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Sociality of sperm whale off Ischia Island (Tyrrhenian Sea, Italy)

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ABSTRACT

1. The sperm whale (*Physeter macrocephalus*) is one of the eight species of cetaceans routinely encountered in the Mediterranean Sea; however, information on the social organization of sperm whales living in the basin remains scarce.

2. The social behaviour of sperm whales within female units, and groups of males are reported, made over an 11-year period (2002–2012) in waters around the islands of Ischia and Ventotene (Tyrrhenian Sea, Italy), an area characterized by the presence of a submarine canyon system and a coastal marine protected area ('Regno di Nettuno' MPA).

3. Different types of aggregations were identified, consisting of social units and two arrangements of males (bachelor groups and clusters). Close clustering at the surface was recorded both for social units and bachelor groups, with evidence for long-term relationships between females (as expected from other studies) and, surprisingly, also among some immature males.

4. Such long-term associations between individuals in bachelor groups may allow immature males to benefit in several ways, including optimizing feeding efficiency.

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KEY WORDS: sperm whale; sociality; Mediterranean Sea; behaviour; conservation

INTRODUCTION

The sperm whale, *Physeter macrocephalus*, is the largest toothed whale, and also the most sexually dimorphic, with females and males reaching maximum lengths of about 12 and 18 m, respectively. Fully-grown males are approximately three times as heavy as mature females (Best, 1979; Rice, 1989). In addition, mature males and females are geographically segregated. Sexually mature females (8.3–9.2 m long) and their dependent offspring (immature individuals of both sexes) travel in groups of about 20 animals within tropical and subtropical and temperate waters (Best, 1979; Rice, 1989; Whitehead, 2003). These groups are usually encountered as temporary associations of two or more smaller stable social units, which in some cases are based around matrilines (Whitehead *et al*., 1991; Richard *et al*., 1996; Mesnick *et al*., 2003). Female sperm whales are believed to remain in the same group throughout their life, but males leave at between 15 and 21 years of age to form 'bachelor groups',

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loose aggregations of similar sized and aged individuals. Bachelor groups typically contain either pubescent males (8.7–10.3 m long) or sexually, but not socially, mature males (11–12 m long) (Rice, 1989). “Socially mature” males, able to compete for access to females, are typically found in the cold waters of higher latitudes in small groups; the largest males (>16 m long) are often observed as solitary individuals (Rice, 1989). It is not known whether males return to their natal grounds to mate or roam more widely, perhaps even moving between ocean basins (Rendell *et al.*, 2005).

The sperm whale is one of the eight cetacean species routinely encountered in the Mediterranean Sea. All age and sex classes have been reported in both the eastern and western basins of the Mediterranean (Frantzis *et al.*, 2003; Drouot *et al.*, 2004; Drouot-Dulau and Gannier, 2007), from newborns to mature males (Mangano, 1983). Together with the Hellenic Trench (Frantzis *et al.*, 2003), the Balearic archipelago (Gannier *et al.*, 2002; Drouot-Dulau and Gannier, 2007; Pirotta *et al.*, 2011), and exceptionally the Ligurian Sea (Notarbartolo di Sciara and Birkun, 2010), the Tyrrhenian Sea (Drouot *et al.*, 2004) is one of the few areas in the Mediterranean Sea in which social units and immature/mature males are observed. This paper describes (a) the sperm whale social distribution and organization in the Tyrrhenian Sea, around the Italian islands of Ischia and Ventotene, and (b) social organization within female units, and groups of males, over an 11-year period (2002–2012).

METHODS

Study site

The study area, situated in the south-eastern Tyrrhenian Sea (Italy), extends over some 8800 km^2 and includes the waters around the islands of Ischia and Ventotene (Figure 1). It is characterized by the presence of several canyon systems, erosion channels along Ischia Island’s edge, and a large submarine valley between Ischia and Ventotene. The whole area is described as ‘Cuma’s Canyon’ (Pennetta *et al.*, 1998; De Alteriis and Toscano, 2003; see also Mussi *et al.*, 2014).

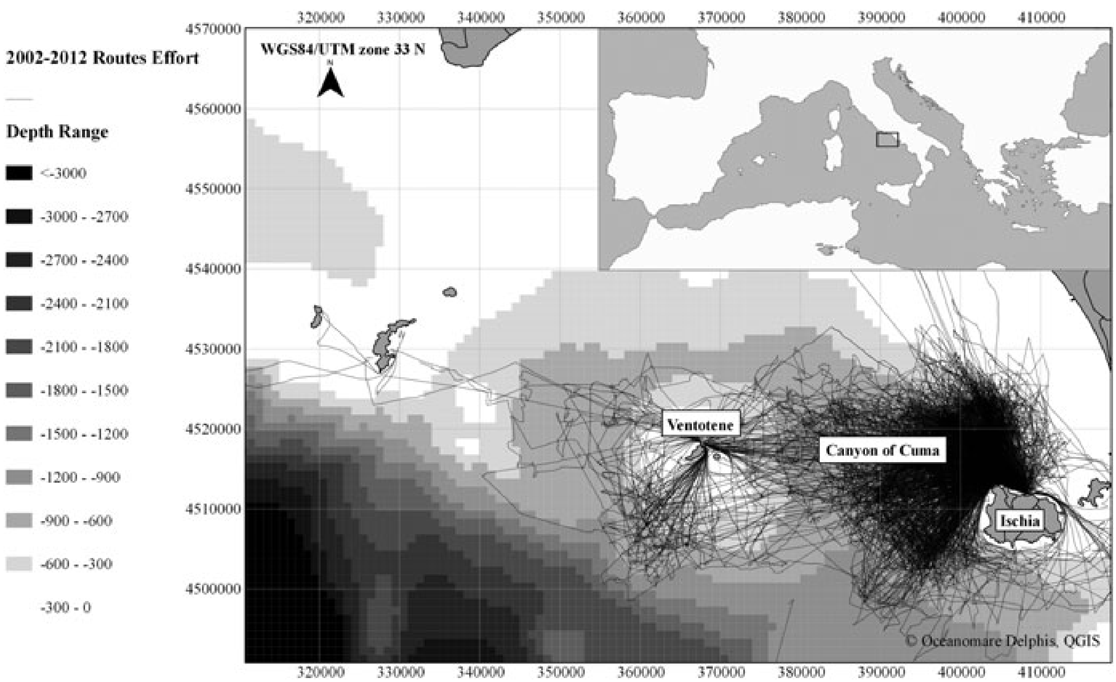

Figure 1. The study area, located in the south-eastern Tyrrhenian Sea (Italy). It includes the Island of Ischia and Ventotene and covers about 8800 km^2 of sea surface. The total effort in km (2002–2012) is reported.

The study area is well known for its high biodiversity and for the presence of large pelagic predators, including seven species of whales and dolphins (Mussi and Miragliuolo, 2003; Pace *et al.*, 2012). Key species in the pelagic trophic web in this area include the euphausiacean *Meganyctiphanes norvegica* (Mussi *et al.*, 1999). The waters around Ischia Island have been recently classified as a marine protected area ('Regno di Nettuno' MPA) and are listed in the last IUCN Cetacean Action Plan as critical habitat for the endangered short-beaked common dolphin (*Delphinus delphis*) Mediterranean subpopulation (Reeves *et al.*, 2003). The area is also an important economic and recreational resource, supporting commercial fishing and shipping as well as leisure boating and marine tourism.

Survey and data collection

Observations of sperm whales were made between 2002 and 2012 from *Jean Gab*, a 17.7 m sailing vessel powered by 145 hp diesel engine. Surveys trips were carried out only in sea state 3 or less during good light conditions, at a vessel speed between 2 and 4 knots. Data were collected by at least three experienced observers during dedicated visual and acoustic surveys within the study area, from June to October each year. Survey tracks were laid out to provide an approximately even coverage of the study area, although taking prevailing weather conditions into account. During all surveys the data logging software 'Logger 2000' (IFAW; http://www.ifaw.org) was run continuously on a laptop connected to a GPS with the vessel's location being recorded every 3 min. Visual and acoustic detections of cetaceans, numbers of whales heard regularly clicking and sighted, as well as behavioural observations were entered manually in Logger for all encounters. Definitions of social behaviour at surface are reported in Table 1.

Searches for sperm whales were carried out by scanning continuously with the naked eye and using 8× binoculars, with height of eye of approximately 3 m above sea level. In addition, a 100 m long towed stereo hydrophone array (100 Hz–22 kHz bandwidth) incorporating two hydrophones spaced 3 m apart was monitored continuously. Differences in time of arrival of whale clicks on the two hydrophones were used to determine the bearings to the vocalizing whales. Rainbow click software (IFAW) was used for this purpose.

When sperm whale clicks were detected the whales were tracked acoustically until they were sighted at the surface. Whales observed at the surface were approached carefully. Once within 300 m, the boat would be slowed and manoeuvred parallel to the course of moving individual(s). At this point the start time and location for a 'visual encounter' were recorded. The animal(s) were then followed using both visual and acoustic means until either the weather conditions deteriorated (e.g. poor visibility, sea state >3) or until all animals present had been identified photographically. Whitehead's focal group protocol (Whitehead, 2004) was used to collect behavioural data at the surface.

Visual sightings with sperm whales were considered as different encounters if they were made on different days or were of unambiguously

Table 1. Different behaviour at surface observed in social contexts

Behaviour	Definition
Sidefluke	A portion of one fluke seen oriented vertically, but moving horizontally, above the water surface (indicating that the whale is turning sharply) (Whitehead, 2003).
Surface roll	A whale rolling (> 90°) at the surface of the water along its principal axes.
Lobtail	Flukes lifted above the water and then thrashed onto the water surface (Whitehead, 2003).
Spyhop	A slow raising of part of the whale's head above the water surface (indicating that the whale is oriented nearly vertically in the water) (Whitehead, 2003).
Breach	A leap from the water, showing at least half of the whale's body (Whitehead, 2003).
Rubbing	A whale actively rubbing a body part on another individual.
Synchronously blowing	Two or more whales blow simultaneously.
Synchronously diving	Two or more whales dive simultaneously.
Floating	Hanging or lying flat on the water surface.

different groupings encountered on the same day more than 60 min apart (group composition was confirmed ashore afterwards using photo-identification images). The type of the encounter (see below), the number of whale(s) present and their behaviour were recorded. Sperm whale sex/age class was determined whenever possible by direct observations of the genital area, either visually or by viewing underwater videos (Figure 2). Individuals with an estimated body length >12 m were assumed to be males.

All sightings were accompanied by real time records of the following temporal and environmental variables: date, time, latitude and longitude coordinates, presence or association of other species (cetaceans, fishes and/or sea birds visually detected), vessels within 100 m of the whales, cloud cover, Beaufort sea state and visibility; distance offshore, depth and water temperature were later extracted from existing data.

Photo-identification

A digital SLR camera (Canon Eos 10D) equipped with a high quality image stabilized telephoto zoom lens (100–400 mm F4.5–5.6) was used to take photo-identification images. Images were stored in JPEG format (12 bit, 2.4 MB, 3072×2048 pixel).

Photographs of the right and left side of the dorsal fin area and the trailing edge and both the dorsal/ventral side of the flukes were taken. Patches, nicks, notches, scars or other irregularities were used to identify individuals (Whitehead and Gordon, 1986). Photographs were assigned a quality (Q) value of 1–5, with 1 representing a poor image which could not be used for identification and 5 indicating a high quality image capable of showing even subtle fluke markings for use in identification (Arnbom, 1987). Only high quality photographs ($Q \geq 3$) capable of allowing positive identification of well-marked individuals between years were added to the identification catalogue (to date, consisting of 60 whales).

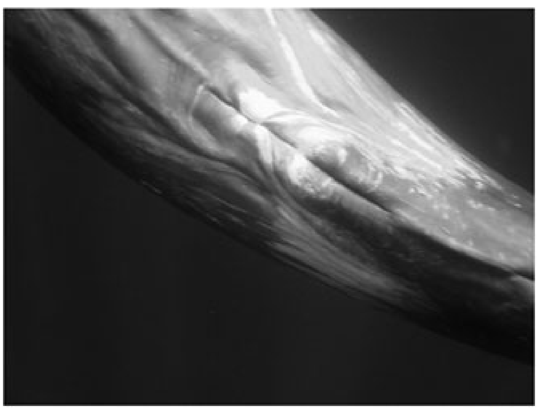

Figure 2. Genital area of a male sperm whale visually assessed.

Whales classification

The following sex/age classes were identified:

- calves (C): all whales having a total length less than 6 m; calves bearing foetal folds were considered as newborns;
- juveniles (J): all whales having a length of approximately 6 to 7 m;
- adult female (FA): all whales having a length of 8 to approximately 11 m, associated with a J or a C within a social unit;
- immature males (MI): all whales having a length of approximately 8 to approximately 11 m, certainly sexed with direct observations of the genital area;
- possible immature males (MIK): all whales having a length of approximately 8 to approximately 11 m that were only seen within a MI assemblage of two to four individuals but were not certainly sexed with direct observations of the genital area;
- adult males (MA): all whales assumed to be mature having a length of approximately 11 to approximately 15 m;
- large bulls (ML): all whales assumed to be mature males having a length of more than 15 m;
- unknown sex/age (UK): all whales having a length of approximately 8 to approximately 11 m seen within a social unit (SU), bachelor group (BG) or cluster (CL), not certainly sexed with direct observations of the genital area (possibly, mature females and/or immature of both sexes are included).

Encounter types

The following encounter types were classified:

- solitary individuals (SI): a single individual with no other sperm whales visually or acoustically detectable around;
- social units (SU): all whale groups of at least four individuals that included calves or juveniles in at least one encounter;

- bachelor groups (BG): aggregations of similar-sized/aged whales comprising immature, and sometimes mature males (Lettevall *et al.*, 2002);
- clusters (CL): all encounters other than SI, SU and BG, i.e. a number of whales (in the study area, generally 2–5 UK, sometimes including MI and MIK individuals) showing coordinated movements within 100 m of one another (Whitehead and Arnbom, 1987).

RESULTS

Encounters and population structure

In total, 243 sperm whales were observed during 99 visual encounters made in the course of 840 days at sea between 2002 and 2012. This represents some 35509 km of track-line (Figure 1), 6369 h of searching effort (before encounter starts) and 277.3 encounter hours. Thirty-eight per cent (n=38) of the encounters were with solitary individuals (SI) (Table 2). Social units (SU), mainly seen in October–November, were quite rare (n=6, ~ 6% of the encounters) and mixing of more than one social unit in large aggregations was never observed in the study area. Bachelor groups (BG; n=21) mostly occurred in 2008 and 2009, while clusters (CL; n=34) were observed with higher frequency in 2005 and 2008. Group size ranged from singletons to a maximum of eight whales, with an average (±SE) value of 6.66±0.55 for SU, 2.95±0.20 for BG and 3.08±0.29 for CL.

Forty-eight per cent of the encountered whales could be classified into six distinct classes (see methods for details) (Table 3). Mature (MA) and immature males (MI) comprised about 31% of the individuals seen (n=74); however, considering an additional number of 16 whales classified as possible immature males (MIK; see methods), the total proportion of males would be probably close to 37%. Females (FA), juvenile (J) and calves (C) accounted for 11% (n=26), while 127 whales remained of unknown sex/age class (UK).

The location of the encounters with different group types is plotted in Figure 3. Sperm whales were mainly distributed in an area north-west of Ischia island, where the bottom depth is between 600 and 800 m (60% of the total encounters; Table 4). SI and CL seem to be spread over the entire area, extending from relatively shallow waters (where the bottom depth is about 300 m) to the deepest ones (900–1000 m); BG were primarily located between 600 and 800 m (71.4% of the encounters) while SU appear to be more isolated and far from regions where higher numbers of other types of encounters were recorded (Table 4). Notwithstanding, no differences between group types emerged in the average depth of the encounters (Kruskal–Wallis: $H_{(3,\ N=99)}= 2.489$, $P=0.477$).

Table 2. Number of encounter types and number of individuals (in brackets) over the study period (2002–2012)

Year	Solitary individuals (SI)	Social units (SU)	Bachelor groups (BG)	Clusters (CL)	Total
2002	1 (1)	1 (5)	-	-	2 (6)
2003	2 (2)	1 (5)	-	-	3 (7)
2004	1 (1)	-	-	4 (13)	5 (14)
2005	3 (3)	-	-	6 (17)	9 (20)
2006	2 (2)	-	1 (4)	4 (9)	7 (15)
2007	5 (5)	1 (8)	-	4 (12)	10 (25)
2008	1 (1)	-	8 (29)	6 (18)	15 (48)
2009	8 (8)	2 (14)	7 (18)	2 (5)	19 (45)
2010	11 (11)	-	4 (9)	3 (8)	18 (28)
2011	-	1 (8)	1 (2)	2 (13)	4 (23)
2012	4 (4)	-	-	3 (8)	7 (12)
Total	38 (38)	6 (40)	21 (62)	34 (103)	99 (243)

Table 3. Number of encounters by sex/age class during the study period (2002–2012)

Sex/Age class	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Total
Calves (C)	1	0	0	0	0	0	0	2	0	1	0	4
Juveniles (J)	1	2	3	2	0	1	0	0	0	2	0	11
Adult female (FA)	3?	0	0	0	0	2	0	3	0	3	0	11
Immature males (MI)	0	0	1	2	5	0	21	19	15	1	5	69
Possible immature males (MIK)	0	0	2	0	1	0	5	5	2	0	1	16
Adult males (MA)	1	1	0	1	0	0	0	1	0	1	0	5
Large bulls (ML)	0	0	0	0	0	0	0	0	0	0	0	0
Unknown sex/age (UK)	0	2	8	15	9	22	22	15	11	15	8	127
	6	5	14	20	15	25	48	45	28	23	14	243

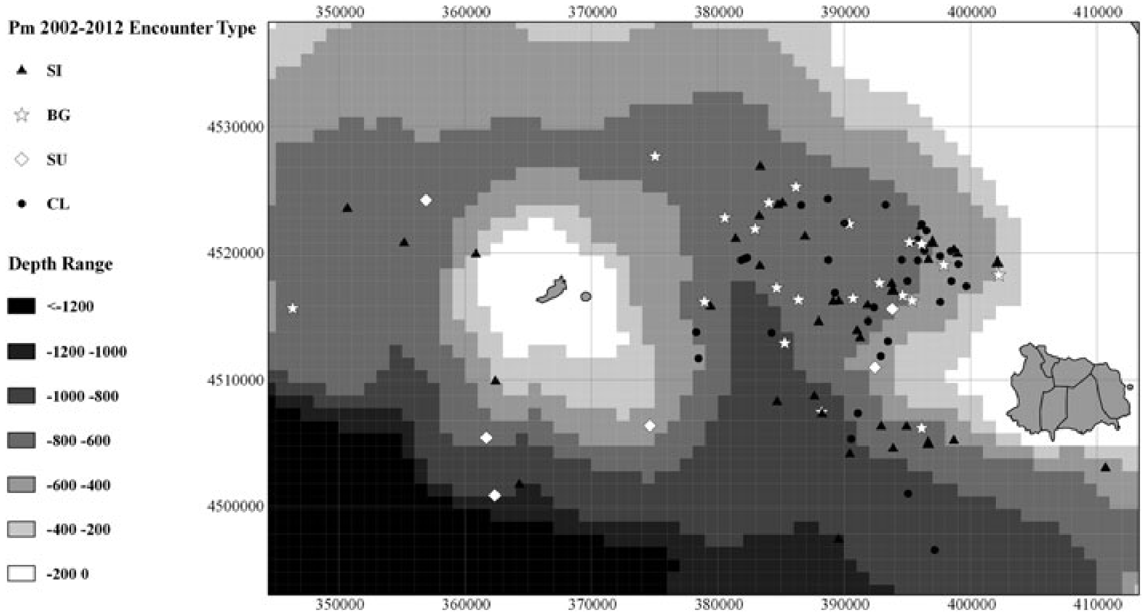

Figure 3. Distribution of the encounter types 2002–2012 (SI=Solitary individuals; BG=Bachelor groups; GR=Groups; SU=Social Units; CL=Clusters; see Table 1 for details).

Table 4. Relationship between group type and depth (2002–2012)

	Depth (m)			N. of encounters per depth range			
Encounter type	Average (±SE)	Min	Max	200–400 m	400–600 m	600–800 m	>800 m
Solitary individuals (SI)	670,82 (±60.91)	281,4	999,9	3 (7.9%)	7 (18.4%)	22 (57.9%)	6 (15.8%)
Social units (SU)	649.99 (±91.53)	417,4	930,7	-	2 (33.3%)	3 (50.0%)	1 (16.7%)
Bachelor groups (BG)	680,18 (±30.55)	593,8	818,5	-	5 (23.8%)	15 (71.4%)	1 (4.8%)
Clusters (CL)	642,07 (±51.73)	309,8	938,1	1 (2.9%)	11 (32.3%)	20 (58.8%)	2 (5.9%)
				4	25	60	10

Photo-identification

Useful photo-identification images were taken during 82 of 99 encounters. This dataset contained 180 identifications of 60 individuals obtained between 20 August 2003 and 6 October 2012. Gender/age class was assessed for 21 identified individuals, three were mature males (MA), three were adult females (FA), 12 were immature males (MI) and three were juveniles (J) of unknown gender.

The discovery curve (Figure 4) indicates that the rate of identifying new individuals did not decrease significantly over the course of the study, indicating that the local population was not close to being fully sampled. Twenty (35%) of the identified individuals were resighted between years, and of these, nine (45%) were sighted over 3 to 5 years. Capture–recapture patterns are plotted in Table 5, Table 6 and Figure 5. Twenty-seven whales (45%) were captured only once, 17 (28%) two times, and 16 (27%) from 3 to 19 times.

Members of one social unit were identified on four occasions in three different years (2007, 2009 and 2011; Table 6). Its composition appears to be changed slightly over the time. In 2007, this unit included eight individuals, one female (NARSIL) with an associated juvenile (DIDI), another female (MILA) and five animals of unknown sex/age class (EIWAZ, SIRIO, GIANCA, AURO and HAGALAZ). In 2009, the unit comprised six whales, DIDI associated with a calf (MENKAR) and MILA with another calf (CHRIS), plus EIWAZ and SIRIO. In 2011, the unit had the same core membership as in 2009, with one

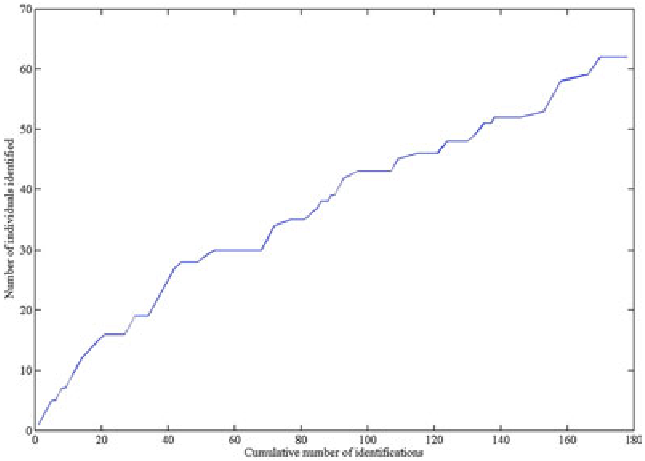

Figure 4. Discovery curve by number of identifications.

additional individual of unknown sex/age class (NIHAL). Two other SU were sighted over two consecutive years (2002 and 2003); however, no good quality photographic data are available from these encounters, therefore preventing any inference on membership.

Long-term associations were found between members of male assemblages as well. Three immature males – NETTUNO, MARK and CRESCENZO – were identified tightly clustered together in bachelor groups on three occasions in 2008 (Table 6); MARK and NETTUNO were also seen together on seven occasions on different days within the same year and in different years (2006, 2008 and 2009). Two other whales, ALETES and BRUNONE, were sighted together eight times in 2009 and 2010, and an additional pair, LOLITA and MANWE (both possible immature males), was located and photo-identified three times in 2008 and 2009. The gender of NETTUNO, MARK, CRESCENZO, ALETES and BRUNONE were confirmed by direct observation of the genital area and/or viewing underwater video (see methods and Figure 2).

Social behaviour at surface

SU members generally displayed all of the types of behaviour listed in Table 1 during social sessions at surface (N=4). Typical behaviour included synchronously diving and blowing, rubbing and breaching. Tail slap and float were rare, being recorded only once. Side fluke and breach were quite common within BG and CL social sessions (N=16 and N=9, respectively), with tail slapping events mainly recorded during interactions between members of BG.

Mean duration of social sessions at the surface of different encounter types of sperm whales varied significantly (Kruskal–Wallis: $H_{(2,\ N=29)}= 6.403$, P=0.040), with an average (±SE) value of 44.75 ±5.45 min for SU (N=4), of 17.10±5.99 for BG (N=16), of 14.44±2.9 min for CL (N=9).

DISCUSSION

In this study, a first effort to delineate sperm whale social distribution and organization in the Tyrrhenian Sea – around Ischia and Ventotene islands – was attempted. Some unexpected and new findings emerged, possibly supporting the description by Whitehead *et al.* (2012) of the relatively small population of sperm whales in the Mediterranean Sea as 'somewhat strange' when compared with populations from both the Atlantic and Pacific. The majority of sperm whale

Table 5. Capture–recapture matrix

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
2002	0										
2003	0	1									
2004	0	0	5								
2005	0	0	2	9							
2006	0	0	2	4	3						
2007	0	0	1	2	1	9					
2008	0	0	1	0	2	0	8				
2009	0	0	1	1	2	5	3	10			
2010	0	0	1	1	2	0	1	3	6		
2011	0	0	0	0	1	5	1	7	1	7	
2012	0	0	1	0	1	0	1	1	1	0	3

Table 6. Capture–recapture histories by individuals over the study period (2002–2012). Light grey rows indicate members of the social unit (SU) sighted in 2007, 2009 and 2011, while dark grey rows indicate immature males (MI) showing stable associations over years

ID CODE	SEX/AGE	2003	2004				2005						2006						2007					2008														
		02/08/03	13/08/04	17/08/04	18/08/04	20/08/04	16/06/05	28/06/05	21/09/05	22/09/05	23/09/05	24/09/05	12/07/06	13/07/06	14/07/06	28/07/06	13/09/06	19/09/06	11/09/07	16/01/07	28/01/07	02/11/07	21/11/07	19/06/08	02/06/08	21/06/08	25/06/08	01/07/08	02/08/08	12/08/08	13/08/08	14/08/08	19/08/08	02/08/08	07/01/08	08/01/08	01/01/08	02/01/08
DAN	MA	X																																				
NOR	UK		X	X							X		X	X			X		X																			
ZOR	MIK		X		X																																	
BRU	MI					X	X							X	X			X																				
ALE	MI																																					
BER	UK		X																																			
LEO	UK		X																							X												
CIR	MA							X																														
EGE	UJ								X																													
LIN	UK								X			X																										
ENE	UK									X										X		X	X															
BET	UK									X	X																											
KAT	UK										X		X																									
ZOY	UK										X																											
SIL	MI											X																										
COR	UK										X				X																							
ANG	MIK															X																						
MAR	MI															X								X	X		X		X		X	X		X				
NET	MI															X								X	X		X		X		X		X					
CRE	MI																										X	X	X	X	X	X	X	X				
MIL	**FA**																				X																	
DID*	**FA**																				X																	
NAR	**FA**																				X																	
MEN§	**UJ**																				X																	
SIR	**UK**																				X																	
EIW	**UK**																				X																	
HAG	UK																				X																	
GIA	UK																				X																	
AUR	UK																				X																	
NIH	UK																																					
TYR	UK																					X																
ELE	UK																									X												
CAS	UK																																		X	X		
LOL	MIK																																		X	X		X
MAN	MIK																																			X	X	
ZEU	UK																																		X	X		
ECH	UK																																		X	X		
SAL	MIK																																					
JOS	MIK																																					
GIS	MA																																					
ALE	MI																																					
AND	UK																																					
ART	UK																																					
SOC	UK																																					
ATH	UK																																					
ULY	UK																																					
PER	UK																																					
IDR	UK																																					
VEG	UK																																					
SHA	UK																																					
ANT	UK																																					
NOC	UK																																					
SAR	UK																																					
ERO	UK																																					
AMN	UK																																					
TES	UK																																					
CAO	UK																																					
ERM	UJ																																					
BRA	UK																																					
VIS	UK																																					
SHI	UK																																					

* This whale (DIDI) was a juvenile in 2007 and a mature female with a calf in 2009.

§ This whale (MENKAR) was a calf in 2009 and a juvenile in 2011.

Table 6. (Continued)

ID CODE	SEX/AGE	2009																		2010																	2011				2012						
		14/03/09	05/05/09	01/05/09	12/05/09	02/06/09	23/06/09	29/07/09	31/07/09	04/08/09	05/08/09	07/08/09	08/08/09	11/08/09	12/08/09	13/08/09	29/08/09	02/11/09	21/11/09	01/04/10	17/04/10	18/04/10	29/06/10	06/07/10	01/07/10	17/07/10	02/07/10	02/07/10	21/07/10	29/07/10	03/08/10	07/08/10	29/09/10	13/01/10	13/01/10	15/01/10	23/06/11	26/08/11	31/08/11	12/10/11	06/07/12	18/07/12	19/07/12	20/07/12	21/07/12	24/07/12	06/10/12
DAN	MA																																														
NOR	UK																																														
ZOR	MIK																																	■	■												■
BRU	MI			■			■				■	■		■	■	■							■	■						■		■		■	■	■											
ALE	MI							■	■		■	■	■	■	■	■					■				■	■		■		■				■		■											
BER	UK																																														
LEO	UK																																														
CIR	MA																																														
EGE	UJ																																														
LIN	UK																																														
ENE	UK																																														
BET	UK																																														
KAT	UK																																														
ZOY	UK																																														
SIL	MI																																														
COR	UK																																														
ANG	MIK																																														
MAR	MI	■																				■															■										
NET	MI	■																																							■	■		■	■	■	
CRE	MI		■	■		■																																									
MIL	**FA**																	■	■																			■									
DID*	**FA**																	■	■																			■									
NAR	**FA**																	■	■																			■									
MEN§	**UJ**																	■	■																			■									
SIR	**UK**																	■	■																			■									
EIW	**UK**																	■	■																			■									
HAG	UK																																														
GIA	UK																																														
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CAS	UK																																														
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JOS	MIK			■																																											
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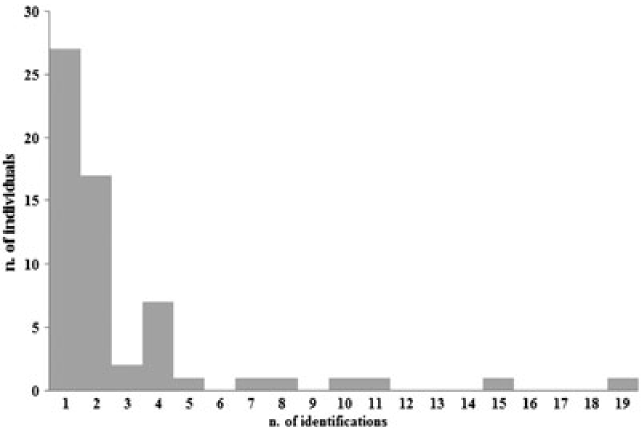

Figure 5. Number of individuals per identification.

encounters in the study area (62%) were with assemblages of individuals belonging to different sex/age classes, ranging from bachelor groups to clusters, to rare social units. The scarcity of encounters with social units (and calves too) may be due to a non-homogeneous sampling effort. In fact, SU were generally observed in October–November, when effort was reduced due to weather; furthermore, the area around Ventotene island – where four out of six encounters occurred – received lower search effort (Figure 1), therefore limiting the detection probability. The small number of SU encounters also affected the opportunity for comparisons of the size of these groups. Average values of 6.66 individuals found in this study were similar to the Gulf of Mexico (Jaquet and Gendron, 2009), showing much lower values than other well-known geographical areas in the Atlantic and Pacific oceans (Jaquet and Gendron, 2009; Whiteheaed *et al*., 2012). By contrast, the average group size for bachelor groups was higher than those reported in other areas (Lettevall *et al*., 2002).

Large bulls were never seen in the study area; this is similar to Drouot *et al*. (2004) observations in the Tyrrhenian Sea. Large specimens were known to inhabit the Mediterranean Sea until the early 1990s, however, the heavy impact of drift netting activities may have changed the population composition with a possible depletion of large, physically mature males (Northridge, 1991).

The photo-id discovery curves showed no signs of reaching an asymptote indicating that the number of individuals visiting or using the area is probably larger than the total identified. At least some (35%) of the identified individuals returned to the area and were resighted on occasions over a year apart. Since no quantitative information is available in other parts of the Tyrrhenian Sea, between Corsica/Sardinia and mainland Italy, it is only possible to speculate about the relative importance of the area within the wider environment. Submarine canyons often have higher biological productivity than their immediate surroundings (Hickey, 1995) and this is often attributed to upwelling at the canyon site enriching the photic zone with nutrients. This increased productivity means marine megafauna often inhabit or feed there (Schoenherr, 1991; Vetter and Dayton, 1998; Hooker *et al*., 2002; D'Amico *et al*., 2003). The Cuma submarine canyon is characterized by high biodiversity (Pace *et al.,* 2012), including key species in the pelagic trophic web such as the euphausiacean *Meganyctiphanes norvegica* (Mussi *et al*., 1999). Thus, good foraging conditions may explain the regular occurrence of sperm whales in this area. The acoustic recordings indicate that creaks (highly directional pulsed train of clicks with high repetition rate, 20–200 pulses per second, emitted during foraging) were produced during more than 90% of the sperm whale encounters, suggesting that feeding activities (Miller *et al*., 2004) regularly occur in the area. Considering the general oligotrophy of the Mediterranean basin (Walle *et al*., 1993; Notarbartolo di Sciara *et al*., 2008) and the influence of oceanographic parameters, such as currents and bathymetry (O'Dor, 1992; Bakun and Csirke, 1998), on resource (squid) distribution and abundance, this area may represent a significant feeding hotspot for the sperm whale.

Some immature males were found to form long-term relationships occurring in tight surface clusters and exhibiting all the types of surface behaviour seen within social units. Bachelor groups of sperm whales had previously been described as 'loose, apparently unstructured, relationships among non-breeding males' (Lettevall *et al*., 2002) and socializing behaviour at the surface was considered 'exceptionally rare among these males' (Whitehead *et al*., 1992; Jaquet *et al*., 2000) and 'when it happened, it was usually in a cluster of two animals and for no more than few hours' (Whitehead, 2006). Our observations, in contrast, suggest that sexually immature individuals in bachelor groups form long-term associations. It is not known if these males are related to each other, or share group-specific feeding specializations (Whitehead and Lusseau, 2012). Young males may benefit in several ways from belonging to stable all-male groups after they leave their SU. They may feed cooperatively, sharing information on the location of prey patches for example; group living may also allow individuals to establish breeding alliances and to practise fighting skills (Chiyo *et al.*, 2011).

The spatial scale of the observations is very small and the number of unknown sex/age class of individuals frequenting the study area is high, thus limiting the possibility of a more robust analysis. Despite these caveats, this represents a significant contribution to the limited knowledge of the species in the basin and a first assessment to support conservation efforts to reduce activities that might disrupt both the behaviour and social organization of a species.

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