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Behavioural strategy of common bottlenose dolphins (Tursiops truncatus) *in response to different kinds of boats in the waters of Lampedusa Island (Italy)*

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ABSTRACT

1. Owing to the increase of boat-traffic in the ocean many studies have been conducted to determine the response of bottlenose dolphin (*Tursiops truncatus*) to this kind of disturbance. This species is affected by boats in various ways and the response depends on the behavioural state of the dolphin but also on the kind of vessel.
2. This study aimed to determine the effect of motorboats and trawlers on dolphins' presence, permanence in the area and whistle parameters in Lampedusa waters (Italy). Sampling was carried out between May and December 2006 and between July and September 2009, using experimental passive acoustic monitoring systems (PAM); a total of 300 h of recordings and 3000 whistles were analysed.
3. The dolphins' behavioural strategies depend on the kind of boats: in the case of motorboats, dolphins preferred to leave the area as the disturbance became too heavy to be tolerated; in the case of trawlers, dolphins changed their acoustic behaviour to compensate for the masking noise.
4. The study highlighted the efficacy of PAM to detect the behavioural response of dolphins, suggesting a novel approach to assessing anthropogenic influences on marine mammal vocalizations in the absence of visual observations.

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KEY WORDS: coastal; behaviour; mammals; shipping

INTRODUCTION

The marine environment contains many natural sources of noise (e.g. wind, surf, rain, biological activity, earthquakes) that have the potential to interfere with the acoustic habitat of organisms, however, marine species have presumably evolved to accommodate these. With the advent of industrialization, however, the ocean has been subjected to a constant and progressive increase in noise due to human activity.

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In coastal waters, where the bottlenose dolphin (*Tursiops truncatus*, Montagu 1821) lives, ship- and boat-traffic may represent the primary source of man-made noise (Buckstaff, 2004; Holt, 2008). Energy of boat noise ranges between 0.1 and 20 kHz (Richardson *et al.*, 1995). Such a range overlaps with that of major communication signals of dolphins – i.e. the whistles – which are frequency-modulated sounds ranging between 1 kHz and 48 kHz (Boisseau, 2005; May-Collado and Wartzok, 2007, 2009) that are generally associated with group cohesion and individual recognition. To avoid signal masking dolphins are known to adopt different strategies including: (i) enhancing the transmission efficiency of signals in the habitat (Morisaka *et al.*, 2005a; May-Collado and Wartzok, 2008); and (ii) using avoidance behaviours both spatially (e.g. moving away temporarily or permanently from the area; Bejder *et al.*, 2006b) and temporally (stopping the vocalization and waiting until the noise decreases; Lesage *et al.*, 1999; Sun and Narins, 2005). Many studies have demonstrated that *T. truncatus* reacts to boat traffic in many different ways: (i) modifying the acoustic features of its vocalization (Buckstaff, 2004; Morisaka *et al.*, 2005b; May-Collado and Wartzok, 2008), altering its normal behaviour (Acevado, 1991; Lusseau, 2005; Papale *et al.*, 2011), increasing the swimming speed and direction and modifying group compactness, size and membership (Nowacek *et al.*, 2001; Mattson and Thomas, 2005; Miller *et al.*, 2008), reducing the use of the habitat when boat-density reaches a high level (Allen and Read, 2000), displaying vertical avoidance behaviour (Lusseau, 2003), reducing resting (Constantine *et al.*, 2004; Lusseau, 2005), and lastly, altering the breathing or surfacing pattern (Janik and Thompson, 1996; Hastie *et al.*, 2003). Despite the majority of studies stressing the avoidance or evasive response of dolphins to the boats, sometimes the presence of boats attracts dolphins, for instance in those cases involving commercial fishing boats (Shane, 1990).

The general scope of this study is to evaluate if *T. truncatus* in the waters of Lampedusa (Sicily Strait, Central Mediterranean) change behavioural strategies in response to two different kinds of boats: motorboats and trawlers. Questions of interest were: (i) whether dolphins were tolerant to boats' presence; (ii) whether they showed different behavioural responses when recreational boats and trawlers were present; (iii) whether they tried to avoid masking from vessel noise by altering their whistle features; (iv) whether there was a difference in the acoustic response depending on the boat type; and (v) whether the acoustic response was stable between different groups recorded in 2006 and 2009.

MATERIALS AND METHODS

Study area

Lampedusa is the biggest island of the Archipelago of the Pelagie (35°30' latitude N and 12°36' longitude E), located at the centre of the Strait of Sicily; it belongs both to the African and the Italian coastal plateaus (Figure 1). A coastal portion of this zone was declared a Marine Protected Area by the Italian Ministry of the Environment, for its naturalistic importance, and in 2005 the Sicily Region established here a Site of Community Importance (SIC – ITA04013). The study area is located around Lampedusa from the coast to 1.5 km offshore, and has a total area of 48 km^2. The area is characterized by heavy boat traffic from June to September, when tourism is at its highest. Owing to the great abundance of fish (among the highest in the Mediterranean Sea), Lampedusa waters are used by trawlers from the mainland of other Mediterranean countries. However, recreational motorboats (small motorized and/or inflatable rental boats and watercrafts) making excursions around the island represent the largest component of boat traffic in these waters (approximately 90% of the total; La Manna *et al.*, 2010). The study was conducted in the waters around Lampedusa as *T. truncatus* is abundant here compared with other Mediterranean areas (Pulcini *et al.*, 2010). The number of dolphins using the study area has significantly increased in the last decade and this is thought to be due to many animals periodically mixing with a small percentage of resident dolphins, as shown by recent photo-identification studies (Pulcini *et al.*, 2010). This trend was particularly evident between 2006 and 2009: in 2009, 70% of the photo-identified animals were not sighted in 2006 and about 15% of them were well-marked animals identified for the first time

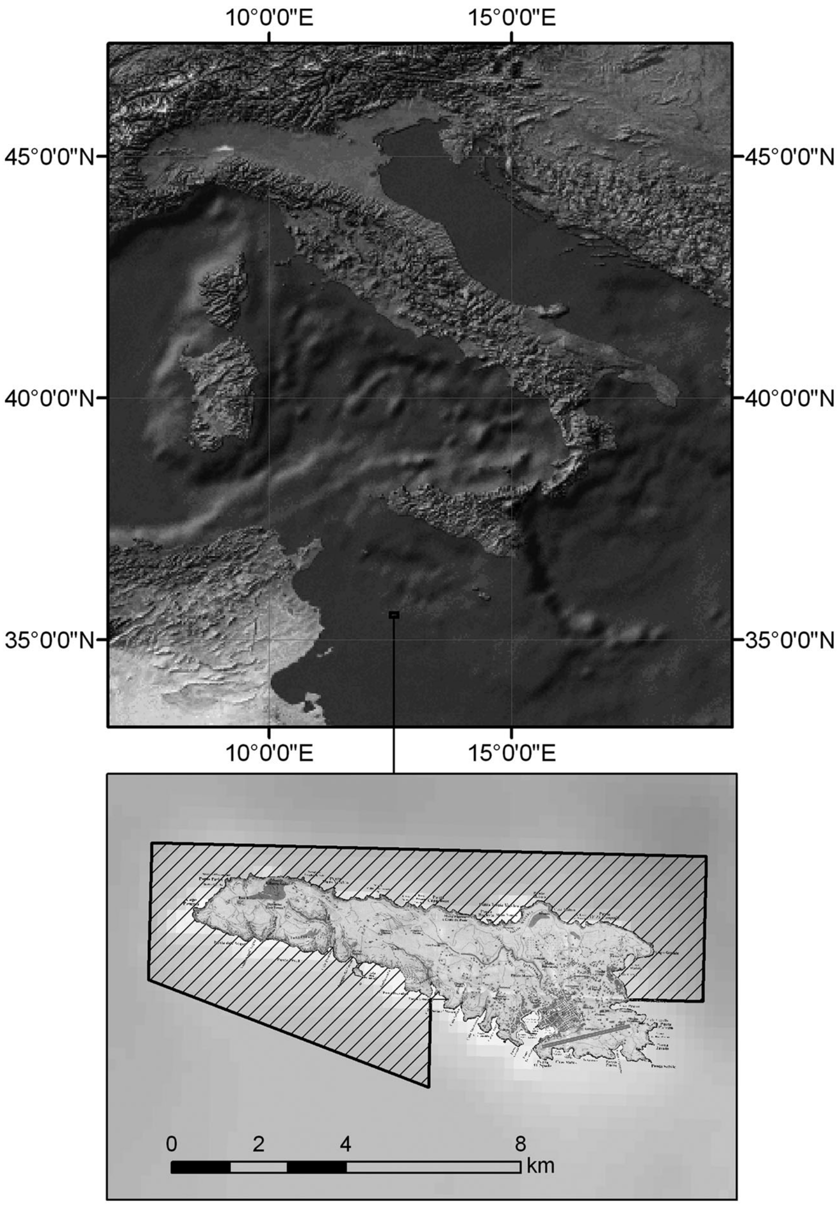

Figure 1. The island of Lampedusa and the MPA limits (dotted area).

(La Manna, unpublished results). These results are not surprising either in terms of geographical location/ oceanographic characteristics or species: the Lampedusa Island lies on the North African continental shelf – about 120 km from the Tunisian coast – where bottlenose dolphins are known to be present and abundant (Ben Naceur *et al.*, 2004).

Sampling

An experimental passive acoustic monitoring system (PAM), was used to measure (i) dolphin presence from their acoustic signals; (ii) index of acoustic dolphins permanence (in seconds); and (iii) duration, frequency and coefficient of frequency modulation of whistles. The PAM used in this study, named RASP (Registratore Acustico Subacqueo Programmabile), did not require the researcher's presence during the sampling and did not emit any acoustic signal into the environment. The system contained a programmable underwater acoustic recorder (M-Audio MicroTrack II), which was hand-deployed from a Zodiac and featured an acoustic release.

The recorders had a programmable timer that can follow any desired schedule. The hydrophone (Sensor Technology SQ2; sensitivity −169 dB re 1 V/1 uPa) bandwidth was 10 Hz–96 kHz; the system offered up to 32 GB of memory per deployment. During the first part of the study (May and June 2006), the timer was programmed to make a continuous 6 h recording, or a 30 min recording every hour for 12 h. After the preliminary analysis of these recordings, it was decided to collect data with an equal interval 10:10, i.e. 10 min of recordings followed by 10 min pause. This schedule appeared the best trade-off between the likelihood of capturing the signal of interest, the battery power consumption and the hard disk storage capacity.

Acoustical and statistical analysis

All sound analysis was performed using Raven 1.3 Software (Cornell University, licensed to Gabriella La Manna). All vocalizations analysed belonged to *Tursiops truncatus*, the only species present in the study area.

To verify the response of bottlenose dolphins to the presence of and disturbance from boats, continuous and 30 min recordings (i.e. May and June 2006) comprising 158 sessions of 30 min were analysed. After a preliminary manual acoustic analysis, sessions were scored according to absence or presence of boats and the related noise as follows: code 0 (zero) was assigned to sessions with no audible vessel noise; code 1 was assigned to those sessions with low noise both in amplitude and dominant frequencies from ships; code 2 was assigned to sessions with loud noise coming from boats, probably close to the recording system. Only sessions classified as 0 or 2 were analysed further, with the aim of excluding those sessions containing noise of large vessels or distant boats. After this selection step, 89 sessions were considered valid for further analysis. The first and the last 5 min of these recordings were eliminated to ensure independence between observations. In the 20 min sessions, the following were measured: (1) the presence of dolphins (the code YES was assigned to sessions with at least one acoustic contact in 20 min while the code NO was assigned to those sessions with no acoustic contacts); (2) the index of permanence of dolphins in the detected area (the span, in seconds, between the first and last vocalizations heard during the session); (3) the disturbance by boats; and (4) the types of boat producing the noise (MB: noise from a recreational motorboat, i.e. small motorized, inflatable rental boats, watercrafts making excursions around the island; TR: noise from trawlers). According to Nisbet (2000) who defined human disturbance as ‘any human activity that changes the contemporaneous behaviour or physiology of one or more individuals’, disturbance by boats was considered to be the presence of boats that was able to alter the dolphin’s behaviour. Accordingly, disturbance was measured using the duration (in seconds) of the boats presence inside the 20 min session, and successively the disturbance was clustered into four categories (Table 1). The

Table 1. Definition of the four levels of boat disturbance

Boat disturbance	
No disturbance (NO DIST)	No vessel noise recorded during the session.
Low disturbance (LOW)	Vessel noise continuously recorded from a minimum of 60 s (5%) to a maximum of 480 s (40%).
High disturbance (HIGH)	Vessel noise continuously recorded from a minimum of 540 (45%) s to a maximum of 1080 s (90%).
Constant disturbance (CONSTANT)	Vessel noise continuously recorded during the session.

Table 2. Definition of the whistle parameters measured by Raven

Parameters	Definition
Low frequency	The lower frequency bound of the whistle (Hz).
High frequency	The upper frequency bound of the whistle (Hz).
Maximum frequency	The frequency at which the maximum power in the whistle (in Hz) occurred.
Centre frequency	The frequency that divided the whistle into two frequency intervals of equal energy (Hz).
Delta frequency	The difference between the upper and lower frequency limits of the whistle (Hz).
Duration	The interval between the start and the end of the whistle (s).

distinction between motorboats and trawlers was made acoustically: trawlers included only those boats accompanied by the unmistakable noise produced by the tickler chain of the trawl gear.

The Pearson chi squared test was applied to test if: (i) the percentage of presence/absence of dolphins was independent of the boats' presence; and (ii) the permanence of dolphins was independent of the four levels of boat disturbance. After testing the normal distribution of data with the Shapiro Wilk test and the homogeneity of the variance with the Leven test, an ANOVA was applied to test if the dolphin permanence changes as a function of motorboat disturbance (one fixed factor, four levels; see Table 1). To verify if dolphins' responses changed as a function of type of boat (MB vs. TR), the two-sample t-test was used to test the permanence of dolphins in sessions where MB and TR were constantly present.

Frequency and duration of the whistles were measured by visual inspection of the spectrogram [1024 point fast Fourier transform (FFT) and frame-length, Hanning window, 50% overlap, F_s. = 24 kHz]. During the acoustical and visual analysis of the spectrogram, each whistle with a signal-to-noise ratio sufficiently high to make it audible and visible in the spectrogram from their start to their end was classified as a 'good whistle' and was further analysed (Table 2); other whistles were classified as 'bad whistles' and discarded from the sample. In addition the coefficient of frequency modulation (COFM) was estimated, calculated according to McCowan and Reiss (1995). The whistle time was divided into 20 equal intervals and the frequency at each point was measured; the COFM was then calculated using:

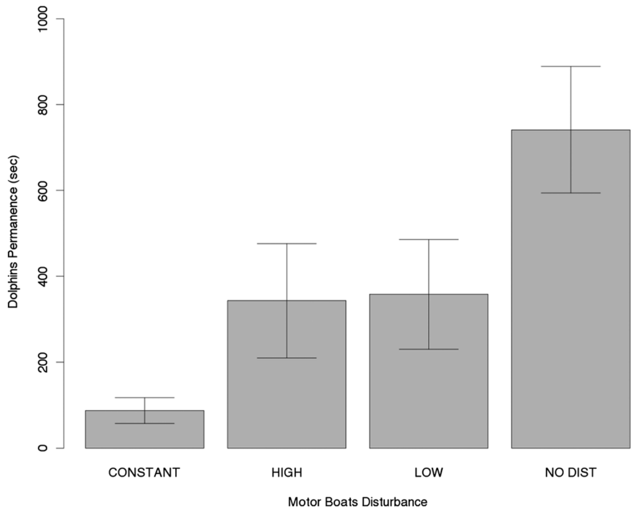

Figure 2. Dolphin permanence as a function of motorboat disturbance categories (n = 31).

$$\text{COFM} = \sum\nolimits_{(n=1,20)} |Y_{n+1} - Y_n| / 10000$$

where Y_n is the frequency at the nth frequency point. A high value of COFM means that the whistle is more modulated in frequency than a whistle with a lower COFM. *Tursiops truncatus* produces whistles with an individual predominant stereotyped contour, interpreted as an acoustical signature and used to identify and locate the individual (Caldwell and Caldwell, 1965); this sequence is usually repeated in a loop. To reduce the risk of collecting whistles from the same individual, each whistle that was recognized as a signature whistle by the observer was considered just once in the following analysis. The normal distribution of data and the homogeneity of the variance were tested with the Shapiro Wilk test and the Leven test respectively. Permutation

Table 3. Number of sessions and relative percentage as function of type of boat, boat disturbance and dolphin presence

	0		MB		TR	
Disturbance	No dolphins	Dolphins	No dolphins	Dolphins	No dolphins	Dolphins
No disturbance	5 (5.3%)	9 (10.1%)	-	-	-	-
Low disturbance	-	-	8 (9%)	6 (6.7%)	0	0
High disturbance	-	-	12 (13.5%)	7 (7.9%)	0	0
Constant disturbance	-	-	0	9 (10.1%)	15 (16.8%)	18 (20.2%)

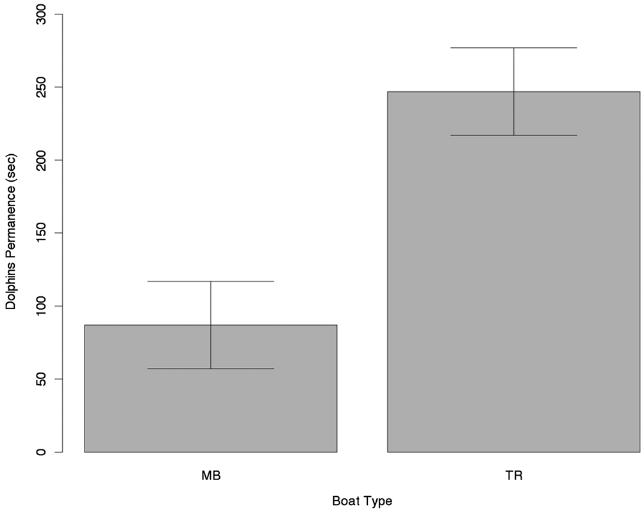

Figure 3. Dolphin permanence as a function of the type of boat: MB and TR (n = 27).

multivariate analysis of variance (PERMANOVA) was applied to verify the hypothesis that the whistle parameters changed in the presence of trawlers or motorboats. PERMANOVA was also applied to a reduced dataset to test the difference of acoustical response between absence/presence of trawlers and year (2006, 2009) on the basis of the hypothesis – supported by photo-identification data – that during these two years different groups of dolphins were recorded. Variables were transformed to $y = \ln(y + 1)$ to retain information on relative concentrations but reduce differences in scale among the variables. Data were transformed with Euclidean distance and analyses were carried out with 9999 permutations of the residuals under a reduced model (Anderson, 2001); differences between levels of factor (boat and year) were tested in detail using pair-wise tests. All descriptive statistics and analyses were carried out using R for Mac, with the exception of PERMANOVA, which was carried out in Primer 6 + .

RESULTS

Tolerance of *Tursiops truncatus* to different boats

From May to December 2006, with the exception of November, and from July to September 2009, a total of 380 h of recordings were sampled. In May and June 2006 79 h of recordings were collected with a continuous or 30 min duty cycle; 89 of the 158 sessions of 30 min, selected as described in the method section, were used to test the hypothesis of dolphins' tolerance to the boats. Between them, 57 sessions contained noise from MB, 18 noise from TR and 14 no vessel-noise (Table 3). Dolphins were recorded before the boat arrived in 4.4% of cases, during the presence of boats in 93.8% of cases and after the boat departed in 1.8% of cases.

The percentage of presence/absence of dolphins was independent from the absence of boats, the presence of MB and the presence of TR (Pearson's chi-squared test, chi-squared = 0.6069, df = 2, P-value = 0.738) and also between the four levels of boat disturbance (Pearson's chi-squared test, chi-squared = 3.1542, df = 3, P-value = 0.368). The permanence of dolphins (in seconds) decreased progressively as the MB disturbance increased (ANOVA, F-value = 5.24, $P < 0.05$; Figure 2). The permanence of dolphins (in seconds) was lower in the case of MB disturbance (87 ± 90 s) compared with TR constant disturbance (247 ± 127 s; Welch two-sample t-test, $t = -3.7762$, df = 21.767, P-value = 0.001; Figure 3).

Tursiops truncatus acoustic strategies to avoid boat noise

Of more than 3000 whistles recorded, only 437 were classified as good whistles (whistles audible and visible from their start to their end) and included in the analysis. The sample was distributed as follows: 120 whistles recorded in the absence of vessel noise, 16 whistles recorded in the presence of MB and 301 recorded in the presence of TR. The descriptive statistics of all parameters are illustrated in Table 4.

All parameters were different in the absence of boats compared with in the presence of MB and TR (Table 5). In particular, the pair-wise tests showed that: (i) all the parameters did not statistically differ in the presence of MB compared with the absence of boats; (ii) all parameters, except COFM, differed statistically in the presence of TR compared with in the absence of boats; (iii) with the exception of low- and centre-frequency, all parameters were statistically different in the

Table 4. Descriptive statistics of whistle parameters

Parameters	Zero				MB				TR			
	Min	Mean	SD	Max	Min	Mean	SD	Max	Min	Mean	SD	Max
Duration (s)	0.06	0.80	0.59	2.87	0.08	0.56	0.40	1.59	0.06	0.99	0.80	5.22
Low frequency (Hz)	1326	6682	2312	13039	1614	7366	3927	15132	1780	7234	2527	16304
High frequency (Hz)	1802	12833	3466	21969	2050	13853	4805	19039	2499	15236	3005	22946
Centre frequency (Hz)	1594	9350	2694	15937	1875	10396	4277	15656	2203	11030	2794	17812
Maximum frequency (Hz)	1594	9142	3297	16125	1969	9803	5048	15934	2156	11219	3500	21937
Delta frequency (Hz)	198	6151	3465	18769	436	6487	3887	12036	404	8002	3163	14823
COMF	0.06	1.85	1.94	7.14	0.02	1.14	1.03	4.09	0.04	2.14	1.64	8.74

presence of TR compared with in the presence of MB; and (iv) all parameters in the presence of MB were larger than in the absence of boats and smaller than in the presence of TR, with the exception of COFM and duration, which were smaller compared with all others (Table 5, Figure 4).

Acoustic strategy stability between different groups

The hypothesis that the acoustical response of dolphins was stable despite different groups being recorded in the two sampling periods (i.e. 2006 and 2009) was tested by comparing the whistle parameters as a function of the factor year, other than boats. In this case, MB was eliminated as a treatment level due to the small sample size obtained when it was stratified per year. PERMANOVA showed that: (i) the main effect of year was that all parameters were statistically different, with the exception of low and high frequency; (ii) the main effect of factor boat was that all parameters were statistically different, with the exception of low frequency; and (iii) the interaction and main effect of both factors were statistically different for low frequency, COFM and duration (Figure 5).

DISCUSSION

Although wildlife responses to humans vary, in general an animal can find human-provided stimuli reinforcing (leading to attraction), aversive (leading to avoidance) or neutral (leading to habituation; Gilbert, 1989). Boat traffic, and the related noise, is a human disturbance that is usually able to elicit a behavioural response in marine animals (Sarà *et al.*, 2007; Slabbekoorn *et al.*, 2010; Bracciali *et al.*, 2012). The findings of this study show that *T. truncatus* tolerated the presence of boats within certain levels. The percentage of presence/absence of dolphins was independent from the percentage of absence/presence of boats of all kinds. Nevertheless, in the presence of boats, dolphins remained in the area until the disturbance reached a certain duration: the more persistent the boats' disturbance, the less likely it is that the dolphins remained in the area. When no boats were present the mean

Table 5. Outcome of the permutational multivariate analysis of variance carried out on the whistle parameters Euclidean matrix, log-transformed using 9999 permutations (MS = mean square)

Whistle parameters	Source	df	MS	Pseudo-F	P (perm.)	Unique perms
Low frequency (Hz)	Boat	2	0.37301	2.9893	**0.0507**	9954
	Res	434	0.12478			
	Total	436				
High frequency (Hz)	Boat	2	1.6907	18025	**0.0001**	9942
	Res	434	0.0937			
	Total	436				
Delta frequency (Hz)	Boat	2	4.8353	10.294	**0.0002**	9952
	Res	434	0.46974			
	Total	436				
Centre frequency (Hz)	Boat	2	1.4687	14.093	**0.0001**	9936
	Res	434	0.10421			
	Total	436				
Max frequency (Hz)	Boat	2	2.4965	17.312	**0.0001**	9955
	Res	434	0.14421			
	Total	436				
COMF	Boat	2	1.3809	4.1032	**0.024**	9943
	Res	434	0.33655			
	Total	436				
Duration	Boat	2	0.59908	5.733	**0.0045**	9999
	Res	434	0.1045			
	Total	436				

acoustic permanence of dolphins was about 12 min; in the case of boat disturbance, the permanence of dolphins reduced to less than 50% (about 6 min) and to about 16% (less than 2 min) when the boat disturbance was constant. This result is in accordance with a study based on visual behavioural observations conducted in the same area by Papale *et al.* (2011), who found a decrease of 50% in the mean sighting time in the presence of boats. In this study, the presence and

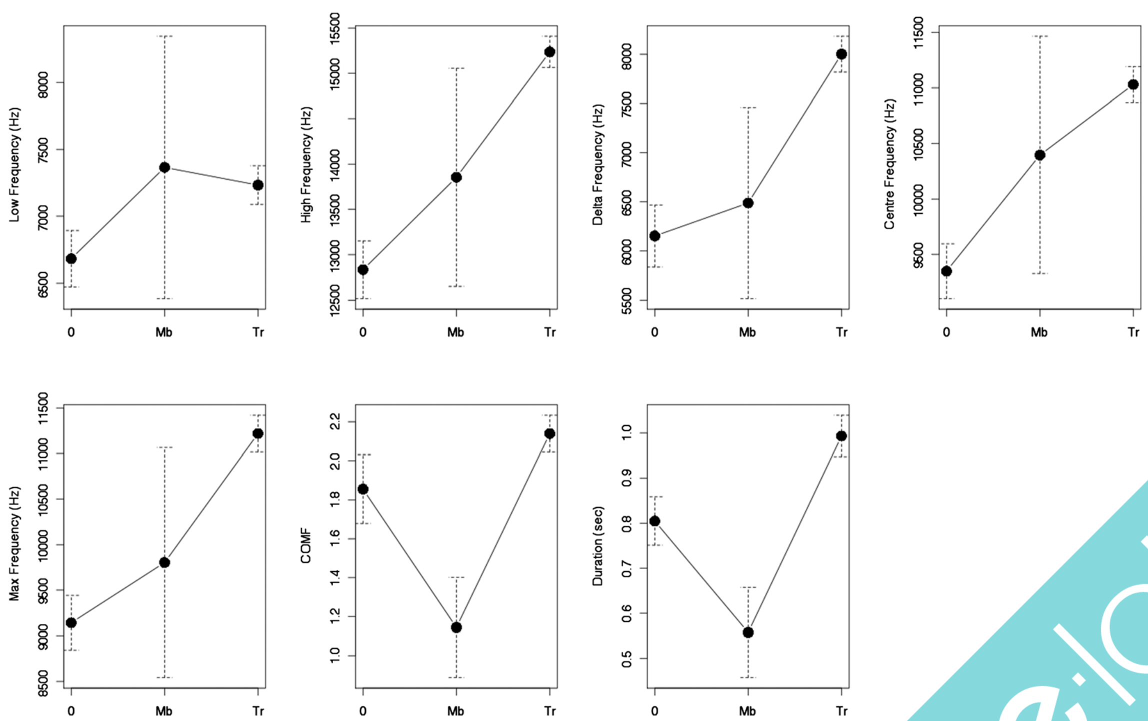

Figure 4. Mean values (±SE) of whistle parameters measured in the absence of boat (0), in the presence of motorboats (MB) and in the presence of trawlers (TR) (n = 437).

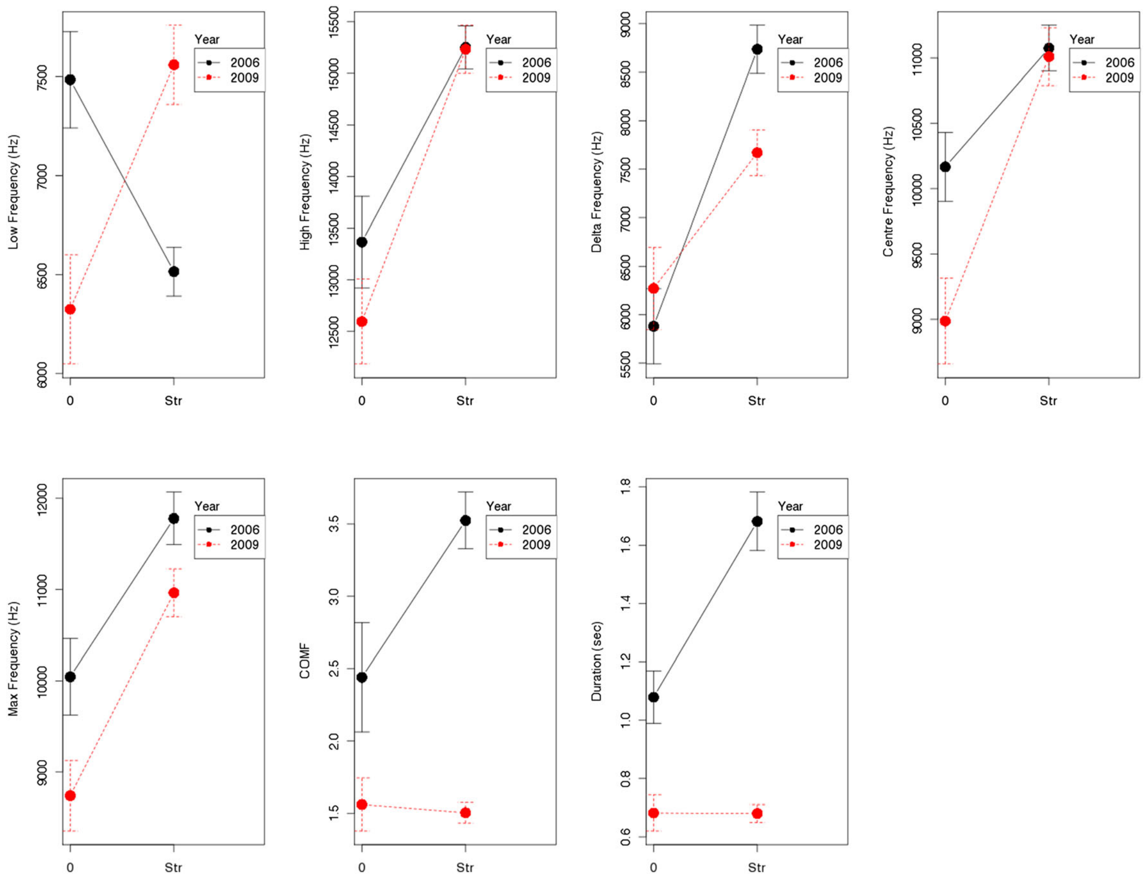

Figure 5. Mean values (±SE) of whistle parameters measured in the absence of boat (0) and in the presence of trawlers (TR) as a function of the year (n = 421).

an index of permanence of dolphins was measured on the basis of their vocalizations. Another explanation of these results could be that dolphins stop vocalizing instead of leaving the area, for example to minimize the detrimental effect of boat noise on their acoustic communication. However, dolphins were recorded vocalizing (thus they were still present in the area) after the vessel noise stopped in only 1.8% of cases; in almost all cases analysed dolphins were present only before and during the presence of vessel noise. This suggests that, with rare exceptions, dolphins preferred to leave the area if the boat disturbance became too much to be tolerated. The response of animals to disturbance is influenced by several factors: (1) type of human activity; (2) human behaviour; (3) predictability; (4) frequency and magnitude; (5) timing; and (6) location. These factors may act in a synergistic way, promoting the impact on wildlife (Knight and Gutzwiller, 1995). The response to boat disturbance was different as a function of the kind of boat present: dolphins tended to be less tolerant of the presence of MB compared with TR. MB stimuli appeared to be more variable, depending on the speed and direction chosen by the pilot (not predictable by animals), more frequent and more concentrated during some hours of the day and around some locations. In contrast, TR usually navigate at constant speed and in a linear direction, over a wide area to the south of the island, in the day and the night. The avoidance response to disturbance also depends on the balance between the benefits of the preferred habitat and the costs of the human impact, and it is also influenced by the distance and the availability of suitable habitat elsewhere (Bejder *et al.*, 2006a). In Lampedusa, *T. truncatus* lives in a quite homogenous habitat, where prey is abundant, at least in the southern region of the islands as demonstrated by the large number of trawlers fishing in this region. Thus, the presence of areas with similar features and prey availability allows the dolphins to escape from the disturbance of boats and its negative impact, by moving to an adjacent quiet zone. The tolerance was greater when the benefit of staying in the presence of boats increased, as in the case of trawlers, likely because fishing vessels provide better feeding opportunities or made the hunting more efficient (Ng and Leung, 2003). Other authors have already reported that in Lampedusa the presence of trawling boats influences the feeding strategy, probably because following the vessels, dolphins may feed on organisms stirred up by the trawl and on fish passed through or entangled in the net's mesh (Pace *et al*., 1998). Some studies provide strong evidence that modification of the communication system has occurred in response to different selective pressures (Lawrence and Correigh, 2002). The rapid alteration of the environment due to anthropogenic impact may reduce the likelihood of adaptation on an evolutionary timescale. Thus, those species with a long life-cycle that precludes adaptation at a pace corresponding to that of habitat change – e.g. dolphins – may have only ontogenetic modification to maintain the efficacy of their signals in a disturbed environment. This could be the strategy adopted by *T. truncatus* because of (i) the plasticity of its vocal behaviour, which remains plastic during the ontogeny and also during the adult stage of life; and (ii) the ability to alter their signals over a large range of frequencies and amplitude. As noise increases, interference with acoustic communication, or masking, becomes more likely because the signal-to-noise ratio decreases. Five different mechanisms that an animal can use to reduce masking of high ambient noise are recognized: (i) increasing the intensity of the signal; (ii) increasing the emission rate; (iii) increasing the duration; (iv) modifying the frequency structure; and (v) waiting until the noise decreases before starting the signal (Parks and Clark, 2007). *Tursiops truncatus* showed an acoustic response to the presence of boats (opting at least for the third and the fourth mentioned solutions), varying it as a function of the kind of boats. The duration of whistles, the high, maximum, centre and delta frequency and the COMF being larger in the presence of TR compared with in the absence of boats could be explained by the attempt of dolphins to compensate for noise. In fact, the energy of recorded TR noise had a dominant frequency of between 0.5 and 10 kHz. Shifting their whistles to a frequency band with a lower level of noise, dolphins may increase the detectability of their signals. The response detected in the presence of MB was more variable. All the whistle parameters, with the exception of low frequency, were not statistically different in the presence of MB compared with in the absence of boats but they were smaller than in the presence of TR. This result may indicate that dolphins need to modify the acoustic features of their whistles to retain the signal information during a feeding opportunity, when group cohesion and exchange of information could be essential for hunting success. However, in the presence of MB, the cost of modifying the acoustic behaviour probably enhances the benefits of remaining in the area contemporarily to the presence of disturbance, thus dolphins decide to leave the area. The lower precision of the parameters measured in the presence of MB (higher SE) could be due to the variable response of dolphins to a more variable stimulus. In fact, while the noise of TR was quite constant due to the small number of trawlers fishing close to the island and their uniform navigation speed (i.e. between 2 and 3 knots), the noise from MB was much more variable because of differences in the types of vessels, size and engine capacity and greater range of speeds and behaviour. In other words, the 'standard' acoustic response to TR noise may be due to the small variability of the stimulus and the typical associated behaviour of the dolphins (opportunistic feeding and travelling behind the vessels). On the basis of a photo-identification study conducted in the area, it was hypothesized that the vocalization of a more resident part of the community was recorded in 2006 and some more migrant groups in 2009. Thus, tests were made to determine if the acoustical behavioural strategy adopted in the presence of boats was influenced by the year of sampling, as a consequence of the different groups recorded. It was found that the high, delta, centre and maximum frequencies were influenced primarily by the presence of boats, being greater in the case of TR than in the absence of boats; the mean values of these parameters were bigger in 2006 than in 2009. Thus, the behavioural strategy appeared to be quite stable over time and between different groups, probably because the frequency parameters of whistles depends on factors such as the size of sound production organs and muscles and/or the environmental background noise levels (Wang *et al*., 1995; Morisaka *et al*., 2005b). Considering the COFM and duration, it appears that the response to TR depends on the year, thus on the groups recorded: in 2009 there was no variation in the presence of trawlers compared with in the absence of boats. These two parameters are those most subject to variation between groups or populations because they may carry additional 'analogic' information such as individual identities or emotional levels (Wang *et al*., 1995). Using a PAM, in the absence of visual observations, it was not possible to verify if dolphins stop emitting signals in the presence of boats or if they change the repetition rate of whistles. Nevertheless, of over 3000 whistles, about 98% of them were recorded in the presence of boats; in addition, if the strategy adopted was to stop signalling in the presence of boats, there should be a larger number of cases in which dolphins vocalize after the boat's passage, but in fact this was true in only 1.98% of cases. Thus, the possibility that the dolphin community stops whistling as a strategy to avoid the high level of ambient noise can be dismissed. In contrast, the change in the repetition rate of the signals cannot be excluded because there is no information about the number of dolphins emitting the whistles recorded. Furthermore, the equipment did not measure whistle amplitude as a function of different noise levels. Thus, further studies should focus on these two last topics.

This study highlighted the ability of *T. truncatus* to adapt its behaviour depending on the type of boat (motor boat or fishing boat), disturbance intensity (expressed in terms of duration) and balance between cost and benefit of staying in the area in the presence of boats. However, as far as population conservation is concerned, this result must be carefully interpreted. Some studies have shown that an increase in the number of vessels in an area led to a decline in the abundance of the dolphins population, probably due to the removal of individuals more sensitive to disturbance (Bejder *et al*., 2006a, b). The same author considers that behavioural responses assessed in a short-term study may lead to confusing results, which must be treated with caution. Another aspect to consider is the effect of boats on the overall behavioural budget of dolphins. For example, the amount of time common dolphins (*Delphinus delphis*) spent foraging in presence of boats was 10% lower than their control budget (Stockin *et al*., 2008). Changes in the duration of foraging may have long-term implications for a population. Thus, while waiting for a long-term evaluation of dolphins' response to boats in Lampedusa, several possible mitigating measures were suggested for the Marine Protected Area of Isole Pelagie. First, mitigating actions for noise and physical impacts of motor boats should be integrated into the objectives and regulation of the MPA. Regulation should include the creation of boat traffic routes and the application of speed limits, with the aim of minimizing exposure of *T. truncatus* to boat noise. Second, the local surveillance of the MPA regulation should be implemented, also employing PAM or video monitoring techniques. In addition, local public awareness of the effects of boat traffic on *T. truncatus* and other marine mammals should be increased through specific educational campaigns.

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