leq r \leq 1$).

if r >0; population increases

r=0; no change in population grow

r<0; population decreases

If recruitment, growth and natural mortality are in fixed ratio in the stock; then Russell's equation, equilibrium condition, can be written as;

$$B_{t+1} = B_t + rB_t\left(\frac{K-B_t}{K}\right) - Ct$$

Linear born and death ratios depend on the abundance and it is assumed that the growth rate is the function of the population size. Since; Russell's equation is not completely realistic due to the fact that, no population exists in nature which can grow forever. There are always some limiting factors like food availability, place to live, competition, predation etc. That prevents population from limitless growth. Moreover, according to equation above, if the biomass is low, r will be higher. It means it comes close to "1". As the biomass increases, the limiting factors (food availability, place to live, competition, predation etc) will take place and the value of r will decrease. Furthermore, if the population biomass continues to increase until the carrying capacity of the environment, the r will be equal to "0 ". After this point biomass stays constant as it is shown in Figure 36. This figure shows the changes in biomass from beginning (t=0) up until to reaching carrying capacity(B=K). From this knowledge, the change in biomass with the derivative of time can be illustrated with the formula as:

$$\frac{dB_t}{dt} = rB_t - \frac{r}{K}B_t^2$$

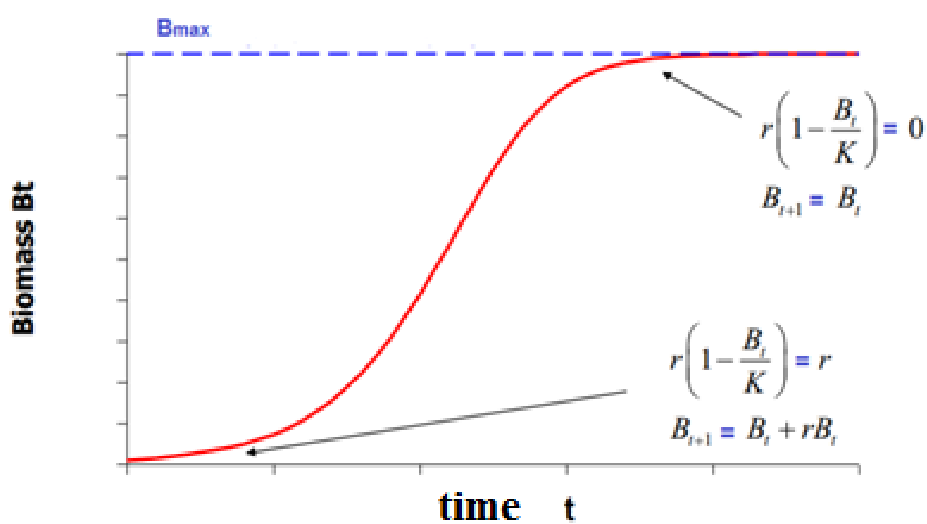


Figure 36: Carrying capacity of an ecosystem. (Figure was taken from the TUBITAK-KAMAG 110G124 Project report)

Up to this point the basic idea behind the surplus production model was demonstrated. For the assessment of fishery these equations should be collaborated with the fishing effect on stock biomass, because they explain the growing of the non-fishing stock. Schaefer (1954) had applied this production model to the fish stock which exposed to fishery. This method has been applied widely in the stock assessment of different species included anchovy (for instance; Peruvian anchovy). After Schaefer (1954), Prager (1994) developed this model by shoving how fishery affects the population growth in the time interval t with the equation of:

$$\frac{dB_t}{dt} = (r - F_t)\, B_t - \frac{r}{K}\, B_t^2$$

After fishery integration the surplus production (SP) will be like in equation below.

$$SP_t = r\left(\frac{K - B_t}{K}\right)$$

In the ASPIC approach 't' was integrated as 'i' to show year pattern for calculating the relationships between B_{i+1} and B_i. Moreover to that ASPIC can calculate average biomass by this year class integration. Finally; annual yield is calculated in terms of weight with the formula of;

$$Y_i = F_i\, \overline{B_\imath}$$

From this knowledge of the amount of death due to the fishing mortality is completely related to the fishing effort and the catchability coefficient, it can be said that ***F=qf*** . If it is integrated to the formula above the result will be as,

$$Y_i = qf_i\, \overline{B_\imath}$$

Where f_i stands for fishing effort for year "i". The ASPIC do not use linear model (as Schaefer (1954) did) to solve these equations, instead it does all these calculations by using least square technique.

Appendix B: ASPIC .a7inp Input

```
ASPIC-V7
# File generated by aspic5to7 v.0.59, at 2014-05-14 16:52:50
"Black Sea Anchovy Production Model Turkey+Georgia_1968-2014 -- MSc thesis _ Gizem"
# Program mode (FIT/BOT), verbosity, N bootstraps, [opt] user percentile:
FIT  222 500
# Model shape, conditioning (YLD/EFT), obj. fn. (SSE/LAV/MLE/MAP):
LOGISTIC  YLD  SSE
# N years, N series:
47  3
# Monte Carlo mode (0/1/2), N trials:
0  30000
# Convergence criteria (3 values):
1.0d-08  3.0d-8  1.0d-04
# Maximum F, N restarts, [gen. model] N steps/yr:
8.0d0  8  24
# Random seed (large integer):
6745249
# 9 Initial guesses and bounds follow:
B1K    0.5  0
```

MSY 250000 1 1500 500000
Fmsy 4.0d-01 0 1.0d-02 1.5d0
q 0.001 1 1.00E+00 5.0e-06 5.0e-02
q 0.001 1 1.00E+00 5.0e-06 5.0e-02
q 0.001 1 1.00E+00 5.0e-06 5.0e-02

DATA
"number of purse senier effot, catch"

CE

1968	5	33135
1969	5	40787
1970	18	67109
1971	18	65353
1972	24	85906
1973	25	84216
1974	29	70802
1975	41	58216
1976	53	67992
1977	58	71366
1978	69	105183
1979	78	133678
1980	104	239289
1981	121	259767
1982	145	266523
1983	162	289860
1984	171	318917
1985	195	273274
1986	210	274740
1987	229	295902
1988	247	295000
1989	262	96806
1990	280	66409
1991	284	79225
1992	163	155417
1993	287	218866
1994	243	278667
1995	262	373782
1996	278	273239
1997	248	213780
1998	209	195996
1999	199	310801
2000	262	260670
2001	299	288616
2002	419	336419
2003	500	268631
2004	443	309256
2005	565	128477
2006	502	229527
2007	528	383061

2008	589	256682
2009	501	225463
2010	428	228944
2011	403	257396
2012	353	165964
2013	223	326104
2014	136	137530
"SSB-Hydroacoustic"
B0
1968	-1
…
1979	-1
1980	270000
1981	320000
1982	150000
1983	300000
1984	190000
1985	150000
1986	50000
1987	100000
1988	235000
1989	32000
1990	48000
1991	92000
1992	-1
…
2014	-1
"Turkey-Hydroacoustic"
B2
1968	-1
…
2010	-1
2011	306000
2012	261000
2013	292000
2014	315000

*… means data continues between the years as “-1 (no data)”

Appendix C: Output of ASPIC

RESULTS FOR DATA SERIES # 1 (NON-BOOTSTRAPPED)
number of purse senier effot, catch

Data type CE: Effort-catch series

Obs	Year	Observed CPUE	Estimated CPUE	Estim F	Observed yield	Model yield	Resid in log scale	Statist weight
1	1968	6.627E+03	1.144E+03	0.0454	3.313E+04	3.313E+04	-1.75642	1.000E+00
2	1969	8.157E+03	1.430E+03	0.0447	4.079E+04	4.079E+04	-1.74114	1.000E+00
3	1970	3.728E+03	1.609E+03	0.0654	6.711E+04	6.711E+04	-0.84021	1.000E+00
4	1971	3.631E+03	1.704E+03	0.0601	6.535E+04	6.535E+04	-0.75635	1.000E+00
5	1972	3.579E+03	1.745E+03	0.0772	8.591E+04	8.591E+04	-0.71856	1.000E+00
6	1973	3.369E+03	1.757E+03	0.0752	8.422E+04	8.422E+04	-0.65084	1.000E+00
7	1974	2.441E+03	1.773E+03	0.0626	7.080E+04	7.080E+04	-0.31985	1.000E+00
8	1975	1.420E+03	1.796E+03	0.0508	5.822E+04	5.822E+04	0.23516	1.000E+00
9	1976	1.283E+03	1.808E+03	0.0590	6.799E+04	6.799E+04	0.34332	1.000E+00
10	1977	1.230E+03	1.807E+03	0.0619	7.137E+04	7.137E+04	0.38453	1.000E+00

11	1978	1.524E+03	1.784E+03	0.0925	1.052E+05	1.052E+05	0.15704	1.000E+00
12	1979	1.714E+03	1.736E+03	0.1208	1.337E+05	1.337E+05	0.01267	1.000E+00
13	1980	2.301E+03	1.624E+03	0.2311	2.393E+05	2.393E+05	-0.34840	1.000E+00
14	1981	2.147E+03	1.487E+03	0.2739	2.598E+05	2.598E+05	-0.36722	1.000E+00
15	1982	1.838E+03	1.381E+03	0.3027	2.665E+05	2.665E+05	-0.28621	1.000E+00
16	1983	1.789E+03	1.282E+03	0.3544	2.899E+05	2.899E+05	-0.33301	1.000E+00
17	1984	1.865E+03	1.168E+03	0.4281	3.189E+05	3.189E+05	-0.46779	1.000E+00
18	1985	1.401E+03	1.089E+03	0.3935	2.733E+05	2.733E+05	-0.25232	1.000E+00
19	1986	1.308E+03	1.047E+03	0.4116	2.747E+05	2.747E+05	-0.22312	1.000E+00
20	1987	1.292E+03	9.878E+02	0.4697	2.959E+05	2.959E+05	-0.26861	1.000E+00
21	1988	1.194E+03	9.145E+02	0.5058	2.950E+05	2.950E+05	-0.26692	1.000E+00
22	1989	3.695E+02	1.002E+03	0.1514	9.681E+04	9.681E+04	0.99809	1.000E+00
23	1990	2.372E+02	1.251E+03	0.0832	6.641E+04	6.641E+04	1.66290	1.000E+00
24	1991	2.790E+02	1.463E+03	0.0849	7.923E+04	7.923E+04	1.65710	1.000E+00
25	1992	9.535E+02	1.548E+03	0.1574	1.554E+05	1.554E+05	0.48484	1.000E+00
26	1993	7.626E+02	1.515E+03	0.2265	2.189E+05	2.189E+05	0.68657	1.000E+00
27	1994	1.147E+03	1.414E+03	0.3089	2.787E+05	2.787E+05	0.20977	1.000E+00
28	1995	1.427E+03	1.234E+03	0.4749	3.738E+05	3.738E+05	-0.14482	1.000E+00
29	1996	9.829E+02	1.111E+03	0.3857	2.732E+05	2.732E+05	0.12233	1.000E+00
30	1997	8.620E+02	1.116E+03	0.3005	2.138E+05	2.138E+05	0.25798	1.000E+00
31	1998	9.378E+02	1.174E+03	0.2618	1.960E+05	1.960E+05	0.22479	1.000E+00
32	1999	1.562E+03	1.146E+03	0.4252	3.108E+05	3.108E+05	-0.30934	1.000E+00
33	2000	9.949E+02	1.085E+03	0.3768	2.607E+05	2.607E+05	0.08660	1.000E+00
34	2001	9.653E+02	1.040E+03	0.4351	2.886E+05	2.886E+05	0.07480	1.000E+00
35	2002	8.029E+02	9.361E+02	0.5636	3.364E+05	3.364E+05	0.15345	1.000E+00
36	2003	5.373E+02	8.537E+02	0.4934	2.686E+05	2.686E+05	0.46306	1.000E+00
37	2004	6.981E+02	7.769E+02	0.6242	3.093E+05	3.093E+05	0.10694	1.000E+00
38	2005	2.274E+02	8.163E+02	0.2468	1.285E+05	1.285E+05	1.27809	1.000E+00
39	2006	4.572E+02	9.191E+02	0.3916	2.295E+05	2.295E+05	0.69825	1.000E+00
40	2007	7.255E+02	8.105E+02	0.7412	3.831E+05	3.831E+05	0.11075	1.000E+00
41	2008	4.358E+02	6.857E+02	0.5870	2.567E+05	2.567E+05	0.45325	1.000E+00
42	2009	4.500E+02	6.621E+02	0.5340	2.255E+05	2.255E+05	0.38608	1.000E+00
43	2010	5.349E+02	6.550E+02	0.5481	2.289E+05	2.289E+05	0.20247	1.000E+00
44	2011	6.387E+02	6.145E+02	0.6568	2.574E+05	2.574E+05	-0.03854	1.000E+00

45	2012	4.702E+02	6.237E+02	0.4173	1.660E+05	1.660E+05	0.28260	1.000E+00
46	2013	1.462E+03	5.560E+02	0.9197	3.261E+05	3.261E+05	-0.96701	1.000E+00
47	2014	1.011E+03	5.115E+02	0.4216	1.375E+05	1.375E+05	-0.68153	1.000E+00

Appendix D: Algorithm of XSA

According to the algorithm; XSA based on a connection between the population (estimated stock size) and the abundance index via catchability (*q*) and the exponent γ. Where q and γ are estimated by using linear regression.

$$\text{CPUE} = q\text{N}^{\gamma}$$

Where q is catchability, N is mean stock abundance, γ is an exponent (Eero, 2002). Moreover to that q is constant with respect to time but γ is change with age and abundance index (Lassen & Medley, 2001). By using the formula below the CPUE values are recovered with the aim of referring the stock.

$$Cpue_{ayf} = Cpue_{ayf}^{obs} / \left[\exp(-\alpha(F_{a,y} + M_a)) \frac{1 - \exp(-(\beta - \alpha)(F_{ay} + M_a))}{F_{ay} + M_a} \right]$$

Where α is start point, β is end in terms of time of the observation which is shown as a fraction of the year. F is fishing mortality, M is natural mortality, *a* means age and *y* means year.

The initial guess of the survivors' number and M is the start point of the iteration procedure of XSA. After that stock size (N) is provided by the application of standard VPA to the catch-at-age data.

$$\ln N_{ay}^{VPA} = \frac{1}{\gamma_{af}} \ln Cpue_{ayf} - \frac{\ln q_{af}}{\gamma_{af}}$$

where *f* means fleet.

The stock estimation correction is done by the formula below, after the relation between q and γ (CPUE-stock relation exponent) is determined by the equations above.

$$\ln N_{ayf}^{corr} = \frac{\ln Cpue_{ayf} - \ln q_{af}}{\gamma_{ay}}$$

The stock abundance index estimates in numbers according to age and year are averaged to supply a new starting point. This average is based on calculating the number of survivors of the oldest age group contained within the catch-at-age analysis. (Lassen & Medley, 2001)

$$\ln N^{survivors} = \ln\left[\frac{Cpue_a}{q_a}\right] - F_{a,cum} - M_{a,cum}$$

In this step F and M are continue cumulatively over the age, until the oldest age is involved. Lassen & Medley, 2001 said that "For a given cohort, there will be a number of such estimates of survivors. These come from different age groups observed in the same abundance index and from different indices (e.g. commercial CPUE and research vessel surveys). The XSA combines these weighted estimates into a single estimate of the survivors of that cohort. This estimate is then introduced into a VPA of the catch in numbers by age and by year thereby obtaining stock in numbers and fishing mortality. This concludes the iteration loop. The next iteration loop begins by using these estimates to calculate the catchabilities (q_a) by age and by index type. The whole process is repeated until convergence. However, convergence is not guaranteed and there are examples where the iteration diverges." in the Virtual Population Analysis - a Practical Manual for Stock Assessment of FAO fisheries technical paper.

XSA uses two approaches by making the assumptions; that fleet catchability is constant (independent of age) above a certain age and determination the ages where catchability is independent of the year class strength (Gonzales-Costas, 2009). The age (constant for all fleets) is user-defined. For each fleet, the catchability value estimated at the specified age, is used to derive population abundance estimates for all subsequent ages in the fleet data set (Kell & Grosjean, n.d.). Catchability by fleet and age can be estimated using the estimates of N and the CPUE indices corrected to the beginning of the year (Patterson et al., 1999). So XSA has a capability of estimation the relationship between CPUE indices and population abundance. And it begins to analyze from the last year's plus group to backwards. And while doing this it does not consider about errors in catch-at-age. Since it is assumed that catch data is completely correct.

Appendix E: R script for XSA

```
library(FLCore)
library(FLEDA)
library(FLXSA)
library(FLAssess)
library(FLash)
library(FLBRP)
library(grid)
rm(list=ls())
setwd("C:/Users/x/Desktop/XSA TURK+GEOR 2005-2014 f4/")
getwd()
bsa.stk <- readFLStock("BSAn00IN", no.discards=TRUE)
units(harvest(bsa.stk))<-"f"
range(bsa.stk)["minfbar"] <- 1
range(bsa.stk)["maxfbar"] <- 3
bsa.stk <- setPlusGroup(bsa.stk, 4)
bsa.idx <- readFLIndices("BSAn11TU")
bsa.idx1 <-
FLIndices(trim(bsa.idx[[1]],age=1:4,year=2005:2014),
  trim(bsa.idx[[2]],age=1:4,year=2011:2014),
  trim(bsa.idx[[3]],age=1:4,year=2005:2014))
bsa.stk <- trim(bsa.stk,year=2005:2014)
```

```
bsa.idx1 <-bsa.idx
bsa.stk@catch.n<-sweep(catch.n(bsa.stk), MARGIN=2,
as.vector(sop(bsa.stk, "landings")), "/")
bsa.stk@catch<-computeCatch(bsa.stk)
plot(bsa.idx1)
plot(bsa.idx1[[1]])
plot(bsa.idx1[[2]])
plot(bsa.idx1[[3]])
xsa.control <- FLXSA.control(x=NULL, tol=1e-09, maxit=30,
min.nse=0.3, fse=1.5, rage=3, qage=4, shk.n=TRUE, shk.f=TRUE,
shk.yrs=5, shk.ages=2,window=100, tsrange=20, tspower=3,
vpa=FALSE)
xsa.control05 <- FLXSA.control(fse = 0.5,rage=0)
xsa.control10 <- FLXSA.control(fse = 1.0,rage=0)
xsa.control15 <- FLXSA.control(fse = 1.5,rage=0)
xsa.control20 <- FLXSA.control(fse = 2.0,rage=0)
xsa05<-FLXSA(bsa.stk, bsa.idx1, xsa.control05)
xsa10<-FLXSA(bsa.stk, bsa.idx1, xsa.control10)
xsa15<-FLXSA(bsa.stk, bsa.idx1, xsa.control15)
xsa20<-FLXSA(bsa.stk, bsa.idx1, xsa.control20)
inames <- unlist(lapply(bsa.idx1,'name'))
names(xsa05@index.res)<- inames
names(xsa10@index.res)<- inames
names(xsa15@index.res)<- inames
names(xsa20@index.res)<- inames
plot(bubbles(age~year|qname, data=mcf(xsa05@index.res), main =
"Residuals SE = 0.5"))
plot(bubbles(age~year|qname, data=mcf(xsa10@index.res), main =
"Residuals SE = 1.0"))
plot(bubbles(age~year|qname, data=mcf(xsa15@index.res), main =
"Residuals SE = 1.5"))
plot(bubbles(age~year|qname, data=mcf(xsa20@index.res), main =
"Residuals SE = 2.0"))
bsa.stk05 <- bsa.stk + xsa05
bsa.stk10 <- bsa.stk + xsa10
bsa.stk15 <- bsa.stk + xsa15
bsa.stk20 <- bsa.stk + xsa20
fsevals <- seq(0.5, 2.0, by = 0.5)
res1 <- propagate(harvest(bsa.stk), length(fsevals))
res2 <- propagate(ssb(bsa.stk), length(fsevals))
res3 <- propagate(fbar(bsa.stk), length(fsevals))
res4 <- propagate(rec(bsa.stk), length(fsevals))
ragevals<-seq(1,4,by=1)
res <- propagate(harvest(bsa.stk), length(ragevals))
for (i in 1:length(fsevals)) {
  xsa.control  <- FLXSA.control(fse = fsevals[i])
  iter(res1,i) <- harvest(FLXSA(bsa.stk, bsa.idx1,
xsa.control))
  iter(res2,i) <-
ssb(bsa.stk+FLXSA(bsa.stk,bsa.idx1,xsa.control))
  iter(res3,i) <-
fbar(bsa.stk+FLXSA(bsa.stk,bsa.idx1,xsa.control))
  iter(res4,i) <-
rec(bsa.stk+FLXSA(bsa.stk,bsa.idx1,xsa.control))}
plot(xyplot(data ~ year, groups = iter, data = res2, type =
"l", xlim = c(2005:2014), main = "SSB", ylab =
"thousands",xlab="Year", auto.key =list(space = "right",
points = FALSE, lines = TRUE)))
```

```
plot(xyplot(data ~ year, groups = iter, data = res3, type =
"l", xlim = c(2005:2014), main = "fbar", ylab =
"fbar",xlab="Year", auto.key =list(space = "right", points =
FALSE, lines = TRUE)))
plot(xyplot(data ~ year, groups = iter, data = res4, type =
"l", xlim = c(2005:2014), main = "Rec", ylab =
"thousands",xlab="Year", auto.key =list(space = "right",
points = FALSE, lines = TRUE)))
retro.yrs <- 2011:2014
bsa.stk.ret05 <- (tapply(retro.yrs, 1:length(retro.yrs),
function(x)
  return(window(bsa.stk, end = x) + FLXSA(window(bsa.stk, end
= x), bsa.idx, xsa.control05))))
bsa.stk.ret10 <- (tapply(retro.yrs, 1:length(retro.yrs),
function(x)
  return(window(bsa.stk, end = x) + FLXSA(window(bsa.stk, end
= x), bsa.idx, xsa.control10))))
bsa.stk.ret15 <- (tapply(retro.yrs, 1:length(retro.yrs),
function(x)
  return(window(bsa.stk, end = x) + FLXSA(window(bsa.stk, end
= x), bsa.idx, xsa.control15))))
bsa.stk.ret20 <- (tapply(retro.yrs, 1:length(retro.yrs),
function(x)
  return(window(bsa.stk, end = x) + FLXSA(window(bsa.stk, end
= x), bsa.idx, xsa.control20))))
plot(FLStocks(bsa.stk.ret05))
plot(FLStocks(bsa.stk.ret10))
plot(FLStocks(bsa.stk.ret15))
plot(FLStocks(bsa.stk.ret20))
bsa.ret <- FLStocks(tapply(retro.yrs, 1:length(retro.yrs),
function(x) return(window(bsa.stk20,end = x) +
FLXSA(window(bsa.stk20, end = x), bsa.idx1, xsa.control20))))
plot(bsa.ret, lty = 1, col = "black", lwd = 1, xlim =
c(2005,2014))

bsa.stk1<-FLXSA(bsa.stk20, bsa.idx1, xsa.control20)
bsa.stk2<-bsa.stk1+bsa.stk20
plot(bsa.stk2)
bsabrp <- FLBRP(bsa.stk2)
catch.sel(bsabrp)
discards.sel(bsabrp)
ggplot(discards.sel(bsabrp), aes( age, data))+geom_point()
ggplot(catch.sel(bsabrp), aes( age, data))+geom_point()
stock.wt(bsabrp)
catch.wt(bsabrp)
discards.wt(bsabrp)
m(bsabrp)
mat(bsabrp)
xyplot(data~age,data=catch.sel(bsabrp),type=c('l', 'p'))
xyplot(data~age|qname, data=FLQuants(sel=catch.sel(bsabrp),
dsel=discards.sel(bsabrp), swt=stock.wt(bsabrp),cwt
=catch.wt(bsabrp), mat= mat(bsabrp), m = m(bsabrp)),
type="l",scale="free")
fbar.obs(bsabrp)
bsabrp <- brp(bsabrp)
fbar(bsabrp)
harvest(bsabrp)
stock.n(bsabrp)
```

```
catch.n(bsabrp)
yield.hat(bsabrp)
rec.hat(bsabrp)
refpts(bsabrp)
plot(refpts(bsabrp))
stock recruitment
refpts(bsabrp)[c('msy', ('fmax')), ]
plot(bsabrp)
fbar(bsa.stk2)[,"2014"]
refpts(bsabrp)['f0.1','harvest']
fbar(bsa.stk2)[,"2014"]  / refpts(bsabrp)['f0.1','harvest']
p4sr <- as.FLSR(bsa.stk2, model=bevholt)
p4sr <- fmle(p4sr)
plot(p4sr)
bsabrp <- FLBRP(bsa.stk2, sr=p4sr)
model(bsabrp)
params(bsabrp)
bsabrp <- brp(bsabrp)
refpts(bsabrp)
plot(bsabrp)
plot(bsabrp, obs=TRUE)
fbar(bsa.stk2)
##  ---- Projection --------------
stf.years <- 3
wts.nyears <- 3
fbar.nyears <- 3
#***** ENTER F01 *********This corresponds to E=0.4
F01 <- 0.49
proj.years <- range(bsa.stk2)[["maxyear"]] + (1:stf.years)
bsa.stf <- stf(bsa.stk2, nyears=stf.years,
wts.nyears=wts.nyears, fbar.nyears=fbar.nyears)
computeCatch(bsa.stf)[,ac(2005:2014)]
rec(bsa.stf)
Fsq <- c(fbar(bsa.stf)[,ac(proj.years[1])])

Fscenarios <- c(F01,seq(from=0,to=2,by=0.1)*Fsq)
Fmults <- Fscenarios / c(Fsq)
bsa.stf <- propagate(bsa.stf,length(Fscenarios))
units(harvest(bsa.stf)) <- "f"
as.data.frame(fbar(bsa.stf)[,ac(proj.years)])
bsa.sr <- as.FLSR(bsa.stk2,model=geomean)
params(bsa.sr)['a',] <-
exp(mean(log(window(rec(bsa.stk2),start=2015,end=2017))))
# PROJECTION
ctrl <- projectControl(data.frame(year=proj.years))
res <- project(bsa.stf, ctrl, bsa.sr)
plot(window(res,start=2005,end=2017))
bsaProj <- project(bsa.stf, ctrl, bsa.sr)
rec(bsaProj)
plot(bsaProj)
output <- data.frame( # F in 2014
  "Fscenario"= c(fbar(bsa.stf)[,ac(proj.years[2])]),
  "Fmult" = Fmults,
  "Catch_2015"=c(computeCatch(res)[,ac(proj.years[1])]),
  "Catch_2016"=c(computeCatch(res)[,ac(proj.years[2])]),
  "Catch_2017"=c(computeCatch(res)[,ac(proj.years[3])]),
  "Landings_2015"=c(computeLandings(res)[,ac(proj.years[1])]),
  "Landings_2016"=c(computeLandings(res)[,ac(proj.years[2])]),
```

```
  "Landings_2017"=c(computeLandings(res)[,ac(proj.years[3])]),
  "SSB_2015"=c(ssb(res)[,ac(proj.years[1])]),
  "SSB_2016"=c(ssb(res)[,ac(proj.years[2])]),
  "SSB_2017"=c(ssb(res)[,ac(proj.years[3])]),
  "ChangeSSB_2015_2017"=100*c((ssb(res)[,ac(proj.years[3])]-
ssb(res)
[,ac(proj.years[1])])/ssb(res)[,ac(proj.years[1])]),"ChangeCat
ch_2016_2014"=100*c((computeCatch(res)[,ac(proj.years[2])]
computeCatch(res)[,ac(proj.years[1]-1)]) /
computeCatch(res)[,ac(proj.years[1]-1)]))
#########################
# Write the table
write.csv(output,file="Anchovy_summary_sheet_2014_new tuning
fleet.csv")
```

Appendix F: Input data for XSA

```
> catch(bsa.stk2)
An object of class "FLQuant"
, , unit = unique, season = all, area = unique

     year
age   2005   2006   2007   2008   2009   2010   2011   2012   2013
  all 128477 229527 383061 256682 225463 228944 257396 165964 326104
      2014
      137530
units:  NA NA
> catch.n(bsa.stk2)
An object of class "FLQuant"
, , unit = unique, season = all, area = unique
   year
age     2005     2006     2007     2008     2009     2010     2011
  0   706215  2030821  2347727  1560513  1500597  1101294  1320465
  1  3494990  8482544 15153057  5787334  7249507  4300290  7639474
  2  2505258  5089526  8124830  7285840  5221673  6397993  6273476
  3  1242319   628706   981958  1214307   973360  1630964  1042206
  4    15568    90314   112651    98178    74523    60833   103715
   year
age      2012     2013    2014
```

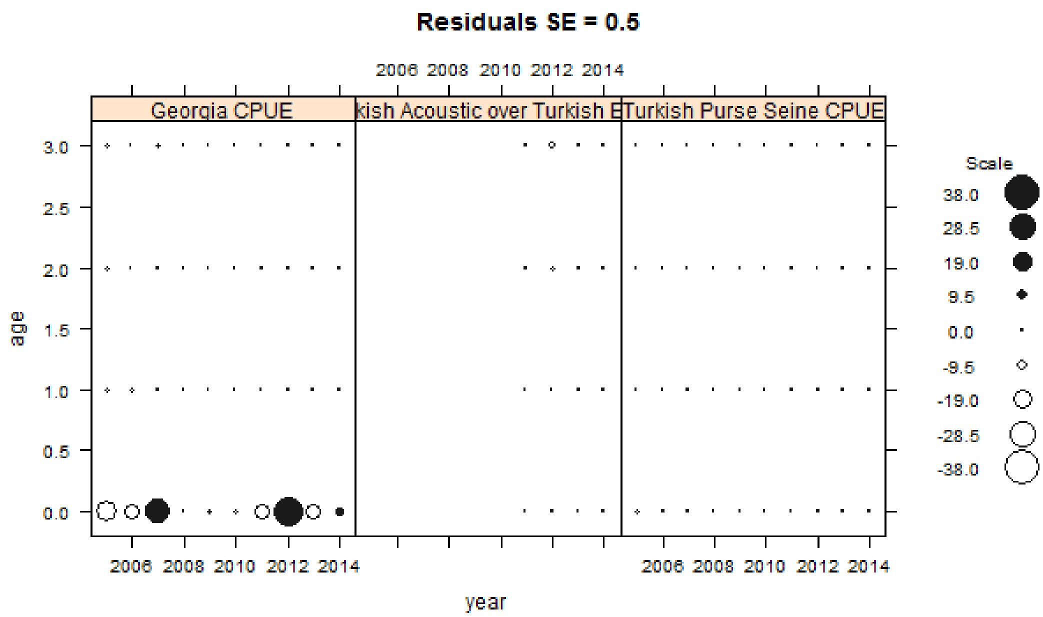
```
  0   5851320  2439260 1462135
  1   9852222 16112084 5638950
  2   2400541  5836266 2964191
  3    114526   462412  286938
  4     31557    85299   50401
units:  NA
> catch.wt(bsa.stk2)
An object of class "FLQuant"
, , unit = unique, season = all, area = unique
   year
age    2005    2006    2007    2008    2009    2010    2011
  0 0.00606 0.00539 0.00530 0.00478 0.00523 0.00507 0.00497
  1 0.01230 0.01290 0.01320 0.01380 0.01310 0.01340 0.01420
  2 0.01970 0.01820 0.01790 0.01900 0.01870 0.01950 0.01840
  3 0.02540 0.02350 0.02340 0.02390 0.02420 0.02440 0.02390
  4 0.01930 0.01940 0.01940 0.01940 0.01940 0.01940 0.01940
   year
age    2012    2013    2014
  0 0.00384 0.00642 0.00482
  1 0.01070 0.01270 0.01250
  2 0.01470 0.01620 0.01780
  3 0.01900 0.02080 0.02180
  4 0.01940 0.01940 0.01940
> discards(bsa.stk2)
An object of class "FLQuant"
, , unit = unique, season = all, area = unique
    year
age   2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
all      0    0    0    0    0    0    0    0    0    0
units:  NA
> discards.n(bsa.stk2)
An object of class "FLQuant"
, , unit = unique, season = all, area = unique
   year
age 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
  0    0    0    0    0    0    0    0    0    0    0
  1    0    0    0    0    0    0    0    0    0    0
  2    0    0    0    0    0    0    0    0    0    0
  3    0    0    0    0    0    0    0    0    0    0
  4    0    0    0    0    0    0    0    0    0    0

units:  NA
> discards.wt(bsa.stk2)
An object of class "FLQuant"
, , unit = unique, season = all, area = unique
   year
age 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
  0    0    0    0    0    0    0    0    0    0    0
  1    0    0    0    0    0    0    0    0    0    0
  2    0    0    0    0    0    0    0    0    0    0
  3    0    0    0    0    0    0    0    0    0    0
  4    0    0    0    0    0    0    0    0    0    0
units:  NA
> landings(bsa.stk2)
An object of class "FLQuant"
, , unit = unique, season = all, area = unique
     year
age     2005   2006   2007   2008   2009   2010   2011   2012   2013
all   128477 229527 383061 256682 225463 228944 257396 165964 326104
        2014
      137530
units:  NA
> landings.n(bsa.stk2)
```

```
An object of class "FLQuant"
, , unit = unique, season = all, area = unique
   year
age     2005     2006     2007     2008     2009     2010     2011
  0  1370000  4070000  4710000  3020000  2960000  2100000  2610000
  1  6780000 17000000 30400000 11200000 14300000  8200000 15100000
  2  4860000 10200000 16300000 14100000 10300000 12200000 12400000
  3  2410000  1260000  1970000  2350000  1920000  3110000  2060000
  4    30200   181000   226000   190000   147000   116000   205000
   year
age     2012     2013     2014
  0 11700000  4890000  2930000
  1 19700000 32300000 11300000
  2  4800000 11700000  5940000
  3   229000   927000   575000
  4    63100   171000   101000
units:  NA
> landings.wt(bsa.stk2)
An object of class "FLQuant"
, , unit = unique, season = all, area = unique
   year
age    2005    2006    2007    2008    2009    2010    2011    2012
  0 0.00606 0.00539 0.00530 0.00478 0.00523 0.00507 0.00497 0.00384
  1 0.01230 0.01290 0.01320 0.01380 0.01310 0.01340 0.01420 0.01070
  2 0.01970 0.01820 0.01790 0.01900 0.01870 0.01950 0.01840 0.01470
  3 0.02540 0.02350 0.02340 0.02390 0.02420 0.02440 0.02390 0.01900
  4 0.01930 0.01940 0.01940 0.01940 0.01940 0.01940 0.01940 0.01940
   year
age    2013    2014
0   0.00642 0.00482
1   0.01270 0.01250
2   0.01620 0.01780
3   0.02080 0.02180
4   0.01940 0.01940
units:  NA



> stock.wt(bsa.stk2)
An object of class "FLQuant"
, , unit = unique, season = all, area = unique
   Year
  age   2005    2006    2007    2008    2009    2010    2011    2012
  0   0.00606 0.00539 0.00530 0.00478 0.00523 0.00507 0.00497 0.00384
  1   0.01230 0.01290 0.01320 0.01380 0.01310 0.01340 0.01420 0.01070
  2   0.01970 0.01820 0.01790 0.01900 0.01870 0.01950 0.01840 0.01470
  3   0.02540 0.02350 0.02340 0.02390 0.02420 0.02440 0.02390 0.01900
  4   0.01930 0.01940 0.01940 0.01940 0.01940 0.01940 0.01940 0.01940
 Age   2013    2014
 0  0.00642 0.00482
 1  0.01270 0.01250
 2  0.01620 0.01780
 3  0.02080 0.02180
 4  0.01940 0.01940
units:  NA
> m(bsa.stk2)
An object of class "FLQuant"
, , unit = unique, season = all, area = unique
   year
age 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
  0 1.32 1.32 1.32 1.32 1.32 1.32 1.32 1.32 1.32 1.32
  1 0.81 0.81 0.81 0.81 0.81 0.81 0.81 0.81 0.81 0.81
  2 0.56 0.56 0.56 0.56 0.56 0.56 0.56 0.56 0.56 0.56
```

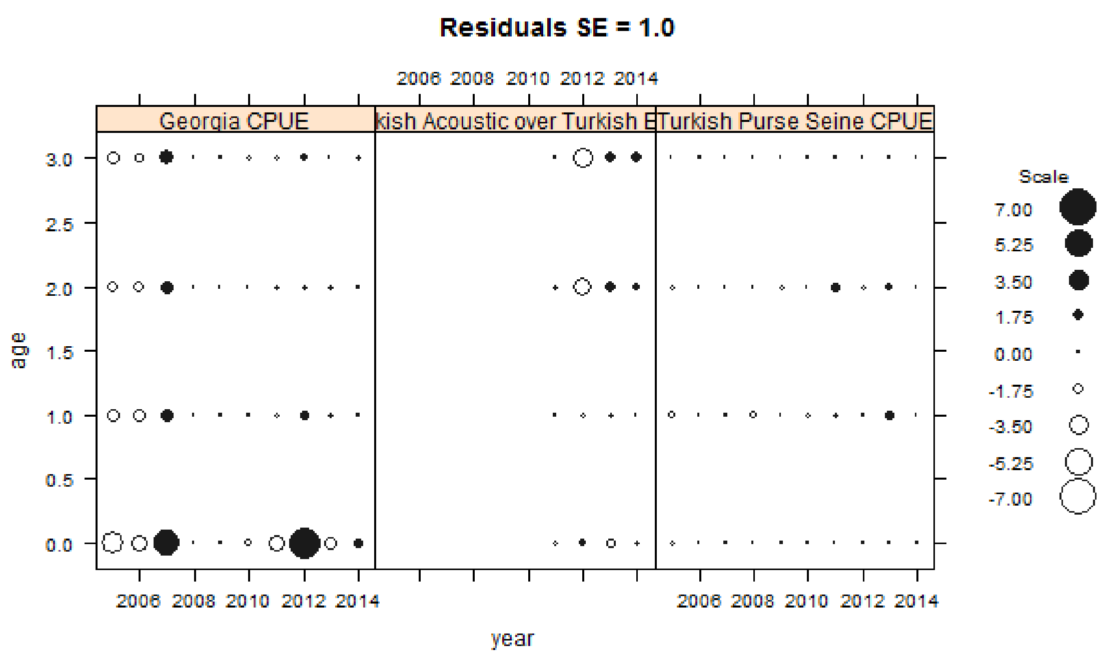
```
  3 0.48 0.48 0.48 0.48 0.48 0.48 0.48 0.48 0.48 0.48
  4 0.48 0.48 0.48 0.48 0.48 0.48 0.48 0.48 0.48 0.48
units:  NA
> mat(bsa.stk2)
An object of class "FLQuant"
, , unit = unique, season = all, area = unique
   year
age 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
  0 0    0    0    0    0    0    0    0    0    0
  1 1    1    1    1    1    1    1    1    1    1
  2 1    1    1    1    1    1    1    1    1    1
  3 1    1    1    1    1    1    1    1    1    1
  4 1    1    1    1    1    1    1    1    1    1
units:  NA
```

Appendix G: Model Results of XSA

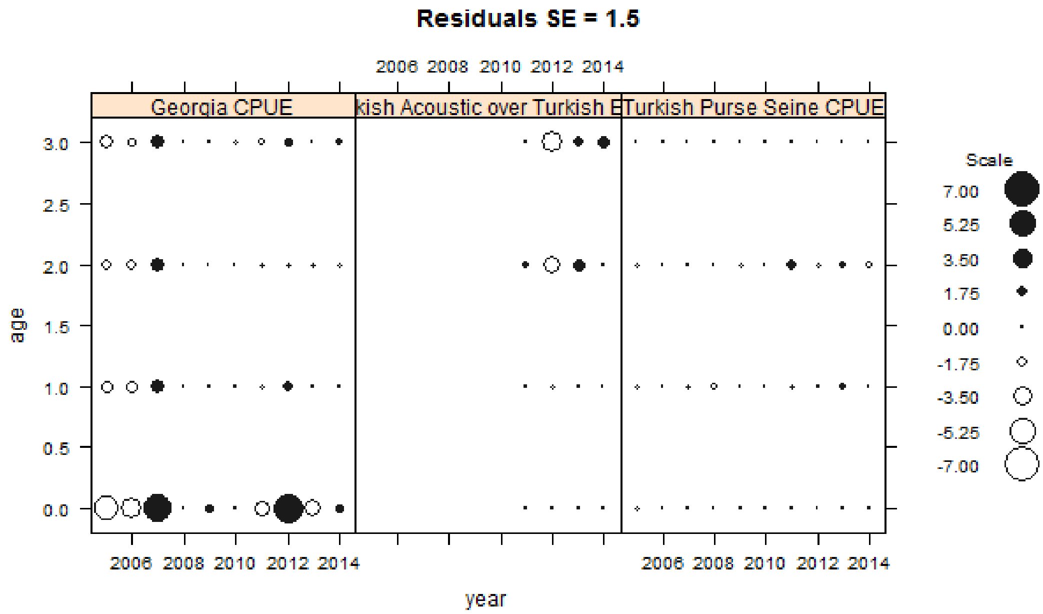
Residuals



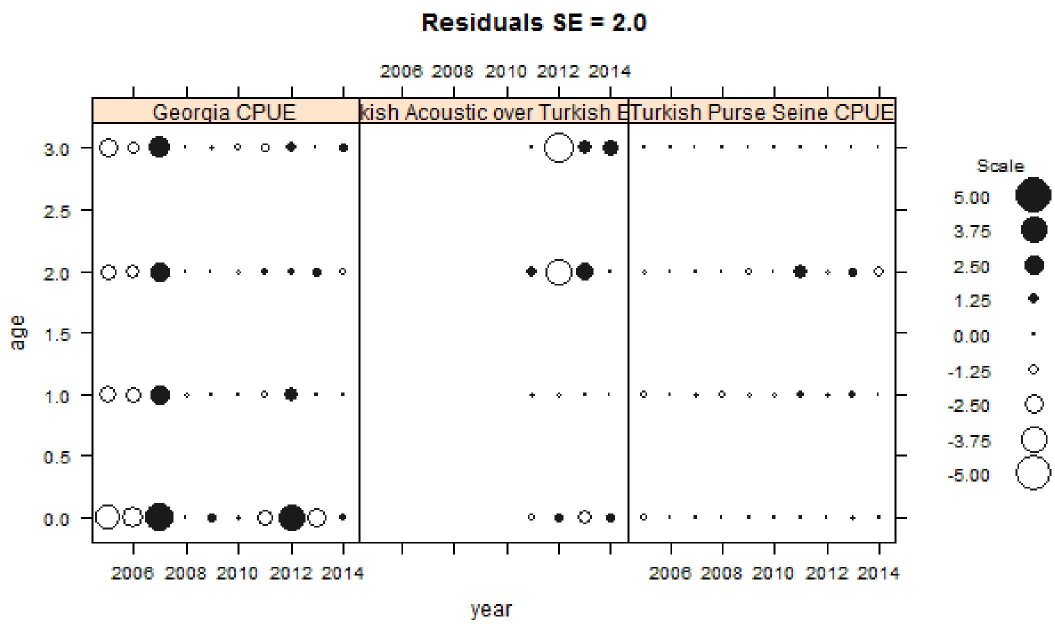
Residuals of the Tunings of Georgian CPUE, Turkish Acoustic over Turkish EEZ and Turkish Purse Seine CPUE with fse=1.5 and 0.5 shrinkage



Residuals of the Tunings of Georgian CPUE, Turkish Acoustic over Turkish EEZ and Turkish Purse Seine CPUE with fse=1.5 and 1.0 shrinkage.

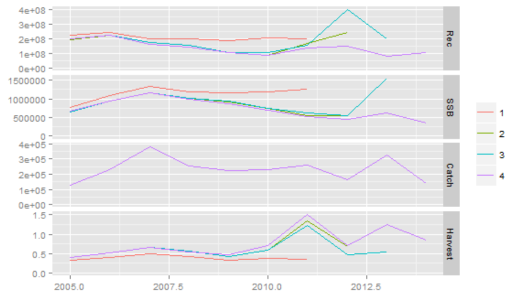


Residuals of the Tunings of Georgian CPUE, Turkish Acoustic over Turkish EEZ and Turkish Purse Seine CPUE with fse=1.5 and 1.5 shrinkage.

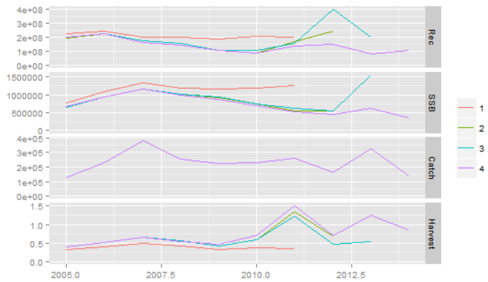


Residuals of the Tunings of Georgian CPUE, Turkish Acoustic over Turkish EEZ and Turkish Purse Seine CPUE with fse=1.5 and 2.0 shrinkage

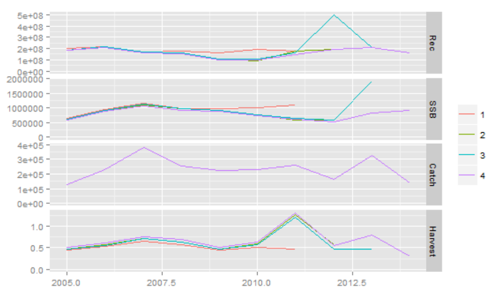
Retrospective Analysis



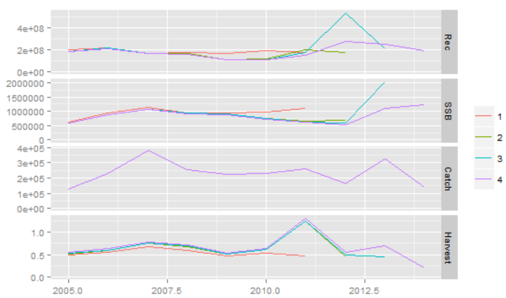
0.5



1.0



1.5



2.0

```
  “stock.n”(bsa.stk2)
An object of class "FLQuant"
 unit = unique, season = all, area = unique
    year
age      2005      2006      2007      2008      2009      2010
  0 178577148 205425040 156309628 154702960 101528471 100734559
  1  29916488  47339252  53826648  40542394  40520069  26346253
  2   6052852  10977514  15401588  13838481  14175593  13190427
  3   2952344   1564010   2423874   2656913   2398146   4150772
  4     35562    216377    267720    205676    176761    149237
   year
age      2011      2012      2013      2014
  0 143673307 298632655 255475557 198127939
  1  26340552  37697728  76751062  66985805
  2   8852149   6622455  10198935  23396942
  3   2698992    315037   1968516   1414769
  4    259074     83909    354645    243245
units:  NA

 “harvest”(bsa.stk2)
An object of class "FLQuant"
 unit = unique, season = all, area = unique
   year
age      2005      2006      2007      2008      2009      2010
  0 0.0076809 0.0193125 0.0294906 0.0197095 0.0290132 0.0213793
  1 0.1925608 0.3128692 0.5483155 0.2408265 0.3123061 0.2806658
  2 0.7932763 0.9504818 1.1973059 1.1927571 0.6682273 1.0266129
  3 0.7655673 0.7154359 0.7236217 0.8699024 0.7256186 0.6921720
  4 0.7655673 0.7154359 0.7236217 0.8699024 0.7256186 0.6921720
```

```
   year
age      2011      2012      2013      2014
  0 0.0179422 0.0386470 0.0186460 0.0143812
  1 0.5706435 0.4973165 0.3779619 0.1349189
  2 2.7757254 0.6531862 1.4153169 0.1834772
  3 0.6750881 0.6201550 0.3547072 0.2981764
  4 0.6750881 0.6201550 0.3547072 0.2981764

units:  f
> fbar(bsa.stk2)
An object of class "FLQuant"
, , unit = unique, season = all, area = unique
    year
age   2005     2006     2007     2008     2009     2010     2011     2012
2013    2014
  all  0.58380  0.65960  0.82308  0.76783  0.56872  0.66648  1.34049
0.59022 0.71600 0.20552
units:  f

> ssb(bsa.stk2)
An object of class "FLQuant"
, , unit = unique, season = all, area = unique
     year
age   2005     2006     2007     2008     2009     2010     2011     2012
2013    2014
  all   562890   851419  1048113   889906   857361   714427   606447
508329 1187786 1289349
units:  NA

> rec(bsa.stk2)
An object of class "FLQuant"
, , unit = unique, season = all, area = unique
   year
age 2005      2006      2007      2008      2009      2010      2011
2012
  0  178577148  205425040  156309628  154702960  101528471  100734559
143673307 298632655
   year
age 2013      2014
  0 255475557 198127939
units:  NA
```

	ssb	fbar	rec	catch	landings
2005	562890	0.5838	178577148	128477	128477
2006	851419	0.6596	205425040	229527	229527
2007	1048113	0.82308	156309628	383061	383061
2008	889906	0.76783	154702960	256682	256682
2009	857361	0.56872	101528471	225463	225463
2010	714427	0.66648	100734559	228944	228944
2011	606447	1.34049	143673307	257396	257396
2012	508329	0.59022	298632655	165964	165964
2013	1187786	0.716	255475557	326104	326104
2014	1289349	0.20552	198127939	137530	137530