Marine Mammal Science

MARINE MAMMAL SCIENCE, **(*): ***–*** (*** 2014)

DOI: 10.1111/mms.12202

Selection of critical habitats for bottlenose dolphins (*Tursiops truncatus*) based on behavioral data, in relation to marine traffic in the Istanbul Strait, Turkey

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ABSTRACT

Marine traffic is a significant source of disturbance to the bottlenose dolphin population in the Istanbul Strait, Turkey. To determine the importance of this threat, behavioral data together with sighting data of both dolphins and marine vessels were assessed for 2012. The current study suggests that the Istanbul Strait is used mostly as a foraging ground for bottlenose dolphins. Nonetheless, in the same area there is intense marine traffic as well as increase of industrial fishing activities in autumn. The findings of this study indicated that high-speed ferries and high-speed boats were the most significant source of disturbance. Moreover, increased densities of fishing vessels resulted in a drastic decline of dolphin sightings. This study highlights that vessel type, speed, distance, and density have a cumulative negative effect on dolphins. In order to mitigate the impacts of vessels, it is necessary to establish managed areas in the Istanbul Strait. Such proposed areas should limit speed and density of marine traffic and have specific restrictions on vessel routes. We propose three different seasonal managed areas according to their values as critical habitat for bottlenose dolphins in the strait.

Key words: marine traffic, bottlenose dolphin, *Tursiops truncatus*, behavioral disruption, critical habitats, managed areas.

Bottlenose dolphins (*Tursiops truncatus*) are commonly found in continental shelf waters throughout their global range (Notarbartolo di Sciara 2002) notably coinciding with areas of high human density and coastal/oceanic usage (Notarbartolo di Sciara and Birkun 2002). According to the IUCN Red List of Threatened Species (IUCN 2014), while the Mediterranean subpopulation of bottlenose dolphins are classified as vulnerable (VU) under A2cde categories, the Black Sea subspecies (*Tursiops truncatus ponticus*) is in greater risk of decline and classified as endangered (EN) under the same categories mentioned previously.

In general, interactions between marine traffic and cetaceans have been the focus of considerable research effort over the last decade due to the extensive overlap of human activities with dolphin habitats (Nowacek *et al.* 2001; Lusseau 2003*a*, 2005, 2006; Williams *et al*. 2006). Intense and increased use of coastal and maritime areas has created environmental pressure on the Mediterranean and Black Sea (European

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Commission 2013). Due to the semi-enclosed nature of those basins, any anthropogenic impact to marine life is identified as a conservation threat (Hoyt 2005) and subsequent effects on the natural environment would be particularly severe (Notarbartolo di Sciara and Birkun 2002).

Cetaceans react to marine traffic either with short or long-term behavioral changes. These can manifest as distinct behavioral changes or abandonment of the affected habitat, respectively (Bejder *et al.* 2006*a*, *b*). The biological importance of these short-term behavioral changes needs to be understood. Lusseau (2004) noted that behavior budgets are directly related to an animal's energy budget, thus changes in an animal's behavior patterns, even if short-term, result in energy depletion for that individual. These individual effects can eventually contribute to long-term consequences for the population.

Marine protected areas (MPAs) aim to protect habitats that either encompass the entire population or serve unique functions for the species, such as habitat patches for feeding, socializing, breeding, or resting. Identifying critical habitats for cetaceans, in particular those of unique functions, is the first step toward good management of MPAs for cetaceans (Hoyt 2005).

The Istanbul Strait (41°13′–41°00′N, 29°08′–28°59′E) lies between the Black Sea and Marmara Sea. It is 31.7 km long and 3.6 km wide at the northern entrance and 2.8 km wide at the southern entrance. It is one of the narrowest straits in the world with a minimum distance of 698 m between the European and Asian coasts. The depth of the strait varies from 35 to 110 m midstream, with an average of 60 m (Özsoy *et al.* 2000) (Fig. 1). Heavy domestic and international marine traffic is found in the Istanbul Strait. In 1936, when the Montreaux Treaty was signed, the number of vessels passing through the Istanbul Strait was only 4,500 per year, whereas today about 46,000 vessels pass through the Istanbul Strait annually (Anonymous 2013). Official statistics reported that on average 130 commercial cargo vessels and 2,500

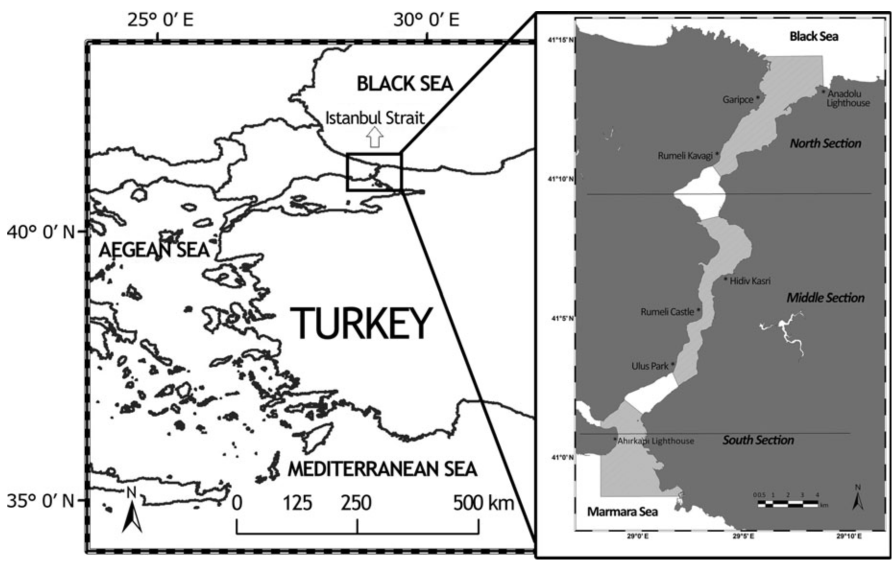

Figure 1. Observation stations in the Istanbul Strait, Turkey. Coverage of land based survey is shown in light gray.

domestic vessels pass through the strait per day (Istanbul Port Authority 2011, Anonymous 2013).

Concomitant with its economic value for shipping, fishing, and recreation, the Istanbul Strait also plays a vital role for marine life. It has three major ecological roles; as a biological corridor, a biological barrier, and an acclimatization zone (Öztürk and Öztürk 1996). It is an important fishing ground and an important habitat for cetaceans (Öztürk and Öztürk 1996, Atar and Ateş 2009). The bottlenose dolphin (*Tursiops truncatus*), short-beaked common dolphin (*Delphinus delphis*), and harbor porpoise (*Phocoena phocoena*) are frequently observed in the area (Öztürk 1996).

Earlier findings suggest that minimizing vessel-dolphin interactions in critical habitats may be an important element in the management of anthropogenic impacts (Simmonds 2004, Anonymous 2010). This kind of management response requires both information on dolphin abundance in those areas, and more fundamentally, an understanding of how sensitive the animals are to different types of impacts. In order to establish this understanding, it is necessary to create a detailed ethogram of behaviors for the affected population and to compare such behaviors across various levels of impact (Lusseau 2003*b*). Thus, our approach was to define critical habitats based on behavioral and sighting data of bottlenose dolphins within the Strait. This study aims to delineate potential managed areas where both dolphins and marine traffic are concentrated, according to their critical habitat features.

Materials and Methods

Study Areas

To collect and analyze data on marine traffic and dolphin behavior, the Istanbul Strait was divided into three sections: South (Ahirkapi Lighthouse), Middle (Ulus Park, Rumeli Castle, and Hidiv Kasri), and North (Rumeli Kavagi, Garipce, Anadolu Lighthouse). Seven observation points were selected, spread along the strait, for land-based surveys (Fig. 1, Table 1). Boat-based observations were made in the entire strait from the southern entrance to the northern entrance.

Data Collection

Data were collected by systematic land and sea observations between 1 January and 30 December 2012. Observations were conducted at each observation point for a minimum of seven hours per day over multiple days, resulting in fourteen land-based

Table 1. Coordinates and altitude of stations in the Istanbul Strait, Turkey.

Station	Coordinates		Altitude (m)
Ahırkapı Lighthouse	41°0′22.49″N	28°59′7.75″E	38
Ulus Park	41°3′42.12″N	29°2′10.89″E	30
Rumeli Castle	41°5′3.41″N	29°3′20.55″E	44
Hidiv Kasri	41°6′18.35″N	29°4′25.25″E	90
Rumeli Kavagi	41°10′40.81″N	29°4′22.48″E	45
Garipçe	41°12′44.38″N	29°6′36.22″E	45
Anadolu Lighthouse	41°13′2.98″N	29°9′7.56″E	55

surveys per month. Seasons were classified as autumn (September, October, November), winter (December, January, February), spring (March, April, May), summer (June, July, August).

We recorded the position and activity of both vessels and dolphins *via* a FOIF LP215L theodolite. Reference points for each observation site were selected and their related azimuths were calculated in order to produce accurate horizontal and vertical angle measurement *via* Pythagoras software (Gailey and Ortiz 2000). Reference points were mostly landmarks at sea level and kept constant throughout the study. When vessels were present concurrent with dolphins, coordinate points were recorded for both the vessels and the focal dolphin group alternately. Although it was not always possible, we attempted to record coordinates for dolphin groups at every surfacing. Vessel coordinates were taken at the moment the vessel entered and left the observation area, as well as whenever a change in direction was made within the area. If the focal group was out-of-sight for more than 10 min, the next sighting was declared as a new group. On average, dolphin groups were visible up to approximately 3,000 m away from each shore station. Pythagoras Version 1.2 software was used to transform theodolite readings into geographic positions, to visualize paths and swimming velocity of dolphins and boats, and to estimate distances between boats and dolphin groups (Gailey and Ortiz 2000).

Behavioral Sampling

A focal group sampling method was used to determine the main activity of the group, rather than focal individual sampling. Group sampling allows for sampling of multiple individuals simultaneously, as well as sampling of behaviors of multiple groups and in this study, proved to be the best method based on less-than-perfect observation conditions, particularly because a primary goal of this study was to determine if dolphin behaviors were affected by differing levels of marine traffic. Although Altmann (1974) and Mann (1999) recommend focal individual sampling or scan sampling instead of focal group sampling, due to the potential for observer bias, observational conditions in this study required a less intensive sampling methodology. Throughout the study, field observers simultaneously collected data on the focal groups including coordinate, group size, composition (*i.e.*, juveniles present), behavior, distance to all vessels within 1,000 m, and reactions to vessels present. At many of the observation points with dense marine traffic, (some sites having up to 50 vessels within 10 min), there was not enough time to collect individual level data together with the quantitative data on marine vessels. Therefore, to test the accuracy of our group sampling, focal group sampling together with scan sampling were carried out during the pilot study. The results from focal group and scan sampling were similar. Thus, only focal group sampling method both for land and sea observations was used for the rest of the study. The behavioral state of dolphins was sampled every 3 min after the first sighting. Behavioral states were defined as traveling, diving, surface-feeding, resting and socializing, and milling (Table 2). The behavioral states were defined to be mutually exclusive and cumulatively inclusive and as a whole, they described the entire behavioral budget of dolphins. The behavioral states were similar to those used in previous studies (Lusseau 2003*a*, Constantine *et al.* 2004), however, they were modified for the Istanbul Strait according to our pilot study.

When the distance between marine vessels and dolphins was less than 400 m, marine vessel presence was recorded as "present" and if the distance was >400 m, it was recorded as "absent." The limit of 400 m was determined based on previous studies

Table 2. Definitions of behavioral states.

Behavioral state	Definition
Traveling	Group is moving steadily in a constant direction with short and relatively constant dive intervals. *Travel-fast*: Group is moving steadily in a constant direction with short dive intervals but the speed of the group is faster. *Travel-dive*: Group is moving steadily in a constant direction but the time spent underwater is more than the time spent at the surface.
Diving	Direction of group movement varies but is characterized with steep dives and direction of the individuals are varies. Most likely represents feeding behavior.
Surface-feeding	Direction of all movements varies but is characterized by a great deal of activity and splashing at the surface. Fish may also be seen from the surface.
Resting and socializing	*Resting*: Group is moving steadily in a constant direction at very low speed with short dive intervals. Group activity level is very low with no splashing at the surface. *Socializing*: Diverse interactive behavioral events are present.
Milling	No clear movements. Individuals face different directions.

(Constantine and Baker 1997, Bejder and Samuels 2003, Lusseau 2003*a*, Bejder *et al.* 2006*b*) and subsequently, was termed the "reaction zone." In addition, minimum distances were also estimated for neutral reactions of dolphins towards the vessels, and this confirmed choice of the 400 m limit.

To determine the effect of marine vessels on dolphin behavior, behaviors both preceding and following vessel encounters were identified. Preceding behaviors were defined as the core behavior of a focal group prior to a vessel encounter. The reaction of dolphins to marine vessels was categorized as follows: (1) "Positive" when dolphins were swimming toward vessels, (2) "Negative" when dolphins were swimming away from vessels, (3) "Neutral" when dolphins did not change behaviors despite vessel presence, and (4) "Undetermined" when the reaction was not identifiable. In addition, vessel type, approximate distance from the focal group, and total vessel abundance was recorded within a 100 m, 400 m, and 1,000 m radius from the group.

Marine Vessel Sampling

Marine vessel presence was recorded every 10 min during land observations. Vessels were classified into seven categories: high-speed boats (HSB), fishing boats (if the length was <10 m) (FB), ferries (FE), high-speed ferries (HSFE) and fishing vessels (if the length was >10 m and using a sonar system) (FV), and big (the length >200 m) (BCS) and small commercial cargos (the length <200 m) (SCS).

Boat Surveys

Boat surveys were carried out for a minimum of 7 h, twice a month to collect behavioral data in relation to marine traffic and to conduct a photo-ID study. GPS points of both the research vessel and the dolphin groups were recorded using the software, Logger 2010, Version 5. During boat surveys, a protocol was developed to eliminate the potential effects of the observation vessel and to minimize its impact on the focal dolphin group. As such, our observation vessel approached focal dolphin groups from the side or rear of the group at an idle speed whenever possible. The focal group was followed from a minimum distance of 50 m to a maximum of 400 m and if the dolphins approached closer, our vessel speed was reduced or the engine was shut off. Any changes in the behavior of the focal group due to the presence of the observation vessel were also recorded in order to measure our impact.

Data Analysis

SPSS 20 statistical package was used to carry out the statistical analyses on the spatio-temporal patterns of dolphin sightings. Dolphin sightings, the number of marine vessels present, reactions of dolphins under different vessel types and vessel densities, behavioral states, and behavioral transitions under seasons, sections, and marine vessel presence were analyzed. General log-linear analyses were carried out to determine if there was a relation between dolphin sightings and seasons or sections. Moreover, general log-linear analyses were also employed to examine the effect of season and section on the number of marine vessels. The Z-test for proportions was employed to analyze the effect of different marine vessel types on the reaction of dolphins. Even though the type of marine vessels is an important factor on dolphin reaction, it is by no means the only potentially important element. Therefore, the impact of overall marine vessel density must also be examined. As such, the number of marine vessels within a 400 m radius from a dolphin group was counted for every ten minutes and the relation to the behavioral reactions of dolphin groups were also analyzed through the Z-test for proportion. General log-linear analysis was conducted to examine the effect of marine vessel presence, season, and section on the likelihood of transitions between preceding (state at time t) and following behavior (state at time $t + 3$ min), as described in Lusseau (2003*a*, 2004) and Lusseau *et al*. (2009). Therefore, whether the observed count of following behavior (F), given preceding behavior (P), was influenced by the marine vessel presence (M), seasons (S), and sections (L) was tested. Following Lusseau *et al*. (2009), the effects of different factors were tested by comparing different fitted models using a likelihood ratio test. The model's null hypothesis stated that following behaviors were independent of marine vessel presence, season and location, given preceding behavior, as indicated by PF, MSLP. All possible models were tested and the best fitting model was chosen through the lowest Akaike Information Criterion (AIC). The importance of each factor was also tested using a likelihood ratio test. For example, if boat effect was introduced to the null model, the significance would have been found by subtracting the goodness of fit and degrees of freedom between the first and later model ($G^2 = G^2_{\text{first model}} - G^2_{\text{later model}}$), which is the likelihood ratio testing the significance of the addition of the factors with degrees of freedom equal to difference in the degrees of freedom between the two models. Thus, the effect of different factors can be tested at various stages by adding the effect of different models that have already considered other factors.

Esri ArcGIS software was used to create a GIS environment that included the distribution of dolphin sightings and marine vessel presence in the area. Dolphin sightings were mapped for each season. The "Kernel Density" function was used to create a raster map for dolphins and marine vessels within a circular neighborhood for each raster grid cell of 30 m with a radius of 500 m for dolphins. Kernel density data were processed by mask extraction. Mask extraction extracts the cells of a raster that correspond to the areas defined by a mask. Later, percent volume contour has been used to visualize the core zones for dolphins and marine vessels. We present the impact of marine vessels visually by overlaying the core zones both for vessels and dolphins in each season through percent volume contour.

Results

Seasons, Sections, and Dolphin Sightings

In total, we conducted surveys for 156 d (920.10 h), of which 28 d were boat surveys and 128 d were land surveys. Bottlenose dolphins were encountered on 88 d and focal groups were followed for a total of 113.45 h. General log-linear analyses of dolphin sighting data showed that dolphin sightings were significantly affected from seasons, sections and their interaction terms ($P < 0.05$). Dolphins were encountered more often during spring and summer than autumn and winter. The sighting rate for spring, summer, autumn, and winter was 77%, 62%, 34%, and 30%, respectively. Although the largest number of sightings occurred during spring, there was no significant difference in sighting rates between spring and summer ($P = 0.79$). According to the parameter estimates, sightings did occur significantly more often in spring than in autumn or winter. With regard to the assigned sections of the strait, dolphins were spotted significantly more in the south and north sections than the middle. The sighting rate for south, middle, and north section was 85%, 21%, and 48%, respectively. When the interaction factor between seasons and sections were considered, the autumn and winter sightings of the middle and north sections were significantly less than the spring sightings of south sections ($P < 0.05$) (Fig. 2). However the seasonal sightings of the south section weren't significantly different than each other

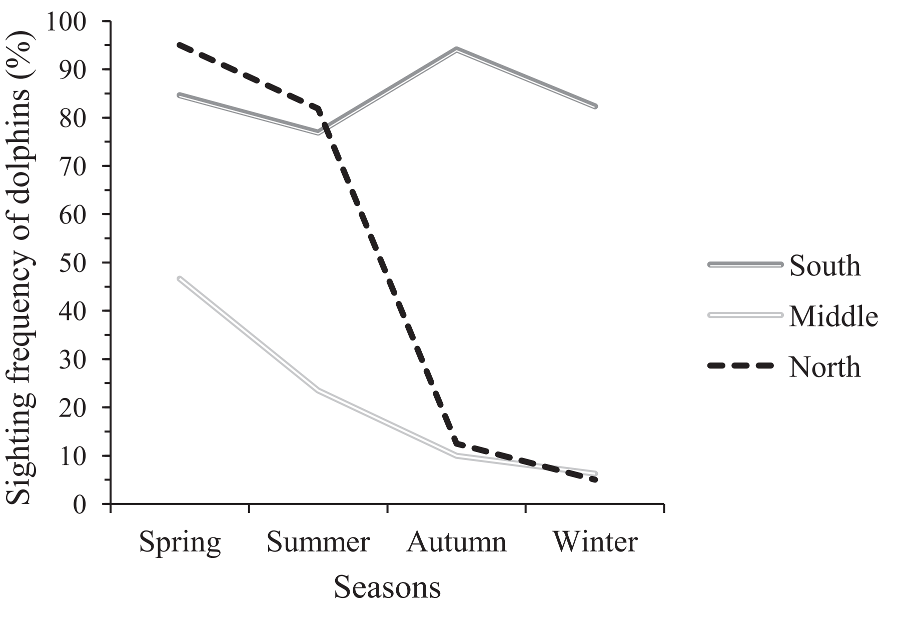

Figure 2. Sighting frequency of bottlenose dolphins for each section and season.

($P > 0.05$). Moreover, autumn sightings for north section dropped from 80% to around 10% (Fig. 2). Additional examination of dolphin density maps showed seasonal differences and dolphins tended to inhabit in both the North and South sections more frequently than middle section. Also, during spring and summer in the North section, the highest dolphin densities were found within 400 m from the shore, while in the South section the highest dolphin densities occurred during autumn and winter 2,000 m off the Ahirkapi station (Fig. 3).

Behavioral Differences Across Seasons

Also, significant relationships exist between dolphin behaviors and seasons ($G^2 =$ 119,699, df = 12, $P \leq 0{,}0001$). The most dominant behaviors overall were traveling, surface feeding and diving for all seasons. According to the Z-test for proportions, traveling behavior was significantly higher for spring and summer, diving was highest for autumn and winter, and surface-feeding was significantly highest for winter. Socializing and resting behavior were extremely rare in all seasons and sections. Approximately 40% of resting and socializing behavior was observed in spring and 30% in winter. During autumn, no resting was recorded and socializing was only sighted on three occasions.

Marine Vessel Traffic

Marine vessel traffic was significantly related to both seasons and sections of the Istanbul Strait ($P < 0.05$). Irrespective of season, the middle section of the strait had significantly more marine vessel traffic than any of the other sections ($P < 0.05$). Each section possesses the highest number of vessels during autumn months. While south and middle section had the least traffic in spring, north section held the least traffic in winter months.

Reaction of Dolphins Towards Marine Vessels

Over half of the time (54.8%), marine vessels appeared together with dolphins inside the reaction zone (within a 400 m radius of the focal group). Based on Z-test for proportions, dolphins showed the highest number of negative reactions toward high-speed ferries and high-speed boats (Z-test, $P < 0.05$) (Fig. 4). While 54% of reactions were negative towards HSBs, it was 95% for HSFEs. Fishing boats typically elicited neutral reactions by 86% and highest positive reaction were recorded for big cargo ships (Fig. 4). Mapping the area used by boats to most likely to induce a negative reaction (HSFEs and HSBs) in dolphins revealed that there was considerable overlap of core zones preferred by dolphins with areas most often used by HSFEs and HSBs in all seasons (Fig. 5). Although HSFEs appear to greatly disturb dolphins, they occurred least often while fishing boats, ferries and high-speed boats, occurred most often in 400 m zone with dolphins (Fig. 4).

Notably, dolphins appear to react not just to specific vessel types, but also to the overall density of vessels in their habitat. Dolphins displayed the most negative reactions when the density of vessels within the reaction zone was higher than two, regardless of type, and displayed the most neutral reactions when there was 0–1 vessel in the reaction zone (Z-test, $P < 0.05$).

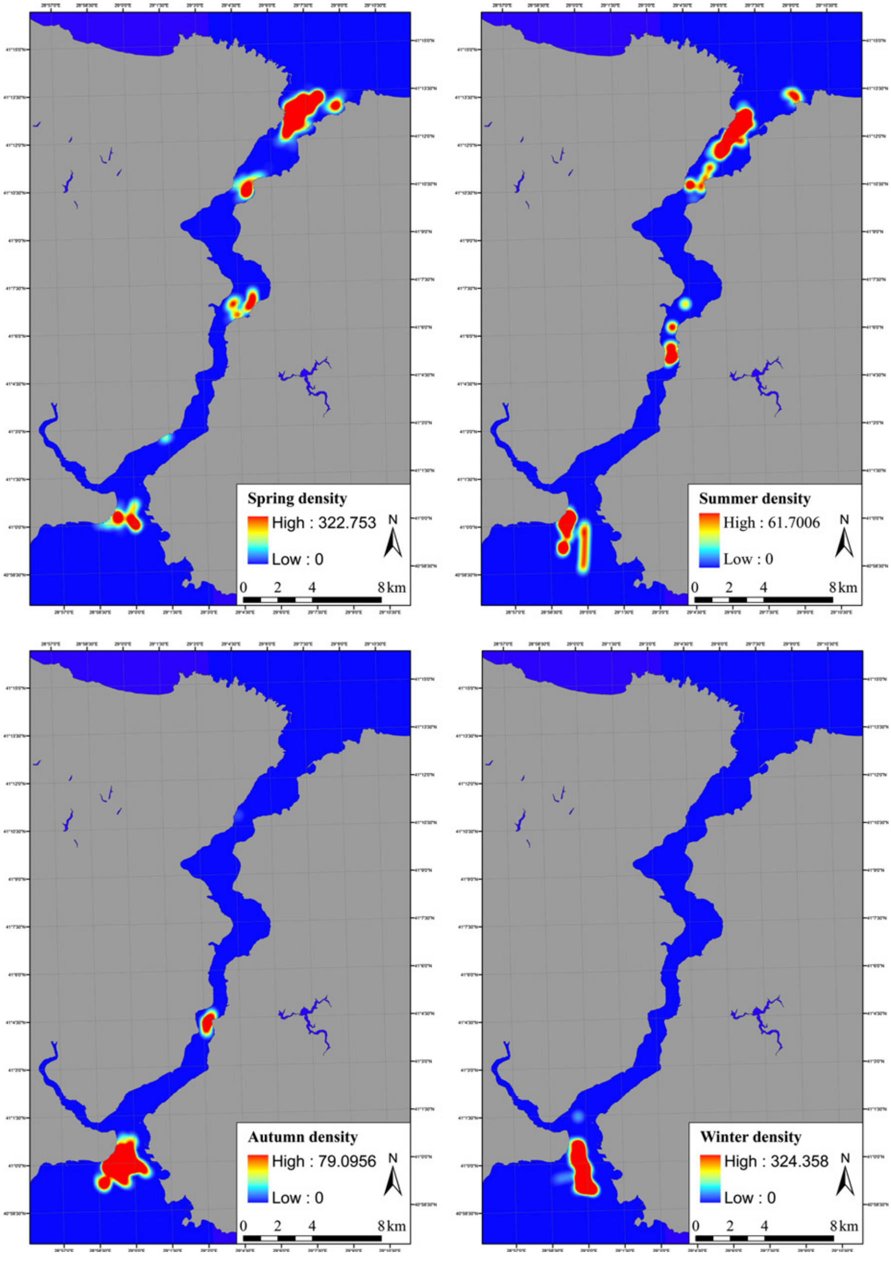

Figure 3. Bottlenose dolphin density per km^2 for each season: Spring (March, April, May), Summer (June, July, August), Autumn (September, October, November), and Winter (December, January, February).

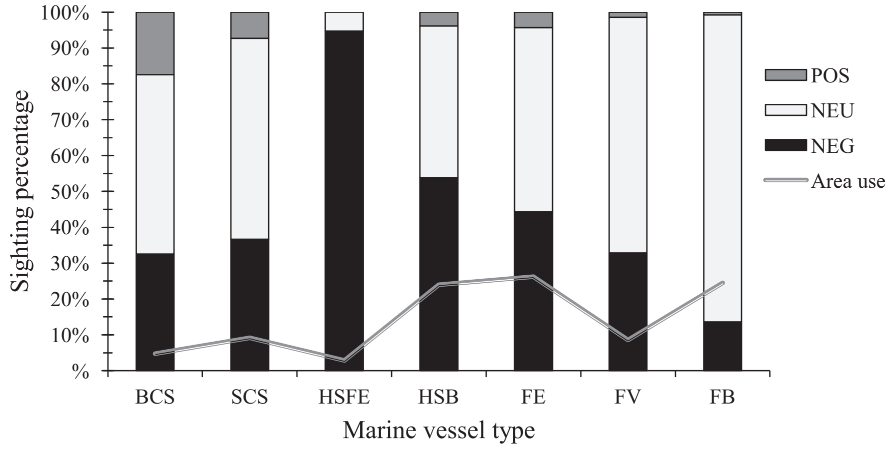

Figure 4. Percentages of dolphin reactions and area use of marine vessels. The numbers of the top of the graph show the total number of observations of each vessel type: Big Cargos (BCS), Small Cargos (SCS), High-Speed Ferries (HSFE), High-Speed Boats (HSB), Ferries (FE), Fishing Vessels (FV), Fishing Boats (FB).

Behavioral Transitions

Based on focal group sampling, 1,825 behavioral transitions were recorded and of these, 780 occurred with no vessels and 1,045 with vessels within the reaction zone. In order to determine which factors most impacted changes in dolphin behavior, we assessed reaction zone vessel densities, season and section effects on the first order behavioral transitions using a five-way log-linear analysis. The model considering marine vessel and season effects (MPF, SPF, MSLP) and the marine vessel model (MPF, MSLP) had lower AIC values and thus were found to be the best-fitting models by far (Table 3). Neither the null model, indicating that no factors effected behavioral transitions, nor the saturated model, which considers all interactions, provided a significant improvement on the explanation of the data variances. Thus, marine vessel presence and marine vessel presence together with seasons are the best models to explain the behavioral transitions of bottlenose dolphins in the Istanbul Strait.

The significant effect of each factor to the model was also analyzed. Adding the marine vessel, season and location factor to the model caused significant changes on the models. While marine vessel and season were considered the most important factors on the behavioral variance, location was considerably low in its effect despite being present in most of the best models. Its presence alone did not provide any information to the models.

Discussion

Bottlenose dolphins in the Istanbul Strait exhibited an abundance of both feeding and traveling behavior in all seasons and were rarely observed, in the same area, socializing or resting. Marine vessels were present together with bottlenose dolphins, within a 400 m radius of the group, in over 54% of the observations in present study. Such substantial marine vessel presence not only results in visible disturbances to dol-

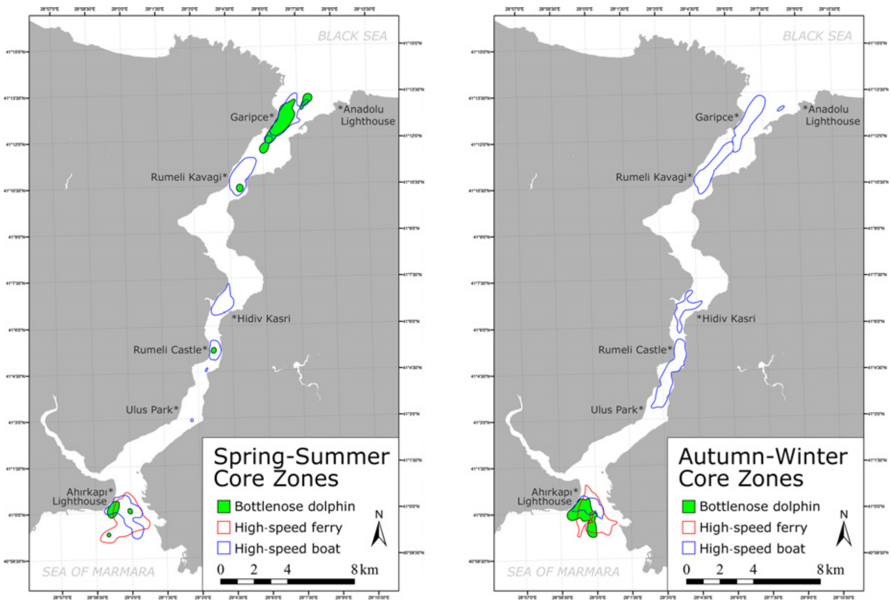

Figure 5. Overlapped core zones for bottlenose dolphins, HSBs and HSFEs under seasons in the Istanbul Strait.

Table 3. AIC values for all the models researched. The combination of main effects shown as "+," the interaction shown with "*." G^2 = goodness of fit, df = degrees of freedom, AIC = Akaike Information Criterion.

Model	G^2	df	AIC
MV+SEASON	136,788	228	-319,212
MV	213,306	264	-314,694
MV+SECTION	173,521	240	-306,479
MV+SEASON+SECTION	103,284	204	-304,716
MV*SEASON	79,859	192	-304,141
SECTION+MV*SEASON	45,934	168	-290,066
MV*SECTION	156,531	216	-275,469
SEASON+MV*SECTION	84,852	180	-275,148
SECTION	261,647	252	-242,353
SECTION+SEASON	192,394	216	-239,606
SEASON	242,722	240	-237,278
NULL	329,471	276	-222,529
MV+SEASON*SECTION	73,475	132	-190,525
SECTION*SEASON	161,453	144	-126,547

phin behaviors, but appears to be a significant driver of behavioral transitions in these animals. Since short-term changes in behaviors can eventually impact energy budgets of dolphins, we have combined behavioral data with location information to identify critical dolphin habitats and thus propose three managed zones for bottlenose dolphins in the Istanbul Strait.

Dolphins occurred most frequently in spring and summer across all three sections of the strait, while in winter, dolphins congregated in the southern section. This periodic use of different areas, combined with the notably high frequency of traveling and feeding behavior across all seasons, suggests that the Istanbul Strait serves as a foraging habitat for the bottlenose dolphins.

According to the stomach content analysis of bottlenose dolphins, several species of fish such as Mediterranean horse mackerel (*Trachurus mediterraneus*), turbot (*Scophthalmus maximus*), bluefish (*Pomatomus saltatrix*), garfish (*Belone belone*), golden grey mullet (*Liza aurata*), and whiting (*Merlangius merlangus*) were found in their diet (Çelikkale *et al.* 1988, Dede 1999). Based on an analysis of fisheries data, numerous species, most notably horse mackerel and bluefish, migrate from the Marmara Sea to the Black Sea in spring, while European anchovy (*Engraulis encrasicolus*), horse mackerel, bluefish and Atlantic bonito (*Sarda sarda*) migrate back to the Marmara from the Black Sea in autumn (Öztürk *et al.* 2002, Dede *et al.* 2014). The occurrence of known fish migrations coinciding with our observations of dolphins' seasonal habitat use indicate that the Istanbul Strait, in three locations in particular (*See Fig.* 3), constitutes a substantial bottlenose dolphin foraging ground.

According to a photo-identification study run concurrent with this study, not only the resident individuals but also nonresident individuals visited the strait to forage in spring and summer months (AAB, AAÖ, BÖ, unpublished data). These more transient dolphins appeared alongside residents during the spring fish migration but were less likely to appear during the autumn fish migration.

The Istanbul Strait is also important for the fishing industry. In Turkey, it is the second biggest fishing ground after the Black Sea (TUIK 2011). Both small-scale artisanal fisheries and large-scale commercial fisheries are active in the area. 13 fishery cooperatives and 17 fishing ports are located in the strait, with 14 of the 17 ports located in the north section alone (Öztürk *et al.* 2006). The northern section is subjected to intense purse seining from September to mid-April, and the middle and southern sections are utilized by artisanal fishing year-round. Although the current study was not specifically focused on fisheries, substantial numbers of commercial fishing vessels were recorded with an average of 100 vessels daily, during autumn and winter in the middle and north sections. Sometimes more than 50 vessels could be sighted at a time.

Even though socializing and resting behavior of dolphins was rarely seen in the Strait, spring had the highest observation rate of such behaviors, almost none occurred during autumn. Commercial fishing vessels occur more frequently during autumn and winter as well. The increased traffic of commercial fishing vessels during autumn and winter may explain the overall reduction in those behaviors. Whether these behaviors simply decreased in the overall behavior budget due to the marine traffic density in the area or are conducted elsewhere, such as in the Marmara or Black Sea, is not known. However, similar behavioral changes have also been reported for bottlenose dolphins, dusky dolphins (*Lagenorhynchus obscurus*), and killer whales (*Orcinus orca*) exposed to increased marine vessel disturbance (Barr and Slooten 1999, Constantine *et al*. 2004, Lusseau 2005, Ribeiro *et al.* 2005).

As mentioned in Lusseau (2003*a*), an individual's behavior budget is directly tied to its energy budget: a dolphin that must leave its foraging ground to rest or socialize is increasing its energy expenditure with every relocation. Although bottlenose dolphins in the Istanbul Strait may be adapting to the dense marine traffic by moving to other areas to conduct specific behaviors, this short-term reaction can eventually result in long-term energy depletion for the affected individuals. Without any protective measures, these short-term effects accumulate and may lead to abandonment of the area in the long run.

Our results indicate that marine vessel presence not only results in visible behavioral disturbance but also drives behavioral transition. Moreover marine vessel presence together with seasons was also an important factor on the behavioral transition. It is possible that differences in behavioral transitions could be related to how different dolphin groups use the strait across different seasons.

Many factors such as vessel type, vessel speed, vessel density, and distance from the focal group, collectively affect the dolphins in the Istanbul Strait. Among all the vessels, high-speed ferries and high-speed boats caused the greatest negative impact, while dolphins rarely reacted to small artisanal fishing boats. Dolphin reactions were primarily determined by the vessel speed and the predictability of the vessel routes. High-speed vessels caused the most negative reactions because of their speed and unpredictable courses. Similar disturbances by speed boats have been reported in several studies on both odontocete and mysticete species (Ng and Leung 2003, Lemon *et al.* 2006, Bearzi *et al.* 2008, Carrillo and Ritter 2008). Both the type of the nearest vessel and the overall density of marine vessels in the surrounding area were important factors in determining the reaction of the dolphin group. Our results demonstrated that dolphins tended to show negative reactions when vessel density around the dolphins was high, irrespective of vessel type. If a focal group was surrounded by two or more vessels in the reaction zone, a negative reaction was more likely to be elicited. Additionally, there was no significant difference in reaction between 2–5 and >5 vessels. This suggests that after a critical threshold, in this case two vessels within a 400 m radius of the focal group, dolphin groups negatively react regardless of vessel type.

Vessel presence does not only result in behavioral changes; it can also cause immediate physical impacts for dolphins. Some dolphins were observed with sizeable fin nicks or completely chopped dorsal fins. During this study, we recorded some high-speed boats going as fast as 100 km/h with no predictable routes. It is highly likely that such high-speed does not give dolphins enough time to escape from the area and could result in serious injuries to the animals.

As demonstrated by this study, the southern and northern ends of the Istanbul Strait and the northernmost portion of the middle section, near Hidiv Kasri are critical habitats for the bottlenose dolphins. Dolphins were also present in the southern end of the Istanbul Strait year-round. While there is a resident population (AAB, AAÖ, BÖ, unpublished data) in the south, seasonal and transient groups also arrive during the spring and summer season to forage. The northern end of strait was only favored during spring/summer. While the middle section, with the highest vessel density, was the least favorable habitat and had the fewest dolphin sightings across seasons, it is critical to remember that the middle section is a vital spring and summer migration corridor between northern and southern sections (Fig. 3). Therefore, we propose that the southern and northern ends of the Istanbul Strait are priority areas for the establishment of managed areas. The northern end of the Istanbul Strait accommodates a high density of bottlenose dolphins during spring and summer, while the southern end of the Istanbul Strait serves as critical habitat during autumn and winter. The northernmost portion of the middle section appeared to have special importance for dolphin foraging during the spring season.

Since it is important to keep the vessel density down to <2 vessels within the 400 m reaction zone of any dolphin group, the overall vessel density must be limited.

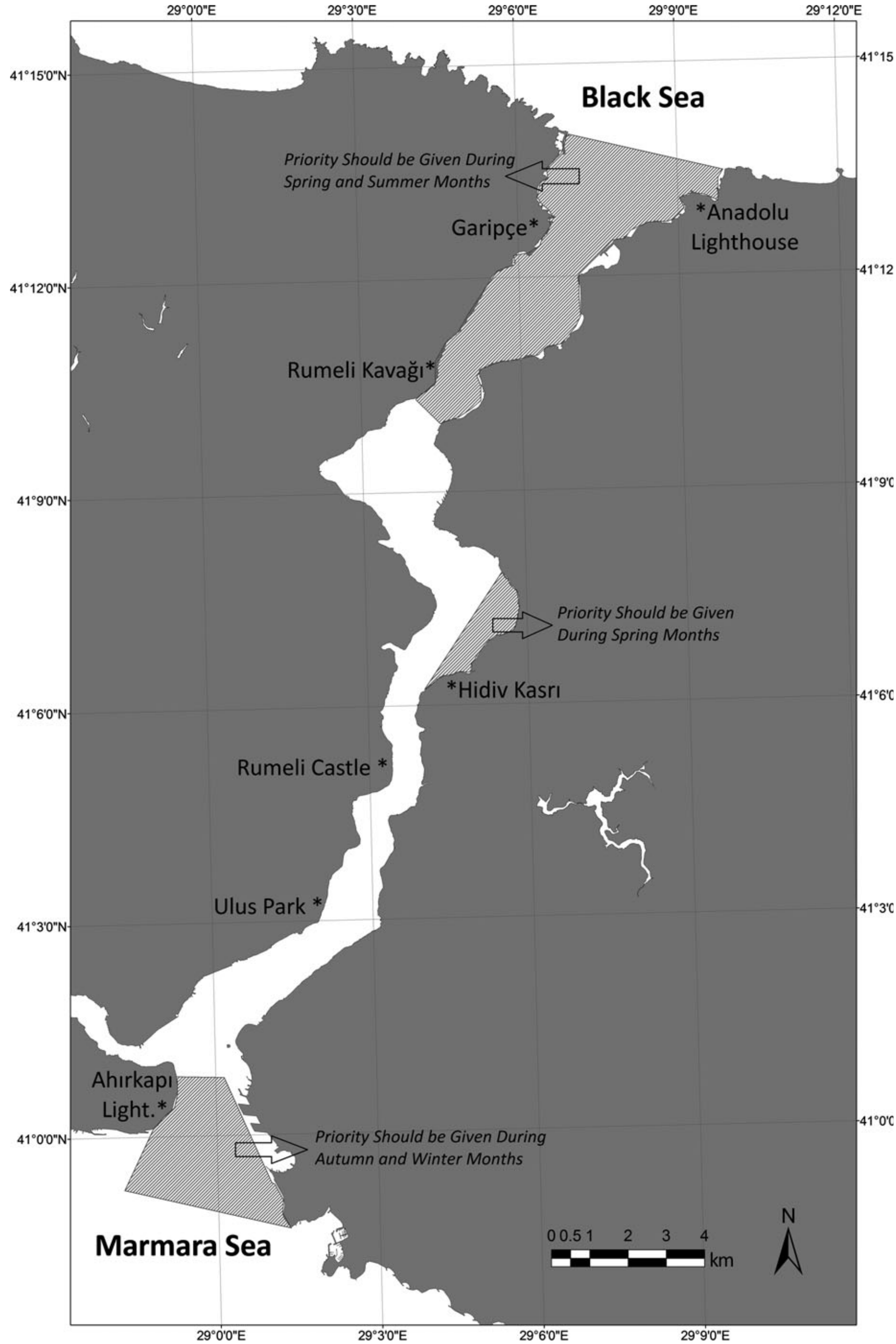

Figure 6. Proposed managed areas in light gray with seasonal priorities noted.

Any proposed protected areas should take into the consideration vessel type, vessel speed, the distance of vessels from the dolphin group and the overall marine traffic density in the area. Even though each factor has an impact by itself, all are mutually inclusive and need to be considered in conjunction. Thus, in terms of mitigating vessel impacts, it is vital to establish mandated limits on the routes and speeds of vessels, like the "No Wake Zones" used in southern Florida for manatee (*Trichechus manatus*) conservation (Nabor and Patton 1989). There is currently a 10 knot speed limit mandated within the strait, however it is routinely violated by recreational boaters and ferries due to lack of enforcement. In the strait, it is also critical to limit marine traffic density within 400 m of dolphin groups to avoid dolphin-vessel interactions. Because of the economical importance of the Istanbul Strait, we propose managed areas that are flexible across seasons, instead of being year-round limitations. The north section covers 33 km^2 and should be in effect for spring and summer. The middle section covers 4 km^2 and should be in effect for spring. Finally, the south section covers 17 km^2 and should be in effect for autumn and winter (Fig. 6).

Unfortunately, the proposed areas have a history of serious ship accidents (Öztürk 2002). Since 1936, international shipping has grown from 4,500 vessels to 46,000 vessels a year. Even though this increase has helped Turkey with its process of economic growth, it has also created risk of shipping accidents. Collision rates in the strait had reached alarming levels by the 1980s (Oral and Öztürk 2006). From 1953 to 2002, there were a total of 461 accidents, some of which having substantial negative environmental effects (Otay and Yenigün 2000, Akten 2004). Even though a traffic separation scheme was adopted and applied successfully since 1994, 58 more ship accidents were documented during 2004–2007 (Koldemir 2009). Areas most at risk for shipping accidents include the southern end of the Istanbul Strait, the middle section up to Sariyer and northern-most end of the strait (Otay & Özkan 2003 and Akten 2004). Some of the most serious accidents have involved tankers carrying oil through the strait and have threatened the lives of people as well as the marine environment (Orakçı 2006). The *Independenta* collision that took place on the southern entrance of the strait resulted in the tenth most serious oil spill in the world (Orakçı 2006).

The most risky areas for shipping collisions overlap with our proposed managed areas in all three sections, most dramatically in the southern mouth of the strait. Historically, most of the ship accidents at the southern end of the strait occurred in January and February (Ece 2006). Because of this, present study provided evidence for a significant bottlenose dolphin population at the southern end of the Istanbul Strait during winter months, a managed area in the southern section of the strait has become of critical importance.

Conclusions

Because identifying critical habitats is the first step towards the establishment of effective managed areas, the current study defined the critical habitats necessary for the continued survival of the bottlenose dolphin population within the Istanbul Strait. These habitats are regularly used by dolphins for feeding, and occasionally, for resting and socializing.

The Istanbul Strait is subject to heavy anthropogenic impacts, such as high marine traffic density and industrial fishing activities. Our results indicate that dolphin sightings and marine vessel sightings in the Istanbul Strait overlapped and dolphins show behavioral transitions which may lead to long-term changes in their energy budgets or abandonment of the habitat, if preventative measures are not taken quickly. The noted seasonal decline in dolphin sightings on commercial fishing grounds could already be an example of such a change.

The study demonstrated that vessels traveling at high speeds with unpredictable routes are most disturbing to dolphins. Although some vessel types, such as high-speed ferries and high-speed boats, were more disturbing than others, higher densities of vessels (>2 within 400 m) cause notable changes in dolphin behavior as well. Even though there is a speed limit of 10 knots established for the strait, it is frequently violated by recreational and public transit vessels, specifically high-speed ferries and high-speed boats. Our findings indicate that vessel type, vessel speed, intensity of marine traffic, and distance from the dolphin group were all factors affecting the reactions of dolphins. Even though each factor had an impact by itself, together they have synergetic effects and must be considered together in assessing the threats to the population.

In terms of mitigating vessel impacts, we propose establishment of three seasonal managed areas where routes and speeds of vessels are restricted and the density of marine traffic are controlled. These seasonal managed areas are based on critical foraging habitat for bottlenose dolphins within the strait, and considered areas that have a high overlap with high-speed vessels and historically suffer from a high risk of environmentally damaging shipping accidents.

Acknowledgments

We would like to thank all the research assistants, fishermen and villagers who helped throughout the process of the collecting the data and Istanbul University for their financial support. We also thank Directorate General of Coastal Safety for permission to use the Ahırkapı Lighthouse. Moreover, we would like to give a special thanks to Shannon O'Connor, M.S. candidate with University of Michigan–Flint, and Ilke Ertem for improving the manuscript.

Literature Cited

Akten, N. 2004. The Bosphorus: Growth of oil shipping and marine casualties. Journal of the Black Sea/Mediterranean Environment 10:209–232.

Altmann, J. 1974. Observational study of behavior: Sampling methods. Behaviour 49:227–267.

Anonymous. 2010. Identification and protection of special areas and particularly sensitive sea areas. IMO Assembly, 61th Session. MEPC 61/9. p 14.

Anonymous. 2013. 2013 Annual report [in Turkish]. T. C. Ulastirma, Denizcilik ve Haberleşme Bakanlığı. Available at http://www.kiyiemniyeti.gov.tr.

Atar, H. H., and C. Ateş. 2009. Türkler'de tarih boyunca su ürünleri avcılığı [The history of the fishery in Turkey]. ACTA TURCICA Online Thematic Journal of Turkic Studies 1:269–281.

Barr, K., and E. Slooten. 1999. Effects of tourism on dusky dolphins at Kaikoura. Conservation Advisory Science Notes 229. Department of Conservation, Wellington, New Zealand.

Bearzi, G., C. M. Fortuna and R. R. Reeves. 2008. Ecology and conservation of common bottlenose dolphins *Tursiops truncatus* in the Mediterranean Sea. Mammal Review 39:92–123.

Bejder, L., and A. Samuels. 2003. Evaluating impacts of nature-based tourism on cetaceans. Pages 229–256 *in* N. Gales, M. Hindell and R. Kirkwood, eds. Marine mammals: Fisheries tourism and management issues. CSIRO, Collingwood, Australia.

Bejder, L., A. Samuels, H. Whitehead, N. Gales, J. Mann and R. Connor. 2006*a*. Decline in relative abundance of bottlenose dolphins exposed to long-term disturbance. Conservation Biology 20:1791–1798.

Bejder, L., A. Samuels, H. Whitehead and N. Gales. 2006*b*. Interpreting short-term behavioral responses to disturbances within a longitudinal perspective. Animal Behaviour 72:1149–1158.

Carrillo, M., and F. Ritter. 2008. Increasing numbers of ship strikes in the Canary Islands: Proposals for immediate action to reduce risk of vessel-whale collisions. IWC Scientific Committee SC/60/BC6. Available at http://www.canariasconservacion.org/Documentos/ShipStrikes-Canary%20Islands.Carrillo%20&%20Ritter-2008%5B1%5D.pdf.

Constantine, R., and S. C. Baker. 1997. Monitoring the commercial swim-with-dolphin operations in the Bay of Islands New Zealand. Science and Research Series 104. Department of Conservation, Wellington, New Zealand.

Constantine, R., D. H. Brunton and T. Dennis. 2004. Dolphin-watching tour boats change bottlenose dolphin (*Tursiops truncatus*) behavior. Biological Conservation 117:299–307.

Çelikkale, M. S., S. Ünsal, F. Durukanoğlu, H. Karaçam and E. Düzgünes. 1988. Karadeniz'de yasayan yunus stoklarinin belirlenmesi ve biyoekolojik özelliklerinin tespiti [The biology, distribution and stock of dolphin species in the Black Sea]. Final project report, Project No. DS. 876. 101.010.1. TKB proje ve uygulama genel müdürlüğü ve KTÜ Sürmene deniz bilimleri teknolojisi yüksek okulu, 80 s [Republic of Turkey Ministry of Food, Agriculture and Livestock, General directorate of project and implementation and Karadeniz Technical University Sürmene Marine Science College] . 80 pp.

Dede, A. 1999. Studies on the marine mammal populations in the Turkish Straits System [in Turkish]. Ph.D. thesis, Istanbul University, Turkey. 62 pp.

Dede, A., A. A. Ozturk, T. Akamatsu, A. M. Tonay and B. Ozturk. 2014. Long-term passive acoustic monitoring revealed seasonal and diel patterns of cetacean presence in the Istanbul Strait. Journal of the Marine Biological Association of the United Kingdom 94:1195–1202.

Ece, N. J. 2006. Analysis of marine casualties in the Strait of Istanbul. Pages 81–95 *in* N. Oral, and B. Öztürk, eds. The Turkish Straits: Maritime safety, legal and environmental aspects. Publication No. 25, Turkish Marine Research Foundation, Istanbul, Turkey.

European Commission. 2013. Commission staff working paper: Executive summary of the impact assessment. European Commission, Brussels, Belgium. Available at http://ec.europa.eu/maritimeaffairs/policy/maritime_spatial_planning/documents/swd_2013_64_en.pdf.

Gailey, G., and J. O. Ortiz. 2000. Pythagoras. Theodolite Cetacean Tracking Marine Mammal Research Program, Texas A&M University, Galveston, TX.

Hoyt, E. 2005. Marine protected areas for whales dolphins and porpoises: A world handbook for cetacean habitat conservation. Earthscan, London, U.K.

IUCN (International Union for Conservation of Nature). 2014. 2014 IUCN Red List of threatened species. Available at http://www.iucnredlist.org.

Istanbul Port, Authority. 2011. Domestic marine traffic guide. Available at http://wwwistanbullimangovtr/tr/indexphp#.

Koldemir, B. 2009. Seyir güvenliği açısından İstanbul Boğazı'nda riskli bölgelerin belirlenmesi: Kaza kara noktalarının güncellenmesi [Determination of risky regions in Strait of Istanbul from the aspect of navigational safety: Updating of the accident black points]. DEÜ Denizcilik Dergisi 1:17–26.

Lemon, M., T. P. Lynch, D. H. Cato and R. G. Harcourt. 2006. Response of travelling bottlenose dolphins (*Tursiops aduncus*) to experimental approaches by a powerboat in Jervis Bay, New South Wales, Australia. Biological Conservation 127:363–372.

Lusseau, D. 2003*a*. The effects of tour boats on the behavior of bottlenose dolphins: Using Markov chains to model anthropogenic impacts. Conservation Biology 17:1785–1793.

Lusseau, D. 2003*b*. Male and female bottlenose dolphins *Tursiops spp* have different strategies to avoid interactions with tour boats in Doubtful Sound New Zealand. Ecology Progress Series 257:267–274.

Lusseau, D. 2004. The hidden cost of tourism: Effects of interactions with tour boats on the behavioral budget of two populations of bottlenose dolphins in Fiordland. New Zealand. Ecology and Society 9(1):2.

Lusseau, D. 2005. The residency pattern of bottlenose dolphins (*Tursiops* spp.) in Milford Sound, New Zealand is related to boat traffic. Marine Ecology Progress Series 295:265–272.

Lusseau, D. 2006. The short-term behavioral reactions of bottlenose dolphins to interactions with boats in Doubtful Sound, New Zealand. Marine Mammal Science 22:802–818.

Lusseau, D., D. E. Bain, R. Williams and J. C. Smith. 2009. Vessel traffic disrupts the foraging behavior of southern resident killer whales *Orcinus orca*. Endangered Species Research 6:211–221.

Mann, J. 1999. Behavioral sampling methods for cetaceans: A review and critique. Marine Mammal Science 15:102–122.

Nabor, P., and G. W. Patton. 1989. Aerial studies of the West Indian manatee (*Trichechus manatus*) from Anna Maria Florida to northern Charlotte Harbor including the Myakka River: Recommended habitat protection and manatee management strategies. Mote Marine Laboratory Technical Report Number 134. 94 pp. Available at http://hdl.handle.net/2075/24.

Ng, S. L., and S. Leung. 2003. Behavioral response of Indo-Pacific humpback dolphin (*Sousa chinensis*) to vessel traffic. Marine Environmental Research 56:555–567.

Notarbartolo di Sciara, G., and A. Birkun, Jr. 2002. Conservation needs and strategies. Section 18 *in* G. Notarbartolo di Sciara, ed. Cetaceans of the Mediterranean and Black Seas: State of knowledge and conservation strategies. A report to the ACCOBAMS Secretariat, Monaco, February 2002. 21 pp.

Notarbartolo di Sciara, G. 2002. Cetacean species occurring in the Mediterranean and Black Seas. Section 3 *in* G. Notarbartolo di Sciara, ed. Cetaceans of the Mediterranean and Black Seas: State of knowledge and conservation strategies. A report to the ACCOBAMS Secretariat, Monaco, February 2002. 17 pp.

Nowacek, S. M., R. S. Wells and A. R. Solow. 2001. Short-term effects of boat traffic on bottlenose dolphins *Tursiops truncatus* in Sarasota Bay, Florida. Marine Mammal Science 17:673–688.

Orakçi, S. 2006. General Directorate of Coastal Safety and Salvage Administration. Pages 54–65 *in* N. Oral, and B. Öztürk, eds. The Turkish Straits: Maritime safety, legal and environmental aspects. Publication No. 25, Turkish Marine Research Foundation, Istanbul, Turkey.

Oral, N., and B. Öztürk. 2006. The Turkish Straits: Maritime safety, legal and environmental aspects. No. 25. Turkish Marine Research Foundation, Istanbul, Turkey.

Otay, E. N., and O. Yenigün. 2000. Volgoneft-248 Oil Spill in the Marmara Sea. Proceedings of the 2nd International Conference on Oil Spills in the Mediterranean and Black Sea Regions, 31 October–3 November 2000, Istanbul, Turkey. pp. 13–23.

Otay, N. E., and Ş. Özkan. 2003. Stochastic prediction of maritime accidents in the strait of Istanbul. Pages 92–104 *in* Proceedings of the 3rd International Conference on Oil Spills in the Mediterranean and Black Sea regions, Istanbul, Turkey.

Özsoy, E., S. Besiktepe and M. A. Latif. 2000. Türk Boğazlar Sistemi'nin Oşinografisi [Oceanography of the Turkish Strait System]. Pages 314–326 *in* B. Öztürk, M. Kadıoğlu and H. Öztürk, eds. Marmara Denizi 2000 Sempozyumu. TÜDAV, Istanbul, Turkey.

Öztürk, B. 1996. Yunuslar ve balinalar [Dolphins and whales. Anahtar Yayınlari, Istanbul, Turkey. p 119.

Öztürk, B. 2002. Oil spills in the Turkish Straits System and the threats to marine biodiversity. Oil Pollution and Conservation of Biodiversity. Proceedings of the Porto Torres (Sardinia) conference, 17-20 October 2002. Available at http://www.medmaravis.org/OilPollution.html.

Öztürk, B., and A. A. Öztürk. 1996. On the biology of the Turkish straits system. Bulletin de l'Institut océanographique de Monaco 17:205–221.

Öztürk, A. A., S. Karakulak and B. Öztürk. 2002. Fishing activities in the Istanbul Strait. Pages 174–185 *in* B. Öztürk, and T. Özkan, eds. Proceedings of the symposium on the Straits used for international navigation, 16–17 November 2002. Publication Number 11, Turkish Marine Research Foundation, Istanbul, Turkey.

Öztürk, A. A., S. Karakulak and B. Öztürk. 2006. Fishing activities in the Istanbul Strait (Bosphorus). Pages 106–115 *in* N. Oral, and B. Öztürk, eds. The Turkish Straits: Maritime safety legal and environmental aspects. Publication Number 25, Turkish Marine Research Foundation, Istanbul, Turkey.

Ribeiro, S., F. A. Viddi and T. R. O. Freitas. 2005. Behavioral responses of Chilean dolphins (*Cephalorhynchus eutropia*) to boats in Yaldad Bay Southern Chile. Aquatic Mammals 31:234–242.

Simmonds, M., S. Dolman and L. Weilgart. 2004. Oceans of noise: A WDCS science report. Whale and Dolphin Conservation Society, Plymouth, MA.

TUIK. 2011. Fishery statistics. Turkish Statistical Institute. ISSN 1013–6177:71.

Williams, R., D. Lusseau and P. S. Hammond. 2006. Estimating relative energetic costs of human disturbance to killer whales (*Orcinus orca*). Biological Conservation. 133:301–311.

Received: 15 January 2014
Accepted: 12 November 2014