DISTRIBUTION OF CETACEAN AND THEIR FORAGING HABITATS IN THE BLACK SEA

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ABSTRACT

DISTRIBUTION OF CETACEAN AND THEIR FORAGING HABITATS IN THE BLACK SEA

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Cetacean hunting was banned in Turkey in 1983. In the following decades, as the ecological shifts in the Black Sea occur, over-increase in the cetacean populations were hypothesized as the cause of the decline in economically valuable pelagic fish species like Anchovy (*Engraulis encrasicolus*) and Sprat (*Sprattus sprattus*). These arguments create the pressure of re-legalization of direct killing of cetaceans, whom are assumed to be foraging mainly on Anchovy. These arguments, although raise concerns from the fishery economy aspect, lacked scientific foundation due to absence of cetacean foraging studies in the Black Sea. Therefore, this thesis study aimed its efforts at determining cetacean distributions and their foraging habitats in the Turkish waters of the Southern Black Sea, to explore whether the assumptions of highly overlapping prey preference and competition of resources did actually hold.

For this purpose, active acoustics data that was collected for Anchovy Stock Assessment research was utilized, with the implementation of recently developed algorithms that enable extraction of cetacean distributions, from the vocalization marks from the echograms. The extracted vocalization marks from the clicks that are assumed to be in higher occurrences during foraging, are quantified within 1nmi running radius. These foraging activities were then compared with the pelagic fish abundances that were analyzed via echointegration techniques from the data active acoustic data set of November 2016.

Both pelagic species, showed high abundances in the western coast of the Southern Black Sea, whereas cetacean distribution and foraging areas were observed dominantly in the eastern coast of the Southern Black Sea. When the cetacean and pelagic distributions were analyzed for spatial and temporal overlap both within layers in the water column and at different times of the day, results showed no significant positive linear correlation between the mentioned top predators and Anchovy. These results are indicative of the inoperative assumption of cetacean foraging pressure playing a significant role in the declining of the Anchovy stocks. Cetacean encounters were shown to be correlated with Sprat distributions, during Night time form the presented GAM results. Therefore, outcome of this study is aimed to be of consideration in management and conservation strategies in the Black Sea.

The methodology used in this study is an innovative approach to cetacean ecology studies, which is opportunistic in nature, is holding great potential for the research of cetacean foraging with the enabling the use of existing concurrent data sets of predator and prey, and further potential of development.

Keywords: Acoustics, Cetacean, Foraging Areas, Black Sea, Pelagic Distribution

ÖZ

KARADENİZDE SETASE DAĞILIMI
VE BESLENME ALANLARININ BELİRLENMESİ

BAŞKIR, Saba
Yüksek Lisans, Deniz Biyolojisi ve Balıkçılık Bölümü
Danışman: Prof. Dr. Ali Cemal Gücü
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Türkiyede setase avcılığı, 1983 yılında yasaklanmıştır. Takip eden yıllarda, Karadenizdeki ekolojik değişimlerin gözlemlenmesi ile beraber, Hamsi (*Engraulis encrasicolus*) ve Çaça (*Sprattus sprattus*) gibi ekonomik değeri yüksek pelajik balık stoklarındaki düşüşün sebeplerinden biri olarak setase türlerinin aşırı artışı öne sürülmüştür. Bu argümanlar, baskın olarak Hamsi ile beslendiği varsayılan setaseler üzerindeki av yasağının kaldırılması için baskı oluşturmaktadır. Bahsi geçen konu, her ne kadar balıkçılık ekonomisi açısından endişe uyandırıcı olsa da, Karadenizde setase ekolojisi çalışmalarının eksikliği sebebiyle bilimsel dayanaktan yoksundur. Bu sebeple, sunulan tez çalışmasının amacı, Güney Karadeniz Türk sularında setase dağılımının ve beslenme alanlarının belirlenmesi, ve öne sürüldüğü şekilde balıkçılık ve setase türleri arasında bir alansal kesişim, dolayısı ile setase baskısı olup olmasığının araştırılması üzerine odaklıdır.

Bu amaçla, Hamsi Stok Araştırmaları için toplanan aktif akustik veri seti, geçtiğimiz yıllarda ekogramlarda gözlemlenen vokalizasyon izlerinden setase dağılımı verisi elde edilmesi üzerine geliştirilen algoritma ile beraber kullanılmıştır. Beslenme sırasında sıklığı

artması beklenen vokalizasyon belirteçlerinin ayıklanması sağlanmış ve 1 deniz mili mesafe aralığında kümelendirilerek beslenme davranışı miktarlarının elde edilmesi sağlanmıştır. Kasım 2016 yılının veri setinden, pelajik balık dağılımları "echointegration" yöntemleri ile analiz edilmiş, ve setase beslenme aktivitesi ile karşılaştırılmıştır.

Her iki pelajik tür de, Güney Karadenizin Batı kıyısında daha yüksek bolluk göstermişken, setase beslenme alanları baskın şekilde Güney Karadenizin Doğu kıyısında konumlanmaktadır. Setase ve pelajik balık türleri su kolonu derinliklerinde alansal ve gündüz ile gece aktivitesini ayıran zamansal sınıflandırmalarla karşılaştırıldığında, sonuçlar bahsi geçen avcılar ve Hamsi arasında bir lineer pozitif korelasyon göstermemiştir. Setase türleri ile anlamlı bir pozitif korelasyonsa, Çaça üzerinde gece saatlerinde GAM analizi sonucunda gözlemlenmiştir. Bu sonuçlar, setase beslenmesinin pelajik Hamsi stokları üzerinde baskın etkisi olduğu varsayımının geçersizliğine işaret etmektedir. Bu sebeple, sunulan çalışmanın sonuçlarının, Karadeniz yönetim ve koruma stratejilerinde göz önünde bulundurulması umulmaktadır.

Çalışmada kullanılan metod, setase ekolojisi çalışmaları üzerinde yenilikçi bir yaklaşım olmakla beraber, av ve avcı verisinin tek bağlam üzerinden kullanılması ve mevcut veri setlerinin değerlendirilebilmesini sağlaması, algoritmanın da geliştirilme kanallarına açık yapısı sebebiyle oldukça önem taşımaktadır.

Anahtar Kelimeler: Akustik, Setase, Beslenme Alanları, Karadeniz, Pelajik Dağılım

To my chosen family,

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1 INTRODUCTION

Turkey, as a peninsula, is confined with four seas that are the Mediterranean in the South coast, Aegean in the West coast, Marmara as a bridge between the latter two, and the Black Sea in the Northern coast; all four seas being rather distinctively different from one another in terms of not only oceanographic properties, but also the fisheries income they provide (Turkmen, Turkmen, & Tepe, 2008). Southern Black Sea is distinctive from other Turkish Seas due to its several characteristics such as; having the highest river discharge among others, eutrophic and hypoxic water masses and its short shelf (Oğuz, Tuğrul, Kıdeyş, Ediger, & Kubilay, 2004). First and foremost, fishery is the primary topic that comes hand in hand while mentioning the Black Sea. According to the long term national statistics, Black Sea holds great importance, as its economic gains from fisheries is more than half of Turkey's total income from fishing (TUIK, 2018). As a result, any concern, development and research on the topic of the Black Sea fisheries holds special importance and attracts vigorous interest which translates as funding as well. Expectedly, the risks and potentials of variables that may affect the amount of income is just as intriguing to research on.

Projects with primary concerns of sustaining and maintaining the fish stocks are of great value due to the mentioned priorities. Which is why, while there is an existing, established and long-term data and management efforts set on fisheries of surrounding countries (EuropeanCommission & High Representative Of The European Union For Foreign Affairs And Security Policy, 2015), knowledge collected on cetaceans of the Black Sea is extremely limited (GFCM, 2012, 2013). With the ACCOBAMS initiatives beginning to come to life in the Black Sea very recently, it is hoped that a foundation of cetacean data set and marine mammal management is emerging for this area in the following years (ACCOBAMS, 1991; GFCM, 2017). This is why the possibility of utilizing fisheries data for the sake of cetacean ecology research and marine mammal studies and management in the Black Sea would be of extreme importance creating a leap whole in the existing imbalance of funds and interest distributed in the food chain of the Black Sea; meaning pelagic species being the main concern and attraction of funds, overriding their mammal predators that are lacking in even the basic population trends and ecological characteristics knowledge of. Considering these, enabling utilization of a methodology used in fisheries, such as active acoustics and data sets of hydro-acoustics surveys for the research of pelagic species, as practiced in this thesis, holds great promise for the unused potential of existing data to extract cetacean data from (Benoit-Bird, Dahood, & Würsig, 2009). Acoustic research has been in practice for many years, since the development of the field after WWI and WWII (Mann, Hawkins, & Michael Jech, 2008) and it is of great importance that methodology used in this thesis enables us to gain some crucial understanding of cetaceans without needing to practice new surveys with limited coverage in terms of time span and spatial area as it is with every initiative with the aim of starting a foundation knowledge on a subject. That is why using the potential of active acoustics data collected for fisheries can jump start our accumulation of knowledge on the cetaceans of the Black Sea.

For the sake of bettering the ecological understanding we have on a given environment, one must concern the holistic approach when such imbalanced importance is given to the different links in the food chain as the ecology of the research area in total cannot be distinguished and isolated with respect to scientific validity and completeness, with potential of affecting the structure of ecosystem (Witteveen, De Robertis, Guo, & Wynne, 2015). Marine mammals being top predators, they do serve as ecological indicators, as "sentinels", for changing or sustained balances (Moore, 2015) and health of the food web for many of them which we lack a complete understanding but can read the clues as the research on top predators build up (Nabe-Nielsen, Sibly, Tougaard, Teilmann, & Sveegaard, 2014). In addition to top predators being the condensed observing point for further down changes in the foraging links, their decline can lead to cascades through marine communities that are not directly under predation pressure (Heithaus, Frid, Wirsing, & Worm, 2008). Unless the top predators are made to be one of the primary concerns throughout management and utilization of ecosystems, undesired causalities are ought to be faced which then would raise the need for recovery following the "trophic downgrading" (Stier et al., 2016).

Striving from such point of view, this study focuses on the three cetaceans in the Black Sea; one being the harbor porpoise (*Phocoena phocoena* ssp. *relicta*), other two being the delphinids, short-beaked common dolphin (*Delphinus delphis* ssp. *ponticus*) and common bottlenose dolphin (*Tursiops truncatus* ssp. *ponticus*) which are species pronounced as concerning topics for many years (ACCOBAMS, 1991; Reeves & Notabartolo Di Sciara, 2006). These three species of cetaceans are hardly researched on in this study area for topics such as; abundance, distribution, foraging areas. These ecological characteristics being very poorly understood, and population trends are yet to be agreed upon. Without proper scientific efforts made on the abundance, distribution and foraging information of these cetaceans, it will stay as a major lack of foundation while debating the amount of prey captured that may or may not cause a decline or fluctuation in the economically valued, there for studied further, fish species (Witteveen et al., 2015).

To carry us further on this issue, in this study the main driving question is to elaborate on the potential prey species cetaceans may forage on in the Southern Black Sea, with the focus on some of the most economically valued; namely Anchovy (*Engraulis encrasicolus*), Sprat (*Sprattus sprattus*) (TUIK, 2018). Hopefully, this study can provide a foundation to the scientific problem of what, where and when the cetaceans show foraging behavior in the Southern Black Sea. Having an idea on these subjects, the management of marine mammals can have a relatively more structured backbone, as with the light of these primary estimations, further analysis can be enabled such as anthropogenic effects and other means of marine management such as the foundational foraging information used in the more advanced models (Nabe-Nielsen et al., 2014).

The main gap of information, or the initial requirement for the cetacean ecology studies in the Black Sea, would be the abundance and the estimation of population numbers, which are lacking in the adjacent countries for the time period of both pre- and post- hunting ban on cetaceans (A. J. Birkun et al., 2014). As of now, the existing studies estimating the number of cetaceans are ranging between 1000s and 10.000s (A. J. Birkun et al., 2014; Saydam & Gucu, 2016). Although it is challenging to provide a rigid number of cetaceans in the Black Sea, considering its cross borders placement between countries, which does not limit the highly mobile species cetaceans are, the most efficient way to address the concerns on the subject would be using long term systematic data that can provide a population trend if not an estimate of relative abundance useful for the management and conservation concerns. With the proposed method, utilization of active acoustic data collected for fisheries research collected widely throughout other seas as well, it is enabled to monitor the distribution and trends with concurrent data collection of cetaceans' potential prey. It has long been strived to collect marine mammal data concurrently with their potential prey species to investigate foraging characteristics, with main channels through acoustic tags, CPODs, dive patterns combined with trawl surveys etc. (Doksæter, Godø, Olsen, Nøttestad, & Patel, 2009; Witteveen et al., 2015; Witteveen, Foy, Wynne, & Tremblay, 2008). Highly valuable data has been collected with these methods, and exploration and combination of the cetacean vocalization detection method used in this thesis, can provide a leap jump for cetacean foraging studies as it enables the use of the extensive amount of fish data being collected (Lawrence, Armstrong, Gordon, Lusseau, & Fernandes, 2016). The possibility of this breakthrough and conjunctive use between fisheries and marine mammal data has been once briefly realized in Doksæter (2009), where the researchers identified possible vocalization echo traces of cetaceans in echograms. With this study, it is aimed to follow up and further explore the possibility of utilization of active acoustics used primarily fisheries research for cetacean studies (M Bernasconi, Patel, Nottestas, Knudsen, & Brierley, 2009; Matteo Bernasconi, 2012), especially to be able to gather foraging information on the cetacean species in the waters of countries with primary focus of sustaining fisheries (EuropeanCommission & High Representative Of The European Union For Foreign Affairs And Security Policy, 2015) economy with raised concerns of cetaceans being responsible for the decrease in fish stocks that lead to the discussion of re-legalization of dolphin hunts (A. J. Birkun et al., 2014).

1.1 Fisheries and Cetaceans in the Black Sea

Interactions between the fisheries, and top predators; not only spatially but also in terms of competition for sources and ecological implications have been a primary concern for several decades (Croll et al., 1998; Romeu, Cantor, Daura-jorge, & Simões-lopes, 2017). The impact of the fisheries, on marine mammals have been increasingly prioritized in the recent years, even though the body of research covering the mentioned issue is considerably smaller in volume then desired taking into account of the required knowledge for advanced projections on anthropogenic impacts (Díaz López, Methion, & Giralt Paradell, 2019; Embling & Fernandez, 2005; Pirotta et al., 2014).

Due to above mentioned importance of understanding the relationship between the fisheries, and the cetaceans, it is utmost priority to study the foraging ecology in the Black Sea top predators. For this reason, gaining knowledge on the preferred prey species and habitat preferences and vulnerability to anthropogenic activities of the cetaceans would acquire great input for the forthcoming management and conservation efforts which have been lacking in efficiency due to lack of data on cetacean ecology in the Black Sea (Díaz López et al., 2019; Andrew W Trites, Christensen, & Pauly ', 1997). Therefore, the focus of this thesis is underlined in terms of significance, as it is standing as a possible foundational research that unravels the overlap between the most economically important prey species with the foraging predator distributions.

With the proposed methodology in this thesis study, the fisheries and cetacean relationship is enabled to be researched with the most readily available data set that is already existing as the long-term active acoustics data with great coverage of spatial and temporal means which can be utilized as raw data for cetacean distribution, concurrently to the potential prey. Hence, the here utilized methodology which was realized by Saydam (2015) holds great value and potential for covering the explained lack of data accumulation.

While mentioning the importance of cetacean ecology and conservation, it should be underlined that the flip side of the coin holds great weight as it concerns income from the fisheries and the negative affect of high abundance of cetaceans being voiced by fishermen within and outside of the Black Sea (A. J. Birkun et al., 2014; Goetz, Read, Santos, Pita, & Pierce, 2013). Such concerns from the fisheries perspective are mainly on the issues of depredation of the catch, and the harm on the fishing gear caused by cetaceans, which is an issue that presents itself as bycaught mammals also (Milani et al., 2019).

The emerging point of this thesis work is the conjunction point between fisherman's will to keep the profit and the fishing gear safe while the cetaceans are assumed to be foraging on the valuable species and harming the fishing gears. It has long been debated whether dolphins are the cause of declining stocks of Anchovy in the Black Sea (A. J. Birkun et al., 2014) but there is little scientific foundation grounding such assumption to be adopted. With the mentioned methodology, it was enabled to address some of these concerns, with a systematic approach, first time in the Southern Black Sea, and holding even greater value as the proposed methodology can technically be applied to the adjacent countries.

This study is the first representation of efforts investigating the foraging characteristics and prey preference of cetaceans in the Southern Black Sea using active acoustic data collected for the long-term fisheries monitoring purposes. In the study done by Saydam (2015) the presence/absence information extraction from active acoustic data has been validated via CPOD analysis and visual observation records. Building on the mentioned analysis methodology, this study is aimed to provide an understanding of foraging areas, and preferred prey species and foraging areas on Anchovy (*Engraulis encrasicolus*), and Sprat (*Sprattus sprattus*) of the Southern Black Sea. Aforementioned pelagic fish species are the utmost importance for the Turkish fisheries in terms of economic income they provide. Anchovy alone holds for more than 60% of the income from the fisheries throughout the whole Turkish fishing efforts (TUIK, 2018). Therefore, the methodology used here holds great potential for cetacean research, first and foremost due to its enabling of utilizing long term data that was collected for fisheries research, without the intention of collecting cetacean data. For the current state, this is a valuable gain as there are much fewer opportunities for conducting research for cetacean ecology, compared to fisheries. This methodology also is providing insight prior to the need for specified investment and has a vast amount of potential for further developing an analysis that can shed light on foraging habits that will be discussed further later on. The aim of this thesis is to provide insight on this subject, as distribution, foraging characteristics, prey selection are topics crucial for driving ecological results that can contribute to our understanding of such complex ecosystem dynamics in the future, especially when commercial fisheries are of concern (Witteveen, Foy, Wynne, & Tremblay, 2008).

1.1.1 Significance of Fisheries in the Black Sea

Fisheries is an important source of income and employment in Turkey (TUIK, 2018). Also, artisanal fishery is an important unit of a smaller scale in terms of the percentage adding to the total income of the country but is valued within the coastal population being the part that does not apply to the fishing ban and goes on throughout the whole year. As the main species of value, the anchovy, not only in the Black Sea where 40% of harvest is of the mentioned species but also worldwide as it makes 10% of all landings (Gücü et al., 2017; Libralato et al., 2018 ; FAO, 2016). Thereby, fluctuations in the anchovy stocks raise significant concern, which anchovy has been known for its oscillations in stocks with drastic incline and decline periods in the Black Sea with many arguments of causality like purse seine fishing, overfishing, (Gücü, 2002) or the invasive species have been put forward to disclose the reason of (Gücü et al., 2017). To draw out possible causes, management strategies have been set to reach the aim of sustainable fishing and better monitoring and regulation of the mentioned stock via set goals on marine pollution, licensing, decommissioning, international cooperation, decreased fishing effort, and restricted mesh size (GFCM, 2017).

1.1.2 Cetaceans of the Black Sea

In the Black Sea, three species of cetaceans are present as resident top predators; Harbor Porpoise (*Phocoena phocoena* ssp. *relicta*), short-beaked common dolphin (*Delphinus delphis* ssp. *ponticus*) and common bottlenose dolphin (*Tursiops truncatus* ssp. *ponticus*), - all listed as subspecies confined in this closed basin (Reeves & Notabartolo Di Sciara, 2006). Abundance of the Black Sea cetaceans are yet to be confidently estimated, yet the present guess is that cetaceans are found in numbers on 1000s or 10.000s in the Black Sea (A. J. Birkun et al., 2014).

Of the mentioned three, The Black Sea Harbor Porpoise is the only species in the genus Phocoena in the basin, which is listed as a subspecies due to this populations genetic and morphological differences to other populations in other seas (Randall R. & Sciara, 2005).

The smallest cetacean in the Black Sea, the Black Sea Harbor Porpoise *(Phocoena phocoena ssp. relicta*), is listed as endangered and decreasing (Reeves & Notabartolo Di Sciara, 2006 ; IUCN, 2008) is the most vulnerable of the mentioned three. This species is known for its shy, discrete nature and coastal distribution, not excluding the subspecies of the Black Sea.

Second largest cetacean of the Black Sea is the short-beaked common dolphin, (*Delphinus delphis ssp. Ponticus*) which is a species listed as Vulnerable at the IUCN Redlist, and as the need for further research is stressed before, the population trend is unknown (IUCN, 2008).

The largest cetacean in the Black Sea, is the Bottlenose dolphin, which is listed as Endangered in the IUCN Redlist and has been stressed for conservation in administrative initiatives as the aforementioned species (A. J. Birkun et al., 2014; Reeves & Notabartolo Di Sciara, 2006).

1.1.2.1 Anthropogenic Impacts and Threats to the Black Sea Cetaceans

When mentioning the cetacean ecology, anthropogenic impacts are bound to be considered, as although habitat preferences in terms of long term environmental parameters such as tidal currents and upwellings are not likely to be majorly affected within relatively short term human activities, other parameters like fishing pressure is acknowledged as a major driving force on the marine top predator populations (Andrew W. Trites, Christensen, & Pauly, 1997). Other activities such as marine traffic, collisions and prey depletion, habitat deterioration and bycatch are also some of the most pronounced anthropogenic affects with known adverse effects on marine mammals (Bayless et al., 2017; Macaulay, Gordon, Gillespie, Malinka, & Northridge, 2017; Stier et al., 2016). Understanding these affects, and the response of the ecosystem is crucial to be able to complete efficient projections with effective management strategies (Heithaus et al., 2008; Pirotta et al., 2014).

Anthropogenic effects of human practices on marine mammals have long been tried to understood. Through long term studies in especially protected area studies, it has been shown that mammals can react to human practices such as marine constructions and traffic differently (Thompson et al., 2010). As in; fisherman boats can attract cetaceans due to its aggregation of prey and also due to discard fish. But at the same time, presence of too many boats around the cetacean pod can cause avoidance of the area (Baş, Amaha Öztürk, & Öztürk, 2015). Similarly, drilling work underwater, for constructions such as pile driving for natural gas and petroleum search, can affect cetacean presence in the area. But the mechanism which the cetaceans are affected are not fully understood in terms of the significance of disturbances due to difference characteristics of these activities (Bailey, Brookes, & Thompson, 2014; Russell et al., 2014). Meaning, many studies have been focusing on understanding the effects of speed, frequency and continuity of disturbances and the amount and type of affects they have on marine mammals. Additionally, studies show that different animals can react differently to these certain anthropogenic affects such as interactions with trawlers (Summary, 2020).

Up until the cetacean hunting ban, the main reason for the decline in the cetacean population from the assumed 1000000s of individuals to the todays estimate to 10000s, was acknowledged as direct killings for the dolphin meat, skin, bone and blabber industry (Barlas & Müdür, 1971). Following the hunting ban, reduced prey availability has been considered an ongoing major threat (Alexei Birkun & Bearzi, 2002).

In the Black Sea, following the banning of direct killing of cetaceans, two major events are known to have occurred that caused significant decrease in the populations. These are two events of morbillivirus epizootic that was observed in the year 1990 and 1994 (A. Birkun et al., 1999). When the timings of these events were considered taking into account of the prey abundance at the time, it was also observed that the mentioned time periods actually overlap with the sudden decrease in the potential prey species which are also focused in this thesis study; namely Anchovy and Sprat, and the infamous introduction of invasive *Mnemiopsis leidyi* in the Black Sea (Zaitsev & Mamaev, 1997). In the following years, this coinciding observations are discussed in terms of causality, and it has been argued that the cause of the decreased health of the cetacean population in the Black Sea was due to lack of prey availability caused by competition within the stocks between fisheries and the cetaceans (Reeves & Notabartolo Di Sciara, 2006).

1.1.2.1.1 Direct killing

Although cetacean hunting was banned in 1983, direct killing incidents are theorized as an ongoing cause of cetacean deaths in the Black Sea as with the case of entanglement and competition for prey, the highly valuable nets and the catch may or may not be compromised against the cetaceans at the incident. With such issues, unless there are designated mammal observers on the vessel, it is difficult to obtain a certain number of direct killing or even bycatch, as the vessel personnel might not be equipped with the will or standard of documentation or reporting of the incident which puts the income at risk by coinciding with the expected landings (Bayless et al., 2017). But the efforts on effective management initiative by stakeholders have been shown to be fruitful when communication between the two subjects of the matter is increased (Murshed-e-Jahan, Belton, & Viswanathan, 2014). Adding these points of views from the fishermen, and the flexible and difficult to restrain nature of the field, we can conclude that without the designated efforts and focused aim of standardized data collection on cetacean foraging ecology and increased communication of all parties on cetacean conservation; the goal of efficient management seizes to achieve its full potential. Even though the directed kills are now illegal, the population is assumed to be not yet recovered after the exploitation period due to ongoing threats (Birkun, 2006).

1.1.2.1.2 Bycatch

The term bycatch stands for the death of an animal from an activity that was not intended to catch the species mentioned. Therefore, although dolphin hunt is not ongoing, there still is an arbitrary number of dolphins and porpoises being bycaught annually, depending on the kinds of fishing gear used as these incidents happen with a higher frequency with certain types of fishing activities, like pelagic trawl nets and gillnets (Tonay, Dede, Öztürk, & Öztürk, 2012).

To avoid bycatch, acoustic deterrent devices were suggested to have an effect on marine mammals to signal the animal to avoid the area with the fishing net. But as the data from that methodology accumulated, it was observed that pingers were not as cost effective as gear modifications considering its low success to deter the animals, if not attract them (Dawson, Northridge, Waples, & Read, 2013).

For the harbor porpoises in the UK, it is known that gillnet, set net and tangle net fisheries are of the main activities that lead to bycatch (Nunny, 2011) . To avoid that, some regulations have been put forward in many countries with the concern of conserving the rapidly declining cetacean population, eg. ban of pair trawling in the coastal waters ie. up to 12 miles offshore, with successful outcomes of reduced bycatch (Barclay, 2010). Additionally, there are measures on the number of bycaught animals that is foreseen to be not harmful to the species in the population level. These precautionary levels have been on the works for some time, as the research on the field accumulates, the further accurate sustainable bycatch measures are aimed to be produced. The initial ratio of the animals bycaught to the population abundance estimates was put forward as 2%, and then decreased to 1.7% and then to 1% as there were concerns of undocumented bycatch numbers being added to those percentages causing significant harm (Nunny, 2011). Although, limited certainty and accountability of this approach has been critiqued in terms of the field applicability (Hammond et al., 2009).

For the Southern Black Sea, the issue of bycaught cetaceans have been studied by Tonay (2012), and similarly to the other seas, it was concluded that gear differences occur in terms of bycatch incidences; Turbot fisheries being a major field of porpoise bycatch, especially between the months May to June, when porpoises were found to be stranded with net marks and containing sprat, mackerel and gobies in their stomachs (Tonay et al., 2012). Even though extrapolating from this point to conclude any idea on preferred prey species might be optimistic, as if the bycatch incidences are weighed more on a certain type of gear, the results from the stomach contents of stranded animals would be unavoidably skewed towards the mentioned gears' target species. Currently, bycatch poses itself as a cause of distress on cetacean populations as study shows that for the common dolphin, within the north-east EU waters, 800 animals are bycaught each year due to pelagic trawling activities (Northridge, 2006).

To sum all the above mentioned threats to cetaceans; anthropogenic impacts, direct killings, bycatch, habitat and prey depletion, epidemics, competition between the fisheries which none of them are stand-alone pieces of the equation, it is apparent that the main obstacle to overcome to tackle the issue is the cooperation between the adjacent countries around the Black Sea basin. If only, the accumulated and combined efforts can be utilized, the effective management and conservation can be put forward. For that purpose, the proposed methodology is holding great potential as it enables the utilization of already existing data source of fisheries acoustic data, for cetacean foraging research.

1.2 Acoustic Research for Marine Mammals

Estimation of abundance mostly is a primitive step in ecology, as well as marine mammal ecology. Whereas in practicality, even the state of art methods are yet to provide an estimation technique solely themselves. Visual observations on; land stations, boats, aerial systems, ships and transects are known to serve for the formation of a foundation on marine mammal ecology. Saying that, relatively low coverage, limited time frame due to weather conditions and day-only data collection of surfacing animals are one of the most lessening downsides of the mentioned technique. Whereas with the addition of hydroacoustics, data has much higher coverage, can provide data form both day and night times, the weather allowance is wider in comparison, submerged and diving animals are also targeted, raw data is less prone to be misread due to unfamiliarity to the collection procedure as it is largely software automated or operator prescribed, compared to visual techniques. Considering such advantages of the acoustic approach, relatively less fruitful the outcomes has been present in terms of marine mammal abundance estimation results, not only Delpinidae but also other Balaenidae (Barlow & Taylor, 2005)(Lewis et al., 2018).

1.2.1 Vocalization of Cetaceans

In early Eocene, about 50 million years ago, ancestors of Cetacean suborder inhabited aquatic environments and the fossil records from 17 million years later in early Oligocene present divergence between Odontoceti and Mysticeti. Although the driving force behind is yet to be discovered, early cetaceans show high frequency hearing adaptations. Today, cetaceans with a minimum of 65 odontocete and 11 mysticete species recognized, are known to have exceptionally well hearing abilities with the broadest range of frequency sensitivity among the animal kingdom (Ketten, 1997), with the echolocation abilities being discovered in the late 1950s (Schevill & Lawrence, 1956).

As the speed of sound in water is 4.5 times faster than in air, Cetacean frequency discrimination ability surpasses the terrestrial mammals', and the ear structure differs as they lack an external ear. Thereby it is difficult to determine the information flow and the structures involved as they are completely internalized. Cetaceans use acoustic cues to deliver information about the source; whales occupying lower frequencies while dolphins are on the higher frequency end of the spectrum (Clarke & Waller, 1997). An experiment revealing such sophisticated echolocation abilities showed that an echolocating dolphin can detect a 2.5 cm metal target with about 72m distance (Murchison, 1980), showing the competence of the biology of echolocation.

Cetacean vocalization has a broad spectrum extending to more than 100 kHz. According to the amplitude and frequency characteristics of these vocalizations, they are categorized as whistles, screams, bray calls or clicks. Ultrasound odontocete clicks are used for echolocation purposes, and the amplitude can be adjusted for the noise level of the environment. On the other hand, whistles are frequency-modulated pulses that can last for 3 s, in a range of 2-30 kHz (Simmonds & Maclennan, 2005).

Cetaceans make use of their acoustic identification capabilities for; tracking and capturing prey, locating and avoiding obstacles, investigating the features of the objects in their environment, determining the water depth, avoiding possible predators, tracking conspecifics and socializing (Branstetter, 2006). Most echolocation studies of dolphins, mostly bottlenose dolphins, are done while foraging is taking place, as the most echolocation index is shown to be observed in foraging activities (Barrett-Lennard, Ford, & Heise, 1996). Bottlenose dolphins make use of both passive and active localization methods while searching for prey. Once a target is detected passively, dolphins mostly rely on echolocation from there on. Such a passive search generally involves scanning of environment with head and body movements which increase the spatial resolution. The strategy used while foraging varies with different environmental conditions like the prey or which species are around that might possess a risk of predation (Romeu et al., 2017). For different intentions, the vocalizations must have different characteristics such as the duration, speed or the pattern of the call. For instance, alarm calls are known to be rapid, brief and undetectable by a potential predator. In contrast, vocalizations for sexual displays ought to have longer durations with a wider range and are repeated and easy to locate by the conspecific females (Tyack & Miller, 2002). With the precise description of these vocalization details, cetacean detection equipment are more and more being implemented at species discriminating competency levels (Amorim et al., 2019).

In a general echolocation incident of a dolphin; a click is executed and an echo is awaited. If a target is not detected, clicks are repeated with a slow rate. Whereas when an obstacle is detected in a short range, click repetition rate increases with short delays for processing the received echo, which takes around 0.2 ms (Simmonds & Maclennan, 2005; Tyack & Miller, 2002). In the light of such knowledge, investigations on foraging echolocation patterns are enabled.

As commonly acknowledged, cetaceans are shown to produce more vocalizations during foraging, compared to non-foraging (Visser et al., 2017). These results show that cetaceans increase their echolocation activities during active searching for prey in foraging areas, in contrast to lower levels of echolocation activities while travelling or resting and socializing. This information is the light to the assumption behind the methodology used in this thesis study; areas where more echolocation activity observed, are likely to be used as foraging areas by the vocalizing cetaceans.

1.2.1.1 Biology of Sound Production in cetaceans

The main organ that is involved in this process is thought to be the larynx, followed by blowhole diverticula and the muscles that act as a plug for internal nares. Different organs used for producing sound might explain the highly differentiated frequency peaks within signals. For the directionality problem, argued organs are the fatty tissue in the head, mainly the melon, air spaces within and the jawbones' reflective properties (Simmonds & Maclennan, 2005). Melon, which is placed in dolphins forehead, is a fatty body that has unusual characteristics that couples acoustic energy from the nasal area to sea water by matching the acoustic impedance of these different media (Tyack & Miller, 2002).

Physiology of odontocete larynx differs from terrestrial mammals', which is known to be the main sound-producing organ in the latter. The question of whether larynx or the nasal plugs are the main source of vocalizations in odontocete has been thoroughly debated. In the case of nasal plug scenario; sound is produced due to friction mechanisms between hard tissues. Antithetically, as Cranford (2000) suggested, odontocete vocalizations can be produced by a mechanism through "phonic lips", which is similar to the terrestrial glottal pulses with the larynx (Tyack & Miller, 2002).

In his study, Cranford (2000) showed that the produced pulse and the lips' parting and closure coincided, with a high-speed endoscope. In a relatively recent study, it has been shown that; the studied animals click with their right pair of phonic lips and whistle with their left pair. It was demonstrated that, with just a single pair of phonic lips, echolocating delphinids can change the click energy levels over five orders of magnitude, change the click centroid frequencies over more than two octaves, and modulate the sound radiation from the melon for beam steering (Madsen, Lammers, Wisniewska, & Beedholm, 2013).

1.2.2 Passive Acoustics

When studying cetaceans, passive acoustic methods are one of the most utilized approaches, along with visual observations of the animals. As acoustic data does not require continuous survey efforts, long term data collected by passive acoustics has long been highly valuable for these highly mobile species, and species discrimination efforts have recently been starting to show greater potential, with especially high correct classification rates on common and bottlenose dolphins (Amorim et al., 2019) which are the two delphinids present in the Black Sea. Although fairly established and widely used and accepted, uncertainty of the detection range of passive acoustic methods, especially pods, are of one of the most argued issues of the field. Detection ranges pronounced has been around 500 meters depending on the heading and direction of the vocalizing animal (Dede, Öztürk, Akamatsu, Tonay, & Öztürk, 2014) for TPODs and hydrophones (Sveegaard et al., 2011) and previous literature go up to 1246 meters with TPODs (Philpott, Englund, Ingram, & Rogan, 2007) and even up to 1776 meters for CPODs (H. K. Nuuttila, Thomas, et al., 2013), and detection ranges as low as below 100 meters (Garrod et al., 2018) has been more recently debated.

Additionally, to the detection range ambiguity, passive acoustic equipment does not as flexibly enable the operator to locate the detected animal or confidently identify the sourcing species and PODs, opposed to hydrophones with operator classified criteria, provide little information on classification that run as black box algorithms. These issues, which are more or less shared problems in the active acoustic approach as well, are still issues that researchers keep in mind while approaching their data sets (Macaulay et al., 2017; Sarnocinska, Tougaard, Johnson, Madsen, & Wahlberg, 2016). Although it is possible that the environment, terrain, water quality, depth and noise can play a role in detection range (Clausen, Tougaard, Carstensen, Delefosse, & Teilmann, 2018), the consensus on a loose limit has not been set to this date. Seasonal behavioral changes are also an important possibility that can lead to different results of cetacean detections in different times of the year (Dede et al., 2014). Noted that during spring, cetaceans were observed to be foraging, especially at night, and looking for fishing grounds in the Bosphorus strait. But in the autumn, look for fishing grounds were not found by Dede (2014), driving the conclusion of cetaceans having not as much pressure for foraging in autumn compared to spring.

1.2.3 Active Acoustics

As explained above, traditionally, passive acoustic data is used for the marine mammal studies and active acoustic data is collected for fisheries research. Although first detection of dolphins in the active acoustic data dates back to as early as 1960 (Benoit-Bird et al., 2009), relatively shortly after the first detection of fish in the active acoustic data in 1920s (Kimura, 1929). The two are being used mostly as coupled when foraging characteristics is the subject of research where, again, active acoustic data is used for the prey information and passive acoustic or alternatively dive tag profile data is collected for the predator (Lawrence et al., 2016; Rasmussen, Akamatsu, Teilmann, Vikingsson, & Miller, 2013; Witteveen et al., 2008).

A more similar methodology to the one used here, which would be a closer translation, to passive acoustic studies would be the wave glider studies with towed hydrophones where detections are grouped into time period classes and quantified accordingly (Bittencourt et al., 2018), assuming the active acoustic equipment acts as a passive listener of cetacean vocalizations and assuming encounters that span across a longer time represent higher echolocation indexes, sourced from larger numbers of individuals (Ferguson, Barlow, Fiedler, Reilly, & Gerrodette, 2006).

Other approach to marine mammal research via active acoustics have been through the backscatter of the animal, mainly by lungs, using sonars and echosounders (M Bernasconi et al., 2009; Hill-Cook M.L., 2006; Quick, Scott-Hayward, Sadykova, Nowacek, & Read, 2017). This approach although is similar to the thesis topic discussed here, due to it being a way of utilization of active acoustic equipment for cetacean studies, the main difference is that the vocalization is not the target, but the echo from the individual animal is. The orientation of the animal and the depth of the observation is mentioned to be valuable sources of information with this approach, with the drawback of needing the animal to remain within the split beam to be able to gather behavioral information, that hypothetically can be maintained by steerable echosounders (Godø, Sivle, Patel, & Torkelsen, 2013). Hence, the emerging field of marine mammal research with active acoustics, has potential standing not only by the available data sources but also via its possibility for bringing newly emerged approaches (Pedersen, Storheim, Sivle, Godø, & Ødegaard, 2017).

In parallel to the approach utilized in this thesis, although not followed through in large data sets, with respect to ecological implications as is aimed in this theses; there have been reported instances where on echograms, certain patterns were observed and suspected to be resulting from cetacean echolocation marks (Bernasconi et al., 2009; Doksæter et al., 2009). In the study of Doksaeter (2009), echograms showed characteristically vertical patterns that were suspected to be of cetacean vocalizations where they were also able to detect traces of marine mammals as they ascended and descended throughout the water column, especially around the deep scattering layer where cetaceans seemed likely to be foraging mainly on. This finding is the only other study to our knowledge, where the opportunity of enabling this data type for cetacean research has been realized, which has been aimed to be developed in Saydam (2015) and followed to ecological implications potential within the scope of this thesis. Therefore, the significance of the here mentioned methodology is standing as both novel and readily acknowledged.

2. MATERIAL AND METHODS

The study was carried out in 2016 November with transects covered by Bilim II RV, in the Southern Black Sea. In this study, frequency response methodology developed by Saydam (2015) was used for the determination of cetacean vocalization detections in the data set. In addition to that, cetacean detections were quantified and pelagic fish schools were analyzed using echointegration processing (Simmonds & Maclennan, 2005). In the echograms, to determine distributions of different pelagic species, the discriminating factor of the thermocline depths acquired by CTD stations carried out during the survey was used utilizing the knowledge of their habitat preferences in terms of water column temperatures. Therefore, the distribution of cetaceans with respect to some of the most economically important pelagic fish species in the Black Sea; of Anchovy and Sprat, was extracted, to enable the understanding of foraging areas of the cetaceans throughout the study period.

2.1 Study area and Period

Study was done in the Southern Black Sea region, of Turkish waters. Survey that provided the data set have been conducted with Bilim-2 Research Vessel between the dates 02.11.2016 and 27.11.2016 and the hydroacoustic data was collected continuously throughout the whole survey period. The data set of 2016 used within the scope of this study is part of a long term survey initiative in the Southern Black Sea where the survey designs have been standardized for pelagic stock assessments (Stepnowski, Gücü, & Bingel, 1993). Therefore, the cetacean ecology study conducted here is opportunistic in terms of its data source nature, as the survey efforts and the data collection is not conducted with the cetaceans in mind, but the data set was utilized post-processing using the otherwise discarded part of the data set, as the cetacean vocalization marks used here is eliminated from analysis as noise, in the traditional fisheries approach.

Coverage of the Black Sea during the survey was done with transects throughout the sea time, beginning with off shore transects, from west to east, and with close to shore transects from east to west headings, as shown in the Figure 1.

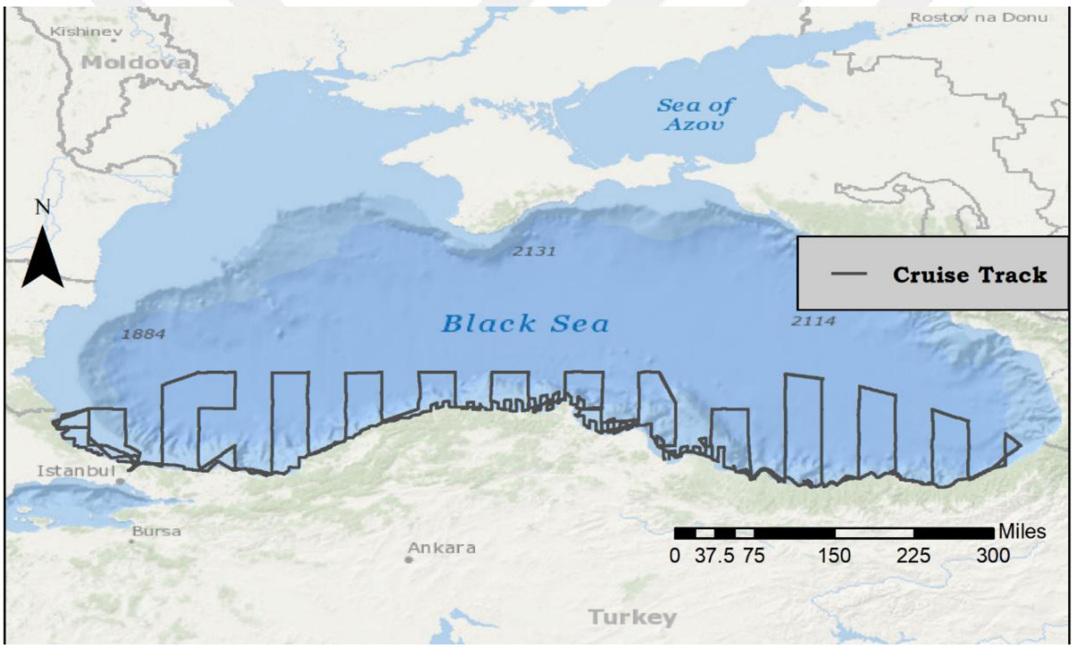

Figure 1. The map showing the cruise track of the RV Bilim II during the 2016 November survey

Environmental physical data collection was also held with CTD probe deployments at stations as well as of trawling hauls. This data provided the thermocline depth information from the water column temperatures which are used to discriminate between species of pelagic fish that are focused on this thesis; namely Black Sea

Anchovy (*Engraulis encrasicolus ponticus),* that habituate above thermocline and Sprat *(Sprattus sprattus)* which habituates below thermocline, as ground truthed via trawl trials as well. Trawl samplings were done, for every transect leg and also hauls were practiced wherever a large school was observed from the echograms during the cruise, resulting in an expected deflection from the transect lines.

2.2 Data Collection

During the survey, 3 types of data has been collected; biological data from trawl hauls, physical data from CTD stations, and hydroacoustic data form the Simrad EK60 scientific echosounder (Simrad, Kongsberg Maritime AS).

2.2.1 Active Acoustic Data Collection

Hydroacoustic data collected is continuous throughout the survey period at sea. Prior to the survey, the echosounder had been calibrated using a copper sphere of known TS, according to Foote et al (1987) (Foote, Knudsen, Vestnes, MacLennan, & Simmonds, 1988). Throughout the survey, acoustic data was collected with Simrad EK60 scientific echosounder in the frequency bands of 38 kHz, 120 kHz and 200 kHz. The 38 kHz frequency of the echosounder was used for the visual tracking of the school during the survey and in post processing for fish distribution analysis. From the fisheries knowledge based on the biological and environmental cues, and acoustic properties, it was enabled to specify the species information of the fish backscatters observed on the echogram. Discrimination of fish species is done with respect to their backscattered energy, TS differences, the densities of the targets, school formation patterns, environmental cues i.e. the depth they are found at, temperature of the water column, whether the observed school is below or above the thermocline, distance to the seabed (Korneliussen, Heggelund, Eliassen, & Johansen, 2009).

In post-processing, the information from 120 kHz frequency band was also used for the frequency response method in the algorithm shown in Figure 2 developed by Saydam (2015) to be able to extract dolphin echolocation detections.

2.2.2 Trawl Sampling

At each transect leg, trawling hauls were performed. These hauls lasted for 30 minutes each, and CTD probe deployments were carried out before and/or after the haul start and end timings. When the haul was collected, the gathering and sorting of the catch was completed prior to measurements. Of the catch, fish were measured in length and weight in 0.5 cm size classes. These measurements were collected mainly for anchovy stock assessment studies as the data set utilized in this study was compiled for pelagic stock research. Additionally, to the set haul numbers, whenever a school pattern of interest in terms of size and or shape was observed, trawling was performed to be able to gain further information on the composition of the species that are came across in the echograms. Completion of all these trawling enabled the analysis of fish schools to be fairly straight forward, as the assumptive credibility of our knowledge on TS, school shapes and environmental parameters were checked multiple times each year at sea.

2.2.3 Oceanographic Data

Oceanographic data on the environmental physical parameters are collected using a CTD probe and by performing deployments pre and post trawling and at each transect. Data on temperature of the water column, salinity, oxygen levels, chlorophyll, and depth of thermocline information were collected. Of the mentioned oceanographic parameters, the temperature change at the thermocline was observed to be the most reliable distinctive parameter to be able to determine the pelagic fish species that are observed on the echogram, when trialed with trawling as mentioned for biological data collection. Therefore, in post processing, depth of thermocline information gathered from these CTD stations was also used to discriminate between sprat and anchovy schools. And finally, open source satellite data was used in this thesis, for sea surface temperature, was generated using E.U. Copernicus Marine Environment Monitoring Service (CMEMS) Information (Buongiorno Nardelli, Tronconi, Pisano, & Santoleri, 2013).

2.3 Data Analysis

Following the survey, the oceanographic and acoustic data collected were set for analysis. Active acoustic data was processed using the Echoview Software (Echoview Software Pty Ltd, Hobart, Australia). In the analysis, there were two parts; postprocessing where the results are extracted and preprocessing where the raw data was compiled and cleaned up to be able to extract information without deflections.

2.3.1 Preprocessing of the Data

After the completion of survey at sea, to analyze the raw active acoustic data collected, it is required to complete several steps of data cleanup to ensure healthy exports without untargeted echoes skewing the results. Mentioned preprocessing steps completed for the scope of this thesis were; noise removal which is a step explained below, manual correction of the detected bottom line where necessary, determination of exclusion zones which are correction of dead zones and near fields; areas of near surface and near bottom shadowing, as well as manual removal of air pockets created at the surface caused by the maneuvering of the vessel when changing heading at the transition of transect legs and CTD stations, and trawl hauls, removal of the backscatter from the CTD probe, removal of the rare unexpectedly high echoes which are suspected to be from cetacean lungs when the animals fall under the echosounder especially when bowriding. Also, to use frequency response technique for cetacean detection algorithm, data has to be of multiple frequencies and has to stand with a relatively high SNR (signal-to-noise) ratio, and does not use integration of noise. By these steps, healthy analysis of the data set was ensured and the raw data were prepared appropriately for the analysis types to be followed.

2.3.1.1 Noise Removal

There are different kinds of noise that can occur in the active acoustic data, resulting due to several different potential causes and sources. These different noise types call for respective noise removal techniques covered within the software or manually by the software user.

Impulse noise is the type of noise that are represented as less than one ping within the echogram. Removal of these can be applied via dB thresholds with ‘advanced operators’ under ‘exclusion’ and specification of the ping width to look for closest sample on each side considering the threshold dB above and below the sample ping tagged as the impulse noise including ping. Transient noise is of similar nature but these are the kind that are represented in multiple pings but are not necessarily continuous throughout the dataset. The other kind of noise named Background noise is observed to be present in the data set continually for multiple hours or longer, possible resulted due to a source that is not apparent only for a limited time but with much higher temporal coverage, e.g. ship traffic, equipment settlement faults, mechanical sources. Intermittent spike noises are composed of noises that are showing the combination of both above mentioned noise types. These can be removed by impulse and or transient noise removal operators (Foote et al., 1988).

If a noise type of consistent characteristics is present, then resampling the exact ping geometry and removal with selection of those is possible using the `match geometry` operand under data manipulation operators. This operand creates a virtual variable from the selected operand 1 and applies these dimensions on operand 2. Utilizing this operand, which is used in the algorithm used in this thesis methodology, the type of backscatter of specified geometry can be selected for (Simmonds & Maclennan, 2005).

2.3.1.2 Exclusion Zones

Deadzone is an area where the backscatter from the bottom or surface detections are not considered as data points. Deadzones can be near surface deadzones or near bottom deadzones (Ona & Mitson, 1996). Surface deadzones occur due to the depth of transducer placed under the hull with the addition of near field effect.

Combining the hull depth of the vessel and the transducer depth, surface organisms are not captured by the hydroacoustic devices that are downward looking and vertically oriented. This measure for the analysis conducted in this thesis study was set as 6 meters. For bottom deadzone elimination, this selection is made between the detected bottom and the detected bottom with a safe distance above the detection line, which can change depending on the characteristics of the data set -whether it is a terrain of many high slopes or not- would be around 2-4 meters (Simmonds and MacLennan 2005). In this study, near bottom deadzone has been set as 3 meters. In the areas where the slope of the bottom is steep, the deadzone would be larger, and such areas are corrected manually in the data set.

2.3.2 Analysis of Pelagic Fish

For the analysis of pelagic fish distributions, initial step is to determine the area to be analyzed in the Echoview software. This was done following the noise removal where minimum analysis threshold has been set at -35 dB, and exclusion zones were set, which leaves the software with only the indispensable data points. After that, the step that was taken was to fit the limits for the desired areas in the water column, where species of pelagic fish is assumed to be present, according to environmental and geographical parameters assigned to each species (Korneliussen et al., 2009). For that purpose, the first limitation is setting the “exclude above line” limit which is at 6m due to reasons explained above. Secondly, the “exclude below line” limit was set at the corrected bottom line of the “best bottom candidate” which was initially detected automatically and then duplicated into an “editable line” where the bottom is elevated 3 meters, corrected for nearfields, line breaks and acoustic shadow areas at high slope terrains. In addition, areas where data should be excluded from the analysis as “no data” was introduced to the algorithm for the volumes where CTD probe, surface air pockets and other organism echoes such as mammal lungs have been detected but should not be analyzed as potential prey of the cetaceans. This enables the software to disregard any untargeted backscatters so that the data set is left with only reliable pelagic fish echoes in the whole water column.

Following, to ensure health of the data set, trial exports were performed and the results were manually checked in Microsoft Excel (2016) for any outlier data points where NASC values, which is the representative of amount of backscatter from the set volume of water depending on the size of the grids introduced to the software. After sourcing the pings that gave questionable NASC values in the export files, these areas are revisited in Echoview to determine the cause of the observed outliers. If these values are concluded to be due to any source of error, noise or contamination, these areas are marked as "no data" areas to be excluded from the analysis following the trial runs. If these values are observed to be due to densely packed fish schools, that were significantly high in size but are not contaminated pings, they are left as is to be included in the echointegration analysis. Completion of double checking all the areas of suspicion in the trial exports were followed by distinction of assumed habitats of pelagic fish of interest, with respect to temperature differences at certain depths in grids of appropriate sizes.

For the echointegration process (Simmonds & Maclennan, 2005), definitions of grids to be dividing the data set is decided as 1nmi distance, and depth of thermocline. For the part of the data that is assumed as below thermocline pelagic species, Sprat, the grids are of 1nmi distance and between thermocline depth and the bottom line and 100 m depth, which ever limit is gained first depending on the location of the ping. This enables the echointegration algorithm to export in dB around -50 dB depending on the size of the individuals in the schools, which is a lower value compared to Anchovy, TS, temperature and depth values sprat is known to habituate. This part of the data set is exported using echointegration, and used in producing below thermocline pelagic fish distribution, which is assumed to be sprat as the trawl trials assured, and referred as so here on after.

Similarly, for the pelagic fish distribution, that habituate above thermocline, assumed and referred as anchovy which represented a higher dB value compared to Sprat, at around -40 dB, same 1nmi distance is used for grid size determination. And for the vertical extent of the grid, the analysis is limited to the water column that fell between the surface, which is at 6 meters for conservative nearfield exclusion, and between the thermocline depth which showed a mean of 32.5 meters averaged for the whole survey (Table 1). Therefore, the upper part of the water column, between the surface and above the thermocline, is echointegrated to produce distribution of pelagic fish, namely anchovy.

Table 1. Depths of the grids used for echointegration on potential pelagic prey distributions

Depth (m)	Above Thermocline (Anchovy)		Below thermocline (Sprat)	
	Exclude Above (surface)	Exclude Below (thermocline depth)	Exclude Above (thermocline depth)	Exclude Below (Bottom up to 100m)
Min	6.0	7.245	7.245	14.887
Max	6.0	67.847	67.847	100.739
Mean	6.0	33.080	32.589	86.205

2.3.3 Analysis of Foraging Clicks

Acoustic data collected throughout the survey via Simrad EK60 echosounder at both 38 kHz and 120 kHz frequency bands are used. Dolphin marks in the echograms are highly visible as their amplitude, in Sound Pressure Level (SPL) is significantly higher than ambient sound. Pulse rate of the Simrad EK60 scientific echosounder used in this thesis study had been operating at 0.5 second. When that value is compared with the 0.2 seconds pulse rate of common dolphins, coverage of multiple clicks within a ping is ensured, therefore continual intermittent noise pattern is confidently captured within the vertical interrupted signal marks.

Another assumption in this thesis methodology for estimating cetacean foraging areas is that foraging animals are more vocal and produce more frequent echolocation clicks than the travelling and not feeding animals (H. K. Nuuttila, Meier, et al., 2013), and increased dolphin density representing increased foraging behavior taking place in the area (Hastie, Wilson, Wilson, Parsons, & Thompson, 2004).

To explore the possibility of dominant night time foraging, day times have been split with regards to sunrise and sunset hours. With local time, which is GMT+3 in the whole survey area and dates, 07:00 and 17:00 were set in subsetted analyses for sunrise and sunset respectively and referred as hereon after.

It is seen important to note an oceanographic property of the survey area, Southern Black Sea, which enables easy processing of the cetacean detections in this data set. And that is, the anoxic property of the Southern Black Sea below around 100 meters depth (Oguz, Ducklow, & Malanotte-Rizzoli, 2000), which ensures the absence of any biological backscatter in the echograms, when used a conservative upper limit for the analyses, taken as 200m in this study. As the cetacean vocalizations detected in the echograms cover the whole ping extent vertically, conservative elimination of the upper 200 meters does not cause any loss of data in the Black Sea basin where offshore depths are usually around 2000 meters, on the contrary, ensures healthy export process as there is no room left for error in distinction between the fish backscatter, noise, and vocalizations below 200 meter depth, in the study area.

2.3.3.1 Frequency response

For this approach, operators determined in Saydam (2015) are used in the Echoview software under the model tree. Operators are the algorithms applied on operands like datasets, using virtual variables; all displayed in dataflow as an intuitive visual representation within boxes. Algorithm flow used can be seen in Figure 2 which enables the operator to end up with only dolphin marks in the echograms with remaining echoes being fully eliminated from the analysis.

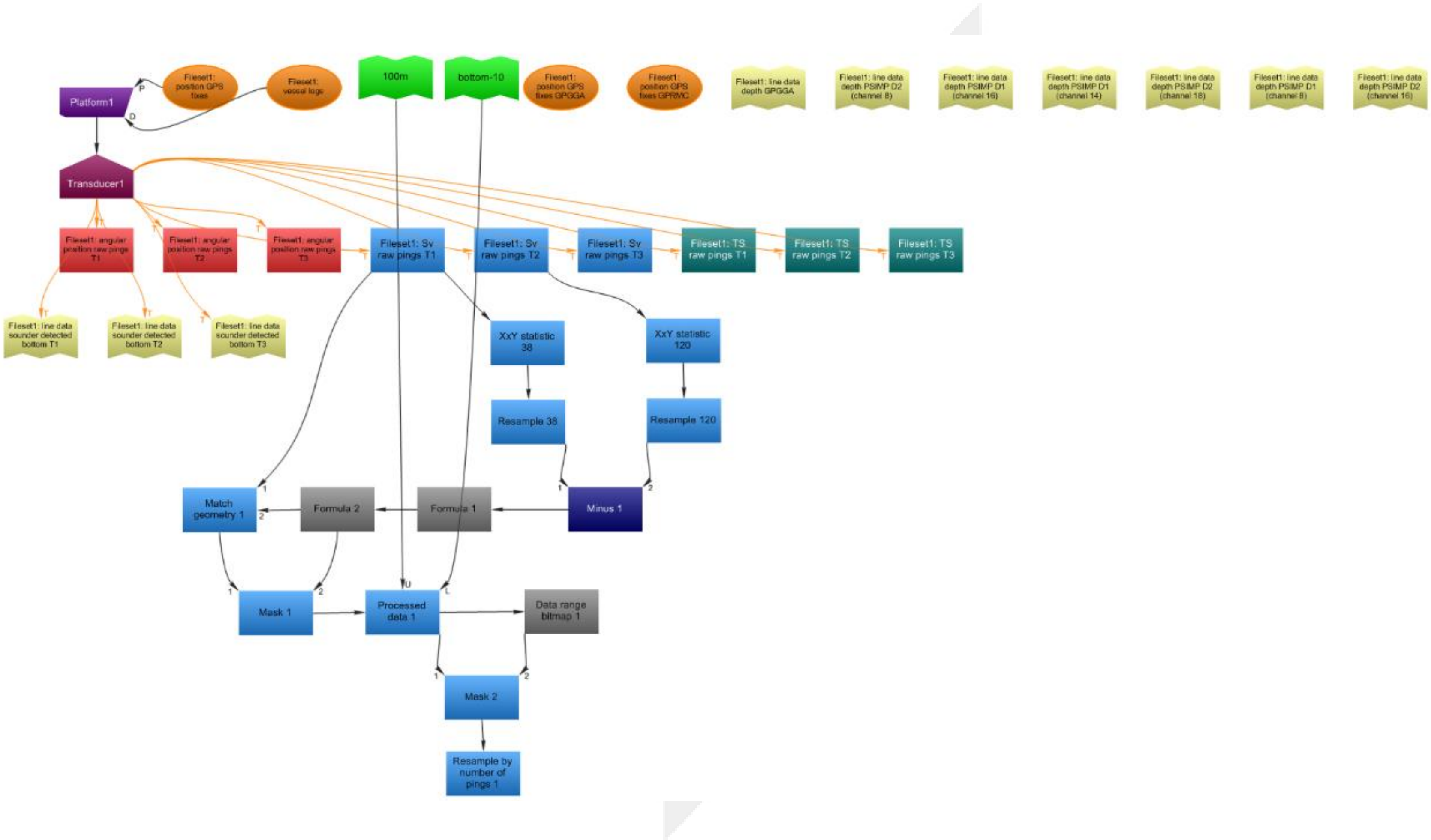

Figure 2. Echoview algorithm used in model flow, for cetacean presence extractions by Saydam (2015)

As the cetacean vocalization marks are represented in the echograms as intermittent vertical lines, that extend across the entire ping, the algorithm used was set to select marks with one ping gap between the signals, which is interrupted vertically, which is a pattern of “noise” discussed beforehand. Therefore, the methodology makes use of the noise data points and extracts cetacean presence information using the algorithm in the above Figure 2 with the echointegration export of data for each ping.

Cetacean echolocation clicks fall in the frequency band of the echosounder used in the survey. As the common dolphin has peak frequency of clicks at 23 kHz to 67 kHz (Au, 1993), the 38 kHz frequency band of the echosounder was the most successful at capturing the echolocating animals, mostly *Delphinus delphis* clicks as the ICI properties and peak frequencies coincide with the echosounder pings, utilizing operands in Echoview with the algorithm developed in Saydam (2015). It can be said that the active acoustic device operates as a passive listener for the dolphin sounds, while capturing the fish backscatters.

As the dolphin positive areas do not give information on the number of individual animals in the detected pods, it is avoided to derive of numbers of cetacean individuals and species discrimination from click patterns for the scope of this thesis (although seemed plausible as a future prospect, as discussed later) that are captured in echograms.

2.3.3.2 Trial of Region Detection

For the bettering and simplification of the methodology developed by Saydam (2015) the initial efforts carried out in this thesis was to test and explore the possibility of dolphin mark selections using “Classify Regions” , “Detect Schools” , “2D School

Detection” with commands run after detection. That approach was seen as worth exploring as the results were compatible to of Saydam's (2015) this would have enabled the usage of the method without frequency response technique and hence the method could have been applied to datasets of single frequency bands. The aim was to specify a way to detect all and only dolphin marks as region detection, as an easily applicable and simplified approach. As the already verified dataset and algorithm were present at hand, we were able to compare the results of different approaches. School detection was carried out on water column below 300m as in the Black Sea, it is widely assumed that there is no possibility of other biological sources to be present to cause any other echo other than dolphin vocalizations that were aimed to be captured. This approach was fairly promising on the dolphin marks, with specified width and heights studied and found to be characteristics of dolphin marks, combined with trial and error with constant comparison to frequency response technique. But the challenge was to disable the software from classifying noise, as dolphin marks. As the frequency response results were collected without the integration of noise, if noise removal was carried out initially, then it was observed that dolphin marks were significantly decreasing in number when compared. This approach was trialed with several combinations and orders, as discussed below. But the possibility was left as the visual dolphin observation and CPOD data was very limited. Although showed potential, automatic dolphin mark detection method was left aside, for the sake of the health of the results as the limited data from visual and CPOD made the comparisons of methodologies weak if tweaked. It was decided to progress with the frequency response technique as it is the already validated method. The simpler methodology is considered to be a possibly more applicable and straightforward approach on other datasets, and to be tested if and when mammal observers onboard and CPOD deployments throughout the survey appears as possible.

For this purpose, data were restricted to 200m-500m depths as this area is known to be free of fish and present echoes are assumed to be either noise or dolphin marks. So, dB thresholds were trialed, and most dolphin mark detection selection with least noise classified as false dolphin marks were observed manually in -75 dB threshold at the 38 kHz dataset. Same was trialed for the 120 kHz dataset but was not observed to be successful, as 38 kHz has more prominent dolphin marks. During these trials, the aim was to enable dolphin mark selection in Echoview that was corresponding with the CPOD detections that were previously established as dolphin observations when compared with visual detections. For that purpose, background noise removal operands were trialed with several max noise/ minimum SNR/ vertical overlap/ vertical and horizontal extent inputs, to check for dolphin marks when subtracted from raw data, with the “Minus” and “Linear Minus” operands.

When school detection operand was trialed for the same purpose, it was observed that the algorithm primarily looks for backscatter to include as a school from the horizontal plane which was the opposite of what dolphin marks were composed of. As school detection was not able to detect schools strictly on vertical planes within one ping, regardless of the variables tweaked to fit, this approach was left with near zero detections.

Although was not successful in the trial of this thesis, with non-systematic observations on board during the surveys, the dolphin marks on the echograms of different species of Delphinus were clearly observed. This was the cue for the possibility of capturing the difference in species with operands as the difference was clear to the eye manually. This approach could prove to be useful if systematic mammal visual observations were conducted and compared for specifying the characteristics of vocalizations that were apparent on the echograms. This method, in theory, can also be applied to existing data sets of concurrent visual observations and hydroacoustic data.

Same approaches were trialed after noise removal also, but was not put forward for further analysis as the established methodology did not use noise removal first, so that might have produced some differences in the results that would not have been able to corrected due to lack of visual observation or comparison of data points in the same survey data via hydrophone results which could in theory take the methodology to a more verified level if PAMGuard criteria for click/whistle determination were translated into echogram algorithms. In the presence of such double natured data, verification of detections would be increasingly specified and applicable to other datasets as click information would have been enabled to translated within the receiver equipment.

2.3.4 Quantification of Data Points

To enable the comparison of dolphin clicks to potential drivers of foraging, data points of each category; Anchovy, Sprat, Temperature, were divided and discriminated regionally and numerically with respect to spatial location. Further analysis is founded on the quantification process where echosounder detection of cetaceans within each ping were cumulated within the running radius of 0.01 degree steps which would give comparable results of relative cetacean amounts (but not individual numbers) to pelagic potential prey amounts which are analyzed and exported within 1nmi grids. During the survey, when the detections on the echograms were observed, an observer (not systematically) tried to locate the animal with respect to the distance from the vessel. Although this effort was not standardized, it was aimed to gather an at least vague idea of detection ranges of the echosounder for cetacean clicks. These anecdotal observations were at times not less than 2 km which was a surprisingly high distance, and should be approached with caution due to being very primitive. Therefore during coordinate rounding, for grouping within distances that were set at 0.01 degree of latitude or longitude depending on the heading of the transect, which equates at a conservative ≈1.2 km, which falls appropriately mid-way within the pelagic fish gridding distances used and the detection range meters pronounced for other passive acoustic studies (H. K. Nuuttila et al., 2018; H. K. Nuuttila, Thomas, et al., 2013; Philpott et al., 2007) assuming the active acoustic device acts as a passive listener of sorts in case of echolocation detections. Any click detection within 1/100 of latitude degree (or longitude depending on the specific transects heading) around 1.2 km, are gathered as one and presence is acquired as a single cluster if there is no other click detection in the continued running radius. The next detection more than 0.01 degree apart from the previous detection is noted as a separate detection.

From this approach, we gathered information on not the number of individual dolphins, but the relative amount of foraging activity in a given area with pelagic fish abundance. This way, it was avoided that pods with low echolocation activity, that area assumed to be not foraging are detected as a high number of animals. As this would bias the results because the purpose of the analysis mentioned is not to find abundance but to find foraging areas in the Southern Black Sea.

To complete this quantification process with the theory explained above, a macro written in Excel has been used to accumulate encounters within the followed range. The steps taken were, first rounding the coordinates of the cetacean detections to 0.01 decimals of latitude & longitude degrees due to reasons explained above. This produced the coordinate of the cetacean encounter where the generalized latitude and longitude class equals to accumulated distance within continued detections and ≈1.2 km between separate batches of encounters. Then the macro combined all the presences numerically, within the limits, adding up the incidents of detections as cetaceans continue to be present in the dataset. That enabled us to have a quantifiable amount of cetacean presences that can put us forward in the conclusions of whether areas of detections are more preferred as foraging areas or not.

Same data points' coordinate grouping step was also performed on pelagic potential prey distributions and the environmental parameter of SST, on locations that were matched to that of cetaceans' presences using macros written in Excel to provide not only prey distributions throughout the survey area, but also specifically at the areas where foraging activity is taking place at 0.01 degree steps. Within this approach, Anchovy and Sprat NASC values and sea surface temperatures were grouped as one for each variable category, that fall within the range of each cetacean encounter, and the mean value of the concurrent data points were assigned to represent the amount of Anchovy and Sprat and SST where foraging activity is assumed to be taking place. This quantification method enabled numerically comparable results between the prey and the predator and the environmental parameter, so that foraging behavior can be discussed further.

2.3.5 Statistical Analysis

To explore the correlations between prey, predator and the environmental drivers, statistical analysis were conducted in R 3.6.1 (R Core Team, 2019) using “mgcv” (Wood, 2017), “LambertW” (Georg, 2016), “boot” (Canty & Ripley, 2019), “ggplot2” (Wickham, 2016) packages. For linear correlation, “lm” model was used in “stats” package (R Core Team, 2019) and for generalized additive models, “gam” function was used in “mgcv” package (Wood, 2017). Comparison of model fits were done using Akaike’s An Information Criterion with “AIC” function in “stats” package (R Core Team, 2019).

For non-normally distributed data transformations, log+1 transformation was used on pelagic prey NASC values. Scale factors were applied to Sea Surface Temperature satellite data as guided by Copernicus Marine Environment Monitoring Service (CMEMS) to reach Celsius units from .nc files exported to ASCII format, using “RNetCDF” (Michna & Woods, 2017) and “ncdf4” (Pierce, 2019) packages in R software.

To explore the scenarios of night foraging, data was subsetted into Day and Night times discriminated by local (GMT+3) sunrise and sunset hours which were 07.00 and 17.00 respectively, averaged for the survey period (Furey, 2019).

3 RESULTS

3.1 Acoustics Data

Pelagic fish backscatters and cetacean detections were mapped using ArcMap 10.7 software, by ESRI ArcGIS, with respect to their abundances and detection amounts respectively. With the exploration of overlap between potential pelagic prey and cetaceans detections within a running radius, foraging areas has been aimed to determined (Cañadas, Sagarminaga, & García-Tiscar, 2002).

3.1.1 Cetacean Detection Distributions

Cetacean detections were mapped, both for the whole data set and for the day time distinction split at sunrise and sunset local hours of 07.00 and 17.00 respectively (GMT+3).

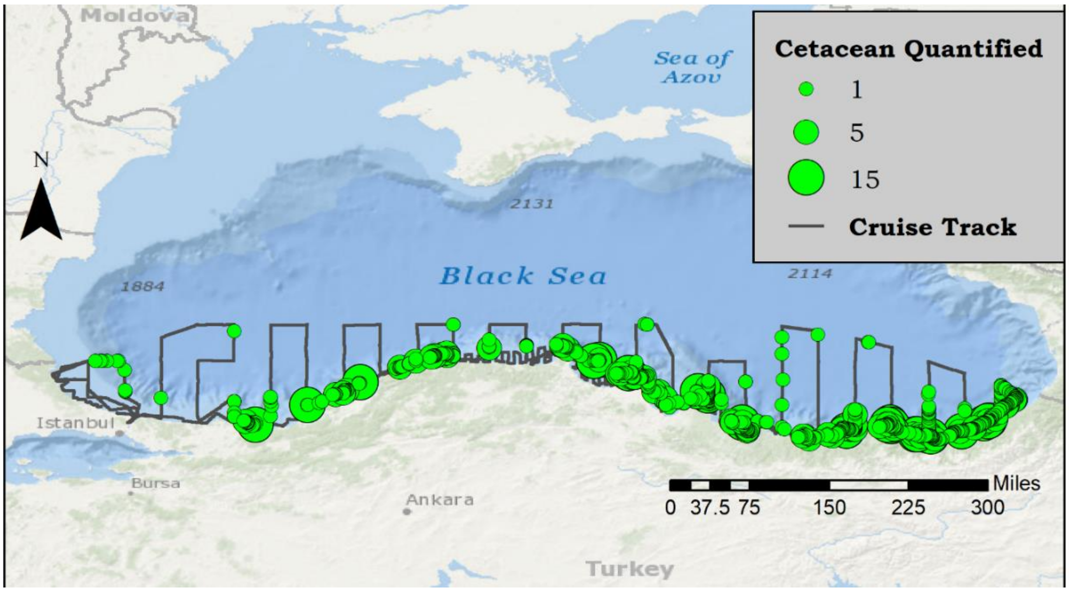

Figure 3. Distribution of Cetacean Detections during the whole survey period

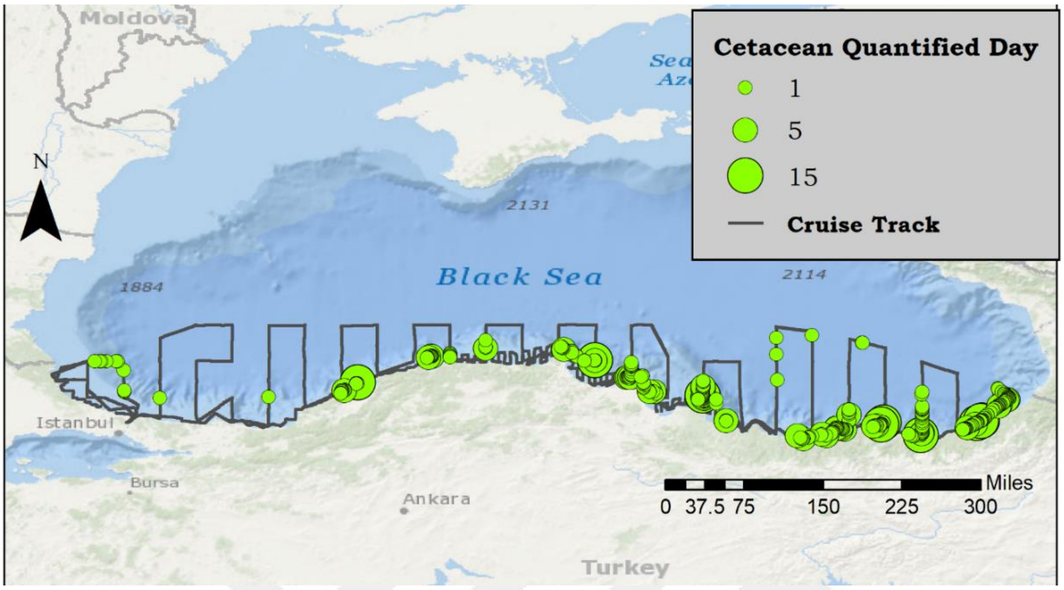

Figure 4. Day time distribution of Cetacean Detections

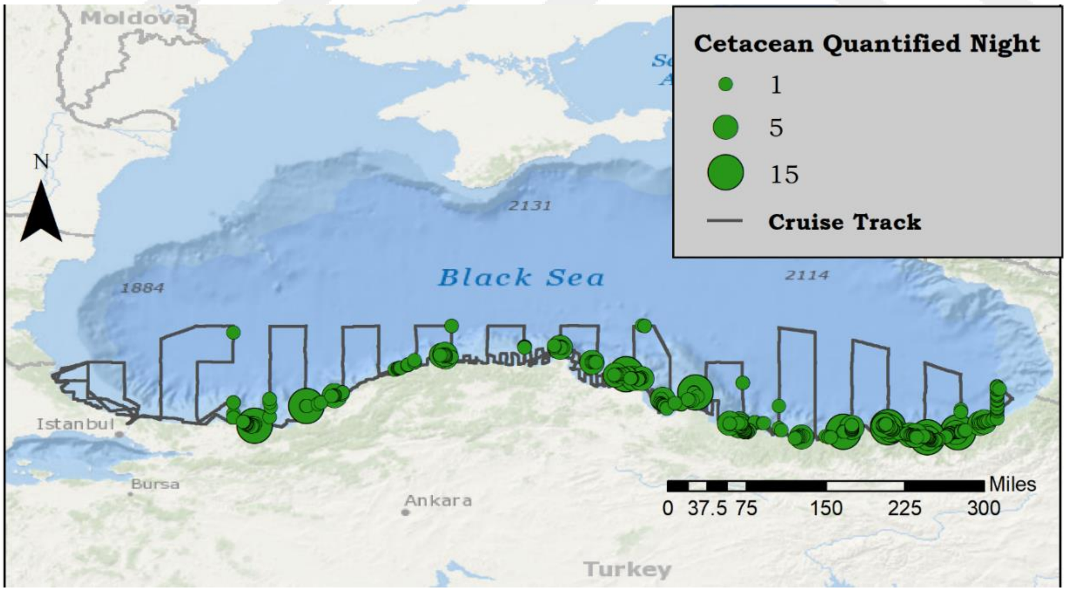

Figure 5. Night time distribution of Cetacean Detections

3.1.2 Pelagic Distributions

Pelagic distributions were analyzed both above and below thermocline for Anchovy and Sprat respectively, and for times of days split at sunrise and sunset.

3.1.2.1 Above Thermocline

Distribution of NASC values above thermocline, are as represented below.

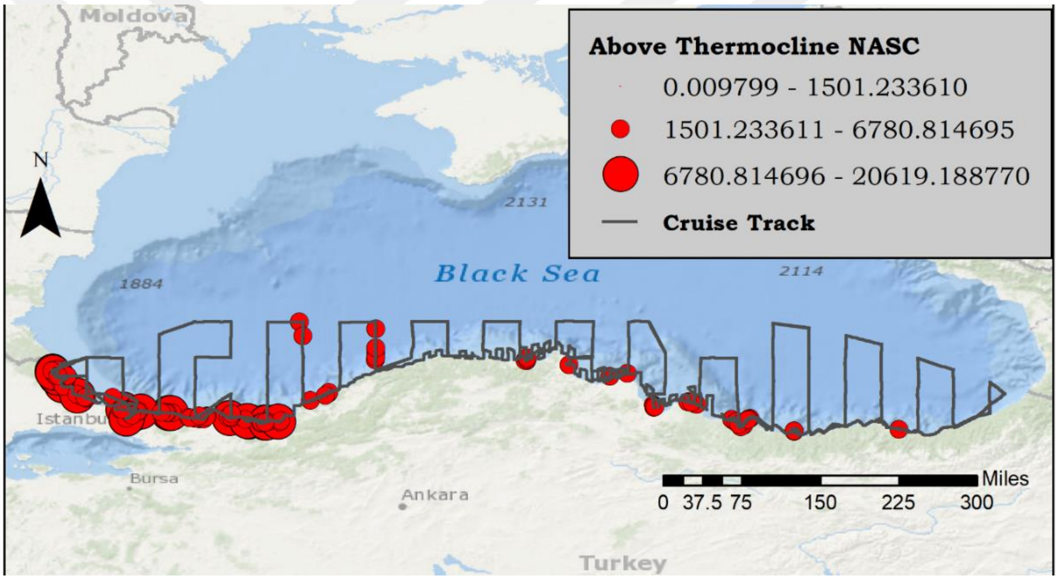

Figure 6. Distribution of Anchovy during the whole survey period

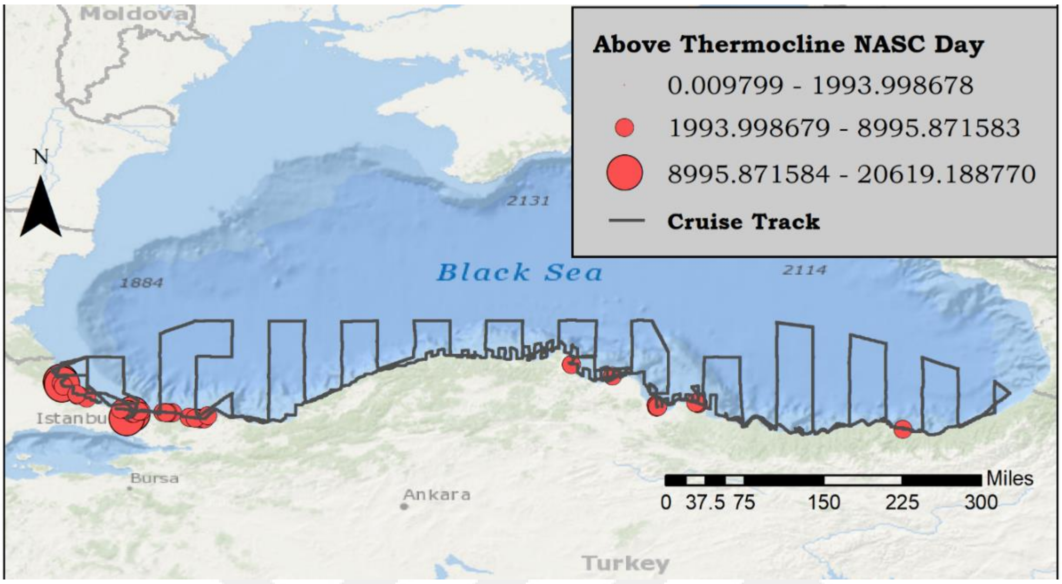

Figure 7. Day time distribution of Anchovy

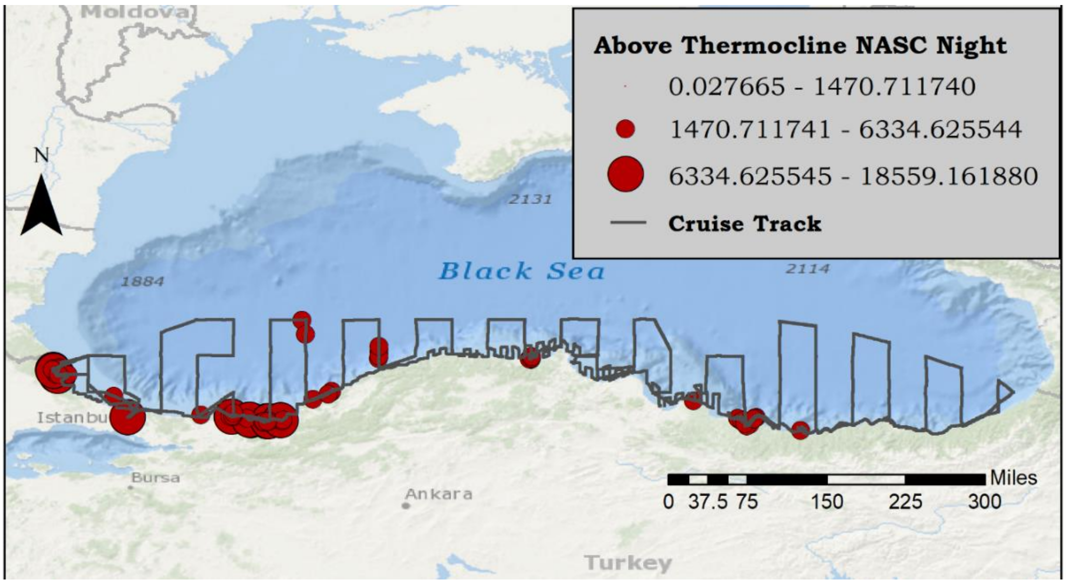

Figure 8. Night time distribution of Anchovy

3.1.1.2 Below Thermocline

Distribution of NASC values below thermocline, referred as Sprat, are as represented below.

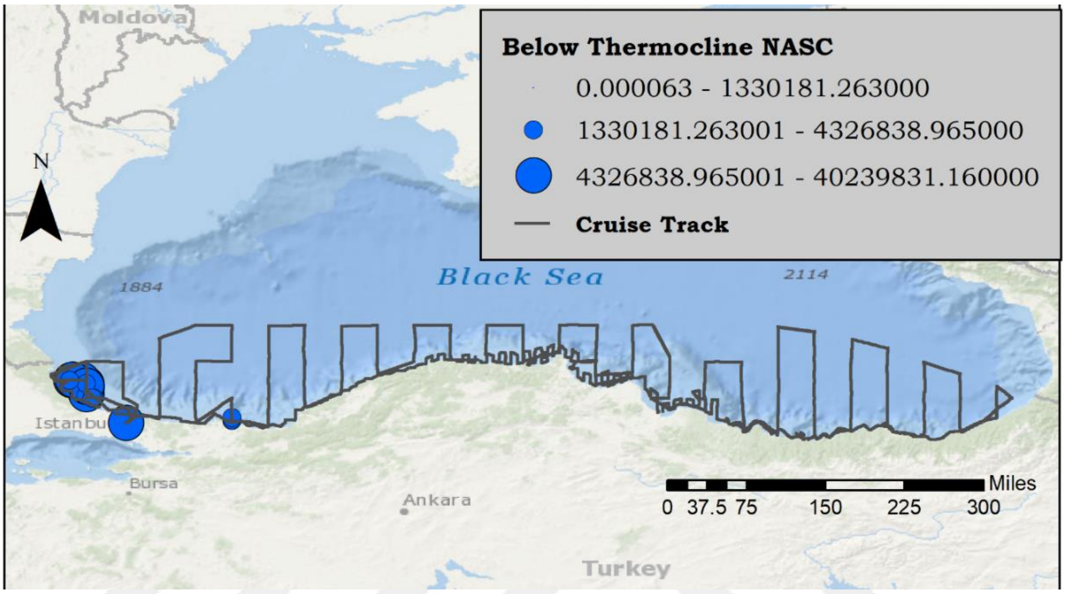

Figure 9. Distribution of Sprat during the whole survey period

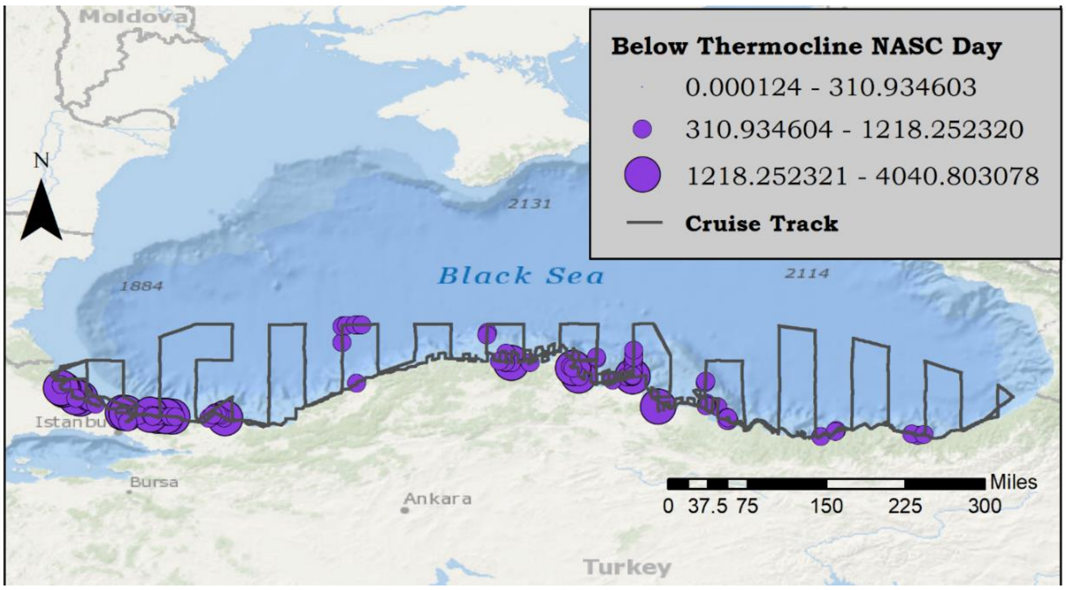

Figure 10. Day time distribution of Sprat

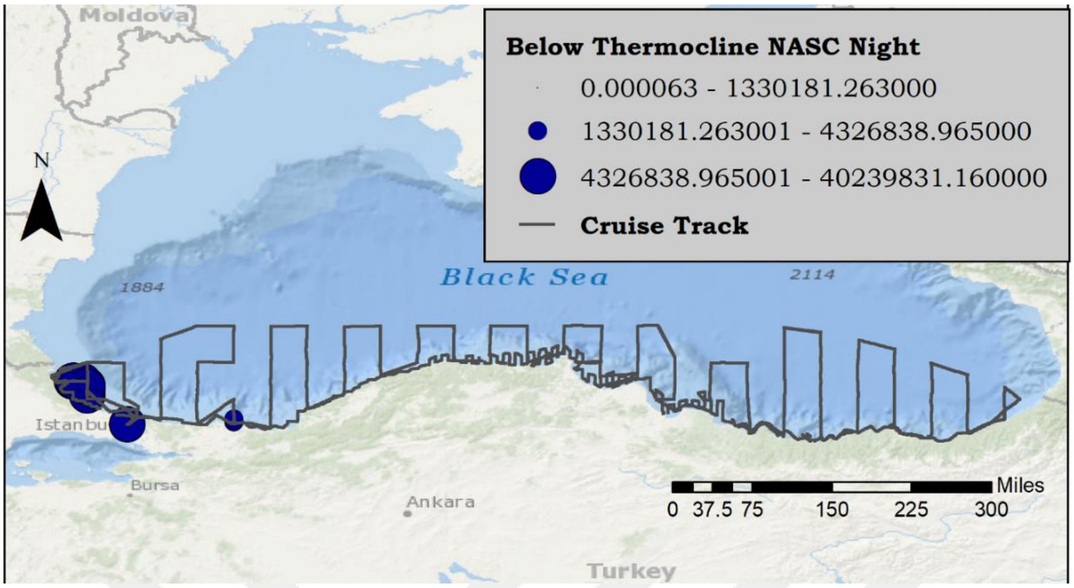

Figure 11. Night time distribution of Anchovy

3.1.3 Correlation Between Prey and Predator

To explore the correlation between cetacean foraging activity and Anchovy and Sprat distributions, datasets were analyzed at the locations of cetacean detections.

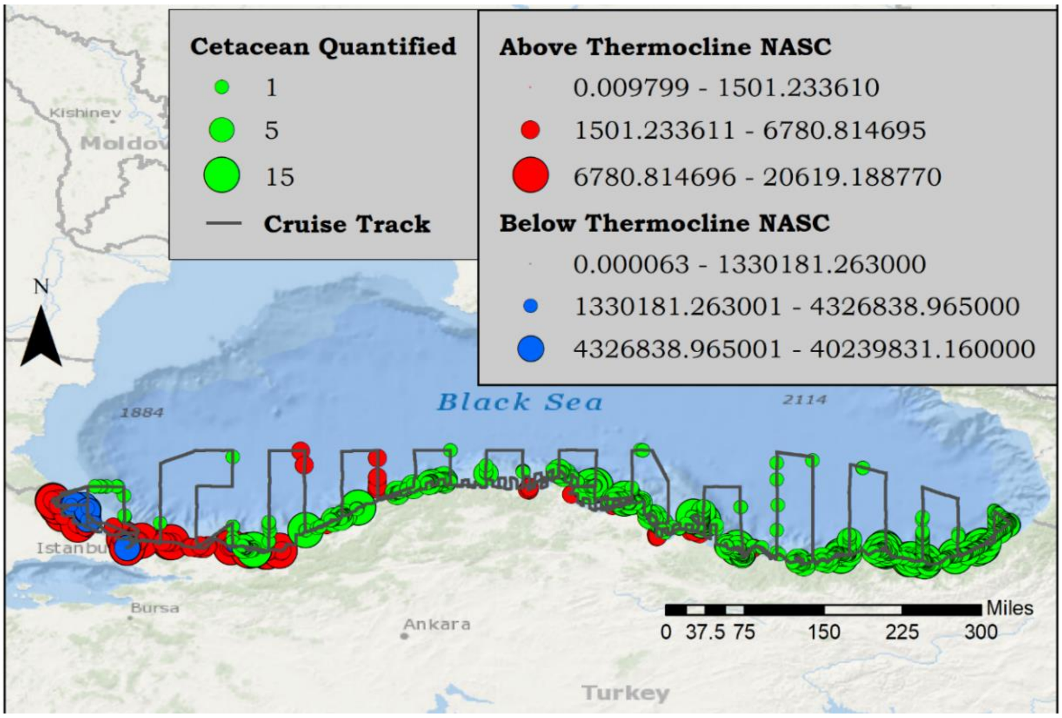

Figure 12. Distribution of pelagic fish and cetacean detections

When shown separate distributions in Figure 12 were analyzed for foraging correlation at the spatially and temporally overlapping data points in R, below represented results were obtained. Pelagic fish NASC distributions, both for anchovy and sprat, normal distribution criteria were not met. Therefore, logarithmic transformations were applied to both data sets. Following, bimodal distributions were observed in the distribution of both pelagic data, especially prominently in Sprat.

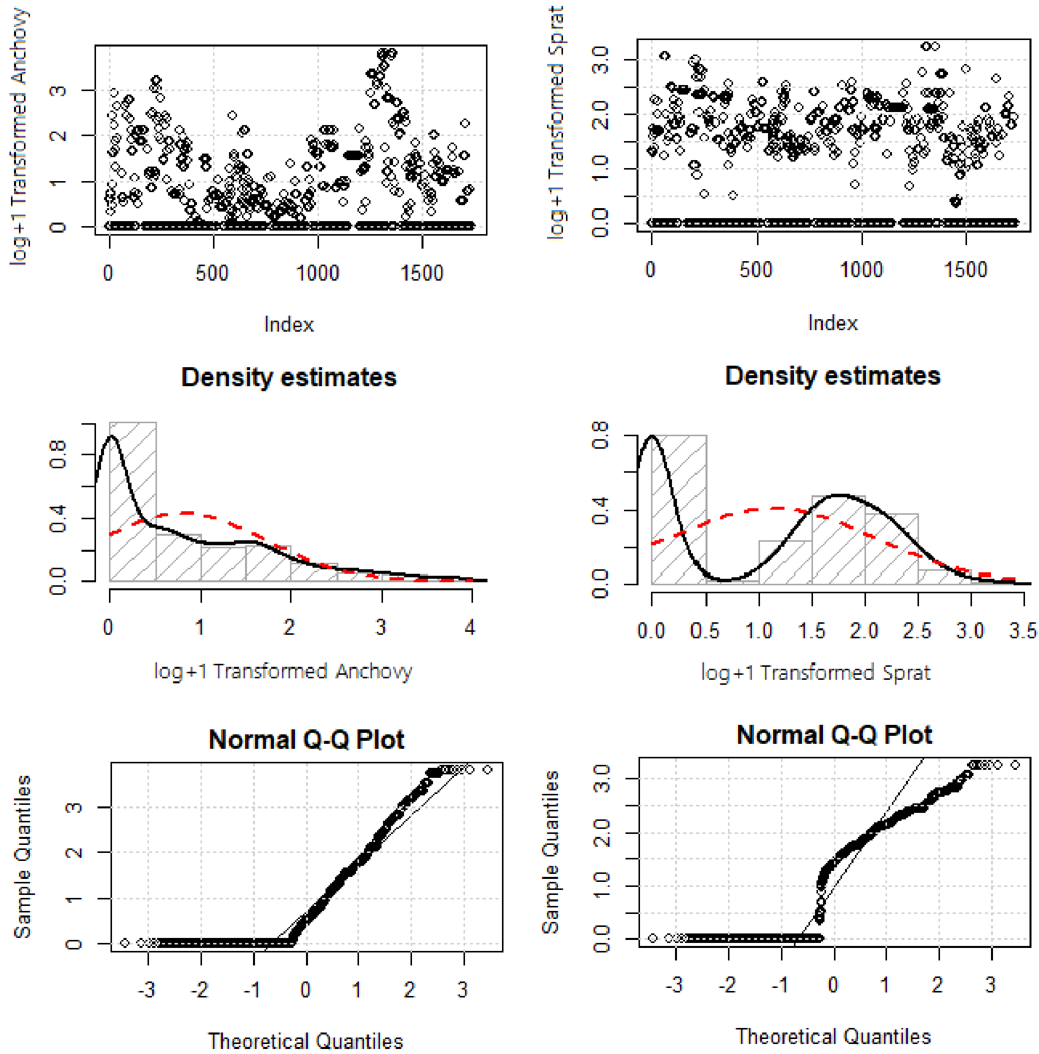

Figure 13. Distribution of Anchovy and Sprat data after log+1 transformation

When linear correlation between the Cetacean Detections and the log+1 transformed Anchovy and Sprat distributions were checked, no such correlation was observed. Lack of linear correlation between potential pelagic prey and the cetacean detections was present in both cases where pelagic preys were analyzed individually and in pair (Table 2).

Table 2. Analysis of Variance Table for the comparison of quantity of potential pelagic prey and cetacean detections

Response: Cetacean detection

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Anchovy					
log10(Anchovy)	1	0.2	0.15084	0.0524	0.819
Residuals	1736	5001.8	2.88125		
Sprat					
log10(Sprat)	1	6.6	6.6390	2.3072	0.129
Residuals	1736	4995.4	2.8775		
Anchovy and sprat					
log10(Sprat + 1)	1	6.6	6.6390	2.3078	0.1289
log10(Anchovy + 1)	1	4.3	4.2805	1.4880	0.2227
Residuals	1735	4991.1	2.8767		

Data was then subsetted into day and night distributions and below means were observed for the criteria of sunrise and sunset times. Anchovy showed higher abundance during the night, opposed to Sprat that is showing higher abundance at day time (Table 3).

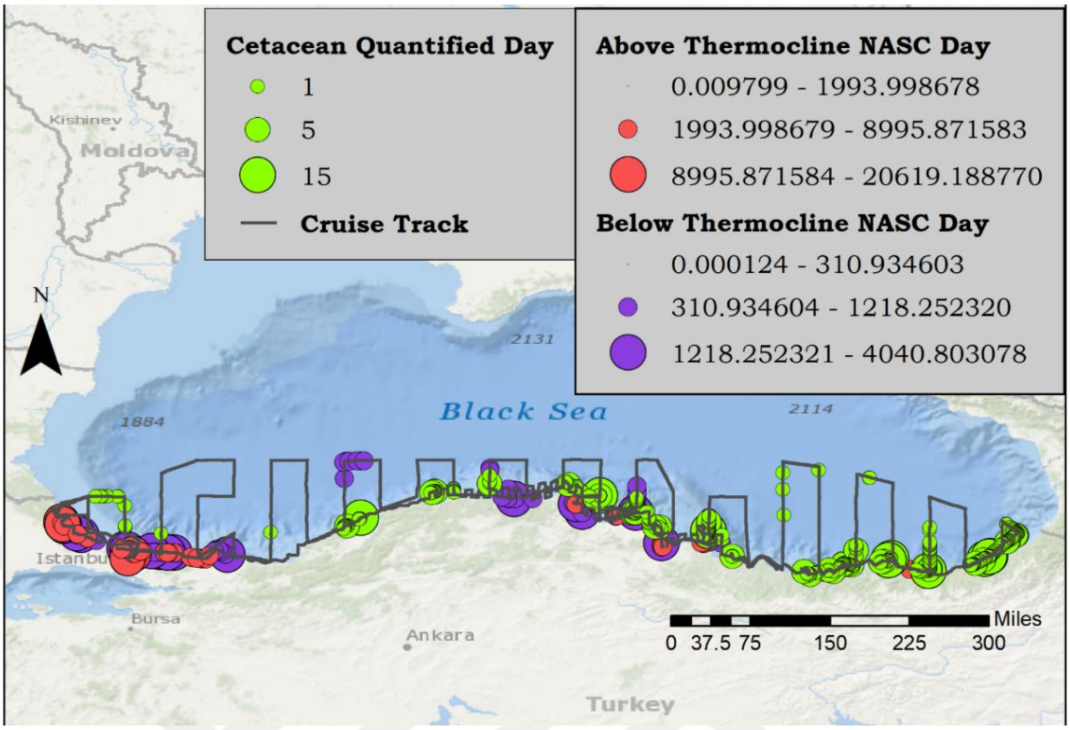

Figure 14. Distribution of pelagic prey and Cetaceans at Day time

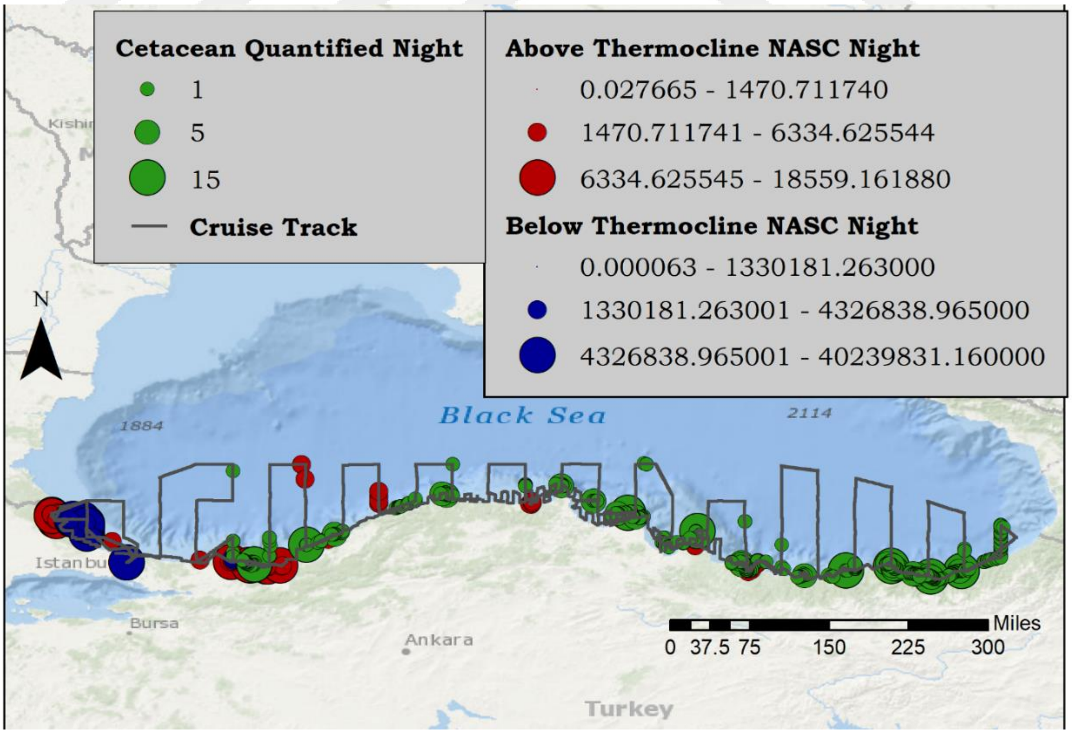

Figure 15. Distribution of pelagic prey and Cetaceans at Night time

Table 3. Mean NASC values of pelagic prey at Day and Night times

Mean NASC	Anchovy	Sprat
Day	65.2867	81.30507
Night	306.8609	70.19584

In the Boxplots produced in R (R Core Team, 2019), the lower and upper parts in the graphs correspond to the first and third quartiles. The whiskers extend to 1.5 * inter-quartile range (distance between the first and third quartiles). Data points beyond the whiskers and plotted individually are the outliers.

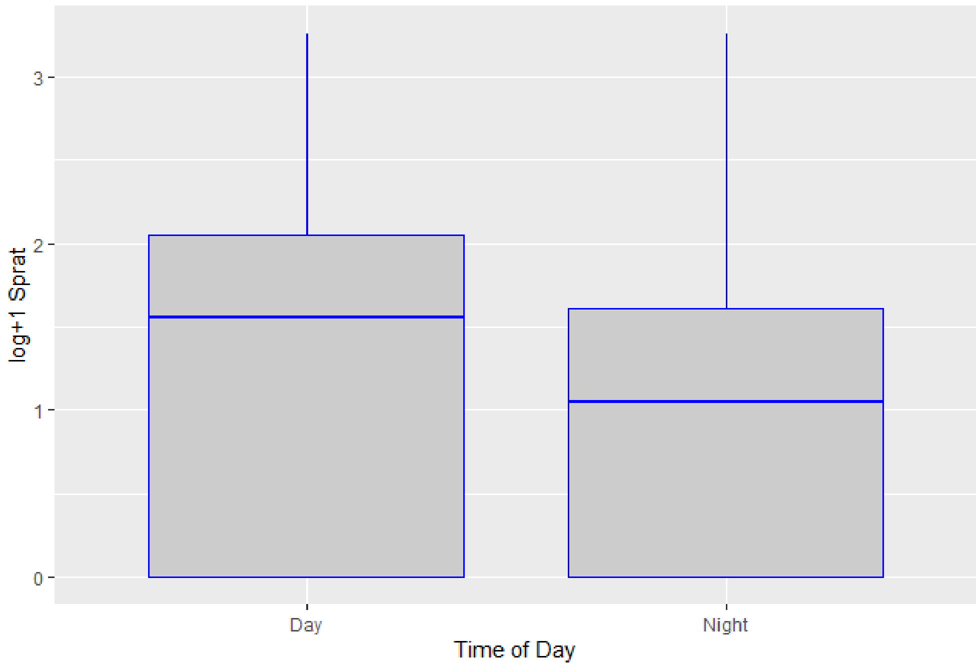

Figure 16. Boxplot of mean Sprat at Day and Night

For Sprat, Day time and Night time distributions at cetacean detection present locations showed statistically significant difference (p-value: 1.296e-08). Sprat distributions were shown to be significantly higher during Day time compared to Night time (Figure 16).

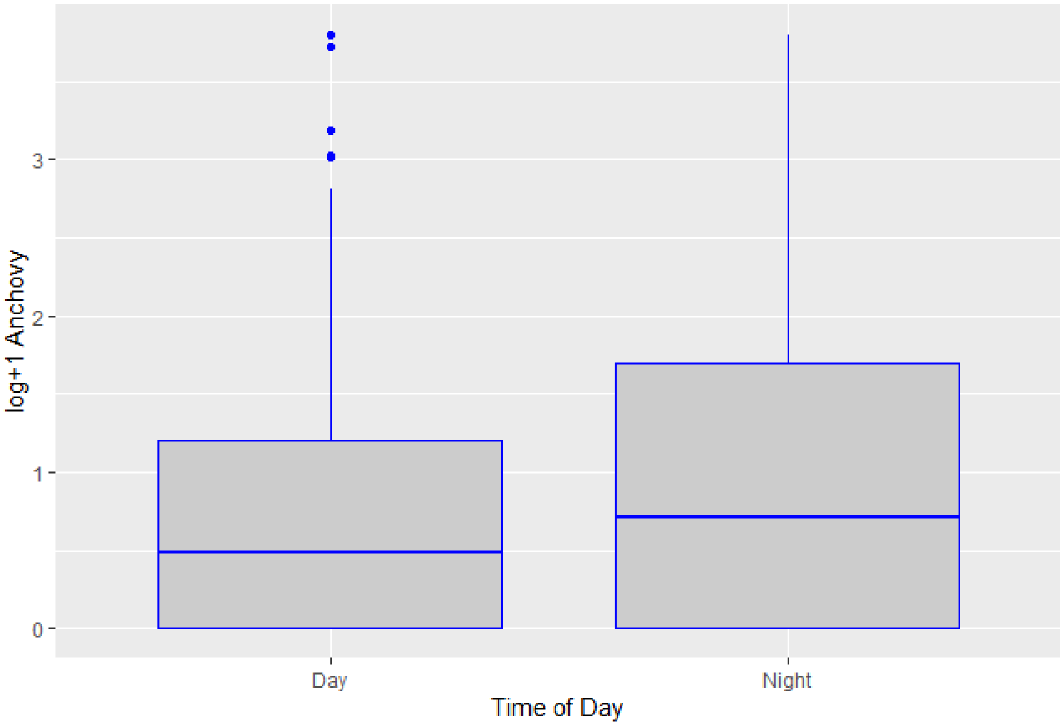

Figure 17. Boxplot of mean Anchovy at Day and Night

Similarly, for Anchovy, Day time and Night time distributions at cetacean detection present locations showed statistically significant difference showed statistically significant difference (p-value: 1.272e-08). Anchovy distributions were shown to be significantly higher during Night time compared to Day time (Figure 17).

When the Day and Night discriminations were further investigated for pelagic fish distributions, it was observed that during the day, there was no statistically significant difference between cetacean present and cetacean absent locations, for Anchovy. At Night time, Anchovy abundances were significantly higher at cetacean present locations. Also, when cetacean present and absent points were analyzed below thermocline at night, cetacean present locations were statistically significantly higher in Sprat abundances (Table 4). In these results, the impact of discrimination of Day and Night times was shown to be statistically significant (Table 5).

Table 4. Pelagic NASC values in a full day for cetacean present and absent locations

	Day&Night	Day	Night
Anchovy			
Cetacan Absent	0.767	0.737	0.849*
Cetacean Present	0.823	0.705	1.046*
Sprat			
Cetacean Absent	1.194	1.339**	0.804*
Cetacean Present	1.120	1.178**	1.010*

Table 5. Analysis of Varience Table of the linear model testing the impact of amount of potential prey at Day and Night times on cetacean encounters

```
Response: Cetacean Detection
                    Df Sum Sq Mean Sq F value  Pr(>F)
log10(Sprat + 1)     1    2.4  2.4063  0.7057 0.40107
log10(Anchovy + 1)   1    0.0  0.0101  0.0030 0.95653
factor(DayNight)     1   14.0 14.0339  4.1155 0.04273 *
Residuals         1128 3846.5  3.4100
---
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’1
```

3.2 Environmental Data

To have a better grasp on the drivers of the cetacean foraging in the Southern Black Sea, Sea Surface Temperature as a potential environmental driver was then added to the analyses (Figure 18).

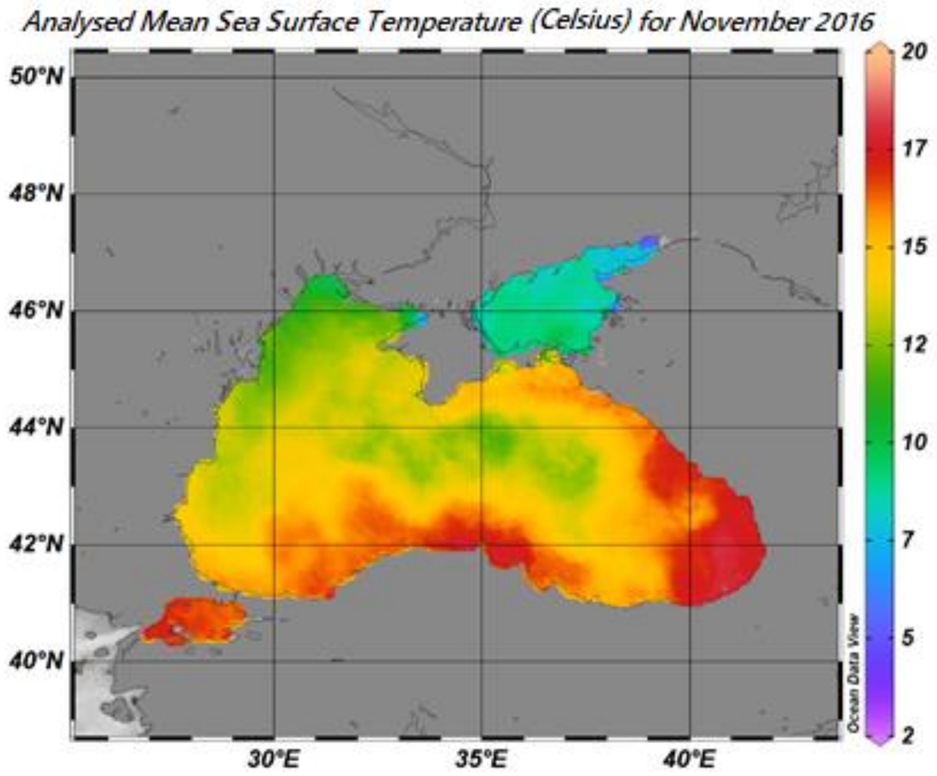

Figure 18. Sea Surface Temperature of Black Sea for November 2016

When SST data was added to the linear model runs these results, in comparison to the runs with pelagic prey values as only parameters, were not shown to be more fitting with the best model explaining only .14% of the variance (Table 6).

Table 6. Analysis of Variance Table of the linear model with both Pelagic Prey and SST

```
Response: Cetacean Detection
                    Df Sum Sq  Mean Sq  F value   Pr(>F)
log10(Sprat + 1)      1    2.4   2.4063  0.7055   0.40111
log10(Anchovy + 1)    1    0.0   0.0101  0.0030   0.95653
SSTmean               1    2.5   2.5107  0.7361   0.39108
factor(DN)            1   14.2  14.2485  4.1777   0.04119 *
Residuals          1127 3843.7   3.4106
```

Table 7. Results of GAM on Pelagic Prey and SST

```
CetaceanDetection ~ s(log10(Anchovy + 1)) +
 s(log10(Sprat + 1)) + s((SSTmean)) +  factor(DN)

Parametric coefficients:
            Estimate Std. Error  t value  Pr(>|t|)
(Intercept)  0.65237    0.02740  23.809   <2e-16 ***
factor(DN)N  0.12541    0.05384   2.329     0.02 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘’ 1

Approximate significance of smooth terms:
                        edf  Ref.df     F  p-value
s(log10(Anchovy + 1)) 1.001  1.003  0.815  0.3674
s(log10(Sprat + 1))   7.797  8.604  1.905  0.0499 *
s(SSTmean)            7.375  8.360  1.134  0.3237
---
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘’ 1

R-sq.(adj) =  0.0122   Deviance explained = 8.86%
```

When these parameters were analyzed with Generalized Additive Model, it was observed that in addition to Day and Night discrimination, Sprat is also presented as a driving parameter for cetacean encounters. GAM explains 9% of the variance, which although is not a high value, is an indicative of overlapping of Sprat and foraging cetaceans during Night times (Table 7).

4 DISCUSSION

For decades, since the banning of the cetacean hunt in the Black Sea in 1983, overconsumption of ecologically valuable pelagic fish by the cetaceans leading to decline in pelagic stocks has been argued, especially as a concerning cause of monetary loss on the fishing gear of fishermen (Reeves & Notabartolo Di Sciara, 2006). Even though the confident estimation of cetacean abundance or population trends have been lacking in the mentioned area, the pressure has been calling for better understanding of the cetacean ecology, especially foraging areas and preferred prey species, to enable better management around the mentioned concerns, and conservation. Therefore this thesis study aimed its effort to gain knowledge on whether or not the assumed predatory pressure on pelagic fish by cetaceans actually exists, utilizing active acoustics data collected for fisheries research, and using the dataset with the algorithm by Saydam (2015) to determine overlap between potential preys and predators of concern.

As the results of the study shows, the cetacean distribution presents itself dominantly in the Eastern Southern Black Sea, whereas the pelagic fish of most economical value, Anchovy, was observed to be abundant mainly in the Western part of the Southern Black Sea, creating a lack of overlap with Anchovy, against the general assumption. Instead, significant results from the GAM analysis indicates possibility of night time foraging of cetaceans on Sprat. This information being revealed leads to the underlining of the significant importance of the methodology used, and the potential of further development as the later discussed improvement areas in the active acoustic study of cetaceans stands.

Predatory pressure has long been a topic of discussion with respect to dominance on the standing stocks; as fishing pressure, mammal foraging, and other top predators as marine birds. But studies have shown that the main pressuring factor on stocks are not necessarily anthropogenic exploitation or mammal consumption, but is predatory fish (Bax, 1991). Hence, when exploring the potential cause for the sudden declines of the stocks, which accumulates to oscillations observed in the Black Sea, the most ecologically sound approach would be considering the relations between the food web steps and environmental changes (Gücü et al., 2017), before concluding the over increase in cetacean populations following the hunting ban in 1983, without competent scientific background to argue so.

For the recovery of the sea mammals after periods of exploitation by direct killings, the common opinion in terms of requirement used to be 20% of the stocks to be present in the sea which has been argued against, as the variables such as spatial distribution, patchiness, search for prey and success in hunting plays significant roles that call for higher presence of prey in the sea to be able to see an increasing trend in the recovering marine mammal population (Camphuysen, Furness, & Camphuysen, 2009).

When considering the effect of fisheries on the top predators, whether or not the targeted species causing a direct competition between fisheries and the cetaceans seemingly is not necessarily a significant driving mechanism, as the main competition in the environment emerges from the primary production, -which effects the quality of the consumed prey that is highly effective in reproductive success of marine mammals- , and not the overlapping targeted species with a lower than assumed percentage of 35% (A. W. Trites, 2010; Andrew W Trites et al., 1997).

4.1 Pelagic Fish Distribution

Observed from the results of this study, pelagic fish distributions are shown to be dominantly present in the western coast of the Southern Black Sea. Specifically, Anchovy is observed to be habituating the inshore area around the Bosphorus Strait, in the Western coast of the Southern Black Sea for November 2016. NASC values of Anchovy were shown to be significantly higher during the night, when large schools are formed, compared to day times which are discriminated by sunrise and sunset hours locally (GMT+3) at 07.00 and 17.00 respectively.

Whereas Sprat is observed to be habituating East of Sinop - which is around the midpoint in the Southern Black Sea- and Western Southern Black Sea. Day time was shown to be presenting higher Sprat NASC values in comparison to past sunset Night hours. These outcomes are parallel to the existing knowledge on the distribution of abundances, observations of big schools during the survey period and catch of Anchovy and Sprat around the Southern Black Sea (TUIK, 2018).

4.2 Cetacean Distribution

From the detections of the cetacean vocalizations that are marked in the echograms, cetacean distributions were observed to be accumulating in the Eastern part of the Black Sea. This part of the study area shows higher incidences of cetacean encounters both in numbers of occurrences and in the higher quantity of the continual cetacean detections. The mentioned two sides of these results are parallel and supporting to the higher cetacean abundances and larger pod sizes shown in Figure 19, in the study of Saydam (2015) with both visual observations and CPOD detections.

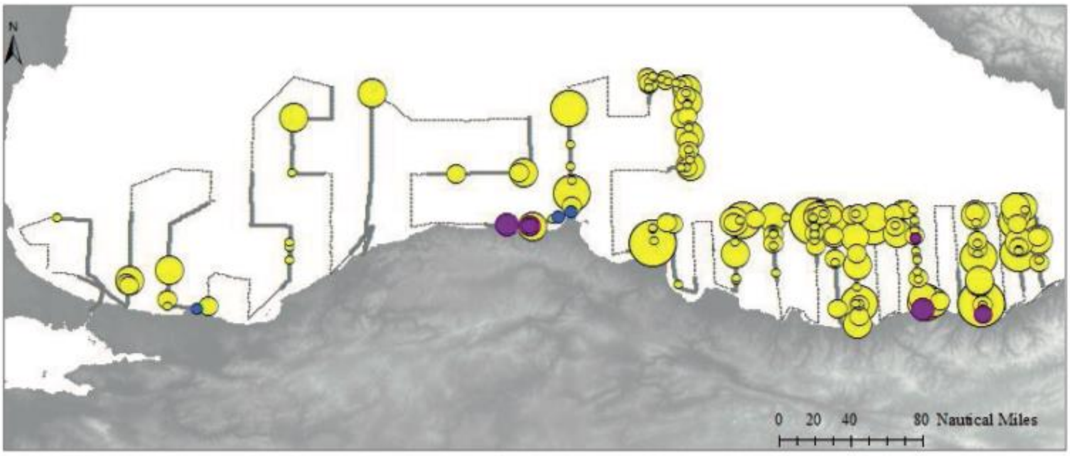

Figure 19. Pod sized of the observed cetaceans by Saydam (2015)

Although the results from the active acoustic detections do not give exact information on numbers of individuals in encounters, the supporting information from Saydam (2015), and anecdotal visual observations during the survey which made apparent that cetacean encounters in the Eastern part of the Black Sea presents itself much more frequently and in higher numbers of individuals in each encounter. Therefore, one of the foundational assumptions made here, higher quantities of detection encounters relating to higher numbers of individuals being present (H. K. Nuuttila, Thomas, et al., 2013) and foraging (Sveegaard et al., 2011b; Visser et al., 2017) in the area, is supported both by existing literature and previous studies in the past surveys.

4.3 Foraging Areas

On observation of the produced distribution maps, cetacean detection amounts were shown to be higher in the shallower areas as expected (Cañadas et al., 2002), again assuming higher detection instances relate with higher numbers of individuals presenting high echolocation indices (Nuuttila, 2013), these results are indicative of foraging areas for the survey period being around the shelf break, in the Eastern coast of the Southern Black Sea. But to conclude long term positioning and characteristics of the preferred foraging areas of cetaceans in the Black Sea, this study should be extended to previous years' data with the addition of bathymetric analysis, to ensure the represented 2016 observation is not a one year instance as an outlier (Cañadas et al., 2002; Tollit et al., 1998), as different cetaceans are known to be capable of tolerating flexibility in their diet to different extents. Specifically, common dolphin, which is most commonly detected species in this data set (Saydam, 2015) due to the frequency bands of the echosounder operating, is one of the most diet diverse species making them less vulnerable to climate change (Sousa et al., 2019), therefore depending on the presence and abundance of the prey species in the current season their diet hence foraging areas might diverge from year to year.

4.3.1 Correlation of Pelagic Prey to Predator

When viewing the results of correlation, and lack thereof, between the potential pelagic prey species as Anchovy and Sprat, and cetaceans in the study area and period, it is apparent that there is no statistically significant linear positive correlation when the whole data set is analyzed. Therefore, it is observed that the amount of Anchovy and Sprat found within a given area does not exclusively relate to presence of foraging cetaceans. Viewing the distributions, it becomes clear that the preferred habitats for foraging of cetaceans are not necessarily overlapping to the areas of pelagic abundance. These results are important implications for the main emerging point of thesis, whether or not cetacean predation is dominantly on these valuable fish, especially Anchovy, as much as assumed. Driving from the result of lack of spatial linear correlation to foraging cetaceans and mapping of the polarized habituation of the West coast of the Southern Black Sea by the Anchovy and East coast of the Southern Black Sea by the cetaceans, it can be concluded that for the given period, results that are confined for the survey period imply to the absence of such overlap that could cause decline in Anchovy stocks if concluded to be a persisting pattern in the area. When the Anchovy data were subsetted to be analyzed specifically at cetacean present locations, significantly higher amounts of fish were observed during night time after sunset, compared to day time which was an already existing pattern of the mentioned pelagic fish, before implementation of the presence of cetaceans into the linear model. Therefore, results imply the presence of increased foraging during night time, at areas of high both fish abundance as visual avoidance is likely to be taking place by the potential prey as the predators of highly developed olfactory and echolocation detections as cetaceans are known to be better night time foragers (Fréon & Misund, 1999).

On the other hand, significant correlations were observed between foraging areas of the cetaceans and Sprat, at night from the results of the GAM analyses. In these model runs, Anchovy abundance did not show correlation to cetaceans. Therefore, the results presented here in this thesis, although only covering a single year's data during fall, indicates the potential presence of cetacean foraging areas in the Eastern Southern Black Sea, with the preferred potential prey as Sprat, opposed to the widely assumed Anchovy which lacked any correlation to the foraging locations.

Similarly to the findings in this thesis, studies have also shown the shared interest in valuable prey as low as <10% covering different fishing gears other than pelagic trawls represented here (Milani et al., 2019). Therefore, assumed foraging preference on economically valuable pelagic fish of cetaceans in the Black Sea were argued against within the represented results, which is hoped to shed light on the way of better management of cetaceans in the studied area.

It should be noted that these results are specifically focused on the mentioned species, hence other potential prey species, especially those that do not have swimbladder (e.g. Bonito) which are not covered in acoustic research in the scope of this study could have been driving the presence of the cetaceans in the observed areas. As 2016 is a year of exceptionally high Bonito catch in the Eastern Black Sea, these results would be elevated to unravel further other mechanisms within the food web if followed up by continued research on cetacean foraging in the Black Sea, throughout longer periods and potentially coupled with catch data from the implied foraging areas; Eastern shelf of the Southern Black Sea.

4.4 Environmental Drivers and other Underlying Mechanisms

When concerning the correlation between cetaceans and potential pelagic preys, the projectability may not be straightforward, and even negative correlations are observed, pointing out to potentially fundamentally different systems taking place in the between the mentioned food web connectivity (Benoit-Bird & Au, 2003). Some of these underlying mechanisms are shown to be driven by primary productivity and currents. Upwelling areas and primary production are shown to be more representative of foraging areas of marine mammals, compared to presence fish species in higher trophic levels (Bittencourt et al., 2018; Cañadas et al., 2002). Therefore, apart from the here discussed SST, other environmental cues, especially upwelling areas in the Black Sea should be studied, which does at times present itself as unexpectedly deep extent of Chla presence in the CTD stations.

Considering the lack of positive correlation between the above thermocline pelagic fish and cetaceans in this study, it has also been observed in other studies where there is a lack of positive correlation between adjacent trophic levels, and even negative correlation, where these results have been argued as an indicative of bottom-up regulation of pelagic stocks in the mentioned sea where resource limitation and patchiness could act as a driver for the predators (Benoit-bird, Mcmanus, Benoit-bird, & Mcmanus, 2012). Although not studied in the scope of this study, such bottom up regulation can in theory be present in the Black Sea considering its oscillations and shorter food webs.

While mentioning primary production and upwelling, it should be noted that in some studies, low Chla levels have been explained as abundant zooplanctivorous fish which indicates high grazing pressure on phytoplankton (Díaz López et al., 2019). To conclude any ecological implications on these mechanisms, the study area should be very well understood, and as currently in the Black Sea with its oscillating nature, amount of understanding on underlying mechanisms are not present, therefore any further discussions concerning such drivers should be approached with caution.

Another potential driver or the cetaceans can be unrevealed if catch were to be explored in terms of the age composition. As quality of the fish impacts the wealth of the cetacean population, these predators could be specifically aiming certain fish of larger age groups, assuming their calorimetric input being higher in value for the cetacean. This argument is seen as valuable especially as the bimodal distribution of the pelagic data is observed in the results presented here. Difference in the sizes of fish, their caloric values, and hence the size of the schools formed at night, could arguably be attracting or repelling factors for the foraging cetaceans. These differences that could potentially cause the bimodal or trimodal differences can be explored whether they are presenting themselves as shelter from predation and preference of age composition of schools by the cetaceans. Therefore, exploring the distribution of the cetaceans with the fish age classes known from the trawling hauls from the surveys may be a valuable source of information, as western coast of the Black Sea could be mainly habituated by the smaller, first year spawners, incoming from the northern Black Sea migrating south in the fall, also considering the the daily behavior of the offshore Sprat during winter and fall (Ivanov & Beverton, 1985).

Additionally, depletion of prey caused by overfishing have been argued as the major cause of decline in the common dolphin populations, both during and after the dolphin hunting ban as the agreed upon theoretical conservation efforts lack in efficiency when put in action (Bearzi et al., 2008). Impact of fisheries and overfishing on cetaceans can be argued not only in terms of habitat deterioration and prey depletion but also entanglement and bycatch of mammals that are endangered (Milani et al., 2019).

4.4.1 Long term oscillations in the Black Sea

Black Sea has been characteristically known for its oscillating pattern across most of its stocks, due to reasons and patterns that are yet to be fully understood. Therefore, prey availability for the cetaceans are likely to be just as oscillatory, in theory forcing the animals to switch foraging grounds and prey preferences from year to year. Although results from 2016 shows parallel patterns to Saydam (2015) where data from 2014 and 2015 was used, in the longer term, cetaceans of the Black Sea might be switching foraging strategies when these sudden declines and increases occur, with patterns that are not yet apparent to the literature with some of the possible effects being introduction invasive species and overfishing (Gucu, 2002).

These foraging strategy altering of marine mammals can be as significant as 80% when abundance of prey stocks changes in the resident area from year to year (Tollit et al., 1998). When searching the literature for the dietary preference shift, it should also be kept in mind that Black Sea with its anoxia, cannot provide demersal foraging to its cetaceans, therefore might be limiting the otherwise observed flexibility, especially in the case for diet-tolerant common dolphin (Sousa et al., 2019). Therefore, before concluding that the foraging pressure of cetaceans on the pelagic stocks, these studies should be carried out on larger data with higher temporal and seasonal coverage. To fully engage in this question, one might want to explore other predators of juvenile stages of anchovy with respect to how they change in abundances throughout these ecological shifts.

4.4.2 Potential Other preferred Prey Species

After discussing the plausible potential reasons of cetacean presence observed, the possibility of a dominantly preferred prey species habituating Eastern coast of the Southern Black Sea still holds as a valid probability. To explore the possible species, regional landing statistics should be studied upon (TUIK, 2018). Stranding data with stomach contents studied, would be a highly valuable source of information, but currently, such studies in the Black Sea are not present at a state where implications on foraging characteristics can be drawn (Tonay et al., 2012).

But in addition to that using active acoustic data for predator-prey relationships and for gathering foraging ecology knowledge where data is scarce, as practiced in this thesis, also presents itself as opportunistic, because the possible use of not only existing fisheries research data but also existing fishing vessels' data from Recreational grade echosounders. Fishing vessels' data can in theory produce valuable information with efficient use of investment in affordable equipment and less requirement of expertise due to its robustness, which is an approached studies by Brough et.al (2019). Hypothetically, this approach can help uncovering relations of cetacean foraging areas to other potential prey species that are not covered in the existing scientific surveys.

So the active acoustic data that has been mentioned as valuable due to its existing volume and wide usage, can be not only limited to scientific echosounders but also recreational grade echosounders that are capable of providing data for predator-prey relationships and habitat usage of predators and potential preys, where accumulated fish or cetacean knowledge and information on biology and ecology is lacking, especially when these efforts are coupled with visual observations and or photographs of the predators at the surface/ trawl samples for ground truthing and even towed cameras as mentioned in Brough (2019).

4.5 Shortcomings and Advantages of the Methodology

A shortcoming of the data set utilized here is that the transect design of the survey is not optimized for cetaceans. As the survey was done for anchovy stock assessments, transects were altered to follow anchovy schools where significantly large school formations were encountered, causing a deflection from the systematically set transects. If the at-sea efforts were also aimed at determining foraging characteristics, transects with closer legs on latitudes could be beneficial. But the main benefit of the survey altering for this aim would be placing trawling hauls at the position when continual foraging clicks are observed on the echograms, as well as oceanographic and biological sampling at the areas of absence of cetaceans (Witteveen et al., 2008). With the addition of continual visual observations, as the patterns on the echograms were seemingly characteristic to the species, on an anecdotal level, further discrimination potentials can be explored.

It can also be beneficial for bowriding behavior to be specifically explored for this case, as there is a possibility of longer detection incidences being due to prolonged bowriding. If visual observations were to be implemented, excluding bowriding data points can be beneficial for the analysis (Hastie et al., 2004), with the indispensable value added by behavioral observation data in the predator prey comparison study.

Lastly, the ambiguity of the detection range could potentially be a shortcoming that presents itself in the results. At the date of writing, there is no existing knowledge on the issue, to our knowledge. Therefore, detection range of cetacean clicks by the echosounder can be potentially much larger or smaller than the vague eye-ball guess of 1.2 km used in this study. Like mentioned, if this issue is aimed to be overcame, coupling of visual and passive acoustics methods should be carried out systematically.

In terms of avoidance, general consensus on both cetaceans and the fish (Brough et al., 2019) is that echosounder pings do not necessarily cause any significant behavioral change, disturbance implications such as termination of foraging or heading away from the echosounder has not been observed (Cholewiak, DeAngelis, Palka, Corkeron, & Van Parijs, 2017). So far, only lower detection rates compared to passive mode and possibly an elevated state of alertness has been reported (Quick et al., 2017).

4.5.1 Applicability of the Method

With this methodology, as the readily existing acoustic data can be utilized for further research of cetacean ecology, relative abundance since 1996 estimates in theory can be achieved which would give highly valuable population trend information. In these follow up studies, calculations on effort can be included to take into account of changes in the survey designs throughout the years. Mentioned existing long-term data should also be explored further in terms of its seasonality coverage, and if present, spring data may be focused on as higher foraging activity is expected, instead of autumn covered here.

This algorithm can be applied not only on the cruises made since 1996, but also theoretically to any active acoustics data set operated at 38 kHz and 120 kHz, at least in the Black Sea. And potentially to other seas, if the applicability of the algorithm can be checked prior, where the concern of selecting dolphin vocalization marks across other biological backscatter could arise if the newly applied study area poses significantly higher densities of echoes. As the Black Sea has characteristic uniqueness discussed priory, lack of biological backscatter below 100 meters might me enabling the ease of use of this method, but data sets in shallower seas or with wider phototropic areas should be trialed first to be able to discuss any further on the applicability of the methodology utilized here.

Specifically for bottlenose dolphin, 120 kHz frequency band data set might be utilized as 38 kHz is used for mainly Common Dolphin in the scope of this thesis. That distinction is made theoretically as Common dolphin clicks have peak at 23 kHz to 67 kHz, and Bottlenose dolphins have click peaks at 110 kHz to 130 kHz, and Harbor porpoise has click peak at 120 kHz and 140 kHz. But for that, verification of the detection method should be completed especially because 120 kHz data set attains much more noise compared to 38 kHz band. Also, presence rate, or at the very least, detectability of, bottlenose and harbor porpoise is much smaller in the Black Sea. Therefore, verification of the cetacean detection ability of 120 kHz frequency bands would be a higher challenge as the assumed abundance of these species are significantly less than common dolphins' in the Black Sea. But if suitable study area with higher numbers of bottlenose dolphin incidences, where efforts can be combined with visual and passive acoustic methodologies for the initial adjustment of the algorithm, the method used here can significantly decrease future efforts for collecting concurrent data on cetacean predator and prey. With such hypothetical well known and studied area, potential of discrimination of behavioral cues and species-specific click can arise, as the ping rate of the echosounder can easily be altered to the aimed pattern.

Enabling this inter-disciplinary approach is believed to be holding great promise for better management of cetaceans especially in areas where competition between fisheries and marine mammals exists, with lack of sufficient scientific foundation for effective management (Jusufovski, Saavedra, & Kuparinen, 2019), as the Southern Black Sea focused in this thesis.

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