Influence of Trammel Nets on the Behaviour and Spatial Distribution of Bottlenose Dolphins (*Tursiops truncatus*) in the Aeolian Archipelago, Southern Italy

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Abstract

We studied the influence of trammel nets on the behaviour and spatial distribution of bottlenose dolphin in the Aeolian Archipelago, Southern Italy. Ninety-six dolphin groups were followed for 98.75 h from 2005 to 2011 during 400 boat surveys. Thirty-three dolphins were photo-identified, and their age and sex were estimated. The encounter rates, residency times, and group sizes were used to model the spatial distribution of dolphins with trammel nets and physiographic variables. Principal Component Analyses were applied to find the habitats selected for different behavioural activities. Encounter rates were significantly higher in early summer when trammel nets were more abundant. Residency times were spatially correlated to the mean number of trammel nets. Group sizes increased with distance from coast but decreased with abundance of trammel nets. Males preferred smaller groups than females, and groups with calves were larger than the other groups. Resting, socializing, and playing groups were larger than groups of dolphins engaged in travelling, foraging, and feeding. Spatial segregation between groups of dolphins with different sizes was observed. Although dolphins benefit from taking fish in trammel nets, this interaction can be dangerous because the fishermen can use harmful methods to deter dolphins from the net. Herein, we proposed that males prefer habitats where they have a higher probability of locating/ capturing a desirable prey such as coastal areas with a greater amount of trammel nets; while for other activities, they may move into safer areas. On the contrary, females prefer habitats for reasons not associated with prey such as social behaviours, resting, or calf care/learning; and they may spend more time in the safest areas, at a distance from the coast, simply feeding when the opportunity presents itself. This study showed that group size/composition data are of critical importance for modeling dolphinhabitat relationships with significant consequences in terms of conservation strategies.

Key Words: group size, habitat use, bottlenose dolphin, *Tursiops truncatus*, feeding behaviour, trammel nets

Introduction

Many studies have shown that bottlenose dolphin (Tursiops truncatus) distribution may be influenced by several factors such as prey distribution (Barros & Wells, 1998; Heithaus & Dill, 2002; Gowans et al., 2008), habitat structure (Lusseau et al., 2003; Wiszniewski et al., 2010), social interactions (Wells et al., 1987), predation risk (Heithaus & Dill, 2002), and breeding success (Connor et al., 2000). Human activities can have a substantial impact on the distribution patterns of dolphins through changes in habitat structure and prey availability on different spatial and temporal scales (Allen et al., 2001; Bearzi et al., 2009). Fishing activities, such as aquaculture farms (Díaz López & Shirai, 2008) and active trawlers (Chilvers & Corkeron, 2001, 2003; Pace et al., 2011), can also influence the distribution and behaviour of bottlenose dolphins-for example, through changes in the distribution of natural food resources, which may affect the costs of feeding competition.

Many studies have shown that bottlenose dolphins have a varied diet (Blanco et al., 2001), and their feeding behaviour is very flexible (Shane et al., 1986; Shane, 1990; Barros & Wells, 1998). Specializations in the diet (Barros & Odell, 1995; Barros & Wells, 1998; Mioković et al., 1999) and the techniques used to capture prey (Krützen et al., 2005; Sargeant et al., 2005; Daura-Jorge et al., 2012) may have an important role in determining dolphin distribution and habitat selection. Of particular interest are situations in which the habitats with high food availability are also the most dangerous for the presence of predators or anthropogenic threats, so the animals may trade off from feeding to resting habitats during their daily behavioural cycle (Heithaus & Dill, 2002; Heithaus & Lawrence, 2006).

In the Mediterranean, the bottlenose dolphin occurs in coastal habitats (Forcada et al., 2004; De Segura et al., 2008; Bearzi et al., 2009), and its diet includes several commercial fish species (Blanco et al., 2001). As in the Mediterranean, fish stocks are generally declining (Bearzi et al., 2006), dolphins are increasingly in conflict with coastal artisanal fishing, including trammel nets (Lauriano et al., 2004, 2009; Bearzi et al., 2009), and serious injuries are quite common (Bearzi et al., 2009; Lauriano et al., 2009). Dolphins can cause direct damage to the trammel nets by stealing benthic fish from the net, damaging and reducing catch, and disturbing fishing operations (Bearzi et al., 2009; Lauriano et al., 2009). These damages cause negative reactions of fishermen, who attempt to deter dolphins from the net or to kill them, often using harmful methods such as harpoons, guns, or dynamite (Bearzi et al., 2009; Lauriano et al., 2009). Although dolphins benefit from taking fish entangled in trammel nets, the association with trammel nets can be dangerous because it exposes the dolphins to fishermen reaction (Reeves et al., 2001). An additional problem is the ecosystem damage resulting from overfishing and habitat degradation over the last few years that has probably exacerbated the perception of fishermen that dolphins reduce fishery products in some Mediterranean areas (Bearzi et al., 2009).

We began a study on a population of Mediterranean bottlenose dolphins (Aeolian Archipelago, Southern Italy) in 2005 (Blasi & Boitani, 2012, 2014). In this area, the inshore occurrence of the species is related to the complex geomorphology of the volcanic islands (Blasi & Boitani, 2012). Physiographic variables, such as depth and distance from the coastline, are found to influence the bottlenose dolphin distribution, and critical habitats were identified as distinct combinations of physiographic variables (Blasi & Boitani, 2012). The bottlenose dolphin population in the Aeolian Archipelago may be relatively small (only 34 individuals classified based on photo-identification between 2005 and 2012).

In addition, the encounter rate and group size are decreasing in the last 10 y, and only a core group of animals is resident in the study area (Blasi & Boitani, 2014). The social structure of these dolphins is very complex (Blasi & Boitani, 2014): female and male groups associate in the study area during the breeding season, and some males, which specialize in trammel net foraging, form small groups and

preferred associations (Blasi & Boitani, 2014). In the Aeolian Archipelago, trammel nets may provide a reliable food source for bottlenose dolphins by offering a concentration of demersal prey species. In this Mediterranean area, the trammel net is the most common fishing gear, and it is used from the beginning of spring to the end of summer to catch demersal species such as red mullet (Mullus surmuletus), scorpion fish (Scorpena spp.), octopus (Octopus vulgaris), cuttlefish (Sepia spp.), blotched picarel (Spicara maena), and bogue (Boops boops). Dolphin-trammel net interactions are dangerous for dolphin groups due to conflicts with local fishermen, and, consequently, may impact dolphin behaviour with direct and indirect consequences on movement patterns and habitat selection.

This study was conducted on data collected during 7 y of fieldwork to investigate the influence of trammel nets on the behaviour and spatial distribution of bottlenose dolphins in Filicudi Island (Aeolian Archipelago, Southern Italy). In particular, we examined the role of spatial distribution of trammel nets in shaping habitat use, size, and composition of the dolphin groups. Behavioural observations allowed us to detect the habitats preferred for different activities like travelling, feeding, foraging, socializing, resting, and playing. To the best of our knowledge, this is the first study to assess the influence of trammel nets on the behaviour and spatial distribution of this Mediterranean bottlenose dolphin population.

Methods

Surveys

The study area covered 280 km² of coastal area around Filicudi, a small island of the Aeolian Archipelago in the Southern Tyrrhenian Sea (Sicily, Italy $-38^{\circ} 35' \text{ N}$, $14^{\circ} 34' \text{ E}$) (Figure 1).

Boat survey trips were carried out in summer (June-September) from 2005 to 2011 and were limited to sea states of Beaufort 3 or less, in good light conditions, and moving at an average speed of 11 ± 4 km h⁻¹. During surveys, the following data were filled out at *10-min* intervals (survey stations): survey start and end times, GPS position (Garmin GPS 12), boat speed, visibility, and sea state/environmental conditions (Beaufort scale). During each survey, the positions and numbers of all encountered trammel nets were recorded.

Sightings

Bottlenose dolphins were sampled using a combination of focal group observations with instantaneous data sampling (Altmann, 1974) and photo-identification techniques (Würsig & Würsig, 1977; Würsig & Jefferson, 1990). Once sighted, the dolphin groups were slowly approached to



Figure 1. Map of the study area: Filicudi Island, one of the seven islands located in the western area of the Aeolian Archipelago (Tyrrhenian Sea, Sicily, and Italy).

record their positions when the boat reached ~30 m distance from the focal group (i.e., a distance small enough to record an accurate location for the dolphin but sufficiently large enough to not disturb the dolphin's behaviour). Location of the focal group, its size, and behaviour were recorded by instantaneous focal sampling at 3-min intervals using a GPS, a tape recorder, and digital video cameras (GoPro Hero2). To avoid negatively biasing the time period, the dolphin groups were recorded in the last position of each sighting; all the sightings ended with the closing of a 3-min interval. During each sighting, the trammel net presence was recorded if the net was within 100 m of the focal group. At the same time, photographs were taken using a 35-mm autofocus camera (Nikon D7000) with a 70- to 300-mm zoom lens. Group size was defined as the total number of dolphins, including calves, photographed in the same group and moving in the same general direction, interacting or engaging in similar activities (Shane, 1990). Group members included any individuals within 10 m of at least one other dolphin in the group. Occasionally, more than one group of dolphins was encountered in the same day; in this case, each focal group was considered as an independent sighting. When a group splits, one of the subgroups was randomly selected and followed, independently of group size and/or activity (Mann, 1999).

Age Classes and Sex

Individual dolphins were classified according to age and sex of individuals within each focal group at the time of sighting (Scott et al., 1990; Würsig & Jefferson, 1990). *Calves* were estimated on the basis of physical characteristics such as the presence of fetal folds or lines and size in relation to the mother (i.e., body length about half that of the mother). The calves were also determined on the basis of typical surfacing behaviour, swimming in infant position (in contact underneath the mother), or spending all of its time with an adult dolphin (Grellier et al., 2003). Juveniles had fewer rake marks and skin lesions and were at least twothirds the length of adults, and *adults* were fullgrown animals with darker skin color and many marks on the dorsal fin and on the body (Hersh & Duffield, 1990). Sex was determined by opportunistic views of the genital region verified by standard photo-identification techniques (Smolker et al., 1992). The consistent and close escort of a calf with an adult (always sighted together and in close contact) was used to define the adult as an estimated female. Although bottlenose dolphins show only a slight degree of morphometric sexual dimorphism, adult males have been shown to acquire a higher degree of scarring on their dorsal fins through intraspecific interactions (Tolley et al., 1995). Although the degree of marking of an individual cannot be used as a definite identifier of sex, adult animals with heavy scarring and multiple fin nicks, which were never observed in close contact with a calf during the study period, were therefore assigned as an estimated male.

Behaviour

Dolphin behaviour was sampled using five categories—(1) feeding, (2) travelling, (3) socializing, (4) resting, and (5) playing (Altmann, 1974; Würsig & Würsig, 1979; Shane, 1990). The behavioural categories were similar to those used in other studies (Shane, 1990; Bel'kovich et al., 1991; Hanson & Defran, 1993). In particular, the feeding activities were identified in the field using the following criteria: (1) one or more dolphins seen directly pursuing a fish or with a fish in mouth; (2) a fish caught and tossed repeatedly in the air and smacked against the surface; (3) defecating; (4) predation techniques of capture, creating a horizontal circle or making a flower pattern in relation to the water surface (Bel'kovich, 1991); and (5) impetuous attack with acceleration near the water surface. Interaction of a focal group with trammel nets was documented if one or more dolphins in the group were feeding within 100 m of a trammel net.

Mixed behaviour was assigned when different individuals in the focal group were simultaneously engaged in two or more behaviours and when the behavioural state of the group changed during the 3-min interval (Hanson & Defran, 1993). Mixed states with two or more behaviours recorded were treated as the equivalent proportion of the 3-min time interval for each record. When different individuals in the focal group were simultaneously engaged in travel and feed (i.e., they were involved in a forage or search for food activity), the mixed state category travel-feed was treated as an independent state (i.e., forage). The 3-min time intervals which included any interaction (excluding play) with the research boat or disturbed behaviour were eliminated from the statistical analyses (about 3% of data) (Altmann, 1974).

Data Organization

The study area was divided into a grid of 280 1-km² cells (Blasi & Boitani, 2012). Only 110 cells were of interest for this study and were monitored at least three times each year and in the range of 95% Confidence Interval (CI) of the average number of kilometres. Fifteen physiographic variables were extracted from 1:30,000 scale nautical charts of the Hydrographical Institute of the Italian Navy and used to describe the complex structure of the habitat (Blasi & Boitani, 2012). Each grid cell was assigned to one of nine habitat types (from #1 to 9) which characterized the study area (Blasi & Boitani, 2012) (Table 1). Dolphin group locations and trammel nets distribution were mapped using *ArcGis 9.2*.

We computed the following descriptors for each cell of the grid: (1) the encounter rate by the ratio n/L, where *n* is the total number of sightings and L is the amount of effort (km); (2) the group size as the mean number of individuals in the dolphin groups calculated for all *3-min* records; (3) the residency time as the total time spent by the dolphin groups (min); and (4) trammel nets as the mean number of trammel nets. For each sighting, the mean group sizes with or without trammel nets were also calculated subgrouping all *3-min* records with focal groups within 100 m of trammel nets or not. The mean encounter rate, residency time, group size, and trammel nets were also calculated for each habitat type, year of sighting, and summer period (early: June-July; late: August-September).

Each behavioural record (a *3-min* interval of recorded behaviour) was assigned to individual scores (1/0). For each score, the behavioural states were reduced to four behavioural classes by subgrouping the behavioural records: feeding, travelling, foraging (mixed travel-feed), and other behaviours (socializing, playing, and resting). Once reduced, the percentage of time associated with each behavioural class was averaged and pooled according to the cells of the grid.

Statistical Analyses

Core distribution areas of dolphin groups with sizes smaller and larger than the mean group size (an arbitrary cut-off value for defining small and large dolphin groups) were mapped with *ArcView GIS 3.2* using the Minimum Convex Polygon (MCP) and Fixed Kernel Method (FKM) (Würsig, 1978; Irvine et al., 1981; Wilson et al., 1997; Defran et al., 1999; Ingram & Rogan, 2002; Kerr et al., 2005).

The statistical units for the analyses were the cells of the grid. Normal distributions of dolphin parameters (i.e., encounter rate, group size, and residency time) and mean number of trammel nets were checked using Shapiro-Wilks tests and the homogeneity of variances using Levene's test. Welch's ANOVA and t-test were used to investigate the differences between groups of data normally distributed. Kruskal-Wallis was used to test the differences between groups if data were not normally distributed. Correlations were investigated using the Spearman Rank correlation coefficient. ANOVA and MANOVA were used to model dolphin distribution with physiographic variables and trammel nets. A first analysis was performed using the mean encounter rates, residency times, and group sizes as response variables and the mean depth, SD depth, slope, and distance from the coasts as explanatory independent variables. We performed independent analyses for all cells, for the subset of cells without trammel nets, and for cells with at least one of the study variables (e.g., encounter rate, residency time, group size, and trammel nets) different from zero (non-zero cells). A second analysis was performed with the mean encounter rates, residency times, and group sizes as response variables and the mean number of trammel nets as an explanatory variable. In this case, separate analyses were applied to all cells and non-zero cells.

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	#1	#2	#3	#4	#5	9#	L#	#8	6#
No. of cells	2	98	1	1	1	134	20	7	16
Depth (m)	107 ± 43	912 ± 515	27 ± 10	33 ± 12	103 ± 40	$1,061 \pm 345$	317 ± 105	657 ± 166	106 ± 87
SD of depth (m)	53 ± 32	13 ± 28	25 ± 9	18 ± 8	143 ± 60	16 ± 36	122 ± 33	193 ± 75	75 ± 47
Distance from coast (m)	$2,439 \pm$	$4,033 \pm$	484 ± 231	848 ± 245	606 ± 250	$6,791 \pm$	$2,445 \pm$	$3,369 \pm$	575 ± 355
	2,207	2,299				1,908	1,461	1,457	
Slope (m/m)	0.16 ± 0.07	0.03 ± 0.06	0.13 ± 0.02	0.10 ± 0.01	0.20 ± 0.05	0.04 ± 0.09	0.39 ± 0.07	0.4 ± 0.1	0.2 ± 0.1
No. of isobaths	2.5 ± 0.7	0.4 ± 0.8	5.0 ± 1.3	5.0 ± 0.9	7.0 ± 2.0	0.6 ± 0.4	2.5 ± 0.6	0.9 ± 0.4	5.5 ± 0.6
Max. depth (m)	200 ± 34	76 ± 182	50 ± 10	100 ± 25	200 ± 80	$1,699 \pm 251$	440 ± 123	428 ± 188	150 ± 60
Max. length of isobaths (m)	124 ± 56	11 ± 22	100 ± 9	181 ± 77	119 ± 70	44 ± 44	96 ± 16	64 ± 43	111 ± 12
Max. distance of isobaths with max. and min.	89 ± 6	1 ± 5	82 ± 23	85 ± 55	97 ± 26	0	92 ± 22	0	66 ± 20
depth (m)									
Min. distance between isobaths with max. and	34.8 ± 15.3	0.9 ± 4.4	39.3 ± 39.9	57.5 ± 21.5	81.82 ± 19.8	0	66.9 ± 21.1	0	50.5 ± 16.4
min. depth (m)									
Mean distance between two isobaths (m)	1.0 ± 0.2	0.08 ± 0.37	7.9 ± 2.9	13.4 ± 1.4	33.4 ± 9.4	0	4.9 ± 3.5	0	12.4 ± 4.9
SD of distance between two isobaths (m)	4.0 ± 1.8	0.2 ± 1.1	12.0 ± 3.0	19.5 ± 8.5	23.8 ± 12.8	0	15.8 ± 7.6	0	16.0 ± 6.0
No. of shallows	1	0	2	2	1	0	0	0	1
Depth of shallow top 1 (m)	43	0	9	б	41	0	0	0	б
Depth of shallow top 2 (m)	0	0	18	31	0	0	0	0	0

With the aim to find habitat preferences for dolphin groups engaged in different behavioural activities, Principal Component Analysis (PCA) was applied to the four behavioural classes (variables) on non-zero cells (statistical units). The emerging principal components' (PCs) scores can be used as a smaller set of new predictors that are independent by construction (Lebart et al., 1984; Jongman et al., 1995). The component loadings (correlation coefficients between original variables and components) allowed us to assign a behavioural meaning to the PCs. The leading PCs' scores (explaining 80% of behavioural variance) were checked by t-test and Kruskal-Wallis for significant differences between groups of cells by trammel nets and group size. The analyses were performed using the software package SAS, Version 8.1 (Freund & Littell, 1986) for Windows and PAST.

Results

Four hundred surveys were carried out over 564 h for a total of 6,204 km surveyed. Surveys were conducted in the morning (from 0600 to 1400 h) in good light conditions (visibility was more than 300 m) and calm waters (mean = 1.07; sea state based on Beaufort scale < 3), with sea state which did not change between early (mean = 0.8, SD = ± 0.5 , n = 270) and late summer (mean = 1.7, SD = ± 1.9 , n = 130) (*t*-test, p > 0.05) or vary significantly from year to year (Kruskal-Wallis, p > 0.05).

A total of 142 sightings were obtained from 2005 to 2011, corresponding to 98.75 h spent with the dolphins (per sighting: mean = 36.9 min, SD $= \pm 35.2$ min, range 12 to 190 min). The dolphin groups covered 1,053 km at an average speed of $10.05 \text{ km/h} (\pm 2.78 \text{ SD})$. During the sightings, 50 changes of group size were recorded (from 0 to 4 changes; mean = 0.6, SD = ± 1.2). The variances of these group sizes were compared to those obtained extracting a group size sample every 40 min from the data matrix (i.e., an arbitrary time interval which was greater than the mean duration of a group association within a sighting mean $= 36.6 \text{ min}, \text{SD} = \pm 38.4 \text{ min}, \text{min} = 12, \text{max} =$ 180). The data used in this paper are based on 96 dolphin sightings that were examined and confirmed by photo-identification.

Trammel Net Distribution and Abundance

Trammel nets were found at 81.4% (mean = 1.28, SD = ± 0.80) of survey stations (n = 1,325). The percentage of survey stations with and without trammel nets did not vary among years (Kruskal-Wallis, p > 0.05). However, during the surveys, trammel nets occurred more frequently in early

(range 1 to 8; 85.71%) than late (range 1 to 6; 14.28%) summer (Kruskal-Wallis, p < 0.01).

Trammel nets were recorded in 36 cells of the grid during the 2005-2011 study period (Figure 2). The mean number of trammel nets per cell was 1.2 $(n = 36, SD = \pm 0.7, range = 1 \text{ to } 9)$. Trammel nets were more abundant in shallow waters, 2.6 nmi. from the coast (habitat type #1) (14.5% of cells) and in coastal areas characterized by habitat types #3, 5, 7, and 9 (29.4% of cells) (Figure 2). We found that the trammel nets data were not normally distributed along cells of the grid (Shapiro-Wilk, p < 0.01). A significant relationship was found between trammel nets and depth for all cells (Spearman Rank Correlation Coefficient, r = -0.7. p < 0.001) and limiting the analyses to cells with trammel nets different from zero (Spearman Rank Correlation Coefficient, r = -0.4, p < 0.01).

Encounter Rate and Group Size/Composition

While the group size data were normally distributed (Shapiro-Wilk, p > 0.01), the encounter rate and residency time data were not (Shapiro-Wilk, p < 0.01). The encounter rate decreased yearly (Kruskal-Wallis, p < 0.001), and it was higher in early rather than late summer (Kruskal-Wallis, p < 0.01) (Table 1). The average group size was 5.4 (SD = ±2.8, range 1 to 18) (Table 2). About 60% of the dolphin groups were composed of ≤ 5 individuals, 28% were groups of > 10 individuals, and only 12% included groups of 6 to 10 individuals. The group size did not change with the summer period (*t*-test, p > 0.05), but it moderately decreased on a yearly basis (One Way ANOVA, p < 0.05) (Table 2).

Thirty-three distinct individuals, including calves (i.e., individuals identified from the presence of a distinct mother), were sighted and resighted at least once across 96 dolphin group sightings. At the end of the study, 64% of the dolphins were classified as adult (n = 21), 27% juvenile (n = 8), and only 9% calf (n = 4). The group size was higher with (mean = 7.91, SD = ±3.75, range 3 to 18 individuals) than without (mean = 3.8, SD = ±3.1, range 1 to 12) calves in the focal groups (*t*-test, p < 0.0001). In addition, the group size was significantly higher for dolphin groups with juveniles and calves than with adults only (*t*-test, p < 0.0001) (Table 2).

The sex was confirmed or estimated for 55% of the photo-identified dolphins (n = 18). In general, females were sighted more frequently (mean = 21.0, SD = ±6.3) than males (mean = 12.1, SD = ±3.4) (*t*-test, p = 0.006), with no difference related to the early or late summer (Chi-square test, p = 0.86). Females were also sighted more frequently in larger groups (mean = 6.5, SD = ±2.3) than



Figure 2. *Trammel net distribution*: The study area showing the 110 cells of 1-km² used in the statistical analyses. The grey scale shows increasing values of the mean number of trammel nets per cell. The habitat type (from #1 to 9) is also indicated within each cell.

males (mean = 3.7, SD = ± 2.8) (Chi-square, p < 0.0001).

Finally, the dolphins' group size was smaller with trammel nets than without trammel nets (*t*-test, p = 0.001), and males were sighted more frequently with trammel nets (mean = 45.4, SD = ±11.3) than females (mean = 28.8, SD = ±8.0) (*t*-test, p < 0.0001).

Dolphins' Distribution and Physiographic Variables Dolphin group occurrence was recorded in 43.6% of the surveyed cells (n = 48), and only 9 of 36 cells with trammel nets were avoided by dolphins. Levene's test of homogeneity of variances showed no significant difference in variances of encounter rate (Levene's test, L = 0.2, p > 0.05), residency time (Levene's test, L = 0.3, p > 0.05), and group size (Levene's test, L = 2.1, p > 0.05) between cells with and without trammel nets. The residency time was significantly correlated to depth (Spearman Rank Correlation Coefficient, r = -0.6, p < 0.0001) and distance from coast (Spearman Rank Correlation Coefficient, r = -0.3, p = 0.003) for all cells (n = 110). The group size was significantly correlated to depth ($R^2 = 0.3$, p < 0.0001) and distance from coast ($R^2 = 0.3$, p < 0.0001) as well (MANOVA; Wilks' lambda = 0.6, n = 110, F = 4.1, p < 0.0001). For cells without trammel nets (n = 74), only the distance from coast was significantly correlated to residency time (Spearman Rank Correlation Coefficient, r = -0.5, p < 0.0001) and group size (Wilks' lambda = 0.6, $R^2 = 0.3$, F = 3.1, p < 0.001). The group size also increased with distance from the coast (ANOVA; $R^2 = 0.3$, F = 5.3, p < 0.0001) for cells with sightings but without trammel nets (n = 22). Finally, the physiographic variables were not correlated to the encounter rate, residency time, and group size on non-zero cells (n = 58).

Dolphins' Distribution and Trammel Nets

Table 2. Encounter rate and group size: Mean $(\pm$ SD) encounter rates and group sizes (GS) of bottlenose dolphin (*Tursiops truncatus*) groups by (1) year, (2) summer period, (3) presence/absence of juveniles and calves in the groups, and (4) presence/ absence of trammel nets. GS range and total number of sightings are also shown.

	Encounter rate			
	(n/km^2)	Mean GS	GS range	No. of sightings
Total	0.09 ± 0.03	5.4 ± 2.8	1-18	96
2005	0.026 ± 0.005	6.2 ± 2.2	1-11	10
2006	0.026 ± 0.006	4.9 ± 1.4	1-8	13
2007	0.027 ± 0.005	5.4 ± 2.2	1-14	25
2008	0.005 ± 0.004	4.6 ± 3.1	1-14	7
2009	0.007 ± 0.003	6.5 ± 3.7	2-17	8
2010	0.005 ± 0.004	6.3 ± 3.5	1-18	18
2011	0.004 ± 0.002	3.9 ± 1.7	1-11	15
Early summer	0.071 ± 0.009	5.5 ± 2.8	1-18	77
Late summer	0.028 ± 0.007	5.4 ± 2.9	1-14	19
With calves		7.9 ± 2.8	3-18	12
Without calves		3.8 ± 2.2	1-12	84
With juveniles and calves		7.1 ± 2.9	3-18	23
With only adults		3.5 ± 1.9	1-12	73
With trammel nets (from 1 to 8)		3.9 ± 1.9	1-8	56
Without trammel nets		6.9 ± 2.1	1-18	40

30), the encounter rate was significantly higher in cells with trammel nets (n = 11, mean = 0.07, mean $SD = \pm 0.01$) than without trammel nets (n = 19, mean = 0.02, SD = ± 0.01) (Kruskal-Wallis, p <0.01). For cells with a group size different from zero (n = 48), the group size was significantly smaller with trammel nets (n = 27, mean = 2.9, SD $=\pm 2.0$) than without trammel nets (n = 21, mean = 4.5, SD $= \pm 1.5$) (*t*-test, p = 0.002). Finally, for cells with the residency time different from zero (n = 48), the residency time was higher with trammel nets (n = 27, mean = 81.8, SD = ± 60.4) than without trammel nets (n = 21, mean = 63.2, SD $= \pm 90.1$) (Kruskal-Wallis, p < 0.01). We reported the relationships of trammel nets with encounter rate, residency time, and group for each habitat type (Figure 3).

Core Distribution Areas (MCP and FKM) for Groups with Different Sizes

The distribution of groups with ≤ 5 individuals (i.e., an arbitrary cut-off value close to the mean group size) (n = 1,102) and > 5 individuals (n = 872) were mapped separately on the study site with *ArcView GIS 3.2*, and the MCP and 95% FKM core distribution areas were calculated (Figure 4).

Dolphin groups with ≤ 5 individuals preferentially used the coastal area (95% FKM = 47.72 \pm 9.67 km²), while dolphin groups with > 5 individuals were more frequently sighted in the northwestern shallow waters (95% FKM = 42.84 \pm 8.97 km²) (Figure 4). The MCP (km²) was higher (35.97 km^2) for groups with ≤ 5 individuals than for groups with > 5 individuals (24.95 km^2) .

Behavioural Pattern

A total of 813 behavioural records were collected (40.65 h) in 38.6% of the total sighting time. The behaviour of dolphins was recorded on 28 cells of the grid. Travelling (25.8% of sighting time) was recorded in 27 cells; feeding (26.7% of sighting time) in 25 cells; foraging (25.9% of sighting time) in 27 cells; and resting, playing, and socializing (21.5% of sighting time) in 25 cells. Behavioural data were not normally distributed along cells of the grid (Shapiro-Wilk, p < 0.01). In addition, Levene's test of homogeneity of variances showed no significant difference in variances of different behaviours between cells with group size larger (> 5) and smaller (\leq 5) than the mean group size (Levene's test, p > 0.1). Resting, playing, and socializing were higher for larger (49%) than for smaller (13%) groups (Kruskal-Wallis, p < 0.001) (Figure 5). Feeding was higher for smaller (24%) than for larger (10%) groups (Kruskal-Wallis, p< 0.007) (Figure 5). Finally, foraging was higher for smaller (42%) than for larger (17%) groups (Kruskal-Wallis, p < 0.002) (Figure 5).

Levene's test of homogeneity of variances showed no significant difference in variances of different behaviours between cells with and without trammel nets (Levene's test, p > 0.1). The behavioural pattern was different between dolphin groups sighted with and without trammel nets (Figure 5). Feeding was higher for cells with (20%) than without (11%) trammel nets (Kruskal-



Figure 3. *Habitat types, dolphin distribution, and trammel nets:* (a) The mean (\pm SD) encounter rate (no. of sightings/km surveyed), (b) the mean (\pm SD) residency time (min), (c) the mean (\pm SD) dolphin group size, and (d) the mean (\pm SD) number of trammel nets were represented for each habitat type from #1 to 9 (excluding habitat type #4 without data).



Figure 4. Core distribution areas: The study area showing the Minimum Convex Polygon (MCP) and Fixed Kernel Method (FKM) density areas of dolphin groups' locations with group size (a) ≤ 5 and (b) > 5.

Wallis, p < 0.01; foraging was higher for cells with (36%) than without (17%) trammel nets (Kruskal-Wallis, p < 0.01) (Figure 5); and, finally,

resting, playing, and socializing were higher for cells without (55%) than with (19%) trammel nets (Kruskal-Wallis, p < 0.01).



Figure 5. (a) *Trammel nets (TN) and behaviour*: The mean (\pm SE) percentage (%) of each behavioural class (travel, feed, forage, and other behaviours) was reported with and without trammel nets. (b) *Group size (GS) and behaviour*: The mean (\pm SE) percentage of each behavioural class was reported for larger (GS > 5) and smaller (GS \leq 5) groups.



Figure 6. *Habitat types and behaviour:* PC1 vs PC2 score plot according to the percentage of explained variance. Different groups of cells, representing combinations of physiographic variables, are identified according to habitat types (from #1 to 9). The leading behaviours (i.e., the behaviours with the highest loadings) for each component were also reported.

The habitat types most correlated to each behaviour were found by PCA. Two PCs explained 88% of variance of the behavioural data (PC1 = 58% and PC2 = 30%). The behavioural scores were normally distributed (Shapiro Wilks, p > 0.01), and Levene's test of homogeneity of variances showed no significant difference between cells with group size larger and smaller than the mean group size (Levene's test, p > 0.05) and between cells with and without trammel nets (Levene's test, p > 0.05). Both PC1 (t-test, p < 0.05). 0.001) and PC2 (*t*-test, p < 0.01) were significant as for differences between cells with group size larger and smaller than the mean group size. On the contrary, only PC1 was significant for the differences between cells with and without trammel nets (t-test, p < 0.0001) (Figure 6). PC1 was negatively correlated with feeding (loading = -0.15), travelling (loading = -0.21), and foraging (loading = -0.42), and positively with resting, playing, and socializing (loading = 0.86). PC2 was negatively correlated with foraging (loading = -0.58), resting, playing, and socializing (loading = -0.08), and positively with travelling (loading = 0.80) and feeding (loading = 0.04). On the PC1 vs PC2 score plot, each cell of the grid was represented according to habitat type (from #1 to 9) and leading behaviours (i.e., the behaviours with the highest PC1 and PC2 loadings) (Figure 6).

Discussion

This study represents the first attempt to outline the influence of trammel nets on the behaviour and spatial distribution of the bottlenose dolphin population in the Aeolian Archipelago (Blasi & Boitani, 2014). We found that in this area, the bottlenose dolphin groups frequently feed in the proximity of trammel fishing nets, particularly in the early summer when the fishing activities are more abundant. We also found that trammel nets may influence the distribution, habitat preferences, and group size/composition of dolphin groups with direct consequences on the behaviour of dolphins.

Encounter Rate, Residency Time, and Group Size

Currently, few studies have measured dolphin's distribution at the appropriate geographic scale of analyses (Allen et al., 2001; Redfern et al., 2006; Panigada et al., 2008). In this study, we (1) employed sampling at a fine spatial scale (1-km²); (2) derived habitat and trammel net maps of similar spatial resolution; and (3) modelled dolphin distribution by using encounter rate, residency time, and group size data.

As observed in other Mediterranean areas (Wilson et al., 1997; Cañadas et al., 2002; Ingram

& Rogan, 2002; Azzellino et al., 2006; De Segura et al., 2008; Panigada et al., 2008), the study area is relatively complex in terms of bathymetry and habitat structure (Blasi & Boitani, 2012). Previous results have shown that dolphin use patterns can be significantly influenced by the highest seabed gradients (Blasi & Boitani, 2012). Furthermore, in this study, we found that the dolphin groups may tend to concentrate in areas where the habitat structure indirectly affects the density of their prey and which have opportunistic food resources. We found a clear relationship between depth and the abundance and location of trammel nets, and, consequently, the prey availability for foraging dolphin groups.

To remove the correlation effect between physiographic variables and location of trammel nets, which may affect the results of the predictions, we applied the statistical analyses to different levels: all cells, cells without trammel nets, and non-zero cells. We found that without trammel nets, the dolphins' group size increased with the distance from the coast, while the residency time decreased; but no significant correlation was observed, however, between physiographic variables and the encounter rate.

The encounter rates were computed using new locations of dolphin groups at the starting points of each sighting; moreover, the boat surveys were mainly conducted in the early morning when the fishery–dolphin interaction was more intense. Consequently, we cannot exclude that the influence of the encounter rate in the distribution model may be underestimated if the cells of the grid with trammel nets were removed from the statistical analyses (Blasi & Boitani, 2012). Our results suggest that at a fine-spatial scale, the distance from the coast is a more appropriate physiographic descriptor of dolphin movements in the presence of trammel nets.

Our results also showed that both the encounter rate and residency time were significantly higher with trammel nets than without trammel nets, while the group size was smaller; moreover, the residency time and group size were highly correlated to depth and distance from the coast. The analyses performed with non-zero cells showed that the encounter rate, residency time, and group size were significantly correlated to trammel nets but not to any of the physiographic variables. We can conclude that the influence of trammel nets on dolphin distribution is more evident at smaller spatial scales as at larger scales, the correlation of trammel nets with physiographic variables may influence the results of the analyses. These results highlight the importance of comparing different response variables in dolphin-habitat models at the appropriate geographic scale of analyses.

Behavioural Model of Dolphin–Trammel Net Interaction

Because of their varied diet (Barros & Odell, 1990; Barros & Wells, 1998; Blanco et al., 2001) and adaptable behaviour (Shane et al., 1986), bottlenose dolphins have been reported to depredate fish from trammel nets in several Mediterranean areas (Lauriano et al., 2004, 2009; Bearzi et al., 2009). In the Aeolian Archipelago, the intensive fishing operations in coastal areas and the lack of dolphin habitat protection (Blasi & Boitani, 2012) may have changed the distribution of food resources (Bearzi et al., 2006) and, consequently, may affect the costs of feeding competition. The Tursiops truncatus population in the Aeolian Archipelago may be relatively small (only 34 individuals photo-identified between 2005 and 2012). In addition, both the encounter rate and group size significantly decreased in the last 10 y (Blasi & Boitani, 2012, 2014), and several malnourished individuals were found in our population (data not shown). The identification of the dolphins' core areas, like coastal feeding areas, can be useful in the preparation of management plans for local marine protected areas in the Aeolian Archipelago.

In complex habitats, like the shallow waters surrounding Filicudi Island, individuals may benefit substantially by cooperating with individuals that have similar foraging preferences (Blasi & Boitani, 2014). As already reported in other bottlenose dolphin populations (Wells et al., 1987; Möller et al., 2002), males preferentially occurred in small groups compared to females. Small groups and preferred associations between males were also formed to forage and feed in the proximity of trammel nets (Blasi & Boitani, 2014). We cannot exclude that some males specialized in trammel net foraging, suggesting that this foraging technique may favor a solitary lifestyle, probably because it is easier for dolphins to forage alone and consume small fish while avoiding intraspecific competition (Chilvers et al., 2001, 2003; Díaz López & Shirai, 2008; Pace et al., 2011).

Behavioural constraints may be essential in driving the development and maintenance of cooperation in this dolphin community (Corkeron et al., 1987; Cockcroft et al., 1989; Heithaus & Dill, 2002; Croft et al., 2006). We found that resting, socializing, and playing groups were larger than groups of dolphins engaged in other behavioural activities (i.e., travelling, feeding, and foraging). In addition, groups with calves were larger than groups of dolphins with adults only. Large bottlenose dolphin groups usually help in the early detection and defense against predators (Gygax, 2002a, 2002b; Croft et al., 2006), also reducing the risk of injury (Heithaus & Lawrence, 2006).

In our study, smaller groups were preferentially found in shallow waters close to the coast, while larger groups were more frequently found in the north-western side at 2.6 nmi from the coast. Larger groups also showed reduced core areas compared to smaller groups. Large group sizes and different spatial distribution for dolphin groups with calves could be an indication of greater protection and more efficiency in detecting, deterring, or repelling anthropogenic pressures. Specific combinations of physiographic variables were selected by dolphins engaged in different behavioural activities. In particular, habitat types #3, 5, and 9 were exclusively associated with the foraging/feeding activities of small dolphin groups in the proximity of trammel nets. On the contrary, habitat types #1, 2, 6, 7, and 8 were significantly selected for different behavioural activities (i.e., travelling, feeding, resting, socializing, and playing) independent of group size/composition and presence of trammel nets. Although dolphins benefit from taking fish entangled in trammel nets, the association with trammel nets can be dangerous because it exposes the dolphins to the negative reactions of fishermen (Bearzi et al., 2009; Lauriano et al., 2009).

As observed in other Mediterranean areas, in the Aeolian Archipelago, several fish species of commercial interest were included in the bottlenose dolphin diet, particularly the red mullet (Mullus surmuletus), the common sole (Solea solea), the blotched picarel (Spicara maena), the painted comber (Serranus scriba), the comber fish (Serranus cabrilla), the bogue (Boops boops), the greater amberjack (Seriola dumerili), and the saddled seabream (Oblada melanura) (Blasi et al., unpub. data). The reduced catch and the damages to the nets result in a negative reaction from fishermen who try to scare dolphins away from the net or kill the dolphins, often using harmful methods such as harpoons and guns (Lauriano et al., 2009). Although entanglements or injuries were not measured in our population, we found a number of skin lesions of anthropogenic origin on several photo-identified dolphins such as linear wounds (33 individuals) (Luksenburg, 2014), gunshot wounds (1 individual) (Lockyer & Morris, 1990), scratches (3 individuals) (Lockyer & Morris, 1990), and mutilations (3 individuals) (Lockyer & Morris, 1985, 1990; Baker, 1992); and many of the injured dolphins were preferentially males (data not shown). In addition, all the individuals were sighted at least one time in association with trammel nets, and the occurrence with trammel nets varied from 19 to 59% among individuals (Blasi & Boitani, 2014).

Resting is a dangerous activity that dolphins engage in because of reduced vigilance at this time and the lack of a refuge from risk factors (Heithaus, 2001; Heithaus & Dill, 2002). As bottlenose dolphins have lower travel costs (Williams et al., 1992) and there is no benefit in staying in dangerous areas, we expected that the dolphin groups rest and socialize in the safest habitats (Heithaus, 2001; Heithaus & Dill, 2002; Heithaus & Lawrence, 2006).

This study supports the hypothesis that dolphin behaviour patterns may drive groups' distribution and habitat preference. The analyses of dolphin distribution and habitat selection suggests one possible behavioral model. As females require higher metabolic needs compared to males, they may prefer habitats for reasons not associated with prey such as social behaviour, rest, refuge, or calf care/learning. According to this model, females with calf groups generally spend more time in safer areas (i.e., the areas more distant from the coast and, consequently, less dangerous for the presence of fishermen) and simply feed when the opportunity presents itself. On the contrary, males may prefer habitats with a greater amount of trammel nets where they have a higher probability of locating and capturing desirable prey; while for other activities (characterized by searching on natural patches of food, playing, socializing, and resting), they may move into safer areas. We can conclude that group size/composition data are of paramount importance for modeling dolphin-habitat relationships with relevant consequences in terms of conservation strategies. Since we have no data on the dolphins' distribution and group size prior to the beginning of this study, we cannot unequivocally demonstrate that trammel nets have been the major cause of bottlenose dolphins' distribution and group size in the Aeolian Archipelago.

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