CETACEAN DISTRIBUTION IN THE SOUTHERN BLACK SEA: AN ACOUSTIC APPROACH

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ABSTRACT

CETACEAN DISTRIBUTION IN THE SOUTHERN BLACK SEA: AN ACOUSTIC APPROACH

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Large numbers of small cetaceans (common dolphin, harbor porpoises and bottlenose dolphins) were hunted in the Black Sea until the hunting of cetaceans was banned in Turkey in 1983. Even though the practice of hunting cetaceans has ceased by Turkish fleets, ongoing threats such as viral infections, overfishing, by-catch, habitat loss, seismic surveys and the pressure of fishermen continue to persist. One of the most overwhelming reasons as to why overcoming these threats proves so difficult, is the insufficient data available for these populations.

This thesis study aims to evaluate the distribution and abundance of the Black Sea cetaceans for the future conservation of these species. To fulfill this role, i) hydro-acoustics, ii) passive acoustics and iii) visual observation methods were performed over transects during two one month cruises held in July and October 2014, covering up to 120 miles off the Black Sea coast of Turkey (approximately 150 000 km^2). For the fisheries hydro- acoustics, three scientific echo sounders (38 kHz, 120 kHz and

200 kHz, SIMRAD EK60) were operated continuously over the cruise transects. For the passive acoustics, C-POD (Chelonia Ltd., Cetacean Monitoring Systems) was deployed at up to the 93 stations. In addition, a new methodology for cetacean detection was developed. During the development of the new methodology, dolphin presence in fisheries hydro-acoustic data, i.e. the "noise", was processed into the "data" by validation with cetacean observation data. C-POD data was used both for confirmation of cetacean species and characterization of cetacean vocalizations. Finally, the abundance of cetacean species in the Exclusive Economic Zone of Turkey were examined using the data generated by the three respective methodologies.

With the combination of these methods, the distribution of especially one vulnerable (IUCN) Black Sea cetacean, the short-beaked common dolphin (*Delphinus delphis ssp. ponticus,* Barabash-Nikiforov, 1935) was assessed. Results suggest that cetaceans, especially common dolphins, are concentrated mainly in the Eastern region of the Black Sea and harbor porpoises are distributed coastally in lesser numbers. Furthermore, bottlenose dolphins were scarcely observed in the study area. As a result of abundance estimations it was found that, common dolphins display the largest population size, followed by harbor porpoises and bottlenose dolphins, respectively. Additionally, comparisons with 11 years of past visual observation data demonstrated an overall decrease in Black Sea cetacean populations. Lastly, the methodology developed proved that the hydro-acoustical data collected for fisheries purposes can also be used in cetacean research.

Keywords: acoustics, common dolphin, *Delphinus delphis ponticus*, abundance, distribution, observation, cetacean conservation, Black Sea

ÖZ

AKUSTİK YAKLAŞIMLAR İLE GÜNEY KARADENİZ SETASE DAĞILIMININ BELİRLENMESİ

Saydam, Gülce
Yüksek Lisans, Deniz Biyolojisi ve Balıkçılığı Bölümü
Tez Yöneticisi: Doç. Dr. Ali Cemal Gücü
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Avcılığı en son Türkiye'de 1983 yılında yasaklanmadan önce, Karadeniz'de bulunan küçük setaseler (tırtak, mutur ve afalina) yüksek miktarlarda avlanmışlardır. Avın, Türk filoları durdurulmasından sonra bile bu popülasyonlar, viral enfeksiyonlar, aşırı balık avcılığı, habitat kaybı, sismik araştırmalar ve balıkçı baskısı gibi hala süregelen tehditler sebebiyle düzelememişlerdir. Bu popülasyonlarla ile ilgili veri eksikliği bu tehditlerin aşılamamasının en büyük nedenidir.

Bu tez çalışması, setaselerin gelecekte korunabilmesi için gereken yayılım ve bolluk verisini sağlaması amaçlamaktadır. Bu amacı sağlamak için, i) hidro-akustik, ii) pasif akustik ve iii) gözlem yöntemleri'nin kullanıldığı, Temmuz ve Ekim 2014'de Karadeniz'in 120 mil açıklarına ulaşan aylık seferler düzenlenmiştir. Hidro-akustik örneklemesi için, seyir hatlarında üç tip eko-sounder kullanılmıştır (38 kHz, 120 kHz ve 200 kHz, SIMRAD EK60). Pasif akustik kapsamında sayısı 93'e varan istasyonlarda C-POD (Chelonia Ltd., Cetacean Monitoring Systems) atılmıştır. Ardından, setase tespiti için yeni bir metod geliştirilmiştir. Bu metotta, hidro-akustikle alınan yunus

sesleri, yani “gürültüler”, gözlem verileriyle doğrulanarak “veri”ye çevrilmiştir. Son olarak, kullanılan üç metodun verileri kullanılarak türlerin Türk Münhasır Denizlerindeki popülasyon miktarı belirlenmiştir.

C-POD ile yapılan biyo-akustik doğrulama ve tanımlama sayesinde yunus ses özelliklerini ortaya çıkaracak formüller bulunmuş ve bütün hydroakustik verisinden özellikle tehlike altında bir yunus türü olan Tırtak (*Delphinus delphis ponticus*) türünün var-yok verisi elde edilmiş, dağılım haritası çıkarılmıştır. Araştırma sonucunda setaselerin-,özellikle tırtağın, Güney-Doğu Karadeniz’de daha yoğun olarak dağıldığı, muturların çok az sayıda ve kıyısal alanda olduğu, afalinaların ise nadiren saptandığı sonuçlarına ulaşılmıştır. Popülasyon miktarı hesaplamaları sonucunda, en büyük popülasyona sahip türün tırtak olduğu ve bunu sırasıyla mutur ve afalinanın takip ettiği belirlenmiştir. 11 yıllık gözlem verisiyle bu çalışmanın sonuçları karşılaştırıldığında ise, Karadeniz setase popülasyonlarının küçülmekte olduğu görülmüştür. Son olarak, geliştirilen metot, balıkçılık amacı ile toplanmış hidro-akustik verilerinin yunus gözlem metodu olarak kullanılabileceğini kanıtlamıştır.

Anahtar kelimeler: akustik, tırtak, *Delphinus delphis ponticus*, bolluk, yayılım, gözlem, setaselerin korunması, Karadeniz

To my dearest family;

Şebnem-Refik Saydam and Tuğçe Terazi,

Including

The new family that I am building with the love of my life;

Ural Yalçın.

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1. INTRODUCTION

Hosting *Delphinus delphis ssp. ponticus* (Barabash-Nikiforov, 1935), *Tursiops truncatus ssp. ponticus* (Barabasch, 1940) and *Phocoena phocoena ssp. relicta* (Abel, 1905), Black Sea is a sea with peculiar characteristics. More specifically, its basin's semi-closed nature can be interpreted as a justification of several adaptations to coastal environment of Black Sea; which resulted in a smaller body size and relatively large skull in Black Sea bottlenose dolphins (Viaud-Martinez, Brownell, Komnenou, & Bohonak, 2008). Therefore, three species are recognized as a subspecies due to their morphological (Tzalkin 1931 and Barabash 1935) and genetic differences (Natoli et al. 2005) from other populations elsewhere in the world (Rosel et al. 1995, 2003).

Being in the highest level in the food web, Black sea cetaceans possess high importance in the ecosystem dynamics and ecological equilibrium of the marine ecosystem (Radu, Anton, Nenciu, & Spînu, 2013). Their status in the food chain, however, makes them sensitive to ecological conditions through bioaccumulation and biomagnification. In fact, Black Sea harbor porpoises were observed to have so high levels of and variety of organochlorine residues that they elevated species' worldwide average in organochlorine accumulation (Tanabe et al., 1997). There are many additional threats to Black Sea cetaceans like illegal direct killing, overfishing, habitat degradation, disturbance and incidental capture in fishing gear (Birkun, 2002) -all of which contributed to their endangered (*Phocoena ssp. relicta* and *Tursiops truncatus ssp. ponticus*) or vulnerable (*Delphinus delphis ssp. ponticus*) status in the IUCN Red List of Threatened Species (Date assessed: 2008). That is why many efforts must be concentrated to understand distribution and abundance of these animals in order to remediate anthropogenic and environmental conditions with negative impact on them.

Hence, a scientific research in Black Sea was required for the *conservation of these endemic species* which is the fundamental motive force for this scientific research.

As stated by IUCN (Birkun, Jr. and Krivokhizhin, 1988), “the lack of knowledge” on the current situation and distribution of the cetacean populations in Black Sea; namely the populations of *Delphinus delphis ssp. ponticus* (Barabash-Nikiforov, 1935), *Tursiops truncatus ssp. ponticus* (Barabasch, 1940) and *Phocoena ssp. relicta* (Abel, 1905), necessitates, and by doing so, rises the importance of the cetacean research in the Black Sea. However, cetaceans, the main concern of this study, exhibit a high degree of geographic variation throughout their distributions (Perrin et. al., 1978). Therefore, assessment of the distribution and abundance of short- beaked common dolphin, bottlenose dolphin and harbor porpoise inhabiting Black Sea requires a spatially comprehensive research. Furthermore, the distribution assessment of Black Sea cetaceans requires several levels of international co-operation which has been the main obstacle for their protection (Birkun, 2002). Performing such an extensive study in an unaccompanied situation, requires highly costly surveys like aerial surveys or cruises with long cruise-tracks. In addition to that, funds given for a cetacean research is generally limited due to lack of economic interests in some countries like Turkey. On the other hand, fisheries is the center of attention due to its economic benefits to a country. For this purpose, combining cetacean researches with fisheries researches bears high potential in contributing data on the situation of cetaceans in Black Sea.

1.1. Black Sea and Cetaceans: *An Overview*

1.1.1. Oceanographic Characteristics of Black Sea

Black Sea is a nearly-enclosed marginal sea with 423.00km^2 surface area (Zaitsev & Mamaev, 1997) and it is shared by six Black Sea countries: Bulgaria, Georgia, Romania, Turkey, the Russian Federation and Ukraine (Figure 1) (Rosselet, 2008). It connects to Mediterranean Sea through Turkish Straits System which is composed of the Bosporus Strait, the Sea of Marmara and Dardanelles Strait (T Oguz, Tugrul, & Kideys, 2004).

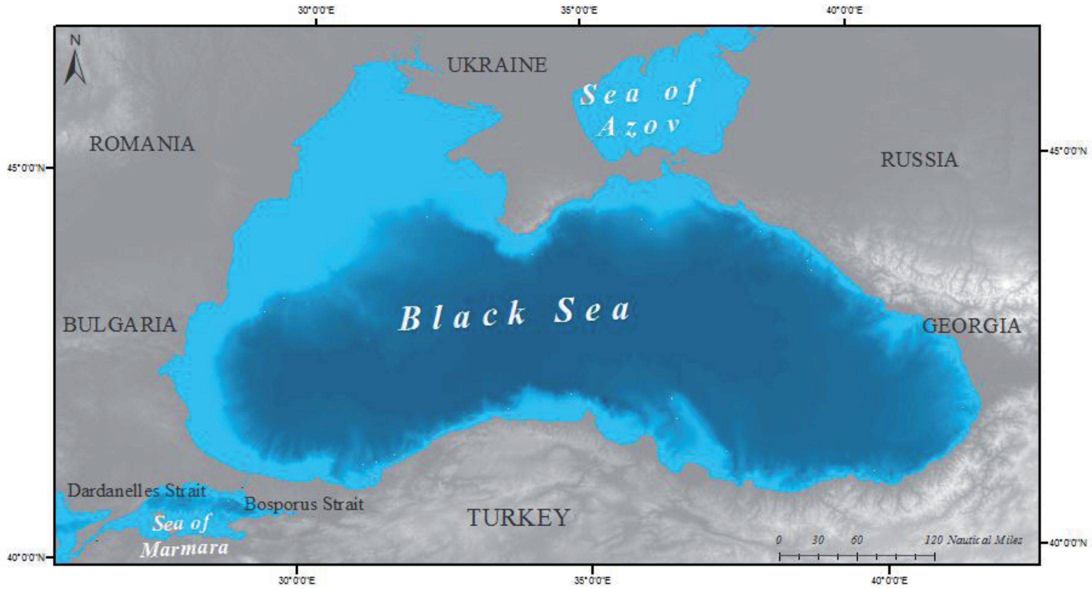


Figure 1: Map of the Black Sea, adjacent seas and countries; map was constructed using the bathymetric data of General Bathymetric Charts of the Oceans (GEBCO; http://www.gebco.net/).

Black Sea has a total volume of 547,000 km3, and a maximum depth of around 2200 m (T Oguz et al., 2004). Temperature of Black Sea surface waters varies seasonally between 8 ^{o}C to 30 ^{o}C (Oğuz et. al., 1993). According to Oğuz *et. al.* (1993) building blocks of the upper layer circulation in the Black Sea are (i) the Rim Current system around the periphery, (ii) an interior cell with two or more cyclonic gyres, and (iii) a series of quasi-permanent/recurrent anti-cyclonic eddies on the coastal face of the Rim Current (Figure 2). Therefore, it has a circulation system compatible to the open oceans with some particular features such as above mentioned wind driven surface circulations, deep water thermohaline circulation and strong surface stratification that constrains the ventilation in a relatively shallow layer (Murray, Stewart, Kassakian, Krynytzky, & DiJulio, 2007).

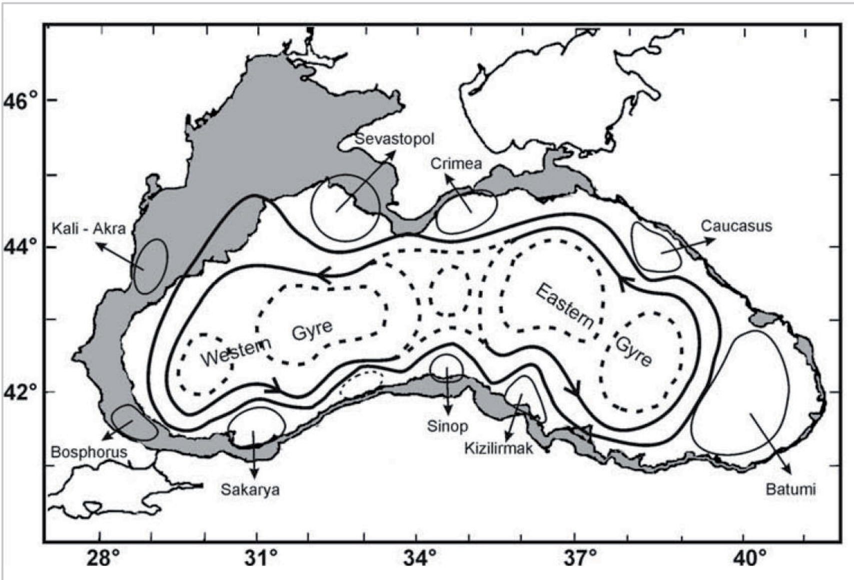


Figure 2: The schematic diagram for the main features of the upper layer circulation in Black Sea (approximately between latitudes of 41^{o} to 46^{o} N and longitudes of 28^{o} to 41.5^{o} E)-derived from synthesis of past hydrographic studies prior to 1990 (Oguz *et al*., 1993; Korotaev, Oguz, Nikiforov, & Koblinsky, 2003; Oguz *et al*., 2005).

One of the most striking feature of Black Sea is its anoxic nature. It possesses a permanent layer of anoxic-sulfidic water which has thickness over 2000 m in the central basin. In the surface layers, there exists an oxic to suboxic water column with thickness of approximately 100 m (Murray et al., 1989). In addition, Black Sea has positive water balance, which means the freshwater input exceeds the evaporation loss. This extra water mass is balanced by the outflow from Black Sea to the Aegean Sea through Turkish Strait System (see below). However, since Black Sea waters are almost brackish (avg. 18 ppt), this outflow takes place on the upper layers. At the same time, Mediterranean waters enter to Black Sea in the lower layers (avg. 36 ppt) and increases deep layer salinity (avg. 22.33 ppt) (Ozsoy *et al.*, 1986; Unluata and Oguz, 1988; Oguz and Tugrul, 1998); which give rise to a strong stratification in Black Sea (Murray *et. al.* 2007).

Black Sea is a very isolated sea, since Bosphorus Strait represents a remarkably narrow channel (avg: 1.3 km) (Zaitsev & Mamaev, 1997). In addition, Black Sea has very large catchment area (over 2 million km). Three of Europe's largest rivers, namely Danube, Dniepr and Dniestr, discharges to the Black Sea, giving rise to the major shelf region of Black Sea (Northwestern Shelf) (T Oguz et al., 2004). Due to these physical characteristics, Black Sea is highly susceptible to anthropogenic effects and has been experienced regime-shifts since 1970s (Niermann et al., 1999). The reason of this substantial alteration in the Black Sea ecosystem functioning is the cumulative effects of excessive nutrient enrichment, strong cooling/warming, overexploitation of pelagic fish stocks, and population outbreak of invasive alien species (gelatinous carnivores) (Temel Oguz & Gilbert, 2007). Because of nutrient and pollutant enrichment that the Black Sea was subjected to through rivers, eutrophication, environmental crisis and subsequent dramatic changes experienced in the past (T Oguz et al., 2004). According to the Daskalov, 2002 and Daskalov *et al*. 2006, the changes in trophic structures happened mainly through the enforcement of two cascade mechanisms: the collapse of large-bodied predatory fishes (due to overfishing-prior to the early-1970s) and collapse of the forage fishes (at 1989 – 1991). Climatic effects acted together with the overfishing and population explosion of the invasive ctenophore, *Mnemiopsis leidyi* which accelerated this process (Gucu, A.C, 2002, Kideys, A.E., 2002, Oguz *et al*., 2003). By the end of the 1990s, small planktivore populations dominated the system again as eutrophication tails off with the diminishing anthropogenic nutrient load and relatively warm winter conditions (T Oguz et al., 2004). Aforementioned mostly human induced alterations also affected ***Cetaceans*** as being a part of the ecosystem and at the highest level of the food chain.

1.1.2. Black Sea Cetaceans

Cetacea is a completely aquatic biological order under marine mammals, which is divided into two sub-orders called *Mysticeti* (baleen whales) with 11-12 species and *Odontoceti* (toothed whales) with 68-72 species (Evans and Raga, 2001). These two suborders are distinguished in two aspects: firstly, mysticetes are predominately larger than 10m in length and they have keratin plates (i.e. baleen) in order to filter plankton and small fishes; on the other side, odontocetes have toothed jaws (sometimes extended as beaks). Secondly, odontocetes have only one nostrils (or blowhole) while mysticetes have two (Evans and Raga, 2001).

There are there species of cetaceans in the Black Sea, namely short-beaked common dolphin *Delphinus delphis ssp. ponticus* (Barabash-Nikiforov, 1935), bottlenose dolphin *Tursiops truncatus ssp. ponticus* (Barabasch, 1940) and harbor porpoise *Phocoena ssp. relicta* (Abel, 1905) all of which belong to odontocetes sub-order. Harbor porpoises belongs to the family *Phocoenidae*, while short-beaked common dolphin and bottlenose dolphin belongs to *Delphinidae* (Notarbartolo-Di-Sciara, 2001).

Figure 3: Picture of Black Sea Short-beaked common dolphin captured during the October 2014 cruise (Delphinus delphis ssp. ponticus))© Photo: Gülce Saydam.

The range of the ***Black Sea Short-beaked Common Dolphins*** encloses almost the entire Black Sea, including exclusive economic zones of all Black Sea countries (Birkun 2006). As these cetaceans avoid waters with low salinity, which is the reason why they never occur in the Sea of Azov (Birkun Jr., A.A, 2008). The most peculiar morphological characteristic of common dolphin is the hourglass shading of black, grey, white and yellow (Figure 1). Additionally, the dolphin's dorsal surface is dark, fading out to grey and white in the side patch and the flipper has dark coloration and often has a strip leading from the beak (William F Perrin, Würsig, & Thewissen, 2015).

D. d. ponticus has Vulnerable Status in the IUCN-Red List of threatened species based on criterion A2cde (Birkun Jr., A.A, 2008). Although, generation time was not estimated for this subspecies, it was assumed to be approximately 15 years according to Taylor et al. (2007). There is no estimate of overall population size (Birkun Jr., A.A, 2008).

Figure 4: Picture of Black Sea Bottlenose dolphin (*Tursiops truncatus ssp. ponticus)*© Photo: http://www.dprgek.ru/redbook/detail.php-ID_SPEC=16025.htm

The range of ***Black Sea Bottlenose Dolphins*** includes the Black Sea; Kerch Strait and the Azov Sea (Tzalkin 1940, Birkun et al. 1997); and the Turkish Straits System (TSS) (Beaubrun 1995, Öztürk and Öztürk 1997). Morphological characteristics

(Figure 4) include light gray coloration which darkens dorsally and laterally, with a light belly and demarcated dorsal fin (William F Perrin et al., 2015). Adult lengths range from about 2.5 m to 3.8 m, varying by geographic location (Read et al., 1993).

T. t. ponticus has Endangered Status in the IUCN-Red List of threatened species based on criterion A2cde. Total population size is unknown but incomplete survey results suggests that the current population size is at least several 1,000s of animals (Birkun, A. 2012). Generation time is unknown as well, and it is assumed to be approximately 20 years (Taylor et al. 2007).

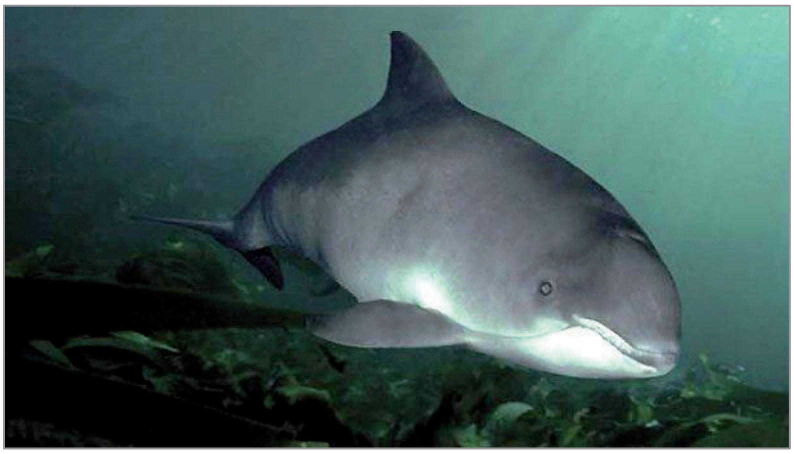


Figure 5: Scientific illustration of Black Sea Harbor porpoise (*Phocoena phocoena ssp. relicta*) © Photo: wikipedia.org

Black Sea Harbor porpoise inhabits the Black Sea, Azov Sea, Kerch Strait (e.g., Tzalkin 1938) in addition to Marmara Sea, Bosphorus Strait (Öztürk and Öztürk 1997) and northern Aegean Sea (Frantzis et al. 2001). Their body length is short with an average length of 1.3 m (Figure 5). They have rotund appearance which is due to the adaptation to limit heat loss in the cold waters like the Azov Sea (McLellan et al., 2002). The body coloration is generally dark gray and almost black at the dorsal side. The ventral portion is contrasting light gray (William F Perrin et al., 2015).

The Black Sea Harbor Porpoise, *P. p. relicta,* has Endangered (EN) status in the IUCN-Red List of threatened species based on criteria A1d and A4cde. Estimated generation time of Black Sea harbor porpoise is 8-12 years. There is no estimation of the present total population size. However, available data suggests that present population size is at least several thousands and possibly in the low tens of thousands (Birkun Jr., A.A. & Frantzis, A. 2008).

Overfishing is one of the major threats that Black Sea cetaceans face. Overfishing on small planktivorous fishes like sprat, anchovy, horse mackerel, caused a 10 fold reduction in fish consumption by dolphin population in the late 1960s (Sirotenko *et al* 1979; Özturk 1996; Daskalov, 2002). Observed decrease of the pelagic fish stocks was thought to inevitably increase the mortality of Black Sea dolphins as they are mainly dependent on them (Celikkale et al., 1988). Resultant great reduction in the dolphin stocks was lead to the ceasing of ***dolphin fishery*** in Bulgaria, Romania and the former USSR in 1966, but continued in Turkey until 1983 (Daskalov, 2002). Before that, mass commercial killing of cetaceans maintained to be the principal anthropogenic activity suppressing Black Sea cetaceans (*D. delphis*, *T. truncatus* and *P. phocoena*) (Smith 1982; Klinowska 1991;Birkun A., 2002). Commercial reasons for dolphin fishery included (i) the capture of wild animals for dolphinaria (Birkun A., 2002), (ii) melting of their blubber for home lighting (i.e. as lamp-oil) or for the productions of pharmaceutics, (iii) the use of meat as a bait in long-line fishery and as a food by fishermen (Silantyev 1903), (iv) the use of remaining for “fish” meal production (Kleinenberg 1956, Tomilin 1957). Beside commercial reasons, they were killed because they were seen undesirable competitors for the fisheries (Birkun A., 2002). For instance, Buckland *et al*. 1992 reported large number of harbour porpoise carcasses were observed floating off the coast of Turkey, with evidence of having been shot especially between 1980s and 1990s. ***Deliberate killing*** is still ongoing threat on all marine mammals; relevant research of Güçlüsoy *et al.* (2004) denotes that five out of thirteen dead Mediterranean monk seals had been deliberately killed within ten years in Turkish Aegean coasts (between 1986 and 1996). Therefore, tolerance of fishermen towards the marine mammals decreased and is expected to decrease further as the fish stock being depleted due to overfishing and illegal fishing (Güçlüsoy *et al.*, 2004).

Another major anthropogenic threat to Black Sea cetaceans is ***contamination.*** According to the studies of Mee and Topping 1992; 1998; 1999, primary threat to Black Sea is human-induced contamination of the oxygenated water layer. The Contamination may has many types and resources. Chemical contamination involves nutrients and organic matters (through rivers), oil and petroleum products, persistent organic pollutants, trace elements, while Biological contamination involves, microbe/faecal contamination and introduction of exotic species (like *Mnemiopsis leidyi* as aforementioned) (Notarbartolo-Di-Sciara, 2001). Contamination directly effects Black Sea cetacean in addition to its indirect effect as a means of deteriorating the ecosystem balance. For example, persistent organic pollutants attain their maximal concentrations in the blubber of cetaceans through bioaccumulation (Notarbartolo-Di-Sciara, 2001). There are more studies on Harbour porpoises in this regard. According to the findings of Tanabe *et. al.,* 1997, contamination by DDTs and HCHs in the Black Sea harbour porpoises were higher than the worldwide average of organochlorine residues in the same species.

Accidental catch in fishing gears (by-catch) is another threat that Black Sea cetaceans face. Several hundreds of cetaceans stranded ashore between early April and June every year, following entanglement and drowning in gill nets (Tonay & Öztürk, 2003). Furthermore, it is estimated that each year at least 2000-3000 individuals of *P. phocoena* and *T. truncatus* are incidentally cached during the sole, turbot and sturgeon fishing season in the Turkish Black Sea (Öztürk, 1996). The studies of Gönener

& Bilgin, 2009, focuses on the success of pingers (acoustic deterrent devices on fish nets) on avoiding *P.phocoena* from gillnets-in order to reduce by-catch with Turbot fishery in Turkish coast of Black Sea. Results shows that, pingers are reducing the by-catch without significantly affecting target and non-target fish size and catch. However, pingers can be a new noise input in the environment; besides, it may give rise to "habituation" problem in the future. In some researches, avoidance behaviors were observed to diminish or change over time, as dolphins habituate or sensitize to these alarms (Cox, 2004).

In Black Sea, there are many shipping lanes which eventually coincide with cetacean habitats and migration pathways. Since ***marine traffic*** is more intense in the coastal water, it is expected that shipping impact is more prominent on harbour porpoise (*P. phocoena*) (Birkun A., 2002). Shipping junctions like Bosphorus are extensively causes traffic stress on cetaceans. Related study of Akkaya Baş *et. al.,* 2014 with bottlenose dolphins in Bosporus Strait, highlights that the vessel type, speed, distance, and density of vessels have a cumulative negative effect on dolphins which necessitates protected areas with reduced shipping density.

Besides from the risk of collusion, marine traffic causes ***underwater noise*** due to cavitation of propellers and motors (Prideaux, M., 2003). Another noise sources includes industrial littoral activities, mineral prospecting (seismic), off-shore facilities being built or in use, military sonar training with underwater fire or explosions (Jasny, 1999; Notarbartolo-Di-Sciara, 2001; Würsig and Evans, 2002). The noise may disturb cetaceans indirectly causing changes in behavior, such as movement away from the sound, increased dive times and clustering behavior (William F Perrin et al., 2015) . Furthermore, noise may give rise to masking of vocalizations of cetaceans that are used for foraging, environmental perception or communication (Au, 1993) which will be further discussed at section *1.2.2Communication and Echolocation in* . More dramatically, loud sounds can cause physical damage (Notarbartolo-Di-Sciara, 2001) and temporary or permanent hearing threshold shifts which affect auditory acuity. In the studies of Evans and Miller, 2004, postmortem examination of humpback whales revealed ear damage caused by military sonar.

It is significant to point out the most prominent ***natural mortality*** factors affecting Black Sea cetaceans, the morbiliviral disease. Due to morbilliviral disease, mass mortality events of common dolphins reported in the Black Sea in July-September 1994 (Birkun *et. al,* 1999 a; Birkun, 2008). Another common dolphin mass stranding event involving at least 100s of dolphins occurred in 1990, however, this time, the reason was unknown (Notarbartolo-Di-Sciara & Reeves, 2006). Besides, recent record of anomalously white harbor porpoise in Black Sea, points out the possible recessive hereditary problems (Tonay et al., 2012)

Previous attempts to assess Black Sea dolphin stocks was problematic with large differences between the results of different research groups (Zaitsev & Mamaev, 1997). For example, Vinogradov and Simonov, 1989 calculated a total population with 60,000-100.000 individuals from the observations from ships and aeroplanes in years 1983-1984. Then in 1987, Celikkale el al., 1989 estimated total dolphin population of 454,440 individuals with the observations from the ships. First reason of differences between estimates, can be due to different sampling methodologies and different sampling area. Dolphin populations in the Southern and Eastern Black Sea, seasonally varies, with especially larger population in Southern Black Sea in the autumn, winter and spring, than in the north (Zaitsev & Mamaev, 1997). This phenomenon rises the importance of the sampling region. Following uncorrected stock assessment attempts were presented in the Table 1.

Table 1: ***D**elphinus **d**elphis, **P**hocoena **p**hocoena and **T**ursiops **t**runcatus* abundance estimates in the selected Black Sea areas; retrieved from Notarbartolo-Di-Sciara & Reeves, 2006.

Species	Surveyed area	Research period	Uncorrected abundance estimates	References
Dd	Turkish Straits System	Oct-97	773 (292–2,059; 95% CI)	Dede (1999)
Dd	Turkish Straits System	Aug-98	994 (390–2,531; 95% CI)	Dede (1999)
Dd	NW, N and NE Black Sea within Ukrainian and Russian territorial waters	Sept-Oct 2003	5,376 (2,898–9,972; 95% CI)	Birkun et al. (2004)
Dd	SE Black Sea within Georgian territorial waters	Jan-05	9,708 (5,009–18,814; 95% CI)	Birkun et al. (2006)
Dd	Central Black Sea beyond territorial waters of Ukraine and Turkey	Sept-Oct 2005	4,779 (1,433–15,945; 95% CI)	Krivokhizhin et al. (2006)
Pp	Azov Sea	2001	2,922 (1,333–6,403; 95% CI)	Birkun et al. (2002)
Pp	Southern Azov Sea	2001	871 (277–2,735; 95% CI)	Birkun et al. (2003)
Pp	Southern Azov Sea	2002	936 (436–2,009; 95% CI)	Birkun et al. (2003)
Pp	Kerch Strait	2003	54 (12–245; 95% CI)	Birkun et al. (2004)
Pp	NW, N and NE Black Sea within Ukrainian and Russian territorial waters	2003	1,215 (492–3,002; 95% CI)	Birkun et al. (2004)
Pp	SE Black Sea within Georgian territorial waters	2005	3,565 (2,071–6,137; 95% CI)	Birkun et al. (2006)
Pp	Central Black Sea beyond	2005	8,240 (1,714–39,605; 95% CI)	Krivokhizhin et al. (2006)
Tt	Turkish Straits System	Oct-97	495 (203–1,197; 95% CI)	Dede (1999)
Tt	Turkish Straits System	Aug-98	468 (184–1,186; 95% CI)	Dede (1999)
Tt	Kerch Strait	Jul-01	76 (30–192; 95% CI)	Birkun et al. (2002)
Tt	Kerch Strait	Aug-02	88 (31–243; 95% CI)	Birkun et al. (2003)
Tt	Kerch Strait	Aug-03	127 (67–238; 95% CI)	Birkun et al. (2004a)
Tt	NE shelf area of the Black Sea	Aug-02	823 (329–2,057; 95% CI)	Birkun et al. (2003)
Tt	NW, N and NE Black Sea within Ukrainian and Russian territorial waters	Sept-Oct 2003	4,193 (2,527–6,956; 95% CI)	Birkun et al. (2004a)

1.2. Marine Bioacoustics

The use of acoustics for the inspection of auditory capabilities, sound production, communications, foraging behavior and all other biological aspects of marine animals, is called marine bioacoustics (W. W. L. Au & Hastings, 2008). Traditionally used methodology for cetacean detection, namely cetacean observation, relies on the human vision, observer attention and weather/ light conditions. Besides, visual surveys detect only a fraction of the cetaceans, because these surveys can be undertaken only during daylight hours and cetaceans spent very limited time on the surface (Mellinger and Barlow, 2003). Sound waves, however, travel long distances through water as acoustic energy propagates more effectively than almost any form of energy in water (W. W. L. Au, 1993). Therefore, acoustic instruments which transmit and receive sound waves are used for the detection of marine organisms far beyond the range of vision (Simmonds & Maclennan, 2005). Although marine environment is relatively more favorable for sound propagation, there are still some limitations such as attenuation, perturbation, Doppler Effect and ambient noise (Lurton, 2010).

Sound has natural importance for the cetaceans since they communicate, navigate, and forage by using sound (Au, 1993). Therefore, the sound characteristics of cetaceans, the sound production mechanism and associated behaviors, have been subjected to scientific research. For example, during his studies with restrained dolphins, Ridgway, 1980, performed noninvasive electrophysiological techniques to investigate auditory capabilities of dolphins. This finding was followed by the target detection capability models of cetaceans (Au, 1990). Then, the numerous scientific researches focused on the production and usage of devices/algorithms that are capable of detection and identification of cetaceans (AQUAclick (AQUATEC, n.d.), the T-POD (Watkins & Colley, 2004) and C-POD (Chelonia Limited, n.d.a), and the A-TAG (Akamatsu et al., 2008); ROCCA (Oswald, Rankin, Barlow, & Lammers, 2007); Morrissey, Ward, DiMarzio, Jarvis, & Moretti, 2006) . Due to the fact that noise disturbs the natural behavior of cetaceans, the effect of anthropogenic noise sources such as seismic surveys and pingers (acoustic deterrents) have also been the subject of much research (Goold, 2009; Gönener & Bilgin, 2009; Berrow et al., 2008).

1.2.1. Principles of underwater Sound

Acoustic (i.e. sound) energy is composed of ***longitudinal waves*** which are molecular vibrations travelling in the water in the direction of propagation (W. W. L. Au & Hastings, 2008). ***Sound intensity*** is the amount of energy passing through a unit area per unit time. Intensity equals to the square of the ***pressure*** applied over time, divided by the specific acoustic resistance of the medium, which is the product of its density, ρ, and the speed of sound, c, in the medium (Gordon and Tyjack, 2001).

$$Intensity = \frac{pressure^2}{\rho c}$$

The pressure and intensity of acoustic waves conventionally defined by the decibel system since it provides a convenient way of expressing large quantities of change (W. W. L. Au, 1993). The **Decibel** is ten times the base-10 logarithm of the ratio of powers. However, most hydrophones are sensitive to pressure, particle velocity, or pressure gradient, therefore, sound pressure is the main measurement in acoustics. As the power is proportional to the square of pressure:

Pressure ratio in dB = 20 log ($p1$ / p_2), where p is the pressure.

Hydrophones are devices that are used to record underwater sound in acoustics (William F Perrin et al., 2015). In systems like hydrophones, a reference level of pressure is necessary to give absolute pressure in dB; which is generally one micro-Pascal in underwater acoustics (p_{ref} = 1 µPa) (Lurton, 2010). The sound pressure in terms of **Sound Pressure Level** (SPL) is,

SPL = 20 log ($p1$ / p_{ref}), where p is the pressure.

As aforementioned, sound originates from a compressional waves moving from a vibrating source in a compressible medium (Gordon and Tyjack, 2001). When a sound is a “pure tone”, the waveform changes in pressure represents a true sine wave. The rate of this wave to complete its cycles called its ***frequency***. **Hertz (Hz)** is the most commonly used unit of frequency such that 1 Hz equals to 1 cycle per second. Frequency spectrum of a sound indicates the amount of energy in each frequency band, and the graphs representing the frequency spectrum is called spectrograms.

Following this brief physical introduction on the characteristics of sound, how cetaceans produce and analyze the sound to explore their environment, to communicate and to forage will be presented in the next section.

1.2.2. Communication and Echolocation in Odontocetes

For the perception of their environment, animals use combination of senses like hearing, vision, smell, taste, touch and sometimes magnetism. As an animal, cetaceans also depend on such senses, however, some senses evolved over others as a result of the adaptations to aquatic environment (Evans and Raga, 2001). As Urick stated in his classic textbook "*Of all forms of radiation known, sound travels through the sea best*" (Urick, 1983; cited in Evans and Raga, 2001). Besides, cetaceans live in an environment which light penetration is very poor. Therefore, they use sound to discover their environment, to find their prey and for communication (Gordon and Tyjack, 2001).

Toothed cetaceans performs several types of vocalizations categorized in two broad topics: narrow band tonal sounds (i.e. whistles) and pulsed sounds (clicks trains and burst pulse calls) (Moore and Ridgway 1995, Richardson et al. 1995, Soldevilla et al. 2008, Henderson et al. 2012).

Whistles are tonal calls which serve for communication purposes. Therefore, they have characteristics ensuring long propagation, such as lower and modulated frequency profile and long duration (Au, 1993, Richardson et al. 1995). On the other hand, click trains are used in echolocation and navigation. During echolocation, these ultrasonic sounds returns as echo from an ensonified object in advance of the perception and analysis by the toothed cetaceans (Au, 1993). Echolocation is performed in a pulse mode; click is send, received, and returning echo is processed. After a specific lag time, next click is emitted (W. W. L. Au & Hastings, 2008). Therefore, they are short in duration and range from 5–150 kHz peak frequencies (range from 23 to over 100 kHz for delphinids with source levels up to 230 dB re 1 µPa/1m) (Richardson et al. 1995, Au, 1993 and 2004, Soldevilla et al. 2008, Pavan, 2014). Individual clicks has about 50 µ sec duration and their repetition rate within a train can vary from 1–2 to several hundred per second (W F Perrin, Wursig, & Thewissen, 2008). The performance of echolocation depends on the source properties of the clicks such as its amplitude and directivity (Madsen & Wahlberg, 2007). According to Au, 1997 and 2004, distant targets are more efficiently detected by high-amplitude clicks and directionality decreases the number of unwanted echoes. According to Henderson et al., 2012, echolocation clicks may increases during foraging behavior to detect and localize prey; likewise, whistles may increase as dolphins forage cooperatively.

Figure 6 presents the frequency interval of odontocete clicks. The cetaceans investigated in this study, namely dolphins and porpoises, shows different peculiarities in terms of the frequency and bandwidth of their clicks. Table 2 represents characteristics of the investigated cetacean species in this study in more detail.

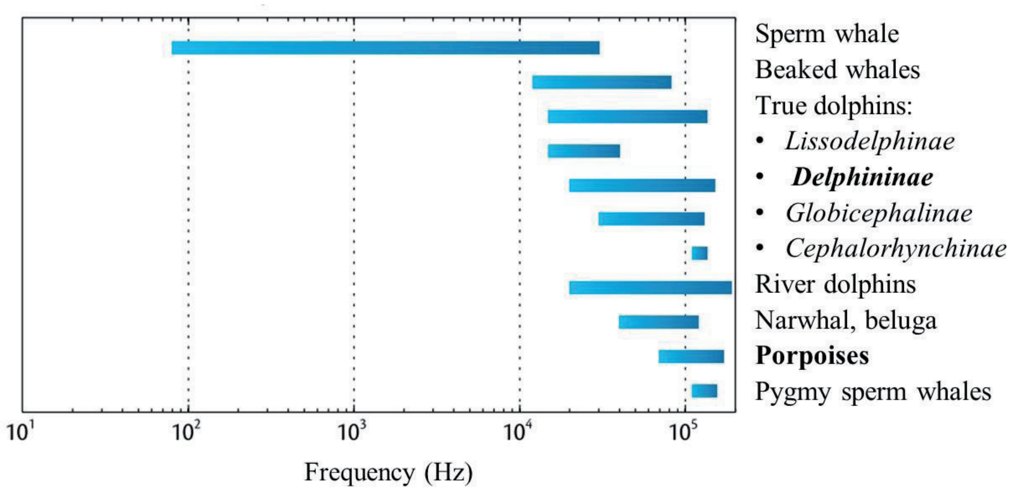


Figure 6: Frequencies of cetacean clicks retrieved from Mellinger, Stafford, Moore, Dziak, & Matsumoto, 2007.

Table 2: Properties of bio sonar signals of the investigated dolphin species: Delphinus delphis, Phocoena phocoena and Tursiops truncatus. The parameters are peak frequency (fp). 3-dB bandwidth (BW). Peak-to-peak source level (SL). Signal duration (t), condition (Cond). Table is compiled from Au (1993); The Sonar of Dolphins, chapter7, 135p.

Species	*fp(kHz)*	*BW (kHz)*	*T (µs)*	*SL (dB)*	*Cond*	*Reference*
Delphinus delphis	23 - 67	17 - 45	50 - 150	-	sea	Dziedzig (1978)
Phocoena phocoena	120 - 140	10 - 15	130 - 260	162	tank	Mohl and Anderson (1973)
Tursiops truncatus	110 - 130	30 - 60	50 -80	220	bay	Au (1980)

Not every odontocete species can produce whistles. For example, some porpoises and sperm whales can only produce clicks. Click signals of non-whistling dolphins and porpoises, such as *Phocoena phocoena*, are at higher frequency with narrower bandwidth and lower intensity than whistling dolphins (W. W. L. Au & Hastings, 2008) (Figure 7).

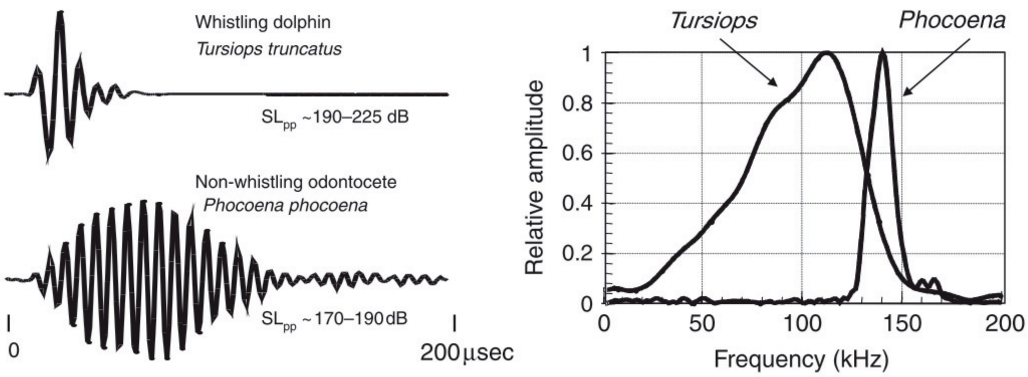


Figure 7: Echolocation signal of a whistling dolphin (*T. truncatus*) and non-whistling porpoise (*P. phocoena*); SL: source level of the signal (see section 1.2.1Principles of underwater Sound) (Perrin et. al, 2015 in ref. Au, 1993)

In general, whistling species such as Bottlenose dolphins can produce whistles and clicks simultaneously which ensures communication to continues as echolocation is performed in situations like foraging (William F Perrin et al., 2015).

Burst pulse calls occur both during echolocation and communication, and composed of series of rapidly produced clicks (Moore and Ridgway 1995). Due to the high repetition rate of these calls, they are perceived as a continuous sound by the human ear (William F Perrin et al., 2015). Some species also produce non-whistle pulsed sounds called buzzes (or squawks, squeaks, blats, buzzes, and moans) (Caldwell and Caldwell 1968, Henderson, Hildebrand, Smith, & Falcone, 2012). Under alarm, fright, or distress conditions, bottlenose dolphins and harbor porpoises are known to produce broad-band high-intensity squeaks (William F Perrin et al., 2015).

1.2.2.1. The Mechanism of Sound Production and Propagation

The head structure of odontocetes is quite complex with unique air sacs and special sound-conducting fats (called melon) (Au, 1993). The exact location of the echolocation signal and whistle production is the structure called the Monkey Lip-Dorsal Bursae (MLDB) in the dolphin nasal complex (Cranford, 1988). Then, with the combined effects of air sacs, skull, and melon, sound propagates in the dolphin's head (Aroyan , 2001) (Figure 8).

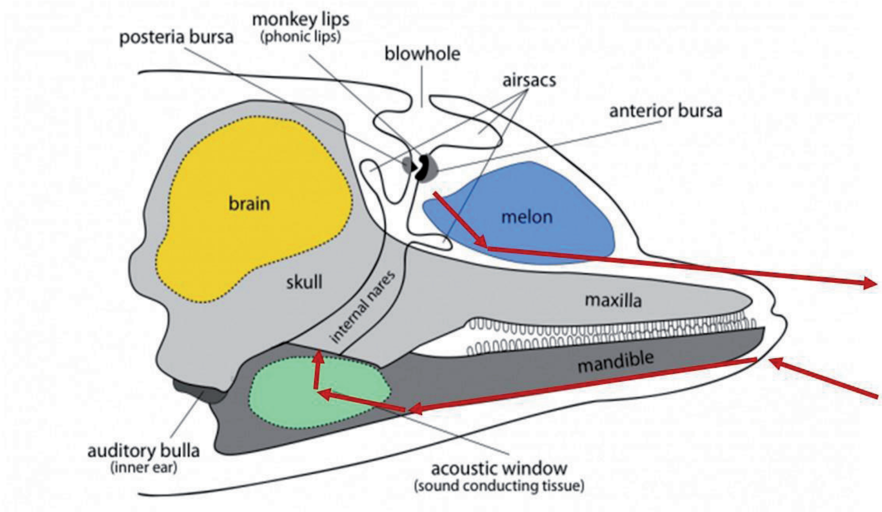


Figure 8: Illustration of dolphin inner head showing the location of the primary structures functioning in sound production and perception. (Modified from http://us.whales.org , Whale and Dolphin Conservation website). Monkey lips (MLDB or Dorsal bursae complex) are the source of sound production. Red lines illustrates the propagation of the produced sound and received echo.

Especially the melon has very low sound absorption characteristic, and functions in directing and focusing of the produced sounds (Varanasi and Malins 1971; Varanasi et al. 1975). Direct sounds and returning echoes enters through the thin posterior portion of the mandible (i.e. lower jaw); which is then transferred by fat-filled canal to the tympano-periotic bone, which contains the middle and inner ears (Norris, 1968a, Au, 1993).

1.2.3. Acoustic Monitoring of Cetaceans

The systems in which target and obstacle detection performed is called **So**und **N**avigation **a**nd **R**anging (i.e. sonar). There are basically two types of sonar systems; firstly, in an *active sonar system* a signal is transmitted by the system and then sends back by the target as echo; secondly, in a *passive sonar system* sound radiated by the target is received by the system (Lurton, 2010). In order to monitor cetacean sounds, passive sonar systems like hydro-phones are used traditionally (W. W. L. Au, 1993).

Species-specific factors influences fixed passive acoustic surveys-making some species more preferable than others. These factors includes frequency profile, vocal behavior and source level. One of the devices used in the study, namely C-POD, is specifically designed for the porpoise detection (Chelonia Ltd., Cetacean Monitoring Systems). Due to the peculiar sound characteristics of porpoises, such as narrow bandwidth and high frequency, a special design is needed (see section *1.2.2 Communication and Echolocation in*).

Fisheries acoustic sonar, namely echo-sounder, is an example of active sonar system. In the following sections, theory and applications of both C-POD and echo-sounders will be further discussed under the *Passive Acoustic Monitoring* and *Hydro-acoustics* titles, respectively.

1.2.3.1.Passive Acoustic Monitoring

With the discovery of Pierre and Jacques Curie (1880a, 1880b) on electric potential production with the mechanical pressure exertion on a quartz crystals, a device for listening underwater sounds (passive acoustic monitoring -PAM) could utilized in World War I. This discovery is followed by the development of fixed autonomous underwater sound recorders (ARs) in 1990s, which significantly decreased the costs and expertise required (Sousa-Lima, Norris, Oswald, & Fernandes, 2013).

Today, there are two types of passive acoustic equipment widely used for cetacean detection; cabled hydrophones (underwater microphone) and autonomous recorders. Former one is deployed in permanent or semi-permanent installations while the latter one is moored on the seafloor or stabilized on water column with a cable and buoy (Mellinger et al., 2007). On the other hand, in the autonomous recorders like CPOD, acoustic data is stored internally, therefore they must be recovered before data analysis can begin.

C-POD is an underwater system that detects and logs dolphin tonal clicks over extended periods (Chelonia Ltd., Cetacean Monitoring Systems). It has piezo-ceramic transducer sensitive to all frequencies below 160 kHz and serves as an omnidirectional hydrophone. With the software, cetaceans can be classified into two groups: Dolphins and porpoises. Besides, ship sonars can be detected. Software used for the analysis is provided by manufacturer (C-POD.exe). High pass filtering can be performed with options of 20 kHz, 40 kHz and 80 kHz.

In the literature, there are many cetacean researches using C-POD for cetacean recording. These include range determination, detection, monitoring, diel or seasonal occurrence, migration patterns, and behavioral assessments (Castellote et al., 2012 ; Nuuttila et al., 2013 ; Roberts & Read, 2015). In the study that was conducted in Istanbul strait, a previous version of C-POD, namely A-TAG, was used. In this one year research, increased number of short range sonars (Inter Click intervals less than 50 ms) and concentrated distribution of cetaceans were observed in spring. This phenomenon was concluded as the result of feeding season in spring (Dede, Öztürk, Akamatsu, Tonay, & Öztürk, 2013).

1.2.3.2.Hydro-acoustics

As a type of an active sonar system, hydro-acoustics relies on the detection of targets within the beam of transmitted acoustic energy. When acoustic energy encounters with a target, it scatters and produce echoes which are detected by a receiver. Acoustic energy and the returning signal are in the form of acoustic pulses. This transmission is performed commonly by the echo-sounders (conventional narrow single beam systems) and side-scan sonars for monitoring and harvesting. The received signals, then, displayed on an echogram which represents an image of a rectangular area on the cruise-track (Klemas, 2013).

The strength of the echo depends mainly on the density difference between the target and the surrounding water. Therefore, in the case of fishes, swim bladder is the organ which reflects the echo most (Simmonds and MacLennan, 2006). The depth of the target is calculated based on the time it takes the reflected pulse to return to the transducer; which also depends on the speed of sound under prevailing environmental conditions.

As sound travels further from the source through a medium, it loses some of its energy. The most substantial reasons of this loss are geometric spreading and absorption. In free space, as sound spreads away from a point source, it takes a form of an expanding sphere (Gordon and Tyjack, 2001). Which means as sound spreads further away from its source, the total sound energy spreads over a larger sphere (with larger radius, *r*,); in other words, its intensity, *I*, is diluted. Therefore***, spherical spreading*** in terms of dB scale is,

$$Transmission\ loss = 10\log\frac{I}{I_{ref}} = \frac{4\pi r^2}{4\pi r^2{}_{ref}} = 20\log\frac{r}{r_{ref}}$$

As sound waves travels, some energy is absorbed and dissipated as heat. Additionally, this absorption increases with frequency of the sound, *f*, (Gordon and Tyjack, 2001). In sea water, ***absorption loss, a***, is approximately,

$$a = 0.36\, f\ (dB/km)$$

If the sound released from the transducer undergoes geometric spreading and abortion as it travels away, then there is a need of a function to compensate this loss. This function is called ***Time-varied Gain (TVG).*** It compensates the signal for these losses, providing a sonar output that is independent of the target range (Simmonds & Maclennan, 2005).

Echo of the transmitted acoustic energy is not the only sound received. Ocean is a noisy environment due to several ***noise*** sources: the sounds originated from animals, the sea surface (in especially heavy weather conditions), geological processes and anthropogenic activities (Gordon and Tyjack, 2001). The most important noise source for this research is the ***calls of marine mammals.*** Therefore, the purpose of the fisheries hydro-acoustic research in this study is sampling/processing the "noise" to extract "data" for cetacean detection. Which means, hydro-acoustic sampling of this study is interested in what is received except the echo of the transmitted ping. From this perspective, echo-sounders were used as a passive acoustic device, even though, it is, in principle, an active acoustic device. Therefore, this brief introduction on fisheries acoustic holds a significant role for the understanding the fundamental norms and questions of the methodology derived, such as, "how would TVG effect the detection of cetacean vocalizations?" or the effect of the transducer frequency on cetacean detection.

The scope of this study is to provide the distribution and abundance of the Black Sea cetaceans which was previously *unknown*. The greatest aim of this contribution is to ensure the prerequisite scientific information for the conservation of these endangered/vulnerable species in future. Since the majority of previously experienced threats (see section *1.1 Black Sea and Cetaceans: An Overview*) are still present in the Black Sea, this action should be realized as soon as possible for the survival of these species. However, assessment of the distribution and abundance of cetaceans inhabiting Black Sea, requires a spatially comprehensive and economically costly research. For example, during this research approximately 150 000 square kilometers were covered. That is the reason why these information gap could not completely filled in Black Sea before. Therefore, the second aim of this study is to develop a new, economically convenient sampling methodology: hydro-acoustics. With this methodology, not only the sampling cost decreases but also the effectiveness of sampling increases. Because, traditional sampling (observational sampling) can be performed during the day and in calm weather conditions. Hydro-acoustic sampling, however, continues day and night. Another advantage of this new methodology is the possibility it provides for the "past" monitoring. Since hydro-acoustics is generally used in fisheries researches, previously collected hydro-acoustic data can be processed to provide past distribution/ abundance of cetaceans.

2. MATERIALS AND METHODS

This study utilizes three sampling methodologies: Direct observation *via* focal sampling of cetacean groups (Hereafter: observation), acoustical sampling of cetacean absence presence *via* hydro-acoustics (Hereafter: Hydro-acoustics) and acoustical sampling of cetacean vocalizations *via* C-POD (Hereafter: C-POD).

2.1. Survey Design

The number of surveys and cruise details were presented in Table 3. The cruises were carried out by two different research vessels and their specifications are presented in Table 4. During the cruises, hydro-acoustic data was collected over transects covering the Turkish Exclusive Economic Zone in the Black Sea; while C-Pod data was collected at fix stations. Simultaneous cetacean observation with focal sampling was performed as a complementary to the acoustic research. For the hydro-acoustics, three transducers were operated continuously over the cruise transects and this data was utilized to detect the presence of short- beaked common dolphin (*Delphinus delphis* ponticus). For the passive acoustics, C-POD (Chelonia Ltd., Cetacean Monitoring Systems) was deployed on the stations. Firstly, from the observational data, spatial distribution of species searched and behavioral analysis of cetacean groups performed. In addition to that, abundance of species were calculated from both observational data, fisheries acoustical data and C-POD data, independently. Secondly, from the hydro-acoustics data, short- beaked common dolphin presence was assessed by *characterizing* dolphin sounds in hydro-acoustics data *via* the validation performed with observational data. Finally, C-POD data was used both for validation of cetacean species and characterization of cetacean vocalizations.

Cruise Date	Cruise Duration	Vessel	Active Acoustics/ Echo sounder type	Passive Acoustics/ Number of CPOD stations	Cetacean Observation/ Number of encounters	Geographical range
July 2014	20days	R/V SÜRAT I	38kHz, 120kHz	14	Chance encounter events n=35	South-Eastern Black Sea; ≈ 19500 km^2 (max 24.08 nmi Offshore)
Oct 2014	20days	R/V BİLİM II	38kHz, 120kHz, 200kHz	93	Sunrise to sunset cetacean observation n=196	Southern Black Sea; ≈150000km^2 (max ≈105.08 nmi offshore)

Table 3: Design of surveys conducted during study regarding the methodologies applied.

Table 4: Specifications of the two research vessels used during the survey; GT: Weight of the vessel in Giga- tons, W: water capacity, Fuel: fuel capacity, P: personnel capacity, E power: engine power. Table is regenerated from the article *Turkey research vessels technical specifications* (Yalçın & Koşar, 2012).

Id	Date of con-struc-tion	Full length (m)	Width (m)	Draft (m)	GT	W (ton)	Fuel (ton)	Max speed (knot)	P	E power (HP)
R/V SÜRAT I	1984	28.2	9,44	1,4	154	18	20	12	16	720
R/V BİLİM II	1983	40.47	9,41	3,97	421	54	100	11.5	29	1045

2.2. Data Collection:

2.2.1. Cetacean Observation:

Cetaceans were observed by naked eye and via binoculars (Nikon ACULON A211 10-22x50) interchangeably, from sunrise to sun set (Figure 9). Continuous observation was done on the upper deck (approx. 14m higher from the sea level) of the research vessel during surveys. Several information about cetaceans like the min-max number of individuals within a group and the bearing of the group according to the vessel route were noted. In addition, coordinate and route of the vessel according to the true north were collected via gyrocompass repeater (ARMA BROWN MK 10), Radar (DECCA RM 1226) and Satellite Navigation and Global Positioning System (Magnovax MX 100) of the research vessel Bilim II and noted in observation sheets (*Appendix A*). According to their morphological and behavioral differences, cetaceans were identified at species level. Then, behavior of cetacean groups were recorded with focal group sampling method. Focal group sampling is continuous assessment of group activity (Mann, 1999) in which one observes whole group and record the dominant behavior. Behaviors of cetaceans were noted as Travelling (TR), Travelling fast (TR-F), Short travelling (S-TR), Surface feeding (S-FE), Resting (RE), Socializing (SO), Travel Diving (TR-D) Milling (MI) and Bow-Riding (BR) (Table 5).

Figure 9: A photograph of Short- beaked common dolphin (*Delphinus delphis*) taken during cetacean observation (left); a researcher performing cetacean observation with binocular from upper deck (right).

Table 5: Definition of the behavioral states of investigated cetacean groups (*Delphinus delphis, Tursiops truncates, Phocoena phocoena*)

Behavioral State *Abbreviation*	Definition
Travelling (TR)	Group moves in a defined direction. animals move as a unit, diving (≤30 sec) (Bearzi *et al.* 1999) and surfacing synchronously at speeds of three to five knots (Mann, 1999)
Travelling fast (TR-F)	Group travels with same dive intervals but at a speed of more than or equal to 9 knots (Bearzi & Politi, 1999)
Short travelling (S-TR)	Group travels very short distances
Travel Diving (TR-D)	Animals swim underwater in same general direction kept during surfacing and submerging in direction of movement. Diving periods are prolonged (≥30 sec) (Bearzi & Politi, 1999)
Resting (RE)	Animals move slowly as a tightly arranged pattern with almost no forward movement, short and synchronous dive intervals are visible (Lusseau, 2003)
Socializing (SO)	High level of activity presents in the group with synchronized jumps or body contacts during tightly aggregated surfacing and diving intervals(Mann, 1999)
Surface feeding (S-FE)	No directional movement as a group. Animals surface and dove in a large circle, then dives in toward the center.(Mann, 1999) Generally cooperative.
Milling (MI)	No net movement of the group with individuals facing different directions; no apparent physical contact between individuals; usually staying close to surface (Shane, 1990)
Bow-Riding (BR)	High level of activity, group surf with the waves created by the vessel.

Observer and sea state (according to the Beaufort scale) were also noted considering their effects over the observation and detection range. In addition, situation of the vessel at the time of observation was noted on the observation sheets as either trawling, navigating or at station. For practical purposes, situation/position of acoustical instruments at the time of observation were noted as well. Once encountered, cetaceans were photographed both as a group and as an individual forming the group *via* Nikon D70 digital camera body and Nikon af vr 80 400mm f/4.5 5.6 ed lens. Especially BR behavior of the groups provided great opportunity for detailed examination of individuals.

2.2.2. Hydro-acoustics Data Collection:

In this study, hydro-acoustic data was collected *via* three scientific echo-sounders (38 kHz, 120 kHz and 200 kHz, SIMRAD EK60, *Scientific echo sounder*, SIMRAD EK System) and recorded using SIMRAD EK60 software (Simrad, Kongsberg Maritime AS, www.simrad.com). During post processing Echo View Software was used (Echo View, sound knowledge, Myriax Software Pty Ltd, Copyright 1997-2015).

2.2.2.1.Calibration

Although hydro-acoustic system focuses on the noise created by the cetaceans, and not influenced by the absolute transceiver performance of the system, echo sounders were calibrated before acoustic surveys for accurate quantitative measurements (*Simrad ER60 Scientific echo sounder Reference Manual*, 2008). At the beginning of the surveys, vessel was anchored in a calm area where abrupt topographical changes in the seabed, strong water currents, heavy marine traffic and dense fish schools are absent. Minimum water depth was chosen as at least 25m. The temperature and salinity profiles were measured by CTD and the water column averages were used for the sound speed calculation. Transducers were calibrated by lowering a reference target, a copper sphere, with a known target strength (TS) into the sound beam. The diameter of sphere is specific to each frequency in order to obtain a TS with minimum temperature dependence (K. Foote 1983). Before lowering, copper spheres were cleaned with water-detergent mixture in order to prevent micro bubble formation over the spheres. Then, they were positioned one by one under the transducers mounted on the hull of the vessels. To manage this, two crew member released a metal sinker attached freely on a fishing line with two arms, one of which was hold at the starboard and other was hold at the portside of the vessel. Then they moved toward the head of the vessel till visual was observed on the echogram. Orientation of copper ball to the desirable position was coordinated by the crew member who is observing measured TS via the software. During calibration, the procedure stated in the manual was followed (*Simrad ER60 Scientific echo sounder Reference Manual*, 2008) and same procedure was repeated.

2.2.2.2. Active Acoustic Sampling

Acoustic data were collected during surveys over parallel transects arranged perpendicular to the Turkey coast. However, due to peculiar characteristics of the coastline and bottom topography, some transects were adopted to represent the marine ecosystem and geography in the best possible way. In addition, due to sudden climatic variations and different capacities of each research vessels both the geographic range and the pattern of transects covered during the surveys were adjusted accordingly (Figure 10).

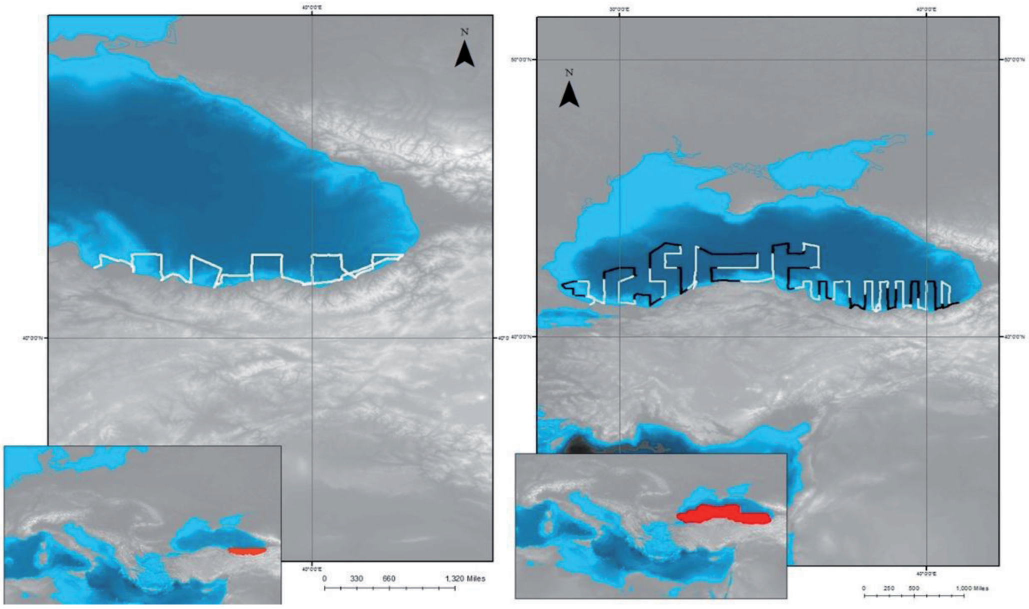


Figure 10: Cruise-track of SURAT-1 during July 2014 acoustical survey covering South-Eastern Black Sea (left), cruise track of BILIM-2 during October 2014 acoustical survey covering Southern Black Sea. Color of the track represents the time period it is covered as before sunset/daytime (white color) and after sunset/night-time (black color).

2.2.3. C-POD Data Collection:

2.2.3.1. Pilot study

To test the performance of the C-POD system and to get experience on devices, a small scale pilot study was conducted. In order to test the compatibleness of the device and planned methodology with the research objectives, first approach was to moor the C-POD to the METU-IMS harbor. During the 2-4 days of moorings, land based cetacean observation was performed to verify detections with device. Second approach was to release CPOD to the sea on stations from a vessel. Releases were practiced from the deck of RV Lamas at around 2 miles off the institute coast. Also, simultaneous cetacean observation performed for visual validation.

2.2.3.2. Surveys

In this study, C-POD (Chelonia Ltd., Cetacean Monitoring Systems) is used to record dolphin/porpoise vocalizations at the stations (Figure 11). C-PODs are self-contained ultrasound monitors that select tonal clicks and record the time, duration and other features of each click to 5microseconds resolution (C-POD user guide, www.chelonia.co.uk/cpod_downloads.htm) (see section 1.2.3.1 Passive Acoustic Monitoring).

C-POD deployed over the 15-45min stations during which vessel was stopped and data collection was performed with 20 kHz high pass filtering option. C-POD was preferred to be deployed in equally spaced multiple stations in order to represent a homogenous sampling points (see further discussion in the 4.5.3 Black Sea Cetaceans: Acoustic Characteristics). For the deployment, mid-water release method which had developed during the pilot study is followed (Figure 12).

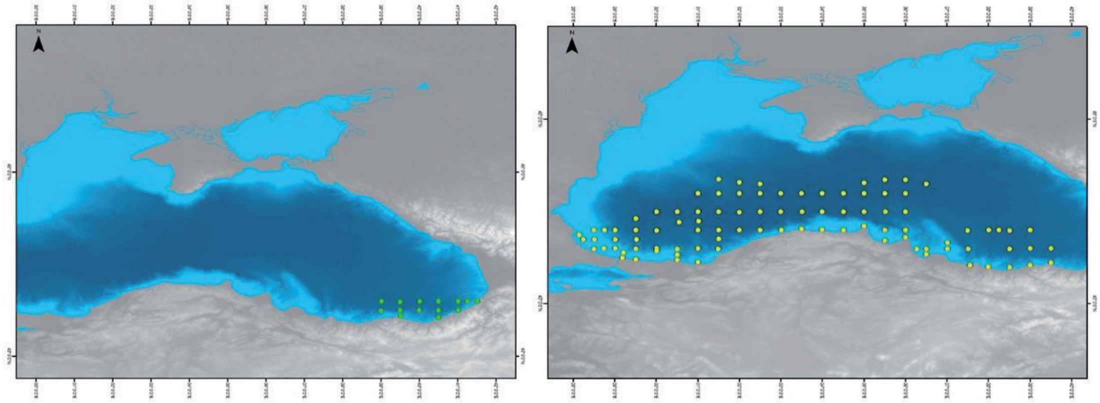


Figure 11: CPOD stations; July 2014 cruise (left), October 2014 cruise (right).

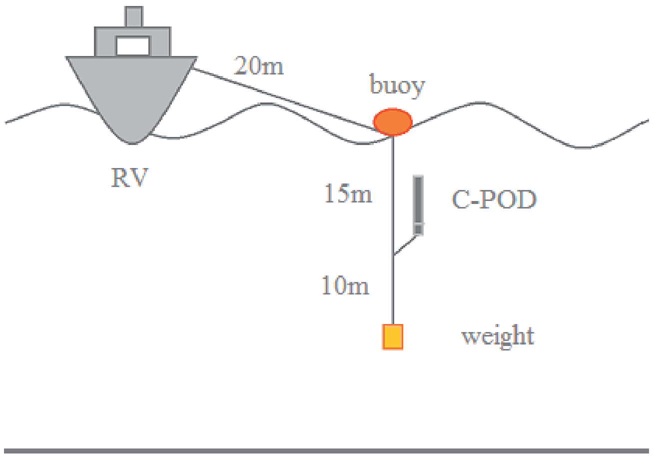


Figure 12: Illustration of developed release method used during C-POD stations.

2.3. Data Analysis

In addition to various software specific for each method, ArcGIS 10. 2 is used for the visualization of spatiotemporal distribution of data and data management (Copyright © 1995–2014 Environmental Systems Research Institute, Inc. (Esri))

2.3.1. Observational Data Analysis: Spatial Variation and Behavioral Analysis

Observation data collected during July and October, 2014 cruises were mapped with ArcGIS 10.2 software with respect to their coordinates, average group sizes and species.

2.3.2. C-POD Analysis

In order to detect cetacean click trains, C-POD data was analyzed with the software provided by the manufacturer (C-POD.exe; Chelonia Limited). The C-POD software uses a digital time domain waveform analysis to detect cetacean echolocation clicks at a 5 μs resolution and 8-bit intensity within a frequency range of 20– 160 kHz. The time and duration of each detected click were recorded. In this study Dolphin/porpoise clicks were analyzed using the KERNO classifier, a proprietary algorithm. The classifier detects click trains (if number of clicks within a train is greater than 5) and assigns them as either Dolphin (other cetacean), Porpoise (NBHF: Narrow band high frequency), Sonar (boat sonar) or Unclassified using their peculiar characteristics (*C-POD.exe: a guide for users*; www.chelonia.co.uk/cpod_downloads.htm). The software also enables to assign quality classes to the trains (High Q, Mod Q, Low Q, and Doubtful) which represents the confidence level of classification considering the chance of the train arising from a non-train source to be assigned as arising from a cetacean. First the raw data file (C1file) was processed to 'detect cetacean clicks with KERNO Classifier' under the 'view+' page. At this stage, classifier automatically creates a CP3 file which contains species class and quality class information. Cetacean clicks of low, moderate and high quality were analyzed in detail by simultaneous inspection of CP1 and CP3 files.

In order to have a general perspective over vocalization characteristics of Black Sea Cetaceans, stations with visual dolphin/porpoise observations were analyzed at the first stage. Afterwards, cetacean detections in all stations was validated for the purpose of quality control assessment by visually checking the data. Main features of trains used during this validation are duration & number of cycles, amplitude & amplitude profile, inter-click interval (ICI) & click rate, frequency & frequency multipath clusters, association (-with other trains) and bandwidth as stated in the manual provided by manufacturer (*Validating cetacean detections*, www.chelonia.co.uk/cpod_downloads.htm) (Appendix B). Since SD card of the device was renewed approximately in every 10 stations, the station of interest needed to be separated from others. Start time of the station was set as the start time of the analysis by "set selection as start" command; likewise, the end of the station was set as the end time of the analysis. This procedure is applied using 1min time resolution. To elaborate on train features of a specific station 10ms time resolution was used. Following the specifications of each species, Kerno-classifier-defined species were validated. Then, high Q unclassified species were inspected for further specification. By this way, false negative and false positive detections were corrected. Finally, train details of all species classes with High, Mod and low Q were exported.

2.3.3. Hydro-acoustics: Echo-sounder Analysis

The hydro-acoustic methodology basically relies on the backscattered sound from the organisms that vary due to their size, orientation and specific material properties (see section 1.2.3.2 Hydro-acoustics). In the theory of fisheries hydro-acoustics, fish schools that are large and dense enough to reflect transmitted sound are detected by the echoes reflected from their swim bladder- since it provides a density barrier with water (Simmonds and MacLennan, 2005). Dolphins, however, requires another methodology since they are fast, big and bear lesser chance to pass through the acoustical beam of the transducer. In this study, dolphins were detected by their sounds emitted for echolocation. Although theoretically other vocalizations of dolphins (such as whistles) can also be procured *via* echo-sounder, echolocation clicks are the one that bears higher efficiency due to their coherent frequency band with echo-sounders and due to their time pattern. The short time span of both echolocation trains and of the interval between each click (inter-click interval) composing an echolocation train, provides an advantage through processing (see section 2.3.3.2 Hydro-acoustic analysis: SV analysis- dB differencing). Therefore, echolocation traces of the most convenient species, namely the traces of *Delphinus delphis ponticus* (Barabash-Nikiforov, 1935), were searched in the acoustic data. Several reasons of choosing this species will be discussed in the following chapters.

Visualization and processing of echo-sounder data were performed with Echo-view software (Echoview Sound Knowledge, copyright 1997-2014 Myriax Software Pty Ltd). Hydro acoustic analysis starts with scrutinize stage. At this stage a surface exclusion zone, an acoustic bottom line, bad data, background noise and other sources of unwanted echo were characterized and accounted for.

2.3.3.1.Scrutinize Stage & Data Quality Check

The objective at the scrutinize stage was to remove "noise" other while identifying and assessing the quality of received signals. When the traditional application of undertaken sampling design considered, noise is the any other sound received other than echoes received from fish schools. However, from the perspective of this study, "noise" is the any other sound received other than dolphin vocalizations. In order to attain this, Echo-View software was used to create an EV file for each day from the relevant raw data file sets. On the 38 kHz raw echogram (SV Raw pings: T1) a <u>surface exclusion line</u> was added at fixed depth (100m). Because above 100 m depth, back-scatterings of fish schools and other organisms masks the dolphin traces. Since the depth of dolphin echolocation traces are not related with the actual depth of dolphins and since it extends to entire ping (i.e. visible in all depths), this exclusion does not cause any data loss in the waters with depths higher than 100 m. Then <u>an acoustic bottom line</u> which is 10m shallower than "sounder detected bottom derived from the data file" is created. These lines were set to be visible in all echograms to guide our judgments. In order to assess data quality, following features were considered and set as regions with specific region classes (Regions are features of EV files that are used to describe the intended use ; and, they are specified by depth and time (Higginbottom, Woon, & Schneider, 2008)):

<u>False bottoms</u>: sea bottom was usually detected very efficiently by the software since energy of the bottom echo is much higher than any other echoes. Therefore, bottom topography was eliminated firstly by adding a line with an approximately 10 m shallower depth than that of echo-sounder-detected bottom; and secondly, by excluding the features below this line from calculations. However, when transducer's acoustic axis is not perpendicular to the bottom, side lobes of transducer ping meets bottom before the main lobe which causes a false bottom. This situation occurs especially places where bottom topography changes suddenly such as shelf-break (Gucu and Sakinan, 2013). False bottoms were noticed while approaching to the continental shelf. Therefore, these regions were identified as 'bad data' regions in the software and excluded from calculations.

Net sounder & CTD: net sounder is a set of acoustical device composed of hydrophones mouthed on the carina of the vessel and transmitters attached to the fishing net. The net sounder is used to determine the position of a trawl net in water column during the trawl operations (http://www.simrad.com/, ©2015 Kongsberg Maritime AS). During sampling, the signals transmitted by the net sounder were recorded by the echo sounder and appeared as thin sharp vertical lines with constant intensity on the echograms. Same logic applies for the CTD device used in the context of this survey (Conductivity, temperature, depth). During sampling, it gave rise to 'V' shaped traces in the echogram. Regions with net sounder traces were identified as 'net sounder' region; likewise, regions with CTD were identified as 'CTD' region in the software.

Heavy weather: heavy weather conditions decreases the reliability of the data because there occurs entrained bubbles underneath the hull, especially when vessel is pitching (Gucu AC. and Sakinan S., 2013). In addition, under heavy weather conditions, these air bubbles near surface can increase the probability of the cavitation formation beneath transducers (John Simmonds and David MacLennan, 2005). Considering these problems, weather condition was recorded during the survey and if bubbles reaches below 10 meters in the acoustic data, they were considered as 'bad data' which decreases the confidence of dolphin detections.

Dolphin: data from simultaneous cetacean observation were used to define 100 percent confident *dolphin regions* if any of the previously-presented features were not decreasing its confidence. This regions were specified by time of the observation. Therefore, specific time of the observation was searched in the data before labeling as *dolphin region. Dolphin regions* are independent of depth; i.e. all the vertical profile of the water column was assigned as *dolphin region*. That is because the depth in echo-sounders, in principle, is assigned by the transceiver according to the time lag between sent ping and retrieved echo (see section 1.2.3.2 Hydro-acoustics). In the case of dolphin vocalizations, however, a direct sound interrupts with this pathway.

In this perspective, dolphin vocalizations are "continuous noise" (not a true echo reflected by a target) in the system, which can intrude this process at any time with a duration that can last more than a ping rate. This results in dolphin vocalization traces on echogram (Hereafter: *dolphin marks*) to be independent of the actual depth of dolphin.

2.3.3.2.Hydro-acoustic analysis: SV analysis- dB differencing

The objective of this stage was to extract dolphin (*Delphinus delphis ponticus*) clicks. The common peculiar structure of the *dolphin regions* were extracted by means of detailed analysis of the overall shape and amplitude of *dolphin marks* (i.e. *D. delphis* clicks recorded on the echogram) in *dolphin regions* (
Figure 13); these are:

- *Dolphin marks* were observed to appear as a few to many intermittent vertical lines extending across entire ping with increasing intensity with depth. This is hypothesized to being result of two phenomenon:

    - *ICI of Short- beaked common dolphins:* ICI (Inter-click interval) of common dolphin (see the part 3.2.2 Train Details) is shorter than the average ping interval used throughout the survey (ping rate: 0.5s). Therefore, most part of a click train was attributed to same ping by the system. This results in dashed vertical lines extending across entire ping, rather than a solid background noise.

    - *TVG function:* TVG (time varied gain) is a function that is used to compensate the geometric spreading loss that occurs as sound wave travels in the water. By TVG function, same fish density produces the same signal at any range in traditional applications of fisheries hydro-acoustics (see section 1.2.3.2 Hydro-acoustics; Simmonds &

Maclennan, 2005). Likewise, there is an energy loss as the sound travels back to the source (i.e. reflected) from a density barrier (like sea bottom or fish). Which means, energy lost is in two-way. Furthermore, the energy loss increases with the depth due to the increased travel path (in both ways) of the sound wave. What TVG does is to compensate sound signal for losses due to spreading and absorption; and doing so, it provides a sonar output that is independent of the target range. How TVG decides the “range” of the target is the “time” passing after the transmitted pulse (Simmonds & Maclennan, 2005). When a continuous sound is received instead of a short echo pulse, like in the case of dolphin click trains, it is gradually amplified as the sound continues. In other words, there occurs stronger amplification through the end of the dolphin train.

- From the echo-sounders working at frequencies of 38 – 120 and 200, highest response to the *dolphin marks* are expected at 38 kHz echo-sounder. This is because of the fact that, short- beaked common dolphin clicks have a peak frequency in between 23 – 67 kHz frequencies (W. W. L. Au, 1993). Therefore, *Dolphin marks* were most prominent in the 38 kHz transducer data.

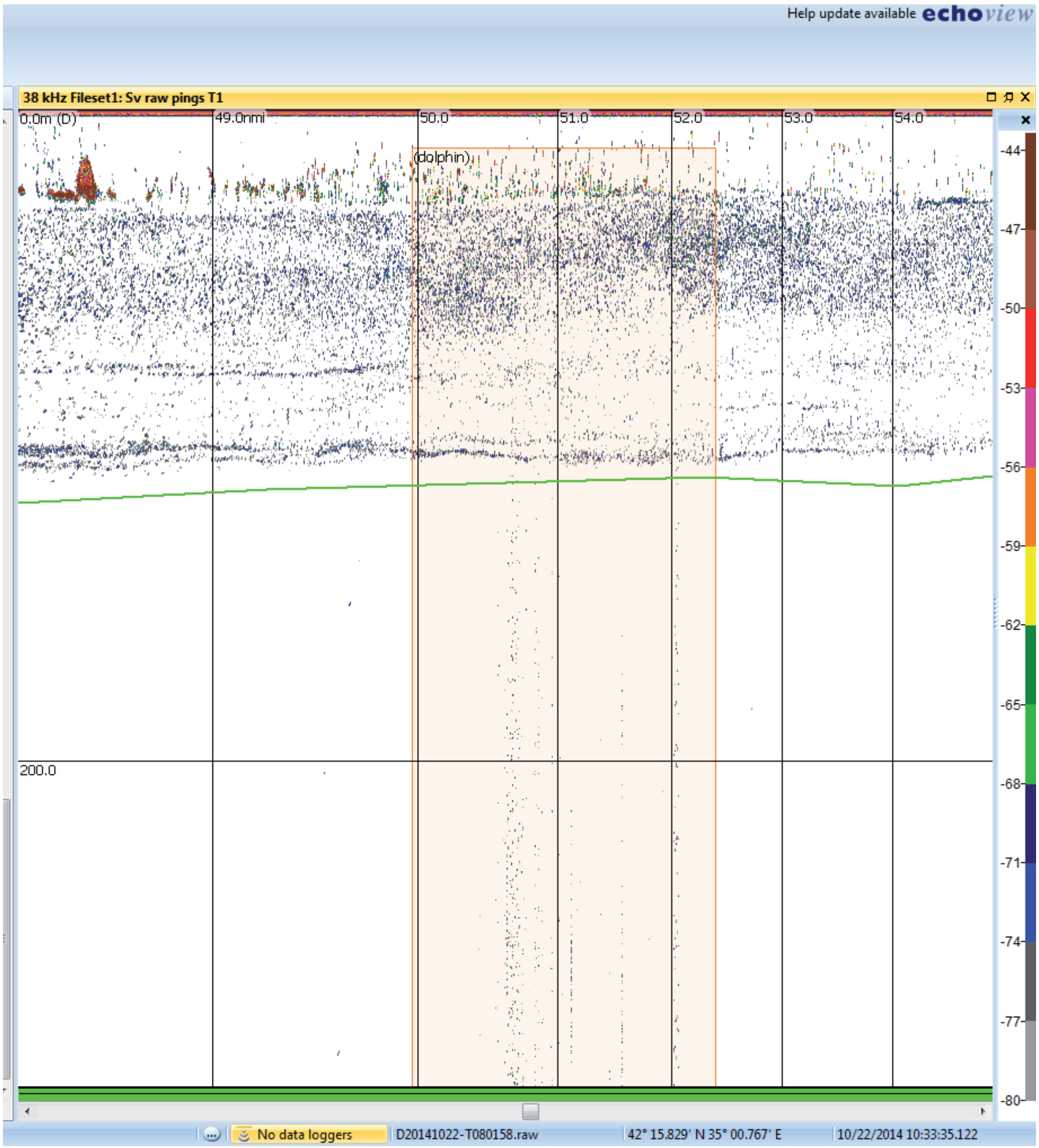


Figure 13: A screenshot from hydro-acoustic analysis of the October cruise. “dolphin” region is added according to time-coordinate data of cetacean observation (Observation no:32, species: D.d. (*Delphinus delphis*), min-max number of dolphin within the group: 15-20, behavior: BR (bow-riding), bearing:320^{o}, vessel route: 350^{o}, distance(meters): 0, date:22.10.14, time:13:25 (10:25 GMT), coordinates: 42 17 908N 35 00 764E, duration: 25min, observer: GS (Gulce Saydam), sea condition: 0 (Beaufort Scale)).

It should be noted that;

- The observed *Dolphin marks* on the echograms are *Delphinus delphis* vocalizations which are mostly composed of clicks rather than whistles. That is due the higher suitability of the frequency range of the system and ICI of the *D. delphis* clicks.

- *Dolphin marks* can either be a click directed to the transceiver or a refracted echo of the original click; yet they are highly visible since the amplitude (SPL: sound pressure level) of refracted echo of *Delphinus delphis ponticus* vocalization is higher than the ambient sound (and by the TVG effect) (see section 1.2.2 Communication and Echolocation in).

- *Dolphin marks* can only show the presence of the short- beaked common dolphin (*Delphinus delphis)*; they cannot show the depth of the dolphin as discussed in part 2.3.3.1Scrutinize Stage & Data Quality Check.

- A *dolphin region* should have at least one *dolphin mark;* it can have a few or many dolphin marks.

In October cruise, the frequency response specialty of *Delphinus delphis* click was used for the built up of the structure of variables (Figure 14). Firstly, 38 kHz frequency SV raw ping and 120 kHz frequency SV raw ping was viewed with -80 dB threshold. Secondly, several operators were added to the echogram in order to concretize the dolphin vocalizations. Operator is an algorithm which acts upon an operand to produce a virtual variable (http://support.echoview.com).

Figure 14: Structure of variables added in the dataflow view of October 2014 cruise.

Added operators were Xxy statistics, Resample, Minus, Formula, Match geometry, Mask, Processed data, Data Range Bitmap. Overall function of these variables is exaggerating dolphin sounds and eliminating other sounds; in other words; illustrating the common peculiar structure of the *dolphin marks* with functions in order to "select" only the dolphin vocalizations within the wide-variety of sounds collected *via* the echo-sounder system. Their specific function are as follows (Higginbottom et al., 2008):

1. Xxy statistic was used to filter echogram in order to convolute data. By this way, variability was reduced and spiky regions were smoothed. Sv raw ping T1 (38kHz) and T2 (120kHz) were filtered with Xxy statistics;
   Xxy 38 and *Xxy 120* variables.

2. Resample-by number of pings- operator is used to bin the samples into larger cells (9.6 cm to 1m.) by a weighted averaging. This operator resamples the input variable using a fixed number of pings in the time/distance domain, and a specified upper range, lower range and number of data points in the range domain (http://support.echoview.com). During resample analysis, weighed mean of all data points was taken (range:300m, number of ping interval:1, number of data points: 300);
   Resample 38 and *Resample 120* variables.

3. Resampled 120 kHz variable was subtracted from 38 kHz, in order to calculate the dB difference.
   Minus 1 variable.

4. Formula operator was added: *Formula 1.* Formula used in the Formula 1 variable was:

   f(p,s) = V1>4

   This formula was configured in order to select the echoes that have stronger frequency response at 38 kHz by using an arbitrary threshold of 4dB.

5. The examination of 100% confident dolphin regions at the 4.step showed that *dolphin marks* (dolphin signatures on echogram) appear as *intermittent vertical lines* extending across entire ping with *increasing intensity with depth* on the echogram. In order to extract these, Formula operator was added: *Formula 2.* Formula used in the Formula 2 variable was:

$$f(p,s) = \left(\text{value}_1(p-1,s)=\text{False}\right) \text{ and } \left(\text{value}_1(p+1,s)=\text{False}\right) \text{ and } \left(\text{value}_1(p,s)=\text{True}\right) \text{ and } \left(\text{value}_1(p,s+1)=\text{True}\right) \text{ and } \left(\text{value}_1(p,s-1)=\text{True}\right)$$

The deemed dolphin signal pattern was as follows, a) there should be at least one ping gap between the signals, and b) the signal should be uninterrupted vertically.

Formula 2.

6. The results of the 5th step are considered as ground truth; i.e. pure dolphin click regions. In order to single out these regions on the original raw SV echogram;

    a. Match geometry operator creates a virtual variable that takes data from Operand 1 and the Start range, Stop range, and Number of data points from Operand 2 (http://support.echoview.com). *Sv raw pings T1* was entered as operand 1 and *Formula 2* was entered as operand 2. By this way *Sv raw pings T1* was resampled to match exact geometry of *Formula 2* variable;

Match geometry 1.

    b. Mask operator was used to apply a bitmap mask on *Match geometry 1* variable according to “true” and “false” values of *Formula 2* variable (Operand 1: *Match Geometry*, Operand 2: *Formula 2).* As a result, *bad data regions* and the areas that do not fit to the previous formulas & operands (like minus) are represented as “no data”- represented with black mask on echogram;

Mask1.

7. Processed Data operator was used to convert data points above the surface exclusion line (100 m) line and below the bottom line to “no data”;

Processed Data 1.

8. Data Range Bitmap operator was used to select data points within -120dB-0dB range on *Processed Data Variable.* Each input value that is within this specified range are converted to be true value and remaining to be false value. By doing that we further select the data points with high amplitude;

Data Range Bitmap.

9. Mask operator was used to apply a bitmap mask on *Processed data 1* variable according to the true and false values defined by *Data range Bitmap.* False data points were converted to "no data" and represented with black mask on echogram;

Mask 2.

10. Resample-by number of pings was used again to resample *Mask 2* variable using 10 pings interval. Data was represented with weighed mean of data points with 10 pings interval;

Resample-by number of pings 2.

In July cruise; the mounting design of transducers were causing a time-lag between the receiving echoes. Therefore 120 kHz data couldn't be used to analyze data according to the frequency response characteristics of the *dolphin marks.* Yet the intensity characteristics of *Delphinus delphis* clicks (intermittent vertical lines) was used for the built up of the structure of variables (Figure 15)

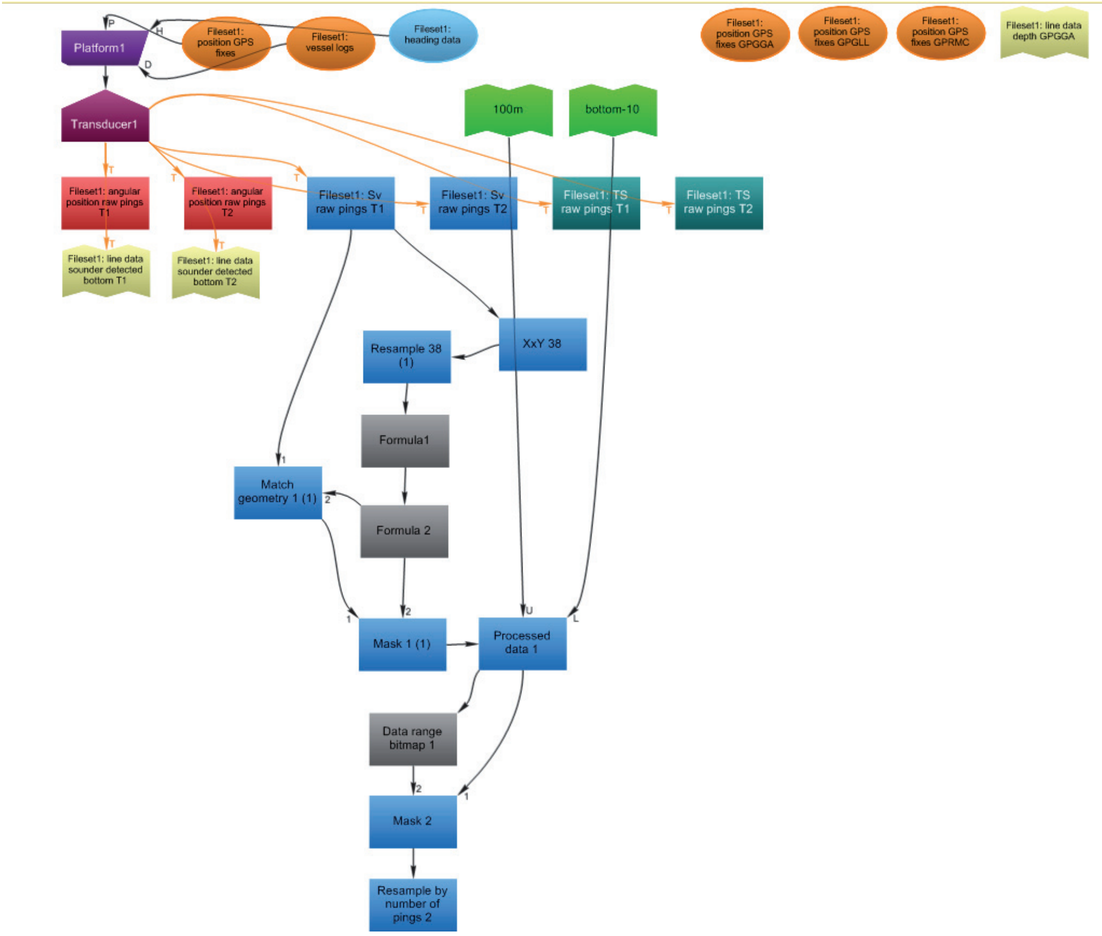


Figure 15: Structure of variables added in the dataflow view of July 2014 cruise.

Therefore, only 38 kHz data was used with a -65dB threshold. Apart from the minus operator, same steps were followed.

2.3.3.3.Export and Mapping

In order to export data, echogram was gridded ping by ping (number of ping: 1, from depth to zero: 50m). Then exported files were opened on excel worksheet and saved in the .csv format. In the final stage, data was imported to ArcGIS software and mapped. During this stage, “Join and Relates” command was used to relate the echo-gram data with the cruise-tract having 1 miles resolution. This step, transforms cruise-track coordinates to *echo-points* having the information of the number of *dolphin marks* (short- beaked common dolphin clicks) attributed to itself; namely *mark count*. This way all coordinates covered during the cruise have information about their echo-status and data were illustrated on a continuous path (i.e. cruise-track).

2.3.4. Verification of Hydro-acoustics as a Tool for Cetacean Observation

During the echo-sounder analysis, visual observation was used to construct a methodology to find out the time & coordinates that short- beaked common dolphin is present in addition to these 100% confident points (visually observed cetaceans). Therefore, this methodology aims to reveal visually unobserved dolphins (due to observer bias) or could not observed dolphins (during night-time cruise-tracks). In order to verify the results i.e. to answer the question *"Does the echo-sounder analysis from hydro-acoustics data work efficiently for the detection of short- beaked common dolphins?"* following hypothesis was raised:

If we can gather the clicks of Short- beaked common dolphins with echo-sounder efficiently enough to analyze for the selection of only short- beaked common dolphin clicks, the number of dolphin marks should increase as we approach to the point of visual observation (the point of 100% confidence of presence) at any spatial point within the coverage of this study.

Several assumptions were taken before testing the hypothesis:

- If there is a short- beaked common dolphin whose sound was recorded; it is as well observed visually; i.e. observation is perfect. Perfect observation also includes the assumption of
    - Vessel navigated continuously; and continuously faster than any Short- beaked common dolphin.

- If there is a visually observed Short- beaked common dolphin; it was vocal and audible by the receiver of the echo-sounder; i.e. echo-sounder works perfectly.

- Although they are highly motile (William F Perrin et al., 2015); there are some regions with higher Short- beaked common dolphin abundance while some others with lower. This might depend on any ecological, biological or artificial factors. Although this is not what is questioned here, this is the next scientific question that should be asked.

Since echo-sounder analysis was aimed to be verified using visual observation, the data limiting one of these methods were excluded from the analysis. These are:

- Visual observation points collected in waters with a depth less than100m, since echo-sounder analysis is limited to higher depths.

- Echo-sounder data that is collected at night, since visual observation is limited to day-light hours.

To test our hypothesis ArcGIS software and Excel was used. In the ArcGIS software; "Join and Relates" command was used (see the part 2.3.3.3 Export and Mapping). By doing this, not only the data were represented in relation with the continuous path where it was collected, but also the coordinates with no *mark count* could be considered. In other words, coordinates with zero vocalizations (mark count=0) were included to the analysis. So, echo-sounder data does not overestimated.

Following that, "Near Analysis" was applied to find out the distance of each *echo-point* to the spatially nearest *visual observation-point* (Figure 16).

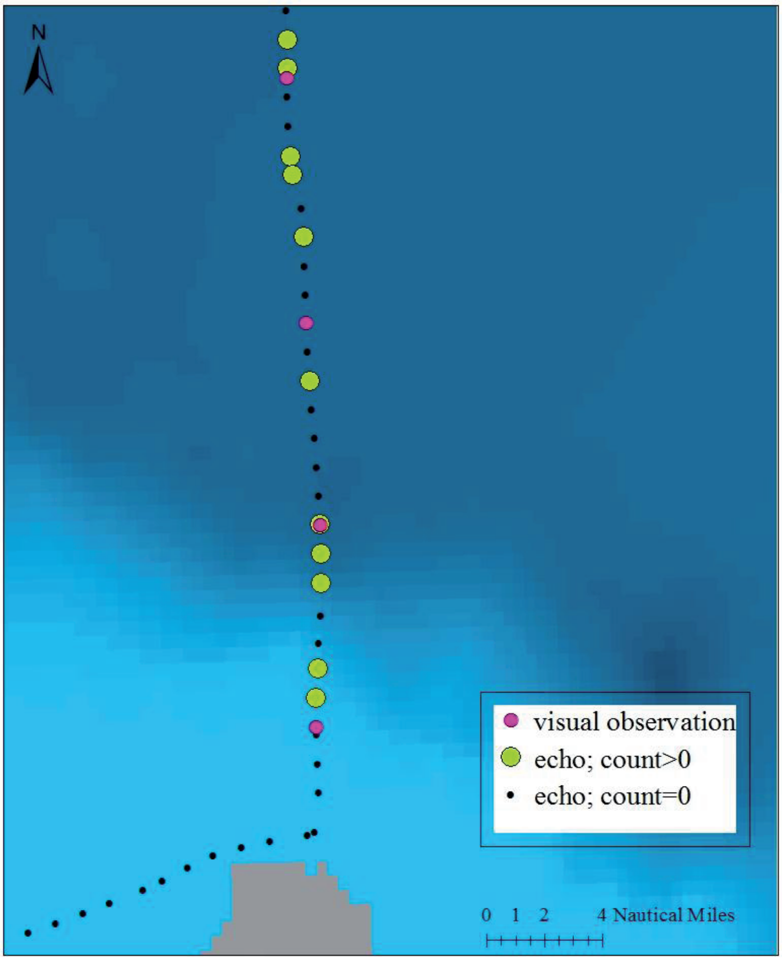


Figure 16: A map of October 2014 Cruise showing *echo-points* with zero *mark count* and with a *mark count* over zero- in relation with visual observation.

Data table was exported and then imported to an Excel sheet. With the help of a Pivot table, the distance (between each *echo-point* to the *nearest visual observation-point*) was divided to 2000m intervals and the average of the *mark count* (number of dolphin marks attributed to a coordinate) values of all *echo-points* (detection coordinates with 1 mile resolution) inside this interval was taken. Finally; the results were illustrated with a graph.

2.3.5. Assessing Consistency between Methods

In order to assess consistency between methods, a comparison matrix was developed. To develop this matrix, methods were coupled and compared according to their spatial extends (ranges) using ArcGIS software. If one assumes that presence of the cetaceans in a given geographical unit would eventually be detected at least by one of the three methods used, and , if detection positive condition of a method is represented as "1" and detection negative condition is represented as "0", then there may logically be eight possible combinations; presence of dolphins may be detected by all methods used (C-POD; Observation; Hydro-acoustics) at a given geographical unit (1:1:1); or one method may detect presence of the dolphins while the others fail (1:0:0 or 0:1:0 or 0:0:1); or one of the methods may fail to detect presence of the animals, while the others don't (1:1:0; 1:0:1; 0:1:1); or finally there may be no dolphins within the range, so that all methods may be detection negative (0:0:0). As the area covered by each method is not the same (i.e. observations are confined to day time and there are no C-POD data on the eastern most part of the Black Sea due to instrument failure) and for the sake of simplicity, the methods were compared mutually. From mutual comparisons, "1:1" and "0:0" represents compatibility while remaining two symbolize incompatibility ("1:0" and "0:1") of the relevant method couple.

Detection positive and negative conditions were searched over the spatial extend of the cruise track. For the comparison of observation and C-POD detections, only the *delphinid* observations at the daylight C-pod stations (n: 55) were used. For the comparison of hydro-acoustics and C-Pod results; hydro-acoustic records within the 1000 meters periphery of the all C-POD stations (both day and night stations; n: 93) were considered (*Figure 17*).

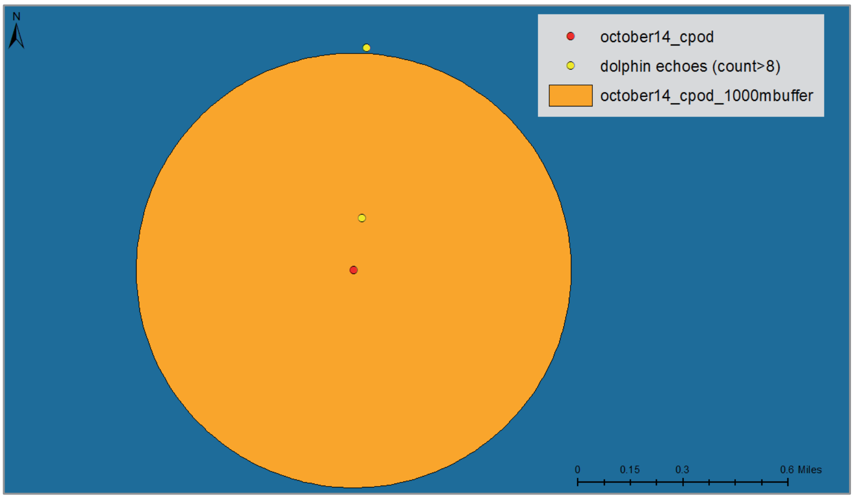


Figure 17: A Screenshot from ArcGIS software showing one C-POD (red color) station and 1000m buffer zone which represents the detection range of the device. Two *dolphin marks* (yellow color) were observable both within and outside of the range.

The assessment of the comparison between Hydro-acoustics and Observation method couple were not as straightforward as previously discussed station-based method couples. In this case, the data was collected continuously and detectability range of hydro-acoustics was not certain.

To compare these two methodologies, "inspection cells" were assigned over the cruise track; that is the track that was transformed to Thiessen polygons whose centers being 300 m away from each other. Thiessen polygons are type of polygons that are generated from sample points using their proximity criteria (Brassel, K., and D. Reif., 1979). In other words, boundaries of Thiessen polygons define the area that is closest to each point relative to all other points (GIS dictionary; http://support.esri.com/). To accomplish this, firstly cruise-track of October 2014 cruise was edited to have points with 300m equal intervals and then thiessen polygons were created from these sample points. Secondly, observational data and fisheries acoustical data spatially related to this layer having thiessen polygons.

Then all four possible combinations were searched on the exported data tables focusing on the "*mark count*" column. Mark count column is the column which is produced after "join and relates" command in ArcGIS software and it is the number of points (spatially related points: observation points or echo-points) within each thiessen polygons (*Figure 18*).

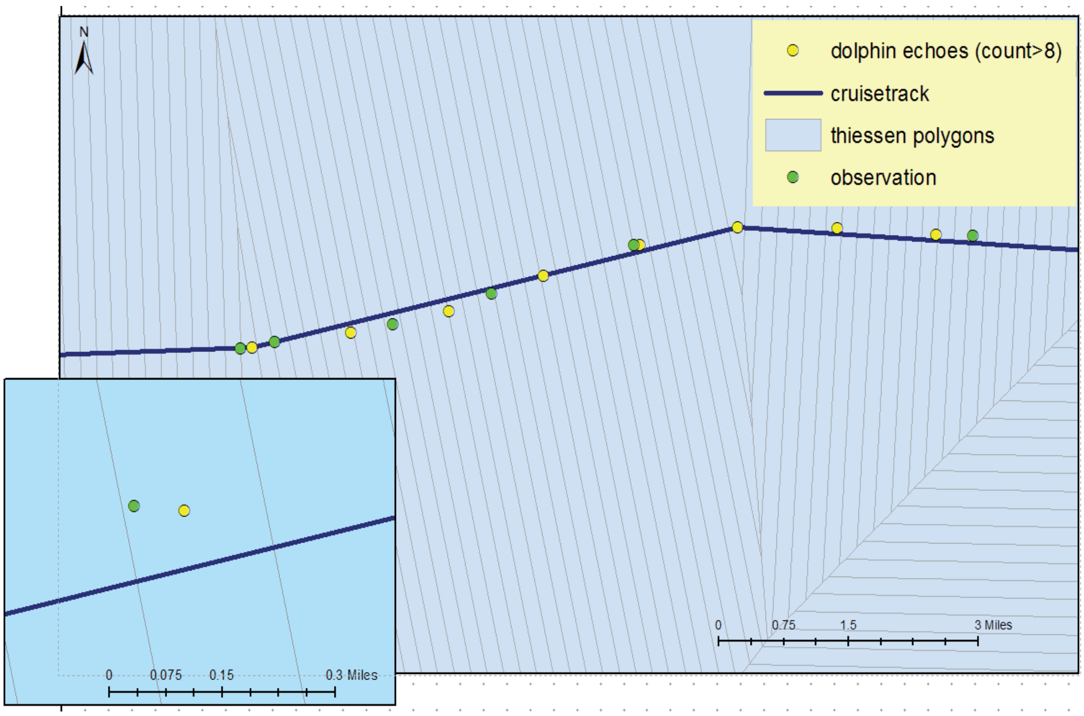


Figure 18: A screenshot from ArcGIS software showing Thiessen polygons, dolphin marks, cruise-track and observation coordinates of October 2014 cruise for the short- beaked common dolphin species. Results of two methods (Hydro-acoustics and Observation) were compared in the context of compatibility and four possible combination ("1:1", "0:0", "1:0" and "0:1") were searched within each Thiessen polygons with 300 m intervals.

2.3.6. Abundance Estimation- Preliminary Approaches for the Estimation of Cetacean Abundance in Exclusive Economic Zone of Turkey

The two of the three methodologies given so far, namely hydro-acoustics and C-POD, essentially target detection of cetacean groups, not individuals and therefore provides only presence-absence data over the entire range of the survey. With direct observation, it is possible to quantify the size of the observed cetacean groups, however this activity is only limited to a certain part of the day, and the detectability of the cetaceans largely depends on the visibility and sea state. At this stage, the presence-absence data obtained via hydro-acoustics were combined with the quantitative observation data in an attempt to provide a series of very crude population size estimates. Three different approaches were proposed and they were tested over the data obtained during October 2014 cruise. The very core of these approaches is to multiply the average cetacean density (number of cetaceans observed per area surveyed) with the respective area surveyed, which, in this case, is the surface area of the Turkish Exclusive Economic Zone (172199 km^2).

$$N = \frac{\# \, obs}{area \ surveyed} EEZ$$

Finally, confidence intervals for abundance estimations were calculated using the standard deviation of group size (i.e. number of individuals comprising the observed cetacean group).

2.3.6.1. Abundance Estimation from Observational Data

In this approach total number of individuals is simply the number of cetacean visually detected during the survey. Here the critical assumptions are;

- Observation efficiency is not affected by the observation range.

- There is no possibility to see one animal more than once (resample: 0)
    - Sampling is continuous and fast enough to ensure animal cannot pass the vessel or it cannot migrate fast enough to catch it at another part of the cruise-track.

- There is no heterogeneity in the habitat/or if there is, cruise-tracks do represent this heterogeneity, so that sampling-area-abundance can be extrapolated to EEZ of Turkey.

As mentioned above, the detectability of the cetaceans largely depends on sea state and varies from day to day depending on the weather conditions. Given that the sea state do not change much within a day, it was assumed that the maximum distance to a detection recorded in a day reflects the detectability range of the very same day. The detection range of hydro-acoustics, $\boldsymbol{D_{ha}}$ takes the effect of daily sea state into account. Sea state was classified using Beaufort scale. There were three sea state commonly encountered: 0-1, 1-2, 2-3. D_{ha} of each species were different; therefore, they were calculated separately. In the days with no cetacean detection record, the average of the days with similar sea state was adopted. The total area surveyed is, therefore, calculated using the following equation:

$$observational\ sampling\ area = \sum_{i=1}^{\#\ days} 2L_iD_i$$

Where L_i is length of the cruise track sailed in day "i"; D_i is the maximum distance to a detection in day "i". Since observation was performed during day-time, only day-time cruise-tracks were considered during this estimation.

2.3.6.2. Abundance Estimation from Hydro-acoustics Data

In this approach it is assumed that the size of the groups are normally distributed around a mean irrespective of their behavior, and the number of groups observed throughout the survey was sufficient to reflect the population mean. The mean group size were then estimated using direct observation data, where the size of the observed groups are recorded. The mean group size, gs, were then multiplied by the number of hydro-acoustic detections, ha (*echo-points* with 8 mark counts and over):

$$\# \, obs = \overline{gs} \, . ha$$

To estimate the range, only the visually detected ***ha*** were used. Then, maximum distance to a group which had recorded (outliers removed) under a specific weather conditions was set as the detection range of that day. Sea state was classified using Beaufort scale. There were three sea state conditions commonly encountered: 0-1, 1-2, 2-3. D_{ha} of each species were different; therefore, only D_{ha} of short-beaked common dolphins was used in calculations. The total area surveyed were then estimated simply multiplying $\boldsymbol{D_{ha}}$ with the total length of the hydro-acoustics transects, $\boldsymbol{L_{ha}}$

$$hydro - acoustical\ sampling\ area = 2L_{ha} \, . \, D_{ha}$$

Note that, with hydro-acoustics only short- beaked common dolphins were detected; therefore abundance estimation was performed only for this species.

2.3.6.3. Abundance Estimation from C-POD Data

In order to estimate abundance using C-POD data, total sampling area covered via this methodology calculated.

$$area\ surveyed_i = \pi\ D_i^2 . n\_stat$$

Where $\boldsymbol{D_i}$ is max range of C-POD (1000 m for delphinids and 500 m for porpoises; http://www.chelonia.co.uk/products.htm); "***i***" stands for the cetacean family, in question; and ***n-stat*** is the number of C-POD stations (93).

Number of cetaceans observed were estimated using the same approach applied for hydro-acoustics, assuming group sizes are normally distributed around a mean. It was further assumed that they can only be one group within the detection range of C-POD and the following equation was used:

$$\#\ obs = \overline{gs_i} . cpod$$

Where $\boldsymbol{gs_i}$ is the mean group size of species "***i***" and ***cpod*** is the number of C-Pod positive stations.

Given that this methodology differentiates only at family level but not at species level, results are available for two Delphinids combined, namely short- beaked common dolphin and bottlenose dolphin, and for *Phocoenidae*, namely harbor porpoise. The total number of delphinids were partitioned to the species simply by reflecting the percentages obtained from observations.

2.3.7. Temporal Variation of Cetaceans between 1996 and 2014

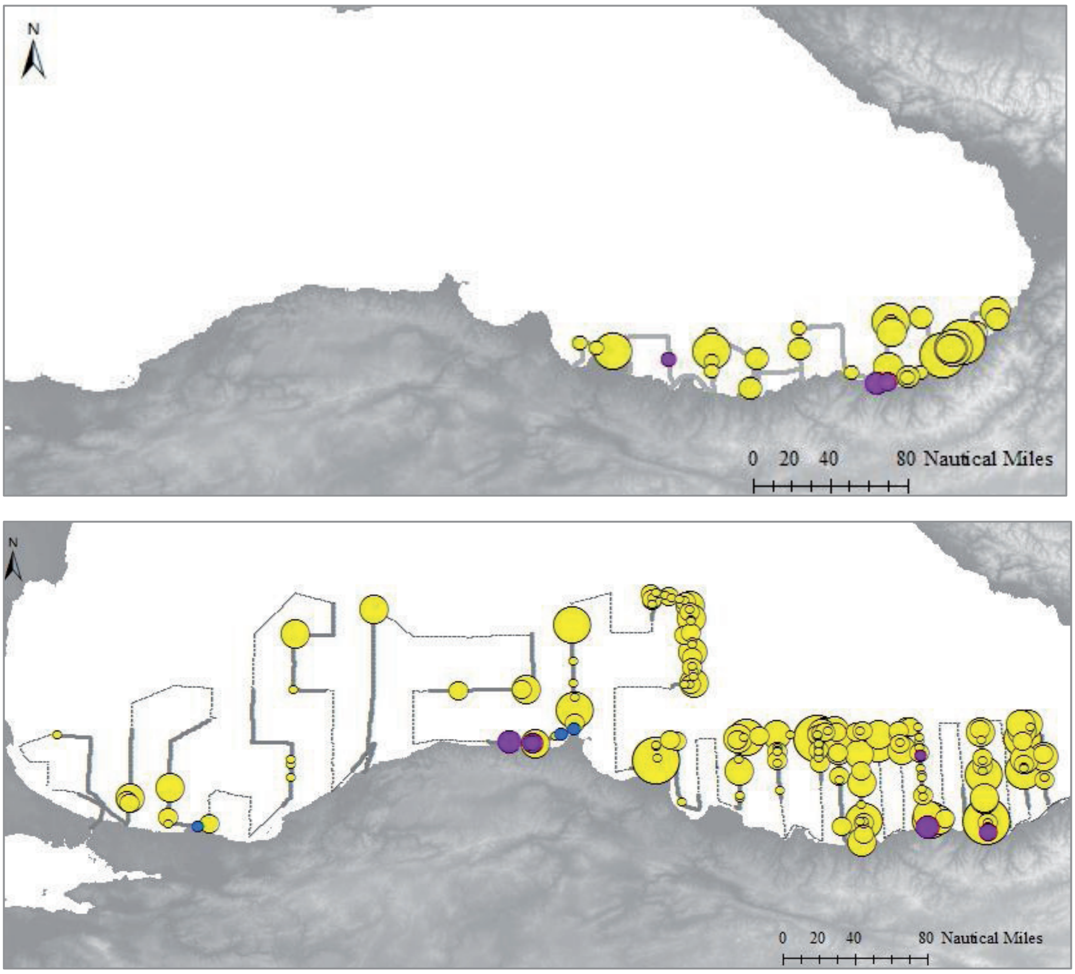
In order to comment on temporal variation of cetaceans, observation data of two cruises, namely July 2014 and October 2014 cruises, were inspected in terms of group size and spatial distribution. Besides, observational data (chance encounter events) collected by METU-IMS researchers during 13 different Black Sea cruises were investigated to attain wider perspective on spatiotemporal variation of cetacean populations (codes of the additional 13 cruises: 1996-2, 1996-4, 1996-5, 1997-2, 1998-1, 1999-3, 2000-1, 2000-3, 2001-1, 2001-2, 2007-7, 2008-u (Unluata) and 2015-1). Daily effort of these cruises were assumed to be same.

3. RESULTS

3.1. Observational Data Analysis

3.1.1. Spatial Variation

Cetacean observation data was mapped with respect to the average group size and the species constituting the group (Figure *19*).



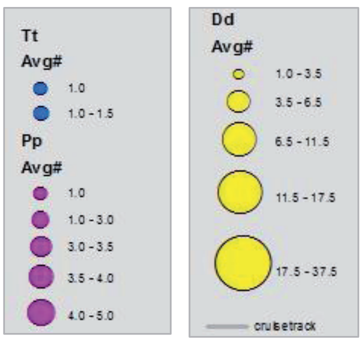


Figure 19: Spatial distribution and average group size (Avg#) of cetacean species Tt: *Tursiops truncatus*, Pp: *Phocoena phocoena*, Dd: *Delphinus delphis* over

the day-time cruise track of July 2014 (up) and October 2014(down) cruises.

During the observational data collection, cetacean group size was assessed as minimum and maximum number of individuals comprising the group. As might be guessed, not every individual was visible during at the time of observation, some were diving underwater or left the group before the count. In order to compensate the uncertainty in the group size, cetacean groups were counted more than once and minimum-maximum number of individuals were noted. Therefore, in the *Figure 19: Spatial distribution and average group size (Avg#) of cetacean species Tt:* Tursiops truncatus*, Pp:* Phocoena phocoena*, Dd:* Delphinus delphis *over the day-time cruise track of July 2014 (up) and October 2014(down) cruises.* average of these were given. If the average group size is 3.5, it does not mean that there were 3.5 individuals; it is impossible. It means, there were a group with minimum 3 and maximum 4 individuals during the time of observation.

During July 2014 cruise all transects were covered daytime (Figure 19, up), however, during October 2014, the cruise transects were covered both day and night. Day-time cruise-tracts were drawn with more emphasis to show over which path the cetacean observation was performed (Figure 19, lower). Different species were illustrated with different colors and the average group size of the groups was represented with the size of the circle as the legend bar of Figure 19 indicates.

On the basis of these maps, distribution of harbor porpoise (Pp) seems to be limited to coastal waters both in July and October, 2014. The only offshore observation made on this species was during October 2014, in Eastern Black Sea, and it was a DEAD harbor porpoise (Id: 152; 41.7356N; 39.24646667E). Another DEAD harbor porpoise observation was encountered during July 2014, which was the only one that was relatively offshore (Id: 32; 41.29267N; 37.50075E). Also, the number of alive harbor porpoise observation was scarce for both surveys (2groups in July, 5 groups in October, 2014).

Bottlenose dolphins (Tt) were observed only during the October cruise with only 3 observation events. All these tree observations had occurred along coastal waters of Southern Black Sea one in the West (coastal waters of Kefken/ Kocaeli City); 41.2144N 30.3646E) and two observations in the middle (coastal waters of the Sinop City; 41.0787N 34.8270E; 42.1192N 34.9851E).

Short- beaked common dolphins (Dd) were the one that is most often observed. On the basis of the distribution maps, it can be inferred that there is an obvious East-West difference in distribution. In July cruise, short- beaked common dolphins were more frequently encountered in Eastern part of South-Eastern Black Sea. Wider geographic area covered during October cruise provided a larger picture about the distribution of short- beaked common dolphin. According to that, short- beaked common dolphins were more frequently encountered in Eastern Black Sea with relatively larger group sizes inhabiting coastal Eastern Black sea waters. Although there are many day-time transects in the Western basin, short- beaked common dolphins were rarely observed with the exception of occasional groups around coastal waters between Şile /İstanbul and Kefken/Kocaeli.

Avg. number of individuals observed within a group are presented in Figure 20. Results of July 2014 and October 2014 cruises (cruise codes are: 2014-1; 2014-2 respectively) were quite similar. Firstly, short- beaked common dolphins (Dd) were the most gregarious species in both cruises (max group size:20, avg.group size: 6,068 in 2014-1; max group size: 37,5, avg. group size: 5,48 in 2014-2). Secondly, harbour porpoises were observed within the smallest groups (avg. group size: 1.75 individuals in 2014-1; 1.33individuals in 2014-2). Bottlenose dolphins (Tt) were observed only during October 2014 cruise and their group size were observed to be somewhere in between regarding the avg. group size of all three species (avg. group size: 4 individuals in 2014-2).

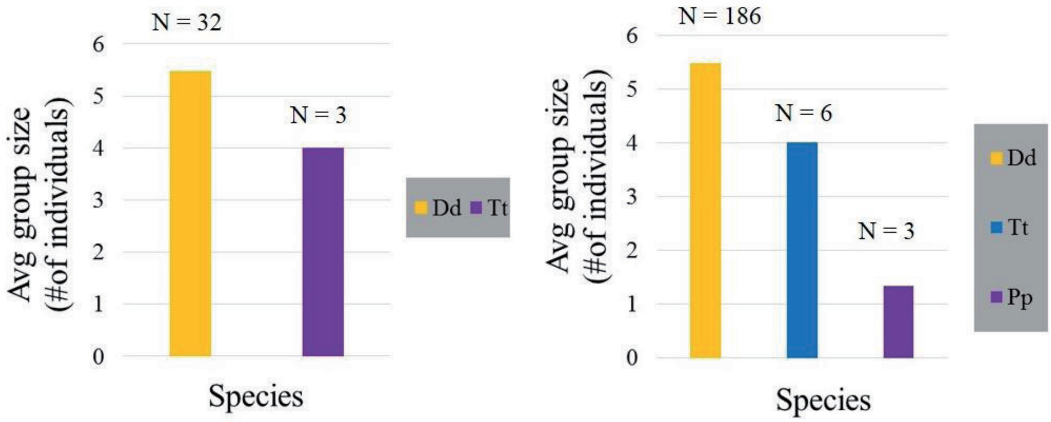


Figure 20: Average group size of cetaceans with respect to species comprising the group for July, 2014 cruise (left), October, and 2014 (right). Color of the bars represents species (yellow: *Delphinus delphis,* blue: *Tursiops truncates,* purple: *Phocoena phocoena*); the sample size of each species (i.e. the number of groups observed) were represented as "N" above the bars.

3.1.2. Behavioral Analysis

Avg. number of individuals observed within a group with respect to species comprising that group was visualized with histograms using Microsoft Excel 2013 (© 2015 Microsoft). Dominant behaviors displayed by each species were inspected and visualized with pie charts (Figure 21). To specify the size of the group for each behavioral state a histogram showing both the number of groups and the average size of that group displaying the behavioral state was drawn. The observation data of the most commonly observed species *Delphinus delphis* was used for this purpose

For short- beaked common dolphin (Dd), the most dominant behavior was observed to be Bow-riding (BR; 91 groups). Bow riding is followed by Travelling fast (TRF: 31 groups), Surface feeding (SFE: 29 groups), Travelling (TR: 24 groups), Travel diving (TRD: 8groups) and Resting (RE: 2groups) behaviors respectively. If all travelling behaviors (TRF, TR, and TRD) were considered as one behavior, then it would be the second most observed behavior. In addition, one short- beaked common dolphin was observed as DEAD.

For harbor porpoise (Pp), the most dominant behavior was observed to be Surface Feeding (SFE: 4 groups); followed by Travelling (TR: 1 group). In addition, one harbor porpoise was observed as DEAD. For bottlenose dolphin (Tt), 2 groups were observed during Surface feeding (SFE) and one group was observed during Travel diving (TRD).

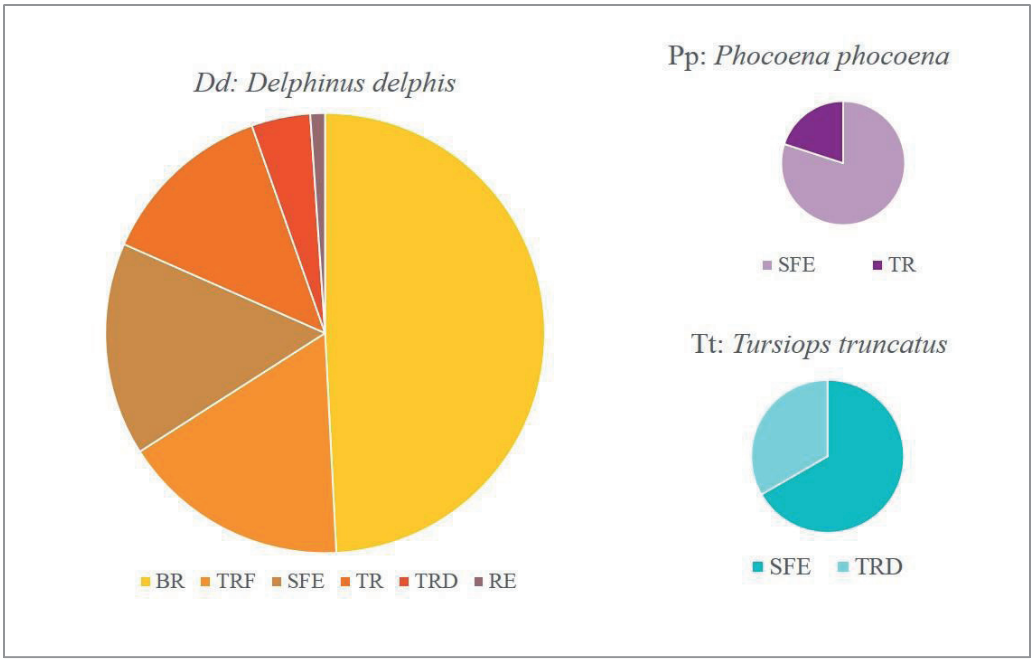


Figure 21: Behaviors performed by each species Dd: *Delphinus delphis*; Pp: *Phocoena phocoena,* Tt: *Tursiops truncatus* during October 2014 cruise (2014-2). The count of cetacean groups enrolling the behaviors were written near the relevant percentage of the chart. Dead observations are included to show relative dead observation between species. For the abbreviation of behaviors Table 5 can be inspected.

In order to understand the size of the group for each behavioral state, the observation data of the most commonly observed species *Delphinus delphis* was used. In Figure 22, it was concluded that the largest groups were formed during the BR behavior while the smallest behaviors were formed during the RE behavior.

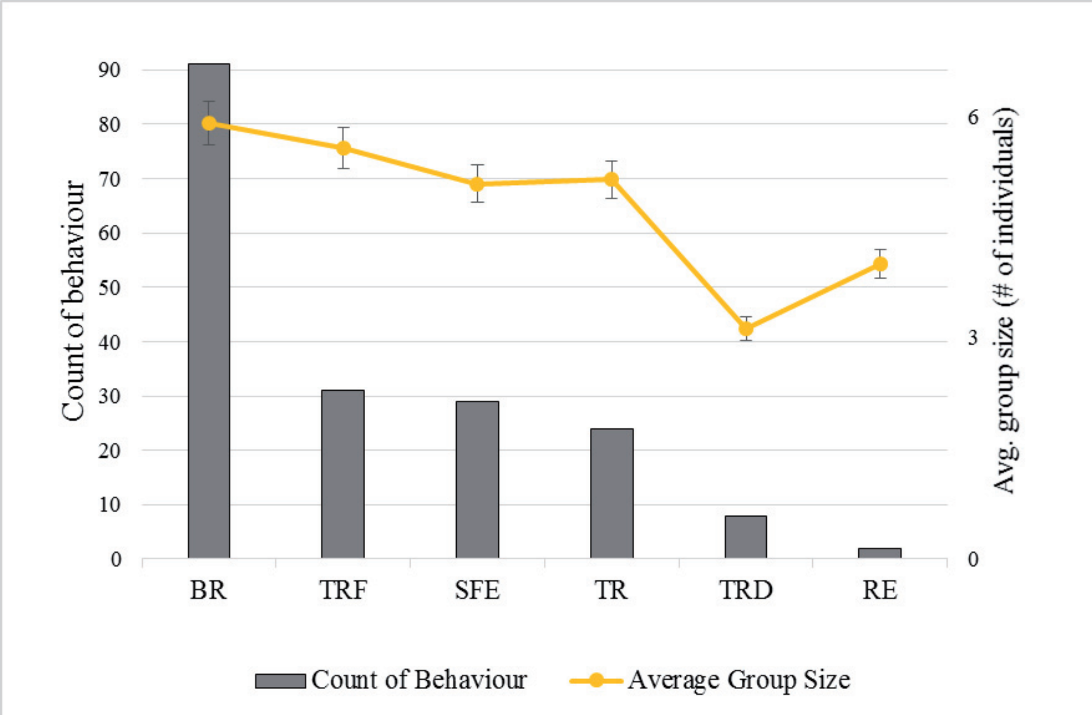


Figure 22: The count of *Delphinus delphis* (Dd) groups showing a specific behavioral state and avg. size of the group (# of individuals) with confidence interval enrolling that behavioral state.

3.2. C-POD Analysis

3.2.1. Detections

As a result of detailed analysis of CP3 files (i.e. processed data file), all species classes were observed; which are namely Dolphin, NBHF (Porpoise) and Sonar. From 14 station performed in July 2014 cruise, 28.57% was Dolphin train detection positive and 14.29% was NBHF train detection positive (High, Mod or Low Q). In addition; in station 6N, click trains of both species were observed. According to the map (Figure 23), dolphin trains were detected in relatively offshore waters of South-Eastern Black Sea than NBHF trains were. Moreover, Sonar trains were detected almost in every station (n: 11; 78.57%).

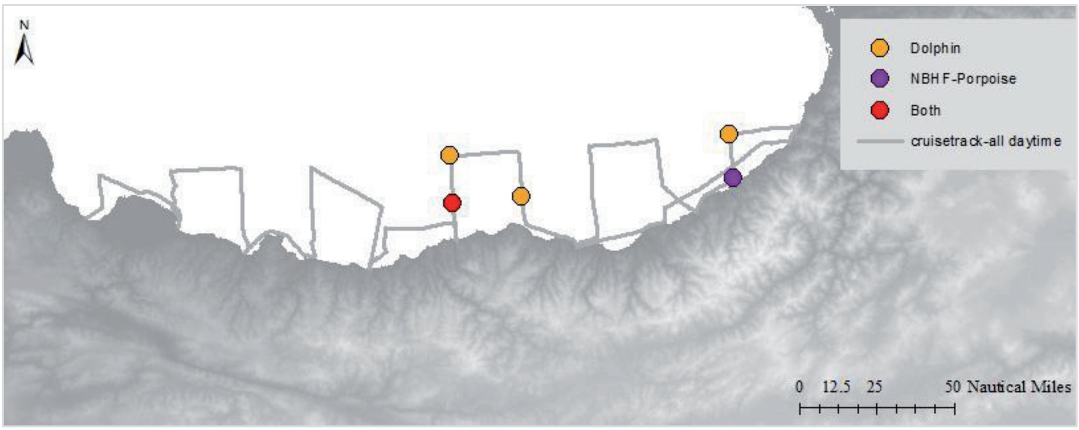


Figure 23: Cetacean detection positive C-POD stations during July 2014 cruise with respect to classified click trains after the analysis.

From 93 stations performed in October 2014 cruise, 11.83% was Dolphin train detection positive and 5.38% was NBHF train detection positive (Hi, Mod or Low Q). Click trains of both species class were observed in 10A station. Throughout the Southern Black Sea (Figure 24), Dolphin trains were detected in relatively offshore waters than NBHF trains were. Sonar trains were observed in 34.41% of stations. In addition to these findings, it is important to stress that almost the half of the stations with detections (n: 7; N: 15) were performed during the night-time.

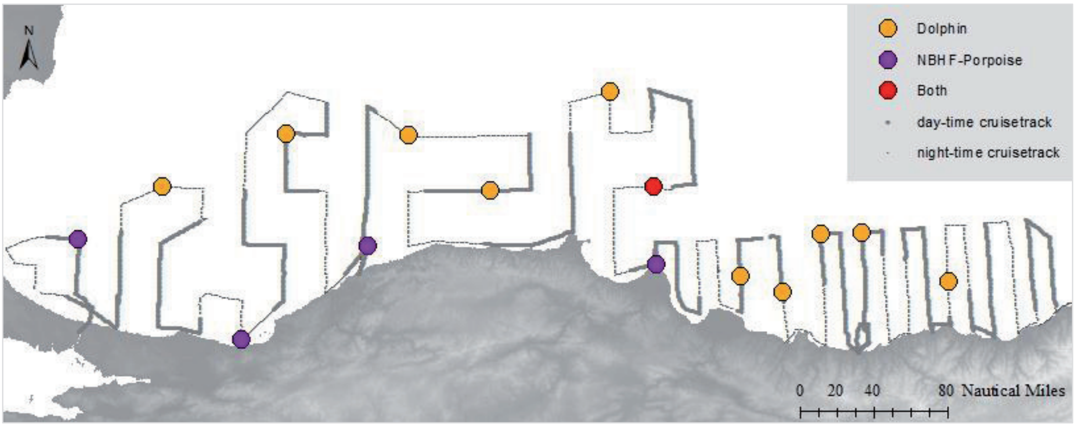


Figure 24: Cetacean detection positive C-POD stations during October 2014 cruise with respect to classified click trains after the analysis.

When spatial distribution of species classes Dolphin and NBHF-Porpoise were inspected in relation with their distance to shoreline, NBHF was detected less than 85 km offshore while Dolphin was detected more than 37km offshore during October 2014. The most coastal observation of NBHF was 6.7km offshore while the most oceanic observation for Dolphin was 156km (Figure 25).

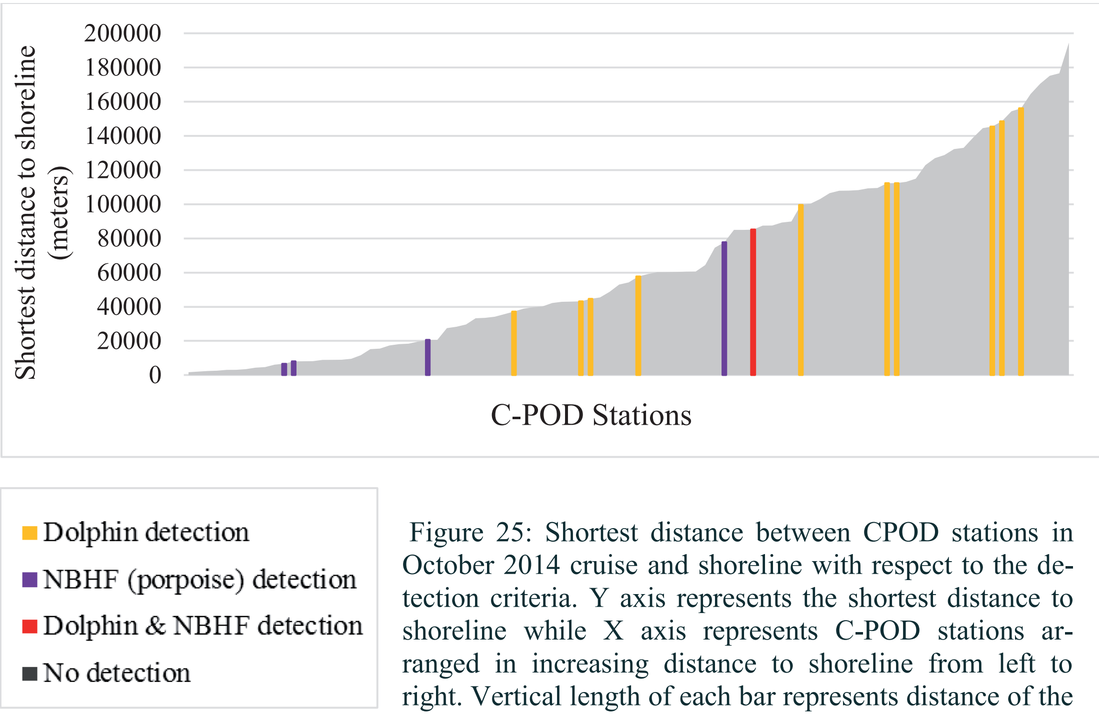


Figure 25: Shortest distance between CPOD stations in October 2014 cruise and shoreline with respect to the detection criteria. Y axis represents the shortest distance to shoreline while X axis represents C-POD stations arranged in increasing distance to shoreline from left to right. Vertical length of each bar represents distance of the station to the nearest shore while color of each bar represents detection criteria.

3.2.2. Train Details

The most distinctive train features of the species class “Dolphin” were:

The duration/ number of cycles was generally less than 15 cycles (Figure 26-c) and observed to be highly variable within a train with generally between 100-200 ms *ICI*. *Amplitude profile* of trains was variable and was between 100-120 SPL in average for a train (Table 6 and Table 7*Table 9*); with a min 10 and max 255 SPL individual clicks (Figure 26-a). Click trains had spread *frequency* pattern with a primary mode between 50- 75 kHz frequencies (Figure 26-b). Multipath clusters in frequency diagram was distinguishable for the Dolphin Species Class.

Table 6: July 2014 *Dolphin (Family: Delphinidae)* click train detection positive C-POD stations (High, Mod and Low Q). Average modal kHz, Average SPL (Sound pressure Level) and Average Clx/s (Clicks per second) value of the trains collected in each station are given. Total number of station is 14 as stated in *Table 3*.

Station Id	*Avg. modal kHz*	*Avg. SPL*	*Avg. Clx/s*
6F	43.00	98.67	1.00
6K	92.00	54.33	5.00
6M	86.40	152.70	11.10
6N	48.00	39.00	7.50
Total	**75.83**	**114.67**	**8.00**

Table 7: October 2014 *Dolphin (Family: Delphinidae)* click train detection positive C-POD stations (High, Mod and Low Q). Average modal kHz, Average SPL (Sound pressure Level) and Average Clx/s (Clicks per second) value of the trains collected in each station are given. Total number of station is 93 as stated in *Table 3*.

Station Id	*Avg. modal kHz*	*Avg. SPL*	*Avg. Clx/s*
10A	34.00	92.00	23.00
10J	62.43	121.74	16.48
10L	38.00	59.00	7.00
10P	45.11	102.44	31.33
11C	128.00	66.00	23.00
11H	43.00	168.00	7.00
7R	38.50	89.25	9.50
8P	52.56	101.56	17.78
9D	37.00	158.00	11.75
9I	38.00	44.00	7.50
9V	48.60	110.00	23.27
Total	**51.69**	**110.56**	**19.75**

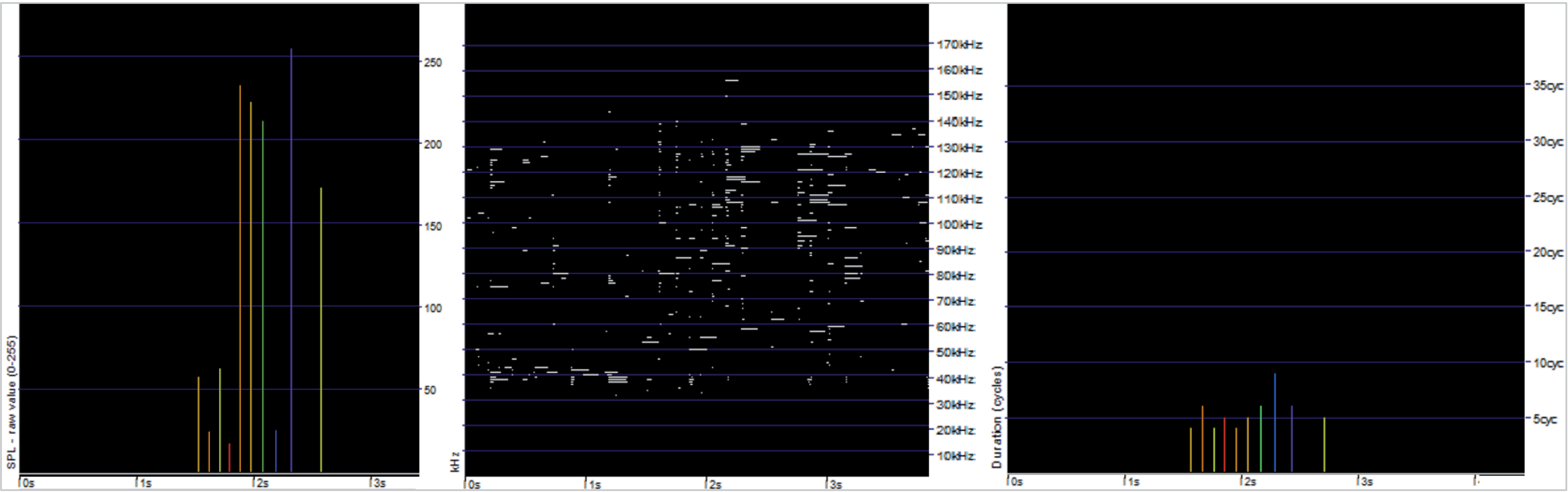


Figure 26: Train details of the Species Class: Dolphin (*Delphinidae*) from the station 8P in 10 ms time resolution. a) Amplitude profile of the train in SPL scale; frequencies of each click is represented by colors (red: 25 kHz, orange: 50 kHz, green: 75 kHz, blue: 100 kHz, navy blue: 125 kHz, purple: 150 kHz) (CP3 file) b) Frequency profile (CP1 file) c) Duration of each click/number of cycles (CP3 file); frequencies of each click is represented by colors as in Figure 23/a.

For the species class NBHF *(Phocoenidae)*, the most distictive click train feature was their higher and much narrower *frequency profile*. The clicks of porpoises was narrow banded and between 125 -140 kHz; with a mode between 120 -130 kHz frequency (Figure 27 /b, Table 8 and Table 9). *The duration/ number of cycles* was higher than Dolphin (Figure 27 /c). *Amplitude profile* was observed to be smother and between 40-90 SPL in average within a train (Table 8 and Table 9); with a min value of 39 SPL and a max value of 250 SPL individual clicks (Figure 27/a).

Table 8: July 2014 *NBHF (Family: Phocoenidae)* click train detection positive C-POD stations (High, Mod and Low Q). Average modal kHz, Average SPL (Sound pressure Level) and Average Clx/s (Clicks per second) value of the trains collected in each station are given. Total number of station is 14 as stated in *Table 3*.

Station Id	*Avg. modal kHz*	*Avg. SPL*	*Avg. Clx/s*
6E	125.00	29.00	15.00
6N	122.00	39.50	5.50
Total	**123.00**	**36.00**	**8.67**

Table 9: October 2014 *NBHF (Family: Phocoenidae)* click train detection positive C-POD stations (High, Mod and Low Q). Average modal kHz, Average SPL (Sound pressure Level) and Average Clx/s (Clicks per second) value of the trains collected in each station are given. Total number of station is 93 as stated in *Table 3*.

Station Id	*Avg. modal kHz*	*Avg. SPL*	*Avg. Clx/s*
10A	129.00	50.00	252.00
10E	124.00	131.00	2.00
7E	128.00	83.00	2.00
8D	125.00	184.00	2.00
8Z	130.75	51.75	69.75
Total	**128.63**	**81.88**	**67.13**

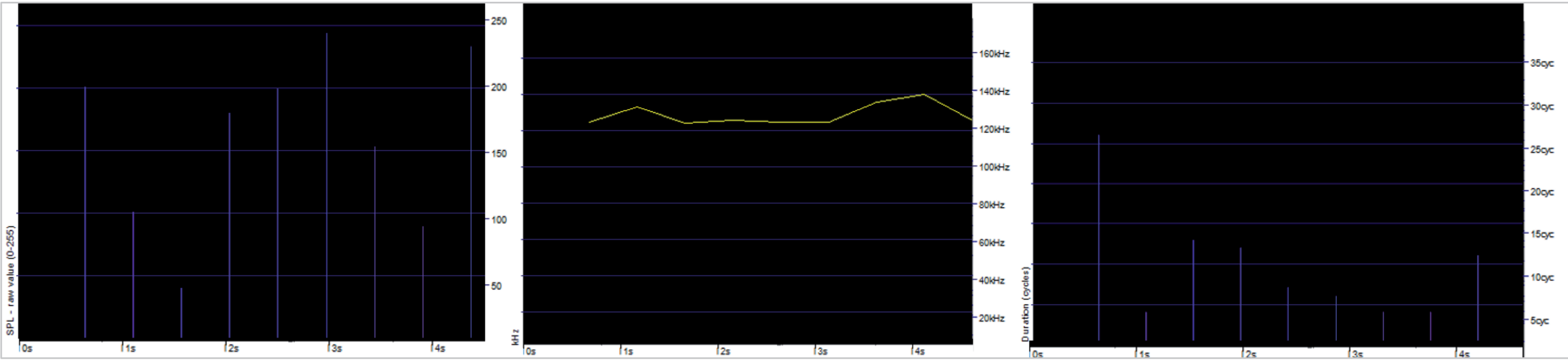


Figure 27*:* Train details of the Species Class: NBHF *(Phocoenidae)* from the station 8D in 10 ms time resolution. a) Amplitude profile of the train in SPL scale (CP3 file); frequencies of each click is represented by colors as in Figure 23/a b) Frequency profile (CP3 file); yellow color represents the moderate quality class c) Duration of each click/number of cycles; frequencies of each click is represented by colors as Figure 23/a.

For the Sonar trains, *frequency profile* (Figure 28/b) was extremely narrow-banded and at 38kHz and 120 kHz frequencies. *Amplitude profile* (Figure 28/a), was smooth and composed of high values of SPL like 200 and 250 SPL. From the same profile, clicks with clearly distinct and distant frequencies were received simultaneously. Thirdly, ICI of the received Sonar trains (Figure 28/c) were stable around 500ms.

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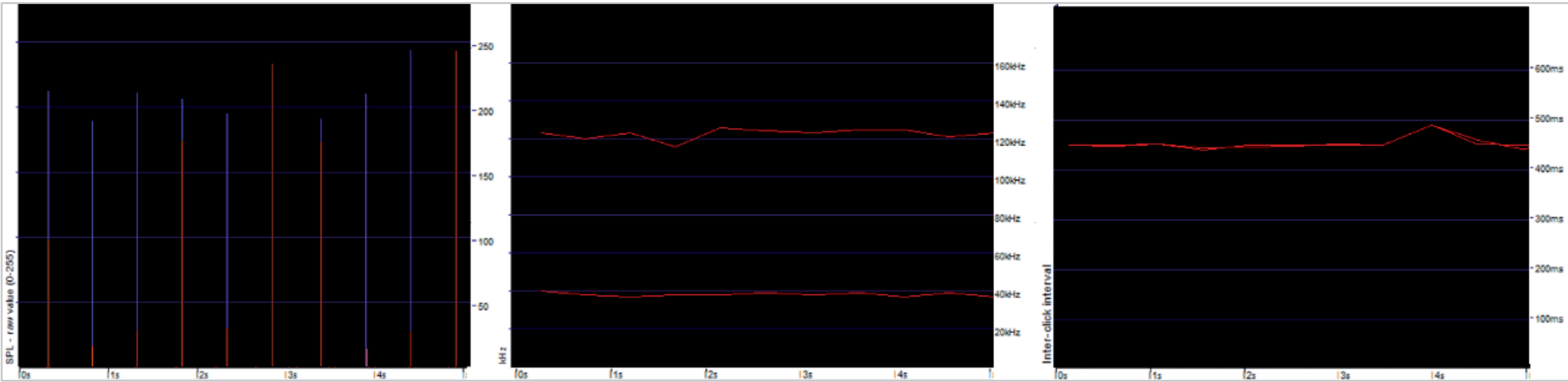


Figure 28: Train details of the Species Class: Sonar in 10 ms time resolution. a) Amplitude profile of the train in SPL scale (CP3 file); frequencies of each click is represented by colors as in Figure 23 /a b) Frequency profile (CP3 file); red color represents the high quality class c) ICI (Inter-click interval); red color represents the high quality class.

3.2. Hydro-acoustics

During the echo-sounder analysis, hydro-acoustics data was processed to reveal *dolphin marks* (i.e. marks of dolphin vocalizations in the echo-gram) while masking any other sound received. Resultant echogram data (Figure 29; left), demonstrates dolphin vocalizations much more clearly than unprocessed/ raw echo-gram (Figure 29; right). While echoes received from fish schools and planktons are visible on the raw echo-gram, they are efficiently masked in the processed one. In addition to that, since *dolphin marks* were selected and exaggerated through *dB differencing* and *Formula 2* (see section 2.3.3.2 Hydro-acoustic analysis: SV analysis- dB differencing), they are significantly more apparent in the processed echo-gram.

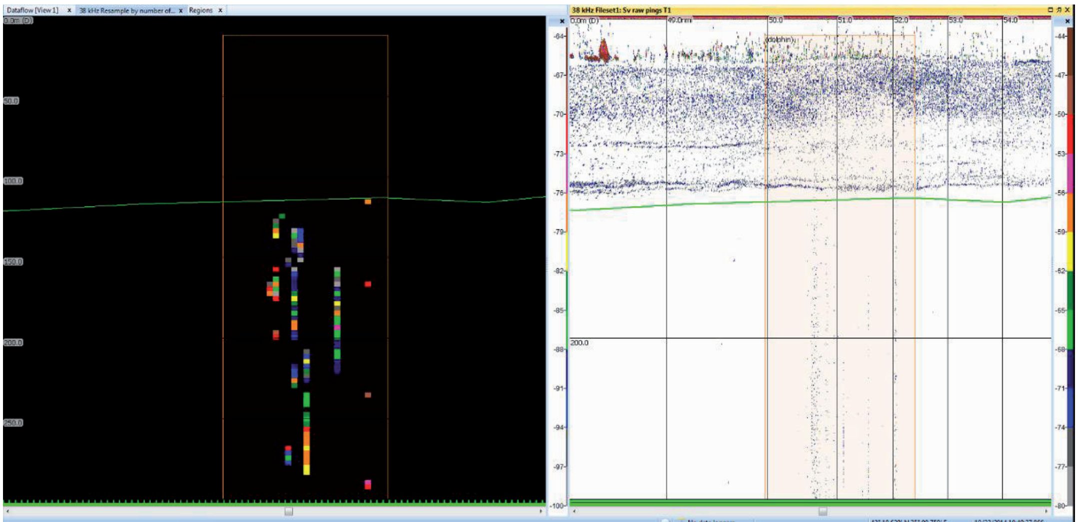


Figure 29: *Dolphin marks* before (right) and after scrutinization and dB differencing analysis (left). Orange rectangle shows the *dolphin region* and green line shows 100m surface exclusion line (see the 2.3.3Hydro-acoustics: Echo-sounder Analysis).

After this processes, coordinates of exported *dolphin marks* were mapped which reveals the spatial distribution of the received dolphin sounds (Figure 30). Yellow dots in the figure represents the *echo-points* which is the reorganized form of *dolphin marks* to relate them with cruise-rack with 1 mile resolution. Black and white lines represents night-time cruise-track and day-time cruise-track respectively. First noticeable implication was how frequent *echo-points* are in the South- Eastern Black Sea Region.

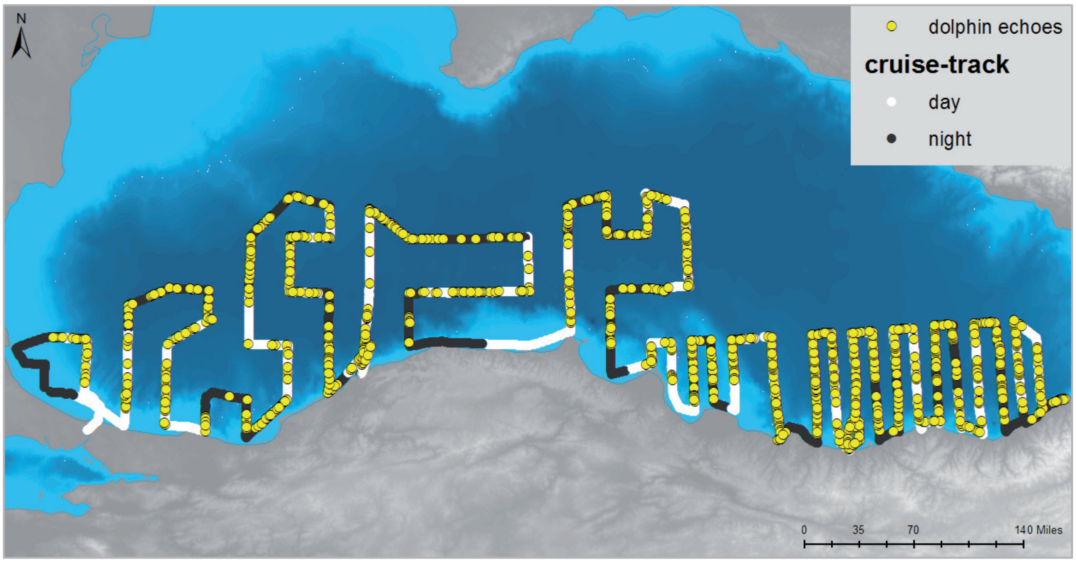


Figure 30: Spatial distribution of all *echo-points* with *mark count* over zero, which is estimated as a result of echo-sounder analysis and spatial analysis, Southern Black Sea, October 2014.

Resultant map is susceptible to be mistakenly perceived as the points of dolphin detections. However, each *echo-point* symbolizes only one dolphin sound received. To call it a dolphin detection, we need several sounds (i.e. dolphin vocalization) since initial clicks are followed by up to four or three more clicks (Aubauer, Lammers, & Au, 2000). Therefore, a specific number (i.e. *mark count*) was necessary to filter the data. In order to set this threshold, the average *mark count* in 100% sure dolphin detections was used (Avg. of *mark count* = 8.28). From this point of view, *echo-points* with a mark count above the average are the points of dolphin detections. By this way, distribution of short- beaked common dolphin in the Southern Black Sea was mapped using hydro-acoustics (Figure 31). Coherently, there were more frequent dolphin detections in the South-Eastern Black Sea Region.

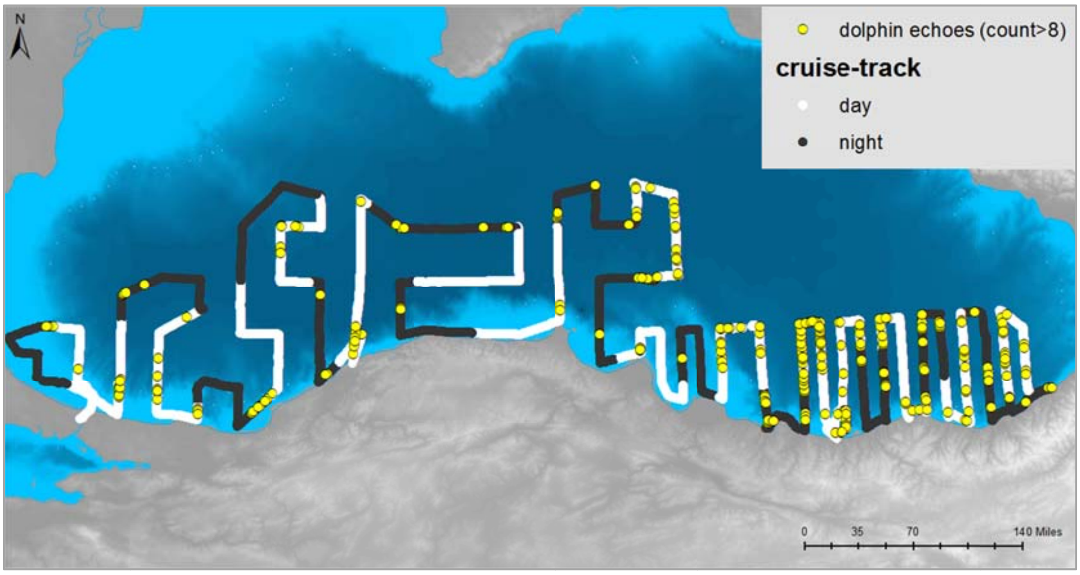


Figure 31: Spatial distribution of all *echo-points* with *mark count* over the average, which is estimated as a result of echo-sounder analysis and spatial analysis, Southern Black Sea, October 2014.

3.3. Verification of Hydro-acoustics as a Tool for Cetacean Observation

Using the Hydro-acoustics to derive the distribution map of cetaceans is a new technique. Therefore, requires a verification process. For the verification, consistency was sought between dolphin sounds gathered *via* echo-sounder and cetacean observations. If there is, an increasing trend in the number of dolphin sounds (i.e. *mark count*) is expected as one approaches to an observation point (For the hypothesis and assumptions see section *2.3.4 Verification of Hydro-acoustics as a Tool for Cetacean Observation*). Because, it is 100 percent confident that there is an individual dolphin or a dolphin group.

As a result of this verification process, following graph was constructed (*Figure 32*). Following statements were extracted from the graph:

- There is a *decreasing* trend in average of *mark count* as diverging from any observation point.
- This decrease is close to be geometrical with the exception around few intervals causing fluctuations in average *mark count*. (14000-1600m; 26000-28000m).

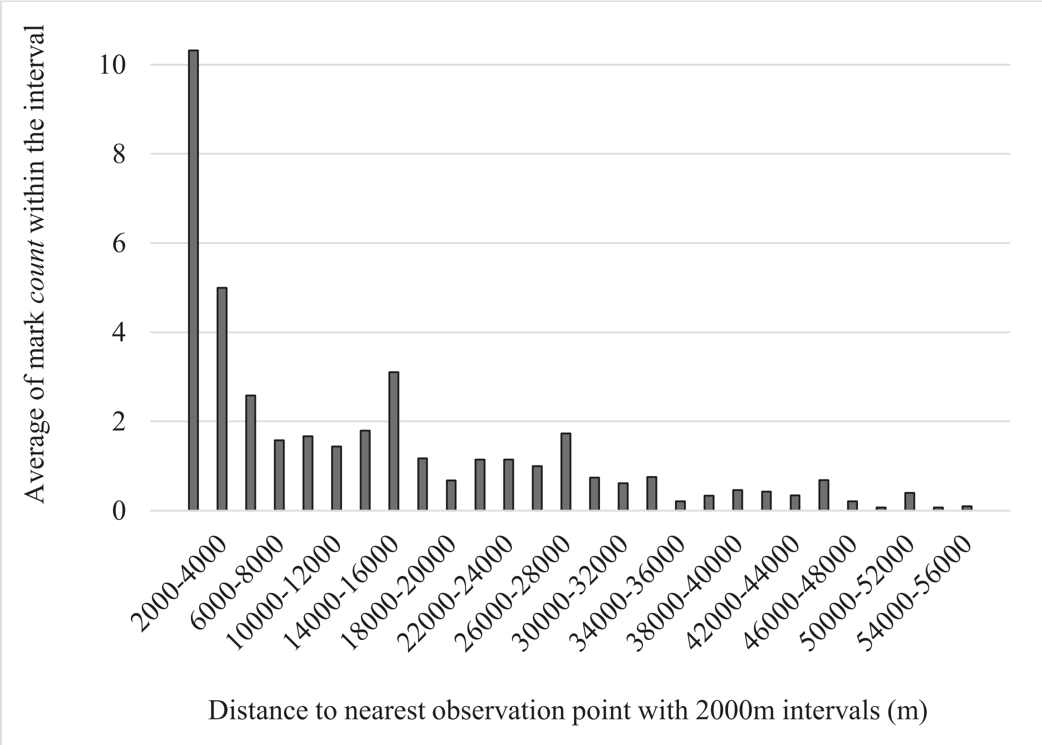


Figure 32: Chance in the average *mark count* as diverging spatially from any visual observation point -with 2000m intervals.

3.4. Consistency between Methods

Throughout this research, three different methodologies were followed in order to assess cetacean distribution and abundance in the Black Sea. In order to understand both the self-efficiency and the correlation of the methods, an approach to compare methods must be taken. Therefore, a comparison matrix was developed from October 2014 short-beaked common dolphin data (Table 10 and Table 11).

Table 10: Detailed comparison matrix between tree methods used throughout the survey: Cetacean Observation, C-POD deployment, Fisheries Acoustics. “1” and “0” numbers symbolize detection positive and detection negative situations respectively. And the numbers are the percent values. Green boxes are compatible situations in percent for relevant method couple (situations “1:1” or “0:0”); likewise Red boxes are incompatible situations in percent (situations “1:0” or “0:1”).

		Observation		Hydro-acoustics	
		1	0	1	0
C-POD	1	3.96	7.27	7.53	6.45
	0	7.27	81.82	4.30	81.72
Hydro-acoustics	1	0.06	1.64		
	0	1.02	97.27		

Comparison matrix was constructed using *Delphi's* data of October 2015 survey.

Table 11: Comparison matrix between tree methods used throughout the survey: Cetacean *Observation*, *C-POD* deployment, *Hydro-acoustics*. Green boxes are compatible situations in *percent* for relevant method couple (situations “1:1” or “0:0”); likewise Red boxes are incompatible situations in *percent* (situations “1:0” or “0:1”).

	Observation		C-POD	
C-POD	14.55	85.78		
Hydro-acoustics	2.67	97.33	10.75	89.25

Comparison matrix was constructed using *D.delphis* data of October 2015 survey.

Over all, there is a very high agreement in the detections. The highest accordance is seen between Observation and hydro-acoustics; 97.33% of the detections matched; while only 2.67 % of the cases missed. This is followed by C-pod vs. Hydro-acoustics, and the least match was found in C-pod vs. Observation comparison, yet only 14.55% of the cases did not match. If we only seek the “1:1” situation, the highest percentage would be between Hydro-acoustics vs. C-POD methods.

All four situation was observed for each and every method compared. For the case of C-POD vs. Observation, in 3.97 percent of C-POD stations dolphin detection *via* C-POD was positive and in 7.27 percent of stations there was no visual observation of *D.d* while C-POD detection was positive. Furthermore, in 7.27 percent of stations, there was not dolphin detection *via* C-POD but there was a visual observation; and finally in 81.82 percent of C-POD stations there was neither visual observation nor detection *via* C-POD. When the overall compatibility was considered, two methods found to have 85.78 percent compatibility (Table 11). What these four situations imply will be discussed in discussion part (see section *4.3 From Noise to data: Validation through Three Methodologies*).

For all methods “0:0” situation was observed to have highest percentage, especially for Hydro-acoustics vs. Observation. In fact, any other situation rather than “0:0” was observed to be quite low for this method couple. As aforementioned in the method part (2.3.5 Assessing Consistency between Methods) “0:0” situation means method results are compatible with each other together with “1:1” situation.

3.5. **Abundance Estimation-** *Preliminary Approaches for the Estimation of Cetacean Abundance in Exclusive Economic Zone of Turkey*

Since this section, the results of the processes that are related to attain the distribution of cetaceans were presented. Before moving any further, it is essential to comment on the abundance of cetacean species as well. With the primary approaches undertaken, this section serves to answer the abundance of the cetacean species inhabiting Black Sea. Following parts focusses separately on the abundance estimates derived from data of three different methodologies applied.

3.5.1. Abundance Estimation from Observational Data

In order to inspect abundance from observational data, the area over which observation performed was considered. In this respect, the daily weather conditions (Beaufort scale) influencing max distance of observation, species and the length of the cruise track were regarded (Table 12).

Since observation of cetaceans only performed during day-time, only day-time cruise tracks had considered (2790 km).

Since during cetacean observation min and max number of individuals within a group was noted, average number of individuals for every observed group was calculated in advance. Afterwards, they summed up to reach total number of cetacean observed. Throughout the survey 1015 short- beaked common dolphins, 21 harbor porpoise and 4 bottlenose dolphins were observed.

Table 12: The result of observational abundance estimation and the variables used during the estimation: D_{obs} (max distance for observation) was constructed according to daily weather conditions and species. Sampling area calculated for each day from D_{obs} and the length of day-time cruise-track. Finally, observational abundance *(N_{obs})* in EEZ of Turkey (172199 km^2) was calculated from *Observational Sampling area (km^2)* and *# of observations (individuals)* (see section 2.3.6.1Abundance Estimation from Observational Data).

			Delphinids		*Phocoenids*
			Delphinus delphis	*Tursiops truncatus*	*Phocoena phocoena*
$D_{obs}(m)$	Beaufort scale	0-1	300	75	100
		1-2	200	50*	50
		3-4	100	25*	25
Observational Sampling area (km^2)			1200	100	380
# of observations (individuals)			1015	4	21
$N_{observational}$			140000 (% 99 CI: 109668 - 143485)	2200 (% 99 CI: 150 – 4882)	5300 (% 99 CI: 1068 – 6812)

**Assumed*

Daily max observation distance was strongly depending to weather conditions. Therefore, although all bottlenose dolphin observations made during 0 weather conditions, a decreasing fashion was assumed for observation. Furthermore, the effect of bad weather was different for each species. As D_{obs} was species-specific, observational sampling area was variable between species as well; with biggest observational sampling area for short-beaked common dolphins. The majority of cetacean observations was belonging to short-beaked common dolphins with a significant difference from other species (Dd: 1015 individuals > Pp: 21 individuals > Tt: 4 individuals). Finally, abundance of short-beaked common dolphins were greatest with 140 000 individuals, followed by harbor porpoise and bottlenose dolphin respectively.

3.5.2. Abundance Estimation from Hydro-acoustics Data

In order to inspect abundance from hydro-acoustics data, sampling area was considered. In this respect, the weather-dependent daily max observation distances and the length of the cruise track were regarded. Since hydro-acoustic data were collected continuously throughout the survey, complete cruise-track was used in the calculations (5190 km).

Table 13: The result of hydro-acoustical abundance estimation and the variables used during the estimation: D_{ha} (max range for detection) was constructed according to daily weather conditions and species. Sampling area calculated for each day from D_{ha} and the length of relevant cruise-track. Finally, hydro-acoustical abundance *(*$N_{hydro\text{-}acoustical}$*)* in EEZ of Turkey (172199 km^2) was calculated from *Hydro-acoustical Sampling area (km^2)* and *ha (individuals)* (see section 2.3.6.2 *Abundance Estimation from Hydro-acoustics Data*).

			Delphinus delphis
$D_{ha}(m)$	Beaufort scale	0-1	300
		1-2	200
		3-4	100
Hydro-acoustical Sampling are (km^2)			2400
*gs: mean group size**			5.42
ha: # of detections			305
# of observations (individuals)			1650
N $_{hydro\text{-}acoustical}$			116000 (% 99 CI: 90867– 118887)

*retrieved from observational data

Since the range of the hydro-acoustic cetacean sampling is not known yet, max distance for observation *(Dobs)* was assumed to be valid for hydro-acoustical sampling. Hydro-acoustical sampling area is wider than Observational sampling area, because hydro-acoustic sampling continues during the night-time. *ha* was 305 which gives # of observations when multiplied by *gs* (mean group size of short-beaked common dolphins). *gs* was calculated again from observational sampling. The hypothesis behind this calculation, is the uncertainty of the number of dolphins giving rise to detection. Finally, hydro-acoustical abundance of short-beaked common dolphin was assessed as approximately 116000 individuals.

3.5.3. Abundance Estimation from C-POD Data

Considering that the maximum detection range of the device which is specific to families *Pelphinidae* and *Phocoenidae*, abundance of cetaceans were estimated from C-POD data.

Table 14: The result of C-POD abundance estimation and the variables used during the estimation: D $_{C\text{-}POD}$ (max range for detection) was retrieved from the literature. Sampling area calculated by simply calculating the area of a circle with radius D $_{C\text{-}POD}$. Finally, C-POD abundance (N $_{C\text{-}POD}$) in EEZ of Turkey (172199 km2) was calculated from C-POD Sampling area (km2), gs (mean group size) and c-pod: # of pos*itive stations* (see section 2.3.6.2 Abundance Estimation from Hydro-acoustics Data).

	Delphinids		*Phocoenids*
	Delphinus delphis	*Tursiops truncatus*	*Phocoena phocoena*
$D_{C\text{-}POD}$: detection range (m)	1000		500
C-POD Sampling are (km^2)	300		70
*gs: mean group size**	5.5		3.5
c-pod: # of positive stations	11		5
$N_{C\text{-}POD}$	35000 ** (% 99 CI: 26786– 35046)		41300 (% 99 CI: 8323– 53085)

*retrieved from observational data, ***Dd* comprises 99 % of *Delphinids.*

Range of C-POD was provided by manufacturer (www.chelonia.co.uk, Chelonia Limited). C-POD sampling area then calculated as an area of 93 (total number of C-POD stations) circle with a radius of $D_{C\text{-}POD.}$ Although there is only 500m difference between delphinid detection range and phocoenid detection range, there was significant difference between C-POD sampling areas due to the square relationship between $D_{C\text{-}POD}$ and C-POD Sampling area. Since there is an uncertainty in the number of dolphins/porpoises giving rise to detection, mean group size was used to multiply *# of detection positive stations* during the assessment of number of dolphins/porpoises detected. Finally, *C-POD abundance (N $_{C\text{-}POD}$)* was assessed as 35000 for delphinids and 41300 for phocoenids. In the visual observational data 99% of delphinids was represented by *Delphinus delphis.* If we assume that the visual detectability is same with the detectability by C-POD, 34900 *Delphinus delphis* and 200 *Tursiops truncatus* were detected by C-POD.

3.5.4. Comparison of Abundance Estimates

In this section, results of abundance estimates were summarized in Table 15 to clarify similarities and dissimilarities between methods.

Table 15: Comparison table which focuses on the abundance estimations of three sampling methodologies: observation (N_{OBS}), hydro-acoustics (N_{FA}) and C-POD ($N_{C\text{-}POD}$). Sampling area for each methodology was compared as well (OSA: Observational sampling area, H-ASA: Hydro-acoustical sampling area, CSA: C-POD sampling area)

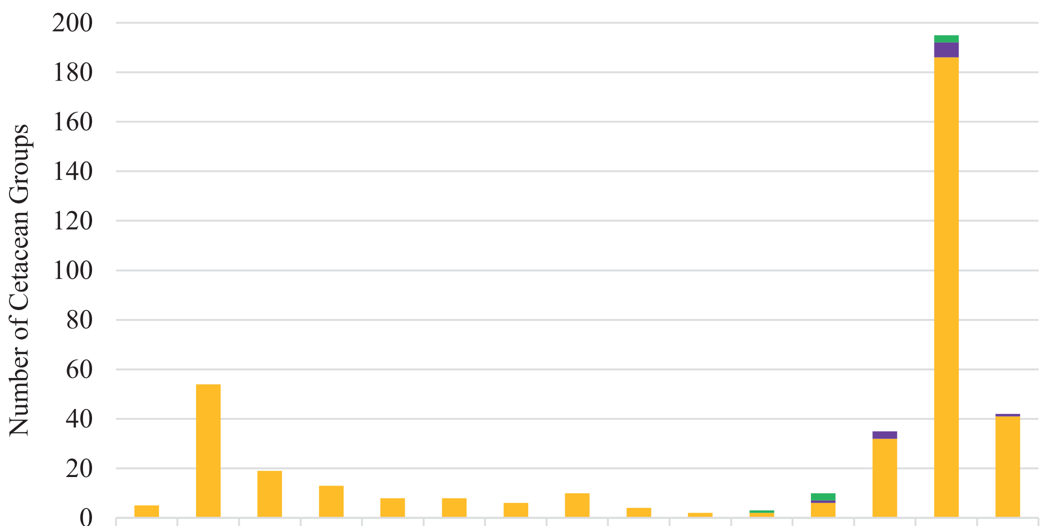
<table>
<tr><th></th><th></th><th>N_{obs}</th><th>OSA (km^2)</th><th>N_{ha}</th><th>H-ASA (km^2)</th><th>$N_{C\text{-}POD}$</th><th>CSA (km^2)</th></tr>
<tr><td rowspan="2">Delphinids</td><td>short- beaked common dolphin</td><td>140000</td><td>1200</td><td>116000</td><td>2400</td><td rowspan="2">35000</td><td rowspan="2">300</td></tr>
<tr><td>bottlenose dolphin</td><td>2200</td><td>100</td><td>-</td><td>-</td></tr>
<tr><td>Phocoenids</td><td>harbor porpoise</td><td>5300</td><td>380</td><td>-</td><td>-</td><td>41300</td><td>70</td></tr>
</table>

On the basis of the Table, even though there is a two-fold difference between their sampling areas, a clear consistency was observed between the abundance estimation of short-beaked common dolphin with observational methodology and hydro-acoustical methodology (N_{OBS} vs. N_{FA}). However, a significant difference was found between abundance estimate through C-POD and through other methodologies. C-POD estimates for Delphinids was substantially lower than the remaining estimates, while for Phocoenids it was higher. Additionally, sampling area of C-POD was narrower than both the observational sampling area and the hydro-acoustical sampling area.

According to observational estimates, short- beaked common dolphin was the most abundant species which is followed by harbor porpoise and bottlenose dolphin, respectively. In C-POD estimates bottlenose dolphin was again least abundant species, however, *Phocoena phocoena* is the most abundant one (*Phocoena phocoena* 41300 *Phocoena phocoena,* 34900 *Delphinus delphis* and 200 *Tursiops truncatus*). Several reasons for this difference will presented in Discussion chapter.

3.6. Temporal Variation of Cetaceans between 1996 and 2015

For the assessment of the temporal variation in cetacean groups, 9 years of past observational/chance encounter data were used (Figure 33). Cetacean group were observed substantially during the October 2014 (cruise 2014-2). Before 2001, only one species was observed, namely the *Delphinus delphis* (Dd, short- beaked common dolphin). This situation changed after the observation of *Phocoena phocoena* (Pp, harbor porpoise) in 2008. Observation of the *Tursiops truncatus* (Tt, bottlenose dolphin) was limited between years 2007 and 2008 with the exception of a few observations in 2014-2 cruise.



	1996 -2	1996 -4	1996 -5	1997 -2	1998 -1	1999 -3	2000 -1	2000 -3	2001 -1	2001 -2	2007 -7	2008 -u	2014 -1	2014 -2	2015 -1
Tt	0	0	0	0	0	0	0	0	0	0	1	3	0	3	0
Pp	0	0	0	0	0	0	0	0	0	0	0	1	3	6	1
Dd	5	54	19	13	8	8	6	10	4	2	2	6	32	186	41

Data Table: Cruise code & Species Composition

Figure 33: Number of encountered cetacean groups and relative contribution of each species to the total number of encounters for each cruise; x axis: number of cetacean cetacean groups; y axis: cruise code; below histogram: data table denoting the number of groups encountered relative to each species; Tt: *Tursiops t. ponticus.* Pp: *Phocoena p. relicta.*, Dd: *Delphinus d. ponticus.*

With the intention of revealing the temporal variation in the average group size of cetaceans, mean group size was estimated for each cruise (Figure 34). As a whole, a fluctuating pattern was observed in mean group size. In addition, the maximal mean group size was observed in May, 2007. Moreover, a seasonal pattern was observed in the mean group size.

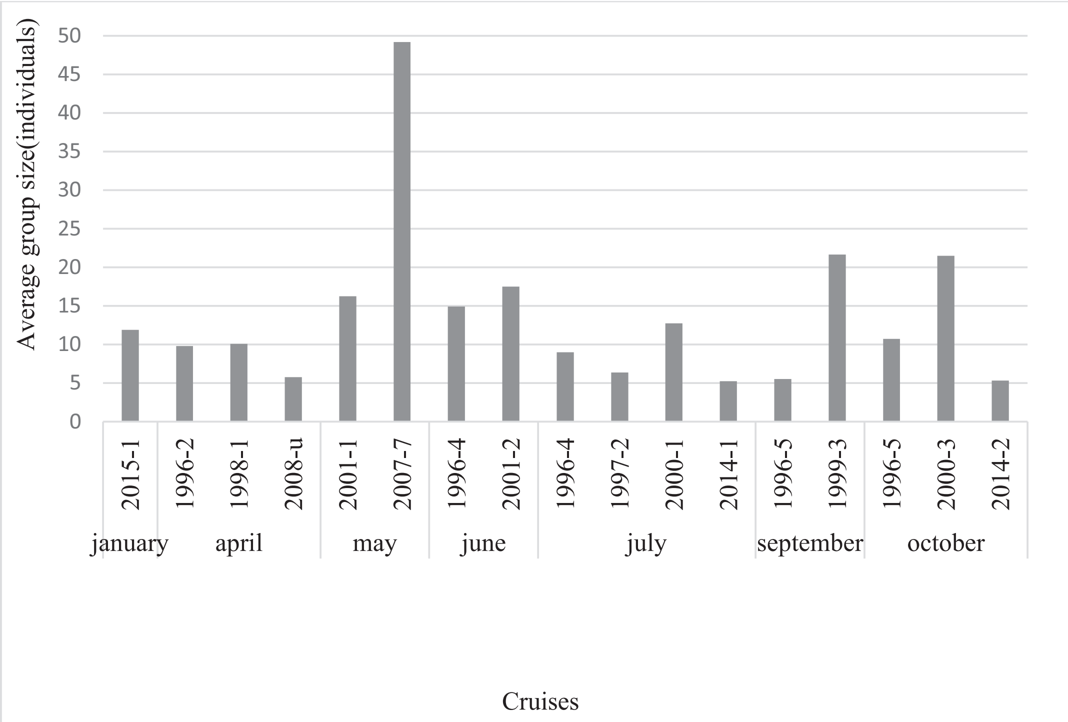


Figure 34: Change in the average group size of cetaceans considering 15 cruises performed in the Black Sea.

Seasonal variation in average group size of cetaceans was more explicitly illustrated in Figure 35. To extract this graph, cruises conducted in the same month was combined. Overall, the group size had bimodal fluctuation; with a major peak in spring and a minor peak in fall season. More specifically, May and June are the months with the highest mean group size (23.472 individuals and 16.2 individuals respectively).

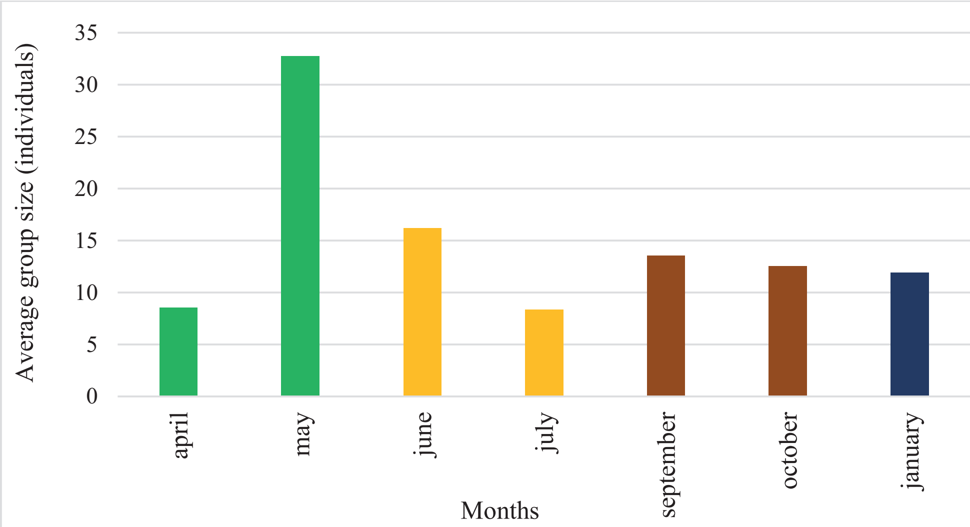


Figure 35: Seasonal variation in the average group size of cetaceans considering 15 cruises performed in the Black Sea; colors represents seasons such as green: spring, yellow: summer, brown: fall, navy blue: winter.

In order to see the yearly change in mean group size, cruises conducted in the same year were combined (Figure 36). From the graph, it can be inferred that the mean group size had been gradually increased until 1999 which is followed by a gradual decrease until 2001. Within the following six years, a remarkable increase was noted. Afterwards, a striking sharp decrease in avg. group size was observed between 2007 and 2008 (From 49.16 individuals to 5.75 individuals within a year). After 2008, a moderate stability is observed with a slight increase in 2015 (January).

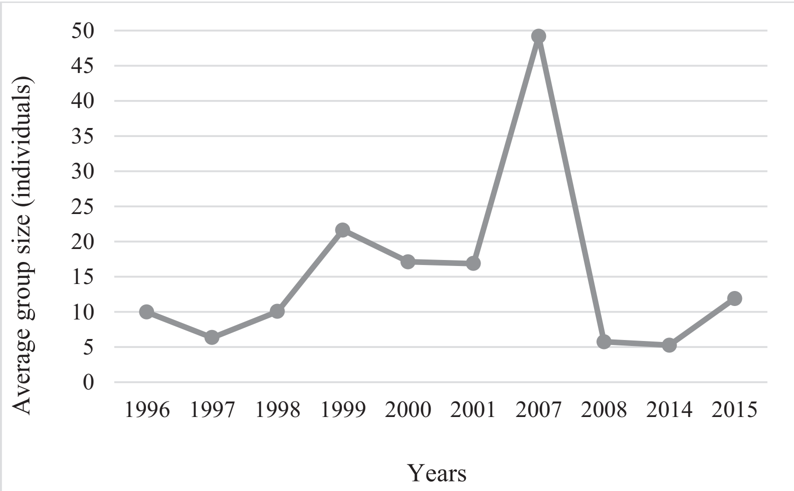


Figure 36: Yearly change in average size of cetacean groups since April, 1996 to January, 2015.

During October 2014 cruise (2014-2), a dedicated cetacean observation (with focal sampling) was performed; on the other hand, only the chance encounter events were noted during previous and the following cruises. Therefore, cruise 2014-2 was the only cruise that is suitable for the inspection of the daily variation in the group size (i.e. group dynamics). In addition, only the observation data of *Delphinus delphis ponticus* was used since it is the most frequently observed cetacean species. In Figure 37, the daily variation in the number of groups was presented together with the daily change in group size. The group size increased around noon (1-2pm; 7.16 individuals) and just before sunset (6-7pm; 17.5 individuals). Number of groups displayed a bimodal distribution within a day; with highest peaks between 8am and 12pm. Second peak was observed between 3-4 pm.

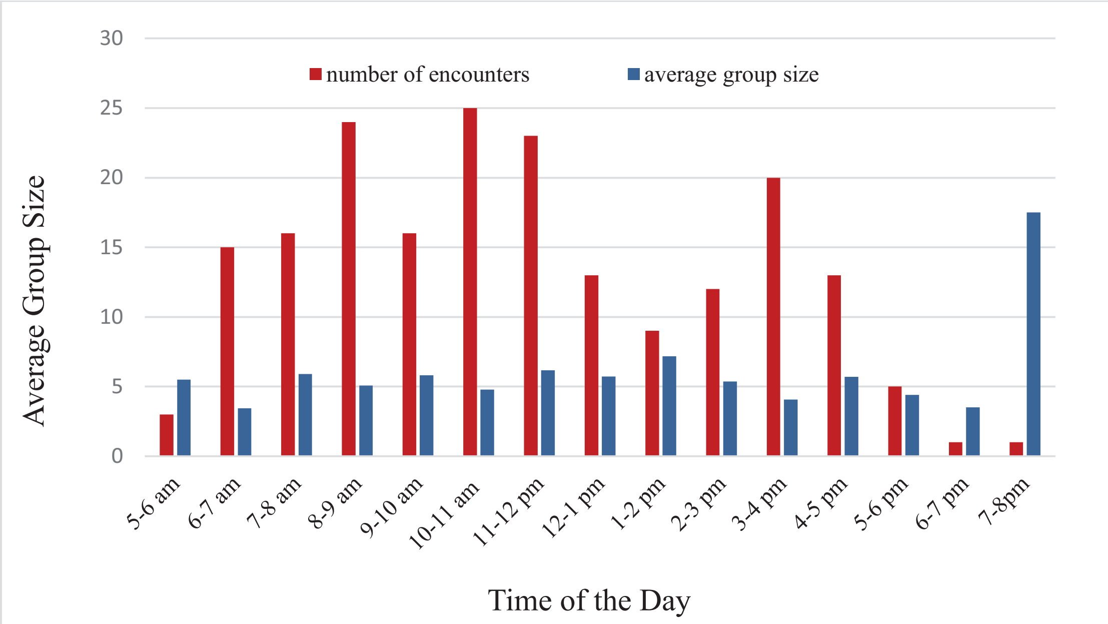


Figure 37: Diurnal variation in group size and the number of encounter; Cruise 2014-02.

4. DISCUSSION

The Cetaceans in the Black Sea is a problematic issue while this biological order is in danger in the eyes of the scientists, the fishermen see them as an ever growing danger to be terminated as they believe they harm their fishing devices and consumes considerable amount of fish (Bearzi, Holcer, & Notarbartolo di Sciara, 2004). The fisheries community claims that their population in the Black Sea has been dangerously overgrew after the ban for their fishery has come to force in 1983 (lastly in Turkey) and they blame dolphins for the collapse of several commercial species such as turbot. To solve this dilemma, and to answer whether or not the trend in their population size is really positive as claimed by the fishermen, is extremely costly. The reason is basin wide distribution of the cetacea order and the lack of practical and inexpensive tools to assess their population. There has been several attempts based on strip transect surveys carried out in the USSR (1967–1974) and Turkey (1987), however they either failed to reach their ultimate target or remained as a case study confined to a certain area and a time frame. Therefore, they discredited by the IWC Scientific Committee (Smith 1982, Buckland et al. 1992, cited in Birkun, A., 2012). Lack of funding has always been to main drawback of a cetacean monitoring program. In this study is a humble attempt to find a solution and to shed light on the basic aspects of the Black Sea cetacean. More precisely speaking, the study tests whether or not, and if possible how hydro-acoustics can be used to evaluate cetaceans. In the following, the applicability of the proposed methodology will be discussed in depth; two other methods, passive acoustics and direct observation, which are commonly used in the cetacean survey will be compared with the hydro-acoustics; and finally findings of the surveys will be further evaluated.

4.2. Usability of fisheries hydro-acoustic data to infer cetacean – Pros and Cons

Needless to say, the fisheries hydro-acoustics is developed for fishes and its working principle is totally different that the method proposed in this thesis. The method developed for fisheries relies on active acoustic; meaning that a transmitter produces a burst of electrical energy at a particular frequency which propagates through the water away from the transducer. It encounters various targets throughout its travel in the water column, such as plankton or the sea bottom. These targets reflect or scatter a part of the pulse back, and some energy returns the transducer. After the burst of sound energy (transmission), the transducer switches into listening mode (receiver) and records whatever it hears in the water until the transducer transmits the next burst of energy. What is heard is not necessary to be the transmitted sound reflected from a target only; the sound from other sources are also recorded during this short period of time between two successive bursts. Theoretically, if a dolphin within a certain proximity vocalizes at the same frequencies as the transducer, its sound would also be recorded by the receiver of the transducer. For fisheries purpose, the energy transmitted and received are then integrated to estimate the acoustical quantity of the targets reflecting the sound energy directed towards them (Simmonds & Maclennan, 2005; see section 1.2.3.2 Hydro-acoustics). However in this study, the transmitted sound, which actually carries the information about fish, is not of any interest, but the noises created by external sources rather than the transmitter itself are. Noise that is recorded concomitantly with the transmitted sound is the main source of information. The method proposed is essentially an algorithm, which basically involves masking of the returning echoes of fishes, plankton, sea bed, etc.; and extracting cetacean footprints (i.e. dolphin vocalizations) within the remaining noise accidentally recorded. Therefore, in a sense, echo-sounder which is an active acoustics device used like a passive acoustics device, such as C-POD.

The most common frequency used in hydro-acoustics is 38 kHz with some auxiliaries, such as 120 and 200 kHz. Peak frequency of the clicks of Black Sea cetaceans is species specific and between 23 kHz and 140 kHz (23-67 kHz for the short-beaked common dolphin, 110- 130 kHz for bottlenose dolphin and 120-140 kHz for harbor porpoise) (W. W. L. Au, 1993).Therefore, although the full cetacean sound spectrum is not covered there are seemingly significant overlaps with the frequencies used for fisheries purposes.

One way to use hydro-acoustic data for cetacean detection could be to inspect echograms visually, as dolphin marks are quite characteristic with a few to many intermittent vertical lines extending across the entire ping with an increasing intensity with depth (see Figure 29). This unique pattern was hypothesized as the result of the (i) Inter-click-interval (ICI) of the short-beaked common dolphin and (ii) Time-varied Gain Function. ICI of dolphins is higher than the pulse rate of the echo-sounder (0.5 sec). According to the Recorded C-POD results, ICI of the Black Sea dolphins 19 clicks/sec (see section 3.2.2 Train Details). This phenomenon causes most part of a click train to be attributed to same ping which results in as dashed vertical lines in the echogram. What TVG function does is to amplify dolphin clicks as it continues. Since this function uses time to attribute the range of any sound, terminal clicks within a dolphin click train undergo higher amplification. Although, this pattern is visually selectable, it would be a laborious work requiring certain level of expertise to visually inspect echograms. More importantly, it would be prone to misidentification and overlooking. Therefore, an algorithm was proposed to imitate and to select aforementioned peculiar characteristic of dolphin vocalization. According to the algorithm, there should be at least one ping gap between the received signals and the signal should be uninterrupted vertically. Moreover, as the clicks of the short-beaked common dolphin have a peak frequency between 23-67 kHz frequencies, it was expected to produce stronger signals at 38 kHz echo-sounder data. Therefore, *dB differencing* was carried out between 38 kHz data and 120 kHz data, favoring the signals with higher amplitude at 38 kHz echo-sounder data.

In order to test the usability of fisheries hydro-acoustic data to infer cetaceans, results of hydro-acoustics were compared with observation data. The point of visual observation is the point of 100% confidence of cetacean presence. Therefore, if we can gather the clicks of short-beaked common dolphins with echo-sounder efficiently enough to analyze to select their clicks, the number of received dolphin sounds (i.e. mark count) theoretically should increase as approaching to that point. As a result of this comparison, a decreasing trend was observed in the count as diverging from the point of cetacean observation (

Figure 32 , section 3.3 *Verification of Hydro-acoustics as a Tool for Cetacean Observation*). This implies that, as ship navigated to the area with short- beaked common dolphin presence, echo-sounder started to receive their sounds, and the amount of received sound increased as approaching to that area. In other words, efficiency of detecting a dolphin vocalizations increases as one approaches to the sound source as should be expected from an accurate recording system (W. W. L. Au, 1993). Therefore, hydro-acoustics was proven to be functioning for cetacean detection.

The number of dolphin producing the received dolphin sound (i.e. dolphin vocalizations on the echo-gram; see section 2.2.2.2 and 2.3.3 for further information) is not certain but necessary for the hydro-acoustical abundance estimation. Because theoretically, there can be a cetacean group with a great number of dolphins with only one individual vocalizing at the moment of recording. Likewise, there can be one very vocal individual which can misjudged as many dolphins. Therefore, number of dolphin sound cannot directly related to the size of the short-beaked common dolphin group. The level of vocalization may differ even for the same individual, depending on the several factors like the time of the day or the specific behavior at that moment (Dede et al., 2013). Therefore, it requires more specific design to relate dolphin sound with the number of individuals within a group. Yet, from observational data, the average number of individuals comprising a Black Sea short-beaked common dolphin group is known. Therefore, for each short- beaked common dolphin detection via hydro-acoustics methodology, it was assumed that there are approximately 5 individuals (see Figure 20).

Another problematic part in the abundance estimation using hydro-acoustics data was the dolphin detection range of the device (echo-sounder). Detection ranges of acoustic devices are usually larger than visual observation (Goold, 2009) which is being one of the advantages of using acoustics as a methodology in cetacean research. Theoretically, the devices bearing Omni-directional hydrophones bear higher detection range advantage than the directional ones (W. W. L. Au, 1993). From this perspective, fisheries sonar which is directed to the sea bottom have relatively limited range of detection. Even in fully developed omni-directional devices that are invented for detecting cetaceans like C-PODs, the max distance for detection is ambiguous and dependent on many factors like the behavior or the orientation of dolphins (Roberts & Read, 2015). Considering the fact that, this methodology (using hydro-acoustics for cetacean detection) is newly developed, it is very soon to comment on effective detection range. Further experimental studies need to be constructed for this purpose. Therefore for the *Dha* (maximum range of hydro-acoustic device) (see section 3.6.2), *Dobs* (max distance for observation) is assumed to be valid. *Dobs* was configured according to the daily sea state in three intervals: 0-1, 2-3 and 3-4 Beaufort scale. As the observation distance and the sea state was recorded during each observational sampling, daily max distance for each observed species and sea-state could assessed. The general trend was the decrease of max observation distance with the heavy weather. Max observation distances were reached during 0-1 sea state for all species: 300 m for short-beaked common dolphin, 100 m for harbor porpoise and 75 m for bottlenose dolphin. This phenomenon is suspected to be the result of the combined effect of observation bias and mean group size of species. As the common dolphin is more playful and gregarious (W F Perrin et al., 2008) it is visible from longer distances. From this perspective, harbor porpoises are expected to have lower observation ranges as they have lower mean group size and smaller body size than bottlenose dolphins (Figure 20). However, they observed in higher detection ranges. The reason could be explained by the avoidance behavior of bottlenose dolphin resulting from the hunting they experienced in the past. But they were representing the lesser percentage of catch (Zalkin 1940; Birkun A., Jr, 2002). Therefore, the dominant reason is observation bias. As bottlenose dolphins is the least abundant species in the Black sea (see section 3.5 Abundance Estimation- *Preliminary Approaches for the Estimation of Cetacean Abundance in Exclusive Economic Zone of Turkey*), they could have overlooked by observers.

4.3. From Noise to data: Validation through Three Methodologies

The study is based on the assumption that hydro-acoustics detects cetacean sounds; which obviously requires validation of what is detected as cetacean is actually a foot-print of the cetaceans. This was achieved by concurrently conducting two alternative methods commonly used in cetacean studies, and by comparing the results with each other. For this purpose, only short- beaked common dolphin was used as this species was by far more abundant in the surveyed area. Also, as there were significant differences between July 2014 and October 2014 surveys that hinder comparability, only October surveys were taken into consideration. That is, in July cruise, cetaceans were observed as chance encounters not like the 12 hours focal sampling method performed in October cruise. Therefore, July cruise observation data did not used in comparison with hydro-acoustics.

The results were quite consistent and satisfactory with a minimum 85.78% match observed in the comparison of Observation and CPOD. Maximum match was observed between Observation and Hydro-acoustics (97.933 %) which is followed by Hydro-acoustics and C-POD (89.28 %). However there are also several cases, in which one of the method displays cetacean occurrence while another fails. The reason for inconsistency is mainly due to the strength of one method for specific case over the others. In general the efficiency and probability of detecting short- beaked common dolphin is quite different for Observation and Hydro-acoustics; due to different behavior displayed at different states of the animal. A surface feeding dolphin (see section 2.2.1) always have high probability of being detected since animal is most of the time at the surface during that state; however at the same time, detectability by fisheries acoustics may be lower (Roberts & Read, 2015). This is due to two reasons; first is the high directivity of echolocation clicks of odontocetes, this is essentially what is detected and recorded by hydro-acoustics (W. W. L. Au, 1993); the second, a foraging animal directs the sonar pulses more towards the sea bed where their prey are (Nuuttila et al., 2013), especially in the surface feeding behavior, dolphins surface and dove continuously in a circular pattern. In this case the pulse would either be masked or absorbed through reverberation before reaching to the echo-sounder. The 2.67 % mismatch presented in Table 15 may, to a great extent, be due to this fact.

On the other hand, weather conditions, and sea state in particular, influences the sighting success of the cetaceans in direct observation. Depending also on number of people involved in observation, there is always a possibility of missing a sighting. Therefore, inconsistency observed between Observation and Hydro-acoustics in the Figure *32* may be due to weakness of direct observation at rough sea. Bad weather condition also effects the detectability efficiency of the receiver. The vessel and the mounted transducers pitches and rolls, the angular motion of transducer is more severe in bad weather; and any movement of the transducer degrades the amplitude of the received signal (Simmonds & Maclennan, 2005) which may mask the sound transmitted by echo-locating dolphins. The percentage of “1:1” condition was quite low (0.06%; see Table 11). For the sake of comparison only daylight fisheries acoustics data was used and this decreased the sample size for the comparison which may accounted as reason for low “1:1”.

Although the methodology proposed here is a challenge to convert noise into a valueable data, in some cases it was evidenced that the noise itself may exerts certain degree of weakness to the method. Essentially underwater noise is an important factor drastically reducing the performance of an acoustic instruments (Simmonds & Maclennan, 2005); and beside cetaceans, underwater noise may be generated by various other sources; including shipboard machinery, propeller, laminar flow of the bubble entrained water along the hull of the ship, electric supply, etc. Each of these have negative effects on acoustic instruments and may be considered as weaknesses against direct observation. The noise factor, may be another reason for low “1:1” and relatively high “1:0” (1.02%; see Table 11) condition for Observation and Hydro-acoustics.

Slightly higher percentage of “0:1” (1.64%; see Table 11) situation in Observation vs. hydro-acoustic comparison might also be attributed to observer bias. Observers could have missed single traveling dolphins or simply misclassified dolphin behavior (Nuuttila et al., 2013). In addition, it should be noted that cetaceans only spend a fraction of time at the surface, where they can be sighted.

Regarding the fisheries acoustics, transducers used in fisheries acoustics are composed of several piezo-electric elements arranged in a fashion to produce a narrow beam, which in return increases the sensitivity at the center direction (W. W. L. Au & Hastings, 2008); meaning that it has directional sensitivity. Furthermore, the fisheries echo-sounders used in this study are composed of narrow-band system therefore it is sensitive mainly on the center frequency with a narrow spectrum (center frequencies used in this study was 38 kHz, 120 kHz frequencies). Despite being an advantage to reduce noise in a fisheries survey, this feature reduces the cetacean detection range remarkably.

During the comparison of Hydro-acoustics with other methodologies, max rage was assumed to be 300 meters, the maximum range of visual short-beaked common dolphin observation. However, this is not known at the moment and further studies conducting controlled experiments should be performed in order to determine the effective range of Hydro-acoustics device. Highest percentage of “0:0” between Hydro-acoustics and Observation (97.27%; see Table 11) is partly due to higher percentage of sampling areas (thiessian polygons; see section 2.3.5) with no detections for both methodologies. Still, this implies that there is overall a good correlation between two methodologies since they both gave negative results for detection (overall compatibility 97.33%).

4.4. Consistency between methods

The percentage of "1:1" situation was also quite low in C-POD vs. Observation comparison. The reason is again thought to be the effect of different dolphin behavior and group size. According to the study of Nuuttila *et al.,* 2013 both behavior (feeding or traveling) and group size contributed to the final model explaining the detection probability of dolphin *via* C-POD. According to their findings detection probability increases slightly for larger group sizes of feeding dolphins, but decreases markedly for traveling animals. But generally large groups are more likely to be detected by observation. So, this dynamic situation decreases the "1:1" situation and give rise to "0:1" or "1:0" situation (both 7.27%; see Table 11) in C-POD vs. Observation comparison. Majority of the "1:0" situation was the detections of harbor porpoise. This may be due to the relatively shy nature and small size of the harbor porpoise which decreases the detection probability for observation (W F Perrin et al., 2008). However, C-POD is a device which is basically designed for porpoise detection. Remaining "1:0" condition can again be attributed to observation bias. "0:1" situations can be related to specific behavior of cetaceans (like surface feeding as aforementioned). Another reason can be the vessel noise, because C-PODs are generally moored at stationary stations (Chelonia Limited, www.chelonia.co.uk), in this study on the other hand, C-PODs were used with a developed release method (see Figure 12 ; section 2.2.3 C-POD Data Collection:). This may make C-POD susceptible to the electricity noise or the pile nose of the vessel which in turn may mask the cetacean echolocation clicks. Highest percentage of "0:0" situation together with the "1:1" situation means that these two situations are 85.78% compatible with each other.

The highest percentage of "1:1" above all method couple is between C-POD and Hydro-acoustics method couple (7.23%; see Table 11). Since both methods are acoustic devices, they have similar constraints and advantages. Besides, methodologies were performed day and night which provides more data comparison. However, this does not mean that all detection by the methods perfectly matched as there were some

“0:1” and “1:0” situations. This is probably due to the fact that, the detection range of hydro-acoustic is shorter than that of C-POD as one has directional sensitivity while the other is omnidirectional. In addition, C-POD has quite high dolphin detection range (max; 1 km). Fisheries echo-sounders used in this study are composed of narrow-band system, while , c-pod is sensitive to a much wider frequency spectrum ranging from 20 kHz to 160 kHz frequency (www.chelonia.co.uk). However, “0:1” situation has higher percentage than “1:0” situation for “C-POD: F. Hydro-acoustics” couple. This can be due to the fact that, short- beaked common dolphins mainly observed while displaying BR behavior, which generally takes place in front of the vessel. Together with this, C-POD deployments were performed at the rear deck of the vessel. Therefore, the orientation of dolphins were generally away from the both acoustic devices; yet more distant to the C-POD. And there is a possibility that carina of the vessel might mask some of the sounds.

4.5. Discussion of Method Accuracy

High consistency between each method, enable us to complement all these data to attain satisfying results. For example; with observation we could only perform sampling during daylight hours and under optimum visibility conditions. On the other hand, most of the time weather conditions such as waves, fog and glare, as well as the direction of sunlight have considerable effect on the ability of observers in the field (Dede et al., 2013). Besides, especially for endangered species with low-densities, long-term continuous visual observation can be very difficult and costly (Kimura et al., 2009). Acoustics provide us to use “hearing” sense in addition to “seeing” *via* cetacean observation. With the acoustics, sampling could performed day & night /or under unfavorable conditions continuously. The number of night-time C-POD stations with detections (see section 3.2.1) and short- beaked common dolphin detections with hydro-acoustics (see section 3.2 Hydro-acoustics) affirm the importance of using acoustics in addition to cetacean observation. Two acoustic methodology was specialized for different target species. While C-POD was highly specialized on porpoise detection, hydro-acoustics method was focused on short- beaked common dolphins-though it can be specialized on different species in the future work (see section *6 FUTURE PROSPECTS).* From this respect, aforementioned two species (harbor porpoise and short- beaked common dolphin) were sampled with higher confidence than bottlenose dolphin. Despite the overall underperformance of the abovementioned methodologies in observation of bottlenose dolphins, some valuable information was obtained by the visual observations in combination with the C-POD. However, since there were two dolphin species and C-POD could only classifies till genus level, detections could not strictly attributed to bottlenose dolphin or short-beaked common dolphin.

4.5.1. Black Sea Cetaceans: Distribution and Abundance

4.5.1.1. Harbor Porpoise (Phocoena phocoena ssp. relicta)

Harbor porpoises, in general and in Black Sea, usually forage near the sea bottom and sometimes near the surface (e.g. on sprat) in waters less than 200 m depth (William F Perrin et al., 2015). In this respect, observed coastal distribution of Harbor porpoise is confirming (see Figure 25). Since the geographical coverage of the two cruises (July and October 2014) overlaps only on the eastern part of the Black Sea, it is compelling to make a seasonal comparison. Yet, coastal distribution of harbor porpoises were observed in both surveys which increases the reliability of this finding.

Two dead harbor porpoises were observed in the offshore waters during each cruise (both in July and in October) which are thought to be drifted to offshore after dead. According to the studies of A. Tonay (Tonay & Dede, 2013; Tonay & Öztürk, 2003), every year several hundreds of harbor porpoises are drowned in gill nets and stranded ashore due to incidental capture, particularly during turbot and sturgeon fishing season.

Abundance estimations of harbor porpoise in EEZ of Turkey was approximately 2 200 individuals when results of direct observation is considered. C-POD sampling provided significantly higher estimate with around 41 000 individuals. These estimates could consider reliable only after loose assumptions on species' affective ranges and on average group sizes considered. However it may still be an important finding as the remarkable difference between these two is, to a great extent, reflected the poor visual detectability of these small sized animals with relatively smaller groups (see Figure 20). Another reason can be higher efficiency of C-POD relative to observation for harbor porpoise detection. There are no estimates of total population size in the literature.

Still, the available information suggests that present population size is at least several thousands and possibly in the low tens of thousands (Birkun Jr., A.A. & Frantzis, A., 2008; Perrin et al., 2015). In this respect, C-POD estimates seems to be higher than expected, while observational estimates are within the expectations. Still, the use of two methodology for harbor porpoise sampling and compatibility between methods increases the reliability of results. In addition to that, there is a possibility that C-POD sampling revealed observationally missed harbor porpoises; therefore, there may have been an underestimation of harbor porpoises in the studies depending on solely observational methodology. During most of the 20th century abundance of Harbour Porpoises in the Black Sea was recognized as being higher than that of Bottlenose Dolphins (*Tursiops truncatus ponticus*) and lower than that of Short- beaked common dolphins (*Delphinus delphis ponticus*) (e.g., Tzalkin 1940; Kleinenberg 1956; Birkun Jr., A.A. & Frantzis, A., 2008). Observational abundance estimation confirms that this pattern is still present (140 000 *short- beaked common dolphins,* 5 300 *harbor porpoise,* 2 200 *bottlenose dolphins*).

When C-POD detections were considered, inshore distribution pattern of harbor porpoise distribution is seen with detections less than 85 km offshore (Figure 23, Figure 24 Figure 25). Higher number of detections of harbor porpoises, especially in the Western part of the basin, can be associated with the seasonal distribution of their prey. According to the stomach content studies of Tonay et al. (2007b), sprat and anchovy are the primary food of harbor porpoises in the western Black Sea; which are abundant in the southern Black Sea in the October-time as will be discussed further below.

4.5.1.2.Short- Beaked common dolphin (Delphinus delphis ssp. ponticus)

Mediterranean short-beaked common dolphin migrate through the Marmara Sea and the Istanbul Strait into the Black Sea (Berkes,1977; Baş, Amaha Öztürk, & Öztürk, 2014). From this respect, observations of short-beaked common dolphins in Western Black Sea (between Şile/İstanbul and Kefken/Kocaeli), can be suspected to be migrating Mediterranean Short-beaked common dolphin. However, migration towards Black Sea starts in spring, which is followed by back-migration to Aegean Sea in autumn. That is the reason why intensive Mediterranean short- beaked common dolphin observations occurs in The Turkish Straits System (TSS) during spring and autumn months (TSS consists of the Bosporus, the Marmara Sea and the Dardanelles) (Berkes, 1997; Öztürk & Öztürk, 1997). On this basis, during October cruise Mediterranean short- beaked common dolphins were migrating through TSS. Therefore, observed short- beaked common dolphins around Şile and Kefken were most probably Black Sea short-beaked common dolphins.

Observational data affirms that, in the Black Sea, short-beaked common dolphins still appears to be the most abundant black sea cetacean despite its over-exploitation up to the early 1980s (Sciara, 2001). During October cruise, short- beaked common dolphins were more frequently encountered in the Eastern part of the Black Sea. This is most probably due to the seasonal aggregations and regular mass migrations of coastal fish prey such as such as Black Sea anchovy (*Engraulis encrasicolus ponticus*) and Black Sea sprat (*Sprattus sprattus phalaericus*) (Tzalkin 1940; Notarbartolo-Di-Sciara & Reeves, 2006). As stated by Notarbartolo-Di-Sciara (2006), annual winter concentrations of anchovies in the southeastern Black Sea provides favorable conditions for wintering concentrations of short-beaked common dolphins. The main reason why anchovy is overwintering in South-Eastern cost of Turkey is the fact that it is protected from northern winds by the Main Caucasus Ridge; therefore not influenced by the cold currents predominant in the Western Black Sea (Chashchin, 1996). In addition, observed bigger size of individuals and larger cetacean groups in the Eastern part also confirms that they are feeding on richer diet by forming foraging groups around highly aggregated fish schools.

When the hydro-acoustics- derived distribution map of short-beaked common dolphin was considered, higher concentrations of dolphins were observed in the South- eastern Black Sea. Same pattern was observed in the observational distribution map apart from the sampling gaps at night. Night-time data provided by F. hydro- acoustics was in continuity with the day-time visual observations (see Figure 31).

Although there is no estimate of overall population size, preliminary data for some parts of the basin suggest that it is currently at least several 10,000s, and possibly 100,000 (Birkun Jr., A.A 2008). Coherently, observational and fisheries hydro-acoustical abundance estimation was 140 000 and 116 000, respectively.

C-POD "dolphins" detections (short-beaked common dolphins and bottlenose dolphins) were mainly in the offshore waters of southern-Black Sea (see Figure 24 Figure 25). Offshore distribution of dolphins and inshore distribution of porpoises can be attributed to several biological dynamics. Niche partitioning can be one of the ecological phenomenon contributing this pattern. It refers to the process in which competing species tend toward different patterns of resource use or different niches as a result of natural selection (Walter, 1991). Possible ecological drivers of niche partitioning include prey competition and feeding interference. Moreover, behavioral responses can act to force this pattern, like the avoidance. In the literature, there are many examples of dolphin aggression towards harbor porpoises where clear signs of multidirectional blunt force trauma present supporting the attacks by bottlenose dolphins (Wilkin et al. 2012; Ross and Wilson, 1996; Cotter et al. 2012). However, in two stations (one in July and another in October cruise) both "dolphin" and "NBHF" class (harbor porpoises) were detected by C-POD; which suggests that such an aggression does/may not exist in the study area. Because in approximately 500m (C-POD max detection range for harbor porpoises, Chelonia Ltd, 2012) radius both class were detected. In this respect, there were no avoidance towards dolphins by harbor porpoises. If so, the cause of broad niche partitioning (inshore-offshore distribution of harbor porpoise-dolphin) can be hypothesized to be due to ecological reasons like the distribution of preferred prey or physiological constraints.

4.5.1.3. Bottlenose Dolphin (Tursiops Truncatus ssp. ponticus)

Black Sea bottlenose dolphin was the least abundant cetacean species. Several possible reasons are as follows: (i) they are less likely to be observed-due to observer bias-since they are forming smaller groups (see section 3.1.1;Figure 20) or they are avoiding the vessel; (ii) they are actually less in numbers. The avoidance from vessel usually occurs due to past history of hunting (William F Perrin et al., 2015). However, if this would be the case, short- beaked common dolphins would be the one who is avoiding the most. Because, in the past, they were representing the 94.8% of the catch composition in the Black Sea (harbor porpoise: 4.7% and bottlenose dolphins 0.5%) (Zalkin 1940; Birkun A., Jr, 2002). In contrast, short- beaked common dolphins were observed to be the species which is most frequently observed mostly during performing BR behavior (see Figure 21). Although there is no estimation of abundance in the literature, they are thought to be at least several thousands of individuals (Birkun, A. 2012). According to the observational abundance estimation, there are 2 200 bottlenose dolphins in the EEZ of the Black Sea. Although this is a crude estimation with several assumptions, it is within the range of related scientific guesses. It should be noted that seasonal dense cetacean abundance in the Southern Black See is arising from the migration of greater part of the Black Sea anchovy stock to the Southern Black Sea in October (Chashchin, 1996)- which may have an effect on all abundance estimations.

4.5.2. Black Sea Cetaceans: Behavioral Findings

Following Bearzi, Notarbartolo-Di-Sciara, & Politi (1997) the most adequate sighting conditions were considered to be reached when (1) at least one dedicated/experienced observer scanned sea surface continuously for cetaceans (2) visibility was good- no fog or rain (3) sea state was 0 or 1 according to Beaufort Scale. For the behavioral observation *via* focal sampling, the most dominant behavior of the group were noted. In respect of observed behaviors of cetacean groups, BR was the most evident behavior, especially for the short beaked common dolphins. This could bring some bias as they are attracted to the observation media, the vessel. However, this is common behavior of the short- beaked common dolphins as they are playful, gregarious mammals and are often bow-riding and darting around at high speed (Jefferson et al.1993; Richardson et al., 1995). Besides, this behavioral tendency makes it more feasible to obtain acoustic recordings (Griffiths, 2009).

There are several thoughts for the reason of BR behavior: (i) playing with the pressure waves caused by the vessel (Murphy et al., 2009), (ii) taking advantage of the waves in order to navigate with less energy. However, the latter one is unlikely, because bow-riding dolphins usually head back to whence they picked up the vessel (William F Perrin et al., 2015). During (chance encounters) night observations of short- beaked common dolphin groups, they were observed to be hunting at the same time they were bow-riding. From this respect, they can be "ritualizing" the hunting behavior as a "play" in the day-time in order to practice hunting. Furthermore, this ritualized behavior can be a way of teaching hunting to the youngsters. The biggest group formation with calves and juveniles was observed during BR behavior (see Figure 22), which is also a supporting evidence to that. Because greatest group size is attained during foraging behavior in dolphins (Henderson et al., 2012). And, bow of the vessel can be an advantageous place to hunt since fishes tend towards the bow of the vessel to avoid the noise. So we need to consider a third option for the reason of BR behavior: ritualized behavior to practice and learn hunting skills.

In accordance with Perrin et al., 2015, feeding behavior, in general, was determined from the asynchronous surfacing and diving movements of a loosely aggregated groups. But most importantly, the flocks of these seabirds-especially gulls-was indicative of feeding behavior of short-beaked common dolphins in the field.

4.5.3. Black Sea Cetaceans: Acoustic Characteristics

As stated in the methodology part, C-POD was deployed in stations instead of mooring- which is more often preferred. But, this would require higher resource and time. For example, in October 2014 cruise we would require 93 different C-PODs to be moored at stationary stations. Under this circumstances of limited fund and time, the best solution was to deploy C-POD at stations. In order to decrease noise of the vessel, a long rope (total: 45m) was used. C-POD is a self-buoyant product (C-POD product specifications, Chelonia Limited, www.chelonian.co.uk) and in order to position it in the mid water (with neutral buoyancy) a weight (10m below) and a buoy (15m above) was attached. Ten meters of distance between C-POD and weight is to protect the device from the potential impacts from the weight in the event of a strong current.

During the deployment of C-POD in the field, some complications were encountered. First one was the risk of having a failure in the C-POD system resulting from instantaneous distraction. Since C-POD was deployed with a rope, it is open to be routed by the strong currents. While Eastern-most stations were covering during October 2014 cruise, rope was directed below the carina of the vessel and withdrawn to the propeller of the ship. Although C-POD system was not affected, this trauma caused SD card removal and data loss. Second complication could be fisheries sonar. Fisheries sonar (echo-sounder) was an evitable noise source for the CPOD, because it had operated continuously throughout the research. Nonetheless, it was avoidable from the data because of the success of classifier in specification (Kerno classifier). Obvious peculiar characteristics of fisheries sonar enabled easy visual validation which increased the success in sonar noise elimination. Firstly, the frequency profile of the sonar (Figure 28/b) was extremely narrow-banded and perfectly matching with the frequencies of the echo-sounders: 38 kHz and 120 kHz. 200 kHz echo sounder was above the sensitivity range of device, therefore not observing it in the CPOD data was an expected result. Secondly, amplitude profile (Figure 28/a) revealed how the echo-sounder pulses with different frequencies matches in time, in other words, released simultaneously. Thirdly, ICI of the received Sonar trains (Figure 28/c) were stable in contrast to the highly variable nature of ICI of cetaceans. Furthermore, this ICI was higher than it would be expected from a cetacean and was perfectly matching with the ping rate of the echo sounder (0.5 sec).

The train clicks of harbor porpoises had very narrow frequency profile with average modal frequencies between 123 and 128 kHz frequencies (min: 122 kHz, max: 130 kHz) with highly variable amplitude profile (between 36- 82 dB SPL; min 39 dB SPL, max: 250 dB SPL) (see Section 3.2.2; Figure 27 /b, Table 8 and Table 9). According to the in tank experiments of Mohl and Andersen (1973), echolocation clicks of harbor porpoises have between 120 and 140 kHz peak frequency (cited in Madsen & Wahlberg, 2007) which is slightly less narrow-banded and at higher frequencies than that of dolphins. Besides, according to a more recent study, peak frequency of harbor porpoise echolocation clicks were 127.5 kHz (W. W. Au, Kastelein, Rippe, & Schooneman, 1999). A slight difference is always acceptable between tank experiments and observations in the wild. Source level (amplitude of the click) was also lower than what is expected (162 dB; Mohl and Andersen, 1973). As appreciated by scientists, recording sounds in the wild can be difficult, which directs scientist to choose tank experiments. Together with this, having a group of animals in a tank merely represents an artificial society that is in one way similar to a society in the wild (W. W. L. Au & Hastings, 2008).

Number of cycles of harbor porpoise clicks (cycle of clicks per second) were higher than that of Dolphin species as expected (Chelona Limited, *Validating Cetacean Detections,* 2013). Signals of Tursiops and other dolphins measured in tanks tend to have source levels of about 170–180 dB, whereas in open waters the source levels can increase to about 210–225 dB (Au, 1993). In this respect, amplitude of investigated dolphin click's a was matching (between 100-120 SPL in average for a train (Table 6 and Table 7); with a min 10 and max 255 SPL for individual clicks)

Short-beaked common dolphin were chosen for the assessment in fisheries hydro-acoustic analysis. First reason is the fact that, they are more numerous and more frequently encountered; which provides us more data to drive a methodology for detection. Second reason is the peak frequency of short-beaked common dolphins; short-beaked common dolphin clicks have a peak frequency between 23 – 67 kHz (Au, 1993). Resultant higher energetic response in 38 kHz echo-sounder is advantageous in many ways. Firstly, 38 kHz transducer has a wider physical surface, which provides greater click gathering surface than 120 kHz transducer. Secondly, since there is higher Rayleigh scattering for higher frequencies (Simmonds & Maclennan, 2005), there is less noise to be eliminated in 38 kHz data than 120 kHz data. Another advantage for us to build up this methodology comes from one peculiar structure of the Black Sea: its anoxic (without oxygen) nature after 200m depth. Due to the past geological events, its shape and its specific water balance, approximately 87 % of the Black Sea is entirely anoxic and contains high levels of hydrogen sulphide (Joiris et al., 2001). This give rise to a largely absent deep pelagic and benthic organisms as well as pelagic fishes. Therefore, dolphins are expected to inhabit oxic waters which gives us higher chance to encounter their vocalizations. Similarly, due to the absence of organisms approximately below 200 m, it is advantageous to process noise spikes and dolphin clicks over a clear background.

Another advantage is the appearance of *Dolphin marks* (see section 2.3.3.2); they were observed to appear as a few to many intermittent vertical lines extending across entire ping with increasing intensity with depth. This is hypothesized to being result of ICI (inter-click interval) of short-beaked common dolphins (Figure 26) and TVG function. ICI (Inter-click interval) of short- beaked common dolphin (see the chapter 3.2.2 Train Details; Figure 26) is shorter than the average ping interval used throughout the survey (ping rate: 0.5s). With the effect of TVG function, dolphin vocalizations amplified more through the end of the click train. As a results, they become more evident on the background noise and fish echoes.

5. CONCLUSION- Black Sea Cetaceans From Past to Present

Black Sea cetaceans face several threats like illegal direct killing, overfishing, habitat degradation, disturbance and incidental capture in fishing gear (Birkun, 2002). As a result of these threats, their populations are now endangered (Phocoena phocoena ssp. relicta and Tursiops truncatus ssp. ponticus) or vulnerable (Delphinus delphis ssp. ponticus) (IUCN Red List of Threatened Species). In order to remediate these threads, many efforts must be concentrated to understand distribution and abundance of these animals. This research was intended to provide required scientific data for the conservation of these endemic species.

Hydro-acoustics is promising in cetacean detections, since it inevitably captures some of their vocalizations. In our case, hydro-acoustics research that has performed in the context of cetacean detection, has provided fund for such an extensive observational research (approximately 150 000 km^2). More importantly, it gave rise to the development of a new methodology for the cetacean detection. Apart from the future potentials of benefiting from fisheries and/or fisheries acoustical researches for the cetacean inspection, we now can also comment on the past distribution of cetaceans by observing fisheries acoustical data that had already been collected. In order to conclude and verify this new methodology two other methodologies used in addition to Hydro-acoustics: Cetacean observation and C-POD acoustics. When hydro-acoustic detections were investigated, a decreasing trend in detections was observed as diverging from a visual observation point (see section *2.3.4 Verification of Hydro-acoustics as a Tool for Cetacean Observation*). Besides, high agreement was observed between the detections of three methodologies (*2.3.5Assessing Consistency between Methods).* In the light of these verifications, hydro-acoustic was concluded as a new tool for cetacean detection.

The significance of this new methodology lies in the low sampling cost, past-monitoring and continuous sampling it provides. Due to its economic value, research-es focusing on fisheries are highly regarded which facilitates the research fund. Therefore, Black Sea researches are generally focused on fisheries researches which usually requires hydro-acoustic sampling. Therefore, it is economically convenient to use hydro-acoustic researches for cetacean inspection. Besides, previously collected hydro-acoustic data can be processed to investigate past distribution/ abundance of cetaceans. Lastly, contrary to the traditional methods such as observational sampling, hydro-acoustic sampling can performed day and night. Therefore, hydro-acoustic sampling provide continuous sampling for cetacean inspection.

All three methodology results investigated to reach distribution and abundance of cetaceans. Higher concentration of cetaceans in the Eastern Black Sea concluded as the result of their prey distribution. Coastal fish preys such as such as Black Sea anchovy (*Engraulis encrasicolus ponticus*) and Black Sea sprat (*Sprattus sprattus phalaericus*) forms seasonal aggregations (i.e. during winter) and regular mass migrations (Tzalkin 1940; Notarbartolo-Di-Sciara & Reeves, 2006). Harbor porpoises were concluded as holding coastal distribution while other species were relatively offshore. Abundance of Black Sea cetaceans were estimated with all three methodologies performed. According to the assessment, there are approximately 130 000 short-beaked common dolphins (140000 by observational sampling and 116000 by hydro-acoustical sampling), 25 000 harbor porpoises (5 300 by observational sampling and 41 300 by C-POD sampling), 1 200 bottlenose dolphins (2 200 by observational sampling and 200 by C-POD sampling). During most of the 20th century abundance of harbor porpoises in the Black Sea was recognized as being higher than that of bottlenose dolphins and lower than that of Short- beaked common dolphins (Tzalkin 1940; Kleinenberg 1956; Birkun Jr., A.A. & Frantzis, A., 2008). Abundance estimations confirm that this pattern is still present.

Abundance estimation of cetaceans should be regarded as a primary approach since it holds several assumptions (see section *2.3.6 Abundance Estimation- Preliminary Approaches for the Estimation of Cetacean Abundance in Exclusive Economic Zone of Turkey*). Besides, the sampling period (October) coincides with the higher concentration of cetaceans in the sampling area (Eastern Black Sea) (Tzalkin 1940; Notarbartolo-Di-Sciara & Reeves, 2006). Therefore, year round abundance is expected to be lower. Still, overall findings were consistent with the previous scientific suggestions (Birkun Jr., A.A, 2008; Birkun, A. 2012; Birkun Jr., A.A. & Frantzis, A. 2008).

When the previous attempts to Black Sea cetacean abundance estimations investigated, findings of Çelikkale *et al.,* 1988 stand out. According to Çelikkale, there were 450 000 dolphins in the Black Sea. As compared with the findings of this study and scientific suggestions in the literature (at least several 10,000, and possibly 100,000 of common dolphin, several thousands and possibly in the low tens of thousands of harbor porpoise, at least several 1,000s of bottlenose dolphin; Birkun Jr., A.A, 2008; Birkun, A. 2012; Birkun Jr., A.A. & Frantzis, A. 2008), this finding seem to be overestimated. When the last 11 years of cetacean observation data investigated (see section *3.6 Temporal Variation of Cetaceans between 1996 and 2015*), a decreasing pattern was observed in the mean group size of cetaceans. This suggest that the cetaceans in the Black Sea are under the effect of past and present threats, which caused a patchy distribution in population with smaller groups. The greatest contribution above all stresses is concluded as the food stress since scattered prey distribution causes smaller groups with patchy distribution ((Bearzi et al., 1997). Another finding of 11years of cetacean observation data is the bigger group size formation in spring months (especially during May). Which is concluded as the result of coinciding birth season. Because, females with calves prefer to bind up with larger groups to decrease foraging stress (Bearzi et al., 1997).

To sum up, Black Sea cetaceans are concentrated mainly in the South-Eastern Black Sea. While common dolphins have region-wide distribution, harbor porpoises dominates coastal waters. Bottlenose dolphins were the rarest cetacean observed while harbor porpoises were more frequent. Coherently, abundance estimations suggests that common dolphins have the greatest population size, which is followed by harbor porpoises and bottlenose dolphins, respectively. Additionally, 11 years of past visual observation data demonstrates an overall decrease in Black Sea cetacean populations. Finally, the methodology developed proofed that the fisheries hydro-acoustical data collected for Fisheries purposes can be used for cetacean inspection.

6. FUTURE PROSPECTS

The hydro-acoustic methodology for cetacean sampling is a new technique, and therefore, an additional scientific research is required to comment on its features. Firstly, its range for cetacean detection is not known yet. In order to determine the range, a controlled experiment with specific number of dolphins should be planned. Secondly, it is not certain that how many dolphins produce vocalizations enough to give positive detection, i.e. what is the threshold for detection. Thirdly, only one cetacean species were used for the constitution of this methodology. It would be interesting to investigate other species as well. Lastly, same approach can be undertaken in different Sea. Because, anoxic nature of Black Sea and the resultant absence of organisms below 200m, have positive effect on the functionality of this methodology.

Observational sampling was performed with a limited number of observers, therefore, in the future studies, more numerous and experienced team should be formed. Because, observed species, especially bottlenose dolphin, have scarce distribution which makes it susceptible to observation bias.

Although, total sampling area in the Black Sea is significantly wide, it would be better to make basin-wide sampling. For this purpose, collaboration with other Black Sea countries holds high potential.

Sampling was limited to two months (July and October) and most of the assessments performed using only the data of the month with wider coverage (October). In order to have ecological perspective on organisms with such a long generation time, year-round sampling (or even sampling many years) could be more convenient. However, this is costly in terms of time and money. Therefore, collaborative and co-operative effort is required.

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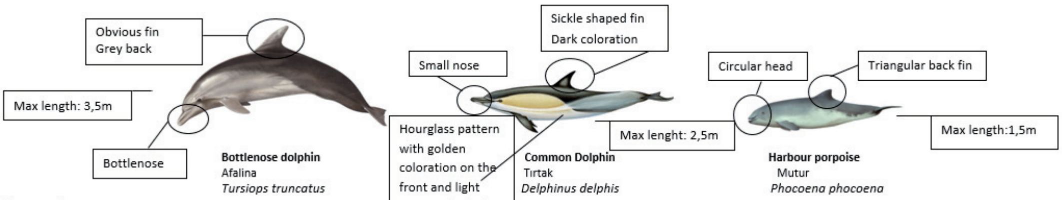
APPENDIX:

Appendix A: Cetacean Observation Protocols

METU-IMS Acoustical Research for the Distribution of Black Sea Cetaceans



Observation:

	Species			Number		Behavior	Bearing	Route	Distance	Date	Time	Lat. (DD°MM')	Long. (DD°MM')	Duration	Observer	Note
No	T.t.	D.d.	P.p.	Min.	Max.											

Please indicate species as T.t for *Tursiops truncatus* için, D.d for *Delphinus delphis* and P.p for *Phocoena phocoena*.
Behaviors are Travelling (TR), Travelling fast (TR-F), Short travelling (S-TR), Surface feeding (S-FE), Resting (RE), Socializing (SO), Travel Diving (TR-D).

METU-IMS Acoustical Research for the Distribution of Black Sea Cetaceans

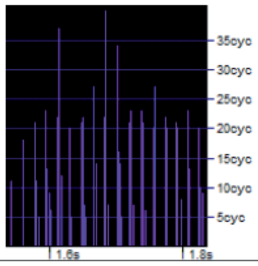
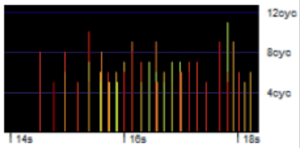
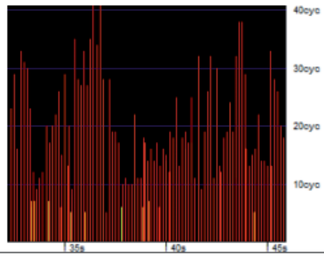
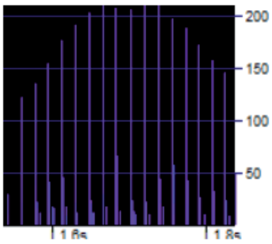
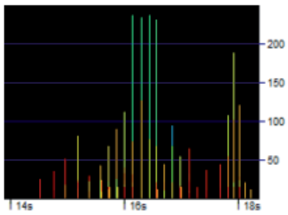
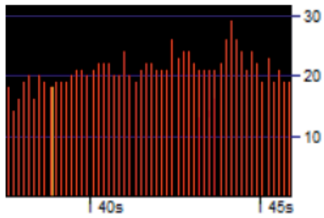
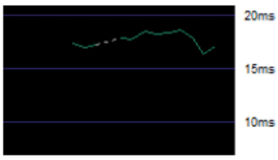
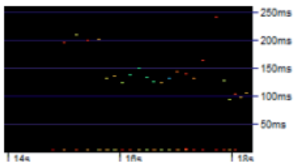
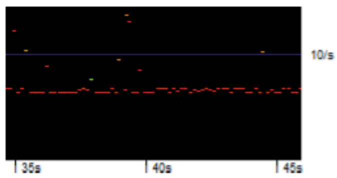
Acoustics:

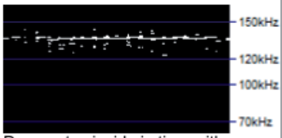
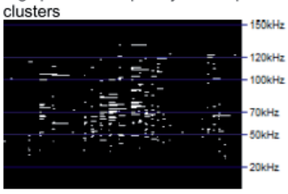
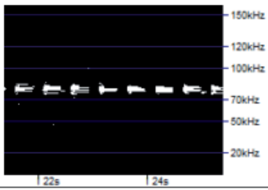
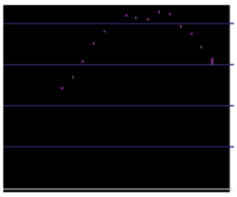
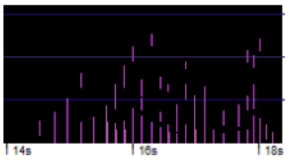
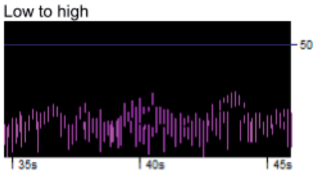
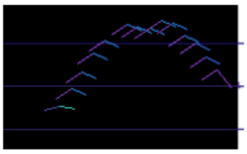
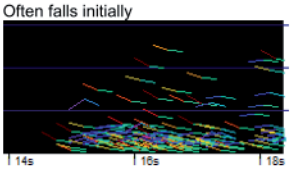
No	Sea-Weather condition	Echo-sounder				C-POD		Vessel				Note
		Running										
		38kHz	120kHz	200kHz	Closed	In the water	On the deck	Trawling	At station	Navigating	Other	

Sea-Weather condition according to Beaufort scale

Acoustics and Observation protocols are connected; they should have same No.

Appendix B: Train characteristics of species as stated in the manual provided by manufacturer (Validating cetacean detections.pdf, www.chelonia.co.uk/cpod_downloads.htm).

Feature	NBHF	Dolphin-like	Boat sonar
Duration number of cycles	Long: often > 15cyc. Rarely > 70cyc. 	Short: few >15cyc 	Very long: often >35cyc Clicks all < 10cyc in a train are rare 
Amplitude	Low - >255	Low - >255. More often >255 than NBHF	Low - >255
Amplitude profile	Often smooth with initial rise and final fall. 	Less smooth but often with initial rise and final fall. Often many clicks >255 	Long sequences with fluctuating amplitude 
ICI / click rate	Continually changing Max ICIs around 250ms = 4/s 	Continually changing Max ICIs longer >0.5s 	Regular or repeated pattern of ICIs. Min ICIs rarely <25ms = more than 40/s 

Frequency	Mostly 132kHz ± 7kHz  Does not coincide in time with a group of lower frequency clicks (these are 'mini-bursts' of unknown origin)	Big spread of frequency in multipath clusters 	Narrow band of frequencies, but sometimes + bands of harmonics or resonances at other frequencies 
Multipath clusters	Small – none to 5 clicks typical	Large, can last for 20ms or longer	Can be even larger and longer
Association	Groups of trains over 2 to many minutes	Groups of trains over 2 to many minutes	Persistent trains with same ICIs seen over the time the vessel is passing – usually less than 5 minutes
Background		Reverberation from dolphin clicks that are not identified as being in trains often contributes many 'stray' clicks to the background before, during and after an encounter.	
Bandwidth Mostly useful when it is low.	typically low or very low 	High 	Low to high 
Envelope Can be misleading due to framing errors.	Rise, then fall 	Often falls initially 	Flat