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Doctoral Thesis

Studies on the ecology of small cetaceans in the Istanbul Strait using acoustical information

Saho Kameyama
Abstract

Growing human populations and economic activity have a negative impact to marine ecosystem, such as marine pollutions, overexploitations, extinction of species and following shrink of biodiversity. Small cetaceans, which belong to suborder Odontoceti, are one of the important mammals that include likely-to-be-extinct species because of human activities in the last decade. More than half of small cetacean species are listed as “Endangered” or “Data Deficient” in the International Union for Conservation of Nature (IUCN) Red List. For effective conservation, the knowledge of their basic ecology is necessary.

In the present study, I focused on the population observed in the Istanbul Strait. Three species are observed in this area; harbor porpoise *Phocoena phocoena*, bottlenose dolphin *Tursiops truncatus* and short-beaked common dolphin *Delphinus delphis*. All of them are threatened subspecies but their ecology based on long-term constant observation has not well documented. I applied passive acoustic monitoring (PAM) with new species discrimination and animal density estimation method to fit on the situation of the Istanbul Strait and obtained the ecological information. The PAM is now widely used for study on small cetaceans, but the species discrimination based on acoustic information is still challenging. I proposed the discrimination method between harbor porpoise and delphinids and evaluated the accuracy by model. Also, I proposed the animal density estimation method which combine the line transect distance sampling approach with point transect estimations in consideration of the misclassification rate of species.

Two-year continuous PAM was conducted by fixed acoustic tag (A-tag) in the middle of the strait in 2010–2011. I revealed that harbor porpoise were detected most in spring (March–May), and there are almost no detections in winter (December–February). On the other hands, delphinids were observed throughout the year during nighttime. The porpoises distinctively showed short inter-click intervals that imply the feeding behavior in spring, suggesting that they were foraging the migrating pelagic fish in spring. It was supported by the previously reported stomach contents of the stranded porpoises which were found in the Marmara Sea and the Turkish coast of the Black Sea.
The animal density and distribution in whole strait were estimated by towed PAM in 2013. Animal density and distribution are one of the most fundamental information for conservation. In the Istanbul Strait, only the distribution of bottlenose dolphin has been available so far. I applied proposed density estimation method which can cover wider range of area by line transect approach based on acoustic cue based point transect distance sampling estimation. Also, I considered misclassification rate of species in estimator. The density was estimated as average of all seasons, it was 0.013 individuals km$^{-2}$ (CV = 0.612) for harbor porpoise and 0.033 individuals km$^{-2}$ (CV = 0.823) for delphinids, respectively. The distribution of harbor porpoise tended to be dispersed in the strait, but that of delphinids tended to be localized in north entrance to the Black Sea. The 50% kernel core area did not overlap between harbor porpoise and delphinids, suggesting the core habitat separation.

I developed the PAM methodology that is suitable for the small cetacean species appeared in the Istanbul Strait, and obtained the ecological information in present study. The results revealed the difference of seasonal behavior, distribution and animal density between harbor porpoise and delphinids within the strait. It implies the effectiveness of PAM also in the multi-species-observed noisy area, and the importance to consider the interspecific difference of ecology for effective conservation management.
Studies on the ecology of small cetaceans in the Istanbul Strait using acoustical information

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1.1. Social Environment Surrounding Small Cetaceans

Growing human populations and economic activity affect the marine environment in various ways, including effects from marine development, pollution, overfishing, and the introduction of invasive species. These impacts result in habitat alteration or loss and even the extinction of species. Biodiversity loss is now of great concern globally.

Small cetaceans are important species not only because many are endangered and threatened by anthropogenic disturbances but also because they are top predators in marine ecosystems. Top predators are considered as key species for maintaining the marine ecosystem because the predation risk has considerable effect on the marine trophic cascade and community by inflicting mortality and inducing behavioral modifications on prey and subsequent lower levels of species in a food chain (Heithaus et al., 2008; Verity and Smetacek, 1996). Because of their position in the food chain, cetaceans are useful to monitor ecological integrity.

Recent social demands for the protection of marine diversity have accelerated the introduction of Marine Protected Areas (MPAs). Although there is no conclusive definition of an MPA, the International Union for Conservation of Nature (IUCN) has defined an MPA as “A clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values” (IUCN 2008). In the
Convention on Biological Diversity (CBD)-tenth meeting of the Conference of the Parties (COP 10), it was declared that “10% of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures” to improve the status of biodiversity by safeguarding ecosystems, species, and genetic diversity. Many studies have suggested that the MPAs can be an effective tool to mitigate anthropogenic impacts on marine mammals (reviewed by Hoyt, 2011). However, this assertion has to take into account the ecology of the target species, such as resting, socializing, feeding, or choice of breeding ground (Ashe et al., 2010; Hoyt, 2011). Both the distribution and the spatiotemporal habitat use data are necessary to establish effective MPAs. A study used behavioral data to establish a conservation strategy for terrestrial animals (Jeffries and Brunton, 2001); however, this kind of approach is not widely used for MPAs. One explicit reason for this is a lack of basic ecological information regarding small cetaceans compared with terrestrial animals.

1.2. Passive Acoustic Monitoring

1.2.1. Development of Acoustic Monitoring

A traditional approach to observing wild populations of small cetaceans is through visual observation from the water surface. Previous studies have revealed the distribution, population density, surface behavior, or habitat use of animals based on visual observations. However, the information accessible from the surface represents merely a fraction of their total behavior manifested when cetaceans rise to the surface and only during daylight hours and during relatively good weather conducive to visual observations. In particular, in the case of hard-to-find species such as the harbor porpoise *Phocoena phocoena* and finless porpoise *Neophocaena asiatica*, effective visual observations cannot be performed at sea during wind speeds above the Beaufort wind scale 2 (light-breeze) (Evans and Hammond, 2004; Shirakihara et al., 2007). An additional problem is that the quality of information can show high variation between observers or between surveys because of the differences in observation experience or limitation of survey effort among individuals and surveys, respectively.
Within recent decades, acoustic observation has seen widespread use for research on small cetaceans as a complementary method of visual observation (Mellinger et al., 2007). In passive acoustic monitoring (PAM), we record the underwater sounds emitted from animals to obtain ecological data such as behavior, distribution, population density, or habitat usage. Notably, acoustics is almost the only tool that allows long-term observation of submerged animals that are not visible from the surface, and PAM has the added advantage of not interfering with the behavior of animals, and its use is not restricted by the availability of visible light or unfavorable weather conditions.

Small cetacean calls can be roughly classified into two categories based on physical features: tonal sound and pulsed sound (Fig. 1.1). The tonal sound can be described as a “whistle,” which has a relatively long duration over a narrow frequency band (2–35 kHz) and generally with frequency modulation. The pulsed sound has a shorter duration over a broad frequency band (5–150 kHz) and can be further categorized into two different types based on the general function: burst pulse and clicks. Burst pulse and whistle calls are considered to be used for intraspecies communication. On the other hand, clicks are mainly used within biosonar signals. It is known that small cetaceans emit clicks and listen to the echoes of sounds bouncing off various objects to achieve environmental cognition underwater. This phenomenon is called echolocation. Many small cetaceans frequently emit clicks at a rate of >1 click min⁻¹ on average, e.g., every 12.3 s in the harbor porpoise and every 6.4 s in finless porpoise on average (Akamatsu et al., 2007). We can easily determine whether a small cetacean species is located within the monitoring area by detecting clicks. It has been confirmed that the probability of animal detection using PAM is higher than that by visual observation for some species [e.g., Yangtze finless porpoise *Neophocaena asiaeorientalis asiaeorientalis* (Akamatsu et al., 2008; Kimura et al., 2013), the Ganges River dolphin *Platanista gangetica gangetica*, and the Irrawaddy dolphin *Orcaella brevirostris* (Akamatsu et al., 2013)]. PAM is now introduced at many research sites as the standard monitoring method.
Fig. 1.1 The spectrogram of a whistle (a), burst pulse (b), and click (c) recorded from a bottlenose dolphin [44.1 kHz sampling rate, 512 points of Fast Fourier Transform (FFT) size, hamming window, and 50% overlap].

1.2.2. Acoustic Monitoring Device: A-tag

There are three types of PAM based on the difference of survey platforms. A towed platform of PAM is generally employed simultaneously with visual observations. When using this method, a stand-alone underwater recorder or hydrophone with a cable is towed from the rear of the research vessel. Many studies have used this method to compare the probability of detection of PAM to that using visual observation (Akamatsu et al., 2008) and wide-range spatial distribution (Dong et al., 2011).

When using the stationary type of PAM, a stand-alone autonomous underwater recorder is used within a fixed monitoring point. The device is generally fixed on a
mooring, buoy, or the sea floor and can operate without human intervention after deployment. This method enables continuous long-term monitoring to determine the seasonal change in temporal distribution (Kimura et al., 2012; Verfuß et al., 2007) and population density (Hildebrand et al., 2015; Marques et al., 2013). More than 40 types of different autonomous underwater recorder have been developed (Sousa-Lima et al., 2013).

The bio-logging platform is additionally provided for PAM. Bio-logging is a relatively novel approach compared with the two previously mentioned survey platforms and is defined as “The investigation of phenomena in or around free-ranging organisms that are beyond the boundary of our visibility or experience” (Boyd et al., 2004). In the case of PAM, the stand-alone underwater recorder is attached to the animal. This method is commonly used in conjunction with another device, such as an accelerometer, thermometer, depth meter, or camera to obtain behavioral data from the same individual. The D-tag is a representative device that can record sounds, depth, temperature, and acceleration along with geomagnetic data in the latest version (Johnson and Tyack, 2003; http://soundtags.st-andrews.ac.uk/dtags/).

Although there are an enormous number of available recording devices, most can be used for only one of the three types of survey platforms. The acoustic tag (A-tag; Fig. 1.2) was initially invented for the bio-logging type of PAM (Akamatsu et al., 2005); however, it can also be used within a fixed and towed survey without major mechanical changes. The A-tag (ML200-ASII; Marine Micro Technology, Inc., Saitama, Japan) is an event recorder targeting the biosonar sounds (clicks), which records sound pressure and the time difference of arrival of sound (TDOA) between two hydrophones when the sound is higher than the preset threshold (138 dB peak-to-peak re 1 μPa). The A-tag does not store the waveform of sounds and consists of two hydrophones placed 60 cm apart, a central processing unit (CPU) (PIC18F6620; Microchip, USA), a 128-MB flash memory, and 2 UM1 batteries. The CPU, flash memory, and batteries are housed in a waterproof aluminum case (Fig. 1.2). A passive two-pole bandpass filter of 55–235 kHz, which includes the peak frequency of major small cetacean species such as harbor porpoise (129–145 kHz; Villadsgaard et al., 2007) and bottlenose dolphin (23–134 kHz; Au, 1993), was used.
The sensitive frequency of each hydrophone can be chosen at approximately 130 kHz or 70 kHz according to the target species.

Fig. 1.2 The fixed type (a) and towed type (b) of A-tag.
1.3. **Study Area**

1.3.1. **The Istanbul Strait (Bosphorus)**

The Istanbul Strait is located as the boundary between Europe and Asia which connects the Black Sea and the Marmara Sea (Fig. 1.3). It is one of the narrowest channels in the world with approximately 31 km long, 0.7–3.5 km wide and 35.8–110 m deep (Alpar and Yüce, 1998). The strait is consisted of 2 layers of water column because of the difference of water density, caused by different salinity and temperature, between the Black Sea and the Mediterranean Sea. Moreover, the water flow of each layer is opposite. The upper layer, which is consisted of the low salinity water from the Black Sea (approx. <20), flows from the Black Sea toward the Marmara Sea. On the other hand, the lower layer which is consisted of the high salinity water from the Mediterranean Sea (approx. >30), flows from the Marmara Sea toward the Black Sea (Tarkan et al., 2005; Yüce, 1996). This specific oceanographic feature functions as the biological barrier or corridor for Mediterranean or Black Sea species. The high salinity of the Black Sea water likely limits the distribution of some marine creatures. For example, 11 cephalopod species has been recorded in the Marmara Sea but no cephalopod is known from the Istanbul Strait and the Black Sea. The recorded decapod species is 177 in all Turkish water but only the 17 species can be found in the Black Sea (Öztürk and Öztürk, 1996). The benthic species is poor in the Black Sea water when compared with the Mediterranean Sea and the Marmara Sea because of the low salinity and the an intensive anoxic water.

Since the strait is the only water way connecting the Black Sea to Mediterranean Sea through the Marmara Sea, it is important corridor especially for the economies of the countries around the Black Sea. Official government statistics reported that 130 commercial cargo vessels and 2500 domestic vessels pass through the strait per day on average (Baş et al., 2015).
Fig. 1.3 Study area, the Istanbul Strait. The red arrow indicates the fixed acoustic observation point.
1.3.2. **Small Cetaceans**

Three small cetacean species from two families are regularly observed in the strait: one porpoise species, namely the harbor porpoise *P. phocoena* and two delphinids, namely the bottlenose dolphin *Tursiops truncatus* and the short-beaked common dolphin *Delphinus delphis* (Fig. 1.4–1.6). All three species are considered as genetically and morphologically independent subspecies that mainly inhabit the Black Sea. The species we observed in the strait possibly belong to these subspecies. Only the harbor porpoise was not only genetically and morphologically but also geographically isolated from the other populations approximately 5,000 years ago (Fontaine et al., 2010). Although observed delphinids in the strait were considered as belonging to the Black Sea subspecies, the extent of the area used as a habitat range within the region bounded by the Black Sea to the north eastern Aegean Sea through the Marmara Sea and Canakkale Strait (Dardanelles) remains unknown. All the observed delphinids are considered as endangered subspecies; the harbor porpoise and delphinids are listed as “Endangered,” whereas the short-beaked common dolphin is listed as “Vulnerable” by IUCN Red List of Threatened Species (Birkun 2008, 2012; Birkun et al., 2008). The Istanbul Strait, the Marmara Sea, and the Canakkale Strait are reported as important areas for all small cetacean species within the Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea, and contiguous Atlantic Area (ACCObAMS), which was signed among 23 countries in Europe (Notarbartolo di Sciara and Birkun, 2010; http://www.accobams.org/index.php). These areas are proposed as MPAs for the Black Sea small cetaceans; however, Turkey has to date not signed the agreement, and no MPAs currently exist along the Turkish coast (Notarbartolo di Sciara and Birkun, 2010; Baş et al., 2014).

Early findings suggest that short-beaked common dolphin migrate from the Mediterranean Sea to the Black Sea through the Marmara Sea and the Istanbul Strait during spring and return during autumn (Öztürk and Öztürk, 1996). In addition, a group of bottlenose dolphins and short-beaked common dolphins were observed to migrate from the Aegean Sea toward the Marmara Sea during April–May (Berkes, 1977). The trigger for these migrations is considered to be pelagic fish, such as sand smelt *Atherina boyeri*, sprat *Sprattus sprattus*, anchovy *Engraulis encrasicolus* and horse mackerel *Trachurus trachurus*, which migrate from the Aegean Sea or the Marmara Sea to the Black Sea during spring (Berkes, 1977; Dede et al., 2013; Öztürk and Öztürk, 1996).
However, regular migration might be prevented by the current heavy marine traffic and other ecological stresses affecting the strait (Öztürk and Öztürk, 1996). In addition, detailed information of the timing of migration, local distribution, behavior of each small cetacean species, or explicit evidence of migration in recent years is lacking.

Fig. 1.4 Bottlenose dolphins (Photo by Ayhan Dede).

Fig. 1.5 Short-beaked common dolphins (Adopted from Protected Resources Division, Southwest Fisheries Science Center, La Jolla, California. swfsc.nmfs.noaa.gov/PRD/)

Fig. 1.6 Black Sea harbor porpoise ((a) Photo by Sergey Krivokhizhin /Brema Lab. Adopted from Notarbartolo di Sciara and Birkun 2010; (b) Photo by Arda M. Tonay)
1.4. Objectives

The objectives of the current study are to develop the PAM methodology for multiple species observation and to obtain ecological information for small cetaceans observed in the Istanbul Strait. As mentioned in section 1.2, PAM is now widely used for small cetacean research; however, the simultaneous observation of multiple species is challenging because of the methodological limitations of discriminating between multiple species by acoustics. Because the ecology of each species must be different, especially in harbor porpoise, the ecology of each species must be determined for effective conservation, including seasonal behavior changes, animal density, and distribution.

1.5. Structure of Thesis

The outline of this thesis is organized as follows:

- Chapter 2: describes a method for discriminating between species using acoustics, between the harbor porpoise and delphinids.
- Chapter 3: describes a proposed new acoustic-based density estimation approach for application over a wide area with consideration of species discrimination accuracy.
- Chapter 4: describes the long-term seasonal change of occurrence and acoustic behavior in each family after adapting the newly developed species discrimination method described in Chapter 2
- Chapter 5: describes the wide-range distribution and estimated animal density after adapting the newly developed species discrimination method described in Chapter 2 and the proposed density estimation approach described in Chapter 3.
- Chapter 6: is general discussion regarding the effectiveness and limitations of the newly developed PAM methodology in Chapter 2 and Chapter 3. In addition, this chapter integrates the results of Chapter 4 and Chapter 5 with implications for the conservation of small cetaceans in the Istanbul Strait.
Chapter 2

Acoustic Family Discrimination Method

Summary

A simple discrimination method between Delphinidae and Phocoenidae based on the comparison of the intensity ratios of two band frequencies (130 and 70 kHz) is proposed. Biosonar signals were recorded at the Istanbul Strait (Bosphorus) in Turkey. Simultaneously, the presence of the species was confirmed by visual observation. Two types of thresholds of two-band intensity ratios, fixed and dynamic threshold, were tested for identification. The correct detection and false alarm rates for porpoises were 0.55 and 0.06 by using the fixed threshold and 0.74 and 0.08 by using the dynamic threshold, respectively. When the dynamic threshold was employed, the appropriate threshold changed depending on the mix ratio of recorded sounds from both Delphinidae and Phocoenidae. Even under biased mix ratios from 26% to 82%, the dynamic threshold worked with >0.80 correct detection and <0.20 false alarm rates, whereas the fixed threshold did not. The proposed method is simple but quantitative, which can be applicable for any broadband recording system, including a single hydrophone with two frequency band detectors.
Chapter 3

Density Estimation Using Acoustic Cues

Summary

Reliable estimation of population density is one of the most basic information to understand ecology and the status of conservation of wild animals. Today, the distance sampling is the most common density estimation method for small cetaceans. In this method, the distance from the survey line (line transect) or point (point transect) to objects of interest, usually it is an individual or a cluster of animals, is used as key information for density estimation (reviewed by Buckland et al., 2001). Recent rapid development of PAM for marine mammals provided the idea of using animal’s sounds to density estimation. Acoustic cue based density estimation method was developed for point transect sampling; however, the coverage area by single acoustic detector is quite limited. For reliable estimation in broad survey area, we need several detectors. In addition, current estimation has not considered the misclassification of detected species. New density estimation method which combines line transect survey approach with point transect estimator with consideration of species misclassification was proposed in this chapter. It can be useful for multi-species density estimation in large survey area.
Chapter 4

Seasonal Change in Presence and Acoustic Behavior

Summary

To understand how sympatric small cetaceans co-exist in the Istanbul Strait, long-term fixed passive acoustic monitoring of harbor porpoises and delphinids was conducted for two years (2010–2011) in the middle of the strait by applying the species discrimination method described in Chapter 2. Both families of cetaceans appeared in the monitoring area from spring to autumn, but there are only a few detections of porpoise in winter. Clear seasonal differences in location and behavior were found only for porpoises. Porpoise click trains were detected more from the south of the monitoring station in spring. Delphinids appeared in all directions during the nighttime (2100–0400 h) in all seasons. The median inter-click interval for porpoises was 40.6 ms in spring, but it lengthened to around 100 ms in summer and autumn. Those of delphinids did not show such clear differentiation among seasons, ranging from 64.0 ms to 88.8 ms. The strait is a well-known migration pathway for pelagic fish in spring. The results in this chapter suggest that the porpoises and delphinids come to the middle of the strait for different reasons, and the short inter-click intervals imply that intensive feeding behavior is exhibited only by porpoises in spring.
Chapter 5

Distribution and Density

Summary

Information on the distribution and population density is essential for the conservation management of wild animals, including the small cetaceans in the Istanbul Strait. Most of this information has been obtained based on visual observation; however, recent rapid development of the PAM methodology has enabled the estimation of the distribution and population density of small cetaceans by monitoring of their sounds. Boat based acoustic towing survey was conducted within whole Istanbul Strait in 2013. The animal density was estimated using the proposed density estimation method in Chapter 3 and the core was core area of distribution was estimated by using the kernel method. The density was estimated as average of all seasons, it was 0.013 individuals km$^{-2}$ (CV = 0.612) for harbor porpoise and 0.033 individuals km$^{-2}$ (CV = 0.823) for delphinids, respectively. The distribution of harbor porpoise tended to be dispersed in the strait, but that of delphinids tended to be localized in north entrance to the Black Sea. The 50% kernel core area did not overlap between harbor porpoise and delphinids, suggesting the core habitat separation.
Chapter 6

General Discussion

6.1. Ecology of the Small Cetaceans in the Istanbul Strait with the Implication for Conservation

In this study, I proposed acoustic species discrimination method (Chapter 2) and density estimation method (Chapter 3) which complement the defects of existing PAM methodology. In addition, I applied proposed methods to reveal the seasonal change in presence and underwater behavior of harbor porpoise and delphinids (Chapter 4), and to estimate the density and distribution (Chapter 5) in the Istanbul Strait. The possible difference of strait utilization between harbor porpoise and delphinids was revealed by summarizing the results in Chapter 4 and Chapter 5.

The harbor porpoises were observed within whole strait, but dispersed core areas were estimated in the middle to north parts of the strait from the towed PAM. Two-years fixed PAM in the middle point of the strait revealed porpoises were mainly detected from spring to summer and almost no detections in winter. Previous study suggested that the small cetaceans come into the strait affected by the migrating pelagic fish (Öztürk and Öztürk 1996) which is suggested as the main prey in spring to early summer for them (Tonay et al., 2007). Our results were consisted with these studies, porpoise appeared to the monitoring area in spring to summer, and have used the sonar signals with short ICIs in spring. It is known that the short ICIs were observed when they were either of socializing or feeding. Taking into account the previous studies, the observed short ICIs possibly connected with the feeding behavior. Besides prey
availability, marine traffic may affect the presence on animals; however, the all commercial fishing were banned regardless of seasons around fixed monitoring area and the number and type of vessels observed around monitoring area is not highly variable among seasons (Baş et al., unpublished data; Dede et al., 2013). Therefore, ship traffic is unlikely to provide the reason of seasonal difference in presence.

The delphinids were mainly observed in the north part of the strait by the towed PAM. This localization trend was supported also by previous study (Baş et al., 2014). Previous visual observation suggested that there are not many encounters in the middle point of the strait without summer; however, two-years fixed PAM in this area revealed that they were detected during nighttime throughout the seasons. The results of our studies did not show clear seasonal change of occurrence frequency and sensing distance, it did not support the hypothesis that small cetaceans come to the strait for foraging in spring at least in the middle of the strait. It is suggested that the primary prey species are slightly different between harbor porpoise and delphinids (especially bottlenose dolphin) in the Black Sea (Birkun 2002). In addition, bottlenose dolphin distribute in the south and north part of the strait during daytime in spring (Baş et al., 2014). Taking into account these previous studies, it is suggested that the delphinids distribute north or south of the strait during daytime but come to or pass through the middle of the strait during the nighttime, and used different prey or geographical prey ground from harbor porpoise.

This study revealed the possible separation of geological distribution and feeding ground/species between harbor porpoise and delphinids within the Istanbul Strait. In terms of conservative ecology, we need to set the different conservation management strategy for each species based on the difference of their usage of the strait. Our results suggest that small cetacean species, especially delphinid species, appear in the middle of the strait not only in spring but also in other seasons. Baş et al., (2014) proposed MPAs for bottlenose dolphins with seasonal priority, including the middle of the strait during spring. I agree that the middle of the strait is important to both harbor porpoises and delphinids as a feeding ground and traveling pathway in spring; however, we should consider that delphinids might use this area throughout the year during the nighttime. This mismatch is a good example of showing the traditional visual
observation might not enough to construct effective management strategy. It is necessary to use multiple methods, such as PAM for nighttime observation, tracking by tag to estimate individual home range or genetic sampling to examine the group structures, to understand the real biology of animals.

6.2. Applicability of the Proposed Methods to Other Species

In this study, I proposed acoustic species discrimination method (Chapter 2) and density estimation method combining the line transect approach to the point transect estimation. I discuss the possibilities of future applications of proposed method in this section.

The acoustic discrimination between harbor porpoise and delphinids with estimation of accuracy is possible by using one parameter, two-frequency intensity comparison, in proposed method. I developed this method using the acoustic event data-logger A-tag in the Istanbul Strait; however, this method can be applied to other species producing narrow-band high frequency (NBHF) and broad band clicks, and by other acoustic device. So far, totally three families, one genus and two species were reported as producing NBHF clicks; family Kogiidae, Phocoenidae, Pontoporiidae, genus Cephalorhynchus, and two species of Lagenorhynchus hourglass Dolphin and peale's dolphin (Morisaka, 2012). Whereas, most of other small cetaceans produce broad band clicks. There are many areas in the world that both NBHF clicks type and broad band clicks type species are observed simultaneously. Especially most of family Phocoenidae species inhabit coastal water, which is the area many PAMs are conducted in, without overlapping the habitat with more than two NBHF clicks type of species. The proposed method is effective to observe coastal NBHF clicks type of species with discrimination from other broad band type of species. In addition, two-band intensity ratio between low frequency (around 70 kHz) and high frequency (around 130 kHz) can be obtained by other broad band acoustic recorders. Obtaining the ground truth acoustic data which is confirmed by visual observation is the most important part of this method. If we obtain the ground truth data once, the proposed method can be used for different species independent from the monitoring device.

The density estimation method which combines the line transect approach with
point transect estimation by considering misclassification of species was proposed in present study. The previous acoustic line transect sampling need to count the individual animals to estimate density, by counting the number of track line of sounds as individual (Gerrodette et al., 2011), the number of each detection as individual by assuming that animals are not to be detected as cluster (Gillespie et al., 2005; Hastie et al., 2003) or the number of each detections with estimation of the group size obtained by visual observations (Barlow and Taylor 2005). If the survey area was exposed by high density of marine traffic, sometimes the track of phonating animals were covered by underwater noises. These heavy marine noises make the individual counting difficult. In addition, it is not reasonable to assume that animals were detected not as cluster except some solitary species. On the other hands, point transect sampling do not need to count individual animals, we need the acoustic cue instead. However, we need several number of monitoring device to cover large survey area, it is costly and might need some effort to equal the parameter of a detections among different devices. Present method is effective in the area that has similar situations as the Istanbul Strait which is exposed heavy marine traffic and difficult to employ several monitoring device.

Similar with the visual observations, PAM is now one of the standard methods to study marine mammals. However, still there are some limitations to expand the applicable study area and species, such as ambiguity of species classifications and deficiency of standardized equipment or detection threshold. I believe this study solved some of these problems and contributed for further development of PAM methodology.
References


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