CURRENT DISTRIBUTION OF THE SMALL PELAGIC FISH POPULATIONS IN THE NORTH EASTERN LEVANTINE SEA IN RELATION TO ENVIRONMENTAL CONDITIONS AND PREDICTING THE IMPACTS OF TEMPERATURE RISE ON THEIR FUTURE DISTRIBUTIONS

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ABSTRACT

CURRENT DISTRIBUTION OF THE SMALL PELAGIC FISH POPULATIONS IN THE NORTH EASTERN LEVANTINE SEA IN RELATION TO ENVIRONMENTAL CONDITIONS AND PREDICTING THE IMPACTS OF TEMPERATURE RISE ON THEIR FUTURE DISTRIBUTIONS

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Stocks of traditionally targeted fish species are in decline in the north eastern Levant Sea due to overfishing during recent decades, while catch statistics show a simultaneous increase in landings of commercially less valuable small pelagic species. Moreover, the number of species in the eastern Mediterranean is increasing due to Lessepsian migration and the response of native species to the continuous migration of lessepsian species is in question. Additionally, warming associated with climate change is expected to affect populations of small pelagic fish. This hypothesis may be of particular importance in the north eastern Mediterranean as it is the warmest basin of the Mediterranean. In this study, the aim was to determine the environmental factors that may have an effect on the distribution of small pelagic fish populations and to predict their possible response to future climate changes.

This study took place within the continental shelf area between Taşucu and the Turkish - Syrian border (33.8º E - 36.2º E). The data were collected between 2009 and 2011 during five hydro-acoustic surveys conducted for the project 108O566 (supported by Tubitak) by METU - IMS during June and October each year. Data consist of fisheries acoustics records, trawl samplings, CTD casts and satellite data. The overall workflow basically involved four phases,: I) As this was the very first attempt to study small pelagic fishes in the NE Mediterranean by a hydroacoustic method, much emphasis was placed on the development of a methodology to identify the species in the pelagic fish fauna; II) mapping the distribution of acoustically identified fishes; III) examining their relationship with environmental factors and finally; IV) predicting the effect of future warming based on habitat suitability.

In the analysis part; the workflow starts with scrutinization which involved; application of calibration parameters to raw data, elimination of noise, and detection and removal of the sea bottom and surface reverberation layers. Subsequently the fish schools and their descriptors were extracted and meaningful school parameters were selected for statistical analysis. Additionally, trawl hauls and CTD data were analysed. School forming typologies were then utilised to distinguish particular fish schools. Finally, information from trawl hauls and clustering of acoustic fish school records were combined and analysed using supervised classification based on artificial neural network algorithm. Species distribution maps were then evaluated using hydrographic data and satellite data in order to determine the factors affecting fish distributions. Generalized additive models (GAMs) were used to investigate the observed relationships and these models were then applied to the construction of habitat suitability maps and used to predict the effect of the warming based on climate change scenarios.

The results showed that the most dominant species in the region was *Sardinella aurita* while the distribution and density of the species *Sardina pilchardus, Dussumieria elopsoides, Etrumeus teres, Trachurus trachurus* and *Trachurus mediterraneus* also exhibited noticeable biomass in the region. *Engraulis encrasicolus*, *Herklotsichthys punctatus* and *Sardinella madarensis* were found to be less abundant. Thermal stratification was found to be an important determining factor of the distribution of different species as this creates two different pelagic habitats, inhabited by the species according to their temperature preference. The species with warm water preference that occupied a temperature range between 24ºC -27º C were mainly concentrated in the regions around river plumes and eutrophic - shallow waters affected by urban runoff. The distribution of this group was mainly associated with high chlorophyll concentration. In particular, the schools of *S. aurita* juveniles found during October preferred the most productive regions between the Seyhan and Ceyhan River inflows. This suggested that this area is an essential habitat for small pelagic fishes supporting the growth of the young fishes. The species inhabiting cooler water displayed two different temperature range preferences, 17 ºC -19 ºC and 19 ºC -21 ºC where the thermocline constituted an upper boundary as the surface layer is substantially less favorable. Due to such thermal limitations the species were located at some distance from the coast but shoreward of the 100 m depth contour. The results of the predictions performed by the GAM analysis suggested that the most important area with regards to habitat suitability for dominant species particularly *Sardinella aurita*, was the inshore parts of the region around the Mersin Bay and the Gulf of Iskenderun along the north eastern corner of the

Levantine Sea. In addition for the entire Levantine Sea the predictions based on GAM analysis indicated that the warm waters of the Nile delta region with its wide shelf area and high chlorophyll concentration exhibited the best environmental conditions. Finally the scenarios tested to foresee the possible impacts of temperature rise demonstrated that warming may result in a remarkable decline in *Sardinella aurita* populations which are already at its marginal temperature limits.

ÖZ

KUZEYDOĞU LEVANT DENIZINDE ÇEVRESEL KOŞULLARLA ILIŞKILI OLARAK KÜÇÜK PELAJIK BALIK POPULASYONLARININ DAĞILIMI VE SICAKLIK ARTIŞININ ETKISINE GÖRE GELECEKTEKI DAĞILIMLARININ TAHMIN EDILMESI

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Kuzeydoğu Levant denizinde aşırı avcılık sonucu ekonomik değeri yüksek alışılageldik türlere ait stoklar azalmakta, av istatistikleri balıkçılık ilgisinin ekonomik değeri daha düşük olan küçük pelajik balıklara doğru kaydığını göstermektedir. Aynı zamanda Lesepsiyen göçü sayesinde tür sayısı hızla artmakta ve buna karşın Akdeniz'in yerel türlerinin bu değişimlere nasıl tepki vereceği bilinmemektedir. Diğer taraftan iklim değişikliğine bağlı olarak denizlerin ısınmaya başladığı bilinmekte ve zaten Akdeniz'in en sıcak bölgesi olan Levant denizinin doğusundaki deniz yaşamının bu değişiklerden etkilenmesi kaçınılmaz gözükmektedir. Bu değişimlerin küçük pelajik balıklara etkisi hakkında bir öngörüde bulunabilmek için bu çalışmada Kudeydoğu Levant denizindeki küçük pelajik balıkların dağılımları ve çevresel değişkenlerle ilişkileri ortaya konmuş, en baskın tür olarak bulunan *Sardinella aurita*'nın olası iklim değişikliğine göstereceği tepki araştırılmıştır.

Çalışmada Suriye sınırından Taşucu'na kadar olup (33,8º E - 36,2º E) kıta sahanlığı içinde kalan alan incelenmiştir. Çalışma verileri, TÜBİTAK tarafından desteklenen - 108O566 projesi kapsamında, 2009 -2011 yılları arasında Haziran ve Ekim aylarında yapılmış 5 akustik sörvey sırasında toplanmıştır. Çalışma verileri hidro-akustik ölçümlerin yanında, CTD örneklemeleri, trol örneklemeleri ve uydu haritalarından oluşmuştur. Bu çalışmadaki analizler ve sonuçlar şu üç başlık altında özetlenebilir; i) akustik olarak tespit edilen türlerin tanımlanması, ii) tür dağılımlarının çevresel değişkenlerle ilişkilerinin incelenmesi ve iii) habitat uygunluğuna bağlı olarak muhtemel sıcaklık artışının etkilerinin incelenmesi.

İş akışı akustik verilerin işlenmesiyle başlamış bu aşamada veri içerisindeki gürültü, deniz tabanı yüzey köpüklenmeleri gibi hedef dışı ekoların temizlenmesiyle tamamlanmıştır. Ham veriye kalibrasyon parametrelerinin uygulanmasının ardından sürü verisinin tanımlayıcılarıyla beraber çıktısı alınmıştır ve hatalara karşı kontrol edilmiştir. Bir sonraki aşamada tür tanımlama açısından anlamlı sonuçlar verebilecek parametreler seçilmiş ve kümeleme analizine tabi tutulmuştur. Buna paralel olarak trol örneklemeleri analiz edilmiş tür tanımlama amaçlı için bir biokütle indeksi elde edilmiştir. Daha sonra ham CTD verisi işlenmiş ve haritalanmıştır. Sürülerin belirlenmesinde türlerin kendilerine özgü sürü yapılarından faydalanılmıştır. En son aşamada trol verisi ve kümeleme analizi sonuçları bir araya getirilerek yapay sinir ağı analizi alt yapısı oluşturulmuş ve uygulanmıştır. Son aşamada tür dağılım haritaları çevresel değişkenler ışığında değerlendirilmiş ve hedef türlerin dağılımlarını etkileyen faktörler incelenmiştir. Türlerin dağılımlarının çevresel değişkenlere ilişkileri genel eklemeli model ile incelenmiştir. Habitat uygunluğu ve sıcaklık değişiminin muhtemel etkileri, genel eklemeli model analizlerinde elde edilen modellere dayalı farklı sıcaklık senaryolarına göre yapılan tahmin sonuçlarına göre değerlendirilmiştir.

Sonuç olarak alandaki en baskın türün *Sardinella aurita* olduğu ortaya çıkmıştır. Kayda değer yoğunluğa sahip diğer önemli türlerin, *Sardina pilchardus, Dussumeiria elipsoides, Etrumeus teres, Trachurus trachurus* ve *Trachurus mediterraneus* olduğu ortaya çıkmıştır. *Engraulis encrasicolus*, *Herklotsichthys punctatus* ve *Sardinella madarensis* gibi türler yoğunluk açısından azınlıkta kalmıştır. Yüzey sularının ısınması ile oluşan tabakalaşma, iki farklı habitat oluşmasına neden olmakta, tür dağılımları çoğunlukla sıcaklık tercihlerine göre bu habitatlarda yerlerini almaktadırlar. *Sardinella aurita* başta olmak üzere 21 - 26 derece arasında en uygun dağılım gösteren sıcak sever türler özelikle klorofilin yoğun olduğu, nehir ağızlarına yakın sığ bölgelerle ilişkilenmiştir. Özellikle Ekim aylarında ortaya çıkan juvenile *Sardinella* sürüleri en verimli bölgeler arasında olan Seyhan Ceyhan arasındaki üretimin yoğun olduğu kıyı alanını tercih etmesi bu bölgenin bölge küçük pelajik balıkları açısından en önemli habitatlardan olduğunu göstermektedir. Düşük sıcaklık tercihleri ile 17 ºC -19 ºC ve 19 ºC -21 ºC sıcaklık aralıklarını tercih ettiği görülen türler için ise Termoklin tabakasının bir üst bariyer oluşturduğu anlaşılmış dolayısıyla kıyıdan daha uzak bölgelerde varlık gösterdiği belirlenmiş yine de en uygun derinlik tercihlerinin 100m yi geçmediği anlaşılmıştır.

Genel eklemeli modelllere bağlı olarak *Sardinella aurita* için elde edilen habitat uygunluğu tahmin haritaları, Nil deltası önündeki geniş kıta sahanlığında bulunun verimli ve nispeten sıcak

sular ile benzer özellikler gösteren ve bu çalışma bölgesine karşılık gelen Kuzeydoğu Levant kıyılarının (Mersin körfezi ve İskenderun körfezi) en uygun alanlar olduğunu göstermiştir. Sıcaklık artış senaryolarına bağlı olarak yapılan testlerde sıcaklık açısından bu türün marjinal sınırlarında olduğu ve daha fazla artan sıcaklıklara ters tepki göstererek hızla azalabileceği ortaya konmuştur.

Anahtar Kelimeler: Küçük pelajik balıklar; hidro akustik sörvey; habitat elverişliliği; genel eklemeli modeller, Kuzeydoğu Levant denizi.

To my parents.

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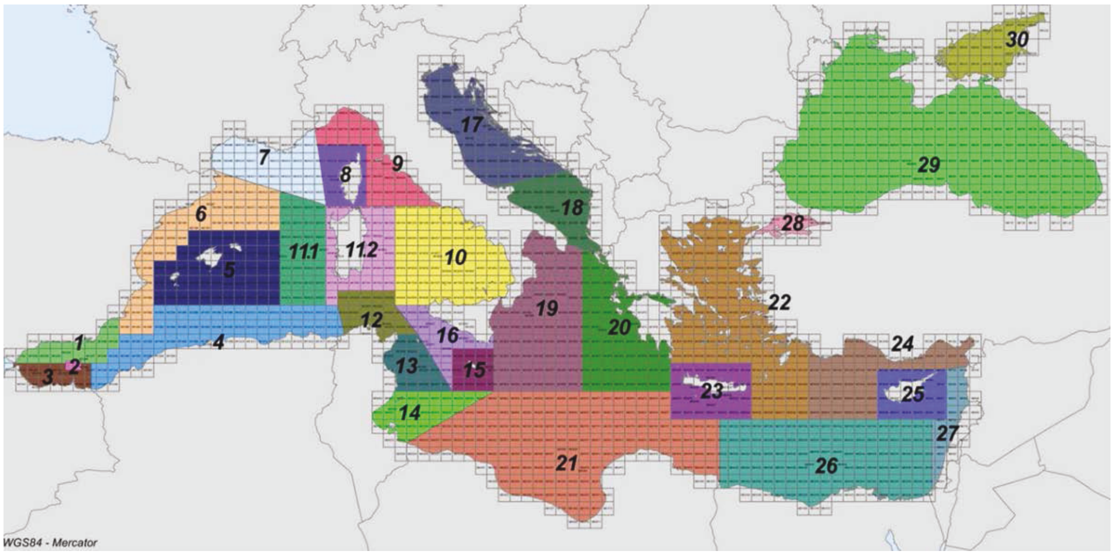
1 INTRODUCTION

1.1 General introduction

The ecosystem of the eastern Mediterranean Sea is remarkable in terms of its high marine biodiversity and vulnerable due to increasing threats to it (Bianchi and Morri, 2000; Pérez, 2008). In the last century, the invasion of Red Sea emigrant (Lessepsian) species became a prominent ecological feature of the area, hence attracting scientific attention due to its continuous and expanding structure with various impacts on ecosystem and human (Belmaker et al., 2009; Ben-Tuvia, 1985; Galil and Zenetos, 2002). Furthermore the impacts of global warming are becoming more evident as the sea surface temperature increases and rate of invasion increases correspondingly (Raitsos et al., 2010). The physical oceanographic conditions of the area are relatively well known. Particularly, the studies after 1990es outline the surface circulation patterns (Özsoy et al., 1993; Robinson et al., 1991). Moreover, owing to increasing number of documentation on the Lessepsian migration, their effects on the ecosystem and their possible effects in the future is becoming better understood (Galil, 2007; Golani, 1998a; Golani, 1998b; Goren and Galil, 2005; Zenetos et al., 2010). The studies on the dynamics and the spatial distribution of the fish communities are critical to assess the impacts of fisheries and other factors such as global warming and invasive species, and to involve marine conservation efforts such as marine protected areas (Ben Rais Lasram and Mouillot, 2009; Gucu and Erkan,2005). Some demersal Lessepsian species have been gaining more attention due to their increasing commercial importance (Ben-Yami and Glaser, 1974; Golani, 1998a; Gücü and Bingel, 1994; Keskin et al., 2011; Torcu and Mater, 2000). Recently the role of pelagic Lessepsians becoming more noticeable as their catch increases as in the case of *Etrumeus teres* (Akel, 2009; GFCM SAC, 2010; Kasapidis et al., 2007). However, regarding small pelagic species, there is a gap on the spatial coverage of scientific studies to obtain a complete understanding of the area. Eastern Mediterranean is separated in different geographical sub areas for fisheries assessments and scientific studies regarding local features as well as with political concerns shown in Figure 1 (GFCM, 2009). These sub areas consist of the Adriatic Sea, the Ionian Sea, the Aegean Sea and the Levantine Sea (GFCM, 2009). In the Levantine Sea, located in the far eastern part of the Mediterranean, few studies exist on the small pelagic fish mainly on some biological aspects and checklists; however the studies on fish communities largely focused on demersal species

(Bayhan., 1988; Golani et al., 2007; Gücü and Bingel, 1994; Keskin et al., 2011; Mavruk and Avsar, 2008).



North Levant	Northern Alboran Sea	**9**	Ligurian and North Tyrrhenian Sea	**16**	South of Sicily	**24**	North Levant
Cyprus Island	Alboran Island	**10**	South Tyrrhenian Sea	**17**	Northern Adriatic	**25**	Cyprus Island
South Levant	Southern Alboran Sea	**11.1**	Sardinia (west)	**18**	Southern Adriatic Sea	**26**	South Levant
Levant	Algeria	**11.2**	Sardinia (east)	**19**	Western Ionian Sea	**27**	Levant
Marmara Sea	Balearic Island	**12**	Northern Tunisia	**20**	Eastern Ionian Sea	**28**	Marmara Sea
Black Sea	Northern Spain	**13**	Gulf of Hammamet	**21**	Southern Ionian Sea	**29**	Black Sea
Azov Sea	Gulf of Lions	**14**	Gulf of Gabes	**22**	Aegean Sea	**30**	Azov Sea
8	Corsica Island	**15**	Malta Island	**23**	Crete Island		

Figure 1. Geographical Sub-Areas (GSAs) (GFCM, 2009).

As far as small pelagic fishes in the overall eastern Mediterranean region are concerned, there exist extensive studies in the Adriatic, the Ionian Sea and the Aegean sea on various aspects such as spatial distribution, habitat preferences and population dynamics (Antonakakis et al., 2011; Azzali et al., 2002; Giannoulaki et al., 2012; Giannoulaki et al., 2003; Giannoulaki et al., 2005; Giannoulaki et al., 2008; Somarakis et al., 2002; Tičina et al., 2005). However, despite its interesting features characterized by Lessepsian invasion and increasing water temperature, the Levantine Sea lacks a comprehensive study to shed light on the situation of the small pelagic fish. Regarding their trophic importance and vulnerability to the environmental oscillations, understanding the ecology and dynamics of the small pelagic fish is essential for a better understanding of the ecosystem (Fréon et al., 2005; Hughes et al., 2005). Moreover the fundamental problems of marine environments, such as global climate change, pollution and overfishing, necessitates large amount of scientific knowledge on the marine ecosystems in order to achieve a sustainable exploitation of marine resources and less human impact and ultimately a healthy ecosystem (Brander, 2007; Caddy and Cochrane, 2001).

Since the beginning of large scale industrial fishing threat on rapid depletion of world fish stocks due to over-exploitation is increasing (Millennium Ecosystem Assessment, 2005; Mullon et al., 2005; Pauly et al., 2005; Worm et al., 2009). Today, current rate of exploitation of all-natural resources, increasing with population growth, cause global environmental degradation that leads to disruption of sustainability with serious impacts even to the human health (Vitousek et al., 1997; Wackernagel and Rees, 1998). Current situation is endangering the future of marine fisheries (Baum and Myers, 2004; Myers and Worm, 2003; Pauly et al., 2002). The issue led many countries to adopt new precautionary approaches in the fisheries management (Pitcher et al., 2009). Yet, it was proven that the conventional fisheries management tools disregarding habitats, interspecies interactions and links with the other ecosystem components are ineffective (Berkes, 2003; Garcia and de Leiva Moreno, 2002; Stergiou, 2002). As underlined by Fréon et al. (2005) comprehensive knowledge on the fish and their environment is necessary for a better use and management and this concern gave rise to the Ecosystem-Based Fishery Management (EBFM) (Pikitch et al., 2004; Sinclair et al., 2002). Hence the importance of the surveys to assess the characteristics of fish stocks is increasing, using direct methods such as hydroacoustics that provides opportunity to sample large spatial scale and fine resolution and asses the several aspects such as year-class strength, relationships between recruitment and environmental factors, distribution, feeding, growth, and mortality (Koslow, 2009).

It is necessary to have a baseline of knowledge about the dynamics and specific functions of each component in the ecosystem in order to make better predictions and planning (Walters, 1997). The primary motivation of this study was to increase the level of the knowledge on several aspects of the small pelagic fish communities in the area to contribute a more clear understanding of the ecosystem of the area of interest. This knowledge will help better regulation of small pelagic fisheries in the area of interest.

1.1.1 Small pelagic fish

Small pelagic fish are defined as "shoaling epipelagic fish characterized by high horizontal and vertical mobility in coastal areas and which, as adults, are usually 10–30 cm in length" that includes typical forage species like sardine and anchovy (Fréon and Misund, 1999). Small pelagic fisheries are important element of economy of many countries as it constitutes 20-25% of the total landings which is the largest proportion of the global marine catches with decadal-scale fluctuations (Alheit et al., 2009; FAO, 2002; FAO, 2010; Fréon and Misund, 1999; Worm et al., 2009) (Figure 2). Furthermore, constituting the mid-trophic compartment of the marine ecosystem, they play a linking role in the food web by supporting energy flow with their vast size of biomass that can vary drastically (Bakun and Broad, 2003; Cury et al., 2003; Van der Lingen et al., 2009). They are also often named as forage fish as they are prey for other animals. Their fisheries carried out not only for direct human consumption but also in a large extent reduction to fish meal or fish oil for industrial purposes (Tacon and Metian, 2009).

Their distribution is mostly confined to upper layer of the sea between 0 and 200 meters depth (Fréon and Misund, 1999). They feed on plankton-based food mainly zooplankton, some even feed directly on phytoplankton such as anchovy and sardine, particularly in early stages (Garrido, 2008; Morote et al., 2010). Due to their lower trophic level in the food web, their distribution is highly dependent on productive waters such as upwelling regions or areas enriched by freshwater inflow (Bahri and Fréon, 2000; Fréon and Misund, 1999; Würtz, 2010).

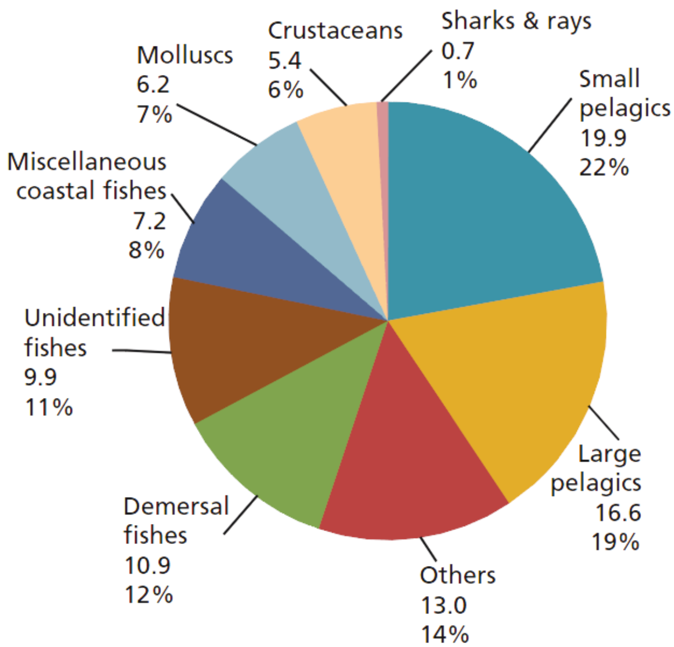


Figure 2. World marine catch by main species groups in 2009 (million tones and percentages (FAO, 2010)

One of the major environmental issues of climate change is the response of the small pelagic fish populations to environmental factors and natural (large?) scale oscillations. The issue has been addressed by Chavez et al. (2003), and they suggested that global warming may alter the responses of fish to their environment, as observed in catches of Peruvian anchoveta (*Engraulis ringens*), in the El Niño–Southern Oscillation (Brander, 2007; Chavez et al., 2003).

The inevitable consequences of climate change stands out as northward movement of species in the northern hemisphere (Perry et al., 2005). This situation particularly risks the endemic species in semi-enclosed systems such as the Mediterranean and the Black Sea (Philippart et al., 2011). Regarding the small pelagics in the Mediterranean, incidence of northward movement has been observed with significant positive relationship between landings and temperature anomalies such as in the case of *Sardinella aurita* (Sabatés et al., 2006). As noted by Sabatés et al. (2006), they expand their established habitats to northernmost parts of western Mediterranean where they did not occur 20 years ago. Similar observation has been published on the same species in the Aegean sea, a gradual shift expanding towards the north, correlation to sea surface temperature and 30-fold increase in what since the early 1990s (Tsikliras, 2008).

Fisheries of small pelagics mainly predominate by purse-seiners, mid-water trawlers (pair trawls), constitute approximately 50 percent of total Mediterranean catches. Small scale fishing fleet, despite being highly numbered and having significant capacity and technical efficiencies in some areas such as inshore waters or lagoons, constitutes a small portion in small pelagic fishery (Papaconstantinou and Farrugio, 2000). Most of the small pelagic species in Mediterranean are distributed close to the coast on the continental shelf. Anchovy (*Engraulis encrasicolus*) and sardine (*Sardina pilchardus*) are the most abundant and targeted species, also round *Sardinella* (*Sardinella aurita*) may be accounted for the eastern Mediterranean. Other species; Mediterranean horse mackerel (*Trachurus mediterraneus*), Atlantic horse mackerel (*Trachurus trachurus*), chub mackerel (*Scomber japonicus*) including other medium pelagics correspond to the 7 percent of the total catch of marine fish in the Mediterranean (Lleonart and Maynou, 2003).

In the Mediterranean different management rules and enforcements are applied separately by each country although the same stocks are shared (Barange et al., 2009; Papaconstantinou and Farrugio, 2000). Standard fisheries independent assessment techniques such as acoustic or daily egg production (DEPM) surveys are carried out in different parts of The Mediterranean such as gulf of Lions, the Adriatic Sea and Greek part of the Aegean Sea (Doray et al., 2010a; Iglesias et al., 2003; Somarakis et al., 2005; Somarakis et al., 2004; Somarakis et al., 2010; Tugores et al., 2010).

The mission of producing scientific recommendations for fisheries regulations in the Mediterranean is held by the General Fisheries Council for the Mediterranean (GFCM) (Caddy, 2012). GFCM consists of 23 members including all The Mediterranean countries as well as Black sea countries (GFCM, 2008). The council members reports assessments of the conditions of fish stocks in predefined geographical sub areas (GSA), discusses scientific recommendation for fisheries regulations, after meetings of several sub groups and scientific advisory committees (SAC) consisted of 23 members including Turkey, (GFCM, 2008). The SAC reports comprises of outcomes from scientific research carried out in regional areas by each member. With the SAC in December 2008, GFCM highlights the importance of the direct assessment methods and necessity of small harmonizing protocols to undertake surveys at sea (GFCM, 2008). For the assessment of small pelagic fish by acoustic surveys, the mission of standardization of data collection protocols is carried out by Pan Mediterranean acoustic survey (MEDIAS) group by annual meetings (GFCM, 2010). MEDIAS covers actively the areas in the Mediterranean EU Member States (Spain, France, Italy, Malta, Slovenia and Greece) with a standardized methodology and involves Bulgarian and Romanian areas in the Black Sea after 2010 (GFCM, 2012). Small pelagics in the northwestern Mediterranean is rather well documented (Coll et al., 2006; Palomera et al., 2007; Tudela and Palomera, 1997). In the northwestern Mediterranean one of the most consistent survey series within the MEDIAS framework is the Pelmed cruises conducted by ifremer in Gulf of Lions since 1993 using the same survey protocol with the primary interest on assessment of anchovy and sardine stocks (Doray et al., 2010b). These hydro acoustic surveys together with Spanish studies in the Catalan Sea, revealed substantial fluctuations in the small pelagic stocks in the area according to the studies based echo-integration principles and species allocation using mid water trawl catch compositions (Figure 3) (Bigot, 2009; Giannoulaki et al., 2011; Martín et al., 2008; Palomera et al., 2007).

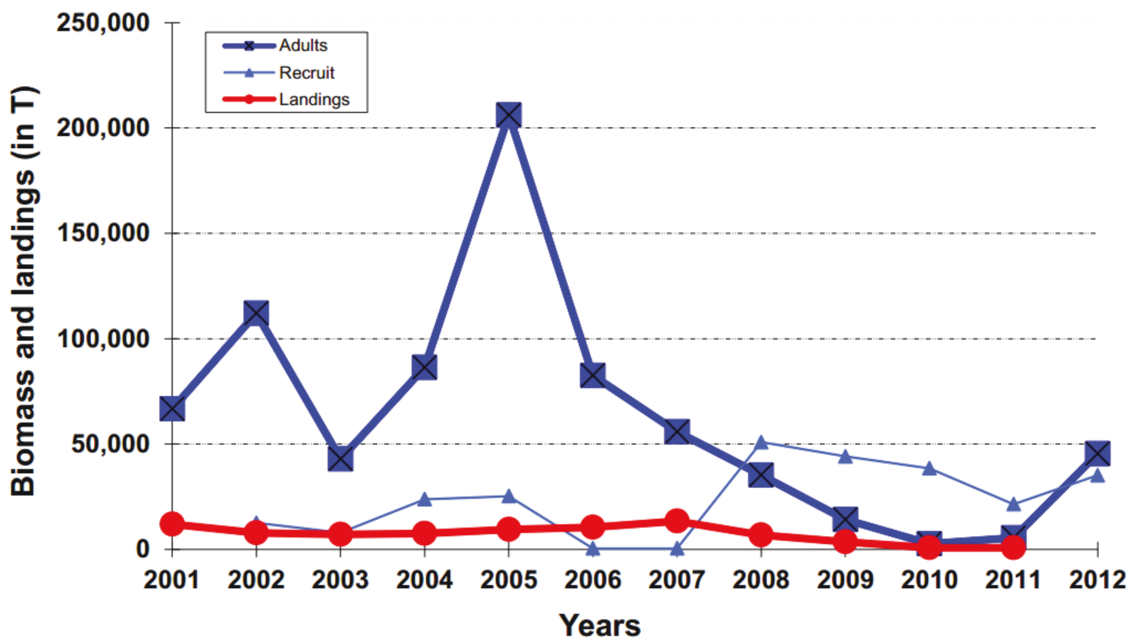


Figure 3. Fluctuations on sardine biomass according to the acoustic survey and comparison with landings. Example from Gulf of Lions (GFCM SAC, 2012)

The Spanish surveys in Iberian Peninsula are routinely held with name of ECOMED since 1990 from the French frontier to the Straits of Gibraltar with similar design of French surveys (Abad et al., 1998; Iglesias et al., 2008). In the central Mediterranean, Sicilian channel and Malta coasts are significant areas in terms of anchovy and sardine populations and since 1998 assessed by acoustic surveys (Bonanno et al., 2005; Lafuente et al., 2002; Patti et al., 2004). In this area, studies unveiled the relationship between the sediment structure and habitat selection characteristics, and found a general preference over the finer seabed substrates (D'Elia et al., 2009). The schooling behavior features and their distribution in relation to plankton patches have also been documented (Patti et al., 2011). The onset of acoustic surveys in the Adriatic Sea goes back to 1976 and focuses primarily on anchovy and sardine populations and reveals the changes and the factors behind these changes (Azzali et al., 2002). The surveys in the Adriatic extend to Croatian and Slovenian waters after 2000 with coordinated cruises under Adriamed project (AdriaMed, 2011). In the Aegean sea Acoustic surveys carried out by HCMR since 1996 illuminating various aspects related to the ecology of the small pelagics in the area mainly anchovy, sardine and round sardine(Georgakarakos and Kitsiou, 2008; Tsagarakis et al., 2012). Greek surveys yielded some significant and interesting results; Giannoulaki et al. (2003 and 2006) revealed the significance of coastal topography over the distribution of the small pelagics in the highly indented coasts of the north Aegean sea and the seasonal difference as well as the effects of hydrological parameters (Giannoulaki et al., 2005). Yet in the same area, based on satellite data, Schismenou et al. (2008) constructed a model based on generalized additive models (GAMs) to predict potential spawning habitats, also Giannoulaki et al. (2008) based on a similar methodology, predicted the presence of anchovy in the Aegean and Ionian Seas and these predictions even extended to whole Mediterranean. These studies in the Mediterranean when combined together, yielded higher level of knowledge on ecological structure of the small pelagics such as density dependency and spatial – temporal presence, derived by habitat suitability models and the spreading area index (Giannoulaki et al., 2012b; Giannoulaki et al., 2011; Tugores et al., 2011). Other countries in the Mediterranean such as Morocco, Algeria and Tunisia are making progress in order to adapt to MEDIAS (GFCM, 2012). Tunisia has been carrying out acoustic surveys for assessment of small pelagic resources intermittently since 1998, coordinated under MedSudMed project concentrated on Central Mediterranean, targeting anchovy and sardine (Hannachi et al., 2005; MedSudMed, 2003). Although surveys of the MEDIAS partners cover an extensive portion in the Mediterranean, the area of Levantine basin remains empty including Turkey. Very few studies exist in the area, that weakly document the spatial occurrence of the small pelagics in north eastern Levant Sea (Mavruk and Avşar, 2010; Oray et al., 2010). However this area, in terms of small pelagics, deserves higher attention due to its distinctive hydrological pattern compared to western regions such as summer surface stratification, higher temperature and salinity characteristics (Özsoy and Güngör, 1993), and ongoing ecological changes due to Lessepsian migration (Galil, 2007; Galil and Zenetos, 2002; Kalogirou et al., 2012)

1.1.2 Small pelagic fishery in Turkey

In Turkey small pelagic fisheries contributes 80% of the total landings mainly carried out by purse seiners with a significant percentage from the Black Sea (Figure 4) (Tuik 2013). Being the most important area for fisheries industry the Black Sea comprises 70% of the total marine fish production however shows fluctuations due to anthropogenic effects such as pollution, introduction of invasive species and overfishing (Gucu, 2012). Highly productive waters of the Black Sea together with the Sea of Marmara support the highest amount of small pelagic fish resources of Turkey due to abundant river run-off, and their peculiar bathymetric and hydrographic characteristics. Exclusively the anchovy (*Engraulis encrasicolus*) comprises 65% of the total landings from this area. The Aegean Sea hosts a remarkably large size of commercially exploited small pelagic community mainly dominated by sardine, anchovy and rounded *Sardinella* shared with Greek fleet (Kapiris, 2007; Tokaç et al., 2010). South coast of Turkey has been taken the least attention in terms of small pelagic fish due its extremely oligotrophic state although considerable portion in catches associated to small pelagics (Kuşat and Koca, 2009). Nevertheless local areas such as gulf of Iskenderun, Bay of Mersin and Antalya, fed by nutrient inputs with land origin in significant rates, hence sustain remarkable small pelagic fish stocks which are often disregarded (Gucu, 2012).

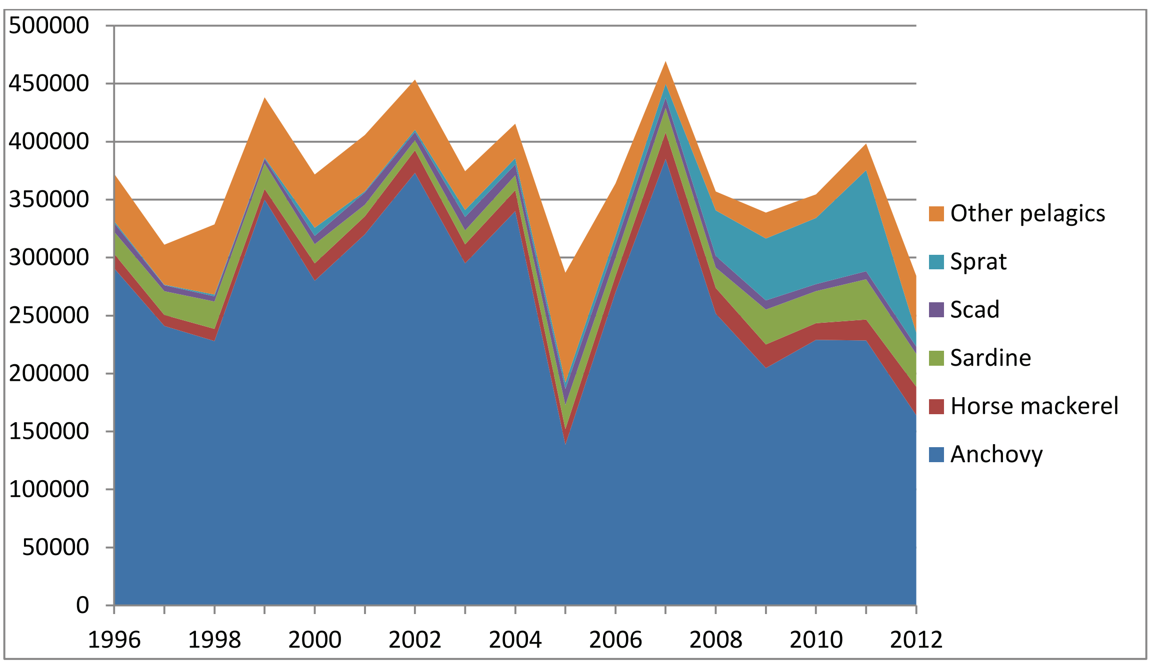


Figure 4. Marine capture fisheries landings in Turkey, in metric tons (Statistics, 2011).

1.1.3 The most common small pelagic fish species in the study area.

The most commons mall pelagic fish species inhabiting the NE corner of the Levantine Sea are round sardinella (*Sardinella aurita*), sardine (*Sardina pilchardus*), slender rainbow sardine (*Dussumieria elopsoides*), round herring (*Etrumeus teres*) and European anchovy (*Engraulis encrasicolus*).

1.1.3.1 Round sardinella (*Sardinella aurita*)

Figure 5. Round sardinella (Sardinella aurita)

Sardinella aurita is one of the most important fish resourcesin the studied area. Fishermen catch *S. aurita* schools using relatively small boats with traditional fishing gear like artisanal gillnets or using artisanal purse seines which operated manually from small boats. Thefishing activities on the *S. aurita* population only take place in areas close to shore mainly over grounds <50 m. S. aurita is a warm water species and it particularly spawns in warm tropically rich waters (Maynou et al., 2008, Binet et al., 2001) . The gonads of *S. aurita* start to develop in April and become mature in one month (Tsikliras and Antonopoulou. 2006, Karakaş 2011). Adults of the species have an elongate body, a relatively rounded belly, and a large number of fine gill rakers and may have average size from 23 to 28cm (Figure 5) (Whitehead 1984). Their populations exist in tropical and subtropical waters of the western and eastern Atlantic Ocean, the Pacific Ocean and the Mediterranean (Froese and Pauly, 2013).

1.1.3.2 Sardine (Sardina pilchardus)

The sardine (*Sardina pilchardus*) is a small pelagic fish species caught mainly with purse seiners and found offshore-ward compared to *S. aurita*. In the regions fishery the proportion of the *S. pilchardus* is smaller when compared to *S. aurita* however it supports important fisheries in the western Mediterranean and Aegean Sea (Parrish et al., 1989). *Sardina pilchardus* is a non-selective planktivorous species with a diet dependent on the local and seasonal availability of prey including copepods, decapod crustacean larvae, and bivalves (Sever et al. 2005., Garrido et al., 2007) (Figure 6).

Figure 6. Sardine (*Sardina pilchardus*)

S. pilchardus, prefers colder waters and reproduce during cold period of the year (develops gonad during autumn and spawns during winter) (Karakaş, 2011, Palomera et al., 2007, Tsikliras and Antonopoulou, 2006).

1.1.3.3 Slender rainbow sardine (*Dussumieria elopsoides*)

Figure 7. Slender rainbow sardine (*Dussumieria elopsoides*)

The Slender rainbow sardine (*Dussumieria elopsoides*) is a non-native fishes in the Levant Basin species that have been described as invasive or locally invasive in the Mediterranean (Streftaris and Zenetos, 2006). *Dussumieria elopsoides* has migrated into the Mediterranean via the Suez Canal and established populations in the eastern Mediterranean off the shores from Turkey to Egypt (Goren and Galil, 2005, Gücü et al., 1994). This species generally found in the purse seine catches mixed with other clupeid species and has been reported as one of the most important commercially exploited Lessepsian species in the north eastern Levantine Sea (Gucu 2010). Distribution of their populations in the world are confined to subtropical waters of the Indian Ocean and the South China Sea. *D.elopsoides* have been described as a school forming pelagic species generally found near shores (Whitehead 1998, Froese and Pauly, 2013). It feeds on zooplankton, mainly crustacean and smaller fish and spawns mainly in spring (Froese and Pauly, 2013) (Figure 7).

1.1.3.4 Round herring (*Etrumeus teres*)

Figure 8. Round herring (*Etrumeus teres*)

Etrumeus teres (Figure 8) (round herring) is another non-native pelagic inshore clupeid fishes migrated to Mediterranean through Suez Canal first recorded in Haifa Bay, Israel in 1961 (Whitehead 1963) and expanded its establishment to Egypt (El Sayed 1994), Iskenderum, Turkey, (Basusta et al. 1997) and soon after expanded its range until central Mediterranean and Aegean Sea (Falautano 2006, Kasapidis et al., 2007). With regards to its contribution to the Turkish fisheries there is no specific study however the existence of the species in the fisheries in various regions of Mediterranean and particularly in the southern part of Turkey has been reported (EastMed, 2010). The species is widely distributed in the world; found in the Red Sea, eastern Africa, Japan, Southern Australia, eastern Pacific and western Atlantic (DiBattista et al., 2012).

1.1.3.5 The European anchovy (*Engraulis encrasicolus*)

Figure 9. The European anchovy (*Engraulis encrasicolus*)

Anchovy (Figure 9) known as a symbol of the Black Sea fisheries due to its high abundance (Knudsen 2009). The species is also abundant in various part in the Mediterranean mainly caught along the coasts of Croatia, France, Greece, Italy, Spain, and Aegean coasts of Turkey. The range of the species also extends along the Atlantic coast of Europe to the south of Norway (Palomera et. al., 2007). However, there are no noticeable records of its fisheries in the south eastern coasts of Turkey despite its existence (Cicek et al. 2006, Turan et al., 2009). The species described to form large coastal schools at shallow depths however also descends to 100 to 150 m depth in the Mediterranean in winter (Palomera et. al., 2007). *E. encrasicolus* feeds on planktonic organisms and reproduce mainly during spring–summer as its spawning dependent on warmer temperatures and tolerates a wide salinity range (Froese and Pauly, 2013).

1.1.4 The study region

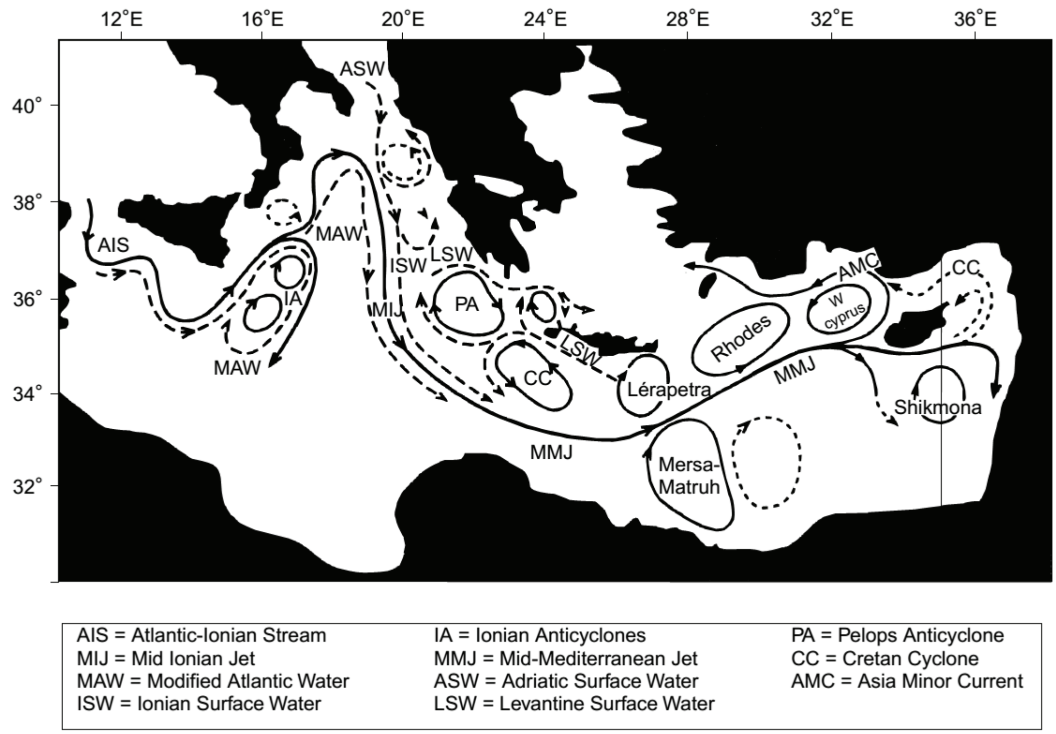


Figure 10. General Surface Circulation of the Eastern Mediterranean Sea (adapted from Robinson et al., 2001)

The circulation of the Mediterranean surface waters are characterized by less saline Atlantic Water (AW) that enters through the Gibraltar Strait flows eastward from the Sicily Strait at the the surface (Figure 10) (Robinson et al., 2001). In the Eastern Mediterranean the AW warms and becomes saltier as it continue to travel eastward and forms the modified Atlantic Water (MAW). This continuously eastward flowing water mass forms the Mid-Mediterranean Jet (MMJ) which generates a series of eddies on its way to east (Figure 10). At the eastern part of the Levantine Sea the MMJ bifurcates generally to the north through east of Cyprus and enters the Cilician basin. In this latter region, which corresponds to the studied area of this work, the MMJ meanders and turns westward and becomes the Asian Minor Current (AMC) (Robinson et al., 2001). In summer the surface of the Levantine basin is characterized by a layer with high salinity and temperature that overlies the AW, and called the Levantine Surface Water (LSW) (Özsoy et al., 1991,1993, Malanotte-Rizzoli et al., 1999). The AMC carries the LSW into the Aegean Sea as it flows westward (Figure 10). This water mass later forms the Levantine Intermediate Water (Özsoy et al., 1991,1993, Malanotte-Rizzoli et al., 1999)

The Eastern Mediterranean is exclusively characterized by its oligotrophic waters and referred as one of the least productive seas in the world. However the north eastern coastal waters of the Levantine Sea has more productive characteristics due to complex atmosphere-sea-land interactions, the presence of a wide shelf area and high river inputs where its effect is multiplied by man-induced eutrophication (Tuğrul et al., 2011). The terrestrial part of the North Eastern Levantine Sea (NELS) holds one of the most productive agricultural regions of Turkey. There are 4 important rivers passing by and washing agricultural wastes to the sea. The rivers Seyhan and Ceyhan flow through the large urban area of Adana, Mersin and Tarsus, and the most fertile plains in Turkey (Akbulut et al., 2009).

The small pelagic fishes had almost no commercial value in the area before 1980's or at least their importance was not known because fishery was concentrated on highly commercial peneaid crustaceans (Gücü and Bingel, 1994). After 1980, the pelagic fish including small pelagic which had been only treated as bait-fish has begun gaining sudden importance (Gucu and Bingel, 2011). This importance is reflected in the landings and also in the number of purse-seiners which did not exist before 1980's. The recent increase in the catch rates of small pelagic fishes (clupeids in particular) is remarkable in the Turkish Mediterranean Sea, in the continental shelf area between 29º E - 37º E especially when compared with landings in the Aegean Sea (TUIK, 2013). However until very recently the scientific studies on small pelagics in the study area were limited to checklists, studies on Lessepsians (Gucu et al., 1993), new records and to some biological aspects of the major species such as rounded sardine (Avşar, 2000; Bayhan., 1988). Therefore a comprehensive and reliable assessment of the state of the small pelagic fishes in the region based on a fisheries independent survey considered as crucial to obtain a baseline for an advanced fisheries management. In the present study, the overall aim is to provide knowledge on distribution and spatial structure of small pelagic fish species in relation to environmental factors in the study area.

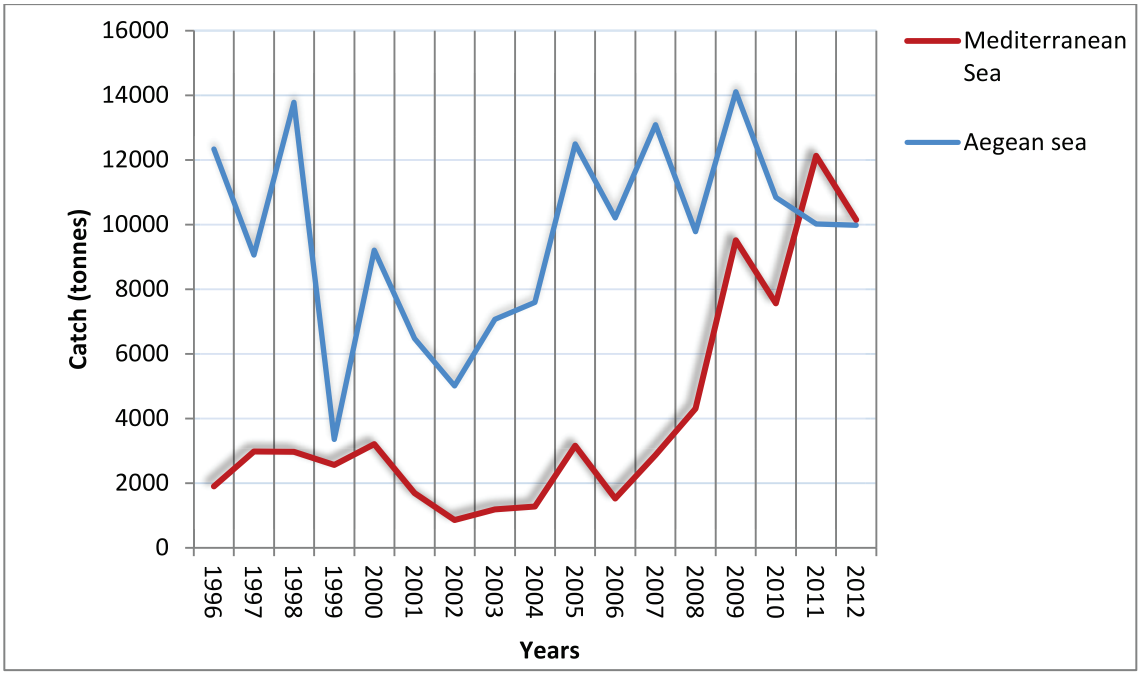


Figure 11. Landings of sardine fishery in the Turkish Mediterranean and the Aegean Seas (TUIK, 2013).

1.2 Hydroacoustic sampling

Hydroacoustics is a common methodology in modern fisheries researches, that involves various applications such as assessment of fish stocks or studies on fish community structures (Simmonds and MacLennan, 2005; Trenkel et al., 2011). Use of acoustics in fisheries investigations goes back to 1960s, stemming from military applications (MacLennan and Holliday, 1996). The fish are effective sound reflectors owing to their swim bladders that contribute 90% of the scattered energy of a fish (Foote, 1980; Foote, 1985). In general for the investigation of any marine organisms different technologies are available based on acoustic principles such as narrow-band single beam systems and multibeam sonars and the development is ongoing with introduction of new advancements such as acoustic lens sonars, broadband systems, pulse compression technology and ocean acoustic waveguide remote sensing (Chu and Stanton, 1998; Foote et al., 1984; Jagannathan et al., 2009; Magowan et al., 2012; Stanton et al., 2010; Trenkel et al., 2009).

The most common method is use of conventional narrow single beam systems named as echo-sounders (Klemas, 2012). These systems generate a directional sound beam by a transducer centered on a reference frequency within a narrow bandwidth (IHO, 2005). Transducers operate based on the mechanism of conversion of electrical energy to sound energy and converting the received echoes back to electric energy.

Being an advanced form of this conventional system, the split beam echo-sounders widely used since 1990s (Barange and Hampton, 1994; Soule et al., 1995). The split beam technology transmits a single beam however uses the phase difference in received sound, rendered by different fragments on the transducer that receives the echoes separately, so allows to locate the exact position of the detected target with reference to the acoustic beam axis (Foote et al., 1984). Different specifications in echo-sounders such as the transducer design and the operating frequency enables to work in different depth ranges and vertical echogram resolutions. Primary factor that determine the vertical resolution is the wavelength of the acoustic pulse hence the operating frequency that may vary from about 12 kHz up to about 200 kHz (Horne, 2000; Simmonds and MacLennan, 2005). As the operating frequency increases the vertical resolution increases, however range of the domain decrease inversely as the absorption increases due to higher particle friction (Simmonds and MacLennan, 2005). Stock estimation was made with reference to a single frequency, however, in many studies; several frequencies have been utilized simultaneously to identify observed species (Horne, 2000; Korneliussen et al., 2008; Korneliussen et al., 2009; Trenkel et al., 2009).

During an acoustic survey the sound is transmitted by the transducer in short acoustic pulses called pings in equal intervals (Figure 12). The returned signal after each transmission forms a vertical line of data, consisting of samples with equal sized bins. Between each ping there is a time lag long enough to receive the echo from the sea bottom before transmitting the subsequent ping and its duration is depended on the depth. Finally each vertical line of data when marked together forms a two-dimensional picture known as echogram.

The received signal is not directly used in the form of returned amount of energy, because the sound intensity decreases as it spreads geometrically with respect to the inverse-square law of energy spreading (Haslett, 1961; Simmonds and MacLennan, 2005). Also some acoustic energy is lost due to absorption as it propagates through the sea and in order to compensate for the transmission loss, the returning intensity is magnified by a time-varied gain function (TVG) and corrected with an absorption coefficient (Simmonds and MacLennan, 2005). In the earlier systems TVG was being calculated electronically, however in recent systems, this is done through digital processing (Stanton, 2012).

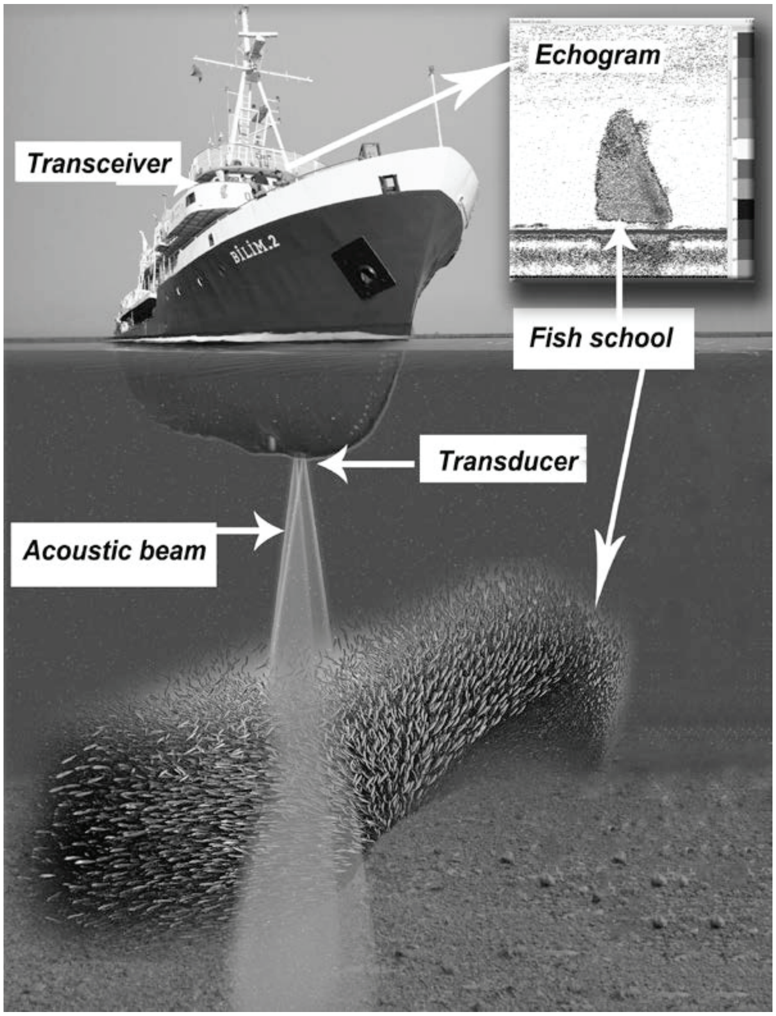


Figure 12. Hydroacoustic sampling

If the energy within the backscattered sound can be assigned to single individuals unit measurement per organism referred as target strength (TS) is used (Simmonds and MacLennan, 2005). TS allow observer to compute average sound scattering strength probability of an individual fish at certain size (Simmonds and MacLennan, 2005). Furthermore, if all the individuals in the water column are distinguishable then it is possible to assess total number of individuals by echo-counting methodology (Dalen and Nakken, 1983; Midttun and Nakken, 1971). In order to resolve two discrete fish the range between them must be large enough at least half the pulse length (Simmonds and MacLennan 2005).

1.3 Species identification

The species identification task is one of the most challenging sections of the study. This is also one of the most problematical areas in fisheries acoustics. With its susceptibility to bias, species identification is pronounced by MacLennan and Holliday (1996) as “the grand challenge of fisheries and plankton acoustics”. This process involves assignation of the backscattered energy to the different species present in the water column. Species identification becomes more complex particularly in multispecies area characterized by changes in the species composition of the schools. Using classification methods, very helpful information can be acquired out of the school descriptors. Classification has been defined as a process of finding a model that describes and distinguishes data classes or concepts, for the purpose of being able to use the model to predict the class of objects whose class label is unknown (Fielding, 2006). Data objects that are classified in the same group should display similar properties based on some criteria.

Species identification on schooling fish using classification techniques based on the school descriptors extracted from echograms has been applied by many studies. The school discriminators such as internal school density, school depth, and off-bottom distance (altimeter) were among the first school parameters used since the very first attempts in school identification carried out by Rose and Leggett (1988) for cod, capelin, and mackerel in the Atlantic Ocean. The authors correctly classified 93% of the schools using these parameters. This was followed by several studies of others (Diner et al., 1990; LeFeuvre et al., 2000; Lu and Lee, 1995; Scalabrin et al., 1996; Weill et al., 1993). Another important application of this technique was by Haralabous and Georgakarakos (1996), using the artificial neural networks classification for species discrimination, based on school descriptors of a single frequency dataset. Haralabous and Georgakarakos (1996) identified sardine (*Sardina pilchardus*), anchovy (*Engraulis encrasicolus*), and horse mackerel (*Trachurus trachurus*) in the Aegean Sea based on acoustic survey data using 120khz dual beam system. A similar study has been carried out in Tunisian waters targeting same species and the methodology based on school descriptors extracted from echograms and classification using artificial neural networks (Hannachi et al., 2004). A caged experiment was done by Simmonds et al. (1996) using a wideband method covering the frequency band between 27 and 54 kHz on caged fish for species recognition by applying neural network and discriminate analysis algorithms. Scalabrin et al. (1996) developed a method for species identification on the measurements with conventional single beam echo-sounder, using the energetic properties of the sound scattered by sardine, anchovy and horse mackerel schools (echo amplitude probability density function) in addition to the echogram – image characteristics. However, Scalabrin et al. (1996) postulate that despite observing clear trends which give remarkable insights, the efforts were not yet at the level required for a high probability of species identification due to limitations of singe beam method and unstable behavior of fish depending on the environmental conditions. Lawson et al. (2001) distinguished anchovy, sardine, and round herring schools on the South African continental shelf using morphometric, energetic, and bathymetric features despite their similarity in size and behavior over a large spatial area. In this study the principal components analysis (PCA) used for selecting the best descriptors and the species discrimination was done by Discriminant function analysis (DFA) (Lawson et al., 2001). Petitgas et al. (2003) developed a classification procedure based on echo-traces and calculated the variance arose due to species identification. Velho et al. (2006) have used general discriminant analysis for identification of echo traces for pelagic fish off Angola. Fablet et al. (2009) have created an automated process to estimate the proportion of species based on school morphology and frequency response in a multi-frequency survey data set, using the echogram similarities using a probabilistic model introduced in Bishop and Ulusoy (2005). Fernandes (2009) has applied the classification-tree system as a processing tool for objective species allocation, using multifrequency information from the ground-truthed echo traces collected during International North Sea Herring Acoustic Survey. Robotham et al. (2010) in a very comprehensive work addressed the identification issue by applying several methods and techniques of supervised learning algorithms. In their study Robotham et al. (2010) developed some complex and sophisticated statistical techniques for fish-species identification.

Within the context of these studies several methods have been developed and applied by extracting descriptors, such as their shape and depth, from individual school, aggregations and layers and used these shape parameters to identify species. Horne (2000) published an extensive review of the acoustic methods and techniques developed until that time enlisting the parameters used in school identification specifying them as shoal descriptors. In his review Horne also pointed that the development of statistical discriminators that reliably classify and identify acoustic targets is the main challenge. Subsequently the working group of ICES for fisheries acoustics science and technology (WGFAST) reviewed the implemented methods and prepared a report describing the state-of-the-art in school identification based on single frequency measurements and defined as "echo trace classification" (Reid, 2000). These parameters were actually became a prominent reference criteria (Burgos and Horne, 2007; Cabreira et al., 2009; Doray et al., 2006; Fernandes, 2009; Robotham et al., 2010; Shen et al., 2008; Velho et al., 2006; Woodd-Walker et al., 2003).

The process of fish school identification as a whole can be termed as pattern recognition or identification and conducted in several stages. These stages in interpreting acoustic data consist of, selecting the data, generating the features, selecting the features, applying necessary classification and evaluating the performance; step by step in more detail:

1. Scrutinization of echograms using masking tools and thresholds. Removing the noise and correcting the inconsistencies in the data
2. Detecting the fish schools generally using image analyzing techniques using necessary criteria
3. Exporting the data and extracting the school descriptors
4. Data examination for any error or outliers
5. Transformation if required
6. Labeling of the schools using trawl data with regards to expert evaluation
7. Feature selection
8. Classification and species identification.

Successful results have been obtained by using these analyses often employing sophisticated classification algorithms sequences (Fernandes, 2009; Robotham et al., 2010). However substantial background information is also necessary to obtain consistent results and finally the knowledge at scientifically trustable level.

1.4 Relationship between small pelagic fish and their environments

The ultimate purpose of this study is to contribute some insights into understanding of ecological role of the small pelagic fish in the North Eastern Mediterranean. Thus, their relationship with abiotic factors has been investigated. A better understanding of the role of environmental factors has been suggested as an essential tool for sustainable fisheries management (Fréon et al., 2005). Fréon and Misund (1999) defines the optimal habitat for a small pelagic species as the area where the various abiotic factors such as temperature, oxygen, salinity, transparency, light intensity or current speed, together with biotic factors such as density dependency, prey or predator, offers the best combination. Another term for identifying the ecologically important areas, concerning the fish preferences is “essential fish habitats”. EU Scientific, Technical and Economic Committee for Fisheries (STECF) in the Mediterranean define this term as ‘‘a habitat identified as essential to the ecological and biological requirements for critical life history stages of exploited fish species, and which may require special protection to improve stock status and long term sustainability’’(Ardizzone, 2006).

There exist numerous studies on various aspects of environmental factors that play a major role on the distribution of small pelagic fishes belonging to different populations all over the world (Cury and Roy, 1989). Environmental factors are important components in determining reproduction success and mortality which in turn affect parental stock and recruitment estimates (Agostini and Oliver, 2002). Although environmental influences are complex and not fully understood, habitat expansion in several important populations, changes in migration patterns, and reproductive success suggested to be related with environmental variability (Fréon et al., 2005). Such effects thoroughly examined in case of ENSO related El Niño and La Niña events. For instance, displacement of the anchoveta stock in Peru, which is one of the most important small pelagic fish stock in the world, suggested as a result of El Niño events (Bertrand et al., 2004). In addition, alternation between species such as anchovy and sardine is another important phenomenon, and its main driving factors were determined as environmental conditions along with overfishing (Cury et al., 2000; Lluch-Belda et al., 1992; Schwartzlose et al., 1999; Takasuka et al., 2007).

Furthermore, Fréon and Misund (1999) stress the complexity of interactions between various factors and states that although the ultimate mechanism could not be understood clearly, small pelagic fish have been observed to change their aggregation pattern dictated by environmental conditions (Fréon et al., 2005). Environmental factors can have direct effects on fish primarily on their metabolism. For example, temperature may affect the growth, feeding rates, swimming speed, and spawning time due to change in rates of metabolic processes (Fréon et al., 2005; Palomera et al., 2007; Pepin, 1991). Fish population tends to spawn during optimal environmental conditions thus affected by changes in environmental conditions (Palomera et al., 2007). Lisovenko and Andrianov (1996) reveal the role of temperature over feeding activity, digestion rate and metabolism of anchovy in the Black Sea. The role of surface circulation dynamics over the spawning habits of sardines and anchovies was tried to be explained for the

California Current region, and results clearly displayed a pattern of spawning in areas when wind drift is generally directed towards the coast and avoidance when there is strong offshore surface transport (Bakun and Parrish, 1982). Bakun (1996) summarizes the requirements for productivity of the small pelagic fish as Ocean Triads, which involves nutrient enrichment, retention of larvae in favorable areas in terms of growth and survival and concentration of larvae in a stable environment with sufficient food supply sustained by turbulence. These requirements are basically related to oceanographic structures such as gyres, fronts, eddies and coastal upwelling (Bakun, 1996). These remarks in the literature increases the curiosity on the relations between environmental factors and acoustic estimation of distribution of small pelagic fish, and this issue has been investigated as an ultimate objective.

1.5 Objectives of the study

The main objective of the study was to examine the spatial distribution of small pelagic fish in the study area based on the data collected within the project of project entitled "Kuzeydoğu Akdeniz Küçük Pelajik Balık Stoklarının İzlenmesi Projesi" (Monitoring the Changes in Small Pelagic Fish Stocks of the Northeastern Mediterranean) supported by The Scientific and Technological Research Council of Turkey (TUBITAK). In order to assess their spatial distribution based on their relative abundances, two major sub tasks have been achieved; 1) Postprocessing the acoustic data , 2) Classification of the observed fish schools to species. Second objective was to investigate the relationship between the distribution of the fish and environmental parameters such as depth, temperature, salinity and sea surface chlorophyll, to determine their habitat preferences. The third objective was to try to predict the impact of warming due to climate change, over the habitat availability of the most dominant small pelagic species in the study area.

1.5.1 Study questions

1. What is the spatial distribution of the small pelagic fish populations in the study area?
2. Is it possible to determine the species-specific distributions based on the available acoustic and trawl sampling data in respect to the distinctive ecological conditions of the study area?
3. Considering that the species identification is one of the most challenging parts of the methodology, can school classification method be achieved using statistical classification techniques?
4. What is the relationship between small pelagic fish distribution and different water masses observed in the region? What are the factors determining the pattern of the spatial distribution?
5. What would be the impact of temperature rise and climate change over fish distribution with regard to habitat suitability?
6. What are the implications of the findings to fisheries management?

2 MATERIAL AND METHODS

Data used in this study were collected within the framework of the TUBITAK project (108O566) titled "Monitoring the Changes in Small Pelagic Fish Stocks of the Northeastern Mediterranean".

2.1 General properties of the study area

The survey area was located within the continental shelf of northeastern corner of the Levantine basin covering an area approximately 7000 km2 located between Syrian border ($35^0$50N' $35^0$50'E) in the east and Ovacik Burnu ($36^0$10'N, 33^0 40' E) in the West (Figure 13 and Figure 14). Based on area specific properties such as bathymetry, hydrography and fish distribution density, the study area was divided into four sub-regions for analysis. First part was the area between Silifke to Erdemli, which characterized by relatively narrow continental shelf, affected by the Göksu River runoff which carries significant amount of nutrients and affects a remarkably large coastal area. On the other hand this part of the study area is far from the pollution source originated from big cities (Özsoy et al., 2008). Second part was from Erdemli to Karataş, covering one of the largest continental shelves in the Levantine Basin, affected by Seyhan and Berdan rivers that drain the highest amount of nutrients into the Cilician Basin and exposed to the sewage and pollution impacts and leaching from over fertilized agricultural areas from Mersin and Adana (Aytok et al., 2013; Doygun, 2005; Güler et al., 2011; Özsoy et al., 2008). Particularly, the inner Mersin Bay receives large amount of chemicals from the local rivers and municipal outlets and displays eutrophic nature (Yilmaz, 1997). The exchange with open waters is rather limited as the Bay is detached from the general circulation pattern of the basin (Besiktepe, 2007). Third part was the relatively shallow Iskenderun Bay with approximately 51m average depth not deeper than 100m in any part. This area has always been an important fishing ground mainly for demersal fish such as red mullet and prawns. The importance of the pelagic fishery is increasing where the round sardinella, sardine, chub mackerel, red-eye round herring and greater amberjack are targeted (Bingel et al., 1993; Gucu and Bingel, 2011).The fisheries is an important livelihood in the region with large size of trawler and purse-seiner fleet however at the same time highly exposed to the industrial pollution and marine traffic especially tankers (Doygun and Alphan, 2006). The fourth part was near Syrian border with very narrow continental shelf and distant from urban and industrial impacts and affected by the basin circulation (Y. Özdilek and Sönmez, 2006).

Table 1. Surface area of the subregions shown in Figure

Region/Depth strata	Area(Nm^2)	Area(Km2)
Mersin 0-50	400	1372
Göksu 0-50	108	370
Iskenderun 0-50	245	840
Samandag 0-50	16	55
Mersin 50-100	545	1869
Göksu 50-200	282	967
Iskenderun 50-200	356	1221
Samandag 50-200	86	295

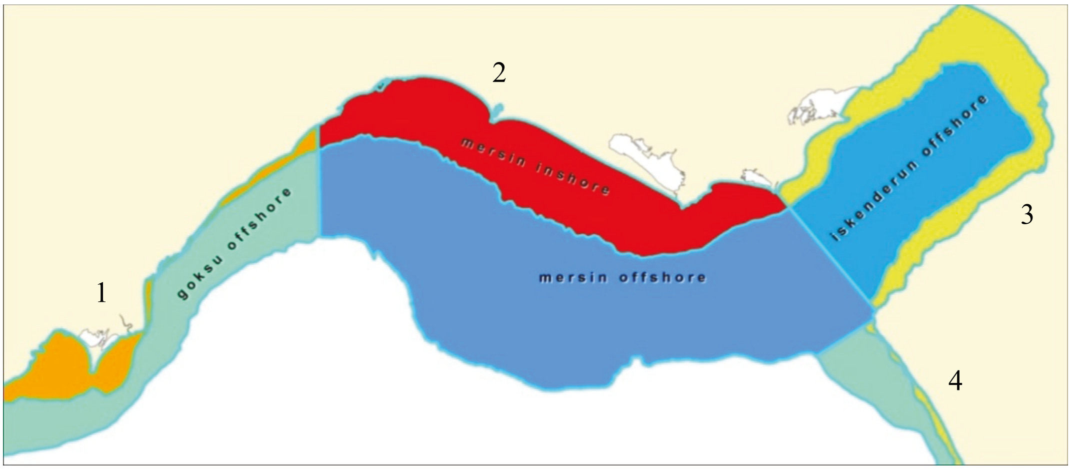


Figure 13. Study area with sub regions. From west to east; Goksu (1), Mersin (2), Iskenderun (3) and Samandağ (4) with divisions 0-50m.and 50 – 200m.

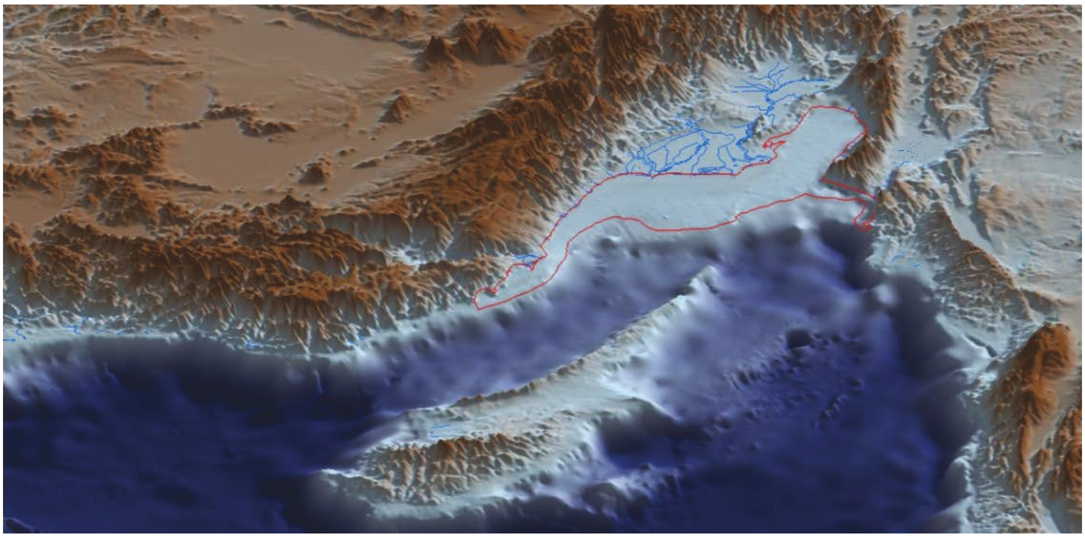


Figure 14. Three dimensional view of the region of interest, the study area is encircled with red line.

2.2 Data and sampling methods

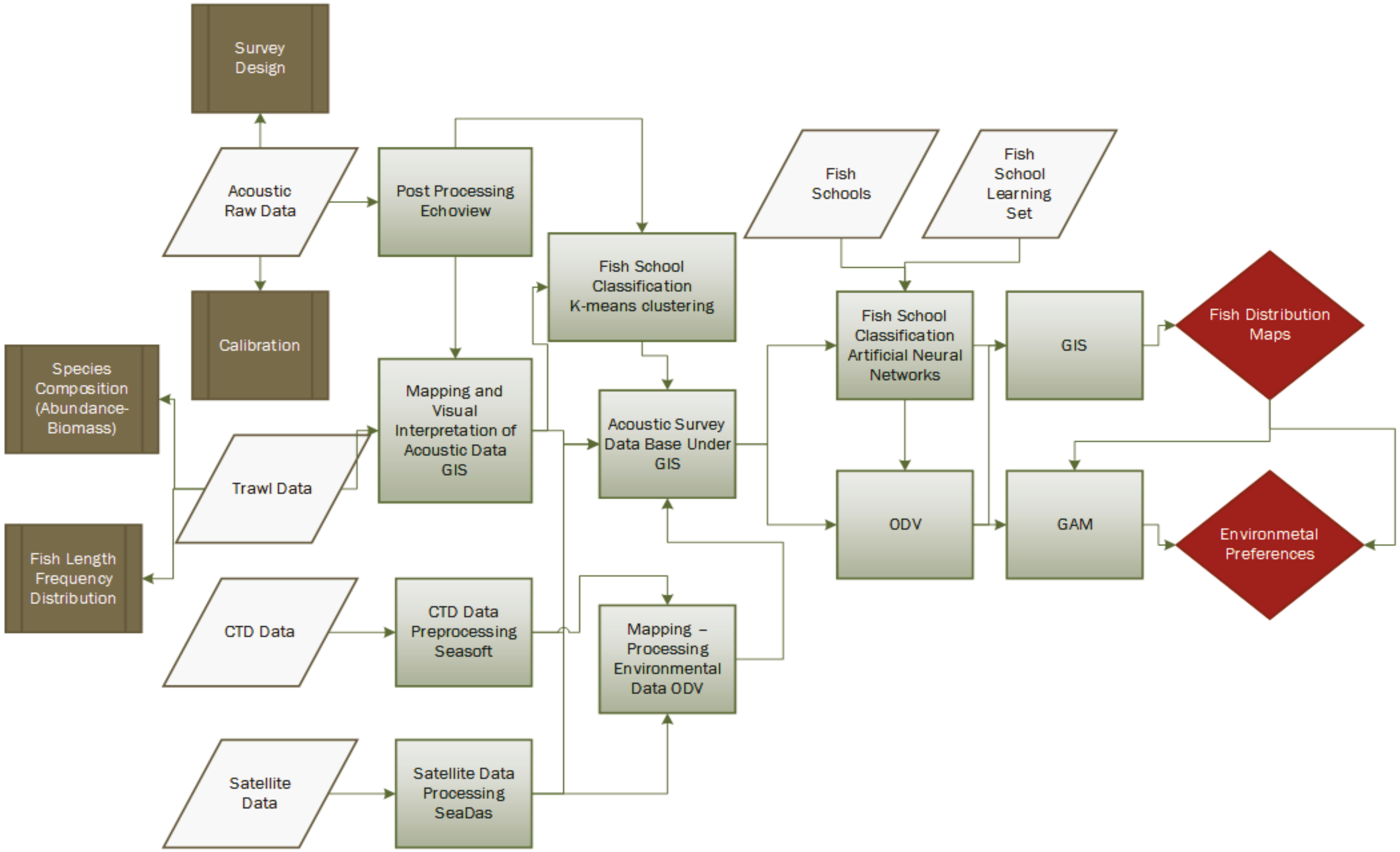


Figure 15. Flow chart of the conceptual framework of the study showing databases and computational tools that have been applied.

The workflow, as shown on Figure 15, started with scrutinization of acoustic data which involved detection and elimination of the noise, sea bottom and surface reverberation layers. Subsequently the fish school descriptors were extracted, checked for any inconsistency, filtered and examined to determine the meaningful school parameters for species identification. The school information and the corresponding trawl hauls were analysed and a biomass index for the species contribution was created. Subsequently, the raw CTD data and the satellite data was processed and binned in accordance with spatial extent of the acoustic data and stored in GIS. At species identification stage, the trawl catch information and clustering analysis were combined and classification analysis was performed and finally species distribution maps were evaluated using the hydro graphic data and satellite data in order to determine the factors affecting the fish distribution.

2.2.1 Hydroacoustic sampling

2.2.1.1 Acoustic Raw Data

In this study the acoustic data were collected onboard research vessels Lamas and Bilim 2 with an outer-side hull mounted echo sounder system. The system designed to be portable for use in both vessels. The transceiver kept in a plastic container for easy carriage and connected to a portable computer onboard. During the cruise data recorded permanently. The recorded part of the echograms was limited to 200m which was maximum working depth. Average recorded file size per day was 2.5 GB.

Due to the probable effect of vessel generated noise that might constitute interference to the acoustic system, the transducer had to be mounted to the best possible position, the exact center in the case of this study. Vessel generated noise mainly originated from, propeller, propeller shaft vibration, aerated and turbulent water flowing across the hull and engine (Mitson, 1993). The transducer was lowered to the depth as deep as possible to reduce the effect of the water that aerated at the bow.

After mounting the transducer, the tests were performed to observe the possible effects of the propeller, engine and ambient noises. At this stage active and passive measurements (transmitter turned on and off) were conducted. Although no significant noise interference detected from propeller and engine, it was observed that the noise increases after exceeding 7 nautical miles speed. Thus the survey speed was tried to be kept at 7 nautical miles maximum.

2.2.1.2 Echosounder specification

Acoustic measurements were collected with a Simrad EY60 scientific echo sounding system using 120 kHz split beam transducer. Split beam transducers calculate target location in three dimensions by comparing phase deviations of the returning signal in 4 sections of the transducer (Foote et al., 1986). In all surveys the pulse length was set to 512 µs, ping interval was 3 pings per second and power was 500W. Parameters were selected so as to capture information from the smallest fish schools as possible while acquiring maximum details of the school shape and avoiding the interference from unwanted particles.

2.2.1.3 Echo Integration

Generally it was not possible to discriminate individual fish particularly in small pelagics as they form dense schools. Therefore in this study the echo integration method proposed by Ehrenberg (1980) was used. In the method the fish echoes were combined to form a common backscattered signal. The total backscattered echo intensity offers a proportional measure of abundance in the water column in a way that, sum of the echoes from all individual targets converted to the total density (Kracker, 2007). This computation was based on the assumption that there was a linear relationship between the received echo intensity and target density (Foote, 1983). This combined measurement of backscatter from each sample volume was called volume backscattering coefficient (s_v) (Maclennan et al., 2002):

$$s_v = \sum \frac{\sigma \mathrm{bs}}{V_0}$$

σbs was the backscattering cross-section and represent the intensity of the backscattered energy of a unit, assigned to an area calculated as a ratio to the incident intensity of transmission (Maclennan et al., 2002). If the intensity of the incident energy at source assumed as (I_0), the distance of the target volume to the transducer as (R) and returned energy as (I_{bs}), and if the absorption was omitted then, the backscattering cross-section was calculated as below (MacLennan et al., 2002):

$$\sigma \mathrm{bs} = R^2 \frac{I_{bs}}{I_i}$$

In order to represent the abundance of the targeted organism in an area the total integrated backscattering energy per area, the backscattering coefficient (s_a), can be divided by the average σbs of the target. s_a was a measure of the energy returned from an area integrated to be two dimensional generally a layer of volume between two specified depth, or the whole range between surface and bottom. s_a was expressed in units of (m2/m2) however generally converted to nautical area scattering coefficient (NASC) by multiplying with 1 nautical mile (1852m) and its unit was written as m^2/nmi^2 (MacLennan et al., 2002). In addition, it was also converted to "scattering" cross-section to backscattering cross-section by 4π which is steradians in a sphere. Hence the acoustic biomass standardized as (Maclennan et al., 2002):

$$NASC = 4\pi(1852)^2 S_a$$

In this study NASC was the elementary acoustical unit used.

2.2.1.4 Calibration

Calibration is one of the fundamental procedures for accurate, precise and comparable acoustic measurements, where the system performance was measured and corrections were performed (Simmonds and MacLennan, 2005). During calibration, a metal (copper) sphere with known target strength attached to monofilament line was lowered into the sound beam about 8-10 meters depth and the measured target strength compared with the known target strength (Foote et al., 1983). The calibration procedure also covers on-axis sensitivity, beam pattern, beam width and split-beam angle sensitivity measurements. At the end the echo-sounder automatically adjusted by the ER60 calibration software.

2.2.1.5 Survey design

Transects were arranged as systematic parallel transects perpendicular to the coast taking the extent of the continental shelf into account. However due to irregular shape of the Iskenderun Bay, the transects were adopted so as to represent the geography of the bay in best possible way (Figure 16). Transects were spaced in every 4 - 5 nautical miles with average transect length of 12 nautical miles.

From 2009 to 2011, 5 surveys were carried out and the number of transects per survey was 45. Time and fund availability was also a factor in determination of transect density. The wind direction was also a criteria in the selection of the orientation of the transects. Roll or pitch of the boat disturbed the data remarkably. Therefore routes shouldering the wind at bow or aft quarter were preferred. The surveys were carried out in June and October. There were several reasons for the selection of the months, such as i) June corresponds to the beginning of warming and hence the beginning of thermocline formation; ii) October was considered as the last period of the thermocline before the winter convection; iii) June is the spawning season for the majority of the small pelagic fishes in the area iv) October is the recruitment period; v) June may be considered as the period when the abundance of the summer spawners are minimum; vi) October is the time corresponds to soon after the end of the fisheries ban, so the abundance is expected to be near at its maximum.

Prior to the surveys in 2009 May, a test transect was performed to observe the offshore extent of the main fish biomass density from the shore to 500m depth, and the NASC values were calculated cumulatively. Highest density percentage was found within 0-100 m strata. Therefore the transects were designed to limit the ending points not shallower than 100 m and in the areas where continental shore was narrow, the ending points were extended to 200 - 220m.

Figure 16. Transects and one nautical mile sampling units on each transect.

2.2.2 Trawl Data

The trawl catch data was used as a primary base for interpretation of the fish composition concerning the number of species, their size distribution and relative contribution to the total abundance. Although acoustic measurements give the total backscattering capacity of the target objects, these signals do not contain information about the species or the type of the organisms reflecting the sound (Lawson et al., 2001). The trawl sampling is an essential part of the species identification and size class determination process (McClatchie et al., 2000). The fish which have been observed acoustically could only be identified and sized with a representative sample of catch (Simmonds and MacLennan, 2005).

Research vessels Lamas and Bilim-2 are different in size, hull and engine specifications. Therefore the trawl nets and doors were not identical. The trawling system and net specifications in Lamas were more alike to demersal type however it was modified to render midwater trawling possible, by enlarging the opening and towing at higher speeds (Figure 17).

a) b) c)

Figure 17. Trawl operation; a) the catch is being hauled aboard; b)taking the trawl cod end aboard; , c)The catch is on the deck.

In Bilim, both doors and the net were particularly designed for pelagic trawling. In both vessels, net sounder system was not available. The location of the trawl net in the water column was estimated with the experience of the skipper who takes the bottom depth, length and angle of the wires and the speed of boat into consideration. The positions of the trawl stations were selected based on the fish school types observed on the echograms throughout the cruise. In general, the track was retraced to start trawling and returned to the position where the atypical echogram pattern was detected. However if the pattern was continuous, trawl was started immediately without returning to a reference point. As far as geographical coverage concerned hauls were performed according to an equally distanced station distribution plan made prior to the survey, if not shifted due to instantaneous decisions. A total of 131 trawls were conducted in five surveys (Table 2 and Figure 18). The towing speed changed between 2.8 – 4.5 nautical miles and the duration was determined based on the fish distribution on echograms nevertheless maximum duration was 30 minutes. The trawl catches were sorted to species, weighed and measured to the nearest 5mm onboard.

Table 2. Surveys; duration, number of CTD casts, trawls and total distance.

Date of Start	Date of End	#Days	#CTD	#Hauls	Total distance (n.miles)
01 June 2009	17 June 2009	17	61	35	943
06 October 2009	21 October 2009	16	145	43	968
01 June 2010	22 June 2010	22	177	30	1042
04 October 2010	20 October 2010	17	208	20	996
13 June 2011	19 June 2011	7	132	24	698
Total		79	723	131	4647

Not all the fish species sampled by the trawl were taken into consideration. Only those of the species displaying true “small pelagic” characteristics (pelagic or semi pelagic) were considered. With that respect a total of 11 fish species were included in the trawl dataset.

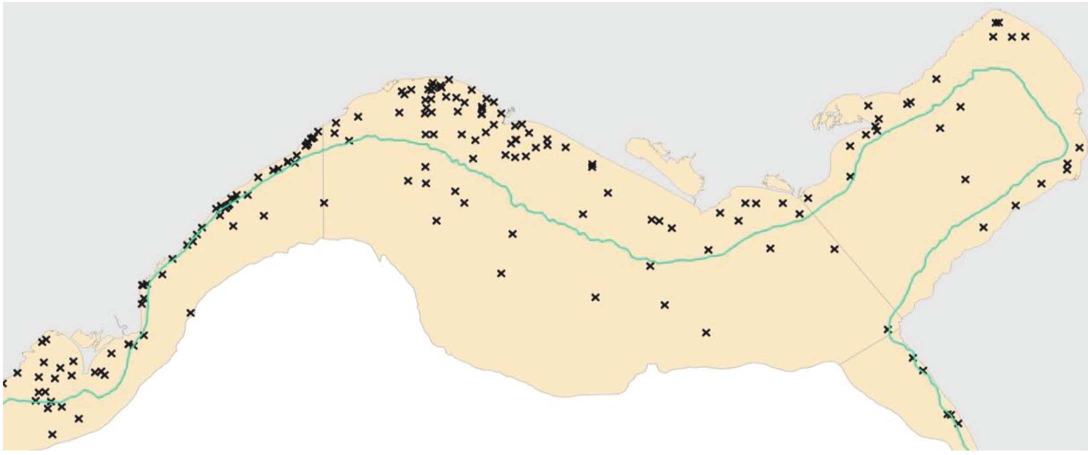


Figure 18. Locations of the trawl stations. Green line shows the 50m depth contour.

2.2.3 CTD DATA - Hydrographic parameters

In order to determine the environmental factors that have possible control over fish distribution pattern, vertical temperature, salinity and fluorescence profiles were measured along the transects. The number of casts conducted per transect changed between 3 -6 based on the length of transects (Figure 19). A Seabird SBE 19 plus conductivity, temperature, depth recorder (CTD) fitted with a Chelsea Turner fluorometer was used at each station. Approximately 150 CTD casts were conducted per survey in average. Number of casts were given in the Table 2 . A protocol was kept onboard for CTD casts including the geographical coordinates, total depth and the time of the stations. The raw data from CTD casts were converted to text format and binned to 1 meter depth for each parameter and filtered using SeaSoft software (Sea-Bird Electronics Inc., version 4.326).

Consequently the data converted to Ocean Data View (ODV) (Schlitzer, 2012) format for further processing. Using 3D calculation method in ODV, the oceanographic variables were calculated for the location of each acoustically detected fish schools.

CTD data was useful as it provided 3D information, giving opportunity to examine the conditions at the depth of fish schools. However, one of the aims of this study was to predict availability of the habitats that meet the preferences of the species in a larger spatial scale than the surveyed area. However, CTD data was not capable enough to characterize such a large scale. Therefore satellite data was also used in the study.

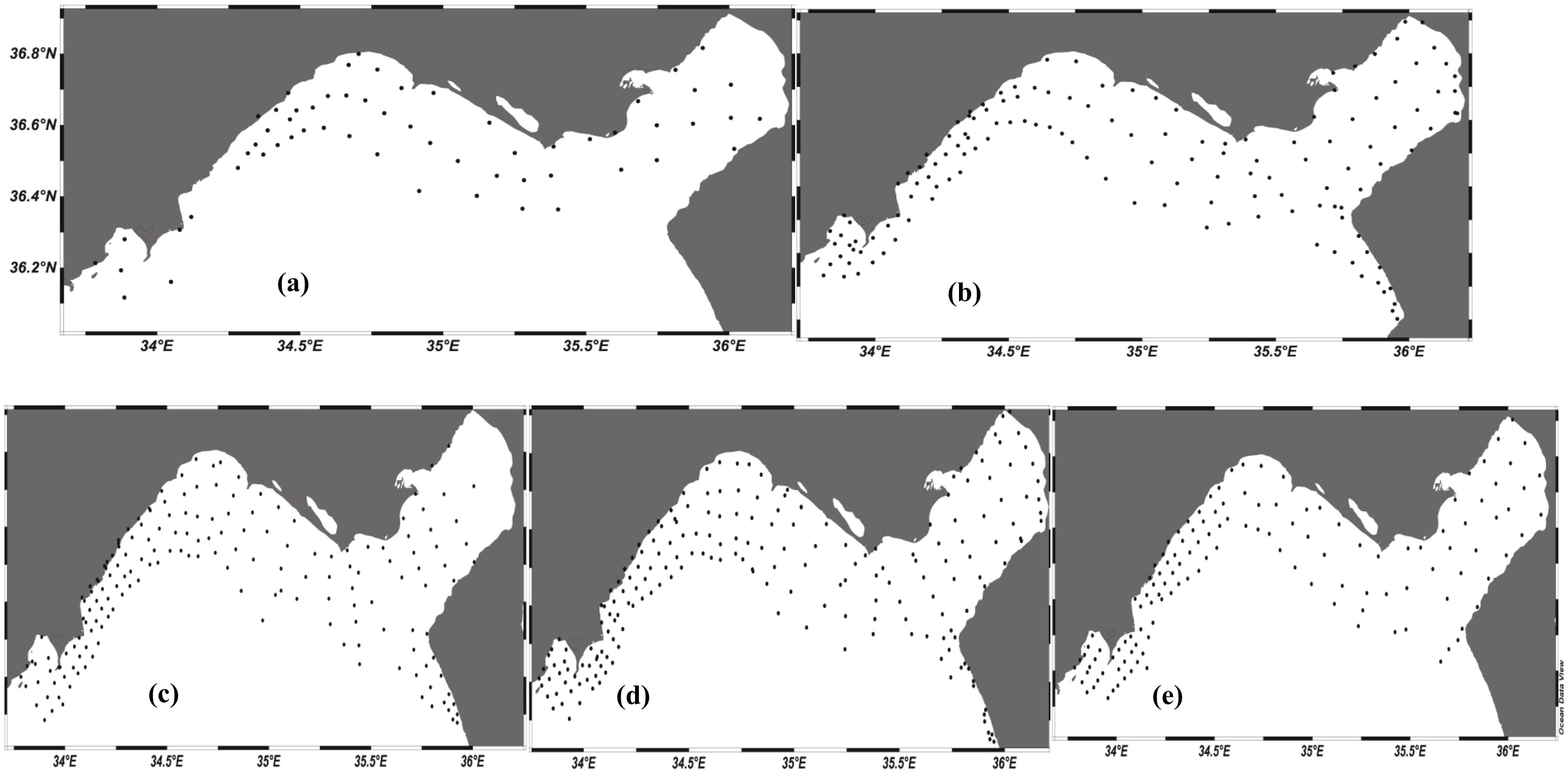


Figure 19. Location of the CTD stations shown as dots corresponding to June 2009 (a), October 2009 (b), June 2010 (c), October 2010(d), June 2011(e).

2.2.4 Satellite Data

Satellite data were used for determination of the spatial and temporal variation in sea surface parameters, namely temperature and chlorophyll. A series of daily sea surface chlorophyll-a (SSC) and sea surface temperature (SST) data of the study area obtained from NASA (http://oceancolor.gsfc.nasa.gov) was collected from the period of 2009 to 2011 derived from The Moderate-resolution Imaging Spectroradiometer (MODIS) images. MODIS is a satellite based passive optical sensor launched by NASA that capture data in different spectral bands radiated from the earth. MODIS sensors are present on-board NASA's EOS Terra (launched in 1999) and Aqua (launched in 2002) satellites. Due to calibration difference for the year 2010 (http://oceancolor.gsfc.nasa.gov/forum/oceancolor/topic_show.pl?tid=3853) between two sensors, the data only from the Aqua satellite was used.

The data was downloaded in hdf format (Level2 products), later on, spatially and temporally averaged and mapped onto a uniform latitude/longitude grid. The temporal averaging was performed within the intervals of the start and end dates of the acoustic surveys. The spatial resolution of this data was about 1 km.

For processing and mapping the Level2 files, SeaDAS 6.2 software working in UNIX environment was used. Level-2 products include flags that were generated as an outcome of certain tests for different predefined conditions. At this stage, pixels with cloud coverage, land and the land interference at coastal area were removed. All files converted to ascii files for further analysis, consisting of X,Y,Z values which were latitude, longitude and geophysical value; SST, SST4 or chlorophyll-a.

A series of corrections were performed to safely replace the CTD measurements with satellite derived data. These correlations involved Krigging interpolation of the CTD data; geographical matching of satellite and CTD interpolated data pairs; correlation analysis between the CTD variables and the satellite data. Another comparison was made between in-situ bathymetry measurements carried out by echo-sounding and bathymetry data obtained from the General Bathymetric Chart of the Oceans (GEBCO 08) of the British Oceanographic Data Centre (BODC) (http://www.bodc.ac.uk/projects/ international/gebco/) as a 30 arc-second grid (approx. 1 Km). Consequently, the data of each survey were pooled and coupled with high resolution SST and Chla imagery (~1 km^2 per pixel) corresponding to the time scale of the surveys by processing as regular grids under a GIS. Bathymetry was also calculated for each grid point derived from BODC data.

2.3 Postprocessing of the acoustic data

The objective at this stage was to identify the received signals, remove the noise, extract the fish and determine their species and sizes. Acoustic data were processed with the Myriad Echoview software. Initially the acoustic records from each day that contain all raw variables were created as file sets in separated collections. With the help of Echoview, GPS data from each file sets were extracted, the cruise track maps were created and any erroneous records were cleaned. The calibration data combined with raw data set and transferred into file sets. Digital echograms for each file set were created using volume backscattering coefficient (s_v) displaying the different scattering targets in different colors referenced in geographical location, depth and ping number.

In order to estimate the relative density of fish schools echo-integration method was used (Dragesund and Olsen, 1965). Echo-integration is applied when the individual fish cannot be resolved and the aim is to measure the density of the aggregations (Foot and Stanton, 2000). Specifically it is the calculation of the echo integral (mean volume backscattering strength) over a volume defined.

The resolution of the data-points in echograms was limited vertically by the sampling frequency and horizontally by vessel speed and ping rate. The vertical resolution was 0.049m. at 120 kHz with pulse duration of 512 µs and horizontal resolution were 1.1 m at 7 knots and 1 ping at 0.3 seconds. The echograms were filtered to −65 dB as threshold for the analysis. Then the sea bottom was automatically detected using the ‘‘maximum Sv backstep’’ algorithm of the Echoview software with back step of 1m. After application of this algorithm there still remain some slipups which need to be corrected manually. Subsequently the bottom line redefined as 0.5 m offset above the detected sea bottom, to exclude the bottom scattering in dead zone. Data 2 to 5 meters below the sea surface were also excluded to eliminate the noise produced by reverberations and air bubbles. The echograms were gridded into 1 nautical mile cells so as to analyze the data within each cell separately recommended by MacLennan et al., (2002). The elementary distance sampling unit (EDSU) was defined as the length of cruise track along which the acoustic measurements were averaged to give one sample. According to Simmonds and MacLennan (2005) the EDSU should be small enough to capture the main spatial structure of the stock but not so small that the correlation between pairs of successive samples was rather large. In this thesis, the EDSU distance was determined by the resolution of the satellite data while maintaining the representation of geographical distribution of the fishes.

2.3.1 School Detection

Fish aggregations were detected and characterized using the ‘‘Schools detection’’ module implemented in Echoview software. Methodology of the school detection was based on image processing techniques (Reid, 2000). The parameters of the fish schools were determined automatically by the SHAPES (Shoal Analysis and Patch Estimation System) algorithm in the Echoview software. The school size parameters used in the algorithm were established (see 3.2.1 Acoustics). The minimum s_V threshold as background was set to -65 dB which was defined for clear detection of all fish aggregations, as a result of trials from -52 to -70 dB for all data sets.

School detection takes two steps. First step was identification of the candidate aggregations, where contiguous groups of data-points were selected. These groups should fulfill the criteria of minimum $\mathbf{s_v}$ threshold, minimum school length and height. Taking into account of the possible gaps within the school and not defining them as separated schools, an ellipse in predefined size (Table 3) moved around the boundary of the candidate, and all the neighboring schools around candidate whose edge falls within the ellipse were connected. To be considered as a ‘‘school’’ by the software, the linked candidates must also meet minimum length and height criteria.

Table 3. School detection parameters and their descriptions.

Settings	Description	Value
Minimum total school length	Schools shorter than this length will not be included in detections.	5 m
Minimum total school height	Schools shorter than this height will not be included in detections.	1 m
Minimum candidate length	Min. length allowed for a single school candidate.	2 m
Minimum candidate height	Min. height allowed for a single school candidate.	0.5 m
Maximum vertical linking distance	Maximum vertical distance allowed between two school candidates.	1 m
Maximum horizontal linking distance	Maximum horizontal distance allowed between two school candidates.	5 m

Each fish aggregation determined as school by the SHAPES algorithm was then again checked visually. Any non-fish objects that were defined as fish schools erroneously were removed. Subsequent to school detection, the schools were initially mapped according to their Nautical Area Scattering Coefficient (NASC) distribution to see the fish density distribution prior to fish school classification. NASC corresponds to the acoustic biomass and used instead of real fish biomass. Here, NASC values were expressed in units of square meters per square nautical mile (m2/nautical mile2).

2.3.2 Feature Extraction

Feature extraction can be described as the selection of the most useful information from the input data. In the course of the classification process this information has been used in order to group the objects into most appropriate category. The detected schools on echograms contain several descriptors which were the parameters used in the school classification phase. The descriptor parameters of the fish schools were determined automatically by the SHAPES algorithm. The descriptors can be assembled in three categories (Reid, 2000).

- **Positional -** The position of the object in time and space, e.g. longitude, latitude, depth;
- **Morphometric -** The shape of the object as seen on the echogram e.g. height, width, area, perimeter length, circularity;
- **Energetic -** The acoustic energy in the object e.g. total, mean or maximum energy, spatial variability in energy or their statistical distribution within the domain.

2.4 Classification and Identification of the fish schools

School identification process involved exploration of the patterns within the school dataset, by identification of the pattern and grouping the similar components and finally labelling each distinct group using the trawl data set. Through the classification the clustering and supervised classification both carried out by using Weka Software. WEKA is the acronym for Waikato Environment for Knowledge Analysis. The open source software developed at the University of Waikato is written in Java and becoming increasingly popular in the field of machine learning. WEKA is free software available under the GNU General Public License. WEKA supports several data mining applications including data preprocessing, clustering, classification, regression, visualization, and feature selection.

2.4.1 Clustering: K-means algorithm

Although the aim was to solve identification problem with supervised classification method, a prior exploratory analysis has been performed to assist the classification using clustering method. The success of the classification depends on the quality and representativeness of the learning set which consist of labelled inputs, so in order to allocate the trawl based species information to echotraces systematically, the assistance of clustering was used. Clustering is basically grouping the similar objects within a cluster while maximizing inter-cluster differences. K-means clustering algorithm was used to group similar schools based on the extracted parameters of school descriptors (Figure 20). The advantage of the K-means clustering method was the easy implementation of the algorithm. There was no need for data training and testing. However method alone had limitations and the results cannot be used directly for species identification. In order to reduce the misperception the parameters related with depth factor and geographical location was not involved. The distinction between inshore and offshore species performed using the trawl species composition. Weka software was used for k-means clustering with cross-validation method that helps to find the best number of clusters within the dataset. This algorithm found the "nuggets" in the data and helped automatically determining the number of clusters in the data. The echo traces in datasets had shown 6 - 8 different patterns according to K-means method. However only 6 of them could be identified considering their overall distribution and catch composition. Finally trawl composition maps overlaid on to the acoustic fish data and the echograms were labeled according to the assumptions described in section 2.4.2.

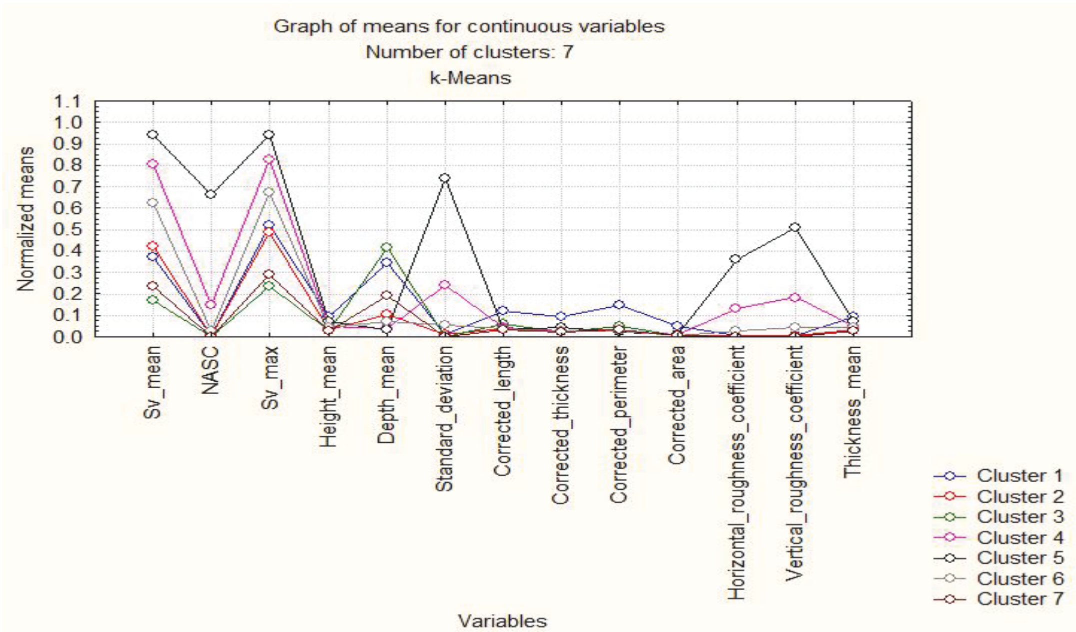


Figure 20. An example shoving the K-means classification with the nodes of the vectors.

2.4.2 GIS mapping of the trawl catch and identification of the schools near trawling areas

As the clustering relied only on school descriptors without ground truth data, they were not expected to give the exact distribution of the fish but to give an insight on the distribution pattern of the different type of schools. So they have to be interpreted again using trawl data. After overlaying the trawl station map over clustered fish school distribution the next step was to identify the fish schools near trawl stations. Initially the area covering two nautical miles radius of the trawl location was determined for each station. The schools that remained within peripheral area of each trawl station extracted and sorted by NASC in decreasing order. During this interpretation all fish schools distributed in and near 500m range of trawling ground were used, however any extreme schools within 2 nautical miles range with NASC values higher than 450 (natural break) were also involved. The schools within the determined area, labelled at unsupervised classification phase, were manually assigned to the species taking into account of the trawl catch composition in that area.

2.4.3 Allocation of species to echo-traces based on trawl catch data

The highest biomass values of catch of each species within whole replicates indicate the effectively sampled schools regardless of their proportions in the specific haul. The upper 95% percentile of biomass of each species was extracted and sorted in decreasing order. The ranking obtained here has been used together with spatial distribution pattern of the species in terms of composition (Figure 21). Although the relative abundances in the catch undergoes high uncertainty, it was assumed that, at least one individual from each species that occur in the trawled area should have been captured. In this aspect trawl catches were regarded as representative only of presence/absence. Factors associated with schooling behaviour of the fish such as school density, depth preference, geographical location, total depth and position in the water column were also considered during allocation. Such a subjective approach was taken due to uncertainties arising from factors such as vessel avoidance and variation in catchability of species. At this stage the identified parts comprise the 5% of the total number of the acoustically detected schools. This set was exported with school descriptors to be used as learning set.

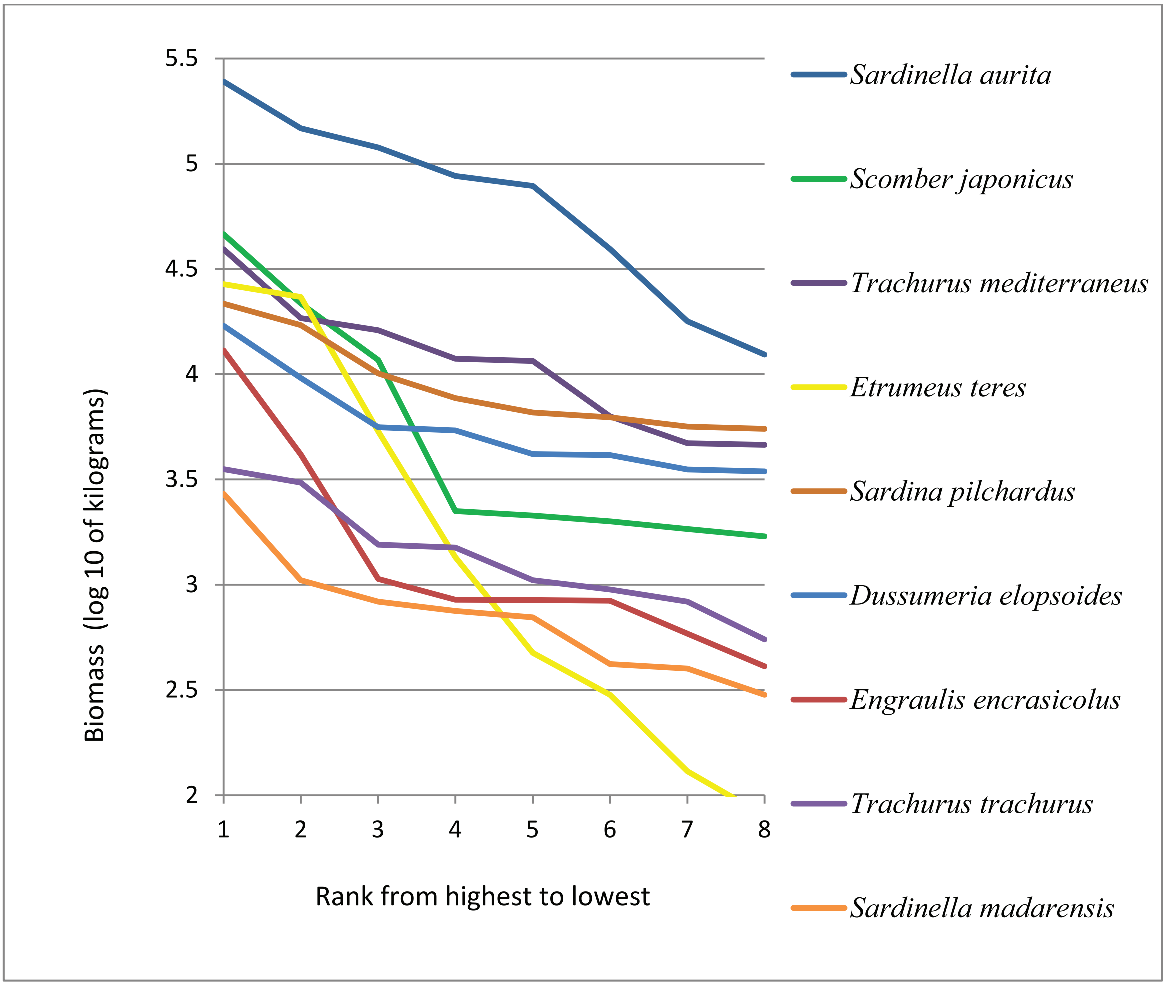


Figure 21. Biomass index for fish species densities based on the 95% percentile of the cumulative fish biomass distribution within 152 hauls. The Y axis is logarithm biomass in kilograms.

2.4.4 Classification using artificial neural networks

The fish schools close to the trawl stations were identified using the trawl information assisted by clusters detected by k-means. However, majority of the fish schools were not in the range of trawl locations. The question here was to identify the remaining school using the information of pre-defined pattern which was the field of the supervised classification (Cabreira et al., 2009). To create an identification model artificial neural network (ANN) was used. The methodology of ANN simulates the functioning of the biological neural networks in form of mathematical models. ANN was comprised of basic elements like neurons; they are called artificial neuron or node or perceptron. The nodes are inter-connected and the connections acquire weights as a function of the sum of the inputs determined by an activation function. The artificial neural network model in this study was built in WEKA using multilayer perceptron (MLP) function. The basic principle is:

$$a_j = \sum_{i=}^{I} X_i W_{ji}$$

Where a_j is the input of neuron j $j;$ X_i is the output value of the neuron i of the previous layer W_{ji} was the weight factor of the connection between neuron i and neuron j (Haykin, 1999). The process can be grouped in two different phases, learning and application. The learning was a critical part that is necessary to produce a consistent and representative output. Back propagation algorithm was used in learning process which has numerous implementations in numerous fields including fisheries science. During learning, the network is trained to categorize the schools according to the pre-defined fish classes. The learning sets were consisting of information on fish schools and their descriptors. Learning is an adaptive process as the system changes the weights of the elements according to the variability of external or internal information that runs through the network. Multitudes of connections are made between inputs outputs and internal units, and finally strength of each connection determines the learning. When an object introduced to networks, initially each connection obtains random weights. Next, the distances of a randomly selected vector (independent variable) to the weighted connections are calculated based on the Euclidean distance. y_{ij} was the distance to (ij) and n was the dimension in input vector.

$$y_{ij} = \sqrt{\sum_{d=0}^{n} \left(x_d - (w_{ij})_d\right)^2}$$

This process iterates until the weights no longer improves the predictions. In a simple explanation briefly; the process comprises transfer functions, where an input,φ , with weight, w, acquiring a coefficient called bias, b , and made active by an activation function, g. The activation function works like a sensor, deciding if the signal is strong enough to transfer or not.

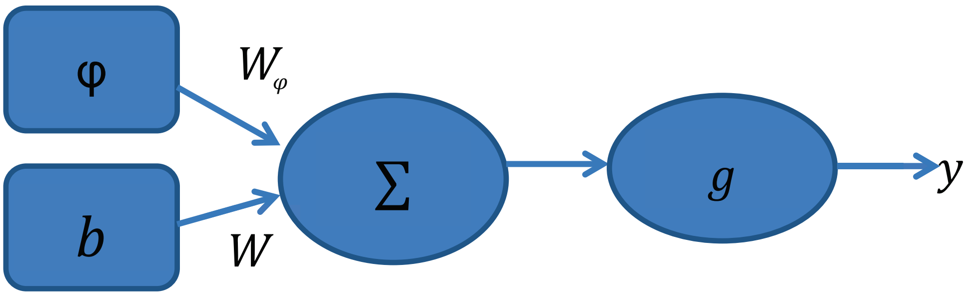


Figure 22. Basic workflow of ANN with described with single input: $y = g(\varphi w + bw)$.

The Figure 22 demonstrates a very simple description of the principle of ANN; however the main network was more complex as it involves multiple inputs and neurons in hidden layer. So the output given in the equation was sum of all weighted inputs wjφj and weighted bias, b_w and applied activation function.

$$y = g\left(\left(\sum_{J=0}^{N} wj\varphi j\right) + b_w\right)$$

Learning progress with iterations, as the error calculated considering the actual and desired output vectors. The algorithm checks the classification results during the process to test the accuracy of the results, by means of random sub-samples from the same learning set. At this point, the labelled training data set randomly divided into two parts; subsequently the test was performed using a portion of the set only for training while excluding the other portion and using it only for test. The detected error during process propagated backwards through the network and used to adjust weights to decrease the error.

In this study training and testing was performed by cross validation with ten folds. In this method, the dataset was randomly partitioned into 10 subsets. At each phase one subset was retained for testing the classification results while the remaining part was used for training. At the end of the iterations, all the samples in the dataset were used for both training and validation.

The reliability of the ground-truth data was one of the important requirements for an accurate classification. However in order to cope with uncertainty due to constrains at trawl sampling, which was the main source for ground-truthing, some trials were performed by changing the learning set for a set of scenarios. This stage can also be specified as fine-tuning procedure progressing step by step, begun with poorer classification success rate and reaching a satisfactory result at the end. The procedure consisted of five experiments starting with the initial learning set obtained from the unsupervised classification stage combined with trawl data. Final classification results were then transferred to GIS mapped and examined. Finally the labels once more marked to the echograms for manual corrections. The corrections were made in the cases, if a fish species id was given marginally to a school, which was unlikely to be there with regards to the expected pattern, i.e., an inshore species observed offshore. The id of such school changed so as to comply with surrounding pattern. These inspections were made using GIS maps including all species information and parameters, and on echograms individually for each school. Finally species distributions maps were created.

2.5 Estimation of the biomass

For the conversion of the echo intensities of the fish to biomass, the empirical formulation suggested by Simmonds and McLennan (2005) has been used. The procedure estimates the mean target strength for species using the formula;

$$TS = b_i + m_i \log(L)$$

b^i and m^i are constants for the *i*'th species. These constants were taken from (Giannoulaki et al., 2011) as b^i=-71.2 and m^i = 20. The backscattering coefficient (σ) required for conversion of NASC to fish abundance calculated using formula;

$$\sigma_i = 10^{(b_i + m_i \log(L)/10)}$$

In order to reflect the size distribution of the insonified fish in the area following formula was used to calculate the average σ_i

$$\overline{\sigma_i} = \sum_j P_{ij} 10^{b_i + m_i \log(L_{ij})/10)}$$

Here L_{ij} is the length of the j'th class of the species and P_{ij} is the corresponding frequency, as deduced from the fishing samples. Finally total abundance is calculated as;

$$\sum A_i (\overline{NASC_i} / \sigma_i 4\pi)$$

Where A_i is the surface area of its strata. Total biomass then calculated by multiplying the average weight of species. Average weight for an average individual of the species per survey calculated using the length weight relationship formula;

$$W = a\, L^b$$

Where "a" and "b" are the constants for one species determined from the trawl catch. The biomass calculations were only performed for the *S. aurita* which was the most dominant species in the area. The length distributions and the constants were taken from Karakaş (2011) as a = 0.0032 and b = 3.326

2.6 Analyzing the effect of environmental variables over fish distribution

A group of environmental variables were selected due to their potential influence on distribution of acoustic density regardless of the species specific distributions (Fréon and Misund, 1999). The selected parameters used in the analysis were; temperature, salinity, depth and chlorophyll-a concentration based on fluorescence measurements.

In order to investigate influence of parameters series of analysis performed including bivariate linear regression, multiple linear regressions, generalized linear modeling and generalized additive modeling. Analysis had begun with data exploration phase to understand the structure of the data such as distribution of the variables and the relationships between variables. In modeling phase the acoustic densities used in two way; i) only where it exceeded zero, ii) data including zeros.

2.6.1 Linear and multiple regression

Linear and multiple regression analysis were performed to explore the relationship between the abiotic explanatory factors and NASC without breaking down the data into species. Data used all together in linear regression, however in multiple regressions, conditional factors included which were sub-regions which represent spatial variability. The significance of regression parameters were assessed by anova tests.

In the next step the multiple linear regression technique was used in order to obtain a better model using all explanatory variables as a linear function of the NASC. At this step sub regions was involved in the analysis as an additional parameter assumed to help to resolve the effect of the spatiality. Subsequently, to ensure that if the constructed model was the optimal combination to explain the data AIC (Akaike Information Criteria) test was applied, which measures the goodness of the fit. Results of this analysis were evaluated based on the multiple r-squared values, which indicate the total variance explained by the model.

2.6.2 Generalized linear model (GLM)

Generalized linear model (GLM) technique considered as an alternative to be used to improve the analysis which was flexible in terms of its capability of using different density curves such as poison distribution, other than normal density distribution which was a requirement of the linear regression. In GLM the predictions fitted by exponential response model linearized by using a logarithmic function (log-link) which allows the predicted response to vary linearly. Furthermore GLM can handle the overdisperison of data owing to Poisson distribution (Zuur et al., 2007). The GLM formula can briefly be written as;

$$g(\mu) = X^T \beta$$

Where, "g" was the link function and μ was the expectations of observations, X was the vector of explanatory variables where the superscript T denotes matrix transposition, β was the regression coefficients. Using the same parameters those in the linear regression analysis, Poisson-GLM was fitted to test their effects. The contribution of each parameter to the model was assessed by using drop-1 variable test where model fitted repeatedly while removing one parameter each time and calculating the deviance.

2.6.3 Generalized additive models (GAM)

Generalized additive models - GAMs were built in order to evaluate the effect of environmental variables over fish distribution (Wood, 2006). GAMS do not require normal distribution alike to GLM which was flexible with regards to statistical distribution (Zuur et al., 2007). Furthermore it provides better fitting than GLM where explanatory variables replaced by smoothing functions. Compared to linear models GAM has superior performance as it allow the representation of complex relationships between species and their environment (Guisan and Zimmermann, 2000). Smoothing functions allow dealing with nonlinear relationships between the response variable and explanatory variables (Hastie and Tibshirani, 1990). GAM analyses have been widely applied in incorporating interactions between small pelagic fish distribution and environmental factors (Giannoulaki et al., 2011a; Murase et al., 2009; Planque et al., 2007; Zwolinski et al., 2011). GAM analyses used to produce smoothed fits for each environmental predictor. Similar to GLM, a link function was used for predictions in GAM. Its formula basically can be written as;

$$g(\mu) = \bar{\mu} + \sum_{i=1}^{n} s_i(Xi)$$

Where, g was the link function μ was the expectations of observations, $\bar{\mu}$ was the intercept Xi was the ith explanatory variable and s_i was the smoothing function for the explanatory variable. For the selection of the GAMs smoothing predictors the ''mgcv'' library in the R statistical software (R Development Core Team, 2004) was used. Similar to multiple linear regression and GLM, each fit was analyzed for the adequacy on the level of deviance explained and the Akaike Information Criterion (AIC). The best model was selected based on the minimization of the AIC score. Selection of the models also involved comparison of diagnostic plots and the percentage of the variability explained by the model (model deviance/null deviance). The degree of smoothing of the models was chosen based on generalized cross validation (GCV) available in the 'mgcv' library. Using the information in earlier steps the GAM model was determined to be used initially with a Poisson distribution structure and log-link function. However negative binomial distribution was also used to compare the model results with regards to dispersion of the residuals and smoothness of the fit. In application of the negative binomial distribution the method 'outer iteration' was used for smoothing parameter selection described in Wood and Wood (2013). When choosing the smoothing parameters a value of theta was determined by iteration which minimizes the AIC of the model (Wood and Wood, 2013). Bivariate GAM models were fitted to pairs of bi-annual surveys, pooled according to the season either June or October. As the ultimate aim of this study was to explain the role of environmental factors on fish species distribution it was essential to use species distribution maps and identify the environmental factors to specify the species needs that link them to their environment. However, initially the effect of environmental variables were analyzed over total acoustic biomass without species discrimination. Each species were analyzed separately to assess the species specific characteristics. In situations where the variance exceeds the mean in the data set or model the term of overdisperison was used (Ver Hoef and Boveng, 2007). In such situation Zuur et al., (2009), recommends either use of quassi – Poisson distribution with an overdisperison parameter or negative binomial distribution. In the case of this thesis the negative binomial model was chosen. Finally, to predict the effects of warming on the distribution of the *S. aurita* the results of Albouy et al. (2013) were used. In their study authors implemented NEMOMED 8 climatic model using A2 IPCC emission scenario where they predict a mean rise of 2.8 °C by the end of the 21st century over entire Mediterranean Sea and their model project a mean rise up to 3.2 °C in the Levantine Sea. The scenario for predictions was constructed with a nominal assumption only taking into account of the temperature increase, disregarding the possible changes in chlorophyll concentrations under changing climate conditions. The predictions were implemented by increasing the temperature 1°C at each step until +3°C while keeping the other parameters same.

3 RESULTS

3.1 Fish distribution

3.1.1 Evaluation of catch data

The catch composition by weight was calculated from the trawl dataset of five surveys consisting 131 trawl hauls and an overall 2253 kg of fish. Together with the targeted small pelagic fishes the total number of species observed in the trawl hauls was 110. Only 34 species were observed more than 13 times (10% of the total number of hauls). Most of the pelagic and semi-pelagic fish were captured (84%) at near shore area at depths <50 m. Most frequently observed species were *Trachurus mediterraneus* (63% of all observations), *Dussumieria elopsoides* (55%), *Upeneus moluccensis* (53%), *Sardinella aurita* (45%), *Saurida undosquamis* (44%), *Pagellus erythrinus (*39%*), Engraulis encrasicolus* (38%) and *Leiognathus klunzingeri* (37%). A total of 1672 kg of school forming species (pelagic, semi-pelagic or demersal) were sampled which were represented by 27 species accounting for 74% of the total fish caught. The fishes sampled includes members of *Clupeidae, Engraulidae, Carangidae, Mugilidae* and *Thunnidae* families, as well as some demersal fishes which often occurs in schools such as *Upeneus moluccensis, Leiognathus klunzingeri, Boops boops, Spicara flexuosa, Pagellus acarne, Spicara maena, Spicara smaris* (Figure 24). Demersal school- forming species constituted 49% of the total fish sampled. This group was dominated by two species; *Leiognathus klunzingeri 496 kg* (41%) and *Pagellus acarne 435kg* (36%). Species in this collection were observed at least 13 times (10% of the total number of hauls) and comprised 496 kg of fish accounting for 30% of the total school forming fish. Within this collection, the species belonging to Carangidae family was composed of 9 species; *Trachurus mediterraneus, Trachurus trachurus, Caranx rhonchus, Caranx crysos, Trachurus picturatus, Decapterus russelli, Alectis alexandrines, Trachinotus ovatus* and *Alepes djedaba*, weighing 93 kg in total. The majority of the Carangidae family was dominated by *Trachurus mediterraneus* (67%) and *Trachurus trachurus* (13%). They were grouped together due to their spatial co-occurrence and similarity in school formation. Their schools were observed close to the bottom and the spread of the distribution increased with depth. Clupeids observed in the samples consisted of 5 species and they accounted for 66.2% of the small pelagics. Among them *Sardinella aurita* was the most abundant fish with a total weight of 194 kg constituting 38.7% of overall catch of small pelagics. The contribution of the other clupeids were; Sardina *pilchardus* 11.1%; *Dussumieria elopsoides* 8%; *Etrumeus teres* 6.9%; *Sardinella madarensis* 0.8%.

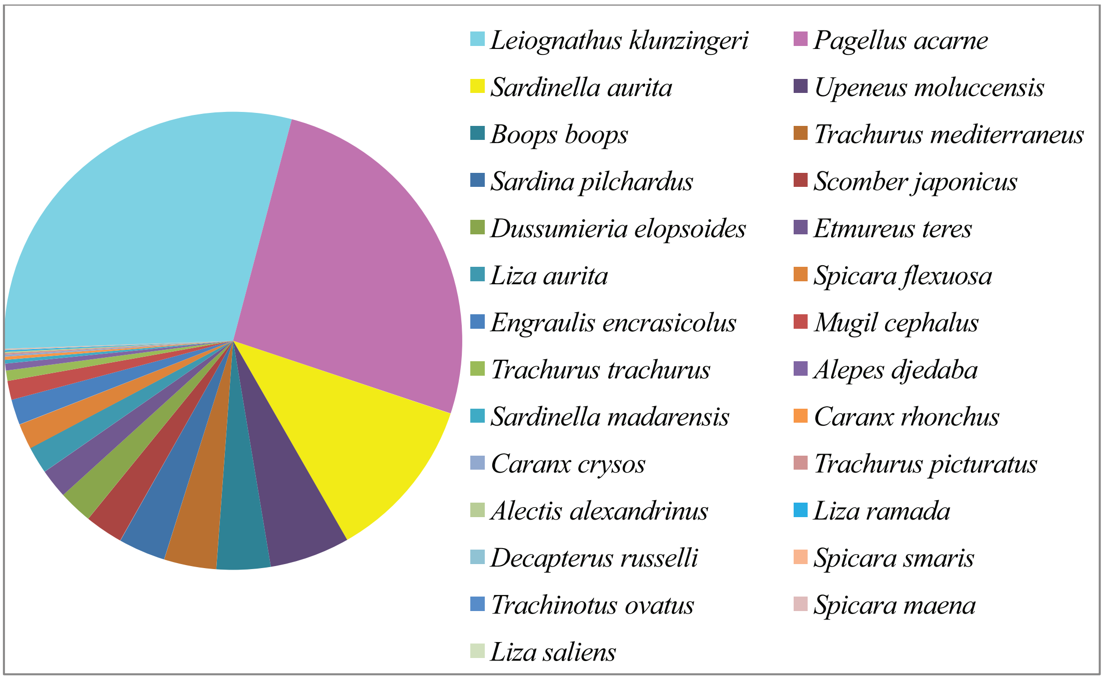


Figure 23. Biomass proportions of fish species in the total quantity of all catches.

Members of the Carangidae family observed in the area represented 18.7% of the small pelagics. Only one thunnid, *Scomber japonicus* was observed constituting 9% of the samples. Two Engraulid species were observed in the samples however they were not discriminated in this study. Together they formed 6% of the samples (Figure 24). The biomass index calculated for the top ranking 95 % of the species (Table 8) indicated that *Sardinella aurita* provides the highest contribution, followed by *Trachurus group*, *Scomber japonicus*, *Etrumeus teres* and *Sardina pilchardus*.

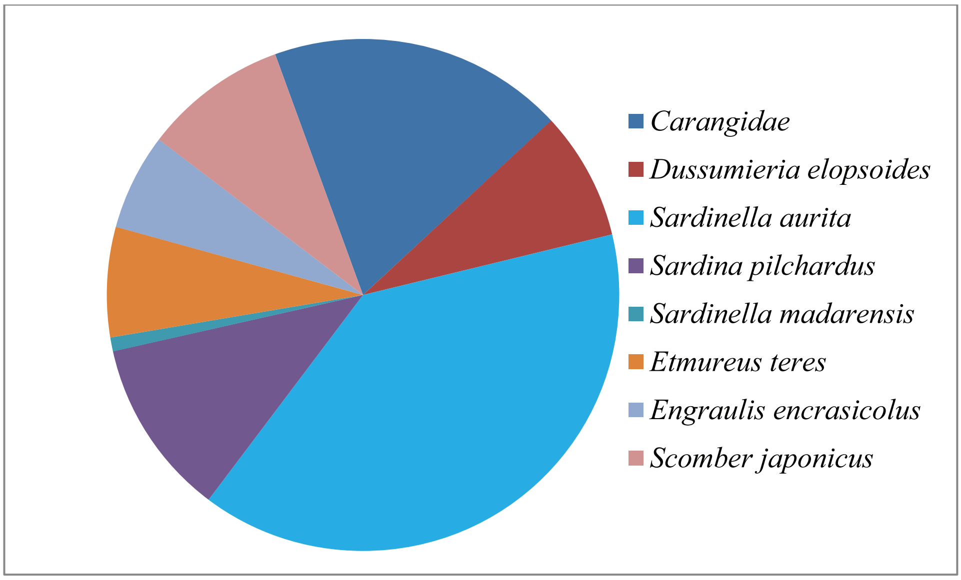
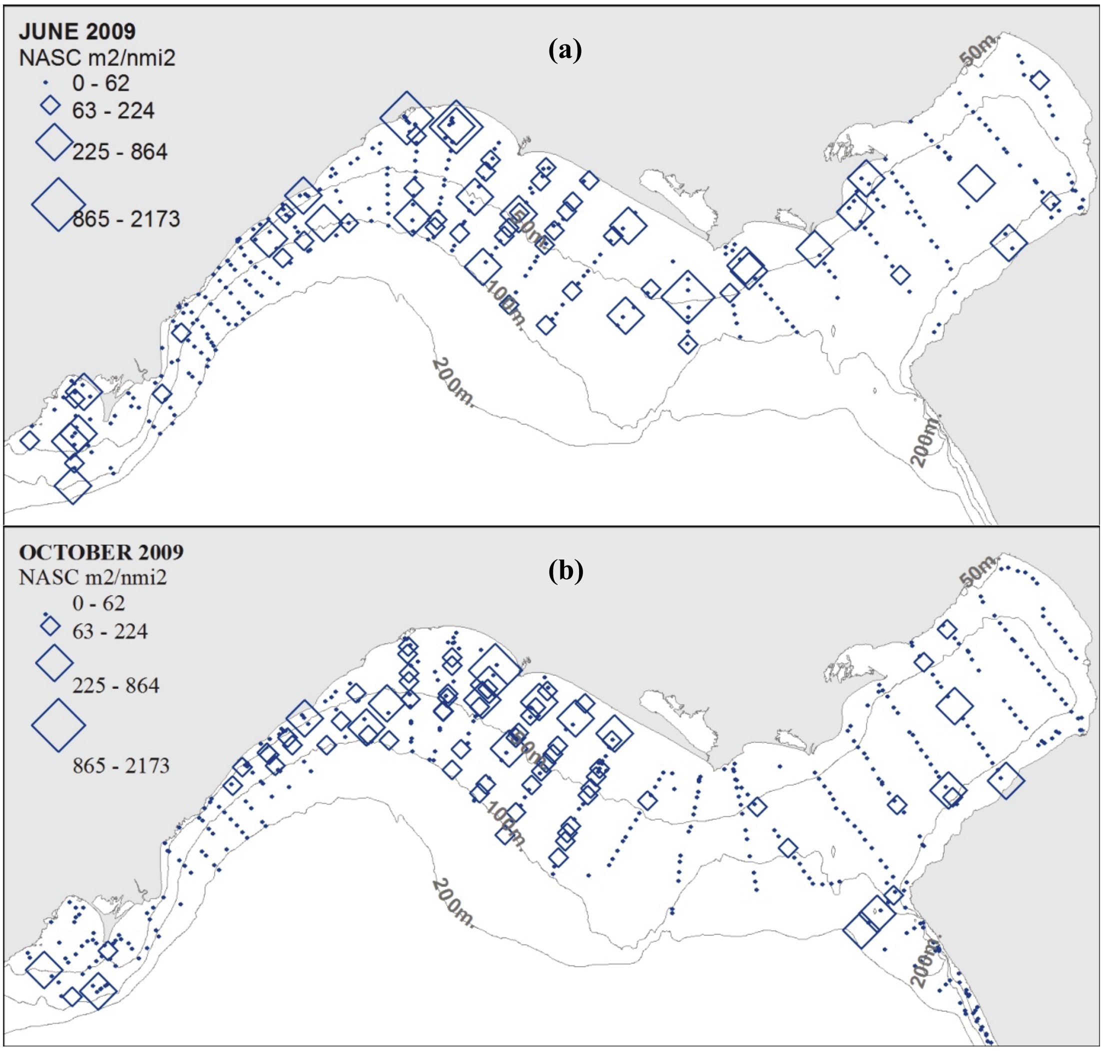


Figure 24. Biomass proportions of pelagic fish species given as total quantity of all catches.

3.1.2 Distribution of acoustic estimates

Totally 3231 fish schools were acoustically detected however 2841 of them were used in the analysis and the rest that were not ensonified at least by two successive pings or not meeting the school criteria were eliminated. The number of schools detected in each transect ranged between 0 and 75 with an average of 10 schools. Among the arbitrarily formed 4 subregions, the SR 2 was the richest in terms of school abundance per transect. SR 2 was followed by SR 3 (Table 4). In order to illustrate the geographical distribution of fish density, the total school echo energy from the whole water column corresponding to unapportioned fish density in the intervals of Equal Distance Sampling Unit (EDSU) (1 nautical mile) was mapped (Figure 25).



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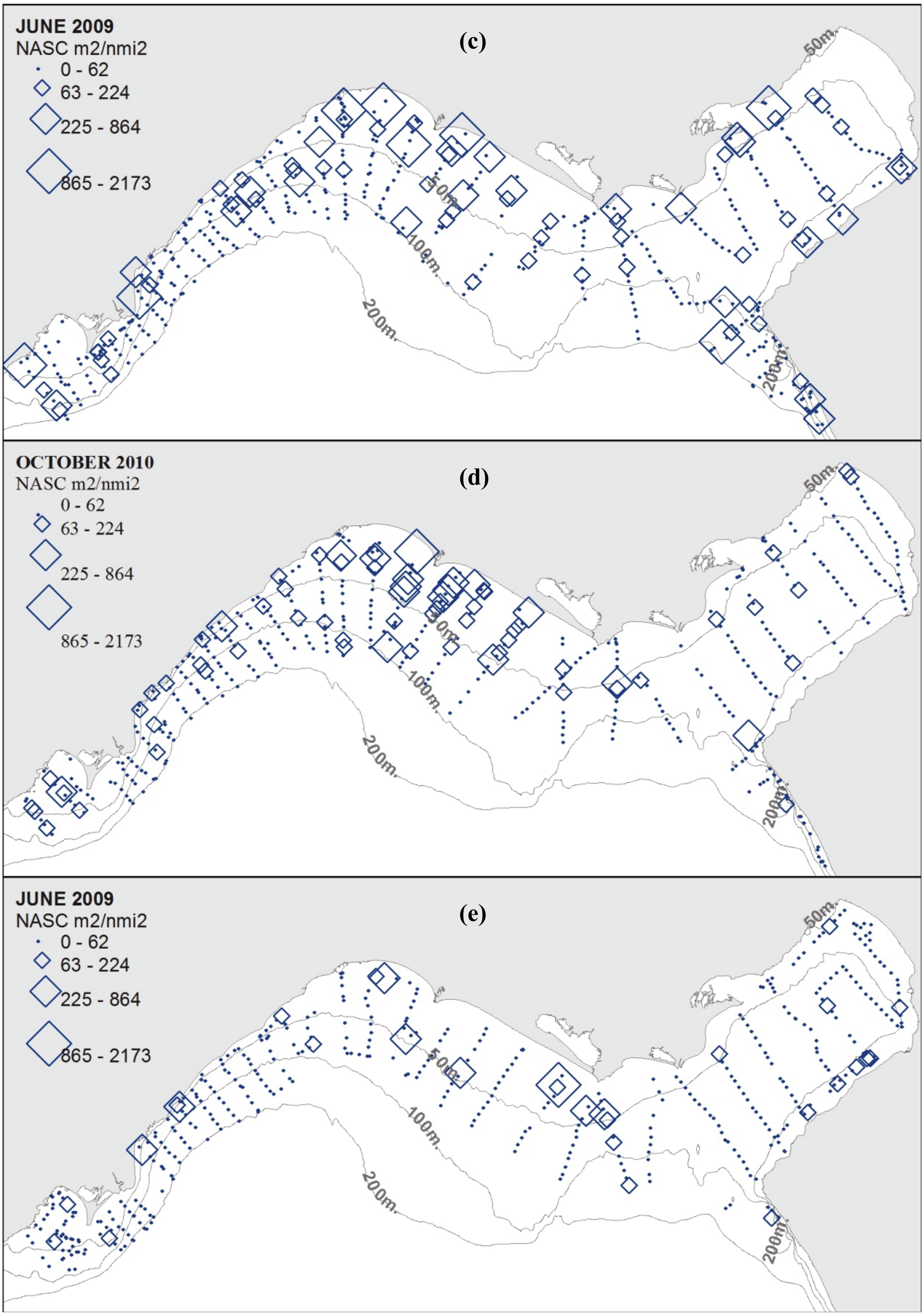


Figure 25. The geographic distribution of unapportioned total fish density estimates based on the results of each acoustic survey, june 2009 (a), October 2009 (b), June 2010 (c), October 2010 (d), June 2011 (e). Each square represents a 1nmi transect segment corresponding to the legend given on the right side of the panels. Background lines are depth contours.

Table 4. Number of acoustic schools observed in each subregion.

Cruise/Subregions	SR-1 (Goksu)	SR-2 (Mersin)	SR-3 (Iskenderun)	SR-4 (Samandag)	Total
2009-06	120	265	187	---	502
2009-10	174	678	85	35	975
2010-06	106	230	143	15	507
2010-10	144	526	95	10	775
2011-06	81	179	125	17	402

Number of schools per survey did not vary greatly in SR-1 and SR-4 and showed similar spatial distribution pattern based on their NASC density. However, in SR-2 and SR-3 (Mersin and Iskenderun) a clear and inverse pattern was observed in terms of number of schools per season. The number of schools was higher in SR-2 in the surveys carried out in October compared to those conducted in June. Just the opposite was observed in Iskenderun (Figure 26). This was due to juvenile fish that appear in nursery grounds located in SR-2.

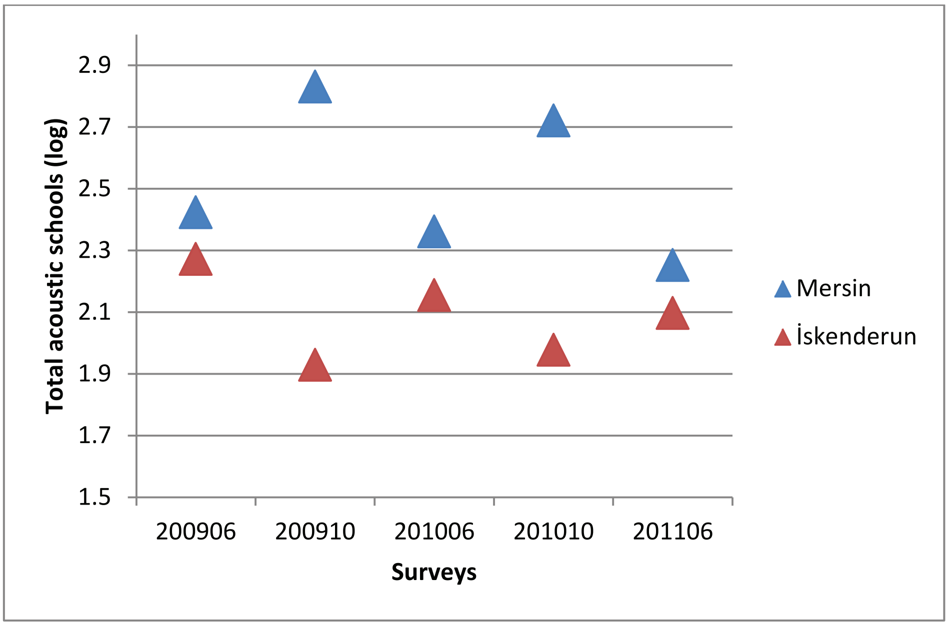


Figure 26. The temporal variability in number of schools in study area. Sub areas SR-2 and the SR-3 (log scale) compared.

Table 5. Average NASC per sampling points per strata.

	Strata	#EDSU	Max	Average	SD
SR-2	0-50	254	5065	262	625
SR-1	0-50	97	3827	195	528
SR-3	0-50	108	962	104	186
SR-4	0-50	10	591	139	178
SR-2	50-200	327	793	67	101
SR-1	50-200	174	927	76	148
SR-3	50-200	125	524	53	91
SR-4	50-200	42	1504	72	233

Regarding the spatial distribution of the school densities the highest acoustic values were detected at shallow parts in SR-2 within the bathymetric stratum of 5-50m. When total NASC per EDSU averaged by simple arithmetic mean (including the zero-NASC intervals), the highest density was observed in 5-50 m stratum of SR-2. In general NASC density at the 0-50 m stratum was higher than at 50-200 m stratum, despite occasional occurrence of large offshore schools (Table 5, Figure 27).

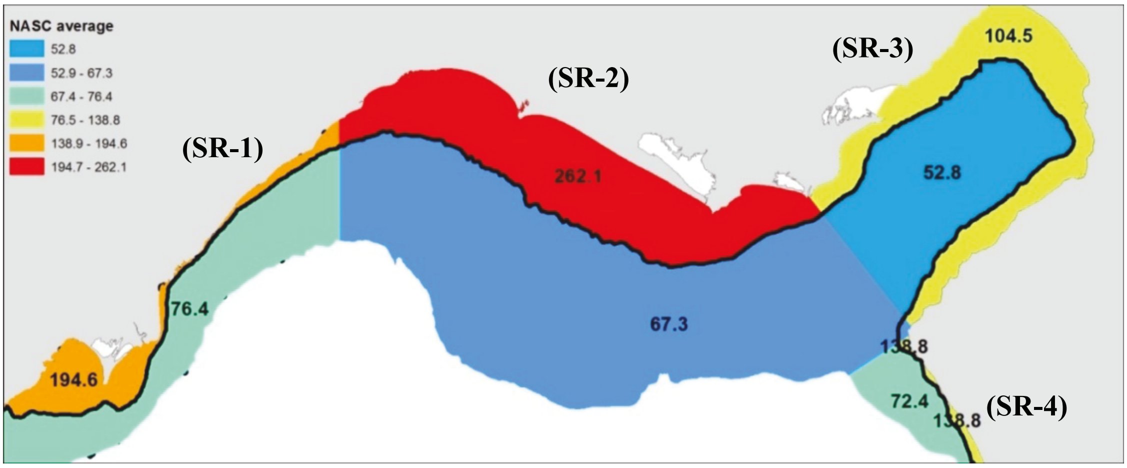


Figure 27. Average NASC values for 0-50 and 50 -200 bathymetric strata. (subregions are colored based on the legend at upper left korner of the figure).

In Figure 28, the distribution of the NASC at inshore – offshore extent was shown as combination of all surveys, with 10m bathymetric intervals. The figure indicates that the highest fish abundance that contributes to the total detected acoustic energy was concentrated close to shore regions mainly below 50m isobaths

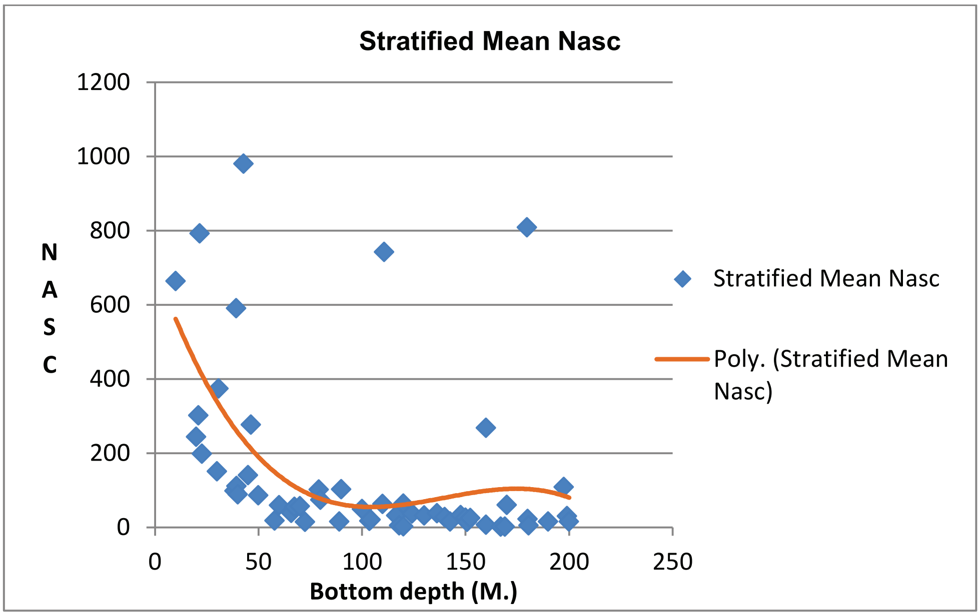


Figure 28. Plot of mean NASC density stratified by depth

Furthermore the general tendency in distribution of the fish schools was to be positioned close to bottom as shown in Figure 29. In this figure the histograms show the number of schools positioned with respect to altitude index values which is an indicator of the vertical offset of the fish schools in reference to seabottom.

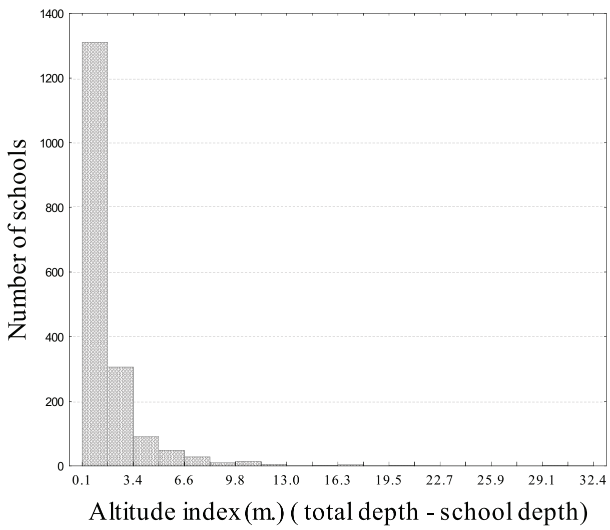


Figure 29. Altitude index; showing the distance between the lower depth of the fish schools and the sea bottom.

3.2 Identification of fish schools

3.2.1 Clustering: K-means analysis

In order to categorize the schools into groups that have similar descriptors the k-means analysis was applied. As the first step the fish school database was checked for extreme values and for co linearity. Those displaying very high or very low values (outliers) or those behaving in an identical fashion were eliminated by analyzing each survey independently. The filtration carried out in this way eliminated almost 10% of the schools initially determined.

Table 6. Parameters used in clustering and an example of k-means Cluster centroids

Attribute	**Cluster 0**	**Cluster 1**	**Cluster 2**	**Cluster 3**	**Cluster 4**	**Cluster 5**	**Cluster 6**
Sv Mean	-35.6	-44.5	-45.2	-47.8	-43.6	-48.3	-47.5
Depth mean	16.8	32.7	39.5	69	55.7	62	74.8
Skewness	3.8	3.9	3	4.8	8.5	3.6	3.5
Corrected length	8.9	11.2	4.9	26.3	20.1	28.7	11.1
Corrected thickness	2.3	2.6	1.7	7.8	3.2	2	2.8
Corrected perimeter	37.6	59.1	31.9	258.2	116.5	114.2	64.7
Corrected area	13.9	14.9	3	87.2	23.8	17.3	17.9
Elongation	4.8	5.6	3.8	4.5	6.7	18.5	4.9
Rectangularity	1.7	2.1	2.4	2.2	3.1	3.2	1.8
Circularity	41.1	88.8	114	320.7	218.1	278.5	98.2
Alt	1.9	1.1	0.9	0.9	0.8	0.4	0.6
Fractal	2	2.2	4.1	1.9	2.3	2.5	2.1
Image compactness	10.3	22.2	28.5	80.2	54.5	69.6	24.6
Coefficient of variation	206.5	176.6	106.7	174.8	317	164	112.1

K-means analysis using tenfold cross-validation resulted in 5 to 8 different clusters. Final decision of the number of clusters was a tradeoff between resolution and convenience for use. The higher number of clusters provided higher resolution however increases the uncertainties by creating artificial sub-clusters. In clustering sv mean and depth were the most influencing parameters. However morphometric and positional parameters were effective to differentiate schools at similar location and similar energy reflection. Based on the information from clustering, 6 main school types were characterized on echograms (Figure 30). The schools with higher Sv-mean located at shallower depths approximately below 50m were the most discrete group as presented in Table 6. The overall distribution of clusters showed a usable pattern (Figure 31). In the next step the consistent patterns that were agree with labeling from clusters visually determined into six groups.

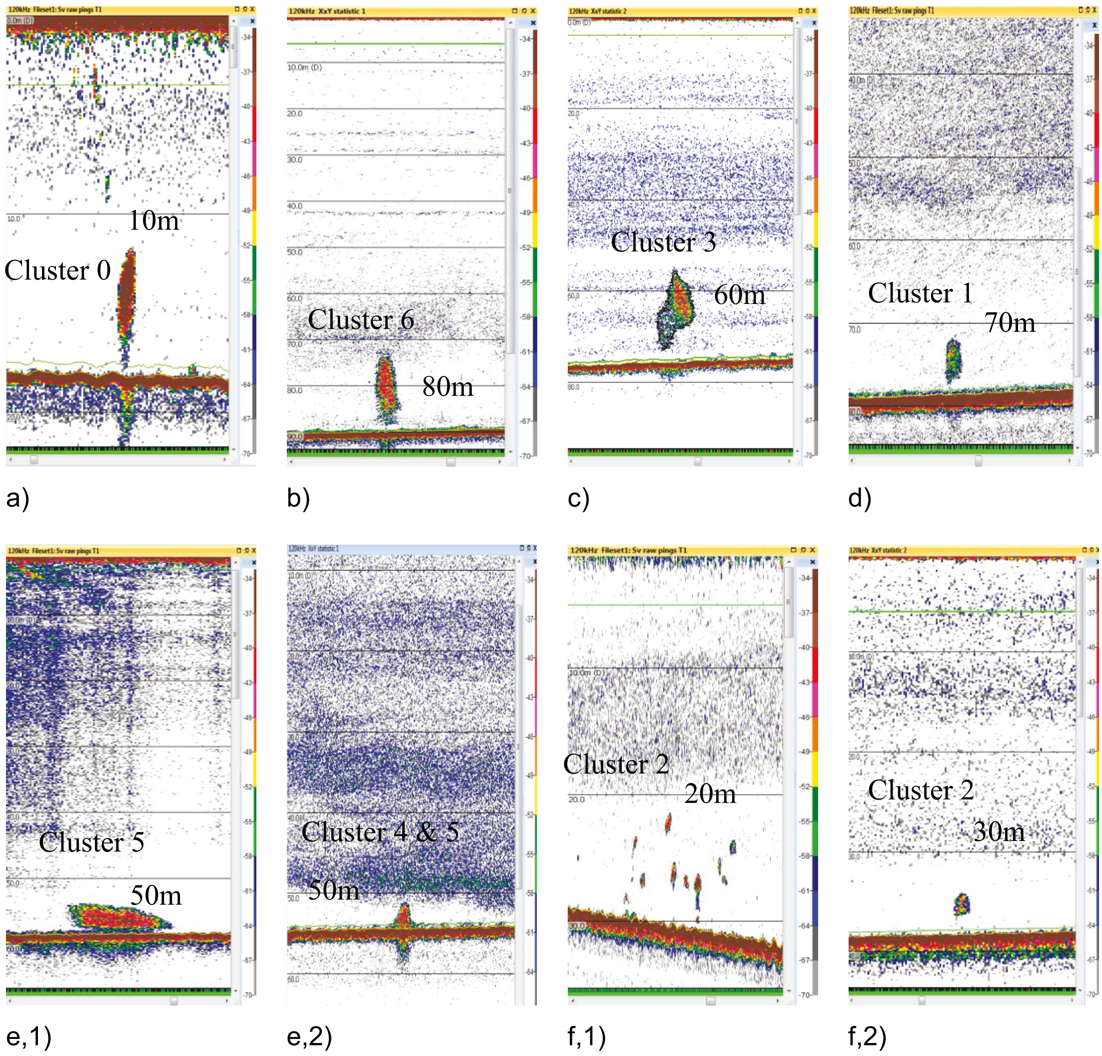


Figure 30 Groups characterized by clustering.

The consistency criteria were depth, energetic features of the school (sv mean and Sv max) and morphometric descriptors listed in Table 6. The examples of fish school patterns shown in Figure 30 were described as;

a) Ellipsoidal schools with a very dense core in the center and high mean sv, co-occurs with other aggregations, constrained in relatively shallow waters commonly between 10 – 50 meters in depth and generally not attached to the bottom.
b) Average sized schools with high density and circular-like shape occurs in deeper depths between 30-200m, occasionally found solitary but in generally co –occur with other small sized schools with varying densities.
c) Large schools occurs in varying densities and shapes, found not attached but relatively close to the bottom occurs at deeper depths frequently between 50-150 meters generally found solitarily
d) Small schools with average densities and irregular shapes found generally between 10 -100 meters with varying position in water column
e) Elongated schools co-occur with other aggregations generally having average densities but occasionally with higher densities, and very close or attached to the bottom.
f) Small schools with very weak densities spread mainly shallower waters between 10 - 40 meters, occasionally found in deeper parts.

Results obtained from clustering were then mapped for each survey and checked for similar spatial pattern and for their consistency with the trawling results (Figure 31).

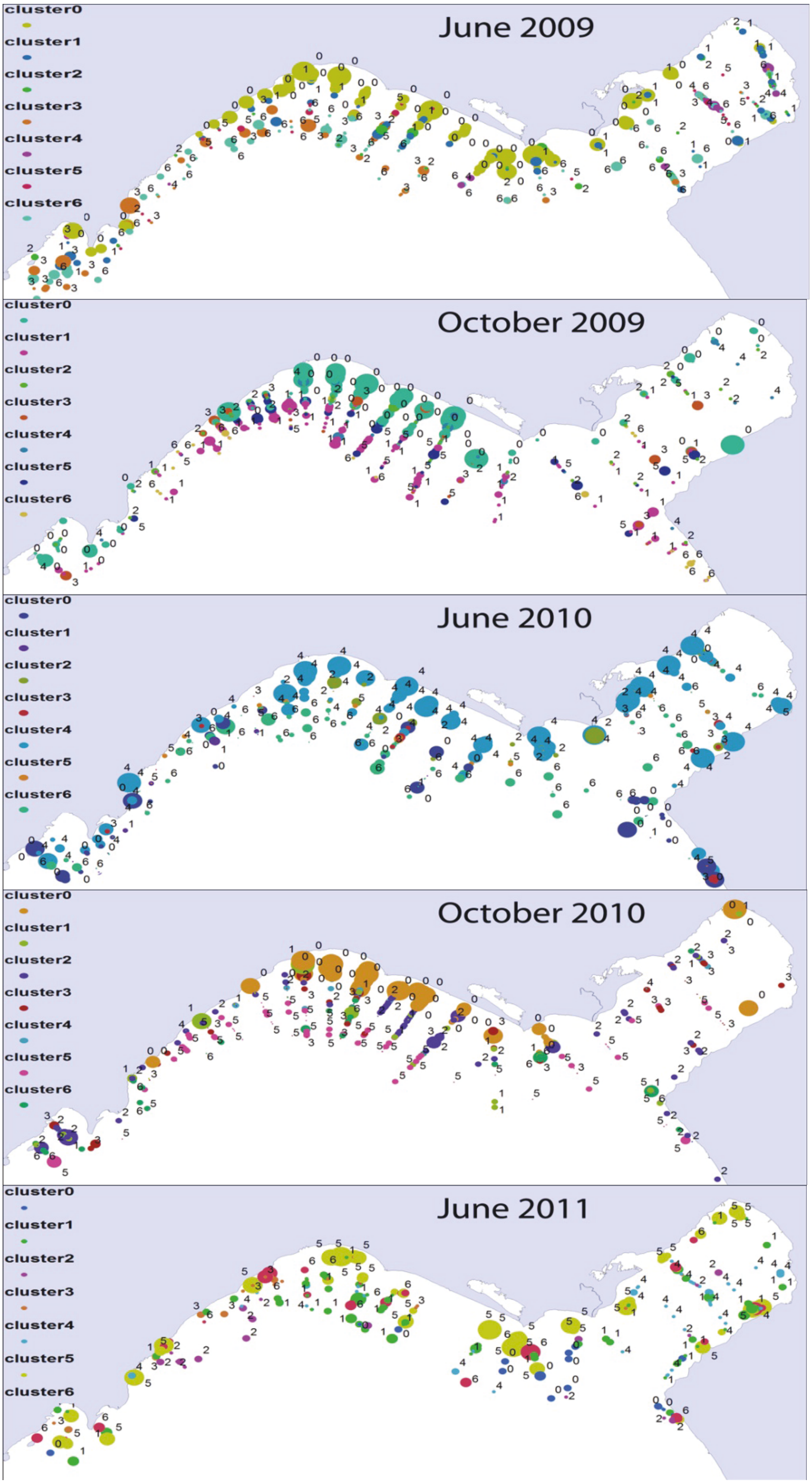


Figure 31.Clustering of acoustically detected schools for each survey. Different colors show different clusters as indicated by the legends on the left sides of the maps

Comparison of the maps representing the statistically determined clusters with the maps displaying the compositions of the control catches suggested existence of 6 groups;

Group a) *Sardinella aurita* (including *Sardinella maderensis*) -SA
Group b) *Sardina pilchardus*.- SP
Group c) *Etrumeus teres* and *Scomber japonicus* – ET
Group d) *Engraulis encrasicolus - EE*
Group e) *Trachurus mediterraneus*, *Trachurus trachurus* and other Carangidae - TT
Group f) *Dussumeiria elipsoides* (confused with small schools of *Sardinella aurita* and *Engraulis encrasicolus*) - DE

The clustering results and their correspondence to species are given on Table 7. The groups and clusters were matched and assigned to clustered schools as in Table 8.

Table 7. Distribution of clusters against identified species

Clusters/ Species	**0**	**1**	**2**	**3**	**4**	**5**	**6**	
DE	0	3	8	0	1	0	0	**June 2009**
EE	0	4	1	0	0	0	0	
ET	0	0	0	5	0	0	1	
ss	13	8	4	0	0	0	0	
SP	0	0	0	0	0	0	2	
SA	36	1	1	1	0	0	0	
TT	3	8	1	0	2	9	1	
Clusters/ Species	**0**	**1**	**2**	**3**	**4**	**5**	**6**	
DE	3	1	8	1	13	1	0	**October 2009**
EE	2	0	1	1	6	2	1	
ET	0	2	1	0	0	3	1	
ss	69	1	41	5	7	4	0	
SP	2	10	2	0	2	3	3	
SA	44	2	11	4	2	2	1	
TT	7	9	3	5	2	0	1	
Clusters/ Species	**0**	**1**	**2**	**3**	**4**	**5**	**6**	
DE	0	0	1	5	5	7	0	**June 2010**
EE	2	3	1	5	0	6	3	
ET	3	2	0	2	1	0	2	
ss	0	0	0	0	2	2	0	
SP	2	3	2	1	6	2	5	
SA	2	0	0	1	29	1	0	
TT	0	0	2	1	9	0	16	

Clusters/ Species	0	1	2	3	4	5	6	
DE	0	0	14	4	0	0	0	**October 2010**
EE	1	0	1	0	20	0	0	
ET	0	1	1	8	0	7	3	
ss	37	11	48	7	2	1	2	
SP	0	1	4	4	0	4	6	
SA	46	4	17	1	0	0	1	
TT	1	7	5	2	0	5	0	
Clusters/ Species	**0**	**1**	**2**	**3**	**4**	**5**	**6**	
DE	0	4	0	9	2	5	0	**June 2011**
EE	1	1	1	1	6	0	0	
ET	4	5	0	1	0	0	0	
ss	0	0	0	0	0	1	0	
SP	0	8	1	0	1	1	1	
SS	0	5	0	7	0	20	5	
TT	0	2	1	0	2	3	8	

After overlaying the trawl station map over clustered fish school distribution (Figure 31) the next step was to identify the fish schools near trawl stations. Initially the area covering two nautical miles radius of the trawl location was determined for each station. The schools that remained within peripheral area of each trawl station extracted and sorted by NASC in decreasing order. Subsequently, only *trachurus* (TT) group identified separately based on their prescribed school form differing from others. This particular form was described as; aggregations attached to bottom, inclined downward and generally elongated. This pattern was captured adequately in clustering.

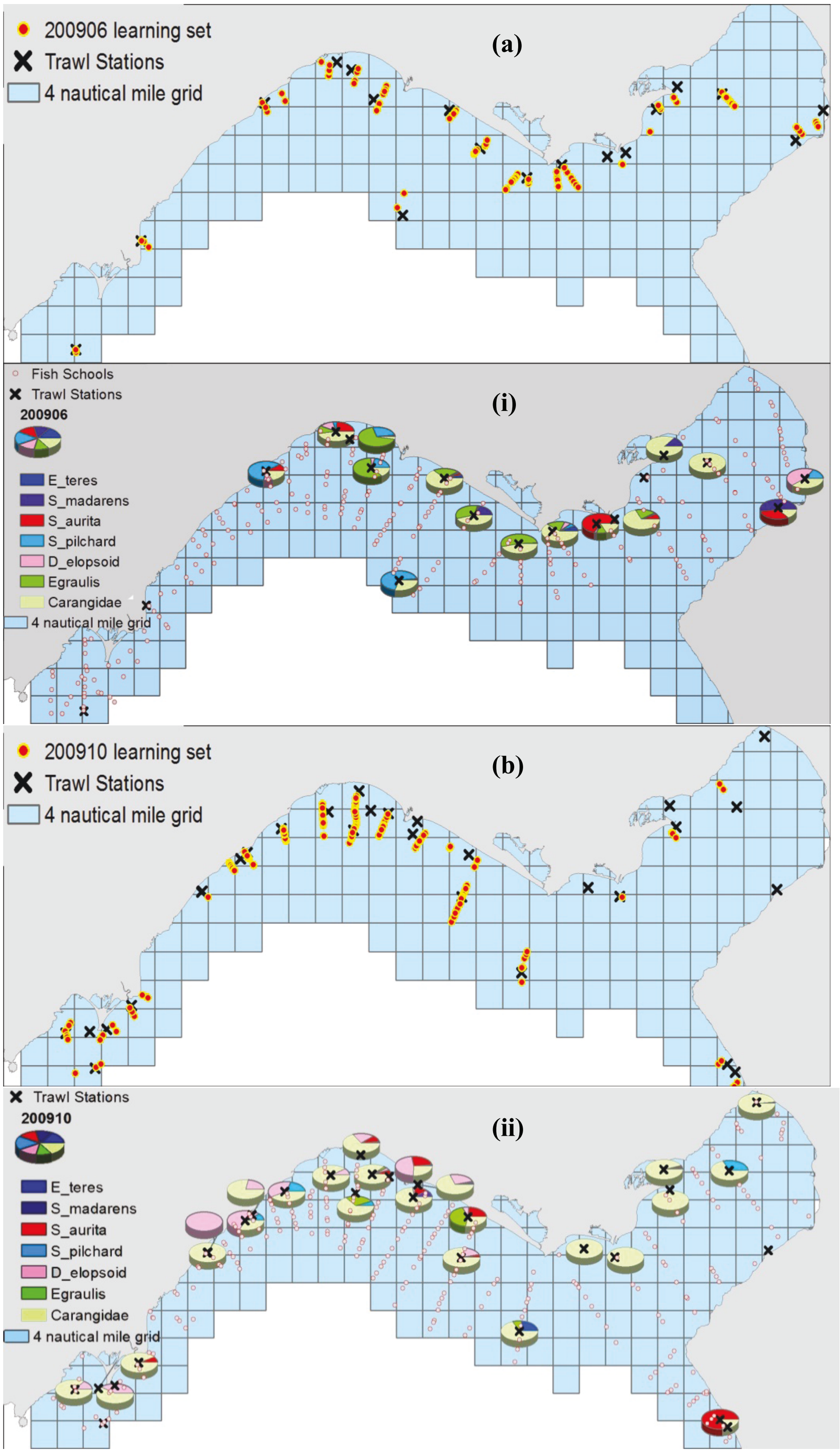
Table 8. 95% percentile of the fish biomass distribution within 152 hauls. The values are logarithm of biomass in kilograms.

Species/Rank	1	2	3	4	5	6	7	8
S. aurita	5.4	5.2	5.1	4.9	4.9	4.6	4.3	4.1
T. mediterraneus	4.6	4.3	4.2	4.1	4.1	3.8	3.7	3.7
S. japonicus	4.7	4.3	4.1	3.3	3.3	3.3	3.3	3.2
E. teres	4.4	4.4	3.7	3.1	2.7	2.5	2.1	1.9
S. pilchardus	4.3	4.2	4	3.9	3.8	3.8	3.8	3.7
E. encrasicolus	4.6	3.5	3.5	3.2	3.2	3.1	3	2.9
D. elopsoides	4.2	4	3.7	3.7	3.6	3.6	3.5	3.5
T. trachurus	3.5	3.5	3.2	3.2	3	3	2.9	2.7
S. madarensis	3.4	3	2.9	2.9	2.8	2.6	2.6	2.5

The location of the selected fish schools near trawl stations are shown in Figure 32. The schools at these points with known clusters labels were assigned to species based on corresponding image pattern and trawl information. Number of selected schools varied between 106 and 289 with an average of 184 schools accounting to 28% of the total number of schools. School distribution per species in selected dataset was rather homogeneous changing between 11% and 1,7%. Two exceptions were *Sardinella aurita* with a strong dominancy of 37% and on the contrary *Etrumeus teres* was scarce accounting for only 8%. Significance of the *Sardinella aurita* dominance in the learning set could have led to misclassification. This was due to tendency of the model to prioritize this discretely abundant group which renders the estimations susceptible to bias. In order to reduce the effect of the dominancy of *Sardinella aurita*, the subset of this group reevaluated and divided into two groups based on the schools descriptors as small *Sardinella* schools "ss " and "SA".

Table 9. The clustered schools remained within the 2nm peripheral area of trawl stations, and selected schools for learning set for further analysis.

	Schools at trawl periphery	Selected schools as percentage of total.
200906	113	12.35%
200910	289	12.31%
201006	134	12.82%
201010	276	18.84%
201106	106	14.93%



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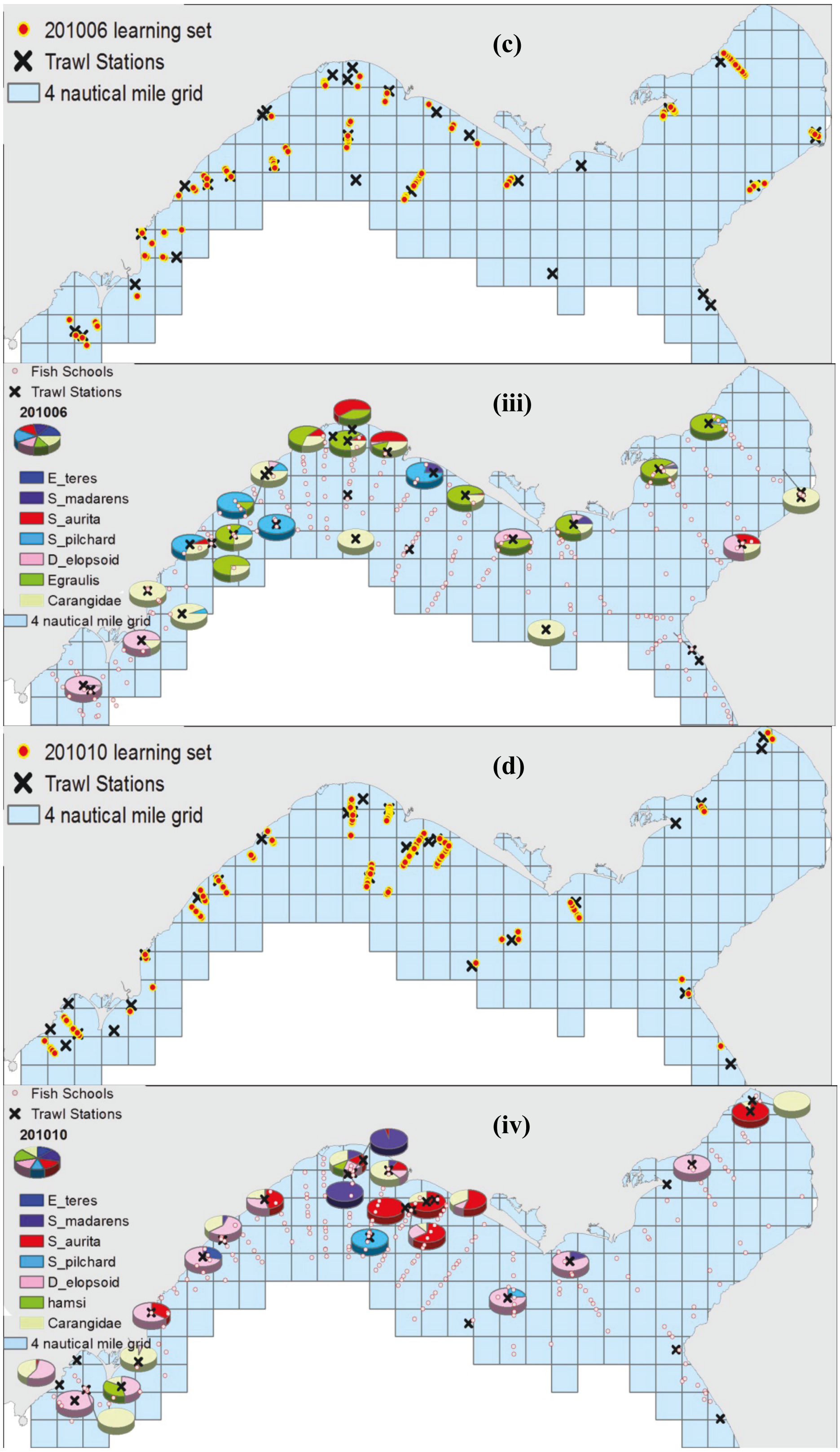

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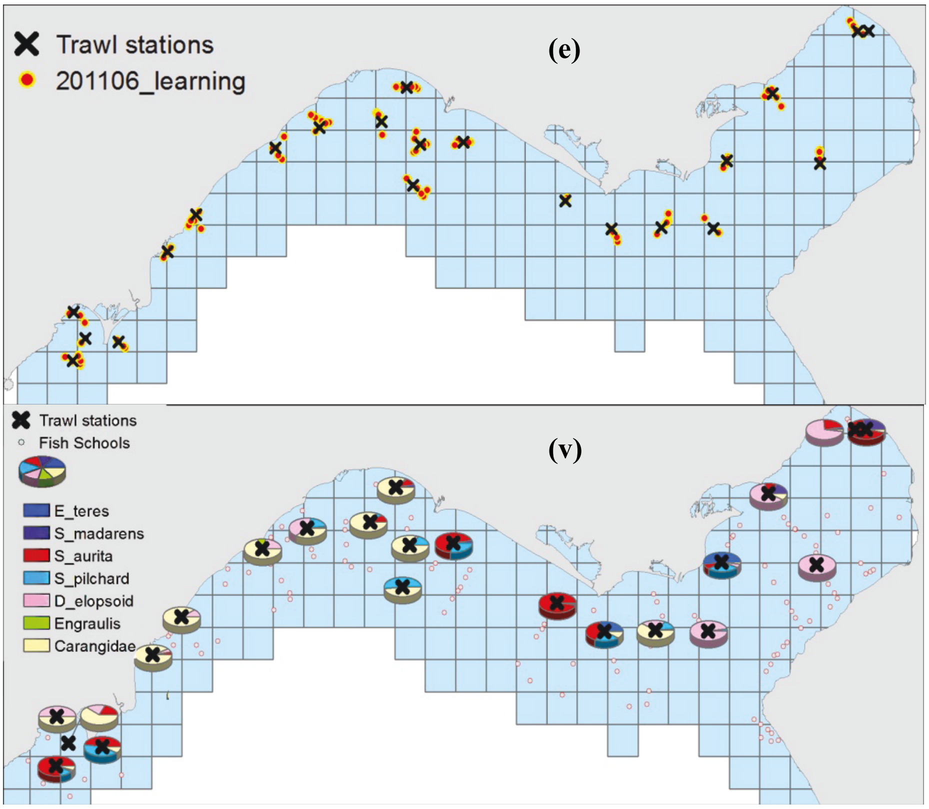


Figure 32. Trawl hauls and fish schools within 4nmi^2 frame.The panels (a), (b), (c), (d) and (e) shows the reference trawl haul for each survey June 2009, October 2009, June 2010, October 2010, June 2011and the acoustic fish schools within the predetermined 2nmi range. Panels (i), (ii), (iii), (iv) and (v) shows species the composition of the trawls based on biomass proportions for each survey in the same order as above.

3.2.2 Artificial neural network (ANN)

The results of the cluster analysis that were combined with trawl data has provided a general image of the spatial distribution of the species and a rough estimation about their proportions within the total reflected acoustic energy. With respect to these results, the *Sardinella* group appeared to dominate the dataset accounting for 59 % in average (Table 7). These labeling obtained for the schools located near trawl stations were then used as input for ANN for identification of the remaining schools in the entire dataset. The results were given in five steps and presented in confusion matrices. Confusion matrices show where the neural network model correctly or incorrectly predicts the classes. This table allows examining the state of the classification by showing how instances from that class received the various classifications. The labels on the rightmost column show the actual classes and the labels at the top raw show the predicted classes. Although it was inferred that the juveniles of *S. aurita* display different school characteristics than adults this was initially disregarded as the level of dissimilarity was not determined. Therefore first trial had focused on the effect of *Sardinella* (SA) group in classification taken as a whole without division. The outcome of the first experiment was appeared to be biased resulting from the dominancy of *Sardinella* group. This was noticeable in the confusion matrix shown in the Table 10. The model showed tendency to predict most of the instances as *Sardinella* group since this group was crowded in the learning set suppressing the other groups.

Table 10. Confusion matrix for ANN at first trial

SA	SP	ET	EE	TT	DE	
514	3	0	2	8	1	**SA**
19	40	8	0	12	2	**SP**
11	3	31	0	4	0	**ET**
24	0	2	22	2	1	**EE**
19	2	2	0	93	1	**TT**
80	4	2	6	2	4	**DE**

In the second experiment two *Sardinella* sub groups involved in the process as if they were different species. Consequently success rate for the first division of the *Sardinella* group composed of larger schools with higher total school echo energy was improved. On the other hand higher confusion shifted to the second division *juvenile Sardinella* (ss) (Table 11). Eventually the results of this experiment showed no significant improvement in terms of overall success however insightful in understanding the effect of the juveniles. As a result the correctly classified instances constituted only 63% of the learning set.

Table 11. Confusion matrix for ANN at second trial

SA	ss	SP	ET	EE	TT	DE	
166	61	1	1	0	11	5	**SA**
34	229	0	2	3	8	7	**ss**
9	10	30	5	1	18	7	**SP**
2	5	4	28	0	8	2	**ET**
0	21	0	3	17	4	6	**EE**
6	9	1	0	0	100	1	**TT**
0	67	1	1	2	7	20	**DE**

The first two experiments had shown the change in the effectiveness of the classification with a better design of the learning set that help to reduce the uncertainty. Based on observations from these experiments, two issues raised for the improvement of the learning sets: dominancy of the fish schools with shallow preference in the learning set due to higher number of trawl hauls in the inshore strata and the spatial heterogeneity of the trawl sampling stations. In order to overcome these issues a new learning set was created that contain derived labels per each school using the pattern explored by clustering and identified using trawl information consisting of 2547 instances. The distribution of classes in new learning set was rather homogenized (Table 12) with a better spatial representation covering the entire study area without locality caused by station distribution of the trawling points.

Table 12. Classes covering the entire area.

Classes	Size	Percentage
DE	303	12%
EE	186	7%
ET	206	8%
SP	400	16%
ss	434	17%
SA	458	18%
TT	560	22%

The third experiment that designed to improve the success rate using the new data set was resulted to even a poorer classification performance with overall success of 59%. where the success rate was influenced by the noise in the dataset as a result of the shortcomings of clustering (Table 13). In Table 14 the class SP and DE exhibited lower success rate in comparison to the others. Here the susceptibility of the classification success to the interference of *S. aurita* dominancy came forward as a problem. In addition another problem was the tendency of *j-Sardinella* group to be confused with *Dussumeiria elipsoides* group.

Table 13. Confusion matrix for ANN at third trial

SA	ss	SP	ET	EE	TT	DE	
351	24	37	5	3	4	34	**SA**
128	109	10	8	18	11	150	**ss**
20	4	298	9	4	40	25	**SP**
13	3	85	70	5	18	12	**ET**
5	8	30	8	60	30	45	**EE**
13	3	80	7	1	440	16	**TT**
21	32	38	5	7	29	71	**DE**

Table 14. Rates of classification success within the class groups. Red – reddish color shows the centroids.

SA	ss	SP	ET	EE	TT	DE	
64%	13%	6%	4%	3%	1%	10%	SA
23%	60%	2%	7%	18%	2%	42%	ss
4%	2%	52%	8%	4%	7%	7%	SP
2%	2%	15%	63%	5%	3%	3%	ET
1%	4%	5%	7%	61%	5%	13%	EE
2%	2%	14%	6%	1%	77%	5%	TT
4%	17%	7%	4%	7%	5%	20%	DE

Fourth experiment was performed by omitting the small *Sardinella* group from the training set. The results showed rather successful classification rates with a weighted average of 78%. The centroids were more discrete in comparison to the previous experiments. The weakest classification results were observed in the *S. pilchardus* group (Table 16). The scores shown in Table 15 suggested rather high confusion rate among the *S. pilchardus* group and *Etrumeus teres* (ET) group due to overlapping.

Table 15. Confusion matrix for ANN at fourth trial

SA	**SP**	**ET**	**EE**	**TT**	**DE**	
395	19	1	1	8	25	**SA**
52	267	7	8	48	13	**SP**
4	66	59	3	10	1	**ET**
6	19	2	96	14	22	**EE**
8	18	3	2	453	5	**TT**
21	5	1	5	2	158	**DE**

Table 16. Rates of classification success within the class groups. Red – reddish color shows the centroids.

SA	**SP**	**ET**	**EE**	**TT**	**DE**	
81%	5%	1%	1%	1%	11%	**SA**
11%	68%	10%	7%	9%	6%	**SP**
1%	17%	81%	3%	2%	0%	**ET**
1%	5%	3%	83%	3%	10%	**EE**
2%	5%	4%	2%	85%	2%	**TT**
4%	1%	1%	4%	0%	71%	**DE**

Last experiment involved generation of a new learning set designed by a cleaning procedure using the information obtained from the previous experiments that help to figure out classification error source. At this stage the last learning set was scrutinized with respect to the instances that were incorrectly classified. The strategy was to clean the learning dataset with regard to class overlapping illustrated in Table 15. These unpredictable fish schools on echograms were treated with reference to their neighboring schools by a decision whether to drop them from the learning set or retain without any alteration. The highest overlap was observed between two pairs: *S. pilchardus*-*Etrumeus teres* and *Dussumeiria elipsoides*-*Engraulis encrasicolus*. The overlapped pairs in similar locations on echograms were eliminated while the discrete ones retained. After cleaning, the learning set size was eventually reduced by 26% of its previous size.

Finally the correctly classified instances were increased to 93.6%. The the accuracy of the results was 87.5% as assessed by 10 fold cross-validation test which was accepted as reasonably satisfactory (Table 17). Therefore, the model parameters obtained at this stage was selected as the best configuration to implement the neural network analysis. The results of the classification performance evaluation were summarized in the Table 17. The correctly and incorrectly classified instances show the percentage of test instances as an indicator of the accuracy. Kappa statistics in Table 17 shows the agreement between the classifications and the true classes where the classifications that may be due to chance were compensated. The outcome (0.83) was a successful accuracy for Kappa analysis since the Kappa range changes in an interval of 0 (random classification) to 1 (total agreement). For the mean absolute error, 0.05 was also successful which illustrate how close predictions are to the eventual outcomes using average of the difference between predicted and actual value in all test cases. The results of the final classification were given on

Table 18 and Table 19.

Table 17. Summary of the stratified 10 fold cross-validation test

Correctly Classified Instances	1175	(87.5%)
Incorrectly Classified Instances	167	(12.5%)
Kappa statistic	0.84	
Mean absolute error	0.049	

Table 18. the final set obtained from the last experiment

SA	SP	ET	EE	TT	DE	
364	5	3	0	5	7	***SA***
6	143	13	1	15	7	**SP**
5	20	73	8	1	1	**ET**
0	3	3	28	6	8	**EE**
6	17	3	1	419	3	**TT**
7	4	0	4	5	148	**DE**

Table 19. The final set obtained from the last experiment

Sardinella	**SP**	**ET**	**EE**	**TT**	**DE**	
94%	3%	3%	0%	1%	4%	**SA**
2%	74%	14%	2%	3%	4%	**SP**
1%	10%	77%	19%	0%	1%	**ET**
0%	2%	3%	67%	1%	5%	**EE**
2%	9%	3%	2%	93%	2%	**TT**
2%	2%	0%	10%	1%	85%	**DE**

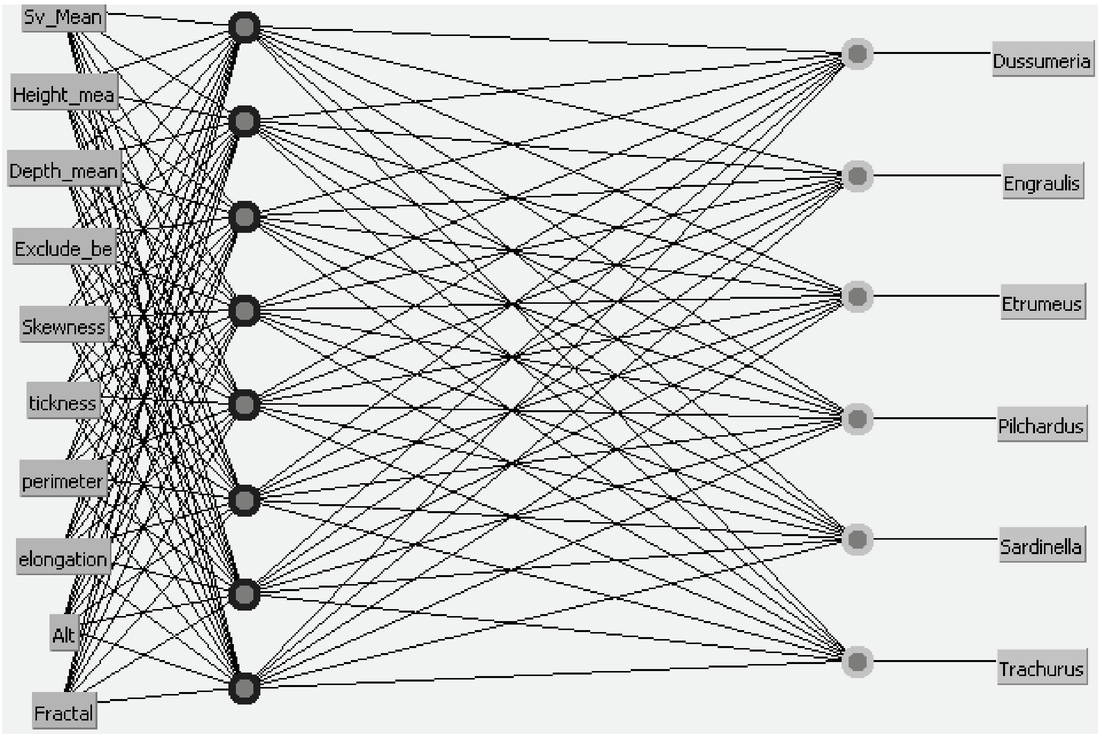


Figure 33. The scheme of the neural network used in the last experiment

Final neural network model had been composed of 10 descriptors, 6 outputs representing major species groups and 8 nodes at hidden layer which was determined by testing the performance of the model using a range of node number (Figure 33). Although quite accurate results have been obtained until now, the final model was relied on idealized instances excluding confusing inputs such as juvenile *Sardinella* group. This group detected at earlier stage which had not been involved at final classification as it was susceptible to confusion. Nevertheless the ss group was significantly abundant in October surveys but relatively scarce in June surveys. In order to analyze the effect of this asymmetrical situation, cross validation tests was performed between surveys. During this test the larger set created earlier at third stage which includes the ss group was used.

First test was between June surveys, and the results were evaluated focusing on *Sardinella aurita*. The model which had been trained using learning set of June 2010 was applied to data of June 2009. The test yielded satisfactory classification with respect to *Sardinella aurita* classification reaching up to 84% success rate. However it was failed when the same model applied on October 2010 (45%) and even yielded poorer result when applied on October 2009 (35%) shown in Table 20. The test performed between October 2009 and

October 2009 resulted in classification rate of 69% which, despite being lower than June to June test, was still good enough when compared to June to October (Table 20).

In Table 20; the TP rate (True Positive) refers to the percentage of the schools classified correctly as *Sardinella* group (the proportion that agrees with the previously labeled schools). The FP rate (False Positive) was the proportion of schools which were classified as *Sardinella* but corresponds to different class compared to previous labels. The precision was the proportion of the previously "*Sardinella*" labeled schools among all those which were classified as *S. aurita*. Higher precision rate at June compared to October surveys were due to smaller number of *S. aurita* estimations. This was also an indication that, the reason for low classification was due to higher number of small *S. aurita* schools in October datasets which justifies the separation of the *S. aurita* group to two subsets.

Table 20. Detailed accuracy of the cross validation test results for *Sardinella* group between surveys.

	TP Rate	FP Rate	Precision	F-Measure
2010 June to 2009 June	0.843	0.067	0.798	0.82
2010 June to 2010 October	0.455	0.041	0.907	0.606
2010 June to 2009 October	0.351	0.021	0.871	0.507
2009 October to 20010 October	0.692	0.124	0.764	0.726

3.2.3 Fish distribution maps

Based on the process described in previous sections fish distribution maps were obtained. The acoustic values of fish schools belonging to the same species in each interval were summed and schemed as pay charts overlaid on the maps respecting the geographical coordinates. The Figure 34 and Figure 35 show maps plotted by pay charts depicting the acoustic biomass density of the identified 7 species. *S. aurita* group with the blue color was the most pronounced species in all surveys dominating the shallow part of the study area mainly concentrated in SR-2. The parts colored pink belong to small *S. aurita* group. Although they were numerous in number, they were not discretely dominant as SA group. The component colored orange, in the pay charts symbolizes the SP group. Their distribution mainly concentrated on offshore waters in varying numbers. The TT group shown with a dark green color has not exhibited a prominent pattern distributed in consistent amounts throughout the area, generally obscured at inshore areas due to dominancy of other groups. *Etrumeus teres* was similar to *S. pilchardus* in terms of localization however spacing rather fewer area in terms of spatial distribution. DE and EE groups were almost totally obscured by other groups due to their wide spread distribution and smaller sizes.

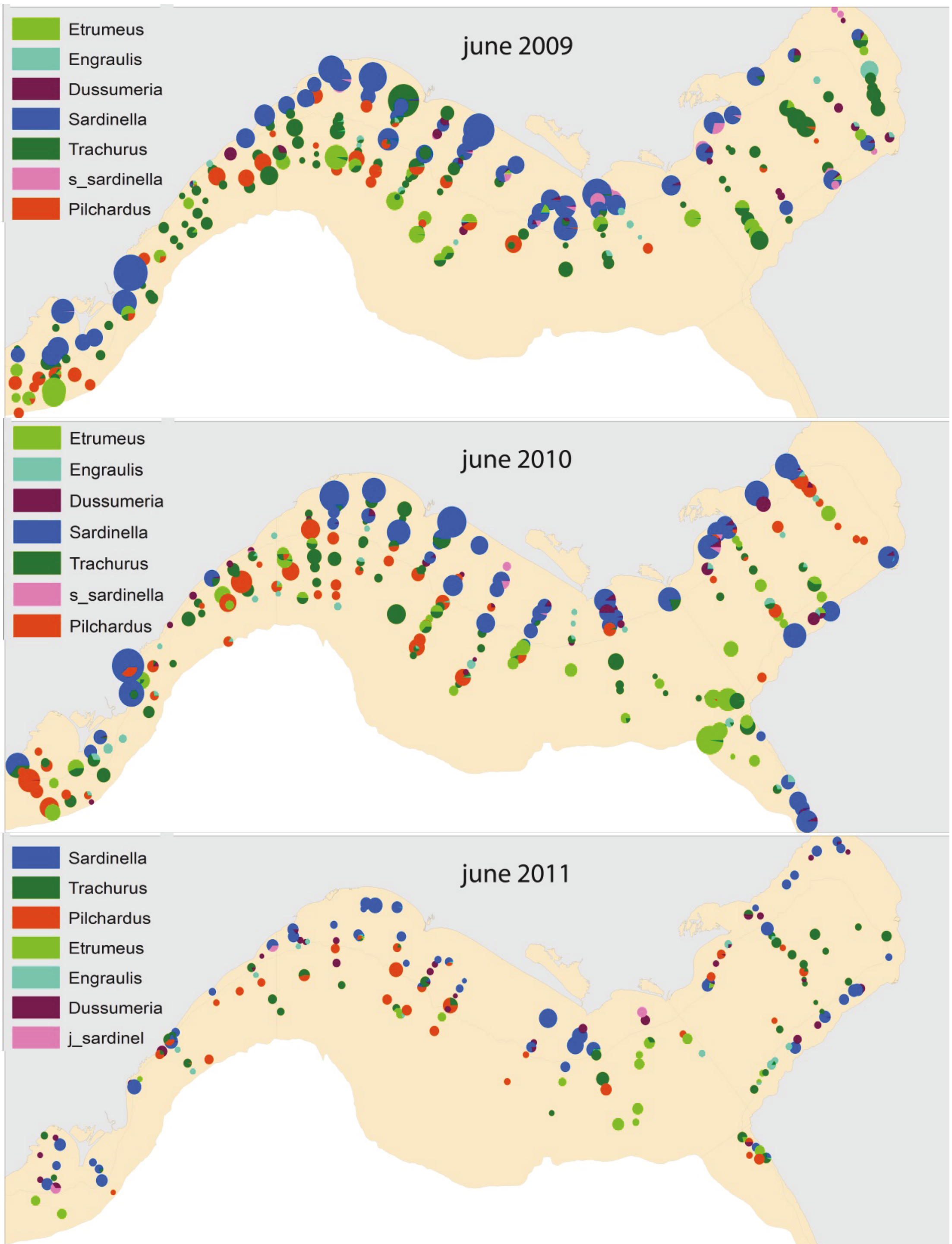


Figure 34. Density of fish distribution in NASC m^2/nmi^2 as apportioned by species distributions during the June surveys.

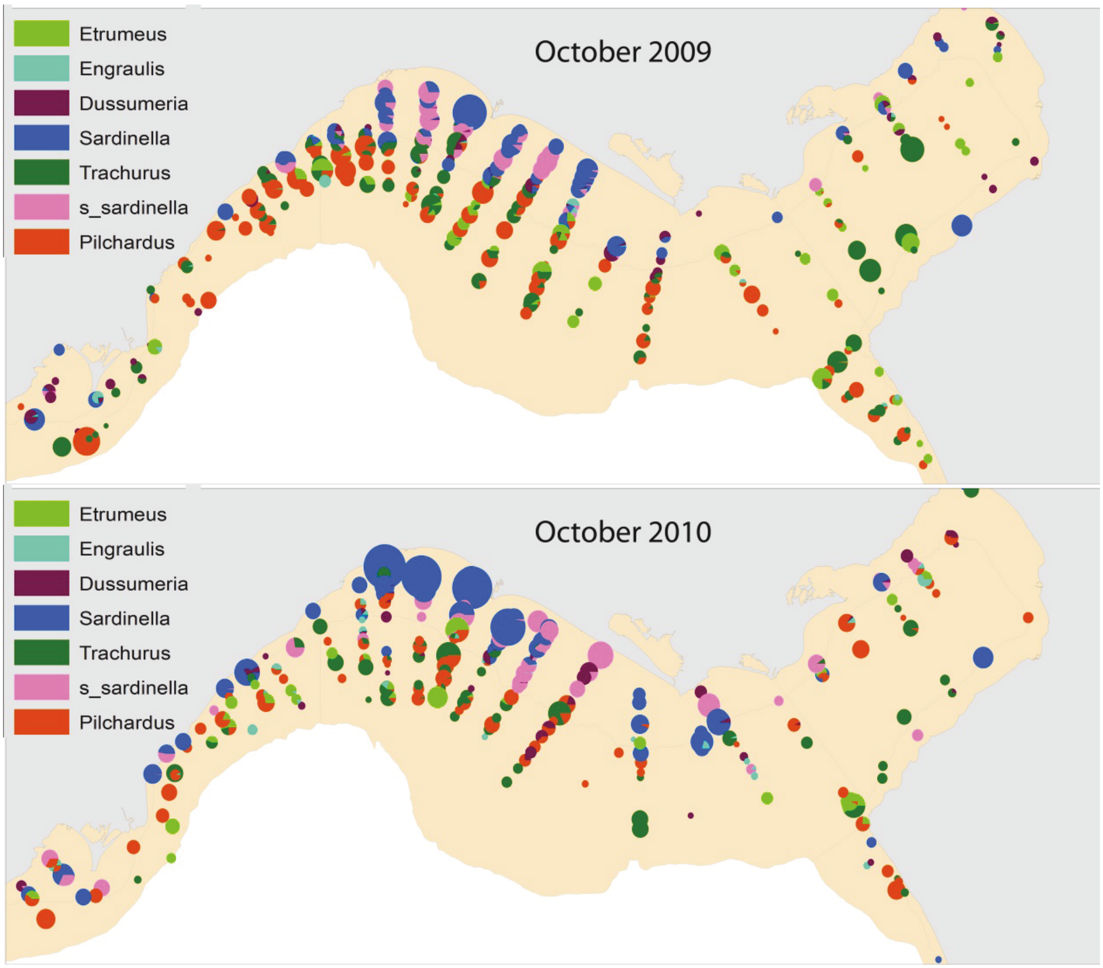


Figure 35. Density of fish distribution in NASC m^2/nmi^2 as apportioned by species distributions during the October surveys.

3.2.4 The characteristics of fish schools with respect to school descriptors.

The influence of each school descriptors was not same for each species individually. The response of each fish class groups to the descriptors showed the role of parameters in classification. Figure 36 illustrates vertical preferences of the fish classes. *Sardinella aurita* exhibited a shallow preference with an average around 20m together with *D. elipsoides* below 30m. *E. encrasicolus* remained in a deeper area with a relatively larger range extending from 60m to below 50m. *Etrumeus teres* had the deepest depth preferences together with *S. pilchardus*. For the *Trachurus* group, the expectation was a wider range extending from shallow depths to deeper areas however; it appears that their main concentration areas situated around 70m.

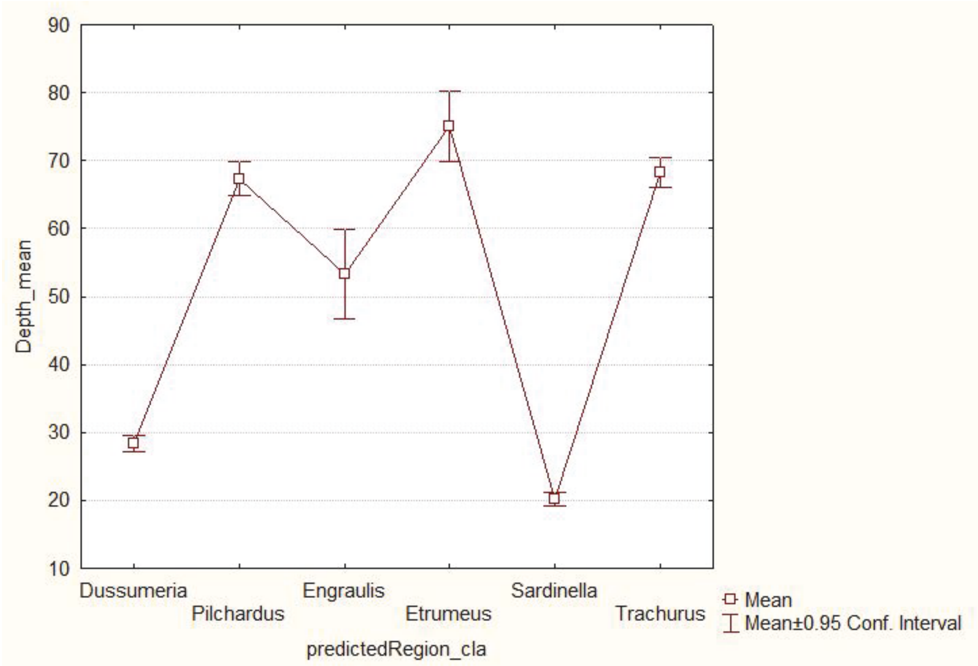


Figure 36. Vertical distributions of the fish schools based on the mean school depth.

The fish schools seem to be positioned vertically generally dependent on bottom depth (Figure 37). The preference of *Trachurus* group as set out by earlier descriptions showed the lowest values in altitude index. *E. encrasicolus* showed a wide range in vertical positioning however bearing the highest altitude values.

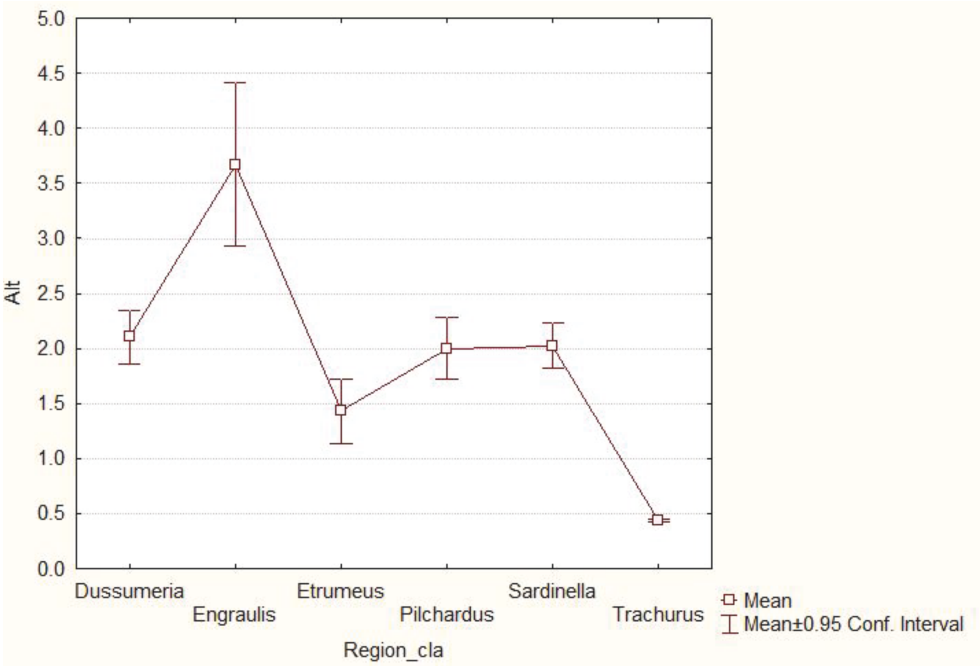


Figure 37. Altitude index showing the position of the fish schools relative to the sea bottom.

As far as morphological attributes of the fish schools concerned, *Trachurus* group showed the highest values on elongation yet again consistent with the earlier descriptions. Although other groups did not show the same distinction the variation was visible (Figure 38). The similarity of *Sardinella aurita* and *S. pilchardus* was also one noticeable.

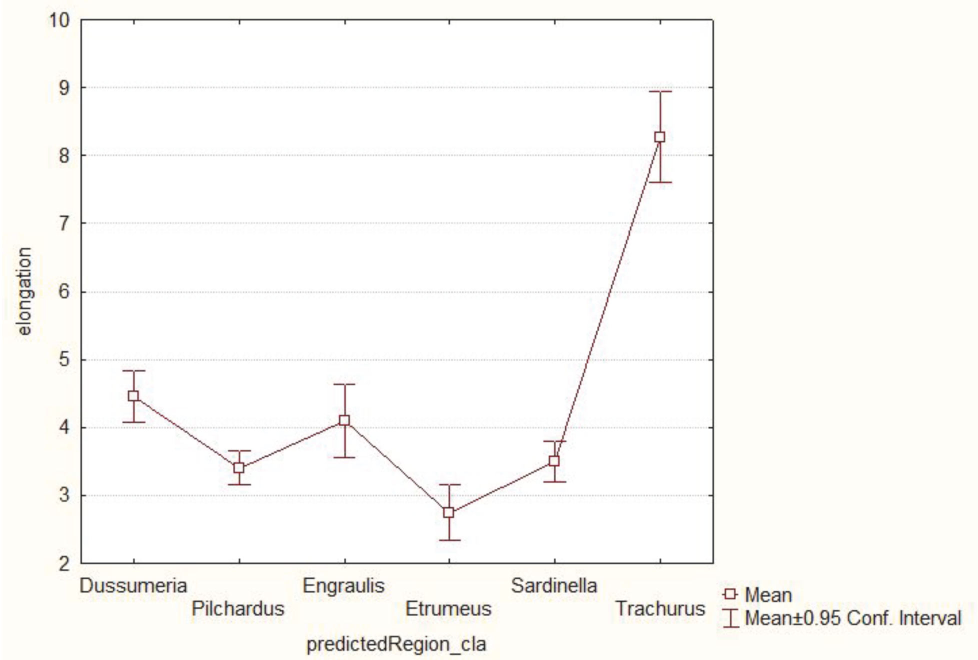


Figure 38. Elongation as descriptor to ratio of school height to school length

In terms of length and height distribution *Etrumeus teres* group have shown a noticeable distinction with substantially greater dimensions compared to other groups (Figure 39).

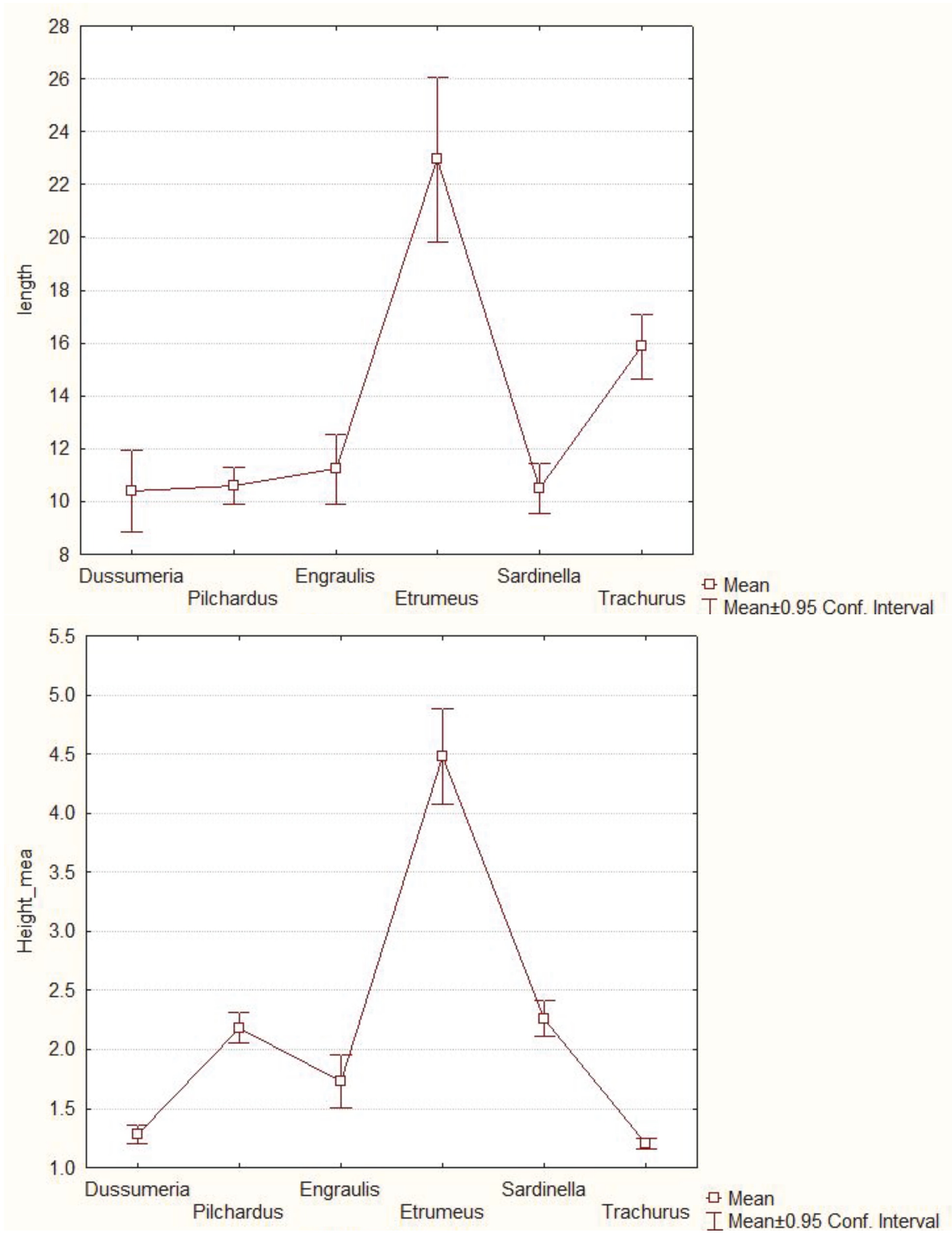


Figure 39. Length and height of the fish schools.

The Sv values being an energetic descriptor showed that the schools of *Sardinella aurita* has the highest packing density, while *E. encrasicolus* species shows a loose pattern with an average Sv below -52db lowest among all groups (Figure 40).

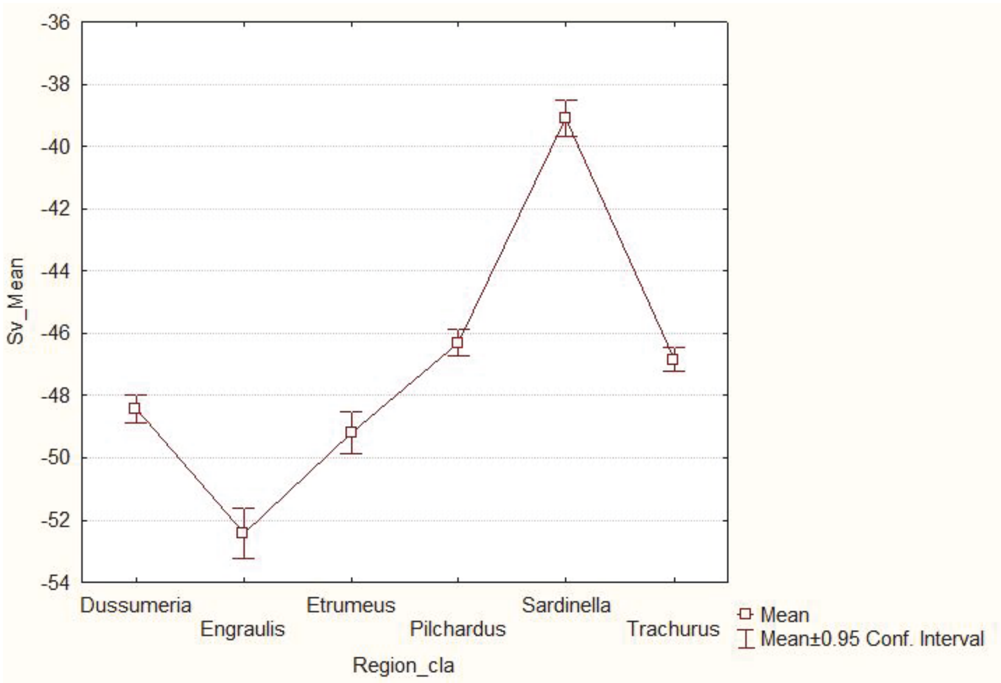
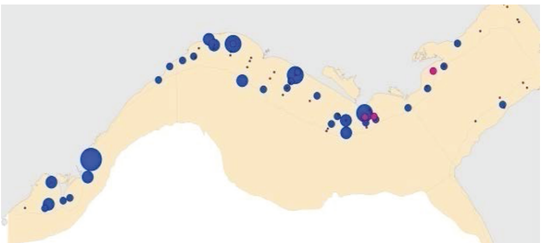


Figure 40. Volume backscattering strength (Sv) as an energetic descriptor

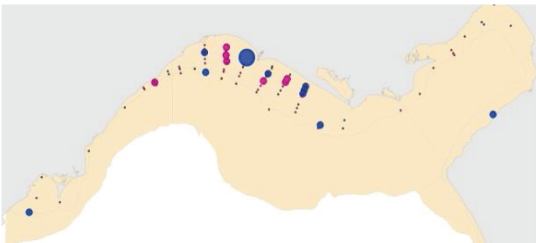
3.2.5 *Sardinella aurita* distribution; adults versus juveniles

Two groups within initial class of *Sardinella aurita* were discriminated in earlier stages of (ANN) (Table 16 and

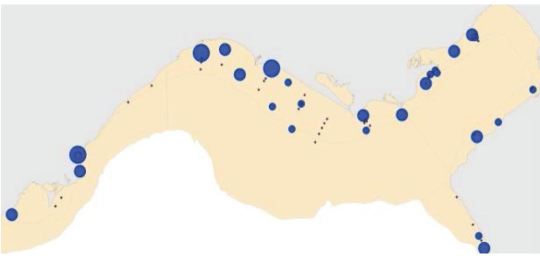
Table 18). In Figure 41 their distribution were shown on the map as the sum of school NASCs of the same species scaled to represent one square nautical mile. The circles with blue color are the *S. aurita* schools while the pink circles show the juvenile distribution. In terms of abundance the small *S. aurita* was higher (912 juveniles and 821 for adults), however their NASC values were significantly smaller than adult *S. aurita* schools. As they were located in similar areas and close to each other they do not exhibit a remarkable distribution on map. However their occurrence in October surveys area notable compared to June surveys. Their main concentration area remained within the Mersin Bay, while extending towards İskenderun in October.



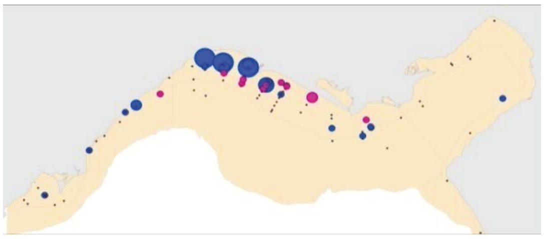
June 2009



October 2009



June 2010



October 2010

Figure 41. Distribution of *S. aurita* group together with their juveniles.

Percentage of acoustically determined fish biomass is presented in Table 21. The highest biomass belongs to *S. aurita*. The biomass of juvenile *S. aurita* was quite high in October and very low in June. *Trachurus* spp and *S. pilchardus* formed 12% and 11% of all samples, respectively. The Lessepsian small pelagic fishes, like *Etrumeus teres* and *Dussumieria elopsoides* placed in the middle of the list. Unclassified schools and the mixed schools formed less than 1% of the acoustically detected fish schools.

Table 21. Relative NASC per species.

	June	**October**	**Total**
Sardinella aurita	62.2%	56.6%	59.8%
S. aurita (juv)	1.3%	10.7%	5.3%
Trachurus spp.	13.3%	10.9%	12.3%
Sardina pilchardus	9.8%	13.5%	11.4%
Etrumeus teres	10.0%	5.6%	8.1%
Engraulis encrasicolus	0.6%	0.6%	0.6%
Dussumeiria elopsoides	1.6%	2.1%	1.8%
Unclassified	1.1%	0.0%	0.7%
Mixed	0.1%	0.0%	0.1%

3.3 Estimation of the biomass distribution of the *S. aurita*

The NASC distribution of the *S. aurita* calculated for each stratum is given in Table 22. The proportions were calculated based on the sub regions shown in the Figure 13which were predetermined based on the NASC density distribution in the areas. The corresponding surface areas are given in the Table 1.

Table 22. NASC per strata for *S. aurita*

Sub region/strata	200906	200910	201006	201010	201106
Mersin 0-50	164.4	100.0	141.7	295.4	45.7
Goksu 0-50	93.7	24.3	151.1	39.7	14.9
Iskenderun 0-50	51.7	13.8	193.4	10.7	13.4
Samandag 0-50	0.0	0.0	116.4	0.0	14.0
Mersin 50-100	0.0	3.2	2.6	4.9	0.5
Goksu 50-200	0.0	1.9	0.0	10.8	3.0
Iskenderun 50-200	1.9	0.0	0.0	5.1	2.7
Samandag 50-200	0.0	0.0	0.8	0.0	2.6

Based on these NASC values, calculated biomass values are given in the Table 23. The estimated biomass ranged between 2295 and 11059 tons. The estimated values were highest in 2010 and lowest in 2011. Highest contribution was from Mersin 0-50 strata during all surveys except from June 2010 where Iskenderun 0-50 strata contributed the highest biomass.

Table 23. The calculated biomass for *S. aurita* given in tons.

Sub region/strata	200906	200910	201006	201010	201106
Mersin 0-50	5883	3577	5070	10570	1634
Goksu 0-50	906	235	1461	384	144
Iskenderun 0-50	1130	302	4230	234	293
Samandag 0-50	-	-	166	-	20
Mersin 50-100	-	156	126	239	24
Goksu 50-200	-	48	0	274	75
Iskenderun 50-200	59	0	0	162	85
Samandag 50-200	-	-	6	-	20
Total biomass in metric tones	**7978**	**4318**	**11059**	**11863**	**2295**

3.4 The distribution of the salinity and temperature in the study area

The measured physical features of the study area were characterized by the warm surface waters with sharp temperature and salinity gradients and stratification due to thermocline growth. The surveys at June coincided with the formation of the seasonal stratification. During these surveys the vertical temperature profiles have shown a noticeable decreasing temperature gradient from surface to 30 m in depth varying between 20°C and 26 °C (Figure 42).

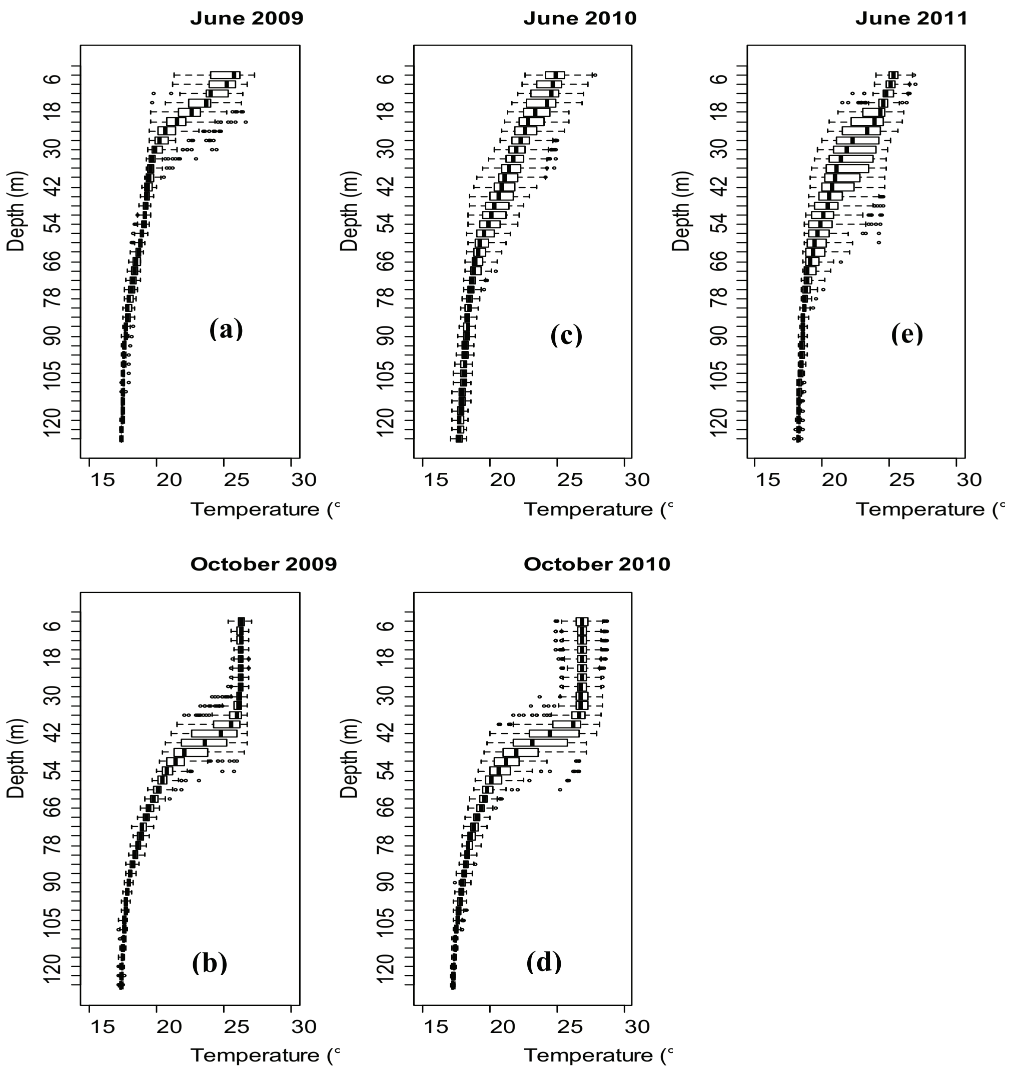


Figure 42. Mean vertical temperature (°C) profiles during the acoustic surveys June 2009 (a), October 2009 (b), June 2010 (c), October 2010 (d), June 2011 (e). Boxplots show the middle of the values between first and third quartiles and the line at midpoint of the boxes represent the median. Whiskers denote the lowest and highest values and the circles beyond the whiskers represent outliers.

In addition in June, relatively homogeneous temperature values were observed below 70 m changing between 17 and 19°C. Thermocline was well developed during October where the temperature and salinity profiles showed a strong stratification (Figure 42Figure 43). During this period, higher temperatures and more saline waters were recorded at surface mixed layer. In October 2009 and 2010, the maximum surface temperature had reached to 27.2 °C and 28.9 °C respectively (Table 24).

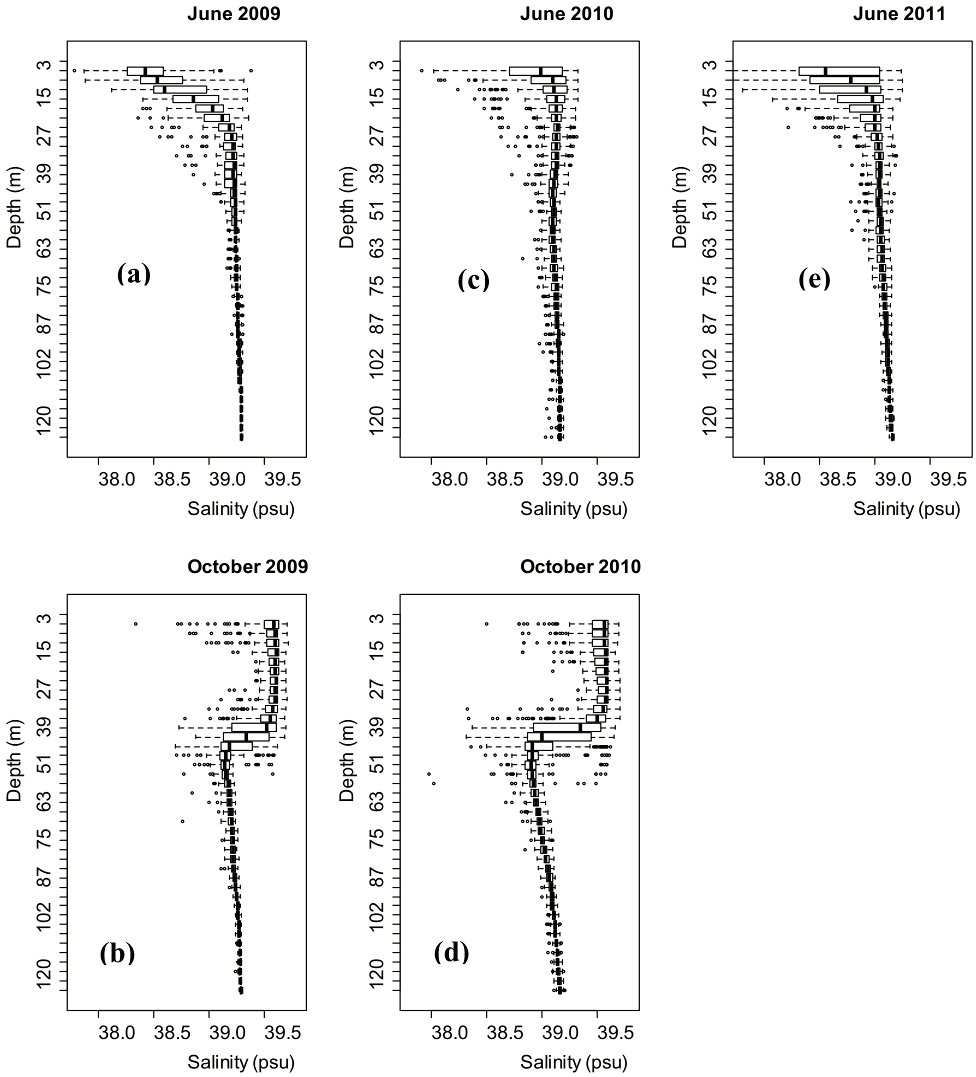


Figure 43. Mean vertical salinity (psu) profiles during each acoustic survey June 2009 (a), October 2009 (b), June 2010 (c), October 2010 (d), June 2011 (e). Boxplots show the middle of the values between first and third quartiles and the line at midpoint of the boxes represent the median. Whiskers denote the lowest and highest values and the circles beyond the whiskers represent outliers.

Such warm and saline water was almost homogenous from surface until the depth of approximately 40m. Starting at this depth temperature and salinity profiles exhibited a rapidly decreasing pattern until being stabilized at approximately 60m (Figure 42). Below this sharp gradient rather homogeneous values in temperature (~18°C) and salinity (~39.2 psu) were recorded.

Table 24. Temperature and salinity values at surface and bottom layers recorded during each survey given as minimum (min), maximum (max) and median values.

	Temp (°C)	Salinity (psu)	Temp (°C)	Salinity (psu)	Temp (°C)	Salinity (psu)
June-2009	**3<Depth<50m**		**200>Depth>50m**		**3<Depth<10m**	
Min.	18.6	37.2	17.3	39.2	19.8	37.2
Median	20.4	39.2	18.2	39.3	24.8	38.5
Max.	26.8	39.4	19.5	39.3	26.8	39.3
June-2010						
Min.	18.4	37.6	16.6	38.8	22.1	37.6
Median	22.4	39.1	18.3	39.2	24.7	39.1
Max.	27.7	39.3	22.1	39.2	27.7	39.3
June-2011						
Min.	18.8	37.2	17.4	38.8	22.3	37.2
Median	23.5	39	18.6	39.1	25	38.8
Max.	26.9	39.3	24.3	39.2	26.9	39.3
October-2009						
Min.	20.2	38.5	16.5	38.8	25.5	38.5
Median	26.1	39.6	18.3	39.2	26.3	39.6
Max.	27.2	39.7	25.8	39.6	26.9	39.7
October-2010						
Min.	19.3	38.8	16	38	24.9	38.8
Median	26.7	39.5	18.2	39.1	26.9	39.6
Max.	28.9	39.7	26.6	39.6	28.8	39.7

The distribution of surface (4m.) salinity values were almost uniform over the entire study area at average 39.5 (psu) except the relatively more fresh regions in the vicinity of the river plumes due to fresh water input (Figure 44). Higher salinity at upper layer during October was noticeable on the salinity profiles (Figure 43). At the surface the salinity range was between 38.8 (psu) and 39.7 (psu) during October surveys (Table 24). During June surveys these values were relatively lower, with a mean ~ 38.7 (psu) and with higher variability ranging between 37.2 (psu) and 39.3 (psu) (Figure 43 and Table 24).

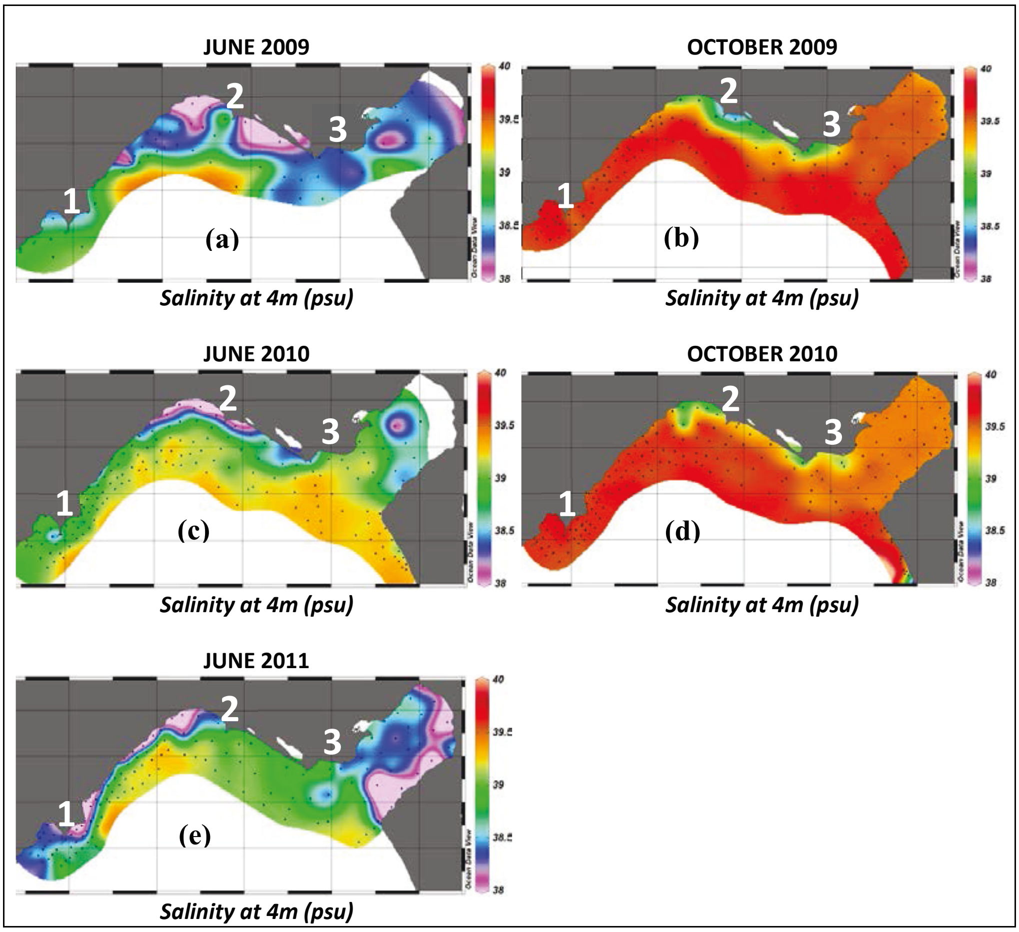


Figure 44. Surface salinity distribution along the study area during ach survey, June 2009(a), October 2009 (b), June 2010 (c), October 2010 (d), June 2011 (e),. River mouths shown as Göksu river (1) Berdan and Seyhan rivers (2) and Ceyhan River (3). The gray dots on the graphs show the CTD Stations and the color scale for salinity was set between 38 (psu) and 40(psu).

3.5 Influence of environmental data on fish distribution.

3.5.1 Examining the data

The metric used in fish distribution analysis was NASC, measured in units of m^2/nm^2 represents a relative magnitude of the fish biomass. Figure 45 shows the distribution of the total NASC data for each survey. Upper graphs of Figure 45 show a highly skewed pattern however follow normal distribution when logarithmic transformation was applied (shown in lower section of the same figure). In addition the data was overdispersed due to existence of extreme values. However these extreme values could not be addressed as outliers as reliability of the data has already been checked in the echogram at postprocessing and classification phase. Data was grouped as June surveys and October surveys in order to represent seasonal differences.

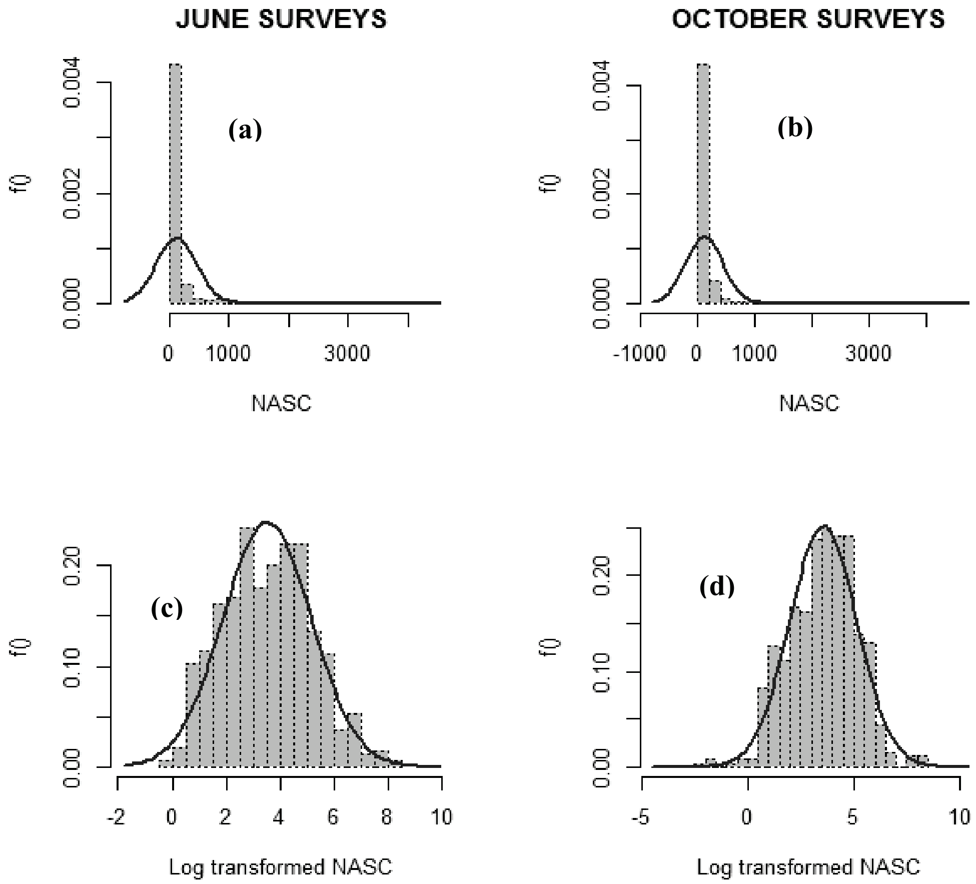


Figure 45. Histograms with fitted normal distribution curve for both surveys. Upper graphs are absolute values of pooled data for June; (a) and October (b) and lower graphs are logarithmic transformation of June surveys (c) and October(d) .

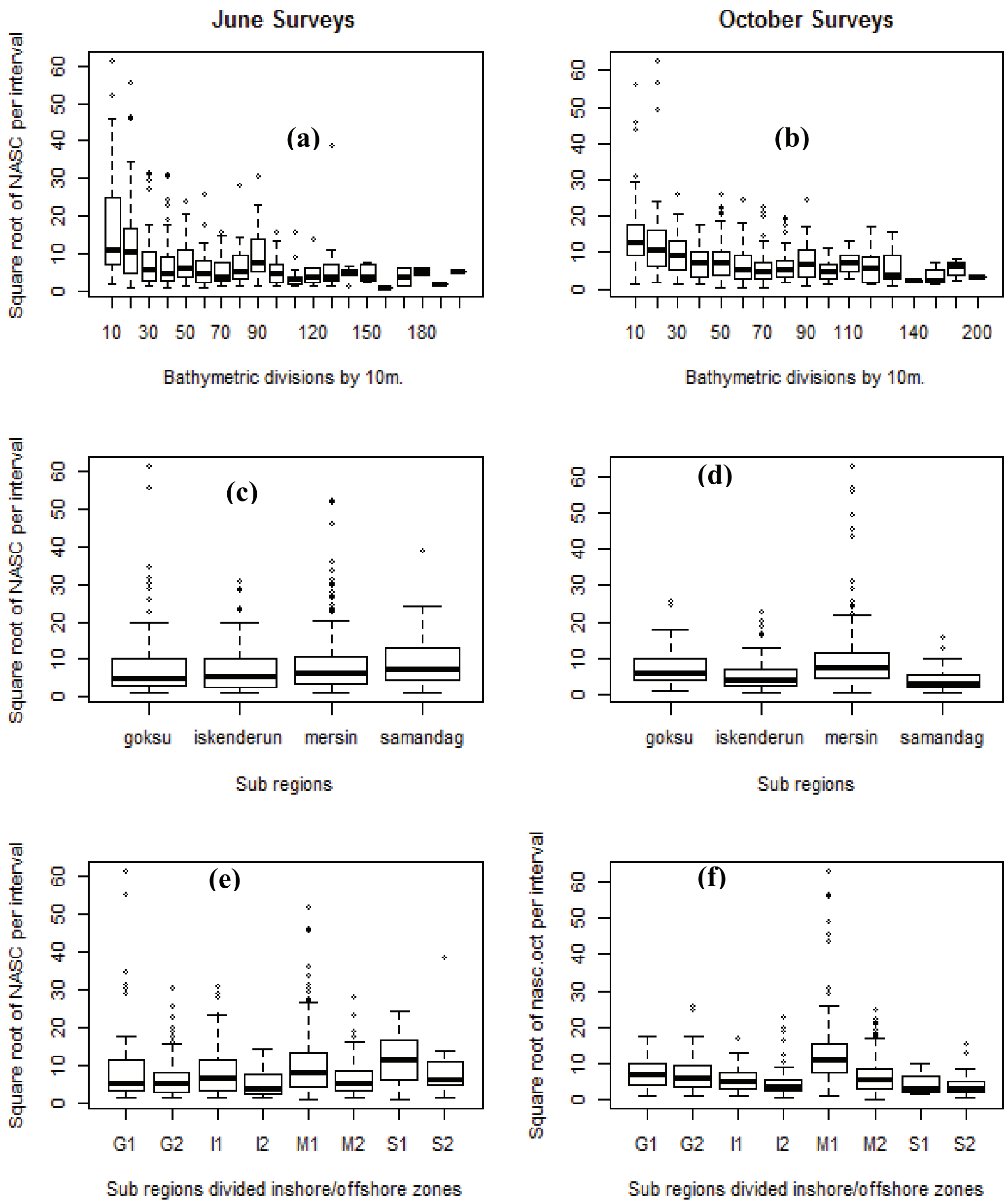


Figure 46. Distribution of NASC within the depth strata and sub-regions. Panel (a) and (b) shows boxplots of squareroot transformed NASC values for depth intervals of 10m. For the same parameter; panel (c) and (d) shows boxplots for each subregions and panel (e) and (f) shows same plot for depth division of subregions based on 50m. contour. Figures on the left and right panels corresponds to June and October respectively.

The spatial and bathymetric differences with respect to the median of the values and extremes are illustrated in the Figure 46. In this figure boxplots show the middle of the values between first and third quartiles and the line at midpoint of the boxes represent the median. Whiskers denote the lowest and highest values within 1.5 times of the range from the first and third quartiles. Circles represent outliers beyond the whiskers. Bathymetric divisions on the figure were made as following description; lower graphs; G1; Göksu (<50m), G2 = Goksu (<50m), I1 = Iskenderun (<50m), I2 = Iskenderun(<50m), M1 = Mersin (<50m), M2 = Mersin (<50m), S1= Samandağ (<50m), S2 = Samandağ (< 50m). In both surveys it can be seen that the higher values were concentrated in the regions below 50m depth. These values were highest in Mersin inshore sub-region. The effect of the depth on the fish density distribution has been shown on the graphs at upper section of Figure 46, where the square rooted NASC values plotted within each 10m depth strata. On this figure it can be seen that the extremely high values were observed in shallow depths followed by a decreasing pattern with increasing depth.

3.5.1.1 Temperature

The histograms on Figure 47 show the temperature estimations extrapolated from CTD measurements corresponding to the average positions of the fish schools within each 1 nautical miles sampling units during both survey period. In this figure the first graphs of each survey groups show the overall distribution of temperature values without depth stratification. In the first graph of October survey the shape of the histogram displays bimodality. This bimodality has been resolved by separating the dataset into two groups; above and below 50m which approximately corresponds to average thermocline depth. Similar situation was observed for the June surveys

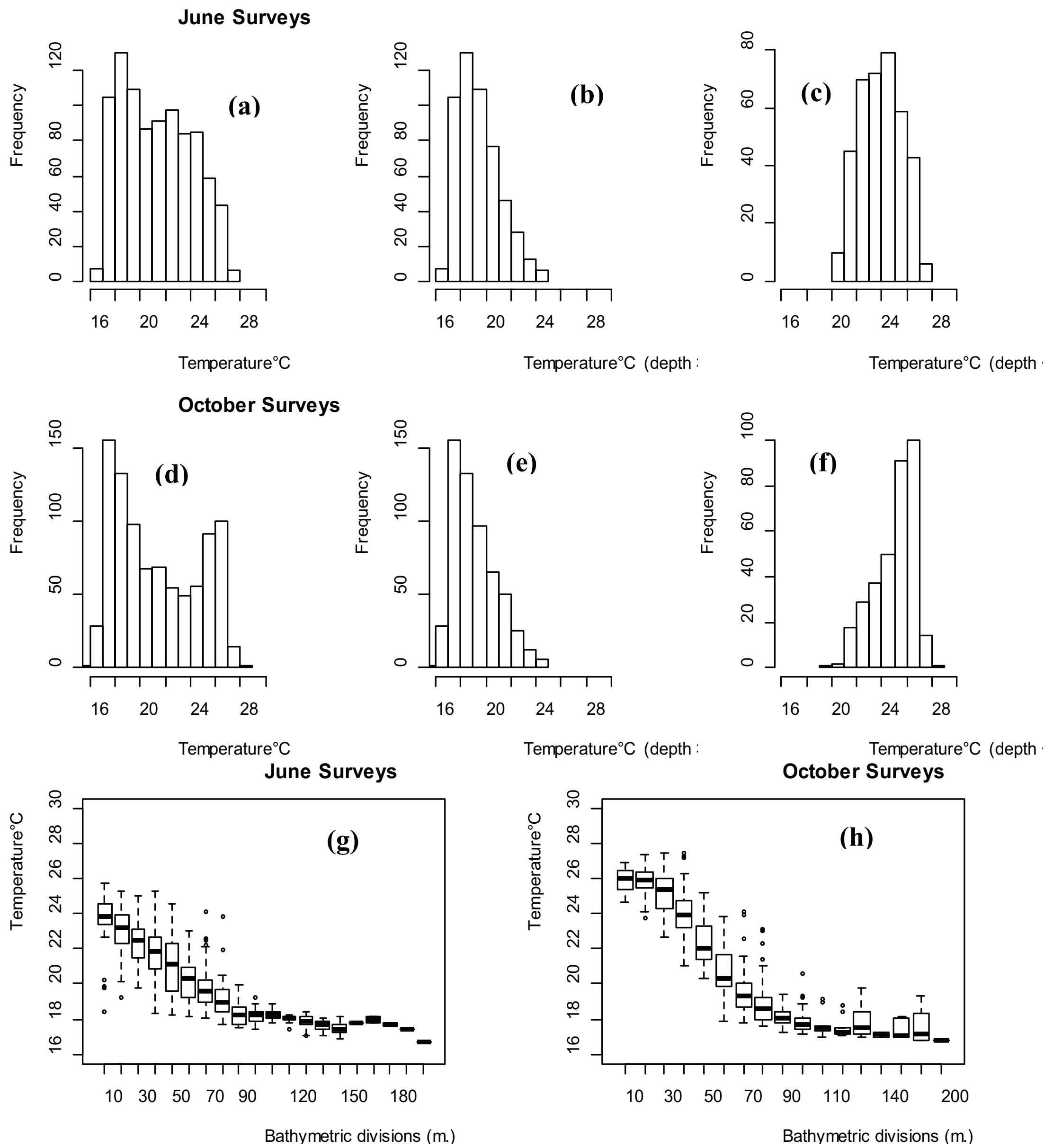


Figure 47. Histograms for temperature values at average depth of schools for each 1 nautical mile intervals. Panel (a) and (d) shows the pooled distribution of temperature values at averaged school depth for June and October respectively; similarly panel (b)-(d) and (c)-(f) shows same parameter for points above and below 50m respectively. Panel (b) boxplot of temperature values for each 10m depth intervals showing median(mid points), middle values(boxes) and min –max values (whiskers) .

3.5.1.2 Salinity

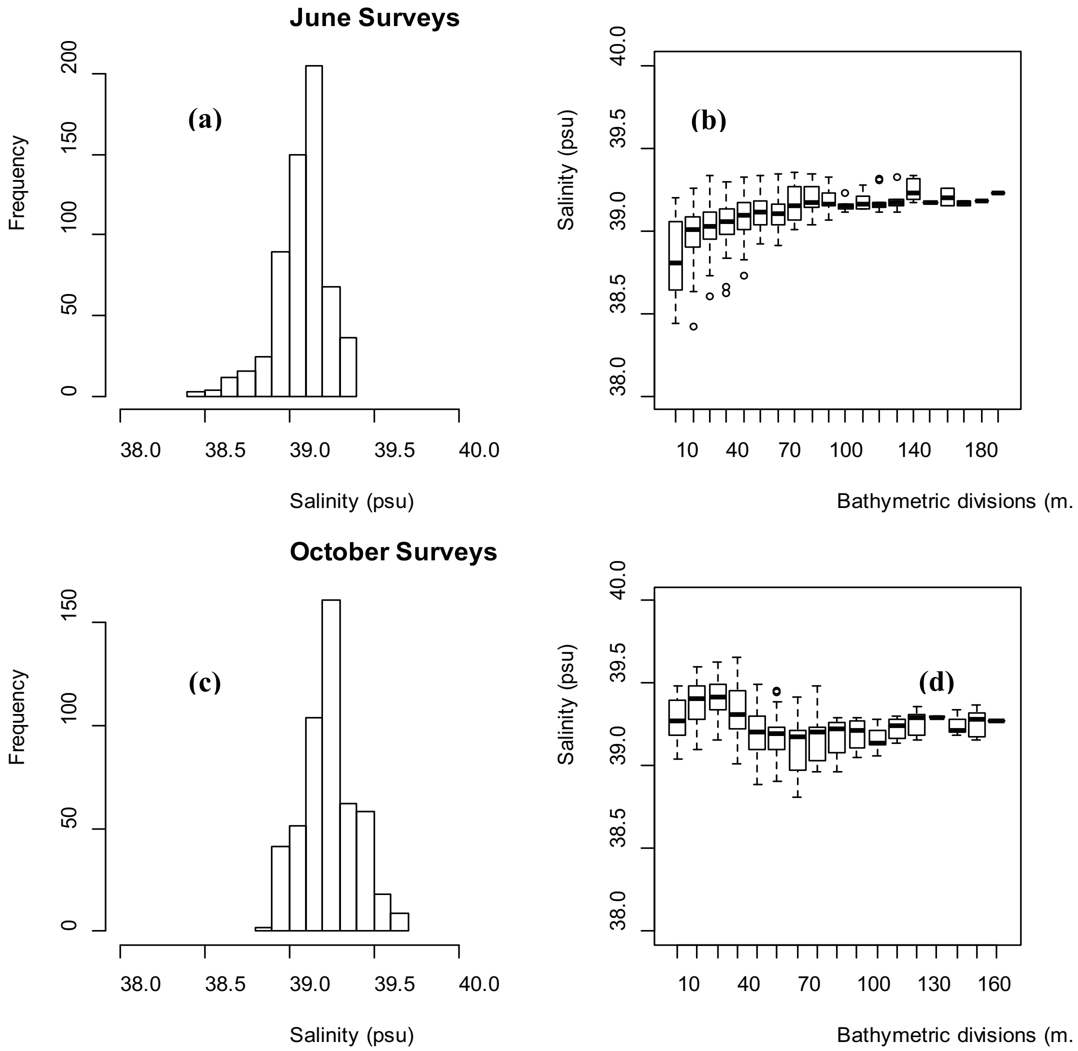


Figure 48. Histograms for salinity values at average depth of schools for each 1 nautical mile intervals. Panel (a) and (c) shows the pooled distribution of salinity values at averaged school depth for June and October respectively. Panel (b) an (d); shows boxplot of salinity values for each 10m depth intervals showing median(mid points), middle values(boxes) and min –max values (whiskers) for June and October respectively.

The salinity values shown in histograms on Figure 48 show a slight skewness in June surveys. In box plots the distribution of salinity values with respect to the depth divisions illustrates an evident picture of the seasonal differences. In June surface waters seems to be dominated by relatively less saline waters compared to deeper layer. In contrast in October surface waters were more saline where its level decreased to the same level of June, with increasing depth. The salinity level seems to be homogeneous for both seasons below thermocline.

3.5.1.3 Fluorescence

Highly skewed distribution of the fluorescence samples in Figure 49, on the left section, were normalized using logarithmic transformation on the middle section of the figure shown as histograms. The graph on the right suggests that depth has an evident control over fluorescence variability as it decreases with increasing depth. In June surveys higher average fluorescence values extends until 100m whereas it starts to decrease at 50m in October surveys.

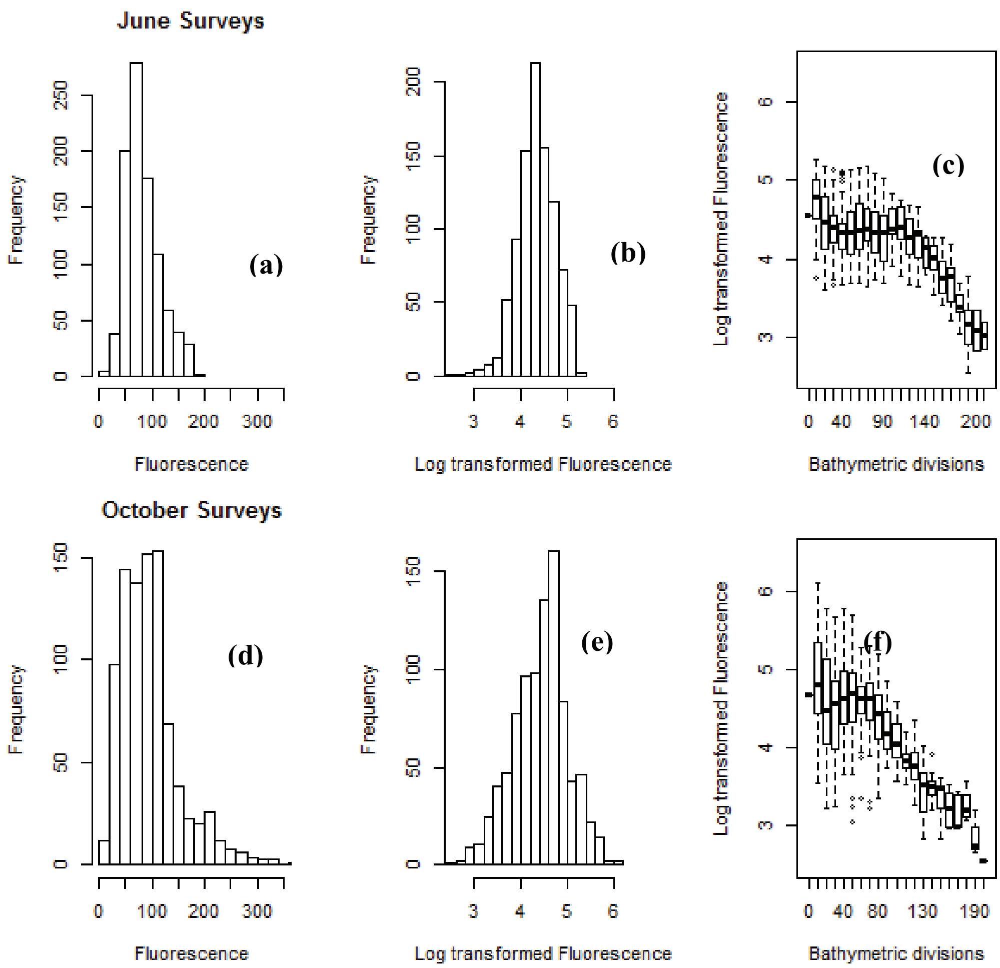


Figure 49. Histograms showing distribution of the fluorescence values at average depth of schools for each 1 nautical mile intervals on panel (a) and (d) for June and October respectively and their log transformed distributions; panel (b) and (e). Panel (c) an (f); shows boxplot of salinity values for each 10m depth intervals

The general tendency observed in June and October were the same; fluorescence drops sharply as moved from coast towards offshore (Figure 49). The difference in variance was higher in shallower depths observed in October surveys.

3.5.2 Assessing the relationships

The significance of the parameters in explaining the variability of the fish distribution was assessed by ANOVA tests (Table 25). In both surveys depth and temperature were highly significant as explanatory variables for log transformed NASC values. The significance level of salinity and fluorescence has varied between surveys, where fluorescence was highly significant in October surveys (p <0.001) while no significant response was observed in June surveys in terms of NASC. The response to salinity was more significant in June surveys compared to the response October surveys.

Table 25. F values and P values for the anova test and t test for estimated regression parameters with significance levels (Significance codes: 0 < ‘***’ > 0.001 < ‘**’ > 0.01 <‘*’ > 0.05 < ‘.’ > 0.1 < ‘’ > 1)

		F value	Pr(>F)	Total explained variability	Significance level
June surveys	Depth	35.656	<0.001	5.6%	***
	Temp	10.641	0.001	1.7%	**
	Salinity	8.4457	0.003	1.4%	**
	Fluorescence	0.8187	0.366	0.2%	
October surveys	Depth	51.852	<0.001	9.3%	***
	Temp	52.299	<0.001	9.4%	***
	Salinity	2.9575	0.086	0.6%	.
	Fluorescence	38.457	<0.001	7.1%	***

When the success of the regression models were investigated with regards to the proportion of the total variance explained as a response to depth, temperature, salinity and Fluorescence the percentage was respectively; 5.6%, 1.7%, 1.4%, 0.2% for June surveys and 9.3%, 9.4%, 0.6%, 7.1% for October surveys. These results were rather poor to explain the total variation in the data.

In order to evaluate combined effect of the variables, the multiple linear regression technique was applied in the next step. As a result, the multiple r-squared values were increased to 15.8% for June surveys where the most significant parameters were temperature and depth.

For October surveys r-squared values were 22.4% where the sub-regions were most significant variable to explain the NASC variability together with depth and temperature.

However the success of the linear model seems to be reduced due to some extreme values concentrated on particular areas having highly influential effect. Such extreme values could not be removed as these points characterized by the nature of the fish distribution. Consequently, these results showed that there may be a certain level of significant relationship between the selected explanatory variables and NASC, however linear regression technique was not able to explain the relationships between aforementioned factors.

Table 26 shows the results of the Poisson regression for June surveys using the NASC value as response variable and depth, temperature, salinity and sub regions as explanatory variables. All estimated parameters were significant at 5% level and among them depth was the most significant parameter. In GLM deviance term used to estimate the variability explained by the model which corresponds to sum of squares in linear regression (null deviance = total sum of squares and residual deviance= residual sum of squares). Analysis was performed by using each distribution models (Poisson and quasi-Poisson) separately with same parameters; however the deviance levels did not change where they explained deviance was 28%.

Table 26. Results of the Poisson regression.

	Estimate	**Std. Error**	**t value**	**Pr(>|t|)**
(Intercept)	52.88	20.36	2.598	< 0.01
Depth	-0.037	0.004	-8.418	< 0.001
Factor(temp)	-2.63	0.813	-3.237	< 0.001
Salinity	-1.137	0.519	-2.191	< 0.05
Factor(sub region)	-0.74	0.24	-3.078	< 0.005

In example in Table 27 the deviance column shows the level of residual deviance if that parameter had not been used in the analysis for June surveys. With regards to the results presented in this table, depth was the most significant factor while salinity seems to have smallest effect among all parameters.

Table 27. Drop 1 analysis to test the contribution of the parameters for June surveys

	Df	Deviance	AIC	LRT	Pr(>Chi)
<none>		143643	146912		
depth	1	174755	178022	31111.7	< 0.001
factor(temp)	9	164476	167726	20832.3	< 0.001
Salinity	1	145632	148898	1988.1	< 0.001
factor(Sub region)	3	149715	152978	6071.8	< 0.001

Table 28. Drop 1 analysis to test the contribution of the parameters for October surveys

	Df	Deviance	AIC	LRT	Pr(>Chi)
		97158	99906		
s_depth	1	99963	102710	2805.3	< 0.001
factor(temp_strata)	10	103486	106214	6327.8	< 0.001
Salinity	1	98459	101205	1300.8	< 0.001
factor(Sub region)	3	101637	104379	4479	< 0.001

Similarly in Table 28 depth and temperature has the highest contribution in explaining the deviance; however temperature in October surveys shows a better fit while depth was the best in June surveys. In Table 27 and Table 28, LRT stands for likelihood ratio tests and AIC for Akaike information criterion. Both show goodness of fit of the different models hence allow comparing the effects of the parameters.

3.5.3 Examination of the nonlinear relationship between NASC and the environmental parameters

This section can be considered as an exploratory phase providing insight to the habitat variability in the region with regards to different features of water masses in terms of temperature, salinity, fluorescence and depth distributions. The acoustic fish distribution data analysed as a whole without partitioning to species level disregarding species specific properties. The analyses based on species level distribution were given in the next section.

The summary of GAM analysis showing the importance of each variable in explaining the total variability in the fish distribution data were given in

Table 29 as deviance explained. And their estimated degrees of freedom as an indication for level of smoothing of each parameter.

Table 29. GAM results for the combined datasets for the June and October surveys.

June surveys		
Predictor	Estimated Df	Deviance Explained
Salinity	8.95	4.09%
Temperature	8.97	9.36%
Fluorescence	8.98	9.17%
Depth	8.97	24.6%

October surveys		
Predictor	Estimated Df	Deviance Explained
Salinity	8.98	7.08%
Temperature	8.96	24.50%
Fluorescence	8.94	21%
Depth	8.94	26.30%

In June surveys, the temperature alone explained 9.4% of the deviance. In essence, the location of the fish schools in the surface mixed layer varied mainly between 20.0 °C and 26.5 °C. and below the thermocline the range was between 16.5 °C and 20 °C. For the October surveys for upper layer temperature varied between 24.5 °C and 29.0°C while lower layer remains between 16.0 °C and 20.0 °C. GAM plots clearly depicts the relationship between temperature and NASC distribution in both June and October surveys where the general tendency was increasing biomass with increasing temperature up to a certain level (Figure 50). The fluctuating relation was characterized by three peaks indicating the temperature preference of the species constituting the main bulk of the acoustic biomass in June survey. These three prominent peaks were at 17.0 °C, 20.0 °C and 23.0 °C, with a strong drop at 19.0 °C followed by a lesser drop at 21.0 °C. The peak at 23.0 °C was noticeable.

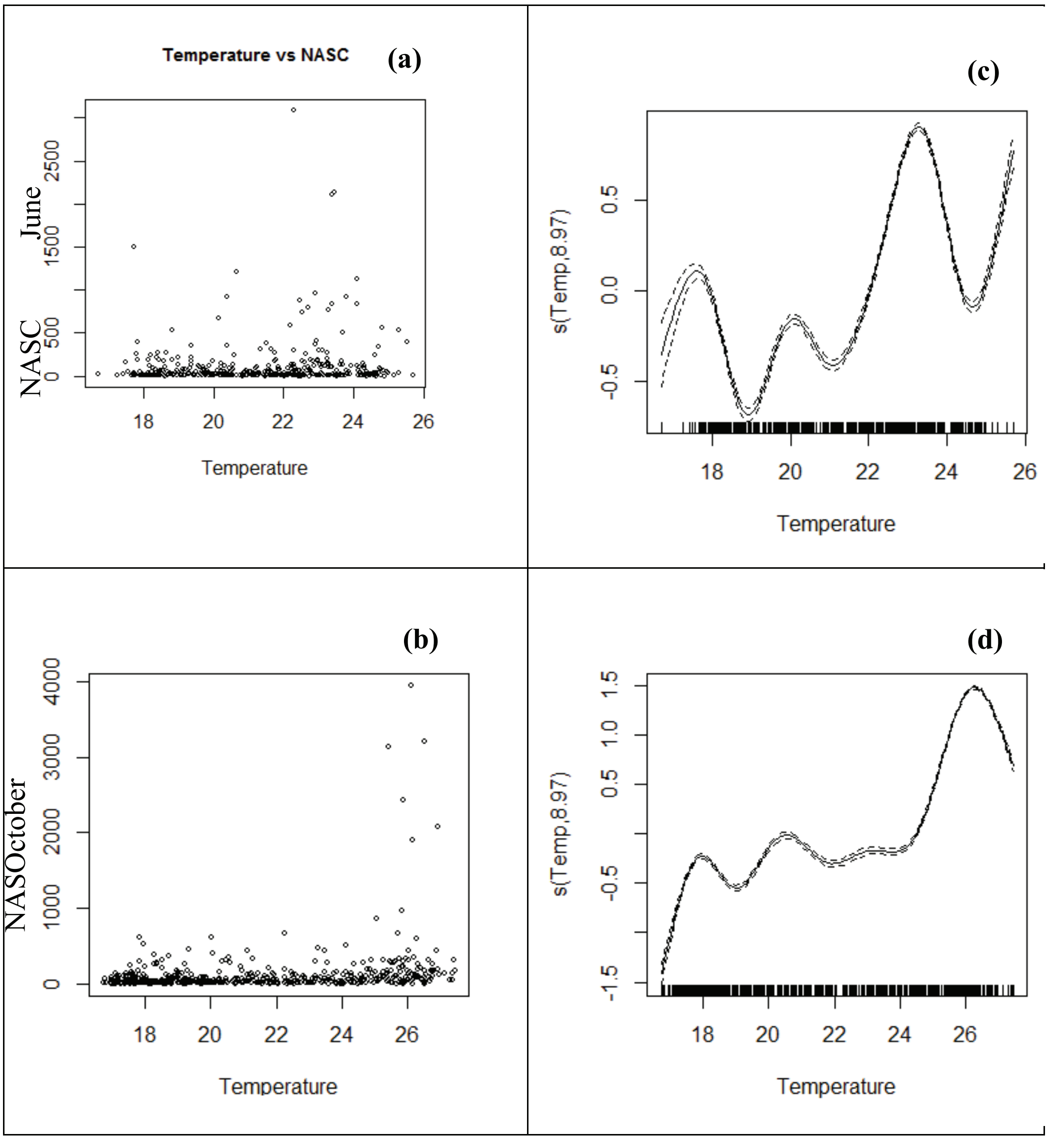


Figure 50. Relationship between water temperature and fish biomass. Figures on the left show scatterplot of temperature against NASC, where panel (a) is for June and panel (b) is for October, and on the right GAM curve for smoothing function of the depth for NASC with 95% confidence bands shown as dotted lines for June (c) and October (d) where the vertical axes show the contribution of the smoother to the fitted values.

The effect of temperature in explaining the variation in NASC was clearer. The fishes appear to have a tendency to accumulate towards higher temperature. The GAM suggests a NASC peak at 26 °C (Figure 51) and two lesser peaks at 19.0°C and 21.0°C. In general the peak values were in good agreement with the peaks suggested by the June model. The deviance explained by temperature effect in October was 26.3% which was much higher than in June surveys.

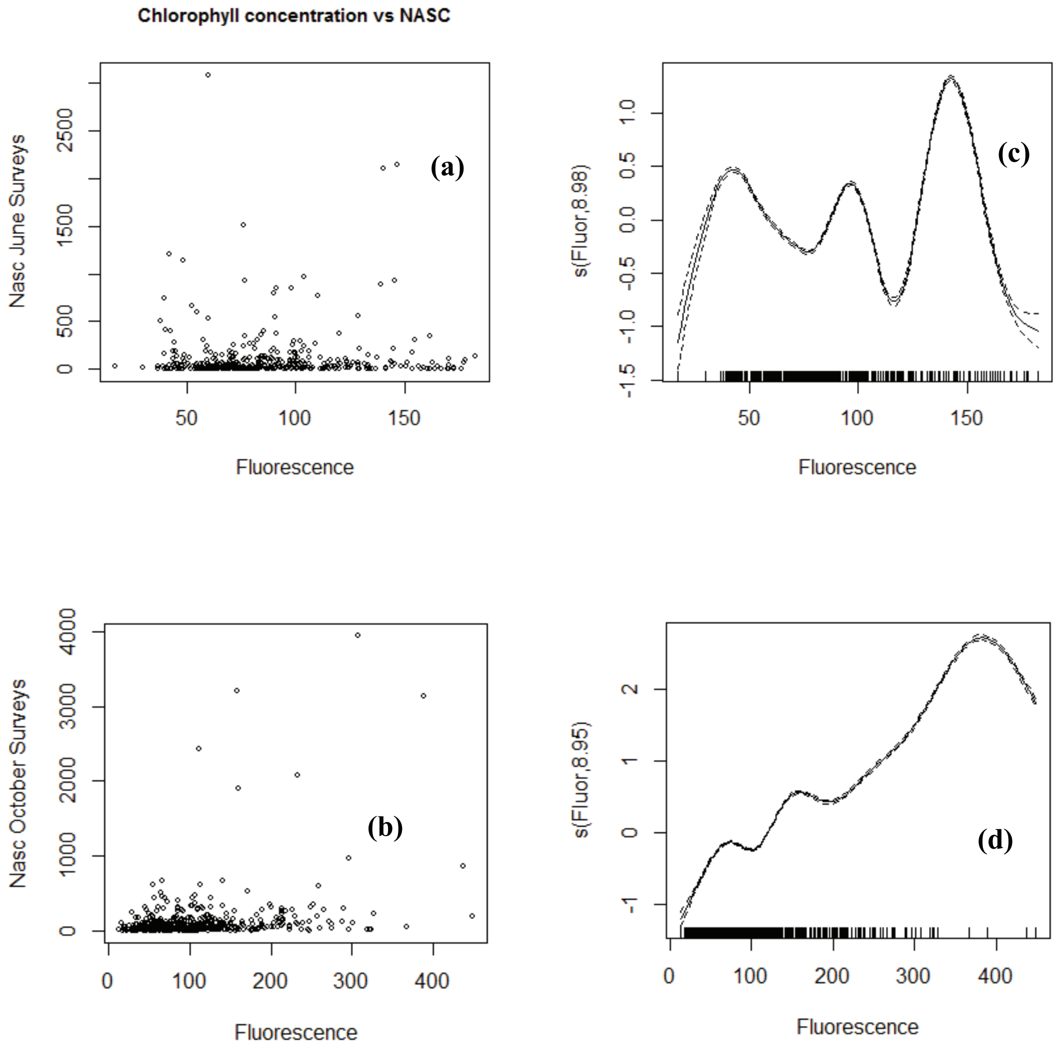


Figure 51. Figures on the left show scatterplot of fluorescence against NASC, where panel (a) is for June and panel (b) is for October, and on the right GAM curve for smoothing function of the depth for NASC with 95% confidence bands shown as dotted lines for June (c) and October (d) where the vertical axes show the contribution of the smoother to the fitted values.

The effect of the fluorescence as a proxy for the chlorophyll concentration resulted in a highly fluctuating curve and explained the 9.17% of the deviance with three peaks in June surveys (Figure 51). Despite irregularity in the relation, it may worth noting that the highest values of NASC were associated with regions where the chlorophyll concentration was the highest. In October surveys the effect of fluorescence was more straightforward showing a significant association with NASC where it increased with higher fluorescence values explaining the deviance at 21% giving a dome-shaped appearance towards the highest chlorophyll values observed in the region.

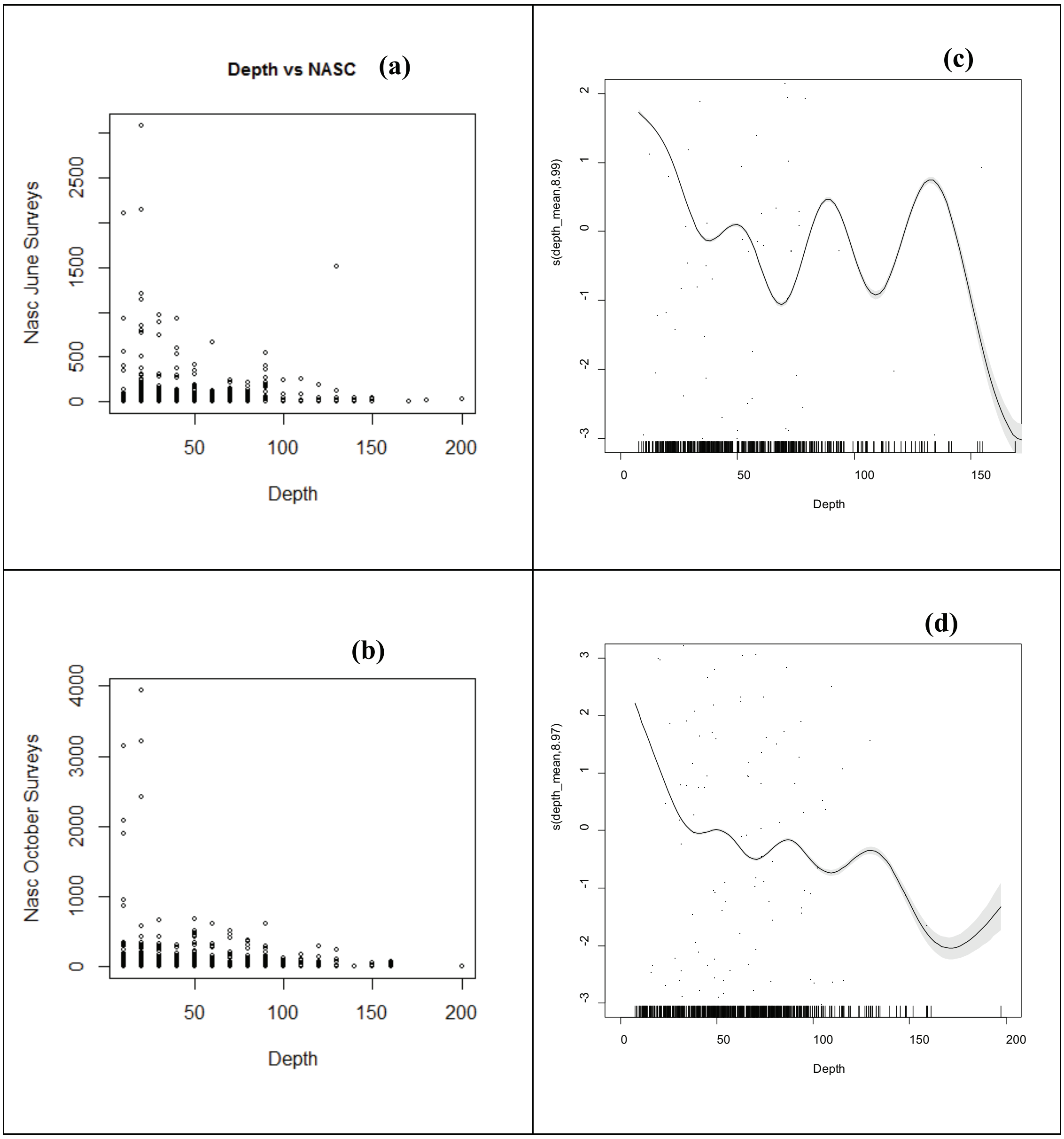


Figure 52. Figures on the left show scatterplot of depth against NASC, where panel (a) is for June and panel (b) is for October, and on the right GAM curve for smoothing function of the depth for NASC with 95% confidence bands shown as dotted lines for June (c) and October (d) where the vertical axes show the contribution of the smoother to the fitted values.

GAM plots for the effect of the bottom depth appears to be strongly associated with NASC in, both June and October surveys. The relation correlates positively and explained24.6% of deviance in Junes and 30.2% in October. Similar to temperature and fluorescence plots for

June surveys dataset, the observed wiggly pattern also existed for the bottom depth and NASC relationship (Figure 52). In lower depths the effect of the bathymetry appears to be peaked at 140m and 80m, however main peak was at 10m where the effect began to increase after 50m. In October a similar increasing pattern observed after 50m however, it showed a flat relationship at the area deeper than 50 m and shallower than 130m. The positive contribution turned into negative after 130 m and remained so until the depth of 170 m was reached.

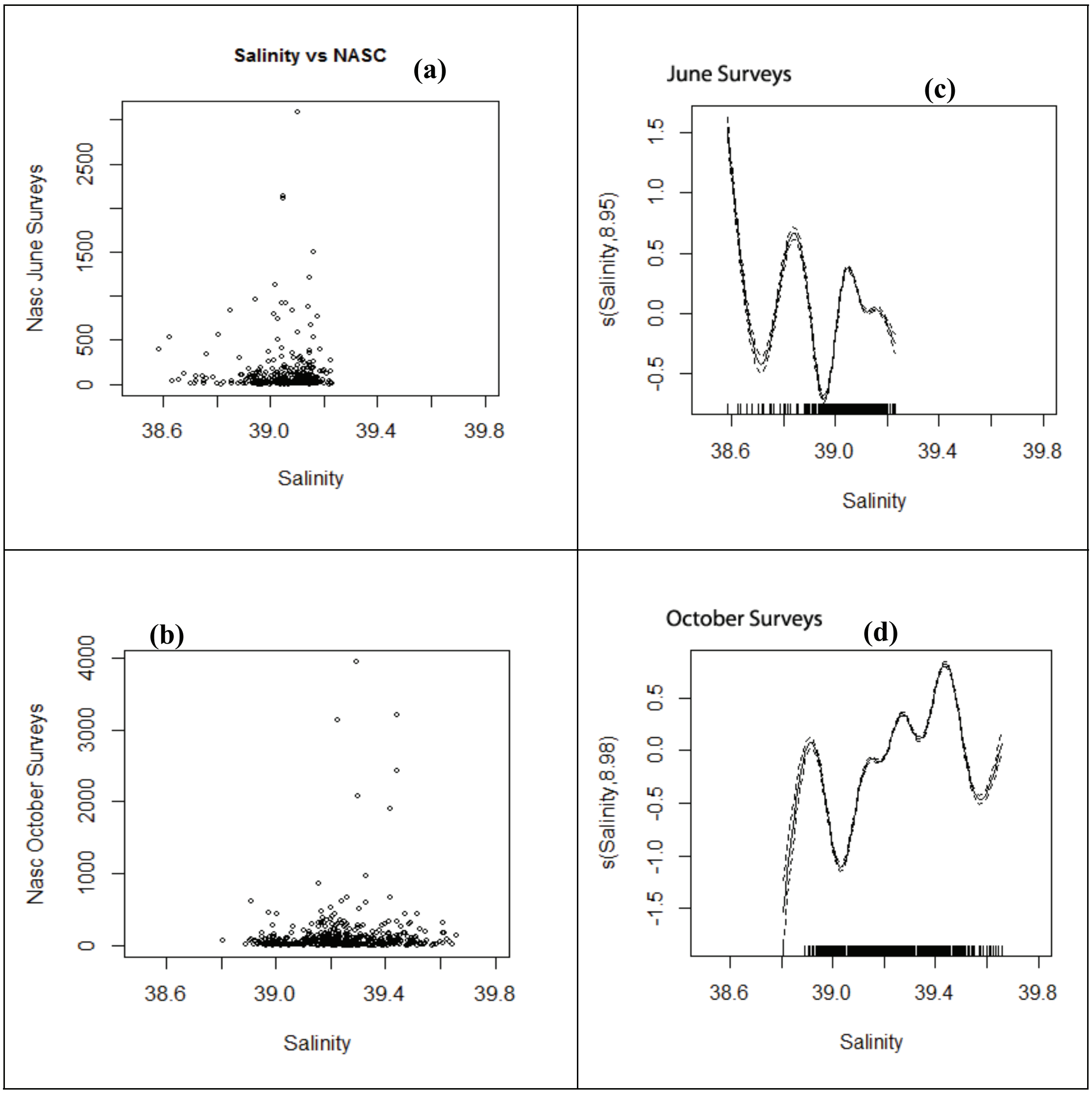


Figure 53. Influence of salinity on NASC. On the left scatterplot of salinity and NASC are shown, panel (a) is for June and panel (b) is for October. Figures on the right show the GAM curve for smoothing function of the Salinity for NASC with 95% confidence bands shown as dotted lines for June (c) and October (d) where the vertical axes show the contribution of the smoother to the fitted values.

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Salinity had the lowest effect in explaining the variability in the data, regarding the explained deviance values (4.09% and 7.08% respectively for June and October surveys). However its effect could not be expressed as negligible due to freshwater flux from the rivers results in lower salinities at shallower areas. However, apart from the areas at river mouths, the surface mixed layer and the layer below thermocline showed different characteristics in June and October where surface waters were less saline in June while higher salinity levels were observed at surface in October. Therefore the peak at lower salinities on GAM plots for the salinity effect can be related to freshwater flux which influences the productivity, thus food availability for fish. Second peak in both surveys corresponds to the area at thermocline or just above the thermocline, which was apparently an important driver in fish distribution (Figure 53).

Finally all four variables, temperature, fluorescence (chlorophyll-a concentration), salinity and depth were selected for GAM models for species specific surveys as they showed considerable variability throughout the study area and believed to be less complicated to interpret biologically. When their effect combined the deviance explained by the model reached to 44% for the June surveys and 45% for the October surveys.

3.6 Species specific distributions

3.6.1 Sardinella aurita

In Figure 54 and the Figure 55 proportional density of the *S. aurita* caught in trawl samples are shown. The cross symbols shows the position of the sampling station. *S. aurita* were not found at the points where the cross illustrated alone, in both figures catch seems to be restricted to 0 – 50 m bathymetric zone, and highest catches were concentrated on the bay of Mersin (SR-2).

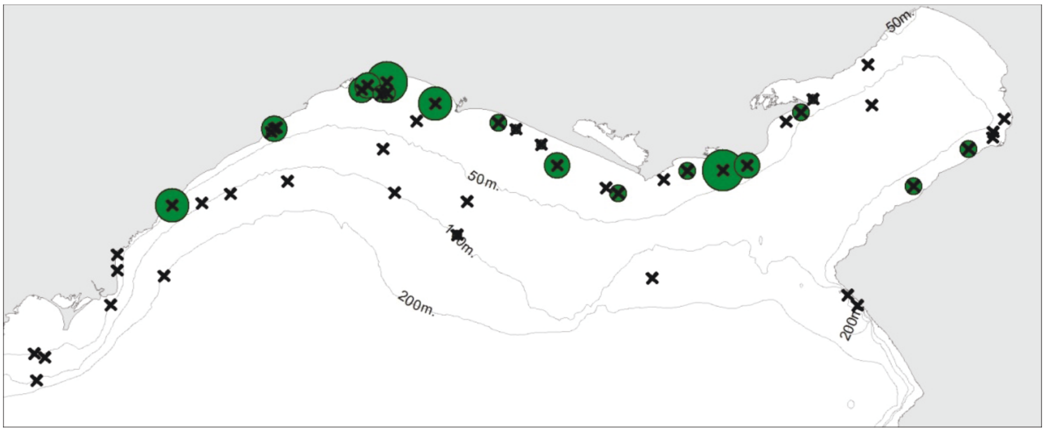

Figure 54. Distribution and density of *S. aurita* in June surveys based on trawl catch. The cross symbols denote the sampling location. Solid green circles are showing the proportional density.

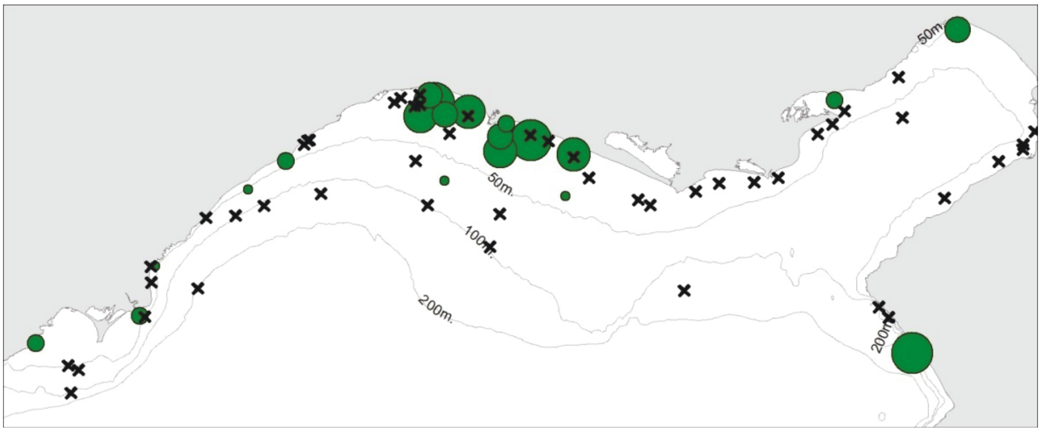

Figure 55. Distribution and density of *S. aurita* in October surveys based on trawl catch. The cross symbols denote the sampling location. Solid green circles are showing the proportional density.

Distribution of acoustically detected adult and juvenile *S. aurita* was separately plotted in the maps given in Figure 56 and Figure 57. In June almost no juveniles were observed in the region except some very small aggregations near to the river mouths. In October the river mouths has more pronounced impact on the distribution of the juveniles and they were observed almost always around the areas near to rivers, namely Goksu, Lamas, Seyhan, Ceyhan, Arsuz and the small creeks along the coast.

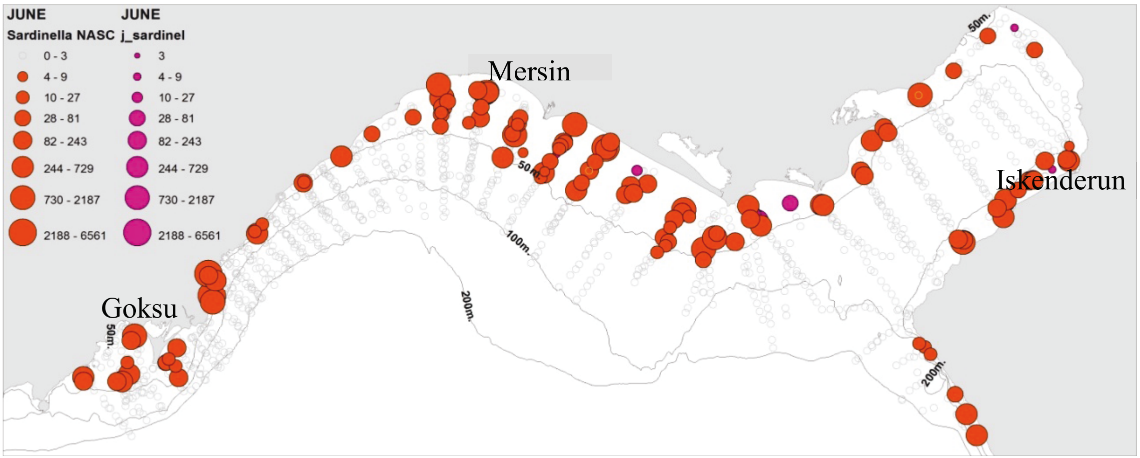

Figure 56. Distribution and density of *S. aurita* and juvenile *S. aurita* in June surveys based on acoustic sampling. Empty circles denote the sampling locations. Solid circles are showing the proportional density.

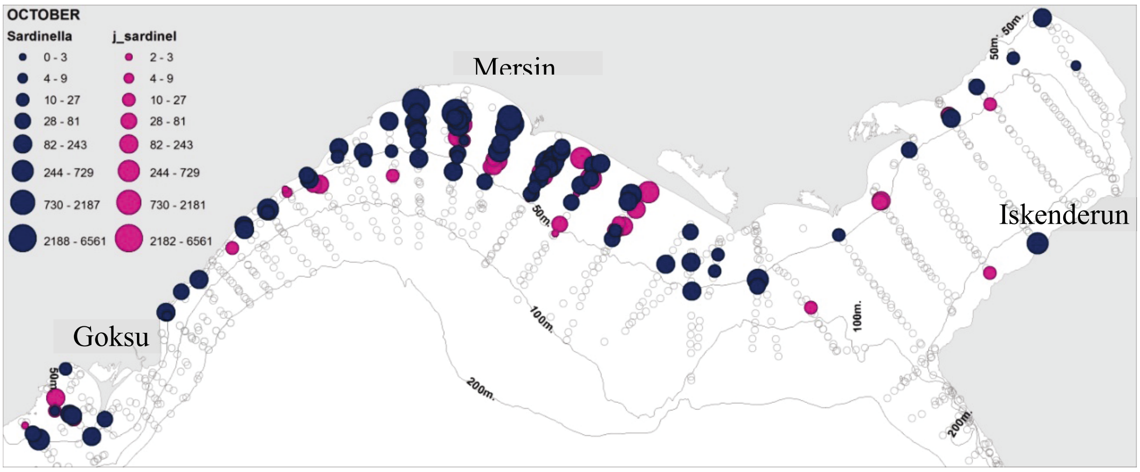

Figure 57. Distribution and density of *S. aurita* and juvenile *S. aurita* in June surveys based on acoustic sampling. Empty circles denote the sampling locations. Solid circles are showing the proportional density.

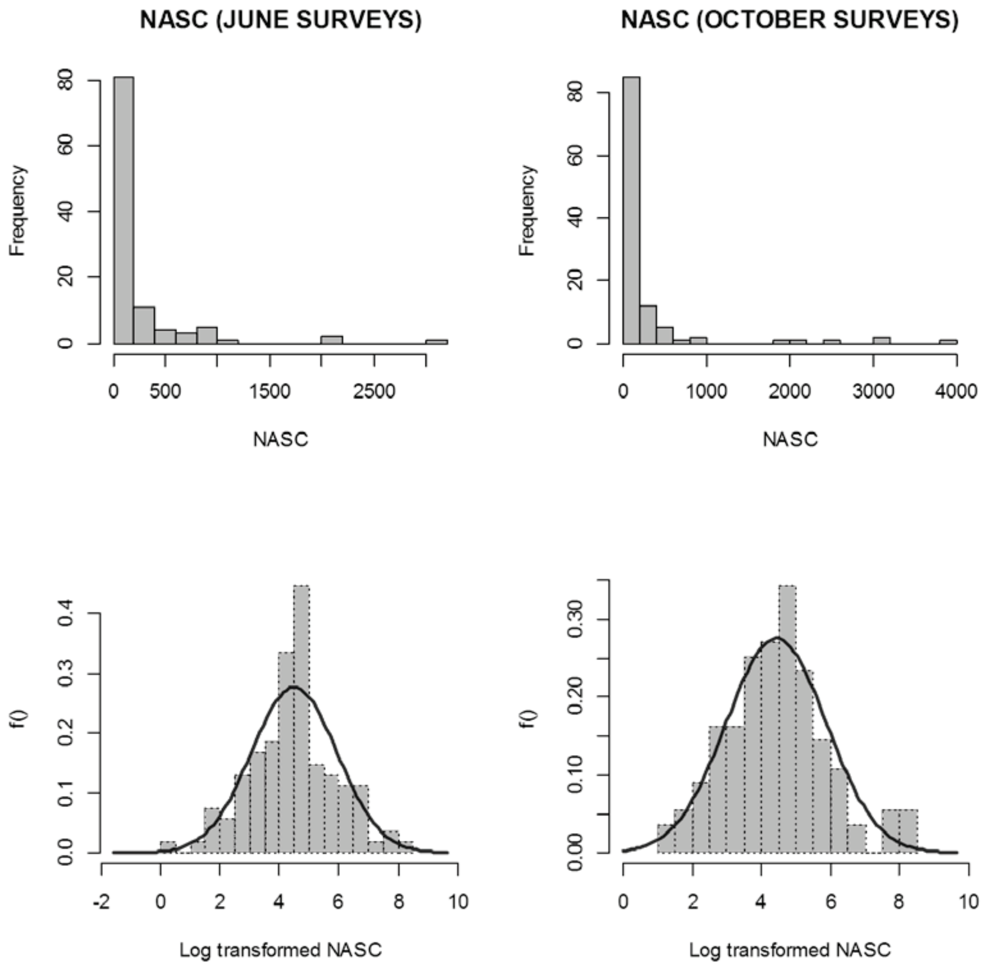

Figure 58. NASC distribution for *S. aurita*, upper figures show actual distribution, lower figures log transformation for June and October surveys.

When the NASC distribution apportioned to species, the zero-values inflated the data (Figure 58). In general 50% of the data was composed of data sets which do not contain a NASC value (or in other words, a fish aggregate). This situation was particularly remarkable for the case of *S. aurita* where the zero values accounted for 87% for June surveys and 88% for October surveys. The density distribution maps indicated that during both sampling period the highest *S. aurita* densities were located in the inshore part of the Mersin Bay with some local exceptions in Goksu and Iskenderun regions, commonly not beyond 50 m isobaths (Figure 56) and (Figure 57). Highly skewed distribution of NASC values were normalized when the zero values were excluded and the data were log-transformed (Figure 58).

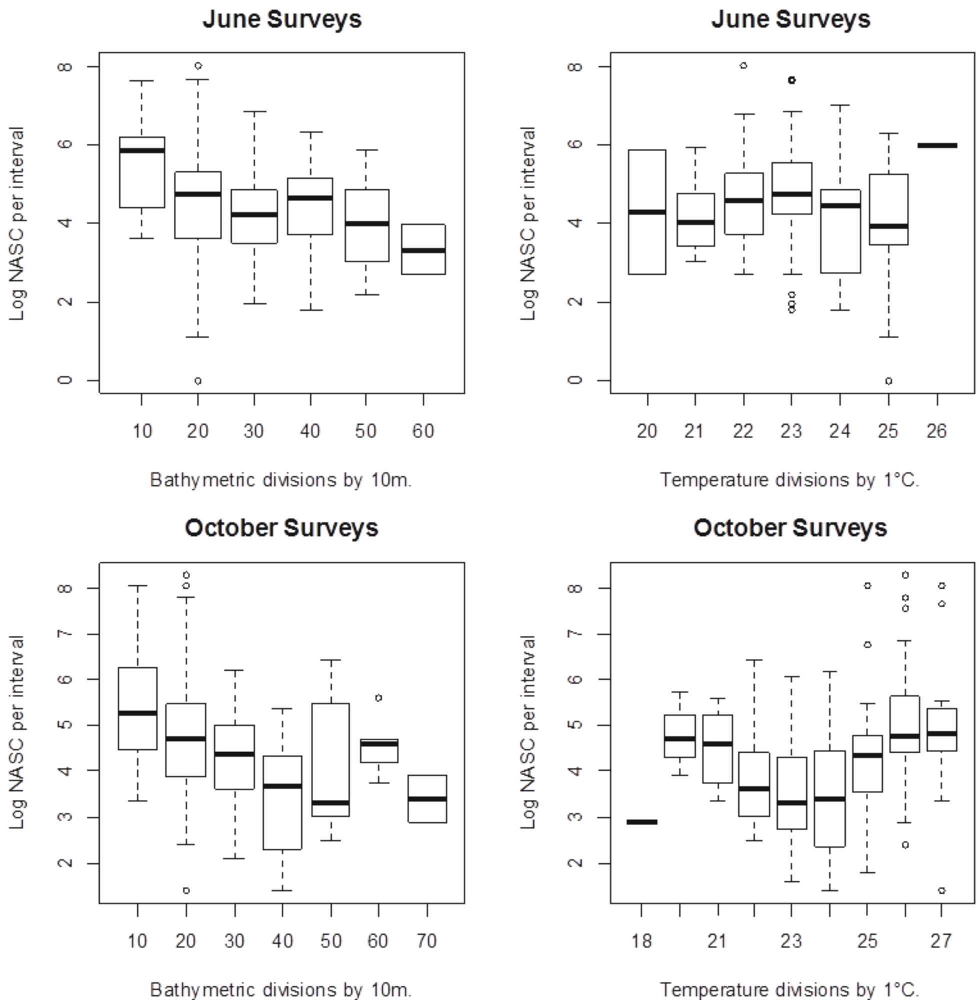

Figure 59. Categorical box plots of depth and temperature for *S. aurita* density in NASC distribution for both surveys.

Boxplots given in Figure 59 show the center of the values between first and third quartiles and the line at midpoint of the boxes represent the median. Whiskers denote the lowest and the highest values within 1.5 times of the range from the first and third quartiles. Circles represent outliers beyond the whiskers. As indicated in the plots, the depth showed a negative relationship with NASC for both surveys when the temperature and bathymetry plotted for log transformed NASC values for *S. aurita* (Figure 59). However temperature displayed a quite different relationship compared to *S. aurita* density in June and October surveys such that; in June it was rather homogenous while it showed an U-shaped pattern between 19°C and 27°C in October. The figure do not show any sign of reference or avoidance reaction for the range of temperature observed in the region during June. In October *S. aurita* seems to prefer the warmer parts with a peak at 26°C (Figure 59).

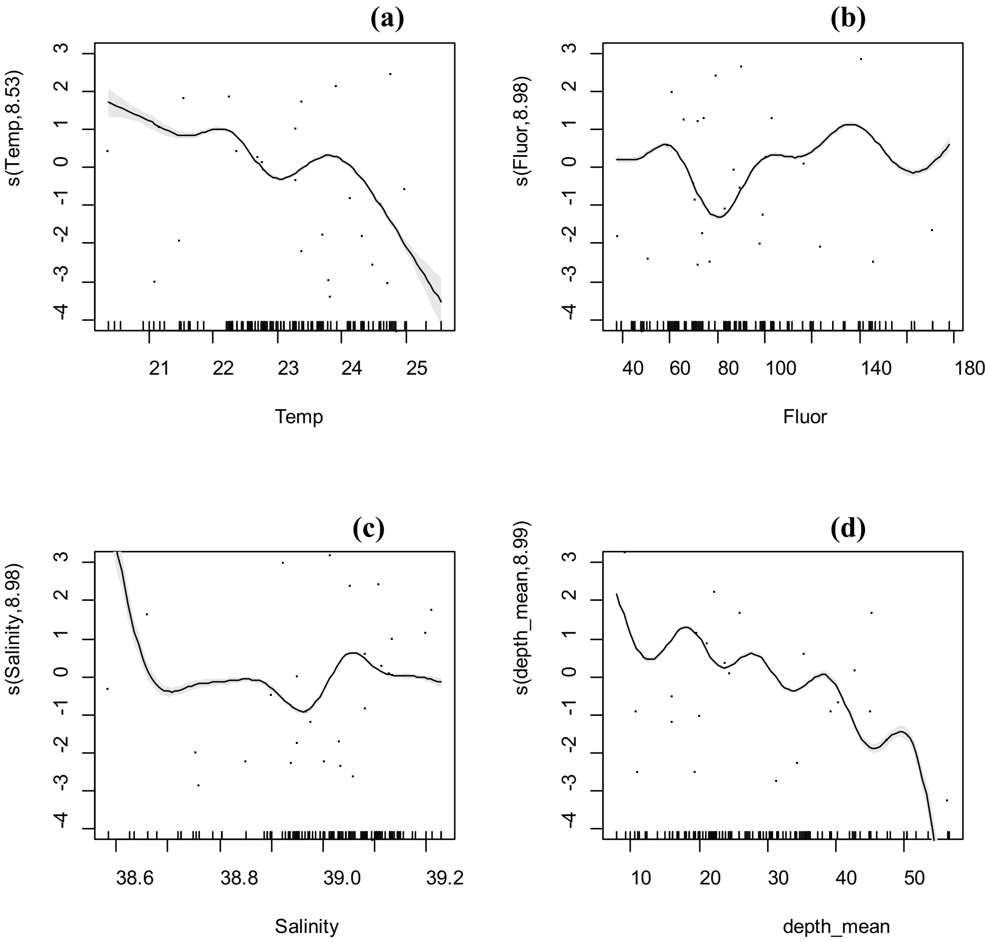

Figure 60. GAM with estimated smoothing curves using Poisson distribution for the effect of temperature (a), fluorescence (b), salinity (c) and depth (d) over *S. aurita* distribution in October surveys. The solid line is the smoother and the shaded areas are 95% confidence bands. The ticks on the x-axis indicate the density of points for different variable values. And the vertical axes show the contribution of the smoother to the fitted values.

The four explanatory variables, namely temperature, salinity, fluorescence and depth were used in GAM models for *S. aurita* to quantify their combined effects on the areal distribution preference.

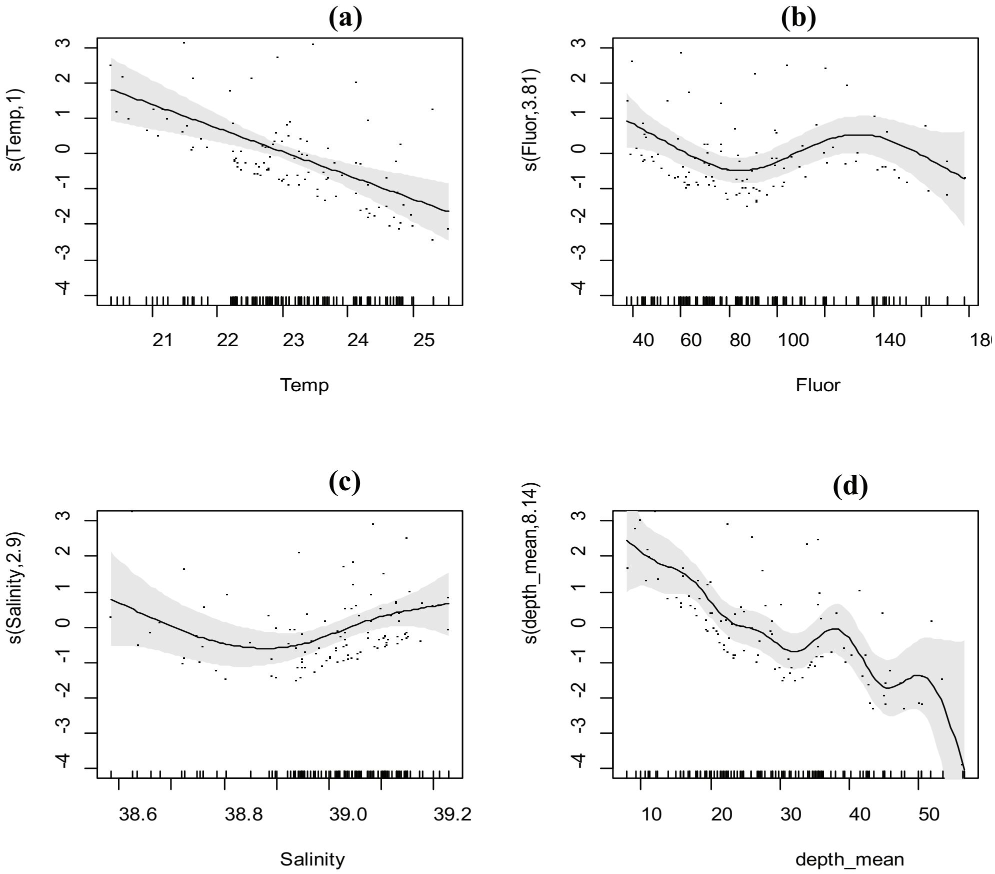

Figure 61. GAM with estimated smoothing curves using Negative binomial distribution for the effect of temperature (a), fluorescence (b), salinity (c) and depth (d) over *S. aurita* distribution in October surveys. The solid line is the smoother and the shaded areas are 95% confidence bands. The ticks on the x-axis indicate the density of points for different variable values. And the vertical axes show the contribution of the smoother to the fitted values.

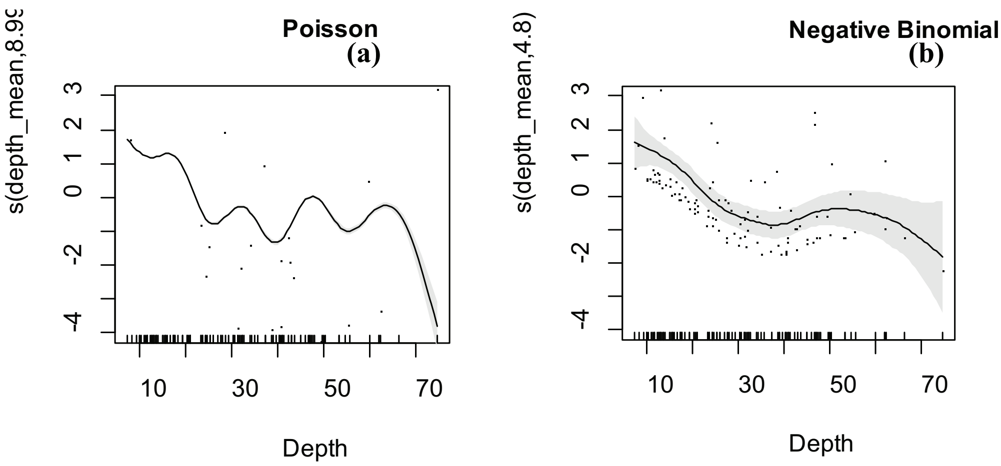

Figure 62. An example to comparison of use of different error distributions; Poisson (a) versus negative binomial distribution (b). The fitted curves show effect of depth over NASC distribution of *S. aurita*.

The negative binomial error a distribution was selected out of the trials testing goodness of fit by Gaussian, Poison and negative binomial distributions. Figure 60 and Figure 61 illustrates the estimated smoothing curves over Poisson distribution and negative binomial distribution respectively. The solid line is the smoother and the shaded areas are 95% confidence bands. The ticks on the x-axis indicate the density of points for different variable values. The example shown in Figure 62 illustrates the models curves obtained using Poisson and negative binomial distributions, where the curves show effect of depth over NASC distribution of *S. aurita* for October surveys. The models using poison distribution required higher number of degrees of freedom (estimated degree of freedom = 9.00) for fitting the smoothing function which at the end generated highly wiggly curves, explained 30.9% of the deviance however difficult to interpret (Figure 62). On the other hand negative binomial distribution gave smoother curves with less degrees of freedom (estimated degree of freedom = 4.796) while generating a better fit explaining the deviance at 30.6 % similar to Poisson distribution. The overall result using all parameters and accommodating negative binomial distribution the explained deviance was 44.5% for June and 56.2% for October surveys.

Depth seemed to be the most important factor negatively correlated with NASC in June surveys (Figure 61). In October, temperature replaces the depth providing a positive correlation while depth provided negative relationship with NASC values (Figure 61). Temperature had a contradicting effect in June and October surveys when compared as it showed negative relationship with NASC in June while it was the opposite in October. However the temperature values above 20°C generally corresponds to the water column at or above thermocline in June. Therefore, in order to test the validity of the negative relationship in June, whole sampling points including the zero values were analyzed by GLM with binomial distribution and logit link function (Figure 63).

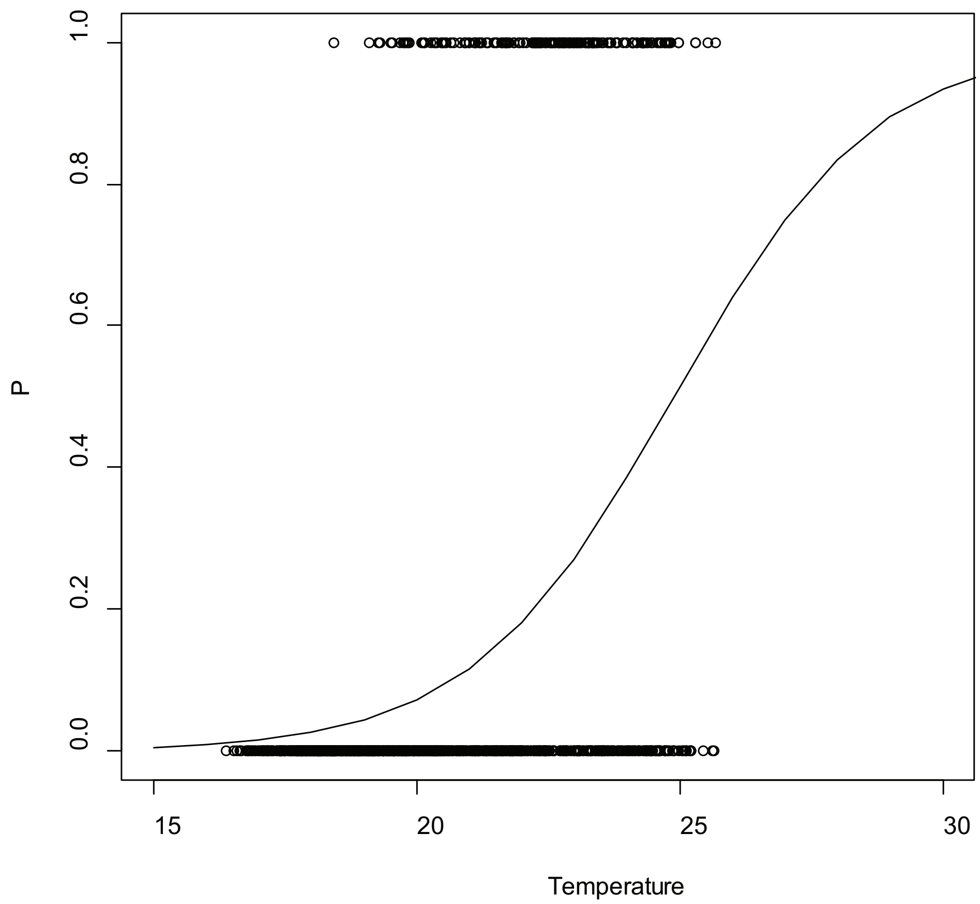

Figure 63. Fit of the Generalized Linear Model for June surveys with binomial distribution for relationship between temperature and NASC values including zero points.

The outcome of GLM based on presence/absence of *S. aurita* provided acceptable fit with regard to the ***p*** values significantly different from 0 at the 0.01% level and with residual deviances in agreement with residual degrees of freedom (Table 30)

Table 30. The numerical output of the Generalized Linear Model in Figure 63.

	Estimate	**Std.Error**	**z value**	**Pr(>|z|)**
(Intercept)	-12.9	0.95	-13.52	<0.05
Temp	0.5	0.04	12.07	<0.05
Null deviance:	1056 on 1322 degrees of freedom			
Residual deviance:	873 on 1321 degrees of freedom			

Finally the results showed that probability of finding *S. aurita* schools increased at higher temperatures. The maximum chlorophyll concentration was higher during October surveys whereas average salinity values were also high in the same period (Figure 64). A more clearly increasing pattern in NASC can be seen in October surveys compared to June due to increasing chlorophyll concentration; however there was also a slightly increasing trend at lower values.

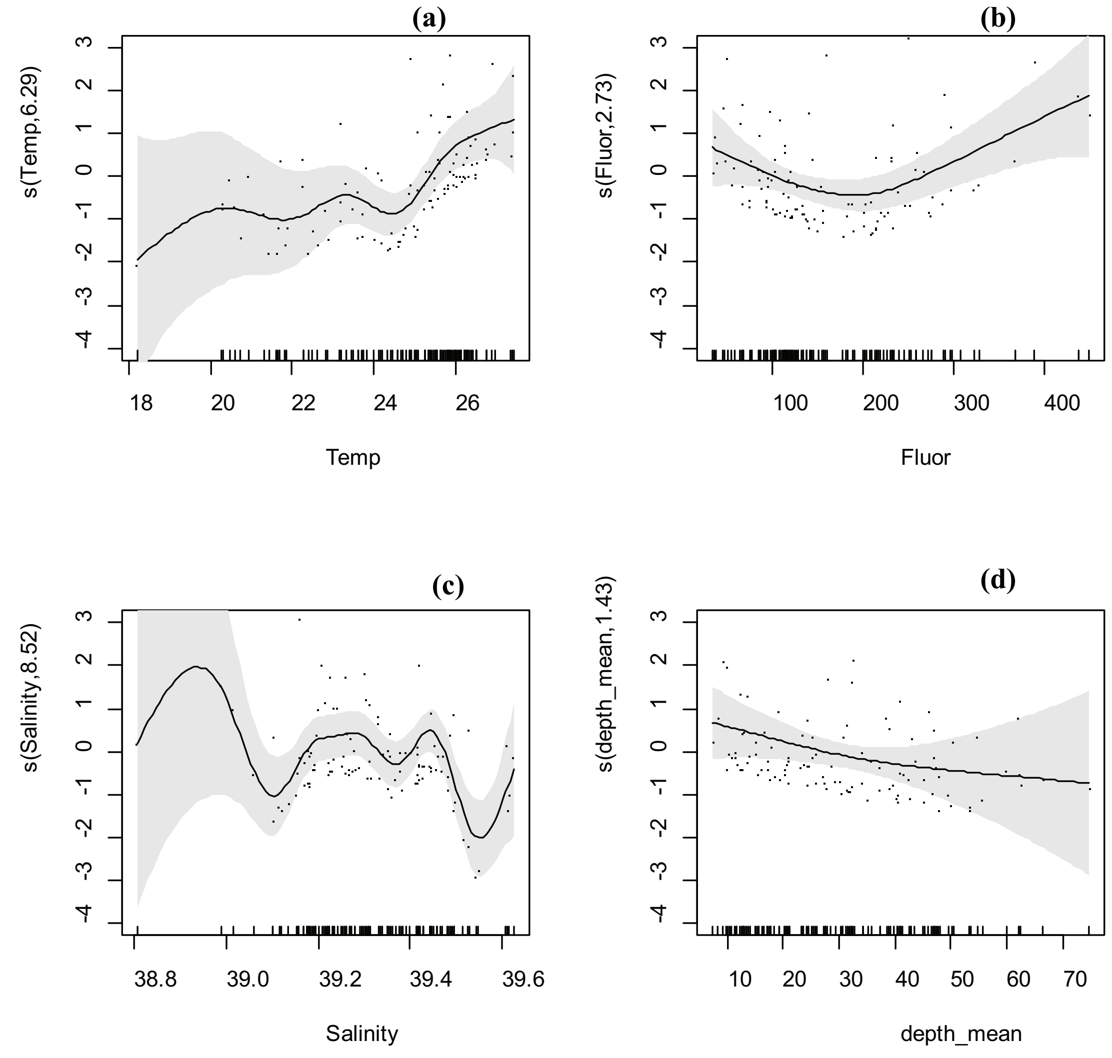

Figure 64. Estimated smoothing curves for the effect of temperature (a), fluorescence (b), salinity (c) and depth (d) over *S. aurita* distribution in October surveys. The solid line is the smoother and the shaded areas are 95% confidence bands. The ticks on the x-axis indicate the density of points for different variable values. And the vertical axes show the contribution of the smoother to the fitted values.

The analyses until here were done based on the parameter values estimated for the average depth of the sampling points. Another set of analysis were done only based on the surface values of the parameters measured with CTD in order to make it possible to assess the usability of the satellite for parameters of SST and Chl-a, in addition to bottom depth. The tests were performed including the observation points with zero values and using negative binomial distribution. 36 different GAM tests were completed in order to compare the effects of parameters for different combination of seasons and parameters. In Table 31 comparison of the GAM '% deviance explained' for the univariate models (i.e. comparing *S. aurita* with each predictor separated shown as shaded) and for bivariate models (i.e. comparing *S. aurita* with the pair of predictors placed in the column and row). For both cases survey period (namely; June 2009, October 2009, June 2010, October 2010 and June 2011) were included as factors. The table separated in three divisions, initially the data used as pooled to involve all records, secondly data from each survey period (as June and October) analysed seperately. The figures 57 and 58 show the effect of the surface parameters; SST and chla

Table 31. Comparison of the GAM results with regards to "% deviance explained"

	Depth	Modis-Chla	Modis-SST	CTD-SST	CTD-Fluor
Depth	54.4%				*ALL SURVEYS POOLED*
Modis-Chla	55.8%	29.1%			
Modis-SST	57.9%	35.3%	13.8%		
CTD-SST	56.8%	*NA*	*NA*	19.6%	
CTD-Fluor	56.7%	*NA*	*NA*	32.7%	26.4%
Depth	55.9%				*JUNE SURVEYS*
Modis-Chla	57.0%	45.5%			
Modis-SST	59.3%	50.6%	16.9%		
CTD-SST	60.1%	*NA*	*NA*	42.2%	
CTD-Fluor	59.4%	*NA*	*NA*	54.1%	48.7%
Depth	54.6%				*OCTOBER SURVEYS*
Modis-Chla	59.7%	46.8%			
Modis-SST	60.3%	56.0%	33.7%		
CTD-SST	58.6%	*NA*	*NA*	35.4%	
CTD-Fluor	58.4%	*NA*	*NA*	42.0%	37.0%

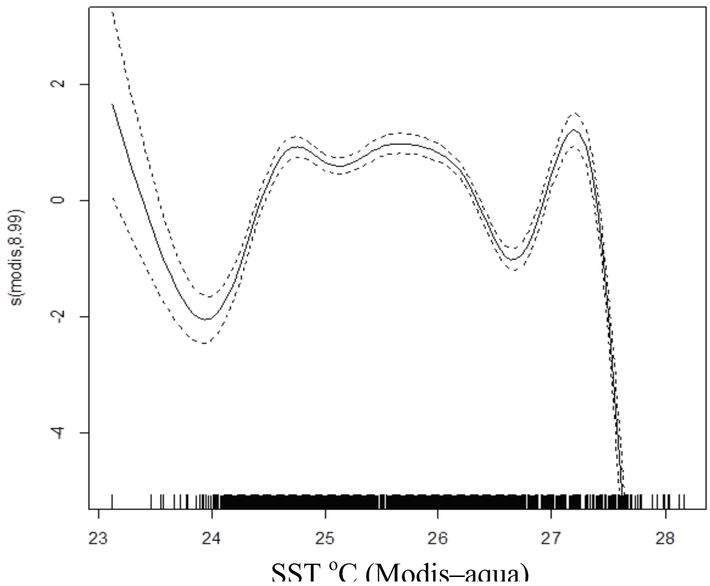

Figure 65. Estimated smoothing curves for the effect of SST derived from Modis-aqua satellite data on distribution of S. aurita tested for the pooled data set, including all surveys. The solid line is the smoother and the dotted lines are 95% confidence bands. The ticks on the x-axis indicate the density of points for different variable values. And the vertical axes show the contribution of the smoother to the fitted values

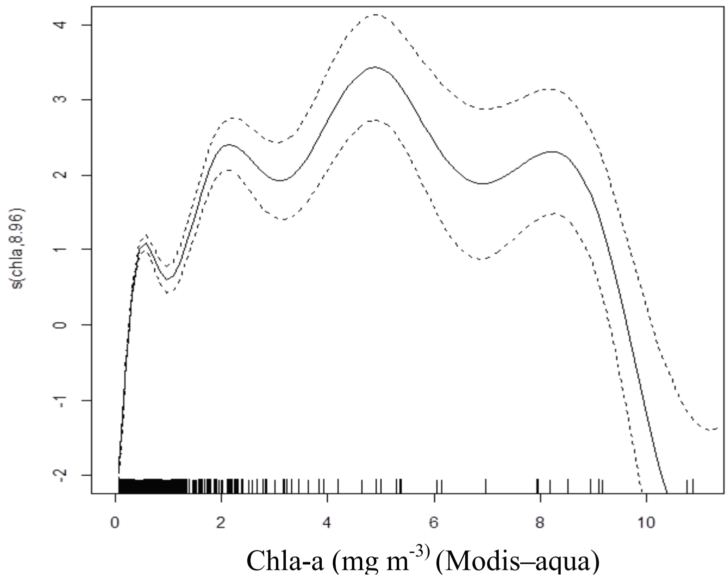

Figure 66. Estimated smoothing curves for the effect of SST derived from Modis-aqua satellite data on distribution of S. aurita tested for the pooled data set, including all surveys. The solid line is the smoother and the dotted lines are 95% confidence bands. The ticks on the x-axis indicate the density of points for different variable values. And the vertical axes show the contribution of the smoother to the fitted values

Sardina pilchardus

S. pilchardus exhibited a distribution pattern relatively offshore compared to *S. aurita*, preferring deeper waters (Figure 68 and 61).

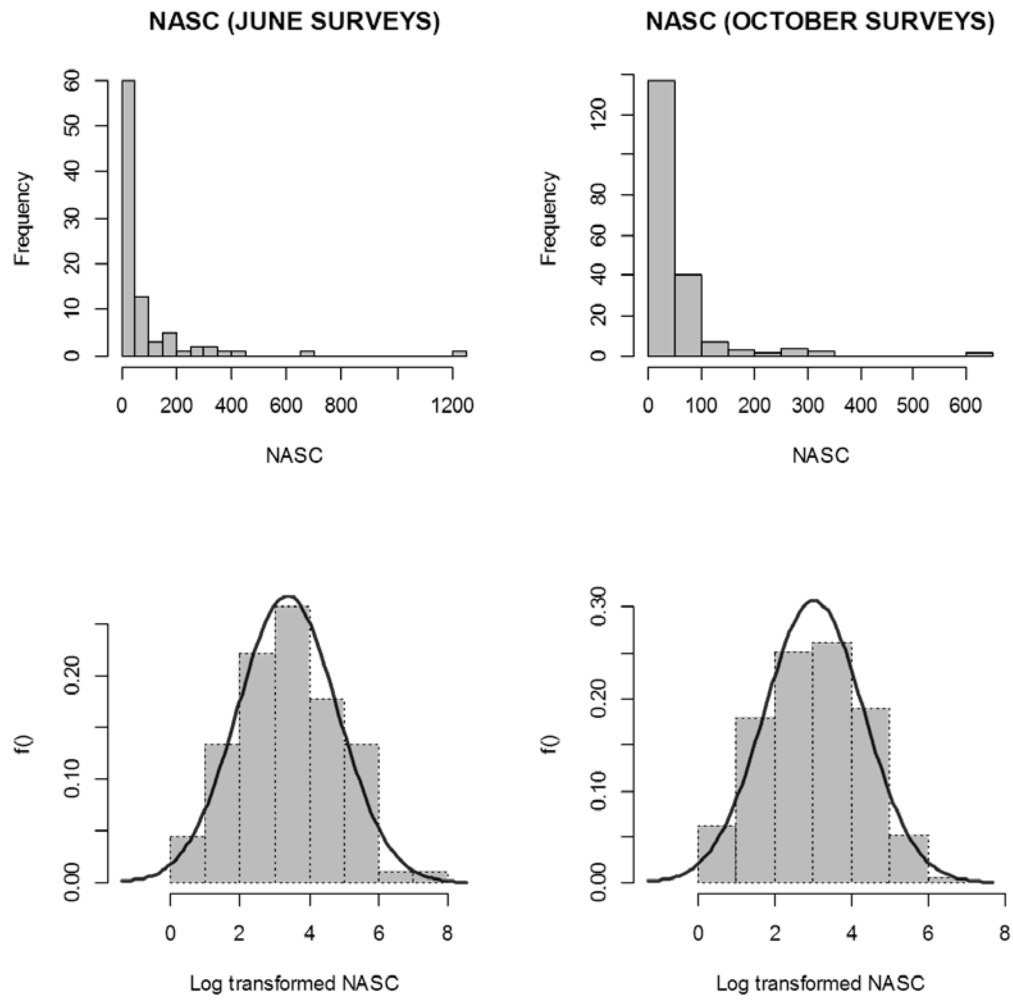

Figure 67. NASC distribution for *S. pilchardus*, upper figures show actual distribution, lower figures log transformation for June and October surveys.

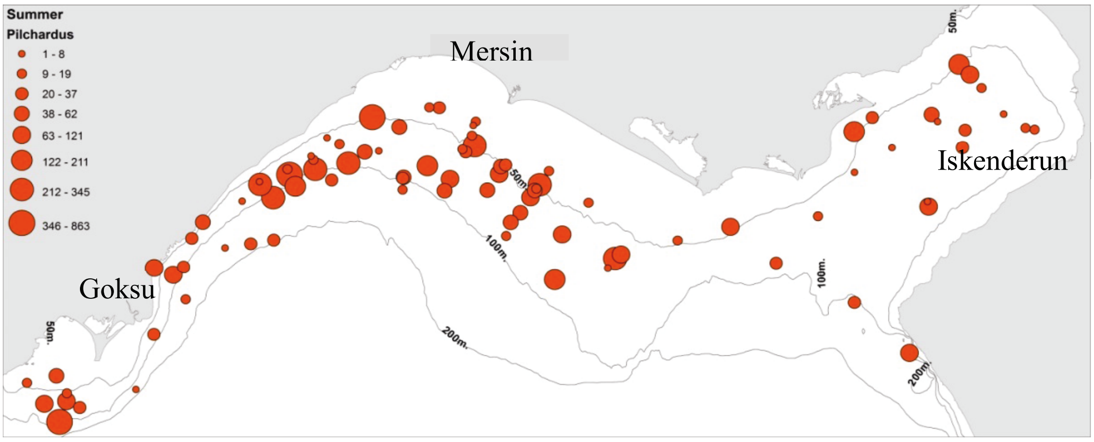

Figure 68. Distribution and density of *S. pilchardus* in June surveys based on acoustic sampling.

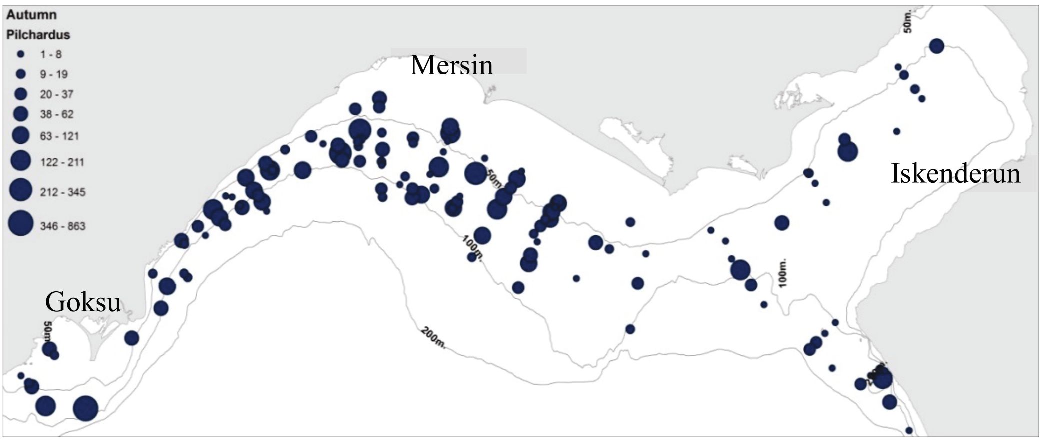

Figure 69. Distribution and density of *S. pilchardus* in June (upper panel) and October (lower panel) based on acoustic sampling.

The total acoustic biomass allocated to *S. pilchardus* exhibited a statistical distribution pattern quite similar to *S. aurita* (Figure 67). The results suggested a similar *S. pilchardus* distribution confined to the area deeper than 40m between Mersin and Goksu regions (Figure 68 and Figure 69). However when the seasons concerned, the distribution of the species occupied a wider range in depth and temperature during October surveys (Figure 70 and Figure 71).

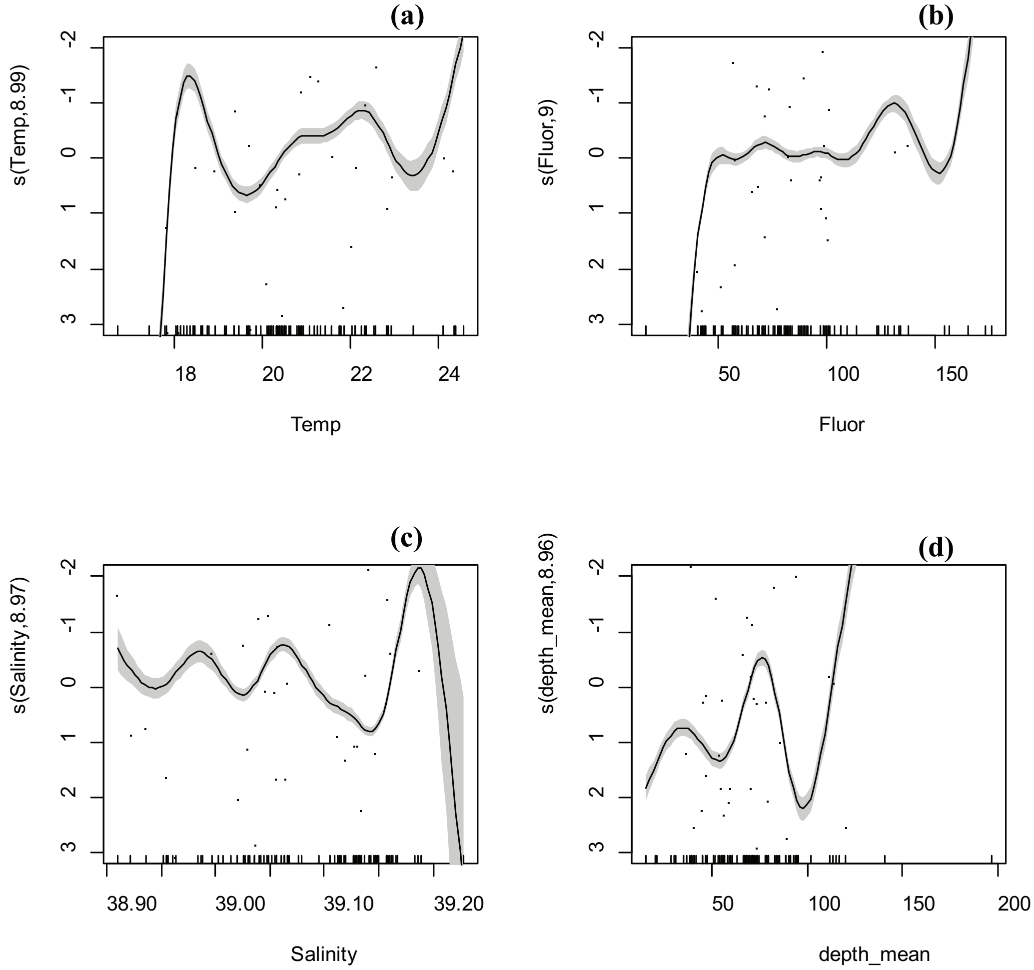

Figure 70. Estimated smoothing curves for the effect of temperature (a), fluorescence (b), salinity (c) and depth (d) over *S. pilchardus* distribution in June surveys. The solid line is the smoother and the shaded areas are 95% confidence bands. The ticks on the x-axis indicate the density of points for different variable values. And the vertical axes show the contribution of the smoother to the fitted values.

The variability in acoustic density of *S. pilchardus* during June surveys explained quite well when Poisson distribution with log link function GAMs applied in GAM and such that the model explained the 69.9% of the deviance. Nonetheless the same success rate was not observed in October dataset for *S. pilchardus* where the model explained only 13.7 % of the variability. Moreover, Poisson distribution has not provided a good fit. The negative binomial distribution provided better result for June dataset. The depth seems to be the most important variable explaining 27 % of the variability alone, and 39.3% when the sub regions used as categorical explanatory factor. Despite the increasing trend at higher depths, number of observations was fewer especially after 120 m isobaths. Therefore the peak at the occurrence was observed at around 70 m (Figure 70). This range shifted to 90m in October surveys, where another peak was observed at 40 m (Figure 71). Fluorescence and temperature were also important variables explained 24.2% and 23% of the variability respectively. In June the preferred temperature range seems to be at 18°C. It increased to 20°C in October. Salinity although statistically significant in terms of p-value, was the least important variable accounting for 16.3% of the deviance. In both surveys salinity peaked at 39.2 ppt value.

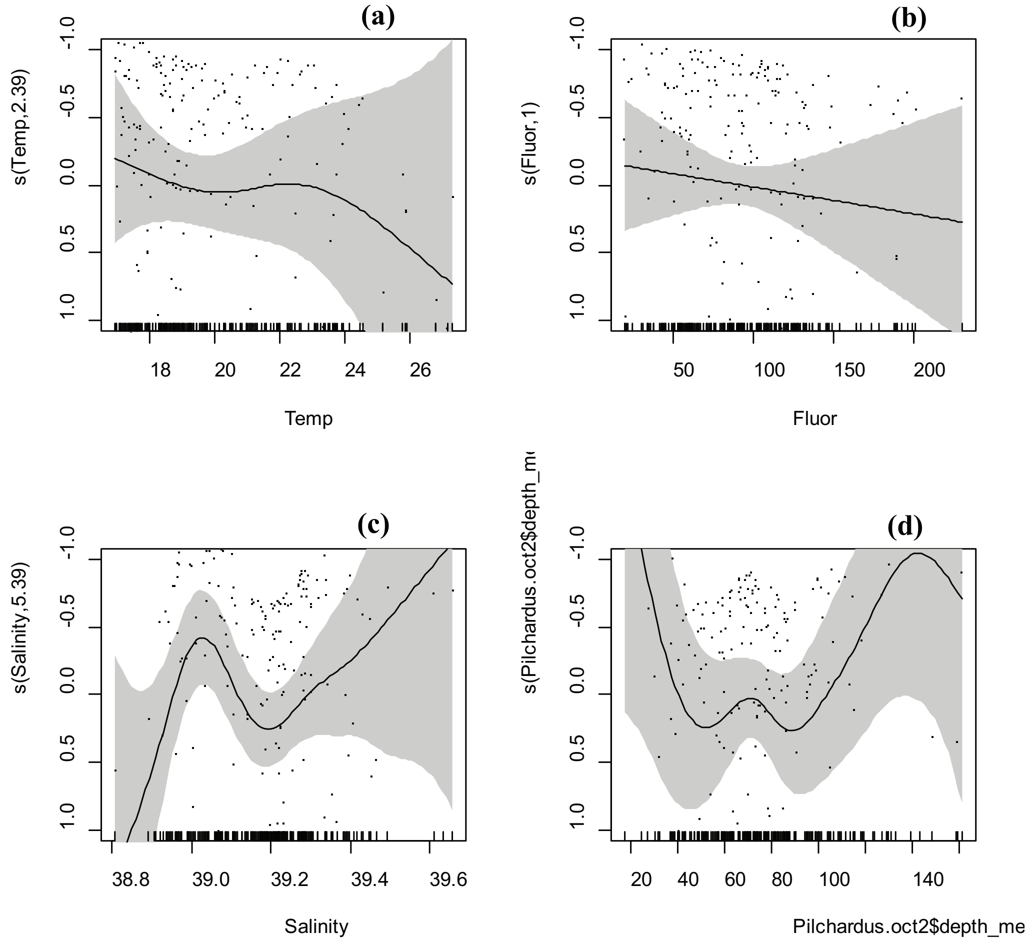

Figure 71. Estimated smoothing curves for the effect of temperature (a), fluorescence (b), salinity (c) and depth (d) over *S. pilchardus* distribution in October surveys. The solid line is the smoother and the shaded areas are 95% confidence bands. The ticks on the x-axis indicate the density of points for different variable values. And the vertical axes the contribution of the smoother to the fitted values.

3.7 Spatial distribution related to SST and Chl-a from Satellite data

Initially the maps created to compare the CTD measurements and satellite derived SST (shown in Figure 72 with the same color scale). Except from the June 2009, the value observed by satellite image in June 2010 and June 2011 were very similar to those measured by CTD and therefore safely interpolated using Krigging algorithm. June 2009 data further examined, before involving in the dataset.

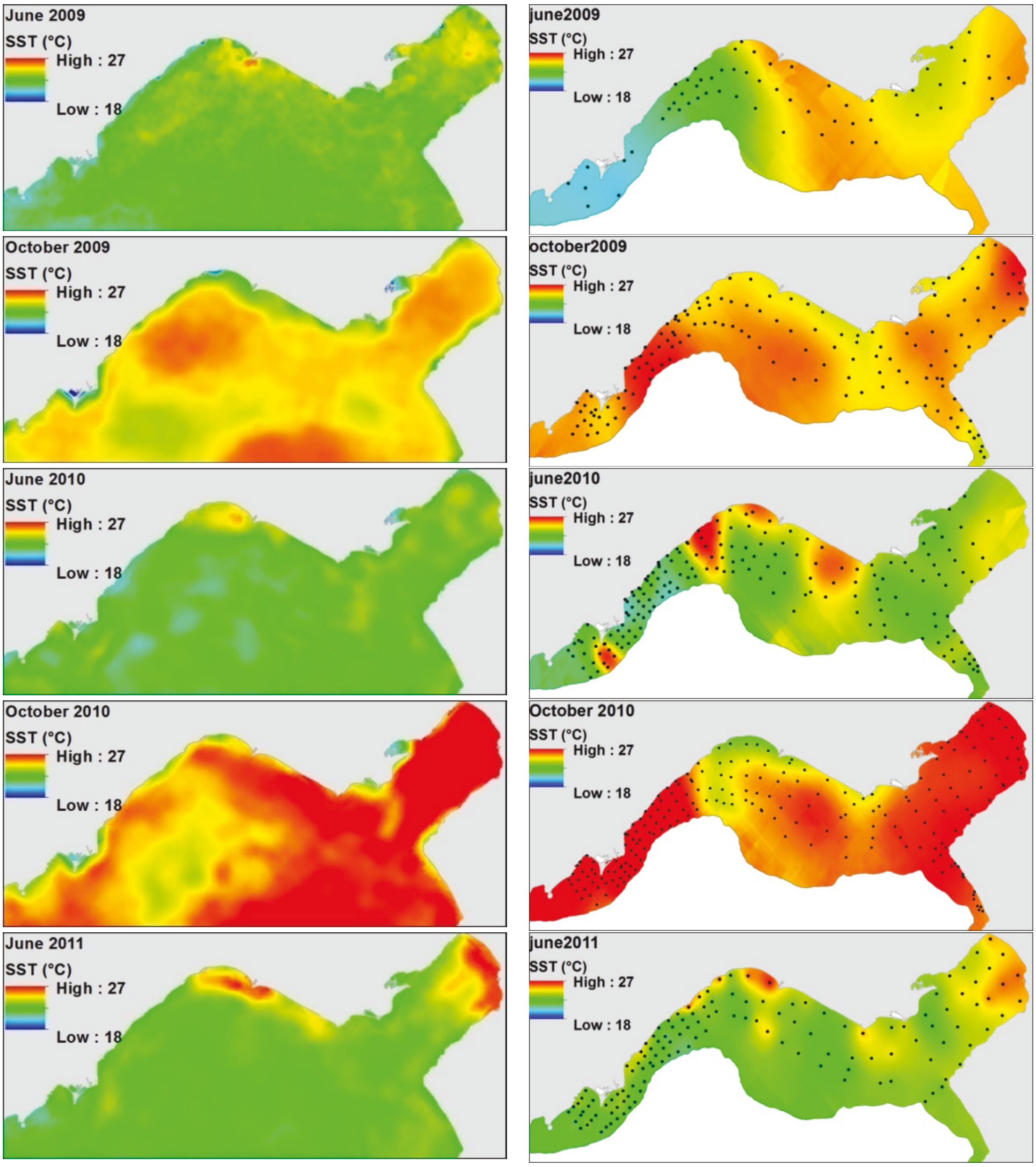

Figure 72. SST distribution. Left panel shows the satellite derived SST, right panel interpolation of SST measured using CTD.

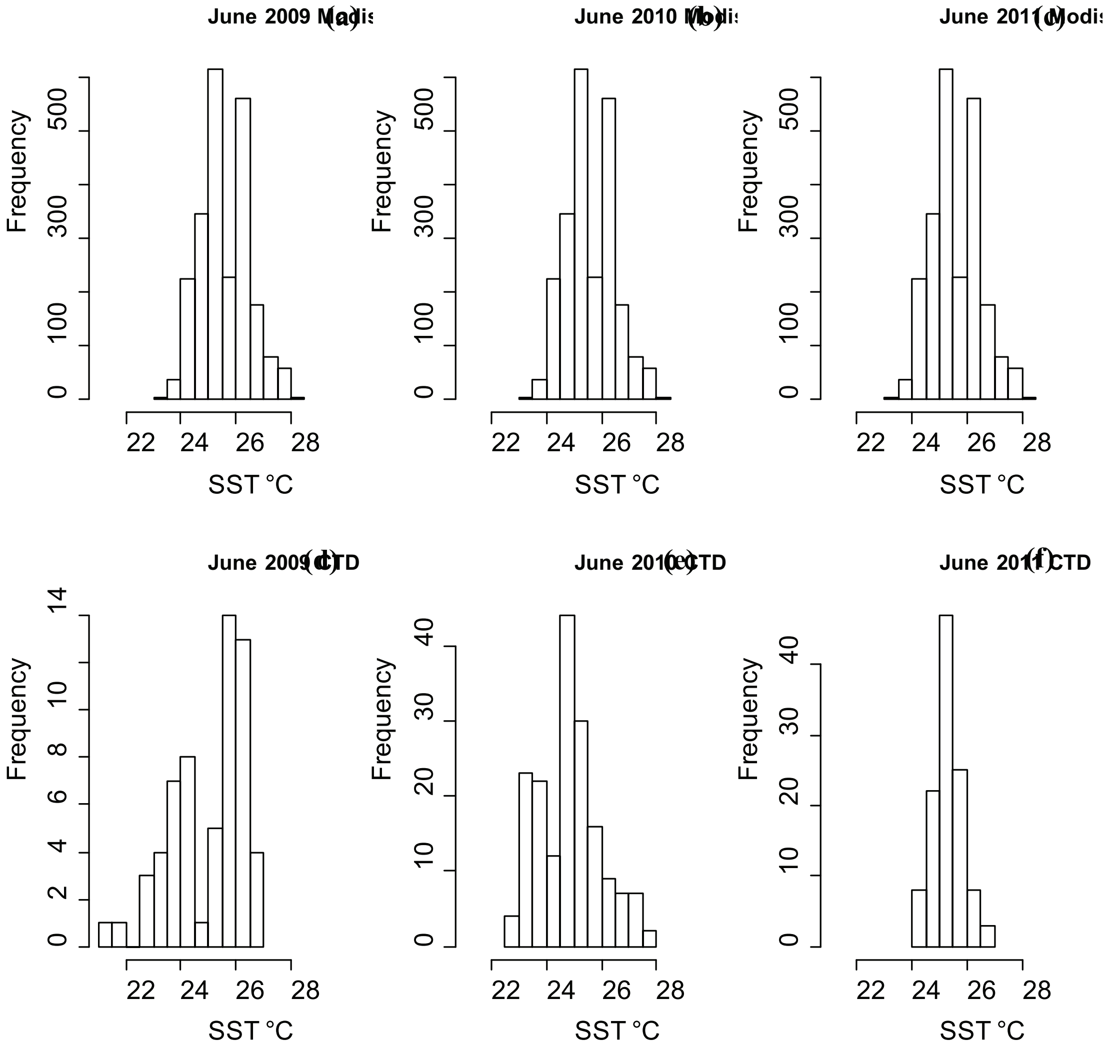

Figure 73. CTD measurements versus satellite SST for June surveys. Panels (a), (b), (c,) shows the distribution of modis-aqua satellite measurements for June 2009, 2010 and 2011. Panels (d), (e), (f,) shows the distribution of modis-aqua satellite measurements June 2009, 2010 and 2011.

In the pooled June dataset, the temperature varied between 23 °C and 27°C with the peak at 25 °C as shown in histograms in Figure 73. In essence, the histograms in Figure 73, display a very similar pattern except for the June 2009 which was eventually represented by a fewer CTD observation points compared to the other surveys. In Figure 72, there was an apparent difference between CTD derived map and satellite data of June 2010. In the maps produced by interpolation of CTD measurements, two warm patches were remarkable, which do not exist in satellite map.

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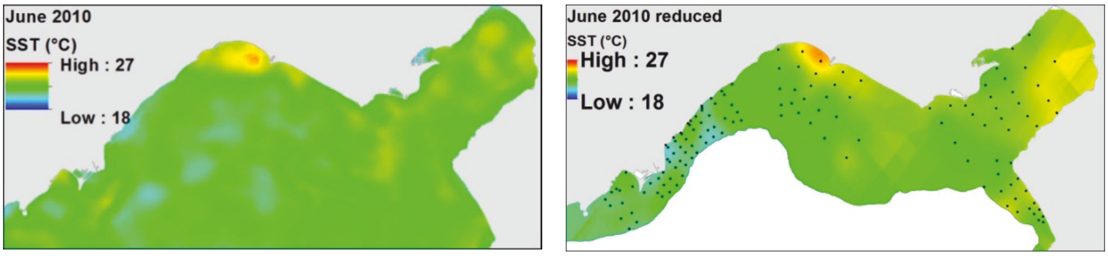

Figure 74. Comparison of satellite derived SST to interpolated CTD measurements excluding the last two days data in June 2010. Satellite derived SST map (left), CTD derived SST map.

When examined carefully, it was noticed that these areas corresponded to the stations performed at the end of the survey. Due to cruise plan followed during the survey, these stations were visited on the return trip during the last two days of the cruise. In the meantime, it was evident that the surface temperature raised drastically, therefore differed from the surrounding points. When these two transects excluded from the interpolation, the result was very similar to the satellite map corresponding to the same time scale. The similarity in SST pattern in two images was particularly reamarkable in capturing relatively warmer patch inside the Bay of Mersin (Figure 74). Chlorophyll concentration maps derived from satellite images and maps created based on in situ fluorescence measurements are shown in Figure 75. Although direct comparison between these two variables cannot be made due to the difference of methods used for estimating chlorophyll concentration, both data present a proxy for the primary productivity in studied area. The empirical comparison showed that the resemblance of these two images was remarkable with respect to the emphasis of the location with higher production such as Bay of Mersin and gulf of Iskenderun. Highest chlorophyll-values were observed constantly at each survey period at inshore part of Mersin Bay with maximum values exceeding 5.0 mg m^{-3}. In Figure 76 averaged chlorophyll-a concentrations for each subregions divided based on 50m isobaths (inshore <50m and offshore > 50m) are given. Along the entire study area highest chlorophyll concentration level was observed at inshore part of Sr-2 corresponding to Mersin Bay with mean values reaching nearly 2 mg m^{-3}.

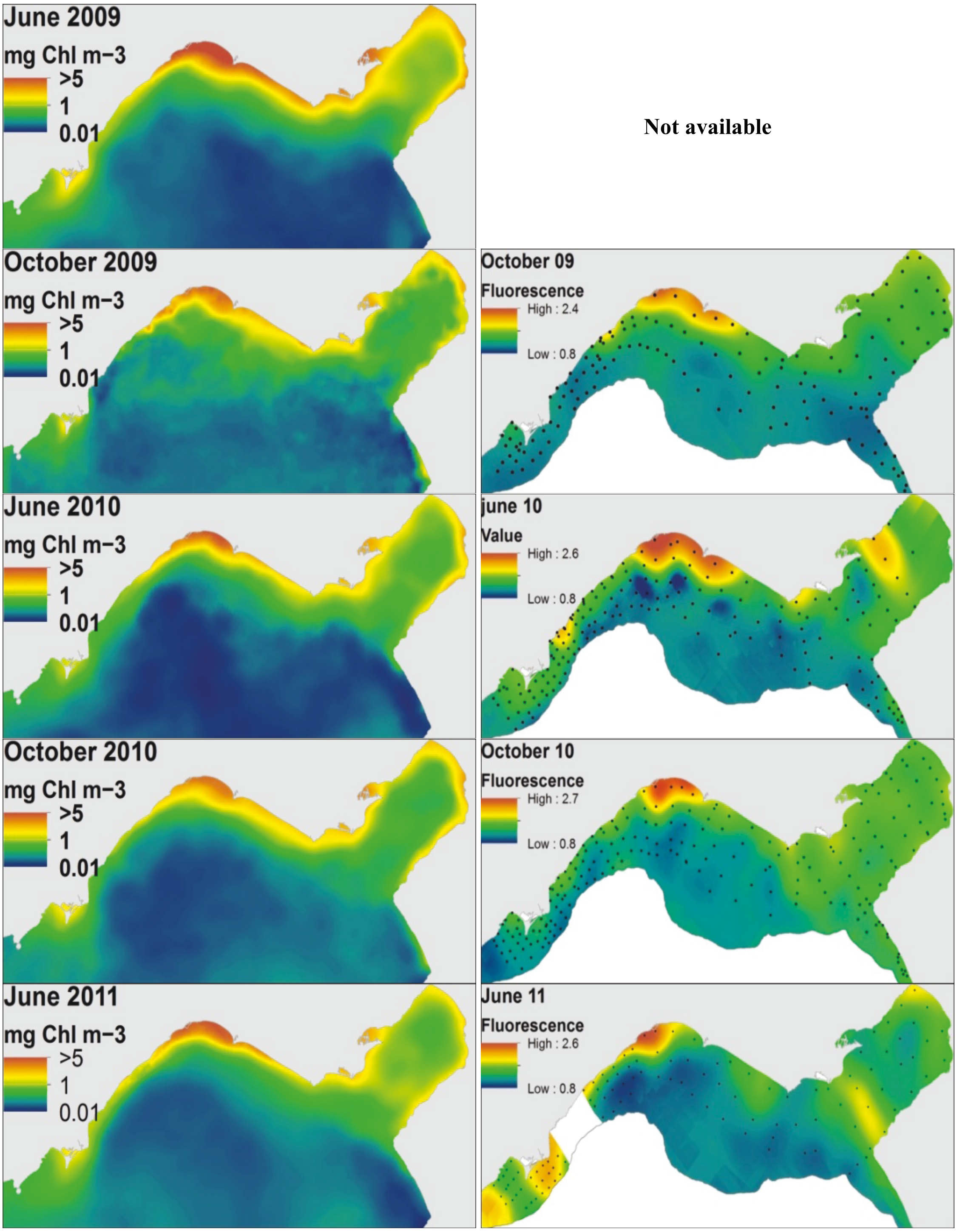

Figure 75. Satellite derived surface Chla distribution

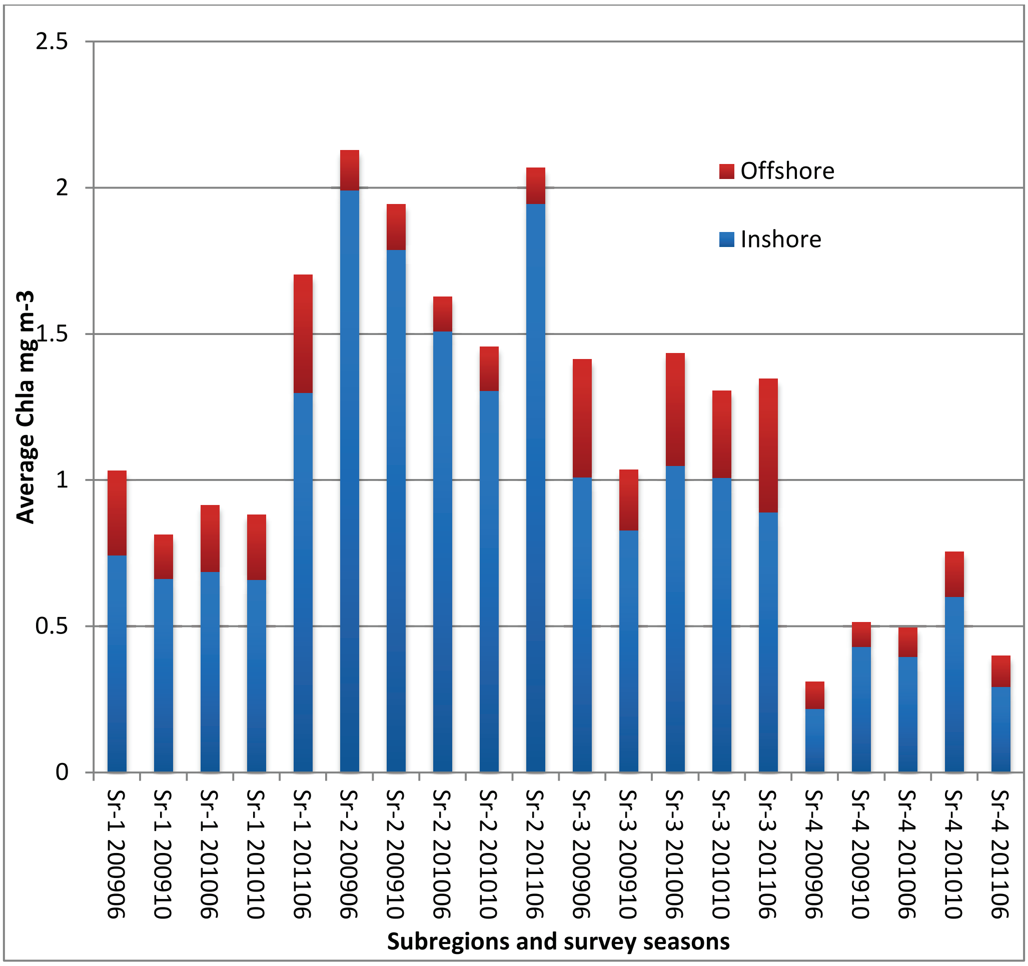

Figure 76. Chlorophyll-concentrations per survey period / per subregions. Blue columns show inshore strata and the red columns stacked over blue show offshore strata.

Furthermore in order to compare the model response of the fish distribution to the satellite derived chlorophyll and fluorescence measurement a series of GAM models were fitted separately without including the effect of the depth and SST (Figure 77). The obtained curves in Figure 77 were similar to the response of *S. aurita* density, where a sharp increase observed at increasing chlorophyll level at small values. The curve has stabilized after a certain level (after 1 mg/m^3 in satellite data).

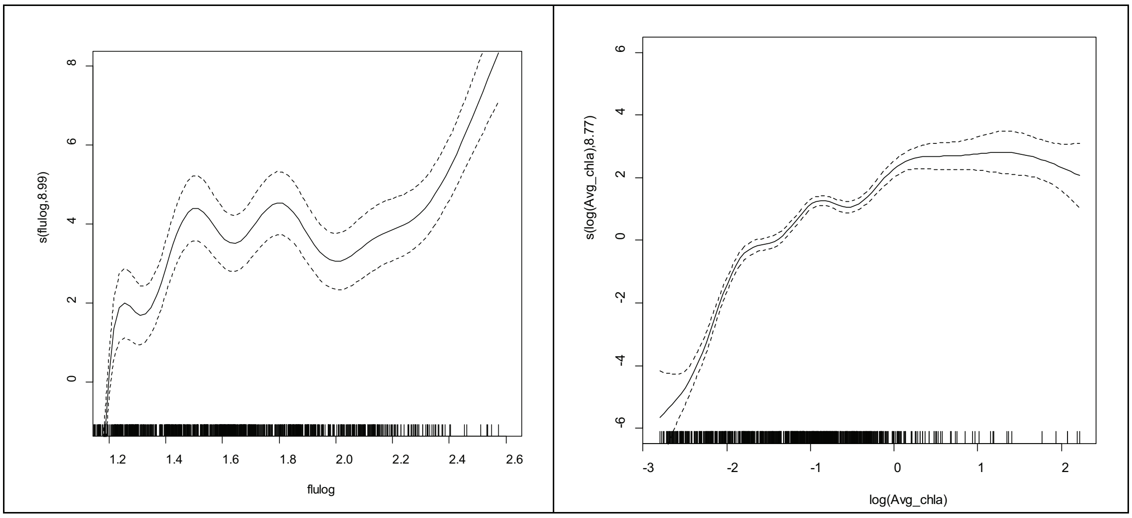

Figure 77. Comparison of the satellite derived chla (a) with the fluorescence measured *in situ* with regards to their effect on *S. aurita* density distribution; shown as estimated smoothing curves The solid line is the smoother and dotted lines are 95% confidence bands. The ticks on the x-axis indicate the density of points for different variable values. And the vertical axes the contribution of the smoother to the fitted values.

Concerning the presence-absence of *S. aurita*, the fitted logistic curves in Figure 78 show S-shape form where the rate of change was high at mid **p** values between 0.2 and 0.8. The figures suggest that the probability of observing *S. aurita* schools increases quickly after 0.1 mg m−3 level and continue to increase until values above 5.0 mg m−3 matching to the high chlorophyll concentration zones.

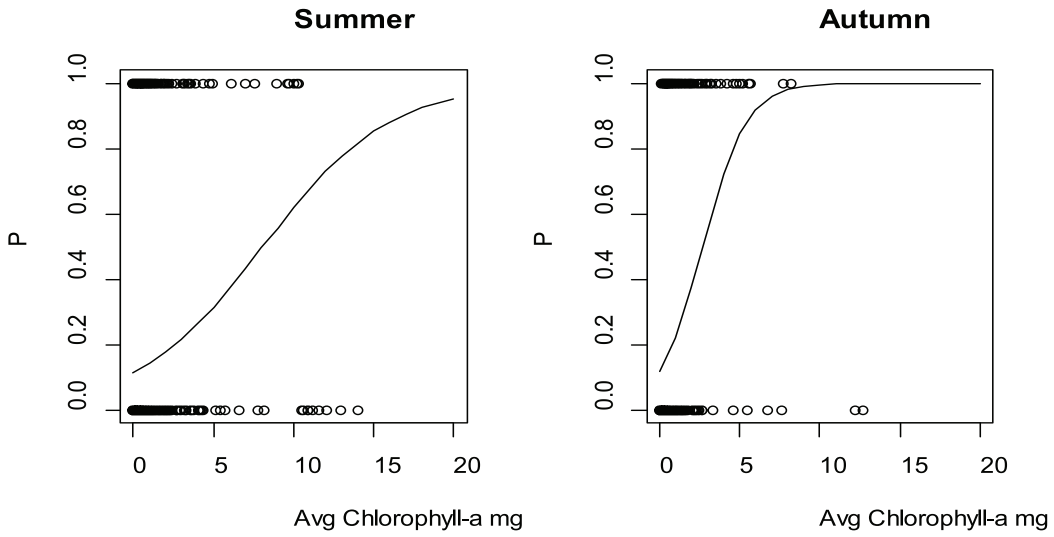

Figure 78. Fit of the Generalized Linear Model for June and October surveys with binomial distribution for relationship between chlorophyll-a and *S. aurita* distribution based on presence / absence.

Pearson correlation analysis indicated that satellite derived chlorophyll concentration was significantly correlated to and fluorescence measurements (R^2=0.69; P<0.05) as the plot of which shown in Figure 79 .

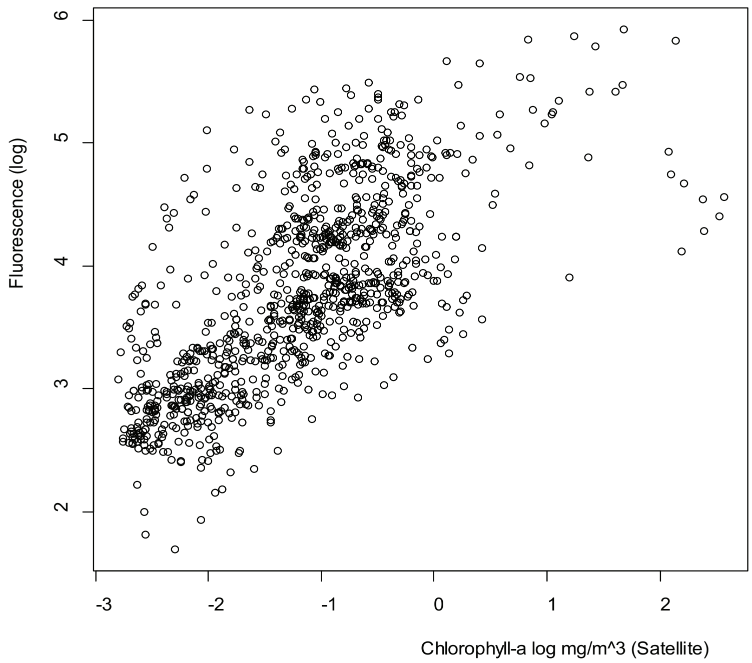

Figure 79. Plot of surface fluorescence measurements (log) to satellite derived chlorophyll concentration (log)

Similar models were fitted for *S. aurita* as a response to satellite SST and in situ measurements. The obtained curves showed similar response to each other, as they showed an increasing pattern until 23°C and a sharp decrease at 26.5°C (Figure 80).

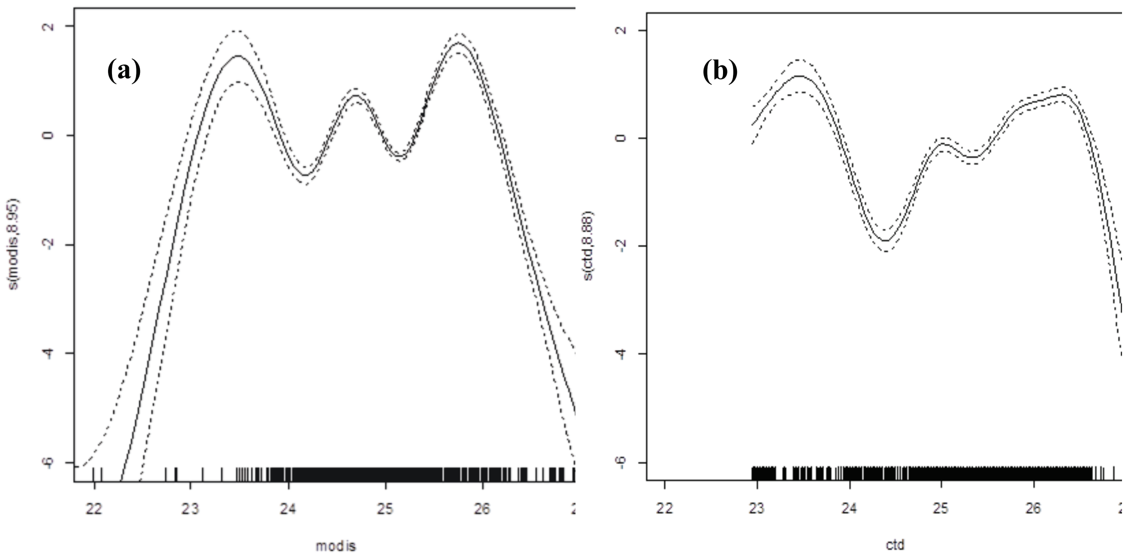

Figure 80. Comparison of the satellite derived SST (a) with the *in situ* measurements(b) with regards to their effect on *S. aurita* density distribution; shown as estimated smoothing curves The solid line is the smoother and dotted lines are 95% confidence bands. The ticks on the x-axis indicate the density of points for different variable values. And the vertical axes the contribution of the smoother to the fitted values.

The Pearson correlation analysis indicated %74 of correlation ($P<0.05$) between processed insitu SST maps corresponding to the survey points and satellite SST for the same points, their plot is shown on Figure 81.

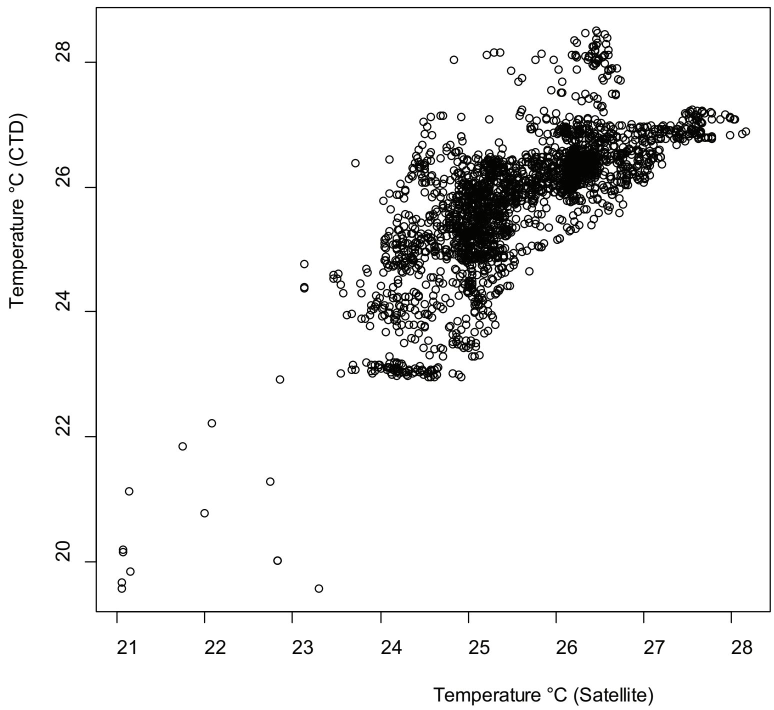

Figure 81. Plot of surface temperature values against satellite derived SST.

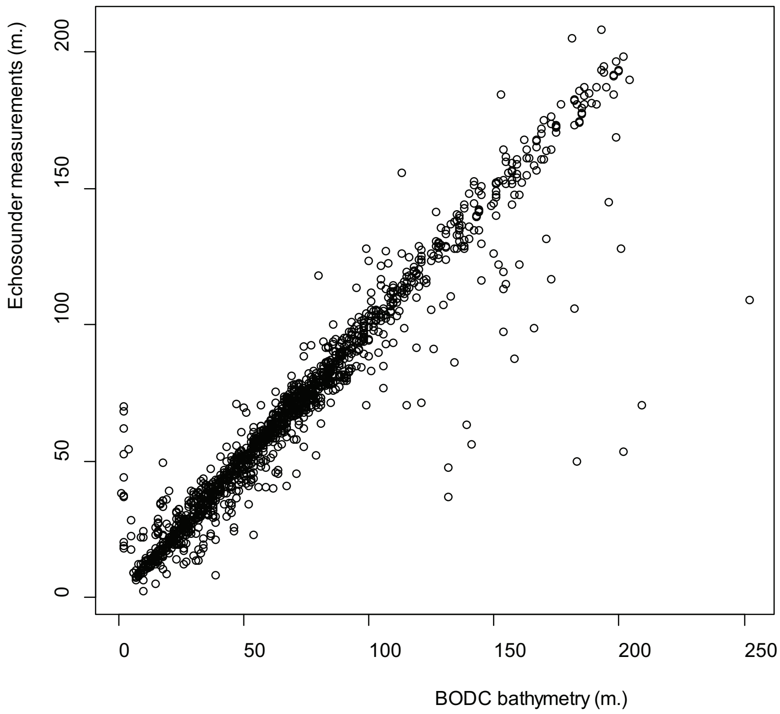

Figure 82. Bathymetry data obtained from BODC against acoustically measured depth.

Lastly, %96 of correlation was found when the consistency of the BODC bathymetry data was tested with the acoustically measured depth by Pearson correlation analysis (Figure 82).

3.8 Evaluating the habitat suitability

In order to identify the optimal habitats for *S. aurita* after the model the GAM constructed for prediction is given below.

Gam (S. aurita) ~ s (SST) + s (Chl-a) + s (Depth)

The use of parameters was justified in previous stage. As a result the model explained %63.6 of the deviance, which was a considerable fraction. The following tests were performed to evaluate the accuracy of the predictions. First test was performed using June dataset. The maps shown in same color scale in Figure 83 were produced by interpolation of observed values and predicted values.

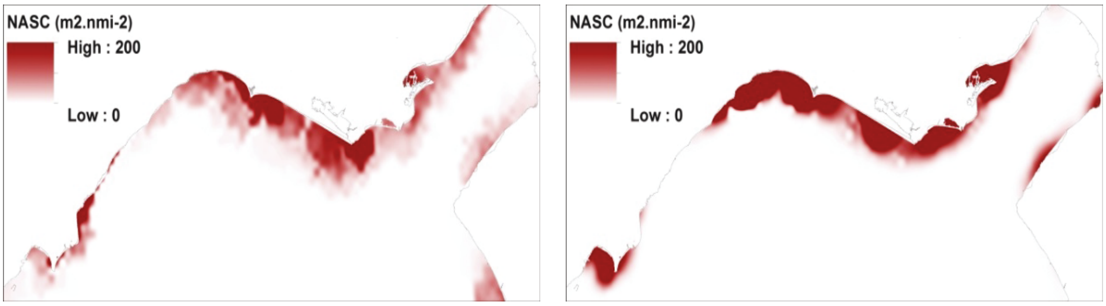

Figure 83.Observed NASC distribution of *S. aurita* (left) and predicted distribution as model result for June surveys.

Both maps were generated by interpolation using Krigging method. Although the predicted values were higher in terms of *S. aurita* density, the locations of the dense concentrations were accurately predicted by the model, particularly at inshore areas of the Bay of Mersin, and western coast of the Gulf of Iskenderun. Subsequently, using the same model a test was performed using October dataset as an input. Similarly very accurate description of the *S. aurita* high density areas was obtained Figure 84.

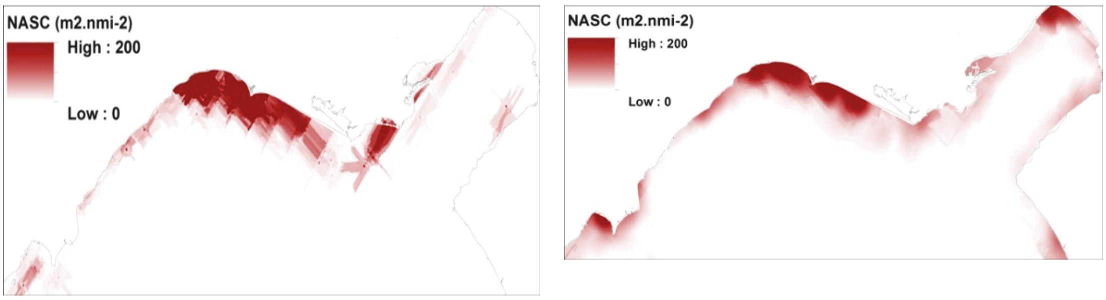

Figure 84. Observed NASC distribution of *S. aurita* (left) and predicted distribution as model result for October surveys.

These results suggest that the model predictions were accurate enough to obtain reasonable estimates of the optimal habitats for *S. aurita* and probable biomass density therein. In the next step, the area for the spatial prediction of the *S. aurita* distribution was expanded to include entire Levant Sea. The required parameters were extracted using a grid system in resolution of 1 nautical square mile. The prediction was performed using the same model obtained in previous stage. Distribution graphic for the parameters used in this analysis are given in Figure 85.

SST imagery shows that eastern part of the Levantine sea was warmer than the west, moreover, the warmest parts were located in South-East of Turkish coasts, corresponding the studied area during the study period, and North-East of Egypt, the wide shelf area in front of the Nile Delta. Similarly these locations were prominent areas in respect to chlorophyll concentration shown in the Chlorophyll-imagery (Figure 85).

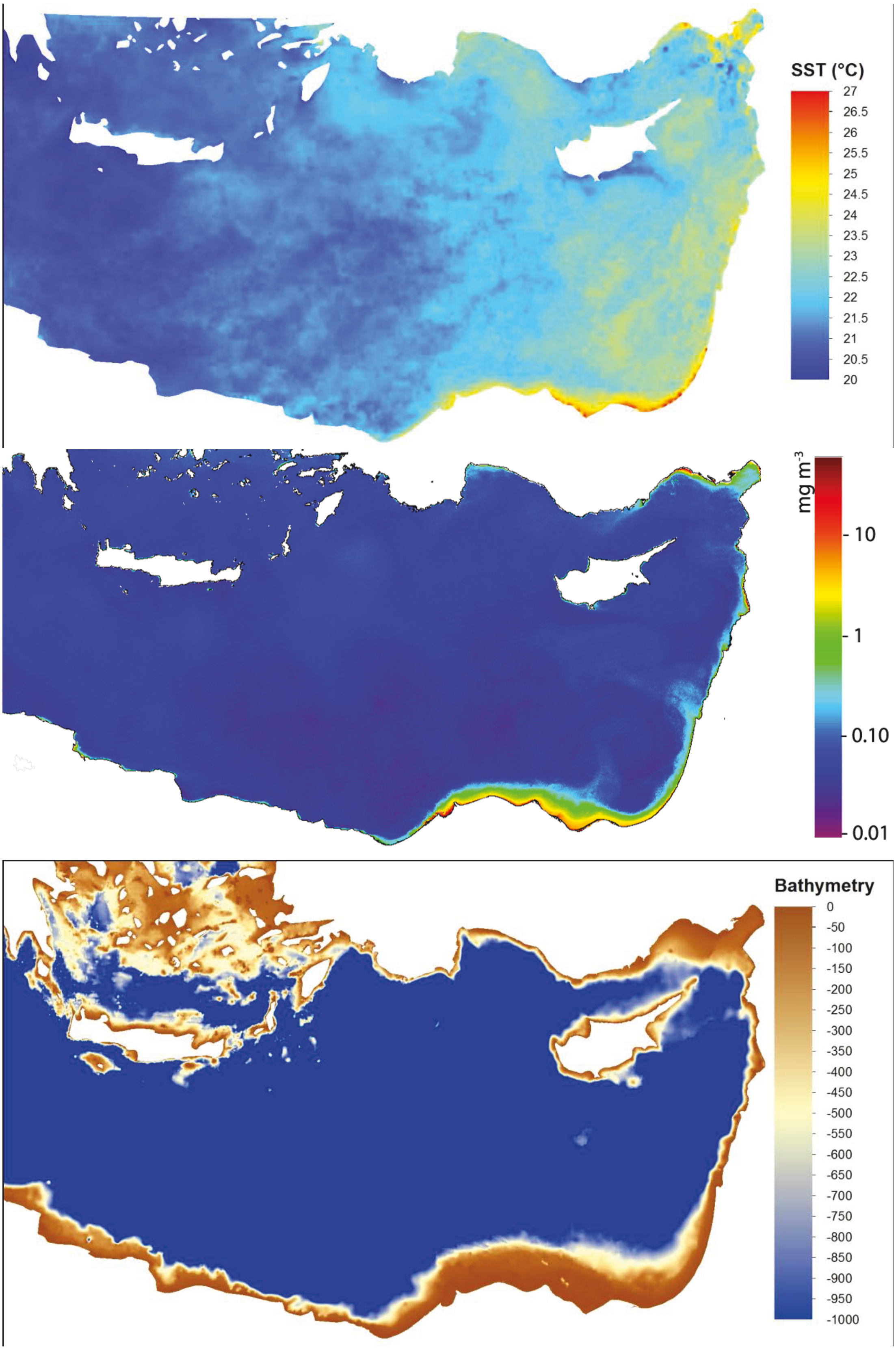

Figure 85. SST, Chl-a and bathymetry for entire Levant sea. SST and Chla maps are monthly average of June 2010

Using the data presented in Figure 85 as input for the prediction the optimal areas for *S. aurita* were determined using the same model. The generated map using prediction output is shown Figure 86. The results suggest that, the largest habitat that meets the requirements of the *S. aurita* located in the south-east coasts of Levantine Sea, mainly corresponding to the wide shelf area of the Nile Delta. When the Turkish coastline examined, the most prevailing areas in terms of *S. aurita* preference seem to be located at the studied area. A secondary core area was located in Gulf of Antalya however in a lesser scale compared to Eastern coasts.

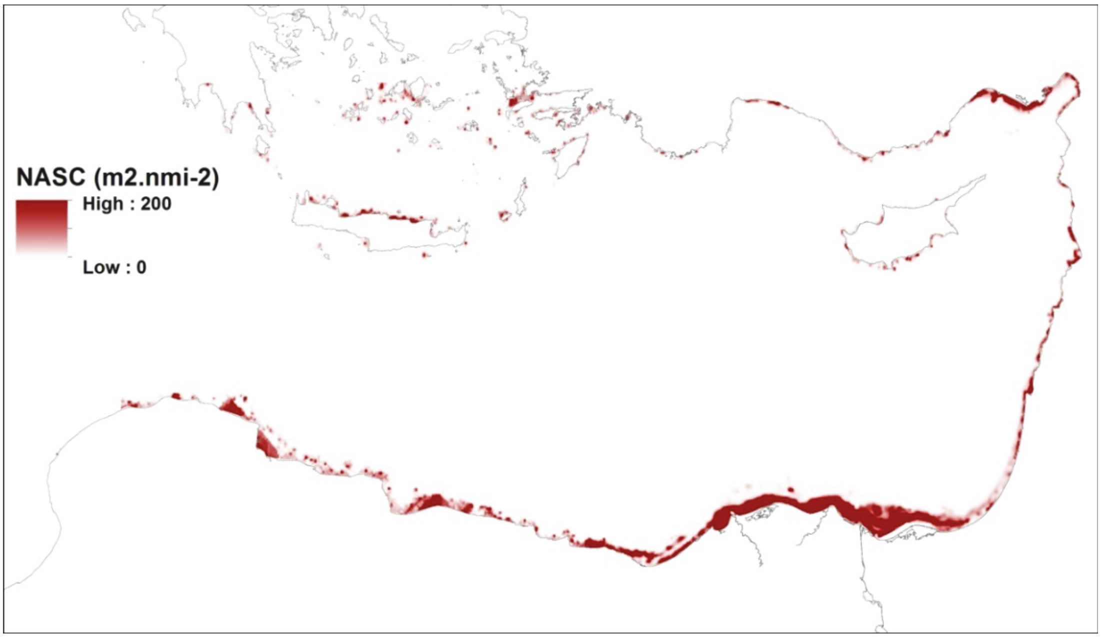

Figure 86. Map of the potential optimal habitats that fit the requirements of *S. aurita* based on model prediction.

3.9 Considerations regarding the climate change scenarios

At this stage to test the effect of the warming on distribution of the *S. aurita*, predictions were preformed based on results of NEMOMED 8 climatic model implemented by Albouy et al. 2013 where they based based their projections on A2 IPCC emission scenario. For that the temperature was increased gradually at each modeling step, while the chlorophyll values were kept constant. For input, June 2010 values were taken. The maps showing the results of obtained distribution with the changing temperature are given in Figure 87. In this figure the maps on the left shows the change in distribution of the predicted *S. aurita* density with gradually increasing temperature. The figures on the right show the change in SST map with increasing temperature.

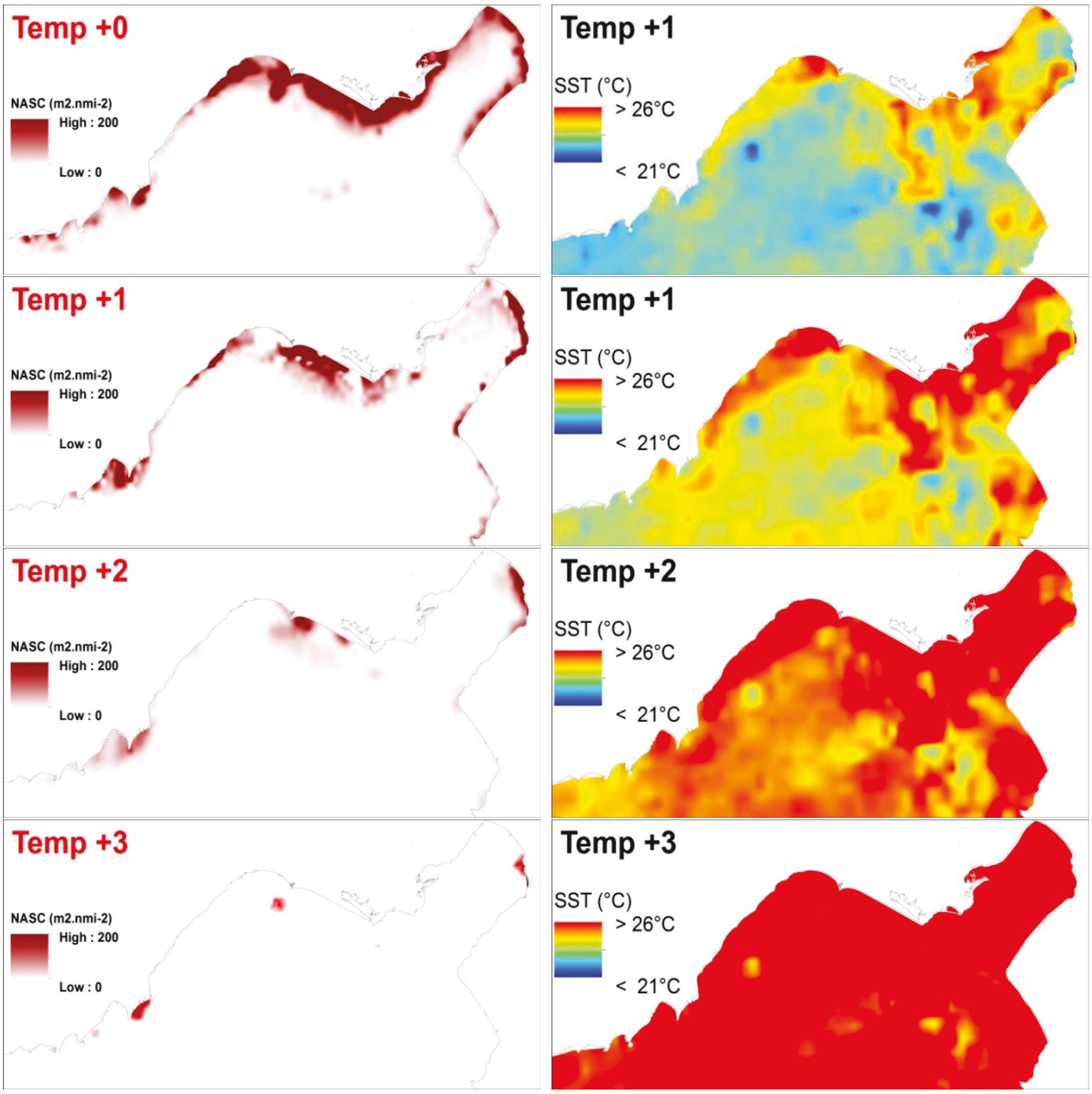

Figure 87. The predicted biomass distribution of *S. aurita* for June 2010 for study area. Maps show predictions for actual conditions and for warming conditions with 1 °C increment at each step (eg. Temp +1 was : 1 °C increase) , the panels on the left correspond to the expected temperature distribution for each 1 °C increment

The predictions suggest a dramatically decline in the estimated biomass with increasing temperature. For June 2010, it dropped to the 68.01% level with +1 °C increase in SST values while the predicted acoustic biomass was corresponding to the 117.25% of the actually observed biomass. A similar sharp drop was observed when temperature was raised +2 °C which resulted in a remarkable drop reducing the *S. aurita* density to 14.4% of the current level. At +3°C rise the species population almost completely disappeared decreasing to the 0.4% of the current level (Table 32.)

Table 32. The estimates of observed predicted biomass for June 2010 with changing scenarios

	NASC	BIOMASS
Observed	8002	7154
Predicted	9382	8388
plus 1	5442	4865
plus 2	1156	1034
plus 3	36	32

In the final stage the climate change scenarios were tested for the entire Levantine Sea. The results were identical to those shown in Figure 87; suggesting a very sharp density decrease with increasing temperature. It was estimated that the *S. aurita* population will reduce 49.3% and 10.8% of its current level with 1 °C and +2 °C rise, respectively. Finally it was found that if the rise in temperature reaches +3 °C above the nominal level the species almost totally disappear in the region dropping to a negligible size of 0.3% of their current level (Figure 88). These projections show that even optimistic climate scenarios suggest a dramatic decrease in the size of the geographic ranges of the species. The models also suggest that the *S. aurita* population will be vanished in the entire Levantine Sea by end of the 21st century, with given conditions in June (Figure 88).

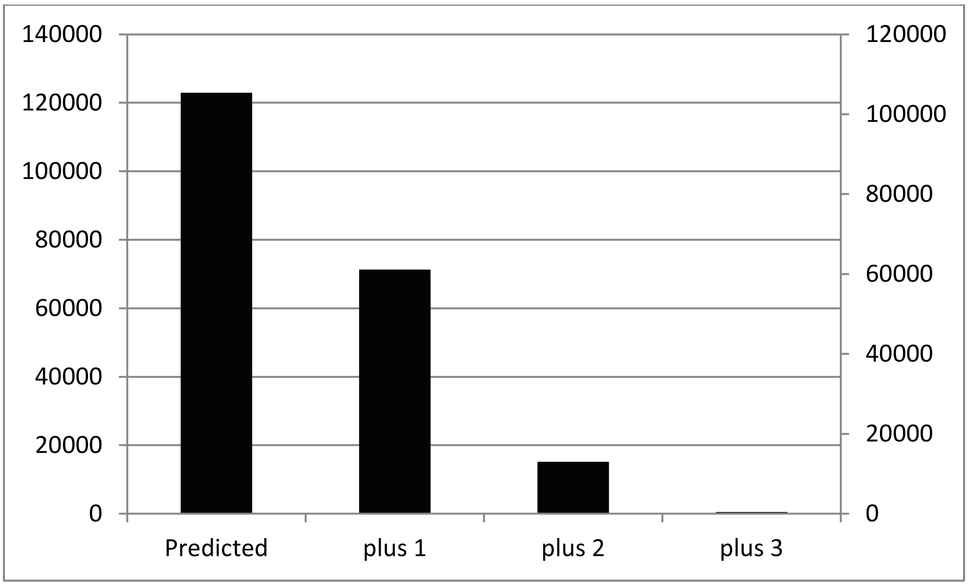

Figure 88. The predicted biomass histograms for June 2010 for entire Lenantine basin according to warming scenarios. Histograms shows, predicted biomass for actual conditions and for warming conditions with 1 °C increment at each step (eg. Plus 1 was : 1 °C increase)

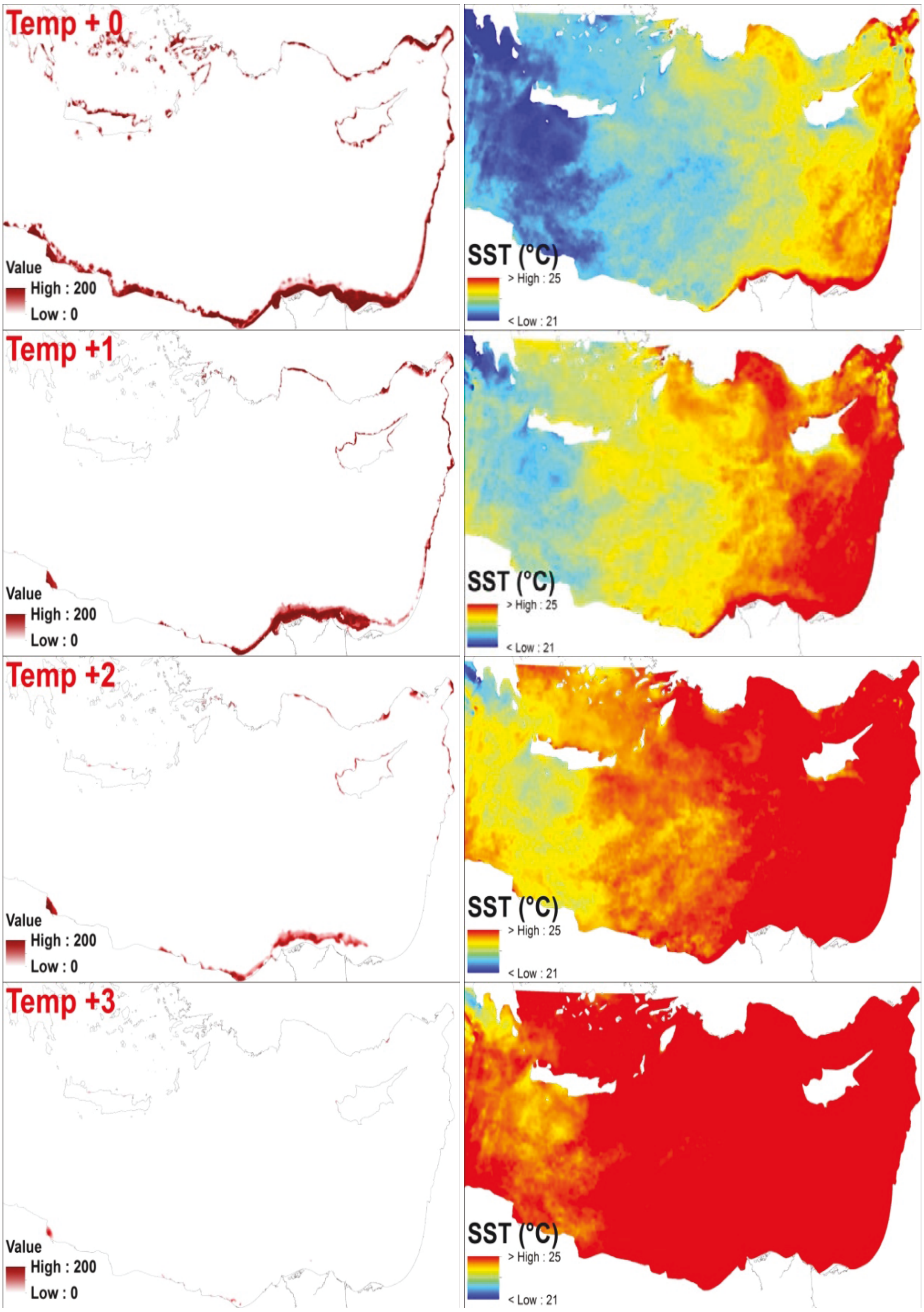

Figure 89. The predicted biomass distribution of *S.aurita* for June 2010 for entire Levantine basin. Maps show the predicted biomass for actual conditions and for warming conditions with 1 °C increment at each step (eg. Temp +1 was : 1 °C increase), the panels on the left correspond to the expected temperature distribution for each 1 °C increment .

4 Discussion

4.1 Species distribution and habitat preferences

The results indicated that the most dominant species *S. aurita* is widely distributed all along the coast in the study area within the 0-50 m bathymetric range. Specifically, the largest acoustic densities and trawl catches for *S. aurita* were observed in the Bay of Mersin where the chlorophyll concentration was the highest. Correspondingly, the GAM results indicated the abundance of this species was very much determined by chlorophyll and depth, including temperature (Table 31, Figure 65 and 66) The broad continental shelf in the Bay of Mersin and its adjacent regions were the main fishing ground for the fisheries including purse seine fishery targeting *S. aurita* in the study area. The reason of attraction as indicated by the results of this work was associated with high production which can be seen in chlorophyll maps (Figure 75). Chlorophyll concentration was a measure of the standing stock of phytoplankton in surface waters; therefore *S. aurita* possibly selects these areas due to high concentrations of food associated with these productive waters. The chlorophyll (proxy for the productivity) seems like trapped in the bay and its concentration decreases sharply in the offshore direction, which in turn constrict the distribution of the fish to the near the coastal, eutrophic areas (Figure 51 and 75). Therefore, findings of this study suggest that, the coastally distributed high biomass confined to a narrow geographical range give shape to the local fishery as well as a purse seine fishery between artisanal and industrial scale has been developed despite the low market price of the species.

The habitat preference of the *S. aurita* population in the study area seems to conform to other populations of the species in the different seas. One of most abundant populations of *S. aurita* off Northwest Africa has been investigated by Zeeberg et al. (2008) regarding the species distribution and environmental dynamics. They found that *S.aurita* was associated with high primary productivity at upwelling areas beside its temperature preferences. Similarly in the case of this study the most favourable areas of *S. aurita* were found to be located in the regions where the primary productivity was high. However unlike to Zeeberg et al. (2008) in the case of this study, the high chlorophyll density in these regions was induced by terrestrial input either by urban runoff or freshwater runoff rather than upwelling.

When the overall distribution of the total fish density considered, different habitat preferences appeared to be exist in the area. In the GAM analysis the effect of chlorophyll concentration on the distribution of unapportioned total acoustic fish density estimates, displayed quite irregular pattern that was characterized by different peaks at lower values and higher values. As the fish density values used in the analysis embraces more than one species, these peaks, could possibly suggest partitioning of the water column by different species. Furthermore, the results indicate that, the temperature had a critical role of in determining the *S. aurita* distribution, in addition to the two parameters of depth and chlorophyll. Increasing fish density values at higher temperatures might be due to the contribution of the juveniles and particularly the young of *S. aurita*, at shallower depths. Larger fish schools were generally associated with hydrographic processes at coastal regions also induced by terrestrial and anthropogenic input that were known to influence the distribution of zooplankton which is the food of the small pelagic fishes.

The fish distribution characteristics showed some differences in June compared to October surveys. The October surveys corresponds to the period when the fresh water inflow at rivers is at minimum in the region (Fujihara et al., 2008) therefore cooling effect due to rivers should be considered as low compared to June). GAM models show that the acoustic density display a clear positive relationship with temperature having peak at 23^{o}C at June and 26^{o}C in October. Furthermore, it seems that thermocline constitutes a barrier limiting the bathymetric range of the species. The distribution pattern of the small pelagic fish in the study area was presented in Figure 34 and 28Figure 35. The dominance of *S. aurita* in the area signifies its advantage in using resources even though it compete for the same biological niche with other species such as *D. elipsoides* which require similar thermal window. The advantage of S. *aurita* can be best described by the suitability of the area for its reproduction. The spawning season of this species is known to last year round or over several months (Ettahiri et al., 2003; Ter Hofstede et al., 2007). According to Tsikliras et al. (2005) in the North Aegean Sea the condition factor of *S. aurita* increases in spring due to increased primary production which supports the energy demand during spawning. Furthermore Tsikliras et al. (2005) argue that the species improve its condition during summer and October to store energy for winter. In the study area findings of Karakaş (2011) showed that the spawning of the *S. aurita* extends from April to June and was determined by the regional conditions mainly a combination of chlorophyll and temperature. Being a warm water species, the area seems to provide its requirements in terms of water temperature, and chlorophyll concentration. Earlier, Ben-Tuvia (1960), Ettahiri et al. (2003), Tsikliras (2005), and Sabates et al. (2006) have found strong association with temperature and *S. aurita* presence with a positive relationship. Ettahiri et al. (2003) linked the spawning of round *S. aurita* with high water temperatures. Tsikliras (2005) found that the gonado somatic index of *S. aurita* was positively correlated with temperature. In a study to investigate temporal and spatial changes in *S. aurita* distribution in the western Mediterranean, the increase in sea temperature seems to favour round *Sardinella*'s abundance (Sabates et al., 2006). It was also suggested that owing to increasing water temperature, *S. aurita* is currently expanding its establishment area in northward direction. The same statement has been emphasised by Perry et al.(2005) that the thermophiles marine fishes tend to expand their ranges toward north in the northern hemisphere due to climate change. In agreement with these earlier studies in other regions, effect of the temperature in this study was noticeable with positive correlation up a point at $27^{O}C$. Consequently the results indicated that the effect of temperature on the distribution of the small pelagics in the area should not be ignored.

Schismenou et al (2008) described the spawning areas of anchovy and *S. aurita* in the North Aegean Sea based on satellite driven environmental variables and presence/absence egg data from ichthyoplankton surveys. In their study, Schismenou et al (2008) predicted *S. aurita* distribution and found that they were distributed closer to coast compared to anchovy. The results of this study agree with the *S. aurita* distribution suggested by Schismenou et al. (2008); however there were noticeable differences in the anchovy predictions. That is; the aggregations of anchovy were in loosely packed aggregations distributed homogenously along the inshore-offshore extent. The anchovy aggregations located at inshore ranges were most probably comprised of a sub population with different characteristics in terms of habitat preferences, or possibly a recently introduced species due to continuous immigration of Lessepsian species similar to findings of Fricke et al. (2012).

Yet, in a similar study, Giannoulaki et al. (2008) modelled the presence of anchovy based on acoustic and satellite environmental data and bathymetry. In their study they used GAM models to predict the potential areas for spawning and presence of anchovy in the Mediterranean Sea. They used depth and chlorophyll as the main predictors for the models and found remarkable agreements between model output and observed distribution patterns of eggs and acoustic results. Based on the relationship quantified by their model, Giannoulaki et al. (2008) made predictions over the potential anchovy spawning grounds in the eastern Mediterranean. One of the areas confirming the preferred combination of temperature and chlorophyll was found in the north-eastern corner of the Levantine Basin which exactly corresponds to the studied area in this thesis. Apparently, this empirical estimates does not conform the existence of anchovy in the stated region. In the study, they discuss the anchovy presence in this area referring to a work done by Turan et al. (2004). However the occurrence of anchovy in the study area was not significant and the species constitutes a negligibly low biomass in the present study (Table 21) in contrary to suggestions of Schismenou et al (2008) and Giannoulaki et al. (2008).

The impact of temperature, depth and chlorophyll on the abundance of the fishes were very clear in the statistical modelling results (Table 31). The study area located in the North Eastern Mediterranean Sea being a warm region seems to provide great advantage to summer spawning species such as *S. aurita*, *D. elopsoides* and *E.encrasicolus*. Timing of gonad development of these species was very much linked to temperature and the availability of food (Karakaş, 2011). There are, on the other hand, winter spawners like *S. pilchardus*, in the study area. Besides the direct effect of the temperature on the species the thickness of the warm surface layer exerts additional advantages as the thermocline draw a sharp boundary between species with cold and warm water affinities. The chlorophyll rich productive waters were confined to the shallow inshore areas as can be seen from Figure 75. Furthermore the thermocline prevents mixing of rich surface waters and the waters that lay below the thermocline. Consequently the warm water species can get better access to the nutritious surface waters when the thermocline is formed. The off-shore distribution of the species with cold-water affinities such as *S. pilchardus* (Figure 68 and Figure 69) may be explained by the deepening of thermocline in early summer and October.

4.2 Predicting habitat suitability and effect of warming

Being a warm water species, *Sardinella aurita* reacts positively to increasing temperature and expands its geographical range as observed in different parts of the Mediterranean Sea (Sabatés et al., 2006, Tsikliras 2008). However warming does not always favor *S. aurita* distribution. Zeeberg et al. (2008) attributed the decline in *S. aurita* to extremely cold and extremely warm periods in Mauritanian waters in their study investigating the fluctuations of the *S. aurita* abundance off Northwest Africa. They associate the decline of the catch rates to SST anomalies observed at +3℃ in a warm period. It is known that distribution of the small pelagics may commence spatial shift when the conditions become less favorable (Checkley et al., 2009). Hence the response of the *S. aurita* to warming does not always necessarily is an expansion but it may also be a shift towards more favorable areas.

Furthermore in the Mediterranean Sea, it was also documented that the temperature ranges above 26℃ adversely affect *S. aurita* abundance (Maynou et al., 2013). The results of this study was in agreement with this condition as the GAM analysis revealed that the optimal range preferred by the species was confined to 24 -26 ℃during warm period (June - October). The habitat suitability maps generated by GAM models explained the distribution of species with combined effect of SST, depth and chlorophyll (Table 31). The predictions revealed that the effect of the increased temperature would result in a very dramatic contraction in available habitats and associated density of the *S. aurita* populations (Figure

87). Such condition would result in a shift in their distribution towards cooler regions altering its distribution towards deeper waters to avoid high temperatures.

However such a shift would not satisfy spawning conditions as the species also require productive regions with high food availability. This was very clear in the model results as the distribution was limited to the areas with high chlorophyll concentration and shallow depth (Figure 86).

In addition, increased temperature may possibly result in thickening of the surface mixed layer. The life of the mixed layer may also be prolonged as cooling would take longer. Such warming in the upper layer would ultimately push the species towards deeper waters with lower productivity and disrupt its reproduction habits. Therefore when the climatic conditions of Levant Sea concerned, there would be no place for the species to move. So the consequences in Levant Sea would result in disappearance of the species. It is then very likely that the ecological niche abandoned by *S. aurita* would be benefited by one of the Lessepsian small pelagic fishes occupying the same trophic level such as *Dussumieria elipsoides.* As an actual situation, the SST maps suggest that the species is already at its marginal temperature limits in the area of interest therefore human impact over their populations should be further examined in detail (Figure 80).

Some methodological considerations

A series of GAM analysis were performed in an attempt to quantify the associations between the distribution of small pelagic fishes and the environmental variables (Table 31). These models were constructed mainly based on CTD data measured at the fix stations therefore may not be usable for spatial prediction for a geographical range larger than that of the surveyed area. On the other hand use of satellite-derived products (SST and Chl-a) produced for entire Levant Sea including the study area, provided better opportunity to expand the prediction results over a larger area. However, due to strong vertical thermal stratification that develops after spring, the water column is characterized by different overlaying water masses, each inhabited by different species. In this case the thermocline acts as a sharp barrier shaping the vertical distribution of the fishes until mixing occurring in winter. Since satellite driven SST and Chl-a data represent the upper mixed layer only, use of such data as environmental proxies was limited to the species preferring the upper layer. Luckily, the most abundant species in the study area, *S. aurita* meets this constraint and therefore selected as the species of interest. Furthermore, *S. aurita* was proven suitable as the GAM analysis performed at earlier stage has shown a strong relationship between distribution of the species and the variables measured by CTD such as temperature and fluorescence and bathymetry.

One important concern was the use of satellite data for the implementation of a prediction that was parameterized based on in situ measurements. As given in the material and method section, a critical elaboration has been made to correlate and calibrate the two seemingly different however essentially the same variables.

In order to make prediction for a large spatial scale, it was inevitable to pool a wide range of environmental conditions. However, October and June surveys varied noticeably in terms of SST data statistics (). The June data were apparently skewed to left (where it is colder); while in October the data is more skewed to right (warmer). Therefore it was necessary to pick one season as the reference season as the aim of study at this stage also included testing the effect of increase in temperature as well as the modeling.

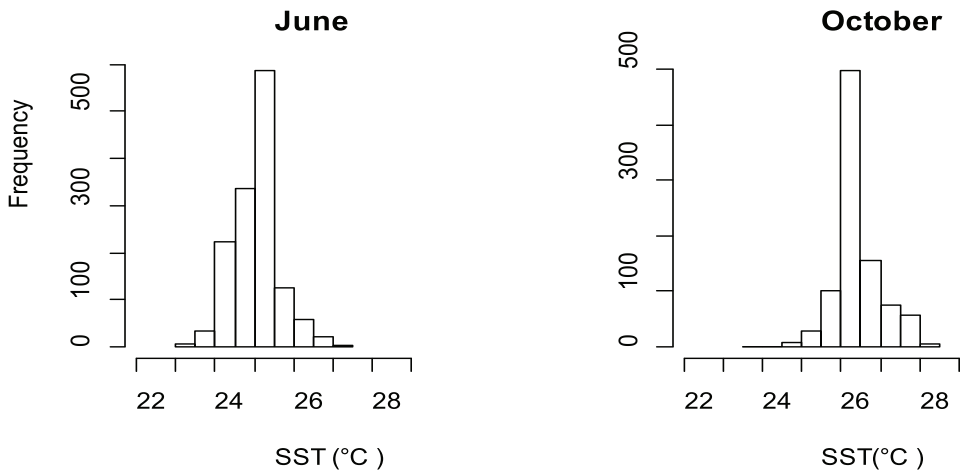

Figure 90. SST values corresponding to the survey points for surveys in June (left) and October (right).

Pelagic fish prefer the optimal environmental conditions during their spawning. The critical and essential conditions occurring during and immediately after spawning are elementary also for the growth and development of the juveniles (Cury and Roy, 1989). Since the June corresponds to the spawning period of the *S. aurita*, it was assumed that grapping the environmental peculiarities in June surveys would, to a great extent, reflect the ecological structure and therefore most suitable for the construction of the GAM model.

Fréon et al. (2005) underline the necessity of a comprehensive knowledge on the fish and their environment for a better use and management. With this respect, identifying essential fish habitats have been seen as one of the important concept to adopt ecosystem approaches to fishery management (Rosenberg et al., 2000). Essential fish habitats (EFH) are defined as "those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity." (Valavanis, 2008). Although main objective of this study was not essentially identification of the EFH areas, several issues were addressed with that respect by explaining the habitat preferences of small pelagic fishes, which also required for identification of EFH's for small pelagic fishes in the study area.

The species dominating the small pelagic species also differs at different corners of the Mediterranean. NW Mediterranean small pelagics are characterized by two species, anchovy (*Engraulis encrasicolus*) and sardine (*Sardina pilchardus)* which were the most important in terms of biomass and commercial interest (Palomera et al., 2007). Sardine (*Sardina pilchardus*) is the main target species in the southwest of the Mediterranean (Bedaria, 2011). The southeastern corner is a region subjected to severe ecological changes within the last century. Mehanna and Salem (2011) underlined the outstanding importance of genus *Sardinella* before the construction of the Aswan reservoir on the Nile River. According to the authors the percentage of *Sardina pilchardus* in the small pelagic fishery in the southeastern Mediterranean has been increased remarkably and reached to the share of *Sardinella aurita.*

When hydrographic, hydro-acoustic and trawl catch data considered together, it is reasonable to suggest that the water column in the study region can be grouped ecologically into three different habitats. Principally the whole area is characterized by a vertical division as the thermocline separates the water column into two distinct layers, one warm water layer and one relatively cold layer. Secondly two distinct water characteristics can be pronounced at inshore - offshore extent that can be attributed to influence of nutrient influx from terrestrial sources such as river runoff and waste water discharges that generate a sharp discrepancy in chlorophyll concentration. The extent of these horizontal sections apparently controlled primarily by width of continental shelf however wind direction and surface currents are possibly important. On the other hand the vertical thickness varies from June onwards until mixing in winter. The results of this study suggest that the presence of such distinct water column properties and seasonal differences have implications in species distribution.

The catch composition of the pelagic trawl surveys carried out in this work displayed highly diverse species richness including Lessepsians. This high diversity was mainly confined to the close-to-shore areas probably due to attraction of above-mentioned warm and productive habitat which seems to support requirements of Lessepsians. Therefore, although, the native species, *S. aurita*, was the main species dominating the small pelagic fish fauna in the studied region, it should also be noted that the Lessepsian fishes are becoming noticeable components of the small pelagic fauna. According to the work conducted by Wassef et al. (1985) in the Egyptian waters, the only Lessepsian small pelagic fish observed in the purse seine fishery was *Dussumieria elopsoides* 1980s, and its contribution was slightly higher than 1%. The results of this study focusing an area further away from the Suez channel, with a remarkable Lessepsian contribution may signify future changes in the pelagic fish fauna yet to happen.

4.3 Species identification

During the surveys of this study, the acoustic system produced a collection of digital pictures namely echograms which are two dimensional slices of the water column. These figures on echograms represent aggregations of fish or planktonic organisms and characterized by the size and the reflected energy of the aggregations. One of the main challenges of this study was to infer accurate information from these echograms regarding the fish schools. The term “fish school” was used to define synchronized and polarized group of fish (Pitcher, 1986). With that respect the term itself may be confusing not only because of the explicit terminology, but also due to use of two dimensional acoustic school morphology. Reid (2000) uses the term of "acoustic school" and inferred not necessarily the real “fish schools”, but a snapshot representation seen on the echograms. In this thesis the term “school” implies “acoustical school” suggested by Reid (2000).

The method used in this study for identification of the species was based on adoption of available methods implemented in similar studies, involving visual scrutinization, use of trawl composition and objective classification. In case of using more than one frequency it would also be possible to classify acoustic data through the comparison of echo strengths recorded simultaneously such as mean volume backscattering strength differencing (Fässler et al., 2007; Jech et al., 2010) or probabilistic classification(Anderson et al., 2007). However acoustic measurements during this study were only restricted to single frequency – narrow band echosounder system, therefore use of multifrequency techniques were not possible.

In single frequency method, most common approaches for species identification of echo-classes are either visual inspection of the echograms based on the appearance of echo traces or on partitioning of the total fish echo-integral based on the species composition of the corresponding control catch. Simmonds and MacLennan, (2005) underline the potential subjectivity in visual inspection method, and suggest that the procedure should be made objective as far as possible. They also state that such success in the method would be based on the experience in the area and requires prior knowledge on certain school typologies. In addition, in mixed-species ecosystems where the characteristics of distinct species are not conspicuous on echograms, it is known that the schools cannot be identified at species level by such methods (Petitgas, 2003). The studied area in this thesis possesses a highly rich species diversity regarding pelagic fish which makes identification impractical by eye from their appearance on the echogram. Lack of adequate experience prior to surveys in the area regarding interpretation the school typologies was also a shortfall for such method.

In control-catch based partitioning method the object is to determine the species and size composition of the local population from the hauls. As already discussed in first section of this chapter, in order to apply such method each sampling stratum should be homogeneous in the species and size composition of the fish therein. However the study area, due to habitat diversity and high species richness the composition was quite variable over the whole of the surveyed area even in the similar depth stratum. On the other hand, it is known that the trawl sampling can be selective. Some species tend to be retained in the net while some others escape due to several factors such as size, shape and aspect ratio of the body, swimming speed, endurance, etc. Also different species may display different reactions to avoid the net, and which eventually may affect catchability. These constraints would result in bias in the estimates of the true species compositions. Variability in the number of trawl hauls performed in different strata due to operational and budget constrains was other sources of uncertainty in this method. Consequently, an estimation built simply on catch based method was considered impractical.

Trawling and sampling the schools were, however, an essential part of this survey. The data collected by this manner were used for so called “ground-truthing ”Simmonds and MacLennan (2005) also underline one of the fundamentals that the sizes and species composition of the control catch should be representative of the local fish populations in the region. However concerning the catch data collected during this study, there were various factors that constrained representativeness. Among them the uncertainty associated with catching efficiency of the trawl gear and catchability of each species, are considered to be the main sources of error.

It is known that there are many factors that may affect catchability including; swimming behavior of the school (Aglen and Misund, 1990; Langård et al., 2006), environmental factors (Stoner, 2004), fishing vessel and gear characteristics (Doray et al., 2010a) as well as factors such as towing speed, depth, time of the day and vessel noise (Fiorentini et al., 1999; Heino et al., 2011; Walsh, 1996). Moreover as a result of variability in natural behavior of species, fish aggregations do not exhibit a uniform spatial distribution and often tend to occur in patchy concentrations. Their position in the water column is non-random and varies vertically as they exhibit rapid horizontal and vertical migrations (Fréon et al., 2005). On the other hand, the volume sampled by a pelagic trawl represents only a narrow slice within the water column therefore reduce probability of been captured.

One of the critical limitations of the present study was lack of depth sensors on trawl gear which in general necessary to provide precise control over the towing depth of the net which is to an extent essential for the reliability of the control-catch. In this study, the depth of the trawl net were adjusted manually by the skipper therefore relies greatly on experience/skill. The net that has been used was a demersal net modified to sustain vertically enlarged mouth opening during operation. The modification includes additional floaters on the head rope and weights on the bottom line. Due to the heavy depressor chains, the net tended to position close to the bottom thus generally bottom contact was inevitable at least at the beginning of the operation. This feature in return provided an advantage since the fish schools detected acoustically were generally distributed close to bottom as illustrated by the altitude of the detections with respect to the sea bottom in Figure 29 .

Since the catch composition considered varies depending on the duration of the contact of the net to the sea bottom, contamination of the catch by untargeted demersal species was unavoidable when the pelagic fish located close to bottom. Hence the sea bed structure in terms of habitat type and topography was also an important factor influencing the results. This sinking tendency of trawl net used in the sampling was probably the main reason why demersal fish accounted for a higher percentage (67%) of the total catch (). The most abundant non-pelagic fishes such as *Leiognathus klunzingeri* and *Pagellus acarne were* fishes that could eventually be detected acoustically and hence contaminate the data. The level of contamination by non-pelagic fishes has not been considered in the study. It was assumed that their contribution to acoustically determined fish density was negligible. This assumption mainly relied on the fact that the fishes positioned very near to the bottom remains within the acoustical dead-zone where the reflections of objects are masked by the echo returned from the bottom (Ona and Mitson, 1996). Therefore despite limited vertical maneuver capability and lack of depth sensor, the system used in this study deemed as capable enough to collect most of the species that exist in the sampling region, at least on present/absent basis.

Another issue that contributes the uncertainty was the multispecific characteristics of the small pelagic fish assemblage throughout the study area. It was generally accepted that a better accuracy and detailed conspecific information can be gathered when there was lesser number of species forming aggregations (Burgos and Horne, 2007; Gauthier and Horne, 2004; McClatchie et al., 2000). However in the study area, although the results suggest that prevailing species was *Sardinella aurita* accounting for the largest proportion of acoustically detected fish density, 19 different small pelagic species were observed 9 of which were Lessepsian fish. High number of acoustically detectable species raises the issue of differences in the capture efficiency due to the possible species-specific factors such as habitat preferences, swimming speed and size (Rose and Nunnallee, 1998). Lack of scientific knowledge on the vulnerability of species to trawl catchability (O'Driscoll, 2003) complicates the problem and shadows the estimation of the true proportion of the species. Therefore multispecies complexity should further be investigated to reduce the uncertainty.

Concerning the species-specific factors, swimming speed was one of the most determining biological factors that affect catchability of a trawl net. *Sardinella aurita* is known to be difficult to catch by a pelagic trawl due to high swimming speed and endurance (Misund et al., 1999). Haugland and Misund (2011) observed the behavior of *Sardinella aurita* by an underwater camera throughout the trawl operation and reported that the species can maintain a speed of about 2 m s^{-1} with the endurance one hour. The average speed of the tows in this study was around 1.5 m s^{-1} which was not adequate to effectively sample *Sardinella aurita* schools. Furthermore tow duration in general did not exceed 30 minutes in order to keep the damage to bottom habitats at minimum level as the most of the samplings had been performed in the areas set aside to protect the nursery habitats. General strategy was to increase the speed few minutes before hauling in order to drive the fish into the net. Apparently this method, despite high amount of escape during hauling, has improved the catchability remarkably and so that *Sardinella aurita* could be sampled.

Overall, the position of the control catches were more confined to the coastal/shallower parts and far from being homogeneous over the continental shelf (Figure 18). Accumulation of the trawl stations on the shallower part may be seen as a problem of “under-sampling” the areas deeper than 50 m. Figure 28 illustrates the distribution of acoustical targets with respect to the bathymetry. The figure may suggest existence of two different domains with a sharp boundary at about 50 m depth. This boundary seems to be a breakpoint as it approximately coincides with the thermocline which divides the warm upper layer from the cold lower layer. As presented by the school recognition parameters, majority of the species has a very low altitude index, indicating that they prefer to stay close to the bottom during day time. This may be due to dietary requirements and/or a strategy against predation (Fréon and Misund, 1999). Therefore it seems that the density of fish was lower when total depth exceeds the depth of thermocline. At this end, the sampling strategy which gives relatively more weight to areas shallower than thermocline depth may be meaningful. However, it should be noted that there were still, some areas (although very few compared to those exist on the shallow waters) with high acoustic density which should not be overlooked.

Consequently due to uncertainties resulting from gear properties and species specific properties as well as variable and diverse trawl haul compositions due to high species diversity, a methodology based on partitioning the echo-integrals in reference to trawl catches observed to be unreliable in the study area. As the accurate allocation of fish acoustic energy to each of the species found in the catches was impracticable, catch data was used only to identify the schools acoustically detected. Therefore estimations on the fish density distributions were performed by hydroacoustic computations based on direct classification of echo traces.

4.3.1 School descriptors

A common approach used for school identification was to parameterize the acoustically observed target clusters. In general, school parameterization was performed according to the aggregation behaviour of the species of interest. The species-specific behaviour varies with the geographical, hydrographical or seasonal differences and therefore temporal changes may be observed in the shape of the schools. Such potential variability in seasonal and interannual school characteristics have been documented by Fréon and Misund (1999) for several pelagic fish species. Therefore, in this study, the school identification was carried out flexibly; taking each season individually and pooling all dataset from all surveys however consequently comparing one dataset to another.

Although there are numerous studies on this area there is no routine, state of the art method applicable globally and addressing all inconsistencies in all regions and species for classification (Fernandes et al., 2006). The uncertainties regarding identification of schools or other type of signals from the fish have long been one of the major problems associated with hydroacoustic method.Horne (2000) pronounced the expression “Holy Grail of the acoustic researchers” to phrase, to a point, the difficulties in automatic identification of the fish. The majority of the recent studies are confined to ad hoc exercises applied to ideal situations and very few of them are tested in variable nature conditions (Horne, 2000). Thus each study was a peculiar case with area specific variability and therefore it was extremely necessary to develop a method specific to the study area and the target species. It was also considered that adapting available techniques implemented in similar cases would be beneficial (Cabreira et al., 2009; Haralabous and Georgakarakos, 1996; Lawson et al., 2001; Scalabrin et al., 1996).The method developed in this study utilizes the basic approach common to almost all similar studies. In order to achieve an objective technique for assigning traces to species based on available descriptors, ICES (International Council for the Exploration of the Sea) assembled the type of parameters which are fundamental for school analysis, into four different groups (ICES, 2000). The parameters, which were also used in the identification (Table 16), were grouped as follows in accordance with ICES (2000);

- Positional: Parameters related with the temporal, geographical and vertical position of the schools (i.e. position in the water column);
- Morphometric: Parameters used to determine the shape of the schools. etc.;
- Energetic – characteristics of the reflected acoustic energy and internal variation of energy within a school;
- Environmental - water depth, temperature etc.

Within this context, the first three classes of parameters of ICES (2000) were directly used for school identification in the study. The last one, the environmental class was indirectly used to assess habitat preferences of the species in question. Among the parameters used Sv_Mean, skewness, Coefficient_of_variation were those related to the energetic features of the schools; mean school depth and school altimeter were the positional parameters; Corrected school length, corrected thickness, corrected school perimeter, corrected school area, elongation, rectangularity, circularity, fractal dimension and the compactness of the school image on the echogram were the schools specific morphometric discriminators.

The morphometric parameters basically defined as deviation of the actual shape of schools from an ideal circle and were one of the most important groups of parameters (Reid, 2000). Despite being a critical descriptor this parameter group including height, width, cross sectional area school morphometric parameters were prone to specific bias due to vertical structure of the acoustic beam. It should also be noted that some of the school descriptors were calculated through combinations of these morphometric variables which includes fractal dimension, elongation, circularity and rectangularity. Therefore co-linearity was a matter of statistical concern. In this study, this issue has been respected in the analysis and the parameters showing any indication of redundancy, such as kurtosis, vertical and horizontal roughness, were eliminated.

Reid (2000) argues that the echo tracing also suffer from the beam effect distortion, therefore, the images seen on the echogram may not be the true representation of the actual school. Another problem was the increase of the beam spread as the depth increases which effects the width of the echo trace of the school. Subsequently, Diner (2001) proposed an algorithm established for school descriptor correction based on echo trace simulation. This study followed that development and the parameters that may be influenced by the beam spreading were processed by this algorithm. Burgos and Horne (2007) were also used these corrections for the detection of walleye pollock aggregations in Bering Sea where they used aggregation length and height as morphometric descriptors. These descriptors were in essence identical to the corrected length and corrected height parameters used in this study. Doray et al. (2006) also used corrected parameters; maximum width, height and cross-sectional area to characterize pelagic fish aggregations around moored fish aggregating devices in Lesser Antilles. In a study carried out in south-central Chile in addition to basic descriptors (length, width and area) fractal dimension of the schools and elongation were successfully used to classify anchovy, common sardine, and jack mackerel (Robotham et al. ,2010). Both of these parameters were also used in this study and they were effective mainly in clustering particularly in discrimination of the schools specially composed by species belonging to Carangidae family.

In this study, number of parameters was reduced by excluding those considered to have potentially very little influence. The geographical locations of the schools were not included since lateral variability along the coast was less pronounced than the bathymetric variability. The eutrophic water mass, which apparently attract the planktivorous species localized in the Mersin Bay, was another factor rendering geography in effective in school identification. The question whether increasing the number of school parameters may help classification has been addressed by Cabreira et al. (2009). In their study 30 school parameters, classified in three groups were used () and the number of parameters were reduced to investigate their effects. Only a slight decrease in classification performance was observed when the geographical locations of the schools were removed. Therefore no effort was considered to be necessary to increase the number of descriptors.

Table 33. The main school descriptors used for classification in (Cabreira et al., 2009).

School descriptor	Symbol	Computations
Energetic		
Volume-backscattering strength*	S_v	–
Maximum volume-backscattering strength*	S_{vmax}	–
Vertical roughness	VR	–
Horizontal roughness	HR	–
Skewness	Skew	Equations (7.7) and (7.8) of Zar (1984)
Kurtosis	Kur	Equations (7.13) and (7.15) of Zar (1984)
Morphometric		
Length*	L_c	$L_c = [L - 2\,D\tan(f/2)]$
Height*	H_c	$H_c = H - ct/2$
Perimeter*	P_c	$P_c = P - 2[(L - L_c) + (H - H_c)]$
Area*	A_c	$A_c = A\,(L_c H_c)/(LH)$
Volume*	V_c	$V_c = L_c(H_c/2)^2$
Fractal dimension	FD	$FD = 2\ln(P_c/4)/\ln(A_c)$
Elongation	EL	$EL = L_c/H_c$
Image compactness	IC	$IC = P^2/(4\pi A_c)$
Rectangularity	Rec	$Rec = (LH)/A$
Circularity	Cir	$Cir = P^2/(\pi A)$
Bathymetric		
School depth	Z_c	–
Bottom depth	Z_f	–
Altitude index 1	Alt 1	$Alt\ 1 = (Z_c + H_c/2)/Z_f$
Altitude index 2	Alt 2	$Alt\ 2 = Z_f - (Z_c + H_c/2)$

The method applied in this work was in essence adopted/modified basing on the methodology employed in the studies mentioned above. Extraction of the parameters and making the corrections was achieved by applying image-analysis algorithms of the Echoview software and by using standard software for this purpose stability and comparability in the results were secured.

One critical assumption in this study (and in most of the other studies of this sort) was that the morphological patterns were stable in all cruises therefore the same set of descriptors used in analysis of each cruises. This was also required for the mutual comparison of the cruises. However, it should be noted that the set of descriptors used during different phases of identification (clustering and classification) were different. This was due to the reason that although the descriptors are the same, the shape and characteristics of the school may differ seasonally (Muiño et al., 2003).This was a quite reasonable assumption since schooling requirements of the pelagic fishes changes throughout the biological calendar; that is spawning fish would form different schools than the overwintering fishes (Bahri and Fréon, 2000; Brehmer et al., 2007; Nøttestad et al., 1996).

Fréon and Misund (1999) describe the fish schooling as an efficient way of conducting underwater movements beneficial to each individual. Pitcher (1986) outlines the benefits of schooling as better defense against predator therefore higher probability of surviving, enhanced feeding success, increased migration efficiency due to hydrodynamic advantages.

An important concern in adopting the constant species specific school typology is the diel variation in school formation. In general fishes tend to change the schooling characteristics within a day (Fréon et al., 1996; Zwolinski et al., 2007). Most of the small pelagic fishes form dense schools located near to the bottom during the day (Gauthier and Rose, 2002). Fréon et al. (1996) suggest that the fish swim randomly at dusk and begin to disperse due to reduced visual contact between individuals, subsequently at dawn they aggregate again when the visual range rapidly increases. This behavior would eventually affect the morphometric and bathymetric descriptors from dawn to dusk. One way to tackle with this problem was to classify day and night schools of each species and to use the time of sampling as a descriptor. However this would insert additional variance and hence reduce the reliability of the results. Therefore this problem was eliminated by surveying only at day time when the fish form more compact schools displaying better resolution.

The list of the selected school parameters varied at different stages of analysis. In clustering using “K-means”, all the descriptors in the list were involved in the very first stage since this was, in a sense, exploration phase of the process. However, at the classification stages only the parameters that were proven to be significant were used and the rest which were likely to show sign of co-linearity were eliminated (and). Reid (2000) defines several byproduct parameters in morphometric group such as image compactness, circularity and rectangularity. These parameters are named as complex descriptors and suggested as that they are all likely to work well with large schools but unsuccessful with smaller schools. In this thesis, number of small schools was rather high. Therefore *image compactness*; *circularity* and *rectangularity* were dismissed in classification phase, except *elongation* which was kept in the set due to its significant impact in clustering.

Table 34. Descriptors used in this study.*selected descriptors used only in classification phase.

Energetic	Morphometric	Bathymetric
Volume backscattering strength*	Corrected length	**Altitude index***
Skewness*	**Corrected thickness***	**School depth***
Coefficient of variation	**Corrected perimeter***	**Fractal dimension***
Vertical roughness	Corrected area	
	Elongation*	
	Rectangularity	
	Circularity	
	Image compactness	

When the overall descriptors were considered, the school depth was the most important parameter. One of the reasons could be the effect of the temperature. Since there was a constant thermal stratification during both survey seasons, the species partitioned the habitat based on their temperature preferences. Temperature was negatively correlated with the depth, which in turn lead the species distribution to be associated with the depth. However when two species with similar depth preferences considered, the role of the morphometric and energetic descriptors turned out to be more important. This was particularly true in discriminating the *S. aurita* and *D. elipsoides*. Both of these species prefer warmer parts of the water column as seen in trawl hauls; however they differ in school morphology. *S. aurita* forms very dense and compact schools with regards to energetic descriptors and form larger schools. *D. elipsoides* schools, on the other hand, were generally less dense and smaller in size. Similarly *S. pilchardus* and *E. teres* were observed at same depth range but *S. pilchardus* were observed closer to the bottom while *E .teres* were more close to surface and formed more elongated schools compared to *S. pilchardus*. Altitude index was a successful descriptor especially for *Trachurus* genus which generally found very close even attached to bottom most of the time. The most problematic part of the water column was the thermocline layer where mixed-species schools occur. This was the most serious threat to the application of species discriminating methods as has already been underlined by Lawson et al. (2001). In this study, this issue has not been elaborated in detail and a certain level of uncertainty was possibly added to the results. It may be suggested for further studies that the other methods rather than school based approach to classify the schools around the thermocline may be preferred to reduce the uncertainty. One good example is the approach used by Petitgas et al (2003), who actually sampled the thermocline layer by control catches, and reflect the species composition within the mix-species layer into the acoustic outputs. However it should also be noted that, in this case an adequate coverage of this area by trawl sampling must be assured.

The final consideration on the school typology was the life stage of the fishes. It was stated that the adult fish and the juveniles form dissimilar schools changing in size, density, morphometric and location (Simmonds and MacLennan, 2005). This phenomenon was clearly observed in the school typology of *S. aurita*; the school parameters of juveniles and adults were quite dissimilar (Figure 30) and therefore treated separately. The typological differences in life stages, on the other hand, helped to distinguish and plot nursery areas of this species (Figure 41). In the two October surveys, the distribution of the juveniles were quite identical; they tend to accumulate at the outer edge of the Seyhan River plume, and to a lesser extent, around Lamas and Ceyhan Rivers. The river plumes are known to attract fish due to high biological activity; particularly they influence fish larvae as a result of superior feeding conditions and may play a significant role in the recruitment (Grimes and Kingsford, 1996).

The total acoustical biomasses of the juveniles were remarkably lower in June surveys when compared to the biomasses estimated in October (Table 21). The difference may be explained by the life cycles of the species. *S. aurita* spawns from April to June (Karakaş, 2011) and June surveys were carried out within the spawning season of the species. The period was therefore too early to observe the juveniles (1-3 months old fish) in the area. The survivors of the eggs spawned in spring recruit to the stock towards the end of summer (Karakaş, 2011) and so that being detected acoustically.

4.3.2 The classification

Another important step in the evaluation of the acoustic results was the objective classification. This techniques, which relies on supervised classification algorithms has been implemented with success in several earlier studies; such as Haralabous and Georgakarakos (1996), Lawson et al (2001) and Fernandes (2009). However these methodologies also require ground truthing for species identification. More specifically; a library of echo traces and their descriptors should be established by the fish schools that have been identified by fishing. However the same concerns regarding representativeness and adequateness of the control catch raises here again. In this study, this bottleneck was solved by an additional step inserted to provide supplementary information when creating the learning sets. That was actually a commonly used clustering technique. The results of clustering based on cross validated K-means technique were used parallel with trawl haul data, in identification of schools near trawl haul. Clustering was helpful as it separates schools based on the differences between species in bathymetric distribution of schools as well as energetic properties and sizes. Aid of clustering was notable especially in doubtful hauls where schools were of species other than that indicated by the trawl's catch. Typical groups characterized by clustering were shown in the Figure 30 by their distinct examples. Among these different shapes, the group "**a**" and group "**b**" in the figure were considered to be separate based on depth of occurrence, while group "**b**" and group "**d**" were recognized by their mean $\mathbf{s_v}$ (on Figure 30). In school types "**c**" and "**d**", morphometric parameters were more important in discrimination. The group "**e**" was distinguished from the others by their altitude index due to association of this species with sea bottom. However it was obvious that clustering cannot be used for ultimate species identification alone due to the inconsistencies in patterns visible in Figure 31. The dispersed multispecies nature of the fish assemblage in the region and particularly the large number of small sized schools created too much “noise” in the data. Also, the descriptors with similar information causing colinearity seem to be the two major potential sources of failure in the method. As a striking example, aggregations clustered as group “**a**” were later assigned to *S. aurita* based on trawl survey results. However in clustering a noticeable portion of *S. aurita* schools were positioned also in bathymetric range as deep as more than 100 m where they should not supposed to be present. This was probably due the misclassification of *T. trachurus* schools which shows high packing density very similar to *S. aurita* schools. However when overall success considered, this method was a useful complementary step to cope with the uncertainty caused by trawl sampling and suggested as a potentially useful tool in automatic species identification. To current knowledge such kind of cross check in identification of the schools near trawl hauls has not been implemented in other studies. This could be helpful especially when there was lack of adequate representative stations.

The school identification using artificial neural network (ANN) has been tested with appreciable success in the earlier studies (Haralabous and Georgakarakos, 1996; Simmonds et al., 1996; Lawson et al., 2001; Cabrera., 2009). In this study this technique also provided satisfactory classification success. It is known that the supervised classification methods are susceptible to error due to weaknesses in ground–truth data set (Kotsiantis et al., 2006). It was already stated that in case of this study, it was likely to have errors in ground truthing dataset due to possible contamination as a result of multi species structure of the ecosystem and gear selectivity. Therefore representativeness or adequateness of the control catch was questionable. This condition hampers us to use the classical “near trawl” identification approach (Petitgas et al., 2003). Therefore a new approach was developed which utilize unsupervised classification (K-means), to improve the learning sets. In such way, the accuracy of the classification method is believed to increase since the ground-truth data set is reinforced in terms of representativeness.

In earlier studies mentioned above, the learning was performed in ANN by randomly partitioning the ground-truthing dataset to different fractions such as 50:50, 60:40, or 70:30%, using one fraction for training and one fraction for test. Different than those of earlier methods, in this study, the cross validation with ten folds was used during learning. The advantage of cross validation was that, all the samples in the dataset were used for both training and validation. Hence the method makes validation of each and every sample in the dataset possible.

Furthermore, the reliability of the results was enhanced by applying additional process based on a fine tuning procedure. This procedure progresses step by step, changing the learning set by taking the error sources, such as overlapping, into account during the classification. This method was useful as it improved the classification success at each step. By this set of procedures, sensitivity of the method has been improved remarkably. More importantly dominancy of a “species group” as in case of *S. aurita* or different patterns in the same group eg. juveniles and adult schools of the same species, or even the different species with similar school characteristics, eg. Juveniles of *S. aurita* and *D. elipsoides* were recognized.

Underrepresentation of some species in the database as oppose to data rich species was a critical issue at the beginning. This problem was solved by modifications in learning set by balancing the number of entries per each species taking the K-means clustering results into account.

A critical assumption in the school identification method applied in this study was that some of the characters displayed by acoustically detected schools were species specific. The behavioural characteristics considered to be expressed by a set of descriptors and they were justified by trawl haul information obtained from control catch as presented in the earlier chapters. A noticeable success in accurate identification was achieved when large bathymetric differences were observed among the species. The success was particularly pronounced when the difference was controlled by thermal stratification in relation to species temperature preferences. However, the identification of the species should be interpreted cautiously particularly regarding those which inhabit overlapping areas such as *S. aurita* and *D. elipsoides*. The rich species diversity and opportunistic behaviour of fish species may result in violation of the aforementioned assumption since they may tend to form mixed schools or schools with very similar typologies.

The ANN is recognized as an effective classification method owing to its ability to handle non-linear relationships between input and outputs, and it is advantageous when there were extreme values as it minimizes their impact (Lek et al., 1996). However, it should also be noted that; ANNs have been recognised as “black box’’, because they do not provide comprehensive information regarding the relative influence of the independent variables in the prediction process (Olden and Jackson, 2002). It is likely that further improvement in classification can be achieved if these concerns are addressed in future studies.

4.4 Implications on fisheries management

The results presented in this study can be used as a general picture of the relative distribution of fish biomass within the studied area. However the source of uncertainties should be diagnosed for better estimates. Timing of survey in relation to the spawning and recruitment has been considered as one of the important source of uncertainty (O'Driscoll, 2004). In this study the timing of the two surveys carried out each year was intentionally chosen to cover spawning and recruitment seasons of the majority of the small pelagic fishes in the study area. The October survey, on the other hand, happened to be carried out at the onset of the fishing season following a 4-5 months of fishing ban and therefore the survey results represent the maximum abundance achieved by the stock for the corresponding biological year.

The estimated biomass of *S. aurita* given in Table 23 was redrawn in Figure 84 in a way to focus on the most inhabited strata (0-50 m) in each geographical unit. Disregarding the absolute quantities, an identical pattern was observed in each unit: high in June, low in October. The only exception was the Mersin in October 2010. This exception most probably reflects the pulse of the recruits joining to the parent stock. As expected, shallow waters of the Mersin Bay were the area where the recruitment takes place. Essentially, the substantially high number of schools was detected in October surveys may also indicate the period of recruitment (Figure 25). An important discrepancy in the biomass estimates of two October survey was noteworthy. It was clear that the recruits are well presented in October 2010 surveys. Both large number of schools and remarkable increase in the biomass are significant evidences of the recruitment. Even higher number of schools detected in October 2009 as oppose to quite low season biomass shows that the population was composed of much smaller schools during this period. Schooling of juveniles has been studied in several small pelagic fish species. One of the common strategies observed was a sort of cumulative clustering (Freon and Misund 2005). Very young fish which are not large and strong enough to swim actively are drifted by the water movements during their early life stages. Therefore they hardly form schools large enough to be detected acoustically. As they grow to a critical size which varies by several extrinsic and intrinsic factors they form small aggregations. Later, this aggregation meets and forms clusters which would eventually form a larger school. The algorithm used in this study relies on schools which were larger than the schooling criteria given in Table 3. Basically small school and hence the juvenile clusters were disregarded. Therefore the high number of schools (678) and low overall biomass (3577tones) observed in October 2009 in contrary to high biomass (5070 tones) and relatively less number of schools (526) in October 2010 was probably a matter of timing of the surveys. It was likely that the young of the year of 2009 were not yet formed sufficiently large schools and they were still in small clusters. The decrease in the total number of schools and increase in the biomass may mean that the clusters which were overlooked due to acoustical limitations were integrated in to larger schools in 2010.

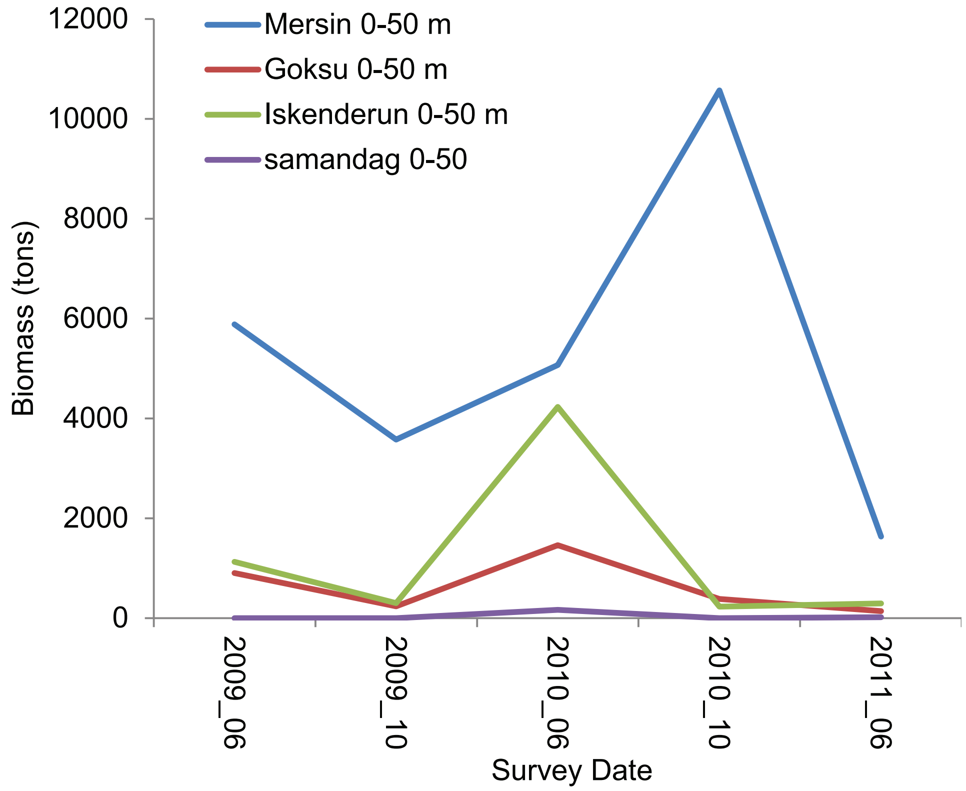

Figure 91. Biomass estimates of the *Sardinella aurita* for each stratum.

The fishery of *S. aurita* is regulated basically by minimum landing size limitation (11 cm) and seasonal closure to purse seining during the spawning season (April-September, subjected to year to year adjustments). As already discussed above, the difference in school typology displayed by recruits of *S. aurita,* enabled recognition and quantification of the recruits. The relative acoustical biomass depicted in Table 21, illustrates that percentage of *S. aurita* recruits is not very high. Small pelagic fishes are characterised by their opportunistic nature achieved by high fecundity and rapid turn-over rate (Fréon et al., 2009). This feature necessitates noticeably high recruitment, eventually higher than what was observed in the area. As the results indicate that summer spawners, such as *S. aurita* gets the best benefit from the seasonal fishery closure as the timing of the regulation protects the spawning fishes. Therefore the seasonal ban to fishery during the spawning season is crucially important for this species. However it seems that the off fishing season regulation applied to the purse seiners is not sufficient to reduce the mortality on the stock during the spawning season. Here it may not be fully speculative to blame the gillnet fishery which, by the existing fisheries notification enforced, is allowed all year round.

Furthermore highly productive condition of the Bay of Mersin might also be a factor in maintaining the sustainability of the stock as it upholds successful recruitment. At the present the freshwater runoff and hence the coastal productivity expected to decrease severely in near future due to numerous hydroelectric dam constructions. These dams known to affect the nursery grounds located in the vicinity of estuaries negatively (Bunn and Arthington, 2002). Accordingly, a decrease in productivity will inevitably influence the *S. aurita* stock as well as the whole ecosystem. Nevertheless, a sharp decrease in coastal productivity in Mersin Bay seems not likely as the urban runoff known to play a major role in nutrient enrichment of the bay, apart from river inflow. However despite its augmenting contribution, situation also raises the concern of water quality which might be important for the survival of the species particularly at earlier stage.

The small pelagic fishes in the study area known to be an important food source for upper trophic level (Gucu, 1995). Although regulations seems to maintain current state of *S. aurita* fishery, an increase in fishing pressure would collapse the equilibrium and eventually hinder the energy flow to the upper trophic levels. The area undergoes a heavy commercial fishing pressure from bottom trawling since 1980's (Bingel et al., 1993). The decrease in demersal fish due to overfishing may encourage a shift of fishing effort from demersal to pelagic fishery in near future. If the fishing pressure increases to serious levels, the resilience of the ecosystem in the area might break down as it is already tackling with competition due to opportunistic Lessepsian invaders and pollution (Hughes et al., 2005).

Being a modern tool in management of fisheries, acoustic surveys have proven to be effective for estimating fish abundance and density in various areas (Simmonds and MacLennan 2005). Acoustics may allow direct estimation of fish biomass and distribution in a large area with high resolution. There are several ways by which hydoacoustic methods are used to infer organisms in the water and it comprise variety of activities, including the study of fish behavior (Fréon and Misund, 1999), the characterization of planktonic communities (Mair et al., 2005) and environmental characterization (Bertrand et al., 2003; Massé and Gerlotto, 2003; Petitgas et al., 2006). The principle however is the same; fishes are insonified by an acoustic signal and reflected energy is recorded. With the now-a-days acoustic technology a schools of fish can be distinguished from the non-fish targets with great precision. However the challenge was to sort and identify the fishes acoustically detected (Fernandes et al., 2006). The methodology used in this study, accomplishing the species identification task in a generally applicable way, can be can be extended to other regions and applied regularly as an up to date monitoring tool.

5 Conclusion

Results of this study has shown that the largest acoustic densities in the north - eastern corner of the Levantine sea were associated with *Sardinella aurita* schools. The species was distributed all along the coast in the studied area within the 0-50 m bathymetric range, however mainly observed in the areas located between 34.5°E- 35.5°E. and particularly in the Bay of Mersin where the chlorophyll concentration was highest. Furthermore, other species with warm water affinities including Lessepsians and particularly *Dussumeiria elopsoides* were most abundant in this warm and productive area. In terms of abundance, *Etrumeus teres, Trachurus trachurus* and *Trachurus mediterraneus* were also noteworthy. The species such as *Engraulis encrasicolus*, *Herklotsichthys punctatus* and *Sardinella madarensis* were found to be less abundant. Results suggest that the highest diversity of species were confined to the close-to-shore areas due to the potential of these areas for the ecological requirements of Lessepsian species. Regarding the distribution of the species with cold-water affinities the off-shore areas of the same region was most preferred and particularly dominated by Sardina *pilchardus*. With regards to the impact of environmental conditions on the abundance distribution of all pelagic fishes; the effect of temperature, depth and chlorophyll concentration were obvious in the statistical modelling results. Particularly on *S. aurita* the effect of the temperature was noticeable with positive correlation up to the point at $27^{O}C$, however values exceeding this limits were found to be adversely affecting their distribution. Besides the direct effect of the temperature on the species the thickness of the warm surface layer exerts additional advantages as the thermocline draw a sharp boundary between cold and warm preferred species. Accordingly the off-shoreward distribution of these species were explained by the deepening of thermocline constituting a an unsuitable area, therefore pushing the distribution of the species deeper or further out, beginning in early summer continued until end of autumn.

These results has filled the gap in the studied region by providing an insight on the distribution and ecology of the small pelagic fish species through information obtained in acoustic surveys in recent years (2009-2011). However, due to the absence of research and past experience in the area, considerable amount of work was dedicated to develop a post processing methodology for the identification of the species. The evaluations showed that conventional methods were impracticable for the studied area due to the high degree of species richness in pelagic fishes and uncertainty due to unrepresentative control catches. Despite identifying the distribution of the most abundant species, this study did not ultimately define the complete distribution of the full species composition of the all pelagic fishes in the study area in the allocated time. However, it has been shown that a supervised classification method based on artificial neural network algorithm was an appropriate tool in answering the needs in hyroacoustic implementations which can be considered as a state-of-the-art methodology. The method proposed in this study was adopted from the studies carried out under similar cases. However the main modification added to the existing applications is, deducing the information from trawl catches by coupling with k-means clustering of acoustic schools on echograms.

Another aspect of this study that attracts attention was the abundances of the Lessepsian species, which suggest that these species are becoming noticeable components of the small pelagic fauna. The SST records showed that the study area holds the warmest water mass when compared with the adjacent areas. When the impact of the expected warming to the habitat availability of the *S. aurita* was analyzed; the results showed that in case of 3^{o}C increment in water temperature, all the suitable habitats of the species could disappear entirely. This result implies that; in regulation of the pelagic fisheries in the region, the vulnerability of S. aurita to the environmental conditions should be considered. Currently, although the regulations seem to help maintaining the current state of the *S. aurita* fishery, the resilience of this species to adverse conditions such as competition against the Lessepsian invaders, pollution and overfishing would eventually weaken.

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