EFFECT OF TEMPERATURE ON THE OCCURRENCE OF THREE MOST ABUNDANT SMALL PELAGIC FISH SPECIES IN THE SOUTHERN BLACK SEA

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ABSTRACT

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It is known that the temperature change in water resulted by the strength and direction of cold winds varying from year to year has an effect on the distribution of small pelagics which have yearly migration cycles in semi-closed systems such as Black Sea. However, how small pelagic species wintering in the southern Black Sea have adopted to this situation has not yet been elucidated. The aim of this study is to determine how the wintering distributions of three small pelagic fishes, Black Sea Anchovy (*Engraulis encrasicolus ponticus*), Mediterranean Horse Mackerel (*Trachurus mediterraneus*) and Sprat (*Sprattus sprattus*), dominant in the southern Black Sea region change in two different years with different cooling rate and direction from a rational point of view. To this end, the region between 28°E and 42°E longitudes of the southern Black Sea was examined to the limit of the exclusive economic zone. The surveys carried out in 2011 and 2016 was funded by TUBITAK (The Scientific and Technological Research Council of Turkey) for the project titled "Determination of Anchovy

Stocks in the Black Sea by Acoustic Method and Setting of Continuous Monitoring Model” within the scope of 1007 projects. Within the scope of these expeditions; CTD, trawl and acoustic data were collected simultaneously. Then, CTD data were analyzed for two separate years to determine the thermocline line and implied to the acoustic data. As a result of this process, the shapes of horse mackerel schools were determined and the structure (height, weight, energy distribution etc.) of these schools were quantified before separating the cold water species, sprat and warm water species, anchovy. For this procedure, schools verified as horse mackerel were used. The schools in the rest of data set were determined according to ranges of these parameters. Afterwards, horse mackerel schools were removed from the data set and the acoustic data which were divided into two separate layers were analyzed for anchovy and sprat. According to the results, all three small pelagic species settled in the wintering area due to cooling resulted from northern winds. In detail, while the adults of anchovy and horse mackerel, which are hot lovers, are mostly observed on the shore, juvenile individuals which have tolerance colder waters, of the same species and sprat were more intense in the open sea. Regarding the coastal zone, anchovy was observed in the eastern, and horse mackerel spread in the western part of the central and eastern parts of the southern Black Sea in 2011. This shows that cold water tolerance of the horse mackerel were more than anchovy in the year 2011. As a result of north-south cooling in 2016, anchovy was distributed in the west and about 10-fold less than that in the east which are probably came from north. Similar to the state of anchovy, horse mackerel was concentrated in the west in 2016. It was finally observed that sprat prefers open waters in winter and the density which is less on the coasts increases in colder regions.

Keywords: Small pelagic fishes, wintering distribution, cooling pattern, hydroacoustic survey, thermocline, Southern Black Sea.

ÖZ

GÜNEY KARADENİZ'DE EN YAYGIN BULUNAN ÜÇ KÜÇÜK PELAJİK BALIK TÜRÜNÜN BÖLGEDE BULUNMALARI ÜZERİNE SICAKLIĞIN ETKİSİ

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Yıldan yıla değişen soğuk rüzgarların gücü ve yönünden kaynaklı sudaki sıcaklık değişiminin yarı kapalı sistemlerde yıllık göç döngüleri olan olan küçük pelajiklerin dağılımı üzerinde etkili olduğu bilinmektedir. Fakat, Karadeniz'in güneyinde kışlayan küçük pelajik türlerin bu duruma nasıl uyum sağladıkları henüz tam olarak aydınlatılamamıştır. Bu çalışmanın amacı güney Karadeniz'de dominant olan 3 tür küçük pelajik balığın alandaki kışlama dağılımlarının soğuma hızı ve yönü farklı olan 2 ayrı yılda nasıl değiştiğinin rasyonel bakış açısıyla saptanmasıdır. Bu amaçla, Güney Karadeniz'in, 28 ve 42 derece doğu boylamları arasında kalan bölge münhasır ekonomik alan sınırına kadar incelenmiştir. TUBITAK'ın finanse ettiği, 1007 projeleri kapsamındaki Ulusal Balıkçılık Veri Toplama Programı için Karadeniz'de Hamsi Stoklarının Akustik Yöntem ile Belirlenmesi ve Sürekli İzleme Modelinin Oluşturulması adlı projenin 2011 ve 2016 yıllarında toplanan verileri kullanılmıştır. Bu seferler kapsamında; CTD, trol ve akustik verileri eş zamanlı olarak toplandı. Daha sonra CTD verisi termoklin hattının saptanmasına yönelik olarak iki ayrı yıl için analiz edilerek akustik verisine işlendi. Bu işlem sonucunda soğuk su sever bir tür olan çaça ile sıcak su sever hamsiyi ayırmadan önce istavrit sürülerinin şekli belirlenerek, bu sürülerin yapısı (yüksekliği, genişliği, enerji dağılımı vs.) analiz edilip sayısallaştırıldı. Bu işlem için, troll verisi ile istavrit olarak doğrulanan sürüler kullanıldı. Veri setinin geri kalanındaki sürüler bu parametrelerin aralıklarına göre saptandı. Daha sonra istavrit sürüleri veri setinden çıkartılarak dikey olarak iki ayrı tabakaya ayırılmış akustik verisi hamsi ve çaça için ayrı ayrı analiz edildi. Analizlerden çıkan sonuçlara göre, üç küçük pelajik türün de kuzey rüzgarlarından kaynaklı soğumaya bağlı olarak kışlama alanına yerleştikleri saptandı. Ayrıntılı olarak, sıcak sever olan hamsi ve istavritin yetişkinleri çoğunlukla kıyıda gözlenirken, daha soğuk sulara toleransı olan aynı türlerin genç bireyleri ve çaçanın açık denizde daha yoğun olduğu görüldü. Kıyı zonu özelinde ise, soğuma paterni ile ilişkili olarak, 2011 yılında hamsinin doğuda, istavritin ise Orta Karadeniz'in batısı ve Doğu Karadeniz'de yayıldığı gözlemlendi. Bu da istavritin, 2011 yılındaki koşullarda soğuk suya toleransının hamsiden fazla olduğunu göstermektedir. 2016'da ise kuzey-güney yönlü soğumanın sonucu olarak hamsinin çoğunlukla batıda olmasıyla birlikte bundan yaklaşık 10 kat daha az olacak şekilde, muhtemelen kuzeyden gelerek, doğuya da kışlamak için yerleştiği gözlemlenmiştir. Hamsinin durumuna benzer olarak istavritin de 2016 yılında batıda yoğunlaştığı görüldü. Çaçanın ise kış aylarında daha çok açık denizleri tercih ettiği, kıyılarda da az olan yoğunluğun soğuk bölgelerde arttığı gözlemlenmiştir.

Anahtar Kelimeler: Küçük pelajik balıklar, kışlama dağılımları, soğuma paterni, hidroakustik sörvey, termoklin, Güney Karadeniz.

To my beloved family

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1 INTRODUCTION

1.1 General Information about Black Sea

The Black Sea is one of the semi-enclosed seas that is connected to the Atlantic Ocean through narrow bosphorus systems with the Marmara, Aegean and Mediterranean seas (Shapiro, 2009). Because semi-enclosed areas are not affected by other seas too significantly, they are useful to observe how human activities affect bigger water masses such as oceans, which is why semi-enclosed seas should be extensively examined (Caddy, 1993)

Annual inflow of the Black Sea is roughly 1/66 of its total volume. Main water gains of the Black Sea are rivers, Azov Sea, Marmara Sea and rain (Table 1). Most of the nutrient-rich water flows into the Black Sea from rivers, such as, the Dnieper, Southern Buh, Dniester, and Danube, however, less so from the Azov Sea and rain. The northwestern part of the Black Sea is the most nutrient rich due to it being very shallow and fed by many rivers. Furthermore, the Black Sea loses the same amount of water from evaporation, flow of water into the Azov Sea and from the upper bosphorus current to the Marmara Sea. (Ivanov and Beverton, 1985)

Table 1: Freshwater balance of the Black Sea (km^3 per year). Adapted from Simonov AI and Altman EN (eds.) (1991) Hydrometeorology and Hydrochemistry of the Seas of the USSR: The Black Sea, issue 1, 449pp. St. Petersburg: Gidrometizdat. Table was taken from Black Sea Circulation / G. I. Shapiro, University of Plymouth, Plymouth, UK

Freshwater supply by rivers	338
Precipitation	238
Inflow from Marmara Sea	176
Inflow from the Sea of Azov	50
Evaporation	-396
Outflow into Marmara Sea	-371
Outflow into the Sea of Azov	-33

There are three main cyclonic gyres in the Black Sea Basin in the east, west and centre because of the configuration of the coast (Shapiro, 2009) (Figure 1). Many eddies which are located between the rim current and the coastline support mixing of coastal water with offshore. (Shapiro, 2009). The rim current encircles the whole Black Sea basin with a 15-25 km on average distance from the coastline. However, the distance between the rim current and coastline increases throughout summer due to lesser wind speed than in winter (Shapiro, 2009). There are three main eddies in Turkey Black Sea Coast near Sakarya, Sinop and Kızılırmak through the west-east direction (Figure 1). Thus, amphibiotic fishes especially small pelagics take shelter in these eddies in winter and prefers mainly the eastern part.

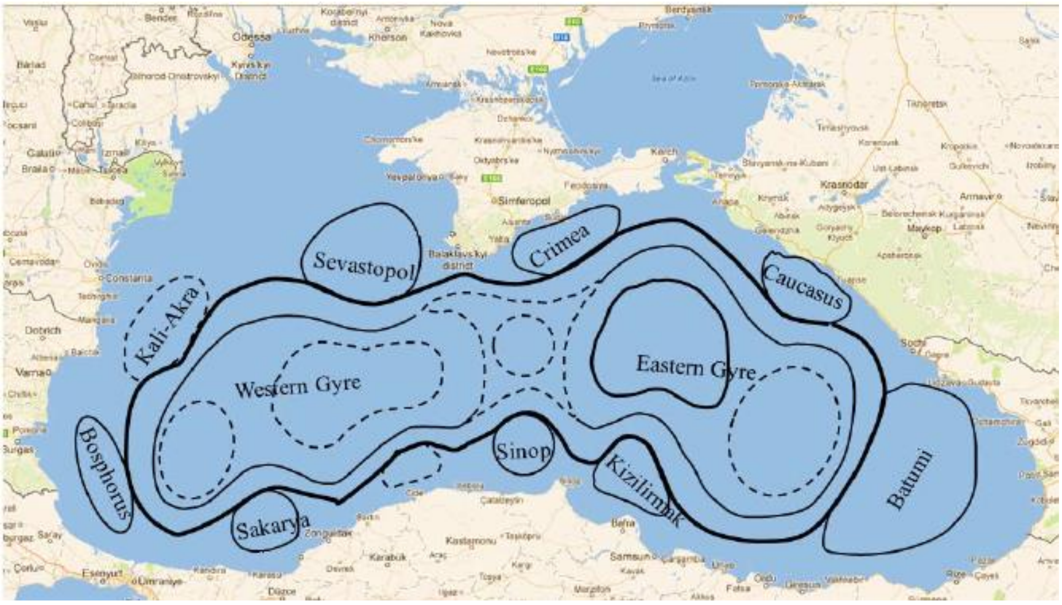


Figure 1: Schematic of the Black Sea surface circulation. The solid lines indicate recurrent features of the general circulation. (Evaluation of the Circulation Patterns in the Black Sea Using Remotely Sensed and in Situ Measurements - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/Schematic-of-the-Black-Sea-surface-circulation-The-solid-lines-indicate-recurrent_fig1_256485436 [accessed 18 Jun, 2019])

The velocity of water at the edge of gyres can reach up to 25-50 cm/s. It is well known that anchovy spawns the whole black sea and laid eggs are drifted by currents (Ivanov and Beverton, 1985). Thus, migration patterns of small pelagics, especially anchovy, and displacement of the eggs are strongly affected by main currents like gyres in the Black Sea.

The Black Sea differs from other semi-enclosed ecological systems with characteristic hydrological and hydrochemical features of its water column, composed of two defined strata. Upper stratum, between the surface and 150-200m in depth, is known as a productive zone and fed with nutrient rich water from land. The lower layer (below 150-200m in depth) which is composed of a poisonous gas, H_2S (Hydrogen sulphide), makes it an unproductive zone. In this layer, anaerobic bacteria reduce sulphates to hydrogen sulphide, producing bicarbonates. This makes the Black Sea water more alkaline as there is more sulphate and less bicarbonate ($CaCO_3$) than in the ocean.

Temperature varies from season to season in the Black Sea and change is most clearly seen in Autumn when mixing takes place in the upper 75m (Rozhdestvenski, 1960). The period of time when the upper water is at its warmest occurs at the end of Agust/beginning of September. During winter, the warmest places are off the Anatolia, Caucasus and Crimia, making them the best overwintering places for small pelagics (Rozhdestvenski, 1960).

Salinity in the Black Sea also varies from region to region. As an example, nearby to the bosphorus the water column consists of two layers; the upper layer, which consists of Black Sea water has a salinity of ~18.2 ppt, whereas the lower layer, consisting of Mediterranean Sea water, has a salinity of roughly 34.9 ppt (Ivanov and Beverton, 1985). At the central part of the Black Sea, salinity is ~18-18.5 ppt at the surface. At the northwest part, which consists of nutrient rich water, salinity drops down to about 13-15 ppt and lastly 16-17 ppt in coastal areas because of the river outflow. Also, salinity increases with depth mainly due to Mediterranean water coming from lower levels of the water column being incapable of mixing completely with the water of the Black Sea.

The most productive area in the Black Sea is its northwestern shelf because of the river input and shoaliness. For this reason, Black Sea Anchovy spawns mainly in this area and migrates to the southern part to overwinter. There are two main phytoplankton maxima which notably effect spatial distribution of small pelagics, one in spring and the other in summer.

1.1.1 Trophic Regulation of the Black Sea

From 1960s to 2000s, the ecosystem of the Black Sea was altered at least three times by environmental or human induced stressors, such as, overfishing, high temperature, too much nutrient loading and invasive species (Oğuz and Gilbert, 2007). When referring to this period of time, the Black Sea can be divided into four in terms of its trophic state.

The Black Sea's 1960s ecosystem is dubbed as healthy mesotrophic, meaning that the flora and fauna were much more diverse than its current state (Oğuz et.al, 2012). For example, there were many fish species including small pelagics such as Black Sea Anchovy (*Engraulis encrasicolus ponticus*), Black Sea Horse Mackerel (*Trachurus mediterraneus*) and Black Sea Sprat (*Sprattus sprattus*), piscivorous pelagics such as Atlantic Bonito (*Sarda sarda*), Bluefish (*Pomatomus saltator*) and Atlantic Mackerel (*Scomber scombrus*), large demersal species such as Turbot (*Psetta maxima*), Black Sea Striped Mullet (*Mullus barbatus ponticus*), Spiny Dogfish (*Squalis acanthias*) and Black Sea Whiting (*Merlongius merlangus euxinus*). In addition, marine mammal species like Short-baked Common Dolphin (*Delphinus delphis*), Bottlenose Dolphin (*Tursiops trunchatus*), Harbour Porpoise (*Phocoena phocoena*) in Black Sea were much more abundant .

In the period of 1970s and 1980s, the stocks of piscivorous fishes and marine mammals was overexploited (Daskalov, 2002). Additionally, primary and secondary production increased abruptly as a consequence of nutrient outflow by the rivers mainly into the northwestern shelf where the nursery ground of juvenile Black Sea Anchovy is situated (Velikova et. al., 2005). Afterwards small pelagics and *Aurelia aurita* became dominant in the system, possibly because of these two abrupt changes, overexploitation and increasing nutrient input into the Black Sea. Thus, annual landing of the small pelagics had its highest peak with 700 kt at the end of the 1980s. In addition to this, because of the abrupt increasing in primary production, hypoxia of the shelf zone appeared which harmed benthic flora, fauna and demersal fish species significantly (Zaitsev, 1992; Zaitsev and Mamaev, 1998; Mee, 2006).

At the beginning of the 1980s, an invasive jellyfish, *Mnemiopsis leidyi*, was carried into the Black Sea with ballast water. In 1989, *M. leidyi* biomass exploded and small pelagic species' biomass, especially anchovy, decreased by a significant amount (Oğuz and Gilbert, 2007). Consequently, the amount of landed small pelagics like anchovy decreased by 75% within a year (Oğuz and Gilbert, 2007). In the following years, with the introduction of *Borea ovata*, which is a natural predator of *M. leidyi*, landing of the small pelagics started to increase to roughly 50% of that caught at the end of the 80s. In addition to this, the period between 1985-1993 is known as a climatic cooling period because of the cooler and severe winter conditions. This was important as the cooler winter winds helps to mix detritus along the water column which makes it available for efficient consumption by primary producers. Because of this, intense production, even eutrophication, took place in the Black Sea in spring and summer between 1985 and 1993. This case was also supported by the model simulations. (Oğuz et.al, 1999; Tian et.al, 2003)

After 1994, the Black Sea ecosystem started to recover itself. With increased landing of anchovy, the beginning of the recovery period of the Black Sea, at least for the Turkish coasts, has begun by diminishing antropogenic effect as a result of stricter laws and the awareness raising effort for fishermen. In addition to this, contrary to the situation between the 83-94 period, the temperature of the sea surface in winter increased about 2 degrees between 1993 and 2000 (Oğuz et.al., 2006). 1994-2000s period is known as the post eutrophication phase although the situation in the North Western shelf and western part of the Black Sea remained the same.

1.2 Hydroacoustic Method

Hydroacoustics are defined as systems that work by using the properties of acoustic waves in water medium. The speed of sound is 1500 m/s in neutral water and once generated, weakens due to friction caused by vibratory water molecules. In denser water, the speed of sound increases, but because the friction will be greater, the sound cannot spread as far as in neutral water. Echosounder systems take this frictional effect into account in the data acquisition section. Low (<18 kHz) or high (>200kHz) sound frequencies can be applied to hydroacoustic surveys according to the purpose. For open water systems, 38 kHz frequency is widely accepted by many countries that share the Black Sea and Mediterranean Sea to investigate small pelagic species. Also, hydroacoustic systems can be set as active or passive. In active systems a sound is generated and the echo is given by the transducer, whereas the sound from marine environments is just listened without generating any sound in passive systems. Passive systems are generally applied for investigation of marine mammals which generate a decent volume of sound for the reciever.

Hydroacoustic techniques have been in development for more than 50 years with many different methods emerging depending on the purpose of examination. In addition to being preferred primarily for the calculation of abundance and biomass of living organisms like fish and phytoplankton; such as side scan sonar which is favorable if the fish aggregations are near the surface zone, acoustic systems can be used to monitor the horizontal and vertical migration of schools or to calculate the migration speed of forage fish species (Makris, 2006). Moreover, because they were originally sonar systems, they can be used to characterize the variations in the bottom topography including sediment type or structure with high resolution data. It can also be applied to typical trawl surveys with less search and sampling effort (Makris, 2006).

Echosounders are common devices that are applied for hydroacoustic systems (Klemas, 2013). They can be divided into three in terms of their detection characteristics of the target; single, split and multi-beam. Single and split-beam systems generate one beam while multi-beam systems generate many beams with different frequencies in one go. This feature of multi-beam systems allow a 3-D inspection of the water column, however, because they are not cost-effective and difficult to sustain, they are not preferred for fisheries sciences. Apart from being very similar, split and single-beam echosounders are separated from each other at the detection ability of the target. Both generate one pulse at a time but the more advanced system, split-beam echo sounders, can precisely detect the location of the target under water with its four section piezo-ceramic plates, while the single beam echo sounders can only indicate whether the target is present in a beam (Simmonds and MacLennan, 2005). Furthermore, split beam echosounders can obtain different fish species school shapes quantitatively (Simmonds and MacLennan, 2005). Split beam echosounder systems are generally used for scientific purposes and can be adapted to seas, lakes or rivers (Simmonds and MacLennan, 2005). For instance, in river estuaries they can be attached to the buoys to monitor the migration of anadromous fish horizontally, vertically or to the vessels to investigate enclosed, semi-enclosed and open water systems.

For the purposes of this thesis, acoustic data that includes the three main small pelagic fish species (Black Sea Anchovy, horse mackeral and sprat) were analysed separately with the split-beam echosounder and the fishes were monitored throughout both surveys for the years 2011 and 2016.

1.3 Ecological Importance of Pelagic Fish Groups

For marine ecosystems, from oceans to semi enclosed marine systems, mainly three types of trophic control mechanisms called Bottom-Up, Top-Down and Wasp-Waist are defined in terms of the predator-prey relationships (Cury, 2000; Shannon, 2000). In bottom-up control mechanisms, the system is mainly controlled by sources such as detritus and phytoplankton (Lynam et.al., 2016). In top-down mechanism, the system is controlled by top predators like dolphins, piscivorous large fishes etc. Lastly, the wasp-waist mechanism includes both types of control mechanisms, meaning that the system is top-down controlled of zooplankton by planktivorous fish and bottom-up control of top predators like piscivorous fish by small pelagics (Shannon, 2000). Very different regions in the world may have similar control mechanisms. While the control mechanisms for the Black Sea, South Africa, Ghana and Japan is top-down control of zooplankton; Benguela, Guine, Humbolt currents are controlled by bottom-up mechanisms. (Cury, 2000) In addition to these, trophic regulation of the marine systems can be altered in a decadal scale or in a period less than that because of the external effects such as those for the Black Sea mentioned in section 1.1.1. Marine ecosystems can surpass external forces which arise from intrusive human activities or environmental factors like successive cooling/warming to some extent. Naturally, none of the systems' variables (many species that belong to different trophic levels) are absolutely stable. Small pelagics can respond to external effects better than higher trophic levels because of their recruitment success. Additionally, depletion in recruitment of small pelagics causes severe damage to the ecosystem. Ecosystems generally tend to fluctuate due to the environmental conditions or internal triggers, termed as the quasi-stable condition of the system (Oğuz et. al., 2006). However, if the external forces exceed limits, the regime of the system as well as the trophic regulation is altered. This change can reach to the point of no return or to a new but unhealthy state. This abrupt alteration of the control mechanism in the system is called Regime Shift. The Black Sea is an example of strong ecological regime shift events. The first author to bring regime shift concept to the Black Sea is Niermann et.al. (1999). According to this author, the primary cause of regime shift is due to the North Atlantic Oscillation. However, this concept was improved with the examination of various other researchers at a later date (Gücü, 2002; Yunev et.al., 2007; Staneva et.al., 2010; Akoglu et.al., 2014).

In the early 1960s, the Black Sea was known as one of the Top-Down controlled period in the World Marine Ecosystems with features such as low phytoplankton standing stock biomass, high zooplankton standing stock, low stocks of small pelagic fish and relatively high stocks of large pelagic predator fish (Oğuz, 2006) In this order, even if there are various amounts of zooplankton to consume by small pelagics, its biomass is essentially controlled by predatory piscivorous fishes. This scheme lasted untill 1973. After this period, a new top-down controlled structure period began. Because of the mass exploitation of large piscivorous fishes, phytoplankton and small pelagics standing stock biomasses doubled as well as forage zooplankton biomass decreasing by half. In this new top-down mechanism, small pelagics, mainly anchovy, dominated the system for more than ten years and consumed half of the zooplankton standing stock biomass.

Competition is one of the factors altering trophic state of a system. In any trophic regulations, small pelagic fishes are very important for the ecosystem because they play the key role as a buffer for higher and lower trophic levels. (Shannon, 2000) In upwelling systems, fish biomass tends to be dominated by one or two pelagic species, such as sprat and anchovy for the Black Sea. However, because each one prefers different habitats due to their temperature and feeding habits, one does not generally occupy the habitat of the other (Van der lingen, 1994). Thus, they are controlled by separate intraspecific competition mechanisms. (Serra et.al, 1998) However, the relation between horse mackerel and anchovy is different from than that of anchovy and sprat.

1.4 Different Pelagic Fish Stocks and Their Fishing Management in Black Sea

According to the Food and Agriculture Organization of the United Nations (FAO) the estimated harvested fish volume is about 80 million tons globally (without discards) and 80% of fish stocks worldwide are overexploited. Small pelagic fish rate in landing is about 30% of the total volume. For the last 40 years, after the depletion of piscivorous fish stocks in the 80s, almost all fishery was done on small pelagics. There are many commercially important fish stocks in the Black Sea (anchovy, horse mackerel, bonito, sprat, whiting, turbot etc.) shared by six countries; Bulgaria, Georgia, Russian Federation, Romania, Ukraine, Turkey. Out of the six Black Sea countries, Turkey has the most powerful fishing fleet. For example, it constituted 48% of all purse seine and trawl boats in the Black Sea basin in the year 2008 (FAO,2010). In 2008, the largest amount (roughly 48.13%) of fish had been harvested by Turkey, followed by Ukraine (32.70%), Russia (10.08%), Georgia (4.14%),Romania (2.78%) and Bulgaria (2.17%) (FAO,2010). Even if the catch rates only show the 2008 landings, it is relatively similar for other years, with two exceptions in the 2005/2006 and 2009/2010 fishing seasons.

Approximately twenty pelagic fish species are commercially valuable in Turkish Seas (Mediterranean Sea, Black Sea, Marmara Sea and Aegean Sea) (Tokaç et.al., 2012). Between these, the Black Sea is the most productive, with a landing of 65% of all fish caught. Furthermore, small Pelagics form 71% of total catch in the Black Sea (Tokaç et.al., 2012)

The analysis conducted in this thesis focuses mainly on three pelagic fish stocks; Black Sea anchovy (BSa), sprat and horse mackerel, with the priority being the BSa and its fishing management. To gauge their current stock state, it is important to first and foremost have an understanding of their ecological behavior and the fishing management implemented.

1.4.1 Anchovy

Anchovy is represented by two different stocks in the Black Sea; Black Sea Anchovy (*Engraulis encrasicolus ponticus*, Aleksandrov), which prefers the Black Sea to spawn and Turkish coasts to overwinter, and the Azov Sea Anchovy (*Engraulis encrasicolus maeticus*, Pusanov), which prefers the Azov Sea to spawn and the Black Sea in Crimean and Georgian coasts for overwintering. In addition to this, a known hybrid type from these sub-species is defined by Chaschin (1996) mainly originate from Crimean coasts. The Engraulids, to which both belong, is a family that make up most captured fish worldwide. Engraulids live in all tropical and sub-tropical marine ecosystems but their preferable area to shoal is in coastal zones. They have a 3-4 years lifespan. While the Azov Sea anchovy can grow up to 15 cm (Slastenenko, 1955/1956), the Black Sea Anchovy can grow in a range of 18-20 cm (Slastenenko, 1955/1956; Fischer, 1973).

With regards to temperature, the BSa is more adapted to warmer waters than the Azov Anchovy and therefore migrates further south as a response to seasonal temperature changes. They spawn in summer mainly in the coastal zone and migrate from the north, where they utilize the very productive waters of the basin for foraging and reproduction, to south, which is warmer in winter (Ivanov and Beverton, 1985). They start to migrate south in Autumn. Besides this general behavior, they follow different migration routes. There are many factors influencing the migration routes; the “food supply” indicates the quality and amount of the food for a species (anchovy), temperature of the sea surface affecting their nutritional condition and thereby their spatial distribution (Shulman and Love, 1999), the direction of winds effecting currents. Northerly cold winds in autmn trigger the migration of both species, Azov and Black Sea anchovies. Nutritional condition is defined as a value of fat content of a fish and therefore can be used to estimate possible different migration routes chosen by fish. For example, fat reservoir of anchovy that landed on Turkey coasts was lower than that of Chrimia in 2005/2006 and 2009/2010 fishing seasons (FAO, 2011). The lipid content of individuals was relatively lower than the values of other years in these seasons (Nikolsky et.al., 2012). Moreover, the SST (Sea Surface Temperature) of the Turkish coasts was about two degrees less than that of Chrimia coasts, explaining why Anchovy overwintered in Chrimia coasts rather than Turkish coasts during 2005/2006 and 2009/2010 fishing seasons. This situation reveals that the SST affects fat content of a fish, its nutritional condition and subsequently the migration pattern of a fish. One group of anchovies, especially those that have been foraging at the most northwestern shelf of the Black Sea since their birth, migrate from north to south through the Romania and Bulgaria coasts. Once they reach the western part of the Turkey coast, they continue their journey from west to east. The other group living predominantly in the northeastern shelf of the Black Sea migrate directly from the middle of the Black Sea- possibly due to the sharp decline of SST caused by Northerly winds.

During the overwintering period, when anchovy form dense schools, fishing is carried out in Turkish Black Sea coasts through purse seine and pelagic trawl. Most fish caught during that period are consumed fresh, but some are bought by fish meat and oil factories. Black Sea Anchovy forms 85% of the total pelagic fish landed in Turkey.

1.4.2 Horse Mackerel

The Carangidae family is represented by two species in the Black Sea: Trachurus trachurus, which mostly inhabits the Marmara Sea, and Trachurus mediterraneus ponticus, (Aleev and Yu, 1957, 1959) which is more abundant and commercially important in the Black Sea. There are occasional records showing that Trachurus trachurus enter the Black Sea from the sea of Marmara, albeit very rarely (Stoyanov et.al., 1963).

The number of horse mackerel populations in the Black Sea has been a highly debated issue for fish and fishery researchers, with some claiming there is only one while others claim there are as many as four. For example, according to Aleev and Yu (1957, 1959) four main subpopulations are present. They are defined by different biological characteristics, such as, choice of wintering, spawning or foraging area, fecundity, feeding habit etc. and take place in south western (Bishopric), northern (Chrimia), eastern (Caucasian) and southern (Anatolian) parts of the Black Sea.

On the other hand, According to Altukhov and Apeken (1963) and Altukhov and Michalev (1964), the Black Sea consists of small (<22cm) and large (>22cm) horse mackerel individuals which should be considered as two different subspecies. Georgiev and Kolarov (1962) and Schulman (1972) also defined two subpopulations in the Black Sea according to their biological characteristics. These two groups can be separated from each other in terms of their growth rate, (Ivanov L. and Beverton, 1985) as well as age of sexual maturity. While small type reaches it at the age of two (Georgiev and Kolarov, 1962), large type reaches its sexual maturity at 3-4 years old (Ivanov and Beverton, 1985).

In addition to these two converse views, some researchers (Kosswig, 1955; Numann, 1956 and Shaverdashvili, 1976) have argued that the Black Sea horse mackerel is a singular stock within the whole basin. According to Shaverdashvili, the “small type” can turn into the “large type” following a thriving anchovy recruitment season.

Trachurus mediterraneus ponticus originated from the mediterranean and is known as the summer spawning fish (Maximov, 1914). Their spawning rate increases between the second half of may and the first half of august and lasts untill september (Ivanov and Beverton, 1985; Demirel and Yüksek, 2012), with an average fertility of 10 000 eggs at once (Demirel and Yüksek, 2012). They lay more than 10 batches in a year (Owen, 1979). They spawn near the water surface of the open sea or into the Marmara Sea where pelagic eggs are then drifted by currents (Daskalov, 1999; Demirel and Yüksek, 2012). Their overwintering areas are the Crimea coast (20-90m in depth), the Caucasus (20-60m in depth), Anatolia and Marmara Sea. After the overwintering period, the spring migration begins at the beginning of May. Individuals which settled in Crimea during the winter go northwest through the Bulgarian and Romanian coasts and from Caucasus and Anatolia to the area off the Strait of Crimea (Ivanov and Beverton, 1985).

Although their main diet is crustaceans (Cabral and Murta, 2002), they also feed on fish larvae, especially that of sprat and anchovy (Stoyanov, 1963; Yankova et.al., 2008) depending on the size of fish. Young individuals mainly eats zooplankton (Yankova et.al., 2008).

The commercial catch of horse mackerel is done with either active or passive methods. While Romania and Bulgaria prefers passive techniques, e.g. trap nets, Turkey and Former USSR prefers active methods, including demersal trawl (Erdem, 2000) and purse seine (Prodanov et.al., 1997). In Turkey, Horse mackerel fishery is done over winter in their overwintering grounds while they are in a more stable and dense state.

The stock state of the horse mackerel has changed dramatically from year to year and has experienced two major depletions. One in the year 1959 (Ivanov and Beverton, 1985) and the other in 1990 (Ak, 2012; Anonymus, 1982-2010). The commercial purpose of netting small type horse mackerel started in 1953 by former USSR (Revina and Saf'janova, 1966). Six years after that, in 1959, the large type horse mackerel population rapidly decreased, almost disappearing from the whole Black Sea basin except for a few small clusters off Anatolia. In 1990, right after the depletion of Anchovy stocks in Anatolia, horse mackerel stocks rapidly decreased once more (Ak, 2012). Although the catch of horse mackerel shows great variation from year to year, the mean catch was calculated as 102 146 tonnes between 1983 and 1990. In 1991, it decreased rapidly to 33 848 tonnes and dropped to its minimum of 13 220 tons in 1999 (Ak, 2012).

1.4.3 Sprat

The European Sprat (Sprattus sprattus), belonging to the clupeids, is one of the boreal (prefers cold water) species which is originated from Atlantic (Ivanov and Beverton, 1985). They can live in a wide range, 8-18°C but generally prefers cold water layer under thermocline (Cautis,1958). Juvenile individuals generally live in warmer upper layers (Ivanov and Beverton, 1985). They migrate from open sea to the coast in spring to forage and vice versa during autumn-winter to spawn as a response to fluctuant water temperatures (Ivanov and Beverton, 1985). Although sprat does not show different diel vertical migration (DVM) patterns compared to other pelagic species, adult individuals scarcely go above the thermocline, especially in spring and autumn (Tserkova, 2013). Sprat feed a significant amount in spring, while in coastal areas, in order to store fat to use throughout the spawning period in autumn, off the coast (Iles and Wood, 1965). Sprat schools are mainly concentrated in the seas covering the European continent including North Sea, Adriatic Sea, Mediterranean Sea, Black Sea and Baltic Sea (Avşar, 1994; Limborg, 2009). Although there are a few different characteristics like life span and size (Prodanov et.al., 1997), different population parameters or nutritional condition (Stoyanov, 1965; Ivanov, 1983) between Adriatic, Mediterranean and Black Sea sprat stocks, there is a lack of genetic studies to confirm multiple stocks. Also, Avşar (1993) indicated that, individuals which live in the Turkey Black Sea coast belong to a single stock.

Although morphological characteristics of sprat vary temporarily and spatially, they start to develop their gonads at a total length of 95-100mm (De Silva, 1973; Peck, 2012) and reach sexual maturity at the age of one (Ivanov and Beverton, 1985). Their reproduction proceeds the most between november and march (Aslanova, 1954; Stoyanov, 1960, 1965, 1966; Cautis, 1971; Dehnik, 1973) while they are in open seas. Temperature is a main environmental factor which affects growth rate, offspring and life continuity of individuals (Grauman and Yula, 1989; Parmanne, 1994). Sprat reproduces water temperature ranging between 6 and 12 °C and need at least 5-6 psu salinity (Elwertowski, 1957; Ojaveer, 2009). Also, decrease in sea surface temperature increases the breeding success of sprat (Daskalov, 1999). Their fecundity can be 20 000 eggs on average in a year (Owen, 1979). The depth that contains the maximum concentration of eggs lies between 30-80 m in general (Ivanov and Beverton, 1985) or 80-110 m in Baltic (Hessle, 1927; Grauman, 1980), possibly depending on the environmental features. In addition to having a shorter life and size in the Black Sea (Prodanov et.al., 1997), sprat individuals have an average lifespan of 5 years and can reach 16 cm (Bailey, 1980).

The general diet of sprat is composed of zooplankton and copepods (Kaartvedt, 2009; Solberg, 2015), with an extreme consuming after reproduction time of the sprat (Lipskaja, 1960). Sprat is the very abundant prey of piscivorous fish (horse mackerel, bluefish, bonito and whiting) and marine mammals in the Black Sea. Specifically, bottlenose dolphins (*Phocoena phocoena*) which inhabit the Northern Black Sea coast predates sprat in winter when their schools are in the coast (Bushuev and Savusin, 2004; Gladilina, 2014). Also, according to Tonay (2007), a study conducted between spring and early summer of 2002/2003, showed that 42 harbour porpoises bycaught or stranded in the Turkish western Black Sea coast, had a significantly high 64.1% sprat in their stomach content.

For this reason, sprat is a critical link between apex predators and secondary production and it stands in the middle of the trophic cascade. With useful meritic characteristics like high individual growth rate, long reproduction time, short juvenile period, sprat can respond to sudden environmental changes and excessive predator pressure (Prodanov et.al., 1997).

Untill the 1970s, before the development of fishing gears, commercial fishing was carried out by traps and coastal nets. At the beginning of the 1970s, Bulgarians; in 1976, USSR; and after 1979, Romanian fishermen started to use trawl nets for commercially important pelagic and bathypelagic fish species (Ivanov and Beverton, 1985). After 1976, an exponential increase in the number of landed sprat was observed, from 10.4 thousand tonnes in 1976 to 96 thousand tonnes in 1981 with the head of former USSR. From 1981 to 1988, sprat catch flactuated in a range between 40.9 and 79.6 thousand tonnes and reached its maximum in 1989 with 105.2 thousand tonnes landing. In 1990, sprat catch decreased to half the amount of the year before, and in 1993, it further decreased to 13.8 thousand tonnes, making it the lowest in the last 15 years (FAO, 1997). The abrupt decrease in 1989 can be explained by the mnemiopsis explosion in the same year. From 1993 to 2006, the decreasing trend was not altered and sprat landing stayed under 10 thousand tonnes (TUIK, 2010). In 2008, sprat stock recovered and catch increased once more to 50 thousand tonnes (TUIK, 2010).

Today, sprat is the second most important fish species for midwater trawlers and partly purse seiners in the Black Sea according to STECF report in 2015. European Sprat accounts for more than 50 % of all landed fish, mainly by pelagic trawlers in the Western Black Sea (Todorova et.al., 2019).

In all Black Sea basin, sprat is caught mainly in the north western part (Tserkova, 2013). Although a fishing ban is implemented throughout April and May in Turkey, ships are allowed to fish for sprat (Kalaycı et. al, 2006). Therefore, most of the sprat catch is carried out in close proximity to Samsun, Turkey between April and May by midwater trawlers (Samsun et.al, 2006). Although there is no confidential source of the amount of sprat landed in the Black Sea before 1993, it is clearly indicated that sprat was mostly caught in Turkey Black Sea coasts after 1993 (TUIK, 2010).

1.5 Scope of the Study

Due to the fact that the Black Sea is a closed sea, there are high environmental changes occurring during the year. Surface water temperatures rise up to 30 degrees in summer, while in the winter the waters freeze in the north. This situation requires small pelagic fishes to move constantly. In the summer, when the conditions are favorable, fishes are scattered all over the basin. In the winter, they migrate in groups to the south where the temperatures are the highest. This is advantageous in terms of fishery. Fish migrating to the over-wintering grounds and forming dense and large aggregations can be harvested easily. However, the same situation led to an increase in the fishing pressure on stocks following the increase in fishing power of the fleet. Anchovy, which used to be fished up to 6 months in the 1980s and 1990s, are being removed from the stock very fast in the last years. More than 90% of the anchovy caught within a year is harvested within 1 or 2 months (Gücü et al., 2017). This situation also imposed an important drawback on the acoustic surveys conducted to estimate the anchovy stock size. It is seen that past acoustic studies conducted in the Black Sea have been carried out in the winter months following the anchovy settlement in the wintering area by Losse and Johanesson in 1972 and Bingel and Gücü in 90s. Considering the over-wintering behaviour of anchovy in the Black Sea, this approach has remarkable adventages as the fish, which are distributed all over the Black Sea is forced to aggregated in a small fraction of the basin.

However, the fact that the fish is taken from the stock very rapidly causes a part of the fish to be inaccessible in the acoustic studies conducted in the same period. This is usually corrected by adding the amount of fish caught until the survey date to the biomass estimated acoustically (Chashchin, 1996). The questionable assumption here is whether or not, the fish always displays the same behavioral pattern. In this study, acoustic data collected in two different years were analyzed and the effects of changes in fish behavior on the results of acoustic studies were investigated.

The data was collected with the support of TUBITAK (The Scientific and Technological Research Council of Turkey) 1007 projects named “Ulusal Balıkçılık Veri Toplama Programı İçin Karadeniz’de Hamsi Stoklarının Akustik Yöntem ile Belirlenmesi ve Sürekli İzleme Modelinin Oluşturulması” (Determination of Anchovy Stocks in the Black Sea by Acoustic Method and Setting of Continuous Monitoring Model). As a subtask, acoustic data was postprocessed and classified in terms of three different target species. The latter was done by using specific temperature preference and school shapes of the concerned species. Also, differences between the method applied in 2011 and 2016 were discussed.

2 MATERIAL AND METHODS

The work done within the scope of this thesis is based on the data collected during the acoustic-trawl surveys were carried out by the vessel, R/V Bilim 2 in 2011 and 2016. During the surveys active hydro acoustic data were recorded. Besides, midwater trawl hauls and CTD samplings were done to support and sort out the hydro acoustic recordings. The dimensions of R/V Bilim 2 are: 41m long, 9.4m wide, 4.3m water level and 421 gross tons. The speed of the vessel througout the cruise was between 8 nmi and 10 nmi.

2.1 Survey Design

The Black Sea basin has two different stocks of anchovy; Black Sea Anchovy (Engraulis *encrasicolus ponticus*) and Azov Sea Anchovy (Engraulis *encrasicolus maeticus*). Even if they are two different stocks, the trigger of horizontal migration of both is temperature (Ivanov and Beverton, 1985; Chaschin, 1996). As the temperature decreases at the end of summer-beginning of autmn, both start to migrate from north to south. Azov Anchovy goes into the Black Sea through the Kerch Strait and Black Sea Anchovy follows the western shoreline of the Black Sea. At the beginning of the winter, November-December, Black Sea Anchovy enters to the Turkish Black Sea coasts on the purpose of overwintering. The Black Sea Anchovy goes directly to its main wintering ground, situated on the eastern Turkish Black Sea coasts (Chashchin, 1996). Afterwards, it settles there parallel to the shoreline and becomes target of an intense fishery by the Turkish purse seine fleet. The surveys were therefore conducted in winter in order to detect the overwintering schools. Two winter acoustic surveys targeting the overwintering anchovy stocks were carried out in 2011 (28th November-20th December) and 2016 (02-27 November).

The purpose of 2011 survey was to gain more information which are detecting areas of main aggregations and the magnitute of volume backscattering levels of overwintering anchovy stocks along the Turkish Black Sea coasts.

Within this framework, systematic parallel transects were arranged perpendicular to the coast covering the continental shelf from west İğneada (28°E) to east Hopa (41.5°E) (Figure 2). The depth range of the survey was 0-100 m, shelf zone. The transects with 8 nmi inter-transect distance were conducted. Also, the spacing between transects were arranged with regard to the migration pace of the anchovy and the spatial extent of the continental shelf (200m depth).

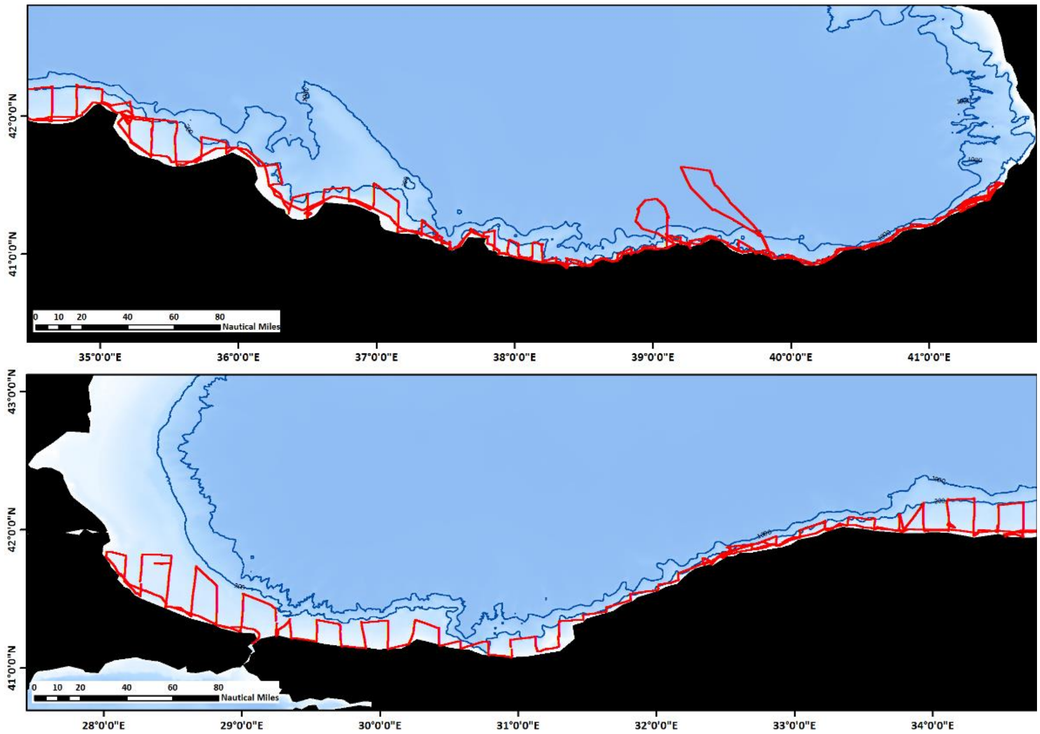


Figure 2: Transects studied on the 2011 survey. Up; east part of the survey. Down; west part of the survey. Upper and lower contours show 1000m and 200m depths respectively.

Based on the experiences from the 2011, survey design was modified in 2016 in a way to cover the majority of the Anchovy stocks. The survey was carried out in two steps. The first step that includes acoustic transects covered the offshore sections beyond the continental slope (>100m depth), along west-east direction (Figure 3-Top); hereafter named “offshore survey”. The second was carried out from east to west with higher intensity transects while not exceeding the continental shelf (Figure 3-Bottom), hereafter named “coastal survey”.

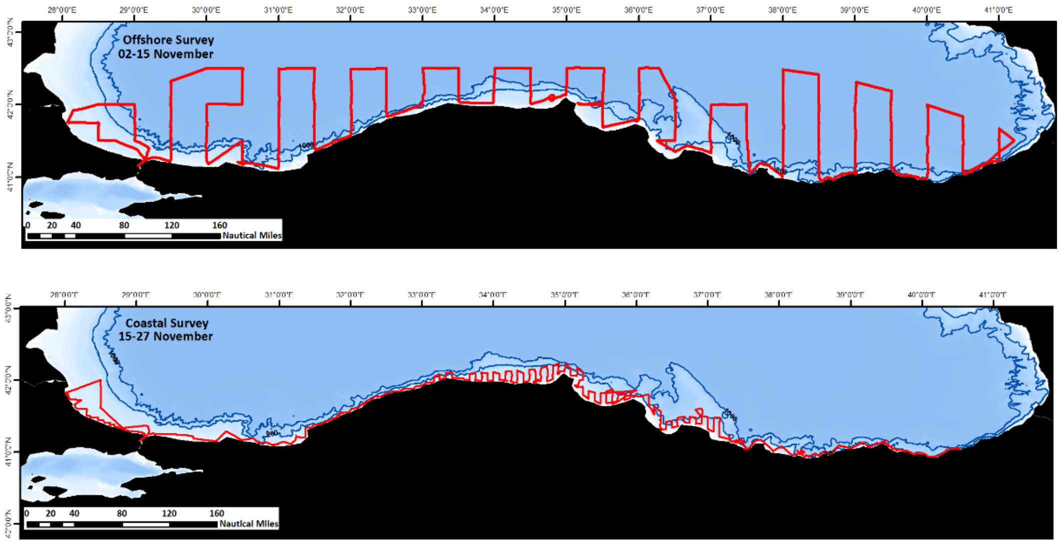


Figure 3: The route of survey for offshore (up) and coastal (down) in 2016

Normally, for the acoustic survey of small pelagic fish stocks, it is suggested to collect data only during the day or night time to decrease bias in the acoustic biomass calculation due to the behaviour, e.g diel vertical migration. Diel vertical migration of fish stocks were studied extensively on oceanodromous species especially small pelagics (Robinson et.al., 1995; Bertrand et al., 2008; Tsagarakis et.al., 2012). Most of the small pelagic fishes including Anchovy, tend to aggregate closer to the bottom, not exceeding the thermocline, under daylight through the water column. At night, they go up in the water column and disperse (Tsagarakis et.al., 2012). Even if the hydroacoustic data were collected just during the day in 2011, according to the hydro acoustic observations in 2016, adult anchovies with their very dense overwintering aggregations in continental shelf do not disperse even at night. As a result of the experimented area in 2011, it was enlarged in 2016 and acoustic data were collected during the day and night throughout the survey.

Mid-water trawl sampling was done in accordance with the acoustic monitoring. In this direction, 61 and 39 mid-water trawl samples were done along the 2011 and 2016 surveys (Figure 4-5).

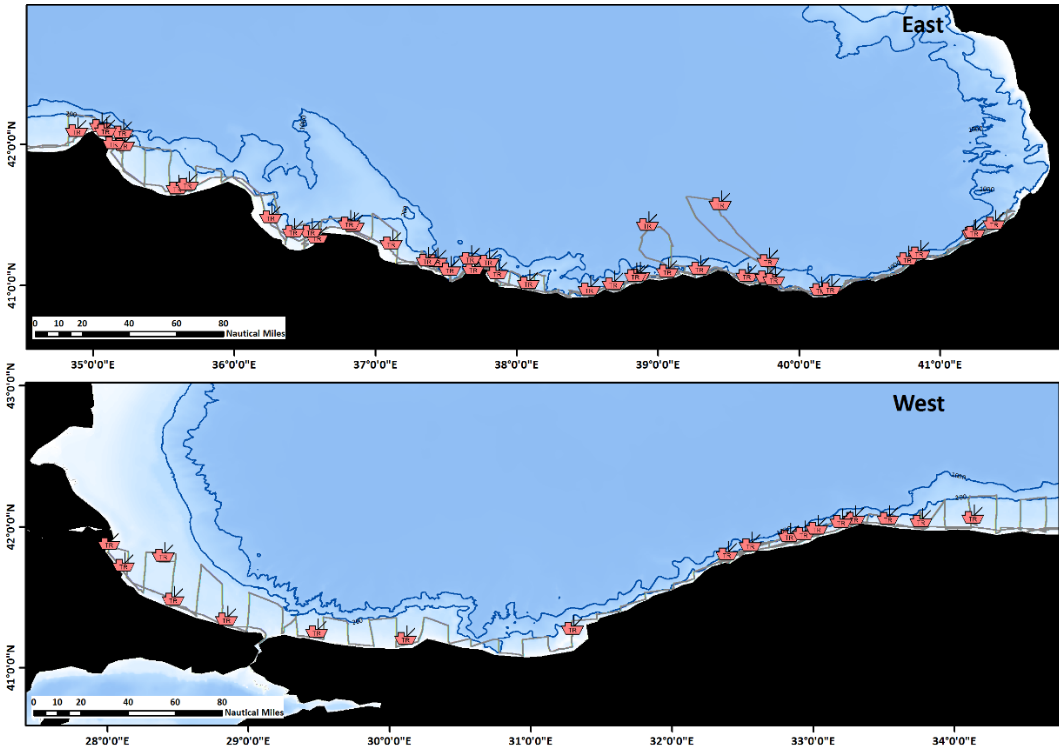


Figure 4: Trawl stations of the 2011 November-December survey

The location of the overwintering aggregations can change in space and time within the season depending on the temperature fluctuation (Chachin, 1996; Gücü et.al., 2015, 2016)**.** Because of the unpredictability and limited recent knowledge in the spatial distribution of the overwintering anchovy aggregations, an adaptive sampling approach was applied during the 2011 survey. This means that when large aggregations with higher acoustic intensities were encountered, the inter-transects distances were narrowed down and number of pelagic trawl hauls (Figure 5) were increased. Furthermore daily changes in the localisation of the commercial fishing fleet was monitored to pin down overwintering grounds. This enabled more effort to be allocated to the main overwintering anchovy groups. In addition to this, similar adaptive approach was applied for 2016 survey where some of the effort was shifted to western part of the coast. Thus, relatively more trawl samplings were done from middle and western part throughout the coast in 2016 (Figure 5).

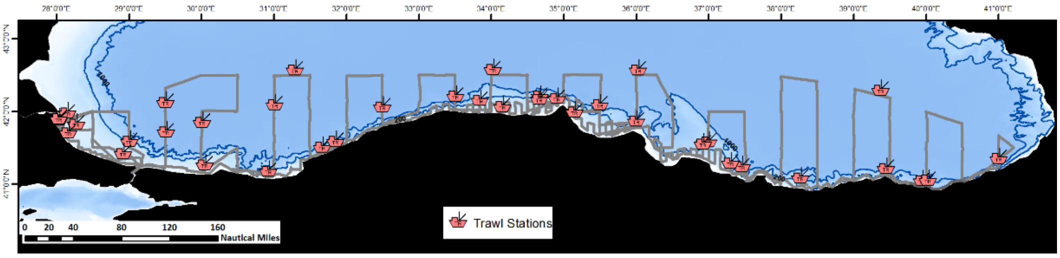


Figure 5: Mid-water trawl stations which were done through 2016-November survey

2.2 Trawl Sampling

Midwater trawl nets produced by COSMOS TRAWL.Denmark having the the same design and dimensions (i.e vertical and horizontal openings of four and nine meters respectively) were used in 2011 and 2016 surveys. Vertical opening in water was measured with the Simrad PI50 Depth Sensors attached to the headrope and footrope at the beginning of every hauling station. In addition to its own software interface, the PI50 Depth Sensor sends outputs to the acoustic data collection software (Simrad ER60). This allows to monitor where the trawling net is in water column and how its depth changes with alteration of the towing speed. The towing speed was changed between 2.5-5.0 knots in order to keep the net in desired limits of the depths and so that to sample the targeted fish aggregations.

To ground truth acoustic data, the number of hauls in both surveys was made based on the observed acoustic patterns such as changing characteristics of the fish schools. At least 3 hauls were done for each day as the weather permitted. Once prominent schools with different characteristics were seen on echograms, hauling was done. Even if there was no school, hauling area was selected randomly by taking account of backscattering energy observations. In this situation areas which had strong backscatter were chosen. The hauling time was fixed to 30 minutes adhering to the MEDIAS (Pan-Mediterranean Acoustic Survey) protocols for examination of pelagic fish in the Mediterranean Sea (MEDIAS, 2017).

After hauling, all the fish caught were taken to the wet laboratory to group and weigh them according to species. After that the size distribution of both small and large pelagic groups were measured. To do that, each species of weighed fish's total length frequency was measured using intervals of **0.5** cm. However, if the total weight of fish in a particular group was too excessive to measure the length frequency individually, total fish caught was subsampled and weighed to represent the whole group. Each subsampled group were weighed and measured because it was admitted that subsampled group characteristics were proportional to all the fish caught.

All the process mentioned above was done at every trawl stations to define the length and species composition of the schools along the cruise track. Defining acoustic clusters with similar features is needed to identify the school composition.

Due to better understanding of composition and size distribution of target species in Black Sea basin, four and six different regions have been identified for 2011 (Figure 6-Up) and 2016 (Figure 6-Down) investigations respectively. Composition and size distribution of each region were calculated separately. For the coastal parts, the basin were divided into four and numbered from “1”, to “4” in west-east direction. Offshore part of the 2016 survey was divided into two as “West” and “East”.

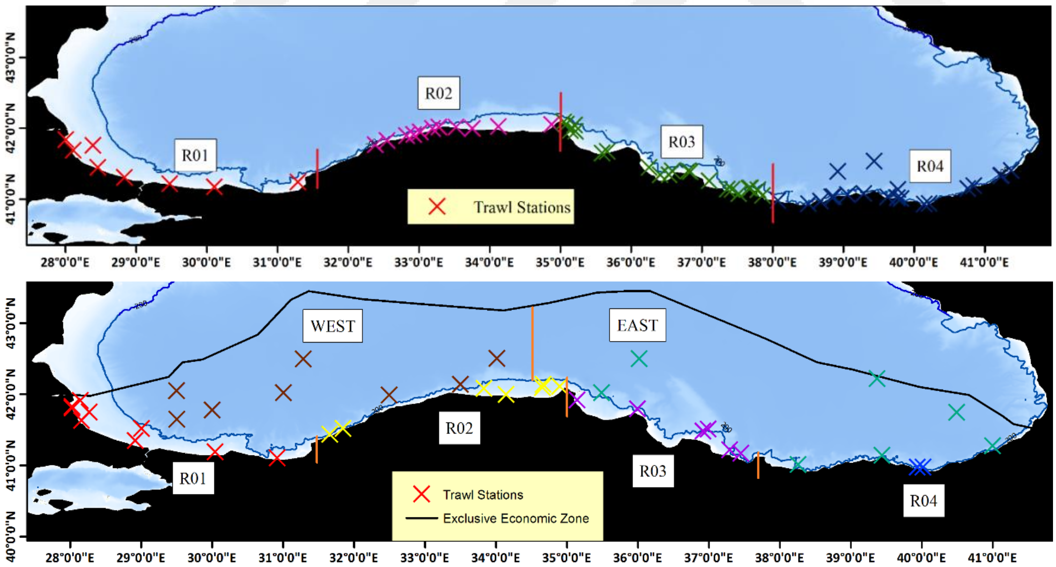


Figure 6: Regions used to calculate composition and size distribution of species in 2011 (up) and 2016 (down).

2.3 Hydrographic Sampling

2.3.1 Data Collection

The spatial distribution of overwintering anchovy varies according to the hydrographic characteristics of sea water such as temperature, salinity, oxygen, chlophyll. Therefore, it was necessary to know horizontal and vertical changes of these parameters of the studied area and to interpret the hydro acoustic data accordingly. The hydrographic sampling were done with CTD (conductivity-temperature-depth) device throughout 2011 and 2016 surveys. In both, three different calibrated sensors which were attached to the CTD probe performed measurements; temperature, conductivity, pressure. Also, 282 and 121 CTD probe were made the 2011 and 2016 surveys respectively (Figure 7 and 8).

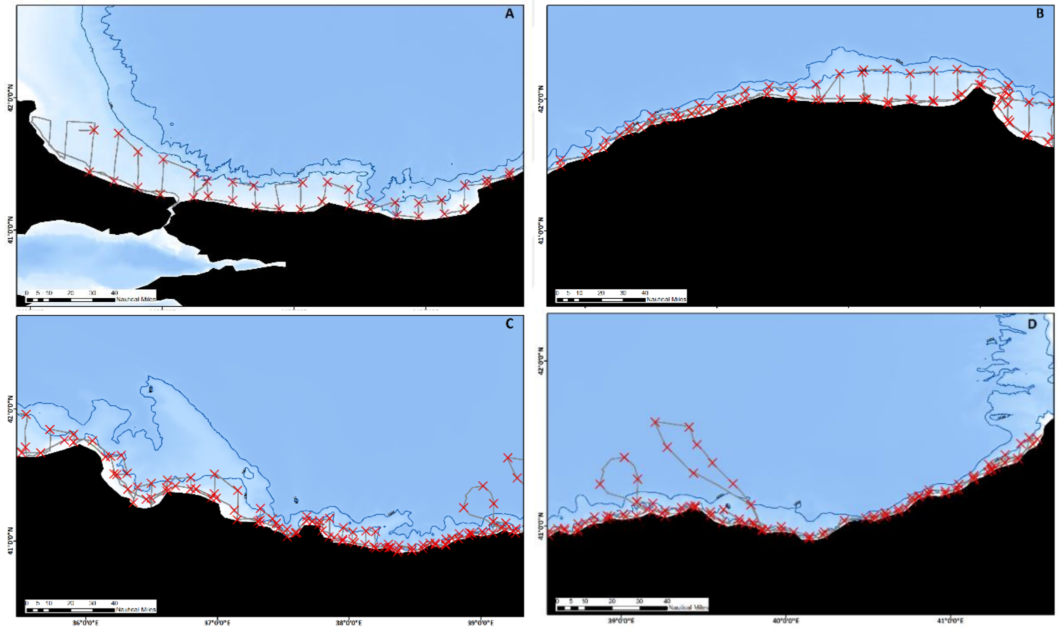


Figure 7: CTD stations of the 2011-December Survey. The direction is from west (A) to east (D)

Due to the hydrographic structure of the Black Sea, it is impossible for the aerobic organisms to live below 200 meter depth which is called anoxic zone. Because of this, CTD probe was not lowered under 200 meter dept in both surveys.

In 2011, the average distance between two consequtive CTD stations was applied between 2-10 nmi depending on the changing frequency of region characteristics and the maximum depths of the CTD stations were between 2 m, near Sinop and 211 m, off Samsun/Bafra.

In 2016 survey, 33 and 88 CTD stations were done along the coastal and offshore surveys respectively. The average distance between two consequent CTD stations were 20 nmi at coastal and 22 nmi at offshore stations. Range depth of the CTD stations in 2016 were from 29 m in bosphorus and 211 m off Sinop. Unlike the year 2011, in the 2016 western side of the Turkey were sampled more because, more fish schools were observed acoustically in western part especially near bosphorus.

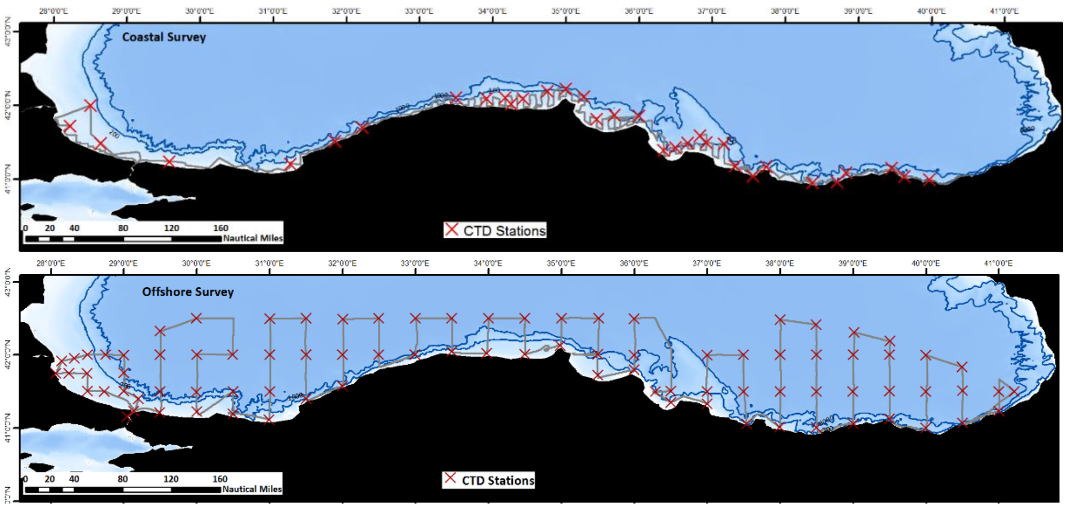


Figure 8: CTD stations of the 2016 November Survey. Up and down shows the CTD Stations of coastal and offshore surveys respectively.

2.3.2 Post Processing and Implementation

For each station, raw data with “.hex” extension were collected to the computer through the surveys. Then it was converted to “.cnv” format. CTD was operated to measure physical parameters of the water column with 0.25 second intervals. In other word, during data collection on the CTD station, sensors measure the related parameters four times in a second. After conversion, “.cnv” files were compacted by bin averaging of 1 meter. This process made the data more practical to apply and analysis for any software.

For the year 2011, temperature profiles of the water column and hydro acoustic data were examined together and the temperature limit was determined as 12 degrees. Afterwards, 12 degree-depths of each CTD station was determined and gethered in an excel folder for later use.

Similar process was followed for 2016 survey with the difference of choosing thermocline depth. In this case, the depths which had more than 0.1 celcius variation with adjacent one were chosen as a limit for each station because the water column was very stratified in 2016-November. However, in many CTD stations fluctuations which had more than 0.1-celsius degree were observed at layers close to the water surface. For this reason, detection of the thermocline depths of each CTD stations was done by taking account of the frequency of the 0.1-celsius variation.

2.4 Acoustic Measurements

2.4.1 Acoustic Equipment

Echo sounders have been widely used to estimate abundance and biomass of organisms with a range from euphausiids and large copepods like Calanus genus to fish species with or without swimbladder as an input for dynamic models of marine ecosystems (ICES, 2015). Acoustic devices work by using the propagation of a sound means that echosounder sends a sound (hereafter called ping) with known frequency and power, and compare it with the power of the sound received. Two types of echosounder, dual and split beam, are preferred for scientific purposes. Therefore split-beam echo sounder were preferred because of its high resolution and accuracy in 2011 and 2016 surveys.

2.4.1.1 Components of the Echo Sounder

Transducers were operated by Simrad EK60 Split Beam Echo Sounder. Also, GPS tracking system was set to the R/V Bilim 2 for 2011 and 2016 acoustic-trawl surveys to detect the location of the acoustic data consistantly. Simrad EK60 Split Beam Echosounder consists of three main parts; transducer, transceiver (General Purpose Tranceiver; hereafter GPT), and processor unit (computer).

Composite Transducers with 7 degrees opening beam angle were mounted to the ship bottom, under 4 meter from waterline to inhibit the effect of ship-sourced noise e.g. propellers and hull of the vessel. Transducers which are produced for split beam echo sounders have 4 seperate ceramic plates detecting the target location under water by comparing recieved signals by each plate (Simmonds and Maclennan, 2005). 38, 120 and 200 kHz transducers were applied to the 2011 and 2016 surveys. However, for the analyses of anchovy, sprat and horse mackerel, data collected with 38 kHz transducer were used. The rest, 120 and 200 kHz were used to clean the data set from unwanted echoes or areas (Figure 9).

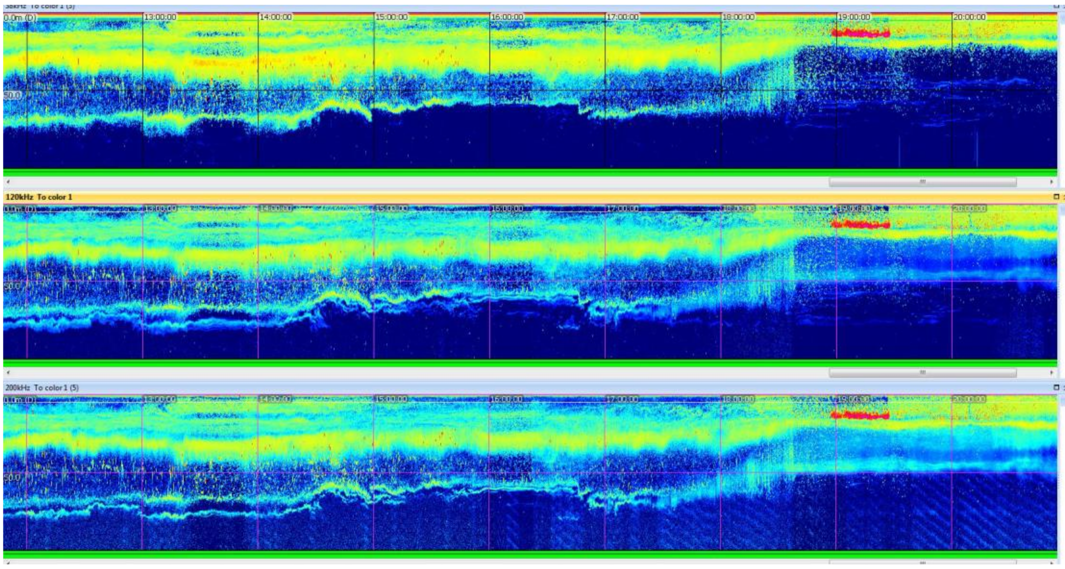


Figure 9: Echograms that have been created to compare 38, 120 and 200 kHz frequencies (taken from Hydroacoustics Handbook for Anchovy, Gücü et.al, 2015)

Standard EK60 GPT box containing transmitter and reciever electronic units was installed to the vessel. Transmitter electronic unit of GPT computes and creates electrical signals to stimulate the transducer to form a ping. Likewise, the receiver electronic unit filtrates and amplifies the signals comes from the transducer (Simrad EK60 Manual, 2012). Also GPT regulates the ping interval throughout the survey.

The processor unit which includes EK60 software was connected to the GPTs with an ethernet cable and adapter. The software was procured by the manufacturer. All ethernet cables from different GPTs was connected to one computer. So that, EK60 system could be controlled from one computer monitor (Figure 9). EK60 software allows to do applications like changing ping interval/setting the duration of a signal etc or track data collected on monitor throughout the survey.

2.4.1.2 Noise

After making sure that all the components were set well, noise level were checked in both surveys by switching off the transmitter. Noise indicates all the signals that does not include living organisms and that are unconnected with the echo sounder propagation. (Simmonds and MacLennan, 2005).

Any vessel specialized for acoustic-trawl surveys causes more or less self noise. Because the receiver part of the transducer is sensitive to the echoes, external unwanted echo producers like propellers, rudders, main engine, gears, pumps etc. in ship ruin the data collected. Also, the movement of the vessel itself causes bubble layer because of the constant water flow under the hull and bubbles around propeller. Once a sound wave hits the bubble near surface, it backscatters and comes back to the transducer. This causes the attenuation on echo because of the weaker signal caused by bubble. In direct proportion to the bubble density, echo attenuation increases.

Another bubble-induced noise is the wind. When the weather is bad, the height of the bubbly layer on surface and its density gets higher. Therefore, acoustic attenuation of the sound increases (Simmonds and MacLennan, 2005). In 2011 and 2016 surveys, to get rid of these effects mentioned above, the transducer hung 4 meters under the sea surface.

2.4.1.3 Working of the Echo Sounder

First, the transmitter produces electric pulse with known input power and transmits it to the transducer. In 2011 and 2016, 2000 watt input power was preferred for 38kHz frequency. Electric pulse triggers and vibrates the transducer. Transducer produces a sound with known frequency by the vibration. The frequency of the sound depends on the material, design and size of the transducer. Simrad 38 kHz piezo-ceramic transducer was used in the surveys to analyze pelagic fish species. This sound is transmitted into the water column. The sound produced by the transducer propogates through the water column horizontally or vertically depending on the setting and the objective of the survey. Transducer was set vertical in the surveys carried out. Until the sent signal gets back to the transducer, GPT measures the input power of the transducer.

The sound propagating through water column hits objects like fish, plankton, seabed, trawl net, anchor etc. and backscatters from these because of the different acoustic impedances between two medium, water and reflector. The larger the difference of acoustic impedance, the stronger is the echo from reflector (Simmonds and Maclennan, 2005). Because of this feature of a sound, fishes can be divided into two in terms of their reflector characteristics; swimbladder-bearing and swimbladderless fish. The first group produces stronger echoes than the second one because air in the swimbladder creates great acoustic impedance contrast with surrounding water (Foote, 2001). The same principle is valid for the other reflectors in water. Copepods like calanus in Black Sea show very weak acoustic backscattering compared to swimbladdered fish but when they are aggregated, they produce stronger echoes (ICES, 2015). According to observations in 2011 and 2016, calanus creates a dense layer just below the thermocline in water column which can effect the density of pelagic fish groups. However, because the treshold chosen for pelagic fishes (-70 dB) is higher than the energy of the echo coming from calanus aggregations, this situation does not effect small pelagic fish analyses. Apart from this, seabed was removed from the data regardfully because it is the strongest reflector in water and even the minor mistake causes big problems while analysing. Also, signals from anchor and trawl net were detected and removed from the data.

The backscattered sound hits and vibrates the ceramics in the transducer. Transducer converts vibration to electrical energy and GPT amplifies this weak electrical energy with regard to theoretical losses like widening of the sound wave during propagation and fraction of an energy by water etc. This function of echo sounder is called Time Varied Gain (hereafter; TVG). TVG function is basically applied automatically by GPT reciever electronics to get rid of these effects on echo.

Also, the time between the beginning of the transmission and end of the backscattering determines the vertical location of the reflector in water column (Simmonds and Maclennan, 2005). After that, GPT compares amplified energy with the input power of the transducer. Thus far, GPT computes the transmitting and receiving powers analogically. Calibration parameters provide this analogy to change the precise values.

In addition to this, to know the average acoustic strength value of a target (hereafter; Target Strength) allows to calculate abundance and biomass. GPT calculates the average value of energy (NASC) in a chosen sampling area. The length of the cruise track chosen to be averaged is called EDSU (Elementary Distance Sampling Unit) (Simmonds and Maclennan, 2005). In 2011 and 2016 surveys, EDSU was chosen as 1nmi. At last, with the information of both, target strength and NASC with a particular EDSU, the abundance and biomass of the target species could be calculated.

2.4.1.4 Installation

All along the both examinations, the units (Transducer, GPT and Processor) of the echo sounder worked simultaneous. At the first stage after setting components to the vessel, each transducer was installed to the computer using EK60 Software provided by the manufacturer. Afterwards, pulse duration and input power parameters of each transducer were applied to the system.

2000 watt input power was chosen and pulse duration was applied as 512 ms for 38 kHz transducer in both examinations. Although recommended pulse duration is 1024 ms for pelagic species according to the MEDIAS reports, 512 ms was preferred in these surveys. This is because 512 ms gives better resolution than 1024 but if the ship is too noisy, better option is 1024 ms. For the both values, noise level were checked on echogram. It was observed that noise were not much to prevent the data collection of pelagic fish species for the 512 ms pulse duration setting. Therefore, all the data collection and calibration were done with this setup.

2.4.2 Calibration

It is inevitable that there are many undetectable GPT and transducer related losses during the transformation of the electricity to the sound or vice versa in the transducer. In addition to this, during the transition between GPT and transducer or transducer and water, there are some loses because of the different acoustic impedances of two mediums. Also, the amount of the losses due to the components of the echosounder may be changed by the environmental conditions, changing in the electrical equipments or aging. This multifaced nature makes the calculation of the loses mentioned quite inconvenient to a degree where it is practically not doable.

For this purpose of the calibration is to change the analogy, mentioned in section 1.4.1.3, to the absolute value which is essential for the quantitative studies to take into consideration of these losses.

2.4.2.1 Standart Sphere Method

Standard sphere method was chosen to calibrate the system in both surveys. Calibration spheres are the balls with known target strength and backscattering cross section. In standart sphere method, the ball is lowered under the vessel and moved in the beam. Then the echoes from sphere are used to calibrate the system by comparing the difference between measured and known target strength of a sphere (EK60 Referance Manual, 2012). The copper balls which are produced for the calibration of different frequencies were provided by the manufacturer. In each calibration, the balls produced for 38, 120 and 200 kHz frequency transducer were lowered one by one into the beam. In both surveys, the copper balls were washed with detergent water solution to get rid of the bubbles around the ball as they change the target strength of a sphere significantly during calibration.

Calibration was performed before the both surveys. The vessel was anchored for calibration to the area where was flat and had no strong currents. In addition, a region with low environmental noise and with sparse of fish schools was selected for a proper calibration. The total depth of the sea during calibration was between 35-40 meters.

2.4.2.2 Simrad ER60 Software

Simrad EK60 Echo Sounder system was implemented in the Simrad ER60 Software so that the requested parameters (power, environmental parameters like salinity and temperature of the water, TS value of the copper ball, pulse duration, ping interval etc.) were applied to the echo sounder. In addition to this, all the calibration and data collection processes was monitored with Simrad ER60 Software.

2.4.2.3 Environmental Parameters

Before the calibration, CTD sampling were done to apply the environmental parameters which are used by the Simrad ER60 Software to calculate the sound velocity in water column. In this part, salinity and temperature values in the depth of the copper ball were applied to the echo sounder. In addition to this, for the calculation of absorption, the frequency of the transducer were entered in the environment window (Figure 10). Also according to EK60 Referance Manual, 2012, the absorption coefficient of the water was calculated by the echo sounder with the referance of Francois & Garrison, JASA December 1982.

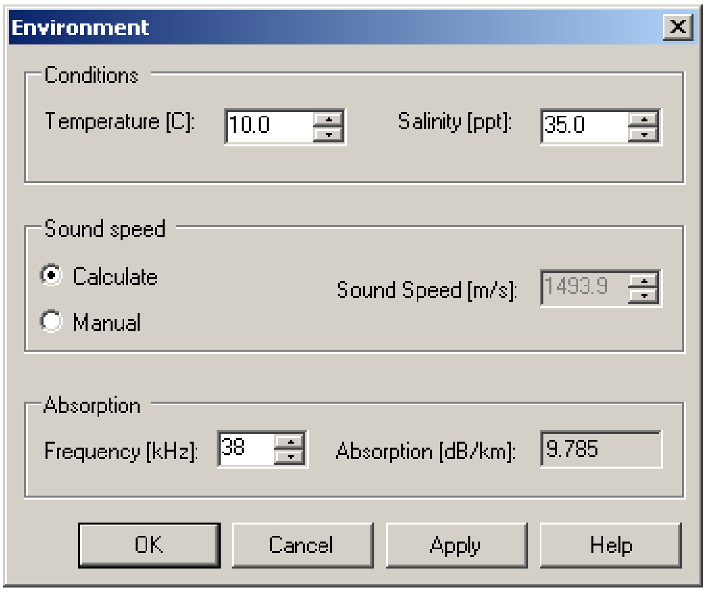


Figure 10: Environment window of the Simrad ER60 Software

2.4.2.4 Other Necessary Parameters for Calibration

Before starting the transmission, parameters which will be used for calibration and data collection were applied. In this case, input powers of 38, 120 and 200kHz frequency transducers were set as 2000, 50 and 50 watts respectively.

The time gap between two signals is called ping rate which was changed according to depth and false bottom appearance during surveys. At this stage it was entered as 0.3 ping per second during calibration and adjusted according to the total depth at a time during survey. This is because if the transducer sends a ping before the previous one hits to the quadrants in the transducer, bottom reflection may appear higher than its real depth which is called false bottom. False bottom may ruin the signal from target (copper ball). For this not to happen, ping rate was adjusted along the survey according to a formula by Parker-Stetter (2009):

$$i = \frac{3 * 2 * TD}{C}$$

i = Ping rate

TD = Total depth of the water column

C = The speed of sound in water

The theoretical target strength of the copper balls were given by the manufacturer (Table 2). The target strength were set as -33.6 dB with 5 dB standart deviation. This value of the standart deviation is accepted by ICES (International Council for the Exploration of the Seas) and other important organizations during calibration. After calibration, this value was not changed.

Table 2: Copper balls with different TS values for various type of frequencies

Frequency (kHz)	Diameter (mm)	Target strength (dB)
12	45,0	–40,4
18	63,0	–34,4
27	42,0	–37,9
38	60,0	–33,6
49	45,0	–36,4
50	45,0	–36,2
70	32,1	–39,1
120	23,0	–40,4
200	13,7	–45,0
710	10,3	–50,5
Target strength calculated for sound speed 1490 m/s. The same sphere is used for 49 and 50 kHz.		

The curve for the 38 kHz sphere is given as an illustration.

The range of the target depth limited between 15 and 17 meters (Figure 11). In any case when the copper ball is not between limits, calibration was stopped untill replacing the ball to between depth limits. This process were performed by 2 people with the commands from the one monitoring the position of copper ball in beam.

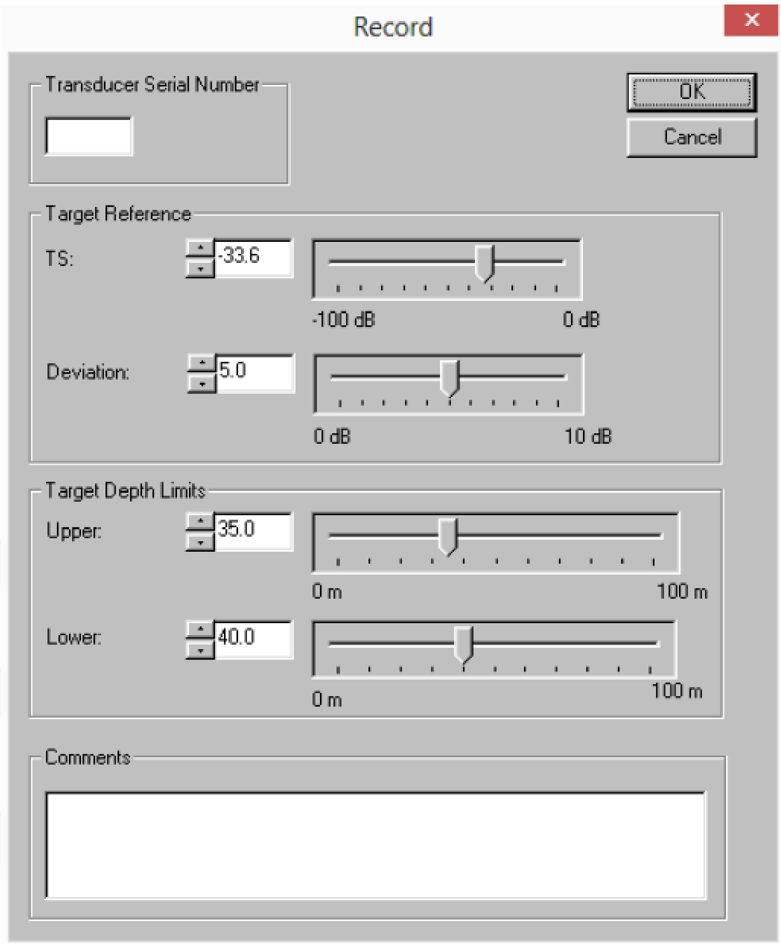


Figure 11: Screen of the Target Referance and Target Depth Limits

2.4.2.5 Data Collection for Calibration

The transducer collects data every time it sends a ping consistently. Data collection was followed from a monitor which includes echogram, calibration and single target position windows. Echogram window shows the depth of the copper ball. The depth limits of the target (15-17 m) were implemented to the echogram window as layer to exclude echoes except from the copper ball so that the strength of echoes and position of the copper ball in the beam were followed clearly. Single target position window shows the location and strength of the echoes in the beam and more physical parameters about target was followed from calibration window. Also, the density of the data collected from each quadrant during calibration were checked from calibration window (Figure 12).

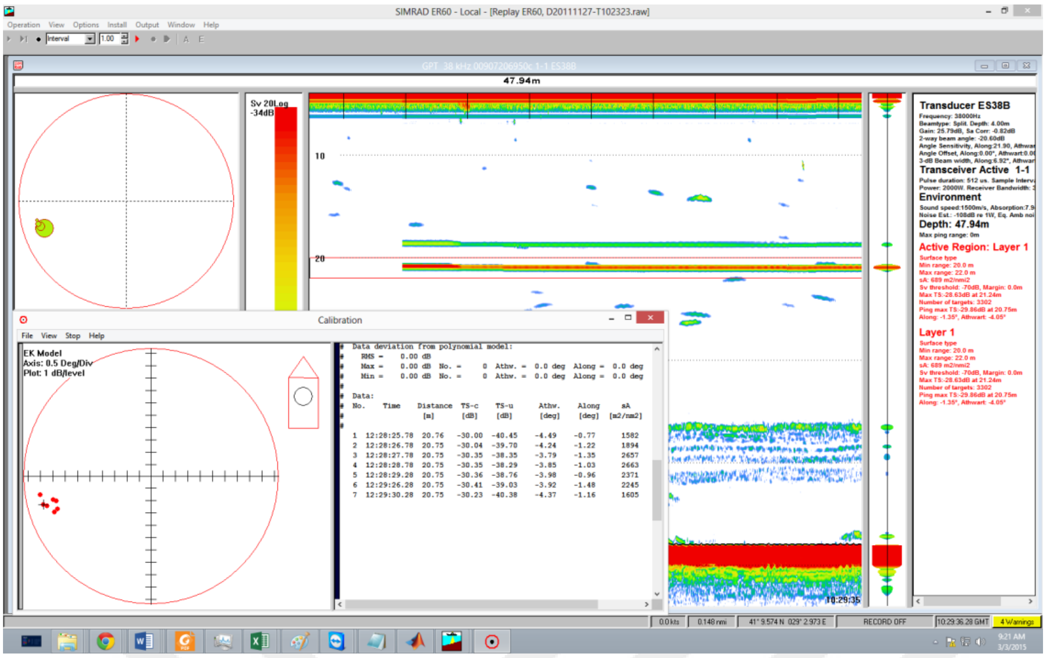


Figure 12: Calibration, single target position and echogram windows monitored during calibration

During the data collection of calibration process, the copper ball were placed on axis of the beam first. After collecting enough data (about 30-40 points) from the axis of the transducer, about 50 point were recorded for each quadrat to cover the whole transducer surface. Covering the whole transducer face is needed for a healthy calibration. A number of 250-300 points were recorded in total during the calibration of both surveys.

2.4.3 Acoustic Data Collection and Analysis

2011 November-December and 2016 November raw acoustic data were recorded along 22 and 23 days with Simrad EK60 Echo Sounder System and were analyzed on Echoview 5.4. The data were collected from surface untill bottom for the both surveys then data were edited for purpose.

2.4.3.1 Acoustic Data Collection

Bottom depth and target strength distribution were monitored while the data was being collected continuously on ER60 software screen. Ping rate were adjusted according to the changing in the bottom depth. Layers were set into the software to get information of willing range of the depth. Input power and pulse duration were kept constant with the ones applied through the calibration.

The name of the recorded raw data files were set with the information of date.

2.4.3.2 Analysis

Echoview program was used to analyze data after each survey. Echoview software reads the raw data and create EV folders with ".ev" extension. For the analysis, EV folders were created for each day separately for 2011 and 2016 surveys. After that, noises, bottom reflections, bad data and surface reverberation were selected and excluded from acoustic data. For this purpose, bottom lines of each day that Ecoview had automatically drawn were upheld in a range of 0.5 to 1 meter depending on the bottom reflection. Therefore, bottom lines of days were checked and reformed manually.

In Black Sea Surveys, the main purpose was defining three different pelagic fish species which are Black Sea Anchovy (*Engraulis encrasicolus*), Sprat (*Sprattus sprattus*) and Horse Mackerel (*Trachurus mediterraneus*). Because of this, species allocation was done by considering the biological characteristics of these species.

Coastal and offshore parts were analysed differently. For the coastal part, the shape of the horse mackerel aggregations were taken into account and analysed with using school detection module while the composition of anchovy and horse mackerel were used for offshore part of the 2016 survey. For the analysis of sprat, thermocline were chosen as the habitat limit. In this case, the upper part of the thermocline through the water column was admitted as anchovy/horse mackerel mix for offshore part and the energy between thermocline and bottom were admitted as sprat in all dataset.

2.4.3.2.1 Analysis of Horse Mackerel and Anchovy

Horse Mackerel shows specific schooling behavior in continental shelf zone with legs through the bottom which can be distinguished easily from other aggregations by school detection module.

School detection module was applied to the data collected in 2011 and 2016 coastal surveys to detect possible aggregations of horse mackerel. The surface and bottom lines were picked as limits of the school detection process. Not all the schools selected by school detection module are biological schools because module may consider the noise or uninterested aggregations or false bottom as a school. Shortly, school detection module picks candidate schools and from these, the ones other than horse mackerel were unselected manually. The applied parameters like minimum length and height, minimum and maximum target strength etc. for candidate schools were given in figure 13. Chosen aggregations which pair with these parameters are called "Region" on Echoview.

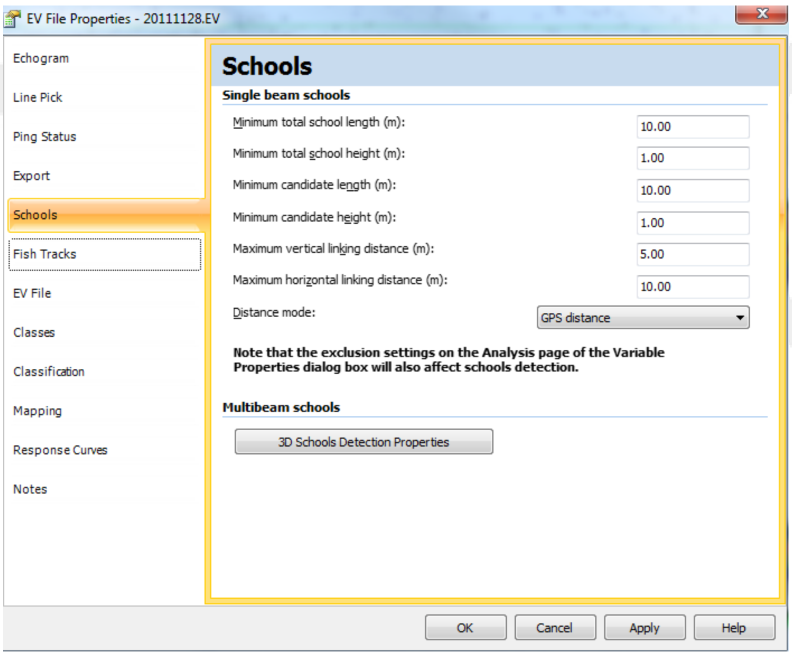


Figure 13: Applied school parameters to detect possible Horse Mackerel aggregations.

Also, the trawl sampling were done to make sure that schools seen on echogram belong to the horse mackerel. In this case, dense horse mackerel aggregations of 2011 coastal cruise were observed from echogram at the western part of the Black Sea from Amasra (32.335E 41.758N) to Sinop (35.366E 41.702N). Therefore, after applying the school detection module to region between Amasra and Sinop, detected schools were exported to see the variables of horse mackerel aggregations. Even if the detection parameters can be many, the ones used to mark horse mackerel schools were given in Table 3. This data between Amasra and Sinop were saved as a referance table of horse mackerel schools. Then, confidance intervals with two times standart deviation of these variables were calculated for determination for the rest of the coastal data. For the 2011 and 2016 coastal dataset, the same intervals of school variables were applied and the rest regions were unselected manually. After making sure that all regions selected by school detection module are horse mackerel, all 2011 and 2016 coastal regions were exported for further use of biomass calculation.

For the coastal anchovy analysis, the data were limited between surface and 12 °C (for 2011) or thermocline (for 2016). Then, all horse mackerel aggregations had been set as bad data and the rest were exported as anchovy.

Table 3: Variables that was used for selecting horse mackerel aggregations. Marked were checked directly while green ones were calculated using unmarked parameters.

Parameter	Definition
Height_mean	The mean height of the school which was analyzed (m).
Depth_mean	The mean depth of the school which was analyzed (m).
Skewness	A numerical measure for symmetry of the tails of the distribution of a data set. When skewness is equal to zero, the data has a normal distribution. Skewness indicates the direction of deviation from the mean. Positive skewness means the left tail is shorter than the right tail and the distribution is skewed to the right. Negative skewness means that the left tail is longer than the right tail and the distribution is skewed to the left. Small set size adversely affects skewness.
Kurtosis	Kurtosis represents a measure of the combined weight of the tails relative to the rest of a distribution. As the tails of a distribution become heavier, the kurtosis will increase. As the tails become lighter, the kurtosis value will decrease.
Corrected_length	The Uncorrected_length corrected for known beam geometry according to the system of Diner (1998)
Corrected_thickness	The Uncorrected_thickness corrected for known beam geometry according to the system of Diner (1998)
Corrected_perimeter	The Uncorrected_perimeter corrected for known beam geometry according to the system of Diner (1998)
Corrected_area	The Uncorrected_area corrected for known beam geometry according to the system of Diner (1998) (m).
Image_compactness	The image compactness is a statistic which measures the ratio between the perimeter (squared) of the observed school to the area of the observed school. A circle has an image compactness of 1.
Horizontal_roughness_coefficient	The horizontal roughness coefficient is a statistic used to measure the dispersion of acoustic energy within the school in the horizontal direction.
Vertical_roughness_coefficient	The vertical roughness coefficient is a statistic used to measure the dispersion of acoustic energy within the school in the vertical direction.
Rectangularity	Rectangularity shows how the school shape close to the rectangle. It measured with the formula "Corrected Area / (Corrected Thickness x Corrected Length)"
Circularity	Circularity shows how the school shape close to the circle. It measured with the formula "Corrected Length/(π x (Corrected Area/2)²) "
Elongation	Elongation of a school was measured by the formula " Corrected Length/Corrected Thickness

Because horse mackerel did not show the same specific schooling behavior, the acoustic data were sorted out using the trawl composition for the offshore part of the 2016 survey. While doing this, the data taken between surface and thermocline were divided into two in terms of their composition in trawl net because they both have not dense school pattern in offshore part of the Black Sea basin.

2.4.3.2.2 Analysis of Sprat

Thermocline layer was used to separate anchovy/horse mackerel mix and sprat aggregations. To do this, first, all horse mackerel school regions marked as bad data on Echoview.

After discarding horse mackerel schools, 12°C and thermocline lines which was drawn by using CTD data, was imported to Echoview for 2011 and 2016 datasets. Regarding to the temperature, the Black Sea anchovy and horse mackerel is more adopted to the warmer-waters than sprat (Chaschin, 1996). Also, anchovy and horse mackerel aggregations were observed at depth up to 12 °C and thermocline through water column while sprat lives under this limit in 2011 and 2016. Thus, the lower part of the temperature lines were analysed to separate the sprat individuals from other two species.

While analysing for both 2011 and 2016 data sets, Acoustic data from surface to bottom through the water column were processed by using "Processed Data" tool on Echoview - Flow Chart. This tool is useful to analyse between two desired lines without deterioration of unwanted parts through water column. Besides, the vertical section between surface (0 meter) and six meters of the water column weren't analysed because of the surface reverberation under transducer. Finally, all data between six meters and 12-degrees (for the year 2011) / thermocline (for the year 2016) lines were analysed with 1-nmi horizontal intervals and 1-meter vertical layers (Figure 14).

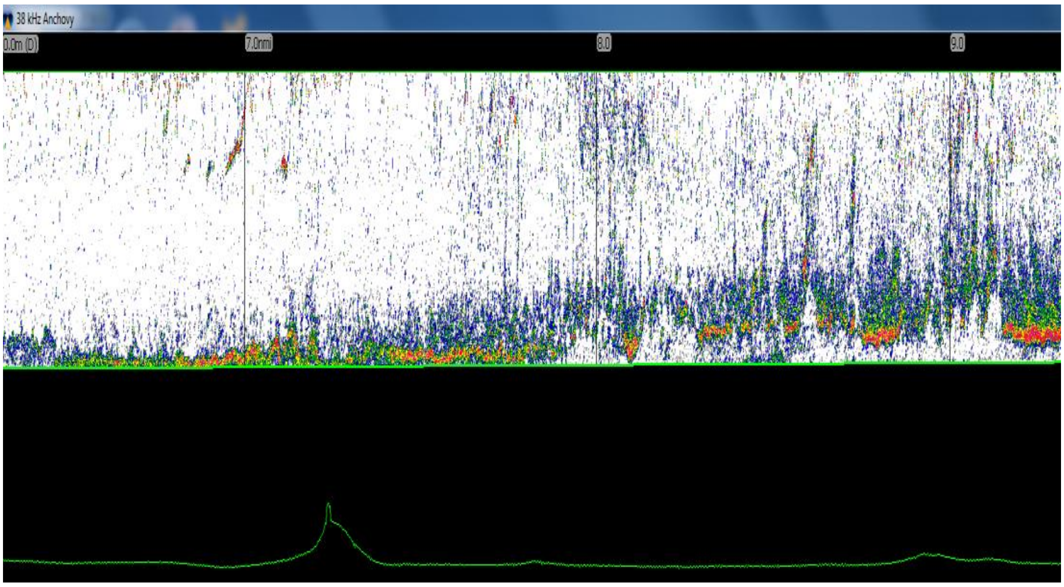


Figure 14: The green lines at above, medium and bottom shows 6m, thermocline and bottom depths respectively. Enlighted area through water column was analysed for anchovy.

2.4.3.3 Calculations

2.4.3.3.1 Target Strength

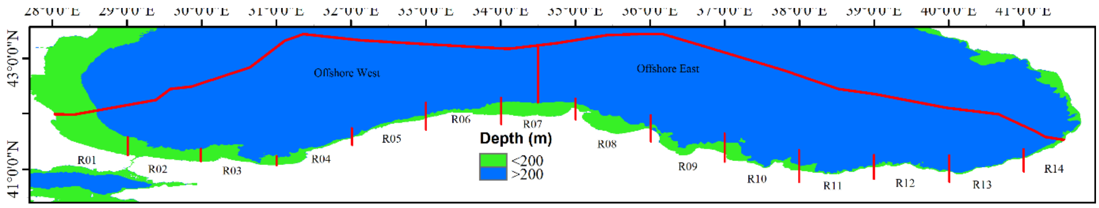
Calculation of Target Strength (TS) was done according to 2015 MEDIAS protocol with length-frequency data collected in 2011 and 2016 trawl samplings with using b20 formula, TS=20log(TL)-71.2 dB. TS, TL and value -71.2db refers to Target Strength, Target Length and b20 value respectively. Because b20 value is species dependent, different b20 values was used for calculation of TS; while -71.2 dB was used for anchovy and sprat, -68.5 dB was used for horse mackerel.

The trawl stations were grouped according to the coordinates of regions given in table 3. The length distribution of each region was then extracted by summing the number of the same length size of fish. according to these trawl stations.were and used for each region in 2011 and 2016 surveys.

2.4.3.3.2 Biomass

2011 acoustic trawl survey (ATS) was done to understand the overwintering localizations of each targeted small pelagic species. Thus, the coastal area which was limited between 200 m depth and coastline was divided into 14 regions horizontally with 1-degree longitude for each. Afterwards the biomass of each grid was calculated separately.

Table 4: Calculated areas for 2011 and 2016 surveys. Coastal areas from "R01" to "R14" were limited between shelf zone (200m) and enumerated from west to east. R14 was not included in the coastal part of 2016 survey. Offshore regions including east and west were used in 2016 calculations.



Region Code	R01 (28°E-29°E)	R02 (29°E-30°E)	R03 (30°E-31°E)	R04 (31°E-32°E)
Area(nmi²)	1116	658	491	247
	R05 (32°E-33°E)	R06 (33°E-34°E)	R07 (34°E-35°E)	R08 (35°E-36°E)
	138	279	617	572
	R09 (36°E-37°E)	R10 (37°E-38°E)	R11 (38°E-39°E)	R12 (39°E-40°E)
	404	353	134	102
	R13 (40°E-41°E)	R14 (41°E-42°E)	**Total (Coast)**	**Total (Offshore)**
	51	109	5271	46101
	Offshore West (28°E-34.5°E)		Offshore East (34.5°E-42°E)	
	22352		23749	

In 2016 ATS , biomass calculation was set on fifteen sections in Black Sea Basin. For the first part of the survey which covers the Turkey EEZ of Black Sea, the area was divided into two, east and west. For the second part, the shelf zone was divided and calculated the same with 2011 coastal survey. However, because there was no acoustic data from the last part in 2016 coastal survey, it was not counted in.

Biomass calculation was done by using the biomass formula that Echoview suggested (Echoview Technical Manual, Volume 1):

$$Biomass\ Density\ (tonnes/n.mi^2) = \frac{\%Contribution}{100}\ x\ \frac{PRC\_NASC}{4\pi\bar{\sigma}}\ x\ \frac{Weight(gr)}{1000000}$$

$$Sigma\ Mean\ (\bar{\sigma}) = \sum_{All\ Species}\left(\frac{\%Contribution}{100}\ x\ 10^{\frac{TS}{10}}\right)$$

Where:

%Contribution = By-ratio of anchovy landed entire fish in survey. The contribution ratio of anchovy to total biomass landed.

PRC_NASC = Proportioned Region to Cell Nautical Area Scattering Coefficient

Weight = The weight of anchovy landed in gram.

TS = Target Strength of all fish species separately.

Because the acoustic data of three pelagic species were seperated successfully, % contribution of species were taken as 100 % in the coastal part of the 2016 and 2011 surveys. Unlike the coastal parts, contribution value of anchovy and horse mackerel were entered to the offshore calculation.

3 RESULTS

3.1 Hydrographic Sampling Results

During the 2011 survey, it was observed that the east and the west were clearly divided into two as hot and cold, respectively (Figure 15). Distinctly, the cold area between Amasra (32.5°E) and Sinop (35°E) hydrographically divided the southern part of the Black Sea into two parts in the year 2016-November (Figure 17-Down). In addition, the reflections of this situation were observed in the coastal part of the same survey (Figure 17-Up).

Although the thermocline depths were approximately the same for both years (≈ 40 meter), there was a large difference between the mean temperature at these depths (≈4 °C). Both cases are probably due to the monthly variation of the water temperature in the year.

Regions given in figure 6 were used to show differences in expedition area.

3.1.1 ODV Results

In year 2011 November-December expedition, maximum and minimum sea surface temperature were measured near Trabzon (13.42 °C) and near Bosphorus (9.98 °C) with the average of 11.85 ± 0.58 °C (Figure 15). Very cold water column were observed from Kırklareli/İğneada (28°E) to Zonguldak/Ereğli (31.5°E) (Figure 15). The mean sea surface temperatures were measured for the R01, R02, R03 and R04 as 10.88 ± 0.45, 11.68 ± 0.36, 12.07 ± 0.51 and 12.13 ± 0.35 °C from west to east. Inspection of vertical profiles given in Figure 16 indicates that thermocline boundary is at depths corresponding to 12°C. According to the CTD measurements, the maximum and minimum 12-degree depths were recorded as 6 (off Giresun, 38.5°E) and 70 meters (between Giresun and Trabzon, 39.5°E) respectively with 32 ± 14 meters on average which is about 8 m above from the mean thermocline depth.

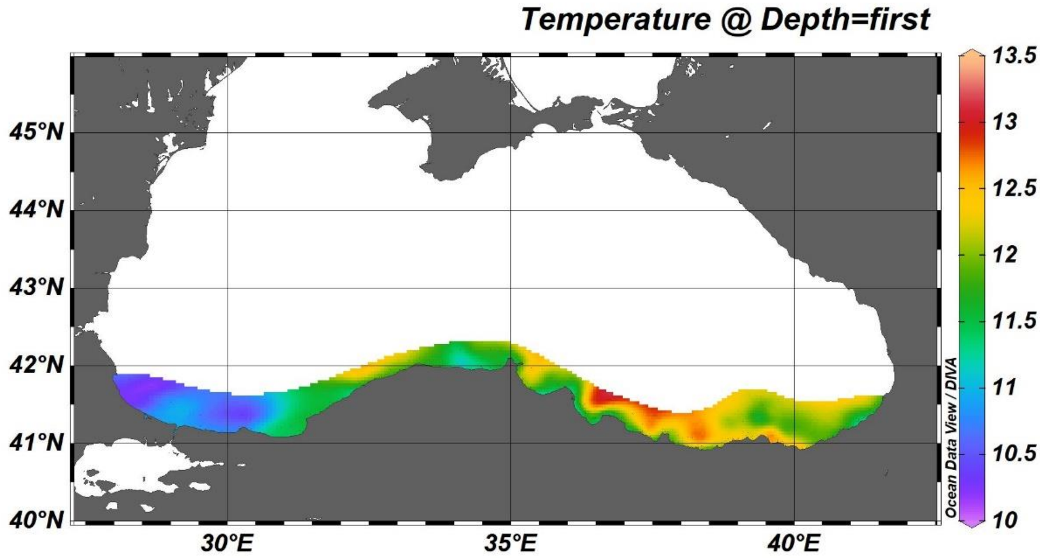


Figure 15: Sea Surface Temperature (SST) map of the expedition area from CTD stations in the year 2011

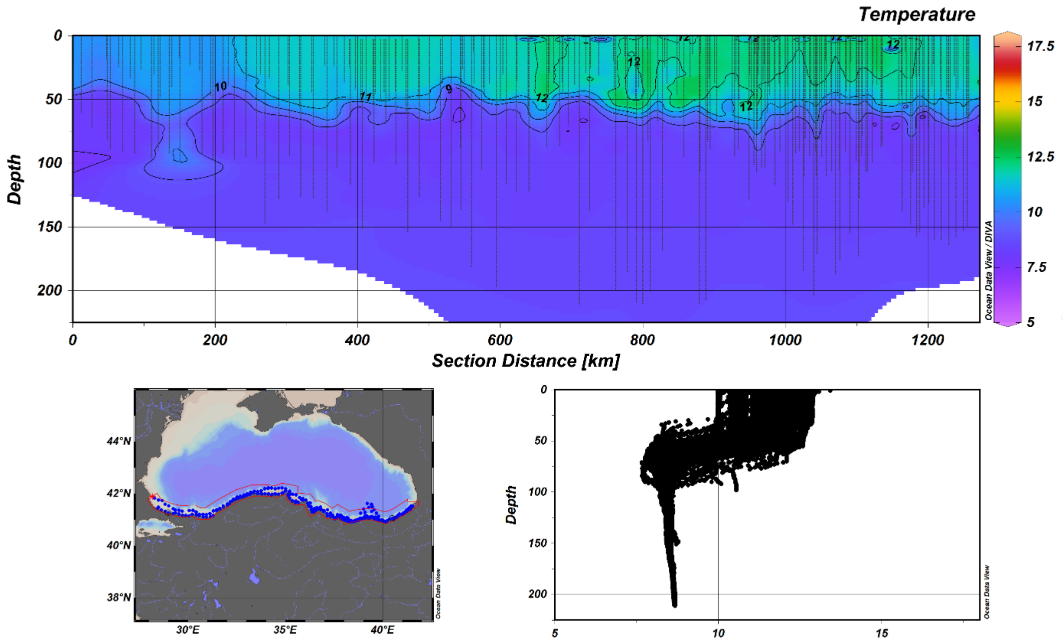


Figure 16: Temperature variation through the water column along the 2011 survey.

For the year 2016, the sea surface temperature were in a range between 12.66 and 17.86 °C with the average of 15.73 ± 0.93 °C which is about 3.88 °C warmer than the one calculated for year 2011. Also, very sharp stratification were observed through the water column in this year. The measured thermocline were in a range between 7 and 68 meters with 33.49 ± 12 meter on average. Also the ODV graphs and calculations show that unlike the 2011 year, partially increase in the sea surface temperature (SST) values from east to west were observed in 2016 (Figure 17). In a west-east direction, the mean SSTs are calculated as 15.42 ± 1.16, 15.49 ± 1.17, 15.37 ± 0.61 and 15.24 ± 0.47 for the coastal regions which are the same areas used for the calculations of 2011 survey. For the offshore regions in the borderline of the Turkish Black Sea Exclusive Economic Zone (EEZ), while the mean SST was 16.15 ± 0.62 °C in the west part, in the east part it was measured as 15.87 ± 0.88 °C.

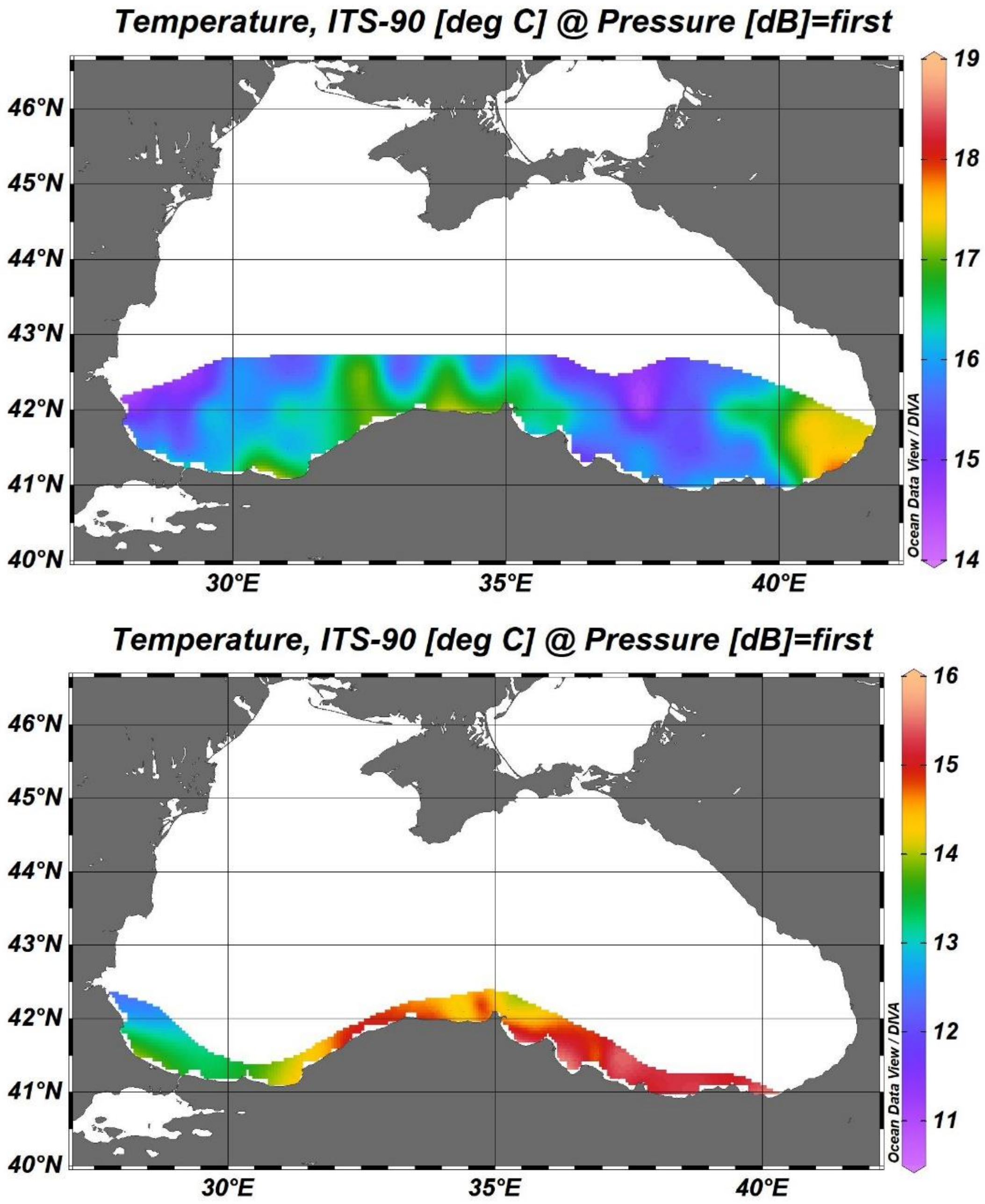


Figure 17: Sea Surface Temperature (SST) maps of the expedition area (Up;Coastal, Down; Offshore) from CTD stations in the year 2016.

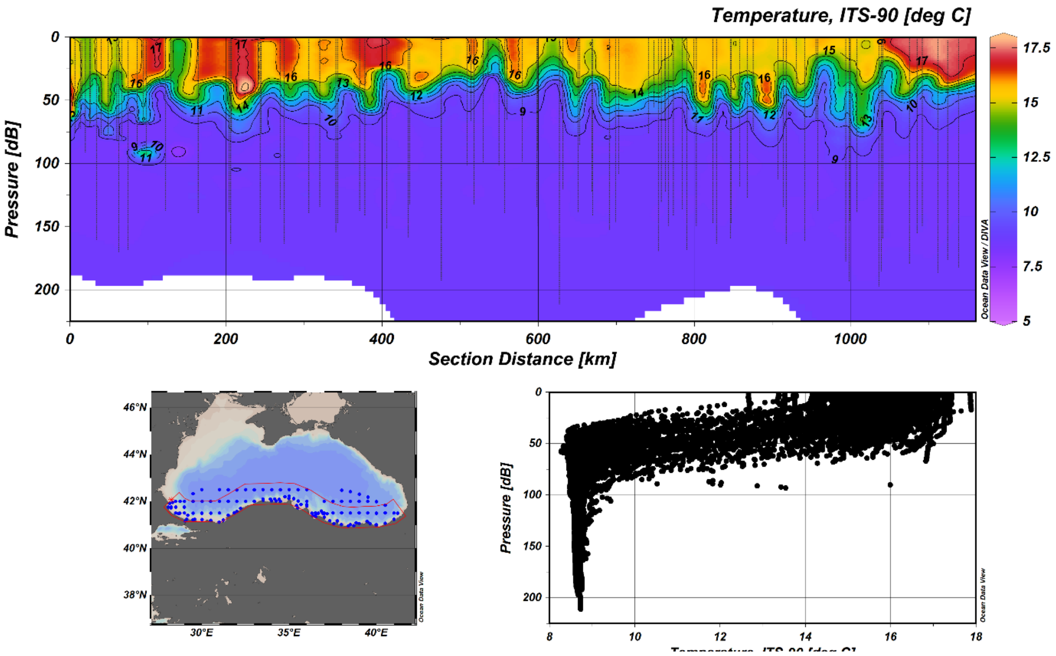


Figure 18: Temperature variation through the water column along the 2016 survey.

3.2 Composition and Size Distribution of Fish Species

In both years, the domination of the small pelagic fish with three different target species were observed from catch data (Figure 19 and 20). Small pelagic group which were constituted 98.628 and 98.702% in 2011 and 2016 surveys respectively, of all the fish caught were sampled from Turkey Black Sea coast and offshore untill the border of the Turkey EEZ. About 3262 kg of fish including small and large pelagic groups were caught from 100 trawl stations in total. According to length measurements, the size distribution of small pelagic species vary from region to region (Figure 21 and 22).

3.2.1 Catch Composition in Weight

In the year 2011, *Engraulis encrasicolus ponticus*, *Trachurus mediterraneus* and *Sprattus sprattus* were consisted ≈95.616 % of all catch (Figure 19). In this survey, 1087.812 kg *Engraulis encrasicolus ponticus* (34.084 % of all catch), 1198.929 kg *Trachurus mediterraneus* (40.754 % of all catch) and 551.420 kg *Sprattus sprattus* (20.778 % of all catch) were weighed in total biomass of fish caught by trawl net. Other fish species including *Gasterosteus aculeatus*, *Spicara* *flexiosa* and *Squalus acanthias* and large pelagics including *Pomatomus saltatrix* and *Sarda sarda* were contributed 16.155 kg (0.618 %) and 25.666 kg (0.753 %) to all the fish sampled (Figure 19).

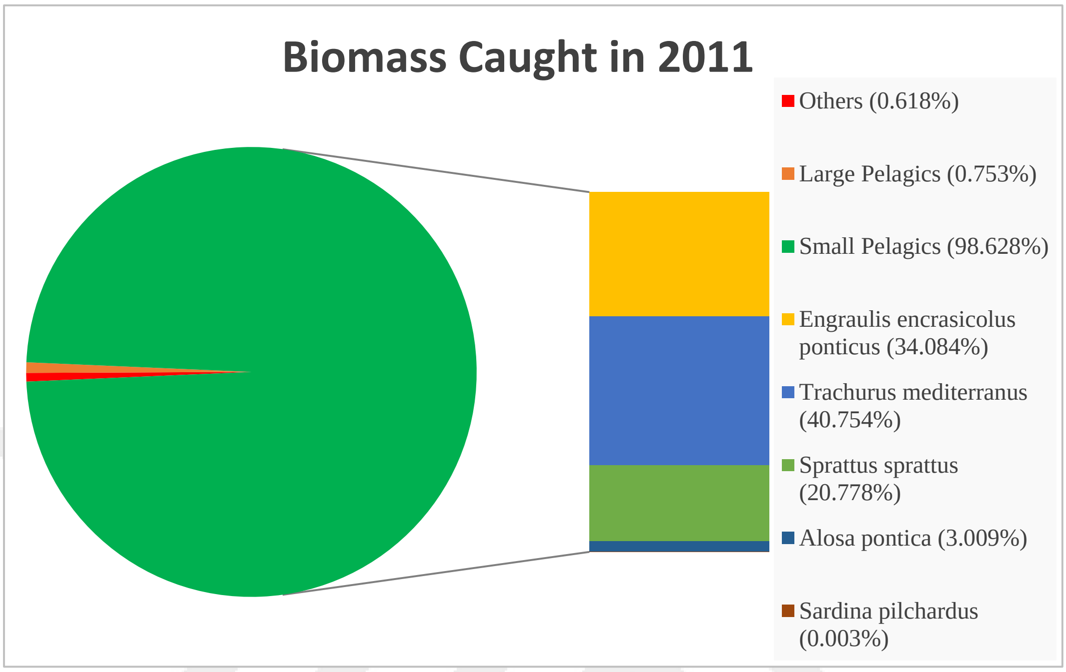


Figure 19: Catch composition of 2011 trawl stations. Pie chart shows the contribution of fishes in samples by trophic groups. Bar chart (right) shows the small pelagics composition and contribution of all small pelagic species to the catch.

According to the pie charts of the composition of the small pelagic species obtained from trawl sampling in 2011, the amount of sampled sprat decreased from west to east with the exception of eastest part of the Black Sea, while the amount of anchovy was observed to increase (Figure 20). Besides that, 77.6 % of all horse mackerel was caught mainly from the central part of the expedition area (Figure 20). Compositions including three small pelagic species were measured by regions. Anchovy biomass contribution to the catch data of targeted three main small pelagics were measured as 0.39, 0.03, 26.23 and 64.11 %, horse mackerel contribution was measured as 11.59, 85.77, 60.40 and 18.42 % and finally sprat contribution was measured as 88.02, 14.19, 13.37 and 17.42 % from west to east (Figure 20).

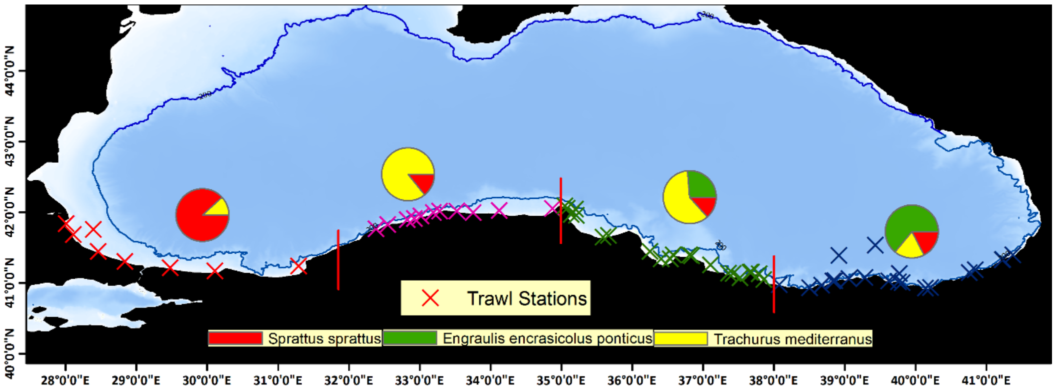


Figure 20: Relative biomass contribution of species along the regions in 2011 by trawl sampling. Trawl data from each stations were pooled per region. (Regions are divided by red straight line and named as “Region 1”, “Region 2”, “Region 3” and “Region 4” from west to east. Trawl stations for each region sampling are represented in different colors: Region 1, Red; Region 2, purple; Region 3, green; Region 4, blue)

In 2016, three targeted small pelagic species were consisted 98.686 % of all catch with 30.640 % of anchovy, 45.219 % of horse mackerel and 22.827 % of sprat contribution (Figure 21). On the contrary to 2011 survey, other fishes including *Gasterosteus aculeatus*, *Spicara flexiosa* and *Squalus acanthias* were not observed (Figure 21). Besides that large pelagics were consisted 1.298 % of all catch (Figure 21) with 3.685 kg of *Pomatomus saltatrix* in biomass. Also, 280.245 kg small pelagics including Black Sea anchovy (81.288kg), horse mackerel (141.547 kg) and sprat (57.410 kg) were sampled throughout the survey.

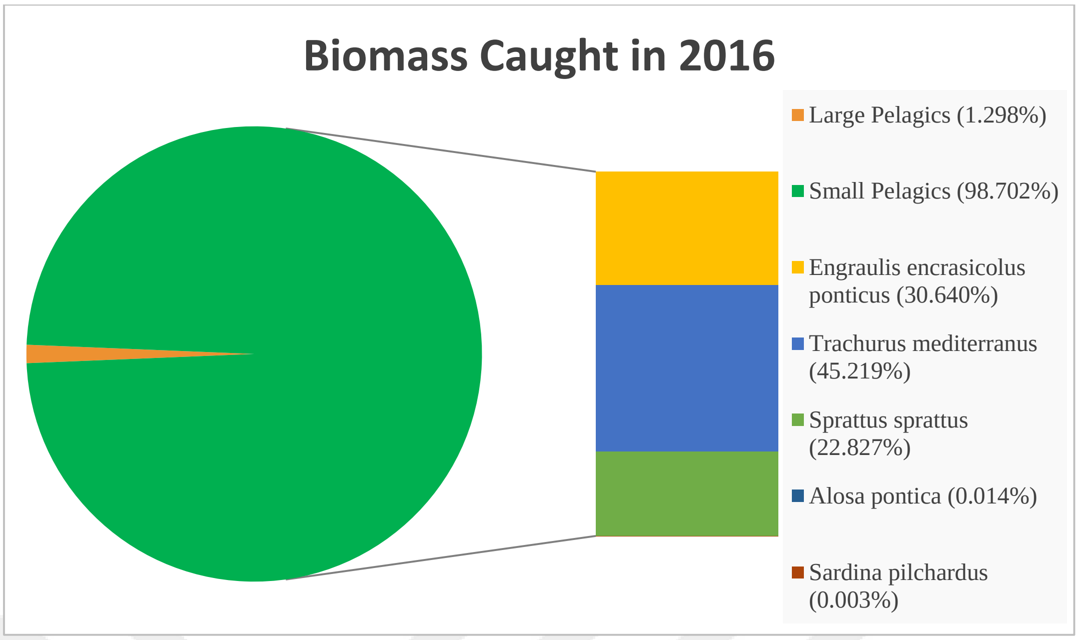


Figure 21: Catch composition of 2016 trawl stations. Pie chart shows the contribution of fishes in samples by trophic groups. Bar chart (right) shows the small pelagics composition and contribution of all small pelagic species to the catch.

According to the trawl composition data of these three species in 2016, more anchovy were observed in trawl nets at the west part of the Black Sea (Figure 22). Contrary to this, more sprat contribution were observed offshore and east part (Figure 22). Horse mackerel were mainly caught from the coastal areas including central and western coast. For the coastal regions, the contribution of Black Sea anchovy were measured as 31.93%, 27.09%, 12.63% and 02.60% displaying a significant decreasing trend in west-east direction. For the offshore regions, contribution of anchovy was measured as 59.06% and 47.95 % for the west and east part of the Black Sea. Sprat contribution were 23.91%, 29.50%, 7.29% and 97.40 % in the coastal regions and 31.08% and 51.29% for offshore from west to east. Also horse mackerel was measured as 44.16%, 43.40%, 80.07% at coastal regions. At the eastest part of the coast line, no horse mackerel were observed in the trawl nets. For the offshore, 9.88% and 0.76% contribution were observed in western and eastern coasts respectively.

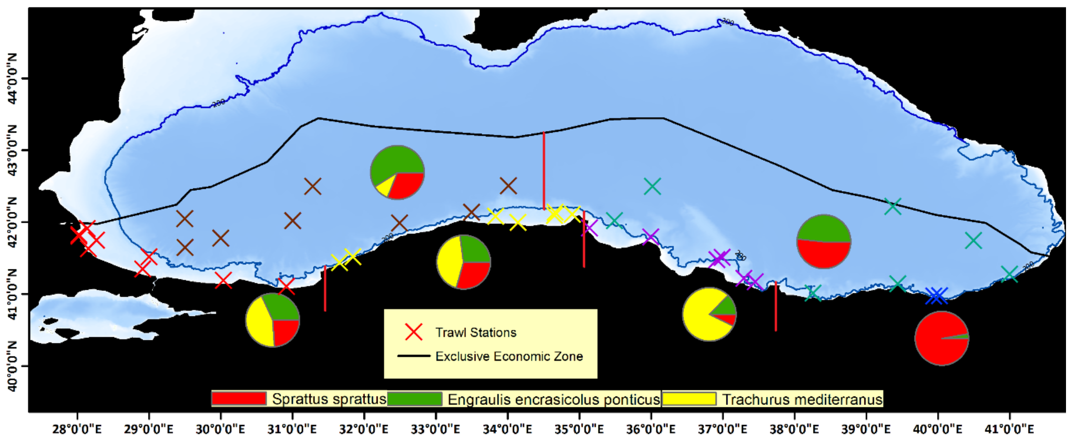


Figure 22: Relative biomass contribution of species along the regions in 2016 by trawl sampling. Trawl data from each stations were pooled per region. (Regions are divided by red straight lines and limited by Turkey Black Sea Exclusive Economic Zone. The regions which are between coast line and 200m depth were named as "Region 1", "Region 2", "Region 3" and "Region 4" from west to east. Off the Black Sea were divided into two and named as "Region 5" and "Region 6" in the west-east direction. Trawl stations for each region sampling were represented in different colors: Region 1, Red; Region 2, yellow; Region 3, purple; Region 4, dark blue; Region 5, brown; Region 6, light blue)

3.2.2 Size Distributions of Species

In the year 2011 and year 2016 a total of 48826 small pelagic fishes, including 25249 anchovy, 11388 horse mackerel and 12189 sprat were measured in length with 0.5 cm interval. After that, size distributions of each species were compared by percentages for years (Figure 23). According to these graphs given in figure 25, while the dominant length group of anchovy measured in 2016 was 5 cm (22.92 %), in 2011 the dominant groups were 7 cm (19.53 %) and 7.5 cm (19.82). For the horse mackerel, dominant size groups were measured as 9.5 cm (28.48 %) and 10 cm (21.92 %) for the years 2011 and 2016 respectively. Finally it was observed that sprat was dominated by 6.5 cm (16.77 %) and 8.5 cm (15.05 %) length classes in 2016 while the dominant class was 9 cm (28.45 %) in 2011.

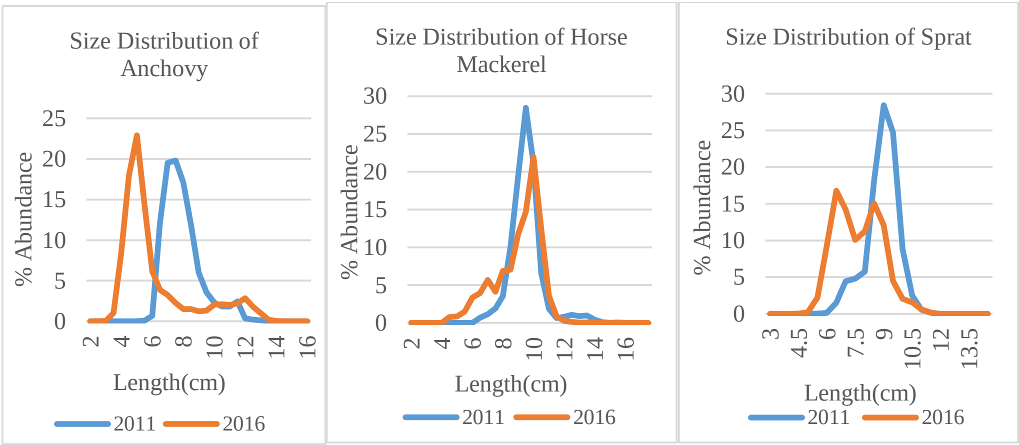


Figure 23: Comparison of the size distribution of three main small pelagic species by year 2011 and 2016.

In the year 2011, relatively longer anchovies with three peaks at 7 cm (23.07 %), 8.5 cm (15.85 %) and 11.5 cm (4.10 %) were observed at the coastal part of the eastern Black Sea, while one peak at 7.5 cm (33.78 %) was seen in the west (Figure 26). In addition to this, from west to east the dominant size classes were measured as 8.5 cm for the Region 1 with 30.72%, 6.5 cm and 7 cm for Region 2 with equally 36.68%, 7.5 cm for Region 3 with 39.61% and 7.5 cm for Region 4 with 27.95% covering of all anchovy caught in abundance. In addition to this, increasing size pattern of the dominant size of the horse mackerel was observed from west to east (Figure 24). While the peaks were measured at 8.5 cm (23.19%) and 9.5 cm (39.09 %) for Region 1 and 2, it was 9.5 cm and 10 cm (32.38% and 28.85% respectively) for Region 3 and, 9 cm and 9.5 cm (27.83, 28.25 %) for Region 4. There was no size distribution pattern for sprat through the survey. In Region 1, Region 2 and Region 3 peaks were observed at 9.5 cm, 9 cm and 9 cm with 51.43, 41.58 and 30.01 % in abundance. Besides that two peaks were observed at 7 cm (15.61 %) and 8.5 cm (30.78 %) size classes at the Region 4 (Figure 24).

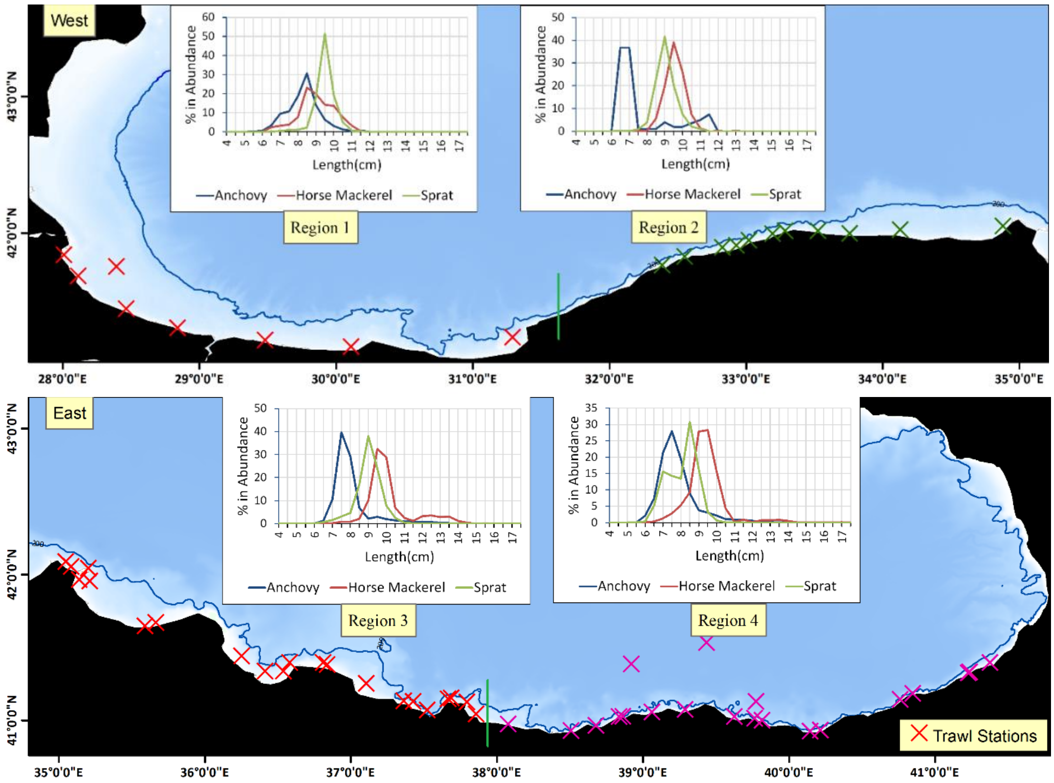


Figure 24: Length frequency of three targeted small pelagic species in 2011. Upper and lower maps show the west and east part of the Black Sea coasts respectively. The regions were numbered from west to east from one to four. Data from different colors of trawl stations represents different regions and were used to create the size distribution graphs.

Coastal part of the 2016 survey, the largest anchovies were sampled near bosphorus. Some exceptional sizes (longer than 14 cm) of anchovies were sampled in region 1 (Figure 25-up). Also three different peaks in size distribution were observed at 7.5 cm, 10.5 cm and 12.47 cm with 6.72%, 11.29% and 12.47% in abundance. Contrary to this, region 2 were strongly dominated by 4.5 cm anchovies with 30.58% and this domination were followed by two smaller peaks at 8.5 cm and 12 cm length groups with 6.51% and 4.51% respectively (Figure 25-Up). Even if the peak in region 3 was also at 4.5 cm, no anchovy were caught longer than 10 cm in there (Figure 25-Down). Finally in region 4 at the eastest part of the Black Sea, , 4 cm and 5 cm anchovies were sampled with 11% and 44% in abundance. For the horse mackerel, even if the longest individuals were sampled from region 1 (about 14 cm), it was observed that in first three region from west to east, the dominant length groups were in a range of 9.5 cm-10 cm. (~30 % of all horse mackerel sampled in abundance). Besides that, no horse mackerel were observed in region 4 trawl samplings. Sprat size were marked with decreasing size pattern from west to east and its peaks were observed at 9 cm, 8.5 cm, 7 cm and 7.5 cm size classes with 46.71%, 24.75%, 29.22% and 22.70% contribution to its size distribution (Figure 25).

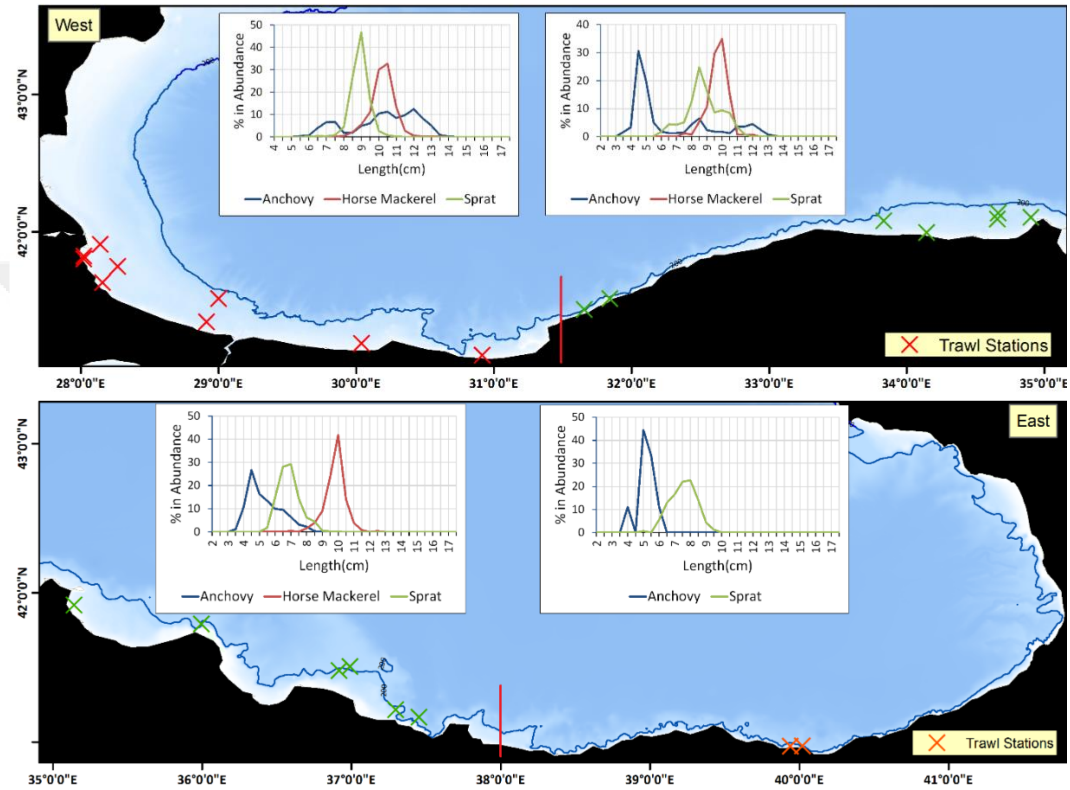


Figure 25: 2016 size distribution of three small pelagic species from coastal trawl stations. The maps up and down shows the west and east parts of the Black Sea respectively. Each map were divided by red straight line and numbered as Region 1, 2, 3 and 4 in west-east direction. Different colors of trawl stations show the ones used to draw the graphs.

At the offshore part of the 2016 survey, anchovy distributed more even from west to east (Figure 26). The peak sizes were seen between 4.5 cm and 5 cm for the both sides of the Black Sea. Also from west to east, while the size of the horse mackerel individuals were decreasing, the longer sprat individuals were caught from the east part of the Black Sea. The dominant length groups were 7.5 and 8.5

cm for horse mackerel with 20.84% and 23.06% in the west and 7 cm with 14.30% in the east. For the sprat, while the west part was dominated by 7 and 8.5 cm individuals with 20.59% and 18.73%, the east part was strongly dominated by 6.5 cm with 36.28% contribution to its size distribution.

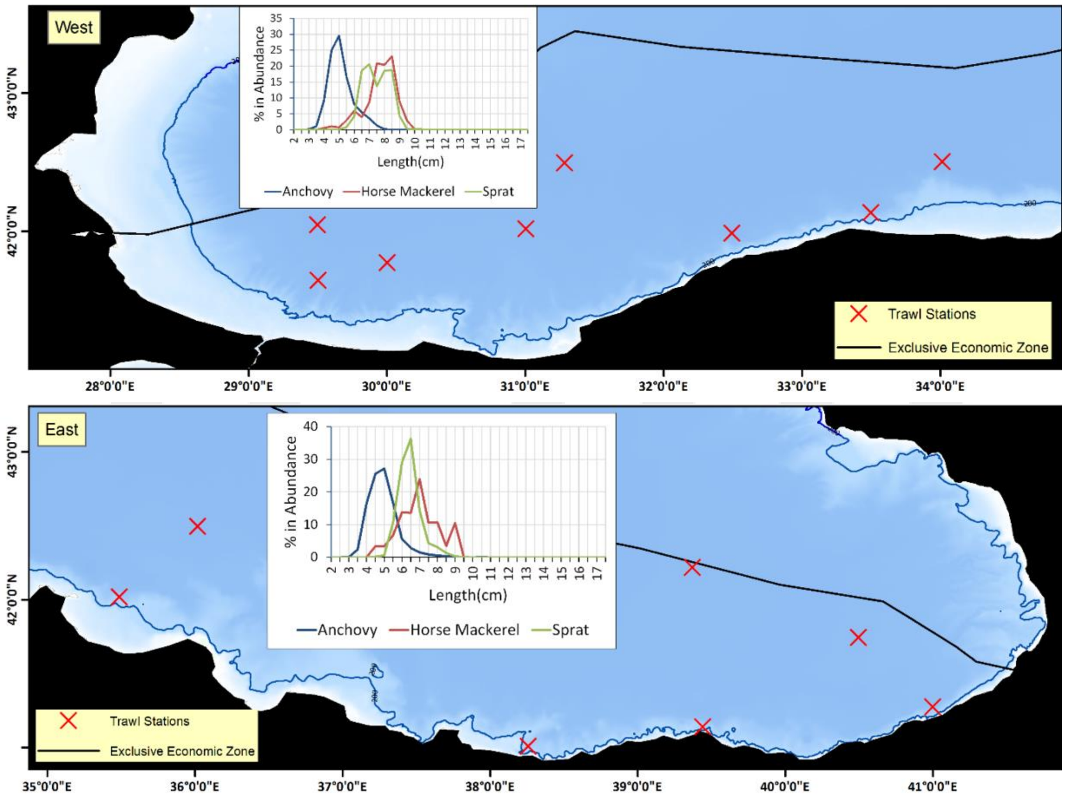


Figure 26: 2016 size distribution of three small pelagic species from offshore trawl stations. The maps up and down shows the west and east parts of the off Black Sea respectively. Regions were numbered as Region 5 and 6 in west-east direction.

3.3 Spatial Density Distribution of the Small Pelagics

Spatial distribution of each target species were mapped based on the results of the acoustic data. According to these maps it was observed that all three target species were 3-4 fold denser in 2011 than 2016. In three species, the most dense aggregation were observed as anchovy at the coastline of Ordu, Trabzon and Rize, between 37.5°E and 42°E (Figure 27). Besides this, it was observed that different species were concentrated on different regions at the time when the survey is carried. While anchovy were observed denser at the east side of the Black Sea in

2011 November-December, it preferred west coasts in 2016 November. The most dense schools of horse mackerel were observed in 2011 at the central part of the Black Sea coasts. The spatial distribution by using averaged acoustic energy (NASC) by one nautical mile interval of all three species in 2011 and 2016 were revealed on maps from figure 27 to 35.

3.3.1 Anchovy

Anchovy were the most dense in the east coast of the Black Sea while they were not seen on the west side in 2011. Especially the central part of Ordu (37.5°E) and its west, very long and wide overwintering schools were observed (Figure 27). In contrast, especially near Bosphorus (28°E-31°E) very dense anchovy schools were observed at the coastal part of the 2016 survey conducted between 15-27 November (Figure 28), although not as intense as in 2011 (Figure 27). In addition, more homogeneous distribution and less NASC values were recorded in the offshore part of the 2016 survey, despite a gradual decrease from west to east (Figure 29).

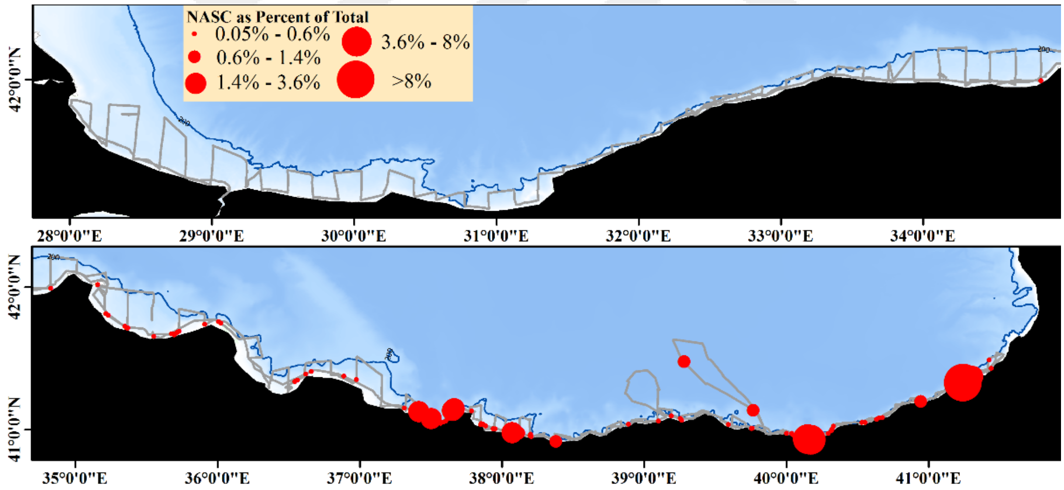


Figure 27: Spatial distribution of Anchovy as percent in 2011 survey(Upper and lower maps show the western and eastern parts of the basin).

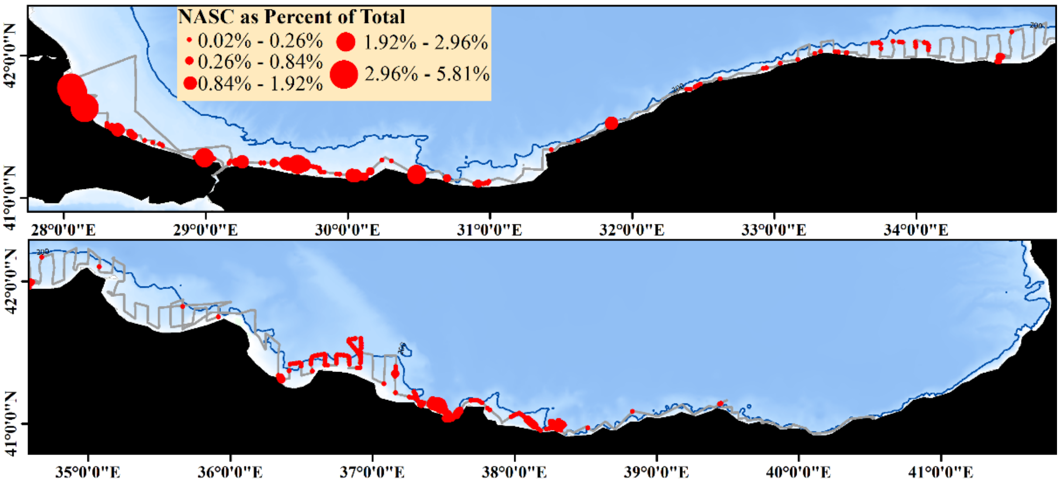


Figure 28: Spatial distribution of Anchovy as percent in coastal part of the 2016 survey (Upper and lower maps show the western and eastern parts of the basin).

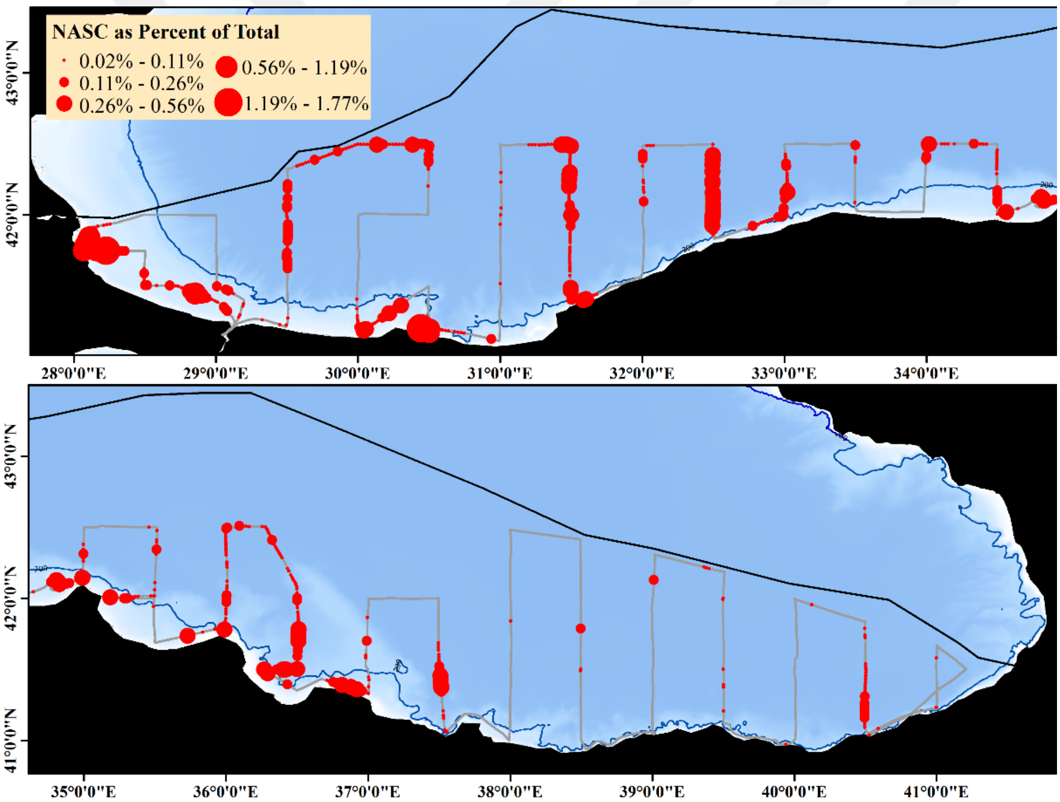


Figure 29: Spatial distribution of Anchovy as percent in offshore part of the 2016 survey (Upper and lower maps show the western and eastern parts of the basin).

3.3.2 Horse Mackerel

In the year 2011, horse mackerel schools were the most dense at the central part of the Black Sea, in a region covering the coastline of Bartın-Kastamonu-Sinop

(31.5°E-34°E) while almost no aggregation were observed at the bosphorus region and few at the east part of the Turkey Black Sea coast (Figure 30). Besides this, homogeneous horse mackerel aggregations with very low percentage of NASC values were seen in the offshore part of the 2016 survey (Figure 32). In both coast and offshore parts of 2016 expedition, gradual increasing in the density distribution of horse mackerel was observed from east to west (Figure 31-32).

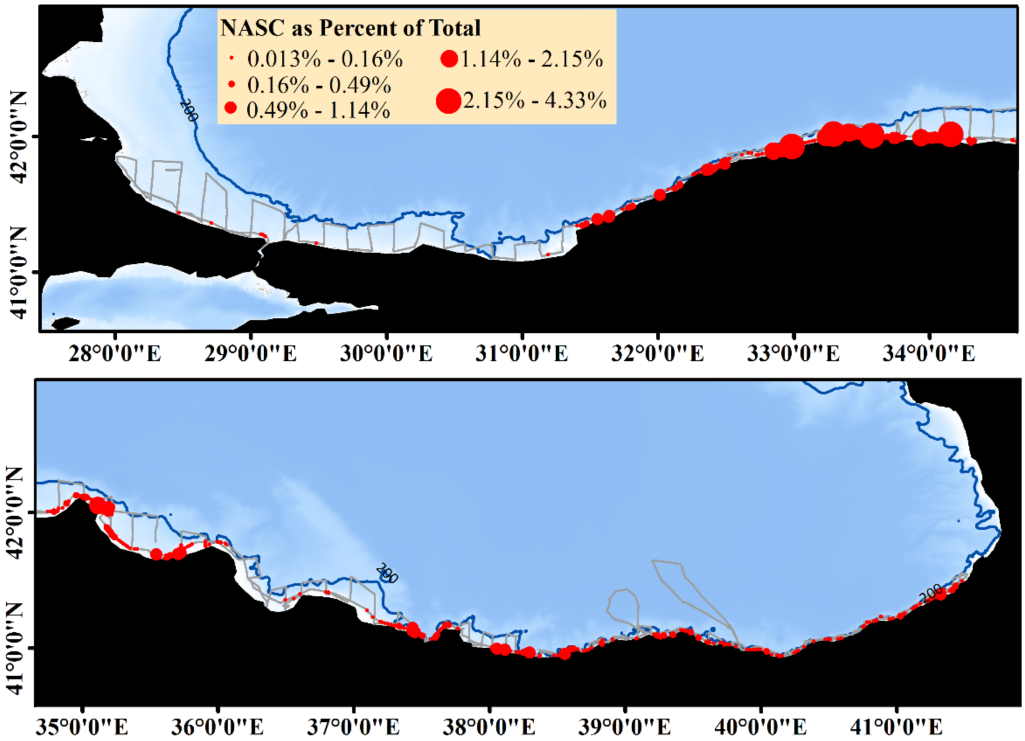


Figure 30: Spatial distribution of Horse Mackerel as percent in 2011 survey (Upper and lower maps show the western and eastern parts of the basin).

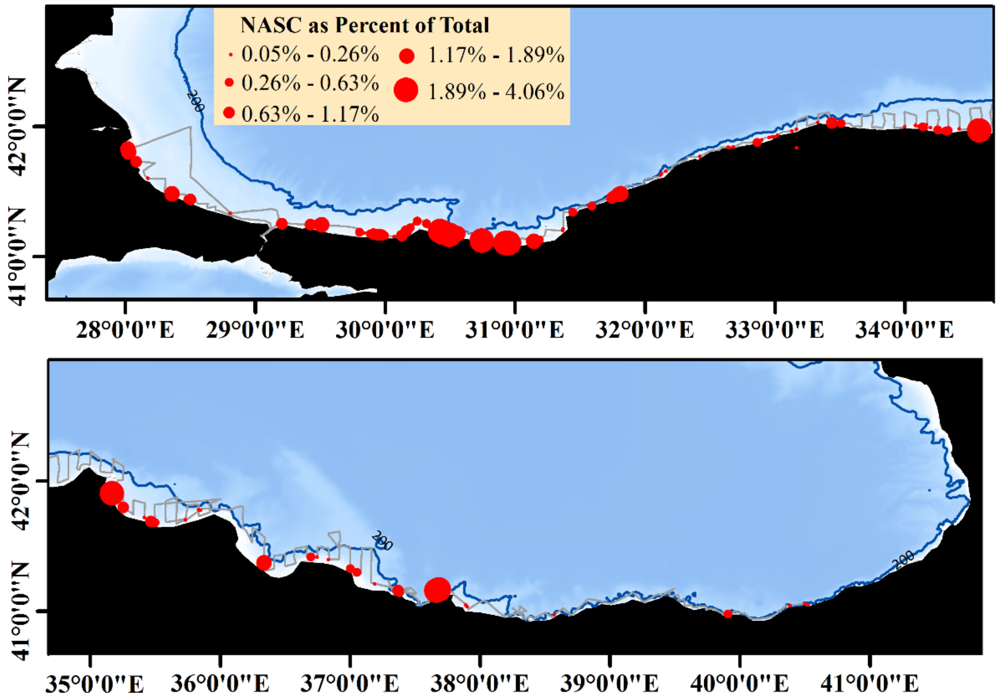


Figure 31: Spatial distribution of Horse Mackerel as percent in coastal part of the 2016 survey (Upper and lower maps show the western and eastern parts of the basin).

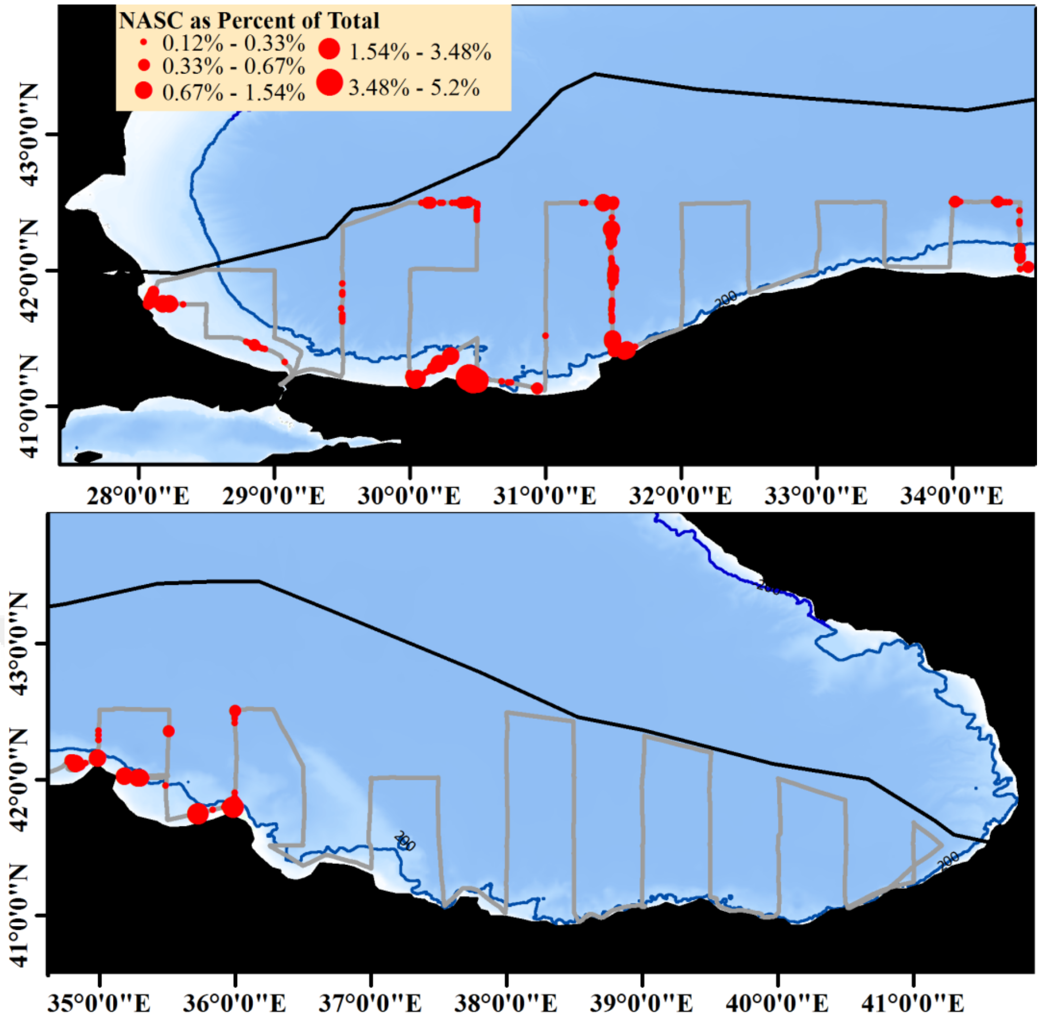


Figure 32: Spatial distribution of Horse Mackerel as percent in offshore part of the 2016 survey (Upper and lower maps show the western and eastern parts of the basin).

3.3.3Sprat

In the year 2011, the highest NASC contribution as percent of sprat were recorded along the eastern part of the Turkey Black Sea coasts, especially at Rize and Trabzon regions, between 37.5°E and 42°E (Figure 33). In offshore part of the 2016 survey, while very high percent NASC of sprat were recorded near bosphorus (28°E -30.5°E) and around Sinop (~34.5°E), with the exception of off Samsun (36°E), very few and less NASC contribution were observed in open see (Figure 35). In year 2016 coastal survey, the acoustic energy of sprat were recorded very low except for a few in bosphorus region (~28.5°E) and less than that in the Giresun-Trabzon region, between 39°E and 40°E (Figure 34).

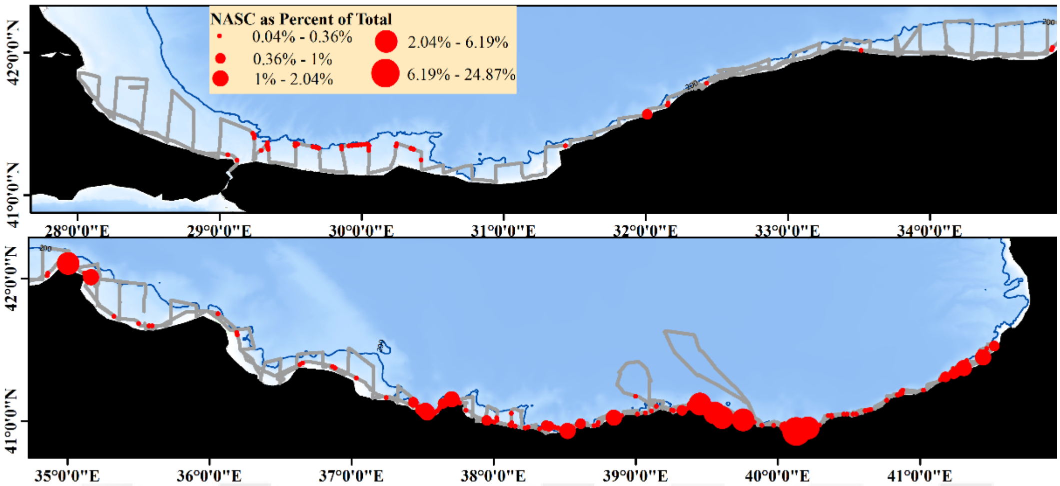


Figure 33: Spatial distribution of Sprat as percent in 2011 survey (Upper and lower maps show the western and eastern parts of the basin).

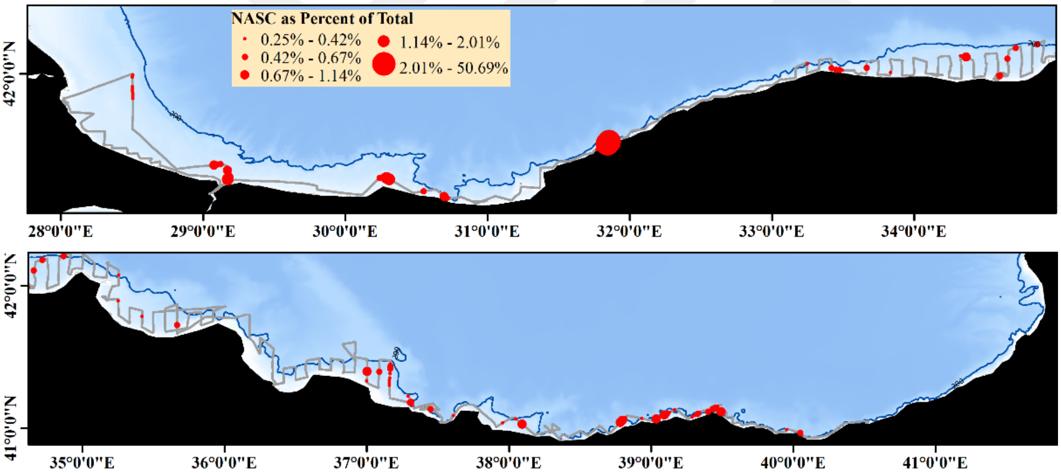


Figure 34: Spatial distribution of Sprat as percent in coastal part of the 2016 survey (Upper and lower maps show the western and eastern parts of the basin).

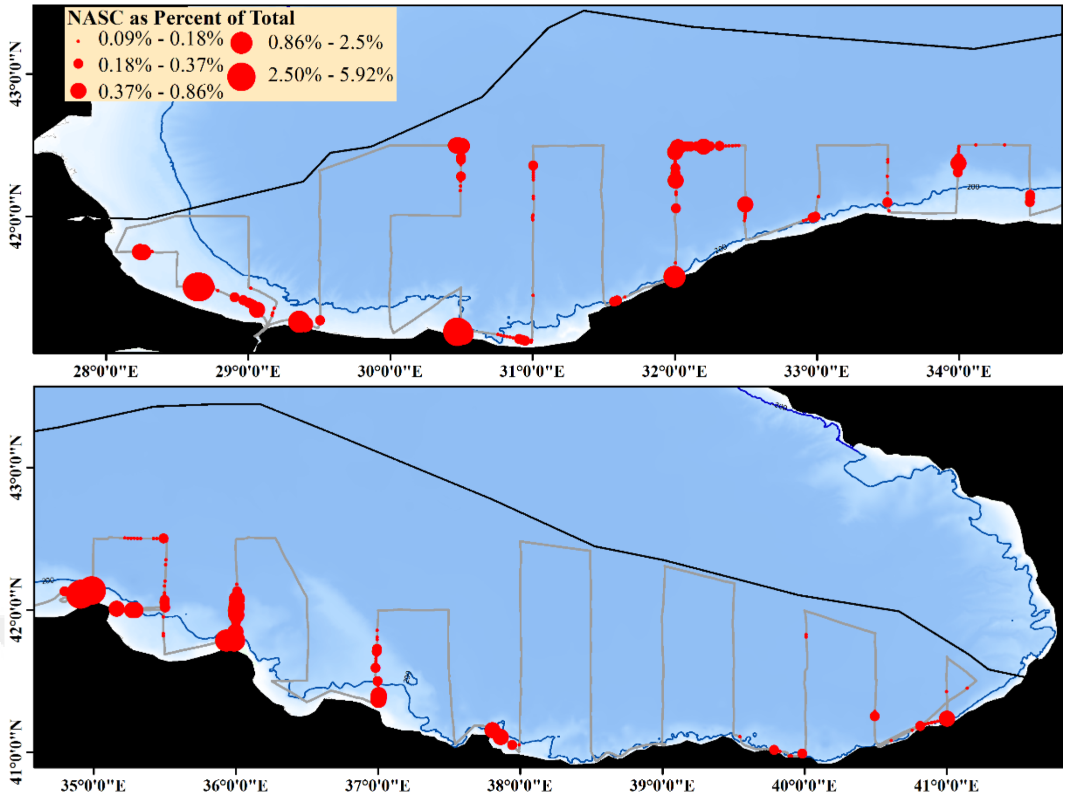


Figure 35: Spatial distribution of Sprat as percent in offshore part of the 2016 survey (Upper and lower maps show the western and eastern parts of the basin).

3.4 Target Strength (TS), Abundance and Biomass Calculations

Target strength, abundance and biomass calculations were done in fourteen and sixteen regions for 2011 and 2016 surveys as mentioned in section 2.4.3.3.2 in terms of the regional features of the basin.

3.4.1 Target Strength Results

TS distribution of each species which was used to calculate the abundance and biomass were given in Table 5,6 and 7. Although the target strength of anchovy and sprat varies so much from region to region, TS of horse mackerel was found higher than that of anchovy and sprat. Also as it is expected, smaller individuals were observed through offshore part of the 2016 survey (Table 7).

Table 5: TS Distribution of target species by regions in 2011 (Coastal Survey) Regions shown in table 4 were used for calculation.

TS	Average	R01	R02	R03	R04	R05	R06	R07
Anchovy	-54.617	-53.999	-51.957	-51.957	-51.186	-51.186	-53.225	-56.015
Horse Mackerel	-49.783	-51.096	-47.156	-50.419	-50.257	-50.257	-49.822	-49.767
Sprat	-53.495	-52.625	-53.906	-53.906	-53.906	-52.896	-53.060	-53.130
	R08	R09	R10	R11	R12	R13	R14	
Anchovy	-54.109	-53.914	-54.570	-54.147	-53.624	-54.878	-54.755	
Horse Mackerel	-49.316	-48.980	-49.818	-50.124	-49.772	-50.153	-50.427	
Sprat	-52.972	-53.441	-53.284	-53.664	-54.369	-53.619	-55.409	

Table 6: TS Distribution of target species by regions in 2016 (Coastal Survey)

TS	Average	R0101	R0102	R0103	R0104	R0105	R0106
Anchovy	-53.286	-50.263	-54.019	-57.647	-57.284	-57.873	-57.873
Horse Mackerel	-50.103	-49.806	-50.579	-54.375	-50.441	-50.441	-50.441
Sprat	-52.803	-52.506	-53.279	-51.891	-53.141	-53.141	-53.141
	R0107	R0108	R0109	R0110	R0111	R0112	R0113
Anchovy	-51.795	-57.380	-57.380	-56.530	-56.984	-56.984	-56.984
Horse Mackerel	-50.441	-49.615	-52.242	-54.501	-51.378	-51.378	-51.378
Sprat	-53.141	-52.315	-54.942	-57.201	-54.078	-54.078	-54.078

Table 7: TS Distribution of target species by regions in 2016 (Offshore Survey)

TS	Average	West	East
Anchovy	-57.231	-57.129	-57.443
Horse Mackerel	-51.659	-51.378	-53.309
Sprat	-54.359	-54.078	-56.009

1.4.2 Abundance and Biomass Estimations

1.4.2.1 2011 Survey

Three target species' density and total biomass/abundance calculations of the 2011 survey were shown in Table 4. Total biomasses of Black Sea anchovy, horse mackerel and sprat within the survey area and during the studied period were estimated as 10 900, 93 300and 15 300 tons respectively. Parallel to this, anchovy and sprat results showed that average density of them are very close to each other with 2.06 and 2.91 t/nmi². The horse mackerel displayed very dense and large aggregations, length of which exceeding 15 km. The density was also very high (17.70 t/nmi²) compared to the other species in the year 2011.

While the total amount of estimated anchovy biomass in each regions covering the west part of the Black Sea, between 28°E and 34°E, did not exceed 30 tons (8.80 tons on average), the least anchovy biomass were calculated as 169 tons (1353 tons on average) in the eastern regions ,between 34°E and 42°E (Table 8a-up). Among the eastern regions the density of anchovy was calculated significantly higher in the area between 37°E-42°E (R09-14). Density and total biomass/abundance of anchovy for the same regions displayed a patchy distribution, not proportional to the neighbouring regions. For example, while estimated anchovy total biomass of R10 is calculated 6-fold higher than R13, R10 were found less dense than R13 (Table 8a-Up). Furthermore it was observed that anchovy preferred some regions than the other in 2011. These regions which include R08, R13 and R14 constituted 80% of all estimated biomass. Exceptionally, R13 were found as the second most dense region with relatively lower value of estimated biomass than other eastern regions (Table 8a-up). R14, which located in the most eastern part of the expedition area were found exceptionally the most dense (19 x 10^6 ind/nmi²) with highest biomass estimation (4800 t).

The highest estimated abundance and biomass of horse mackerel were placed between 31°E and 35°E longitute covering R04, R05, R06, R07 and R08 (Table 8a-Down) which are located in the central part of the Black Sea. Unlike anchovy, it was observed that horse mackerel is more dispersed and dense through the coastal areas (Table 8a-Up and Down). The highest density in number and biomass were found in R06 with the value of 20.75 x 10^6 ind. and 21 400 tons per nmi² respectively. However, even though the density in biomass value of R07 is less than one thirt of R06, the density in number value of R07 was found two third of R06 (Table 8a-Down). Also, it was observed that horse mackerel did not prefer the most western (R01,R02 and R03) and eastern (R12, R13 and R14) regions. However, in comparison, more extensive schools of horse mackerel were observed in the western regions of central part (Table 8a-Down).

Although the highest biomass value of sprat was calculated in R10 (2168.85 tons/nmi²), it was observed that the density was highest in the eastern regions between 39°E and 42°E longitude. In these regions the highest density in number and biomass values were calculated as 11.90 x 10^6 ind./nmi² and 25.80 t/nmi² respectively (Table 8b).

Table 8a: Calculated density and total values of abundance and biomass of Black Sea anchovy (up), horse mackerel (down) for each region in 2011 coastal survey. Regions shown in table 4 were used for calculations.

Region	Density in Number (# of ind.x10^6/nmi²)	Density in Biomass (t/nmi²)	Abundance (# of individuals x 10^6)	Biomass (t)
R01 (28°E-29°E)	0.00	0.00	0.00	0.00
R02 (29°E-30°E)	0.00	0.00	0.00	0.00
R03 (30°E-31°E)	0.00	0.00	0.00	0.00
R04 (31°E-32°E)	0.00	0.00	0.00	0.00
R05 (32°E-33°E)	0.03	0.21	3.96	28.51
R06 (33°E-34°E)	0.02	0.09	6.55	24.32
R07 (34°E-35°E)	0.18	0.27	114.10	169.32
R08 (35°E-36°E)	0.53	1.50	303.98	856.06
R09 (36°E-37°E)	0.34	1.06	137.95	430.01
R10 (37°E-38°E)	3.78	9.08	1335.34	3205.07
R11 (38°E-39°E)	1.61	4.46	215.61	595.15
R12 (39°E-40°E)	0.69	2.44	70.34	249.89
R13 (40°E-41°E)	4.81	10.46	243.91	527.57
R14 (41°E-42°E)	19.16	44.01	2095.04	4798.50
Total	-	-	4526.79	10884.41
Average	*0.86	*2.06	-	-

Region	Density in Number (# of ind.x10^6/nmi²)	Density in Biomass (t/nmi²)	Abundance (# of individuals x 10^6)	Biomass (t)
R01 (28°E-29°E)	0.56	1.63	627.68	1822.51
R02 (29°E-30°E)	0.21	0.61	138.36	401.73
R03 (30°E-31°E)	0.23	1.32	113.79	648.42
R04 (31°E-32°E)	11.94	68.06	2949.58	16808.18
R05 (32°E-33°E)	16.54	118.93	2275.90	16366.94
R06 (33°E-34°E)	20.75	76.98	5782.70	21456.77
R07 (34°E-35°E)	15.18	22.52	9363.87	13896.27
R08 (35°E-36°E)	6.08	17.13	3481.50	9804.40
R09 (36°E-37°E)	0.90	2.79	362.08	1128.62
R10 (37°E-38°E)	6.95	16.67	2452.60	5886.73
R11 (38°E-39°E)	7.65	21.13	1022.04	2821.17
R12 (39°E-40°E)	3.37	11.96	344.52	1223.92
R13 (40°E-41°E)	2.08	4.53	105.60	229.74
R14 (41°E-42°E)	3.28	7.53	358.59	823.52
Total	-	-	29378.81	93318.92
Average	*5.57	*17.7	-	-

Table 8b: Calculated density and total values of abundance and biomass of sprat for each region in 2011 coastal survey. Regions shown in table 4 were used for calculations.

Region	Density in Number (# of ind.x10^6/nmi²)	Density in Biomass (t/nmi²)	Abundance (# of individuals x 10^6)	Biomass (t)
R01 (28°E-29°E)	0.28	0.82	316.95	920.27
R02 (29°E-30°E)	0.92	2.67	605.52	1758.16
R03 (30°E-31°E)	0.58	3.31	285.30	1625.77
R04 (31°E-32°E)	0.34	1.96	84.73	482.86
R05 (32°E-33°E)	0.44	3.14	60.04	431.74
R06 (33°E-34°E)	0.32	1.18	88.50	328.39
R07 (34°E-35°E)	0.93	1.39	576.45	855.47
R08 (35°E-36°E)	0.75	2.12	431.27	1214.51
R09 (36°E-37°E)	0.39	1.22	158.79	494.95
R10 (37°E-38°E)	2.56	6.14	903.61	2168.85
R11 (38°E-39°E)	2.70	7.45	360.42	994.88
R12 (39°E-40°E)	3.80	13.49	388.54	1380.30
R13 (40°E-41°E)	11.86	25.79	601.43	1308.41
R14 (41°E-42°E)	5.41	12.43	591.76	1359.00
Total	-	-	5453.30	15323.54
Average	*1.03	*2.91	-	-

*Density of biomass and abundance were calculated dividing biomass or abundance by related regional area which is shown in table 3.

1.4.2.2 2016 Survey

The abundance and biomass calculations for 2016 survey were done for coastal and offshore areas separately. The results were shown in Table 9a and 9b. For the coastal part, anchovy, horse mackerel and sprat biomasses were estimated as 150 300, 436 000 and 18 200 tons respectively. Similarly, offshore biomass values were calculated as 155 400, 13 400 and 142 400 tons. In the same order, the biomass density values for the coastal zone were 19.15, 22.96 and 2.79 tons/nmi², while offshore values were calculated as 3.24, 0.31 and 3.30 tons/nmi².

Unlike the year 2011, the highest anchovy abundance and biomass values were calculated in the western part of the coastal zone especially near bosphorous covering R01, R02 and R03 in 2016 survey (Table 9a-Up). The anchovy density of these regions, especially R02, were found higher than other regions. Also, R02, R10 and R11 were found the most dense regions in terms of their abundance with the values of 26.31, 20.98 and 15.72 x 10^6 ind./nmi². Although the density in biomass values were calculated very close to each other in R01 and R02 (64.16 and 61.66 tons/nmi²), the density in number value of R02 were extremely higher than R01. Highest contribution of biomass were calculated as 71 600 tons for R01 (Table 9a-Up). For the offshore regions, biomass contribution of east and west were calculated as 119 000 and 36 400 tons. Parallel to this, the density of anchovy in eastern part were found about 3 fold higher than west (Table 9a-Up). Also it was striking that while estimated total anchovy biomass values of coastal and offshore parts are very close to each other, offshore abundance of anchovy is about 4 fold higher than total coastal biomass.

For the coastal part of the survey, the highest horse mackerel biomass contribution was calculated as 312 800 tons in R02 which constitutes 71 % of all coastal biomass (Table 9a-Down). Also, the density in biomass value were calculated as 475 tons/nmi² in the same region. Although highest horse mackerel biomasses were calculated in R01, R02 and R03, the most dense regions in terms of their number were found in R09 and R10 which are located in eastern part of the Black Sea coastal zone. Horse mackerel density and total biomass/abundance values were calculated very low in the offshore part of the Black Sea when compared with the coastal region results (Table 9a-Down). In the offshore results, there was an obvious concentration in the eastern region compared to the west in 2016.

In the year 2016, it was observed that almost 90 % of estimated sprat biomass contribution was from offshore part of the Black Sea (Table 9b). The total coastal and offshore biomasses were calculated as 18 200 and 142 400 tons respectively (Table 9b). Also, while the sprat biomass contribution of western regions were calculated higher in the coastal zone (about 90 % of all coastal biomass), it was observed for offshore regions that the contribution of both parts are slightly different (Table 9b). The density values were also found higher in the offshore part. Within the coastal areas, R04 were found the most dense with 5.62 x 10^6 ind./nmi² and 17.62 tons/nmi² values. Likewise, the density of sprat in the east was higher than west in offshore regions (Table 9b).

Table 9a: Calculated density and total values of abundance and biomass of Black Sea anchovy (up), horse mackerel (down) for each region in 2016 survey. Areas shown in table 4 were used for calculations.

Region	Density in Number (# of ind.x10^6/nmi²)	Density in Biomass (t/nmi²)	Abundance (# of individuals x 10^6)	Biomass (t)
R01 (28°E-29°E)	11.27	44.83	12569.27	50022.56
R02 (29°E-30°E)	10.36	475.19	6820.98	312833.29
R03 (30°E-31°E)	12.50	60.91	6133.53	29889.57
R04 (31°E-32°E)	8.20	26.51	2026.17	6546.23
R05 (32°E-33°E)	1.66	5.37	228.94	739.66
R06 (33°E-34°E)	1.45	4.67	403.27	1302.91
R07 (34°E-35°E)	2.94	9.48	1811.14	5851.49
R08 (35°E-36°E)	5.06	21.29	2896.66	12186.45
R09 (36°E-37°E)	12.62	21.08	5101.45	8524.56
R10 (37°E-38°E)	22.03	17.36	7777.07	6130.87
R11 (38°E-39°E)	3.44	8.07	459.55	1076.94
R12 (39°E-40°E)	2.52	5.91	258.08	604.79
R13 (40°E-41°E)	2.25	5.28	113.57	266.14
Offshore West (28°E-34.5°E)	0.01	0.02	188.86	442.57
Offshore East (34.5°E-42°E)	0.44	0.54	10565.76	12910.64
Total (Coastal)	-	-	46599.67	435975.47
Total (Offshore)	-	-	10754.62	13353.22
Average (Coastal)	6.24	22.96	-	-
Average (Offshore)	0.15	0.31	-	-

Region	Density in Number (# of ind.x10^6/nmi²)	Density in Biomass (t/nmi²)	Abundance (# of individuals x 10^6)	Biomass (t)
R01 (28°E-29°E)	7.40	64.16	8253.27	71584.75
R02 (29°E-30°E)	26.31	61.66	17321.57	40593.02
R03 (30°E-31°E)	6.02	46.60	2953.00	22864.26
R04 (31°E-32°E)	4.65	3.66	1147.59	903.74
R05 (32°E-33°E)	3.12	1.93	428.70	265.81
R06 (33°E-34°E)	2.52	1.56	701.54	434.98
R07 (34°E-35°E)	0.51	2.79	311.59	1721.09
R08 (35°E-36°E)	0.56	0.41	320.99	237.51
R09 (36°E-37°E)	7.41	5.48	2997.31	2217.76
R10 (37°E-38°E)	20.98	21.49	7406.69	7587.72
R11 (38°E-39°E)	15.72	13.11	2098.48	1750.75
R12 (39°E-40°E)	0.93	0.78	95.52	79.69
R13 (40°E-41°E)	0.22	0.18	10.93	9.11
Offshore West (28°E-34.5°E)	2.01	1.63	45026.76	36418.39
Offshore East (34.5°E-42°E)	6.90	5.01	163898.23	119028.34
Total (Coastal)	-	-	44047.18	150250.17
Total (Offshore)	-	-	208924.99	155446.73
Average (Coastal)	5.26	19.15	-	-
Average (Offshore)	4.15	3.24	-	-

Table 9b: Calculated density and total values of abundance and biomass of sprat for each region in 2016 survey. Areas shown in table 4 were used for calculations.

Region	Density in Number (# of ind.x10^6/nmi²)	Density in Biomass (t/nmi²)	Abundance (# of individuals x 10^6)	Biomass (t)
R01 (28°E-29°E)	0.36	1.37	399.58	1528.04
R02 (29°E-30°E)	3.20	9.51	2104.74	6262.65
R03 (30°E-31°E)	1.16	5.40	571.43	2650.14
R04 (31°E-32°E)	5.62	17.62	1387.44	4350.10
R05 (32°E-33°E)	0.13	0.40	17.70	55.51
R06 (33°E-34°E)	0.58	1.82	161.89	507.59
R07 (34°E-35°E)	0.35	1.10	216.40	678.47
R08 (35°E-36°E)	0.26	1.05	149.04	600.91
R09 (36°E-37°E)	0.34	0.57	137.62	230.26
R10 (37°E-38°E)	2.34	1.91	825.78	675.52
R11 (38°E-39°E)	0.76	1.76	101.81	235.10
R12 (39°E-40°E)	1.51	3.48	154.16	355.98
R13 (40°E-41°E)	0.72	1.66	36.23	83.67
Offshore West (28°E-34.5°E)	1.30	3.01	29157.03	67327.54
Offshore East (34.5°E-42°E)	2.54	3.16	60423.20	75037.23
Total (Coastal)	-	-	6263.83	18213.93
Total (Offshore)	-	-	89580.23	142364.77
Average (Coastal)	0.79	2.79	-	-
Average (Offshore)	1.55	3.30	-	-

4 DISCUSSION

4.1Temperature Variation of the Sampling Areas

In this study, the temperature has two aspects. First, it was used to delineate warm water species from cold water fish, such as sprat. Therefore, to define the boundary line separating the two groups of fish was utmost importance. As can be seen from the results of the hydrographical analysis (Figure 16 and 18) the vertical temperature measurements made at regular intervals helped to define these layers accurately.

In both surveys, the depth of thermocline at different stations were found quite different. This might be derived by the anticyclonic eddies near Sinop, Giresun and Trabzon between coastline and rim current (Figure 1). These eddies are known to upwell the deep waters and to uplift the cold water at the lower layers towards the surface (Oğuz, 1993; Staneva, 2001). Thus, occurrence of such mesoscale structures rise the thermocline depth at the centre and descends at the edge of eddies.

Secondly, it was used to understand to what extent the variation in the overwintering grounds of the small pelagic fishes is governed by the temperature variability in the environment. The results indicated that even the 10-day difference was sufficient to cause highly effective hydrographic changes in the Black Sea. At the beginning of autumn, the Black Sea goes into a cooling period and this period starts with northerly winds from the most northern part of the sea and it continues from west to east throughout the Turkey Black Sea coasts in November-December (Ginzburg et.al., 2004), when the both of the surveys were carried out. This east to west cooling pattern was clearly seen in 2011 (Figure 15).

The rate of cooling is also regulated by the strength of the northerly winds and the almost 4 degrees difference is possibly linked to climatic conditions in the region. Chashchin et al. (2015) reported that the variation in the strength and direction of the winds in autumn may result in different cooling patterns, which in turn effects the overwintering behaviour of the small pelagic fishes. As the Figure

18 suggested, 2016 was possibly one of the years which Black Sea displays an unusual cooling pattern progressing from north to south.

It is already known that migration of thermohaline pelagic fish species in the Black Sea is, to a sıgnificant extent, controlled by the cooling of the sea. It is also documented that the temperature is one of the prime factors triggering the overwintering migration (Chashchin 1996). Gücü et al. 2017 suggested the rate of cooling in the Black Sea has a stronger impact on the anchovy, than being exposed to cold or mild winter. On top of that, the distance of the overwintering migration and the selection of overwintering grounds may also be controlled by the cooling. The distribution of fish (Figure 27, 28, 29; Table 8, 9) and the differences in the surface temperature climatology (Figure 15, 17) of the two years suggest that the unusual cooling in the north-south direction, and the warm water mass trapped between 32°E and 34°E longitudes (Figure 17-Up) as a consequence of this event, seems to have caused migratory fish such as anchovy to remain in the west.

Similar effect of temperature contrast, caused one of the other warm water wintering species, horse mackerel mostly to stay in western coastal zone in the year 2016 (Figure 31, Table 9a-Down). Unlike anchovy and horse mackerel, boreal species, sprat remained in open sea because of the cold water mass there (Figure 35, Table 9b).

It is also known that anchovy schools migrate in a west-east direction once they reach the southern Black Sea coast, dictating fishing activity in the region. Therefore, besides acoustic experiments, information on location of fishing fleets can be used to track the migration movement of fish in a desired basin. Based on this information, Figure 36 shows that between 2011 and 2015, the fish migrated from west to east until the eastern part of the Black Sea where they preferred to overwinter.

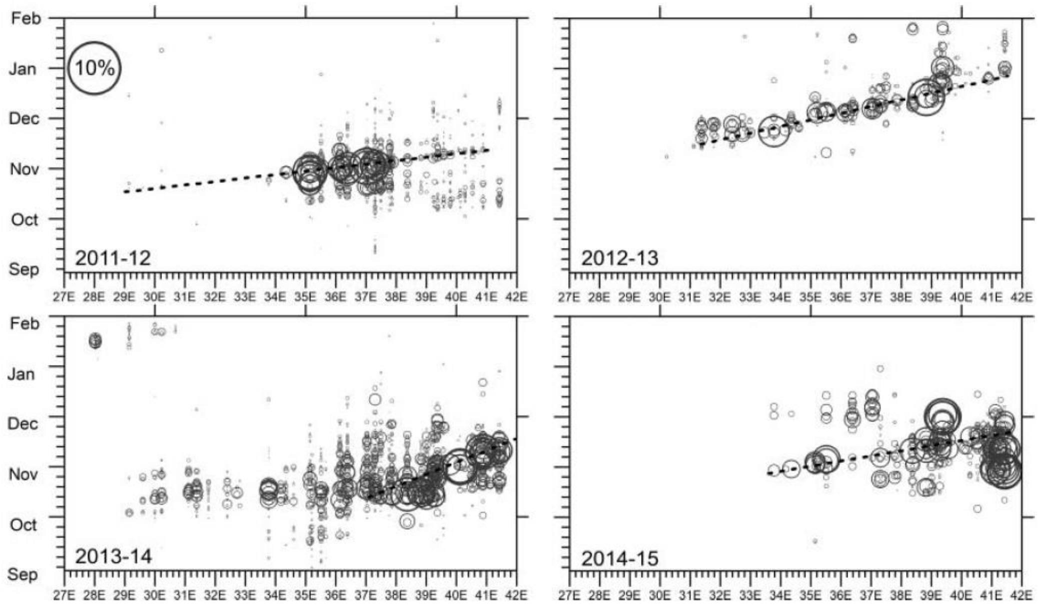


Figure 36: The location of fishing fleet in successive years between 2011 and 2015. Vertical axis shows the months and horizontal axis shows longitudes of the landing ports. Circles shows the percentage of landings to the ports. Dashed line shows the change between east and west. (Figure was taken from Gücü, 2017).

Likewise, according to total landing of anchovy data from TUIK (Figure 37), it was seen that larger amount of anchovy was landed from the eastern part of the southern Black Sea between 2000 and 2018 with the exception of the year 2016. In this year, anchovy was caught mostly in the western part of the Black Sea indicating that instead of heading to the eastern part, the fish found the most suitable environment to overwinter in the western part.

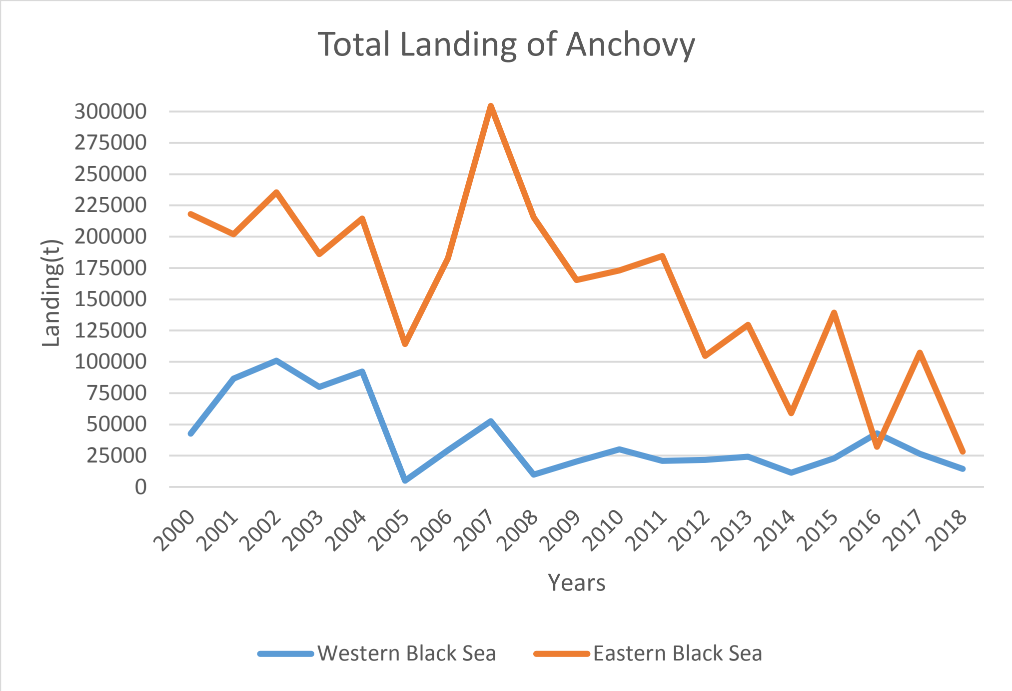


Figure 37: Total landing of anchovy between 2000 and 2016 for eastern and western parts of the southern Black Sea. Data was taken from TUIK website (https://biruni.tuik.gov.tr/medas/?locale=tr)

4.2 Spatial Density Distribution

While high water temperature of the Turkey Black Sea Coast allows anchovy and horse mackerel wide range of living habitat, it pushes the sprat into the deeper waters and narrow its habitat down to between thermocline and sea bottom. However, in the open sea, very favorable environmental conditions were observed in 2016 survey for sprat.

In this thesis, the combination of the cooling pattern of the basin and geographical shape of the southern Black Sea coast were found utmost importance effecting distribution of the three pelagic fishes. From this point of view, it was observed that the studied area were shared by three different small pelagic fish species due to their water temperature preferences. Thus, it was observed from catch and acoustic energy distribution that while anchovy and horse mackerel prefer warmer waters, sprat prefers regions with lower water temperature.

Restriction of trawl sampling

The sampling of anchovy and horse mackerel was successful because they both inhabits in upper thermocline layer of the water column. However, one of the restriction resulted from pelagic trawl net was sprat sampling. Even if anchovy and sprat show the same pattern of diel vertical migration (ascending in the afternoon and descending in early morning), the water temperature limits the vertical distribution of both species in Black Sea. While sprat mostly stays below thermocline, anchovy does approach to the cold waters below the thermocline. Thus, this makes sampling of sprat, horse mackerel and anchovy together a quite challenging issue when the sprat is in the lower water column, away from the thermocline in a daytime. This causes bias in the catch data. However, in the year 2011, cooling from east to west was permitted sprat to forage through the whole water column between İğneada/KIRKLARELİ (28°E) and Ereğli/ZONGULDAK (31.5°E). Thus, sprat contribution of trawl sampling was more accurate there (Figure 22).

4.2.2 Distribution of Anchovy

In contrast to the sprat, the highest biomass, density and catch contribution of anchovy were found in the eastern and western parts of the Black Sea in 2011 and 2016, respectively which are the warmest regions in associated surveys. According to Johannesson and Losse, 1973, the wintering area of the Black Sea anchovy extends from Cape Sinop (35°E) to Batumi (42°E) coast covering the eastern Black Sea coasts in Anatolia. This region is protected from cold northerly winds and currents by the main Caucasus Ridge which is the most favorable region for overwintering anchovy (Chaschin, 1996). This finding was supported by catch and acoustic data in 2011 survey. However, unlike 2011, higher biomass and density distribution of anchovy were observed at the west coast at the time when both beginning (2nd of November) and end (27th of November) of the survey in 2016. According to Webb and Nobilis, 1994, the increasing trend of Danube river water temperature, especially in autumn and early winter has been detected since 1900s. Besides, because the currents on the west side of the Black Sea are mostly north-south oriented (Staneva, 2001), relatively warm water from Danube River into the Black Sea was carried to off İstanbul. However, at the central and eastern part of the Black Sea basin, very effective northerly winds cooled the water. Thus, in 2016, a very favorable environment for anchovy was created on the western coast of the Black Sea and caused the Black Sea Anchovy not to go further to the east.

4.2.2 Distribution of Horse Mackerel

Although many populations and subpopulations in Black Sea were defined by several authors in the past years (Aleev, 1957, 1959; Georgiev and Kolarov, 1962; Altukhov and Apeken, 1963; Altukhov and Michalev, 1964; Shulman, 1972), horse mackerel were considered as one single stock in 2011 and 2016 surveys because there was no noticeable difference between *trachurus mediterraneus* individuals caught and their schools' shapes on echogram. Like anchovy, it was observed that one of the warm water species, *trachurus mediterraneus* were distributed temperature oriented in southern Black Sea coast. Even if there is an absence of their overwintering tempreature preference in southern coast, it was observed that horse mackerel does not distribute in the same coastal areas with adult anchovy aggregations (Figure 27, 28, 30,31). Instead of this, they settle in relatively colder waters than that anchovy prefers in southern Black Sea coast. However, it was found from spatial distribution and biomass/abundance density calculations that horse mackerel schools are partially attached to the anchovy aggregations which can be explained by the feeding habit of horse mackerel. According to Stoyanov et.al., 1963 and Yankova et.al., 2008, horse mackerel individuals partly feed on juvenile anchovy and sprat individuals. Because sprat and some of young individuals of anchovy settles in offshore part, wintering stock of horse mackerel was dependant on the juvenile anchovies in coastline.

4.2.1 Distribution of Sprat

It was seen that even if the contribution of different small pelagic fishes varies spatially, total sprat contribution were found less than that anchovy and horse mackerel in both years (Figure 19 and 21), possibly because of the vertical migration pattern of sprat. Even if the horizontal migration of sprat is not studied much, it is known that they move in short range between inshore and offshore towards the direction of wind (Ivanov and Beverton, 1985). Also, according to Daskalov, 1999 sprat can tolerate wide range of temperature (8-18°C) but its growth rate and reproduction success is higher in cold water masses. Despite the bias resulted from trawl sampling, by reason of the north-south direction of the wind, there was a remarkable highness in offshore catch contribution, density and biomass estimations of sprat in 2016 (Figure 22, Table 9-Down). One of the other reason of the habitat preference of sprat underlies the seasonal migration pattern of sprat. According to the study carried out in Romanian and Bulgarian coasts, even if the sprat is reproductive for the whole year around (Ivanov and Beverton, 1985), it prefers colder coastal parts in spring/summer for feeding/spawning and warmer offshore waters during autumn/winter (Radu, 2010). Concordantly, higher sprat biomass and density distribution were observed in winter time of 2016.

Because of the same reason, the effect of temperature contrast could also be clearly seen on the changing sprat and horse mackerel composition of the 2011 catch data between Region 1 and Region 2 (Figure 20).

4.2.2 Size Distribution

Size distributions of three small pelagic species were done by using 2011 and 2016 trawl data. Accordingly, regional and annual differences were observed for each species. First of all two peaks in the size distribution of anchovy, indicating two different cohorts were observed in 2011 and 2016 (Figure 23, Left). Range of the anchovy size distribution were higher in 2016 indicated that the difference in length between two cohort was more than that in 2011(between 2.5 and 15 cm) because offshore sampling which contains most of the juvenile individuals, was not done in 2011.

According to Giraldez and Abad, 1995, smaller than 11 cm total length of anchovy can be considered as a juvenile in terms of its sexual maturity. In the year 2011 and 2016 juvenile individuals were generally sampled from colder regions. According to Gücü, 2018, younger individuals starts aggregation to overwintering areas about one month later than adults indicating that juvenile anchovies are more tolerant to colder water. However, in the year 2011, while adult anchovies mostly sampled from colder western part, mainly around İstanbul, juveniles were sampled from warmer eastern coast. That is because massive amount of horse mackerel which is the main predator of juvenile anchovies (Yankova et. al., 2008) were sampled from west part. Thus, young individuals of the Black Sea anchovy could not survive there and probably moved to western part. In the year 2016, colder water preferance of juvenile anchovies were clearly seen throughout the study area. While younger individuals were sampled from the whole offshore regions and from the eastern part of the Turkey Black Sea coast, adults were mainly sampled from the warmest region, around İstanbul (Figure 25) .

In the year 2011, relatively longer sprat individuals were sampled from coastal water. According to Ivanov and Beverton, 1985, sprat tends to go to northern offshore waters during autumn/winter and to southern coastal areas in spring/summer to reproduce. Contrary to this, in 2016, sprat was dominant in two different size groups in catch, while in 2011 it was observed that single and longer length group were dominant in the Turkey Black Sea coast. It means that juvenile sprat individuals generally preferred to inhabit in the offshore part in 2016 while adult sprat and anchovy individuals are mixed in the coastal waters in both 2011 and 2016 winters. Also, juveniles stay in warmer upper water column along the first year of their life (Ivanov and Beverton, 1985). In this stage, they are mainly consumed by piscivorous fish like horse mackerel but once they reach sexual maturity, they descend under thermocline. Unlike anchovy, adult sprat individuals were not affected by horse mackerel's distribution in the year 2011 because thermocline separates their habitats and they rarely encounter in water column.

4.4 Acoustic Classification

The classification of the targeted species was one of the other important step throughout this study. In this study, instead of complicated acoustic techniques, three small pelagic species were separated in terms of their vertical and spatial habitat preferances published by many authors mentioned throughout the thesis. Also, instead of holding to the composition of trawl sampling, the vertical plane of the water were divided by using frequent CTD data which is very effective to define warmer upper (anchovy and horse mackerel) and colder lower layer (sprat) species.

In addition to the sprat restriction, trawl sampling causes another bias while sampling anchovy and horse mackerel in coastal areas because they both form dense schools which can reach several kilometers. So that, it is hard to get accurate catch composition data to apply to the biomass formula. However, because of its marker attaching to the bottom of horse mackerel schools, it was so practical and accurate to detect the schools by using Echoview. However, because both anchovy and horse mackerel disperse through the upper water layer, above thermocline, the composition of trawl catch could be included in the biomass formula for the offshore classification in 2016.

5. SUMMARY AND CONCLUSION

In this study, the temperature related distribution phenomenon of dominant overwintering small pelagics in southern Black Sea were developed by implication of new habitat division according to preferences of species. The cooling rate and its path in the basin, supposedly controlled by northerly wind strength and direction seems to have effect on overwintering distribution of small pelagics in the Black Sea. Consequently, two different cooling ways, from east to west and north to south were observed in 2011 and 2016 respectively. In the light of distribution and CTD temperature results, fish distribution in coastal and open sea areas has been found to be remarkably different. While juvenile individuals of sprat and anchovy are dominant in offshore region, coastal part were dominated by anchovy and horse mackerel adults. Along the open sea, colder eastern part were found more dense in terms of anchovy abundance and biomass while sprat were evenly distributed there. It was also suggested that while adult individuals of overwintering horse mackerel stays in coastal instead of moving further to offshore, less dense juvenile aggregations were observed in western offshore part in winter. Unlike horse mackerel, anchovy adults and juveniles shared the basin equally. While adults prefer warmer coastal waters, juveniles prefer colder offshore waters. Finally, sprat were found mainly offshore distributed in winter.

The mixed implementation of school detection and trawl composition have been found very effective and accurate to investigate enclosed seas such as the Black Sea. Different schooling shapes of each species were observed in the basin. This already known fact causes problems while sorting out the acoustic records for different species. In this thesis species specific algorithms were applied. As a result, it was found that this method yielded more meaningful results than the commonly used “Control-Catch Composition” approach. Based on these algorithms, while the anchovy and sprat were separated in terms of their temperature preferences, horse mackerel schools were analysed specificly. Thus, the three dominant small pelagic species overwintering in the southern Black Sea were analytically sorted in a rational way.

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