marine ecology

Marine Ecology. ISSN 0173-9565

ORIGINAL ARTICLE

Changes in cetacean presence, relative abundance and distribution over 20 years along a trans-regional fixed line transect in the Central Tyrrhenian Sea

Antonella Arcangeli[1], Luca Marini[2] & Roberto Crosti[1]

1 ISPRA Dip. Difesa Natura, Rome, Italy
2 Accademia del Leviatano, Rome, Italy

Keywords
Cetacean; Mediterranean Sea; line transect.

Correspondence
Antonella Arcangeli, ISPRA Dip. Difesa Natura,Via Brancati 48 00144 Rome, Italy.
E-mail: antonella.arcangeli@isprambiente.it

Accepted: 11 August 2012

doi: 10.1111/maec.12006

Abstract

From 1989 to 1992, systematic cetacean surveys were carried out twice weekly along a trans-regional fixed transect in the Central Tyrrhenian Sea, utilising passenger ferries as research platforms. Using the same protocol and supervised by the same investigators, the research restarted in 2007, providing the opportunity to compare consistent data over a long 20-year period. The monitored transect (Civitavecchia-Golfo Aranci) runs along a strategic area just outside the southeastern border of the Pelagos Sanctuary. Over the last two decades, an increasing trend of temperature and salinity, in the deep and intermediate layers, has been documented in the region, as well as general changes over the Mediterranean basin. These changes, together with the increasing impact of some pressures (*e.g.* maritime traffic) may have led to changes in oceanographic and anthropogenic features and, subsequently, in cetacean presence and distribution. The research aimed to verify whether any changes occurred in the pattern of cetacean occurrence over the 20-year period along the representative transect in the Central Tyrrhenian Sea. Data from 90 summer weekly runs undertaken in the 1990s were compared with data obtained from 95 runs undertaken in the 2000s. Each ferry run was considered an independent statistical unit: the encounter rate (ER = number of sightings per hour spent on effort) was calculated to compare relative abundance between periods, years and months. Spatial analysis was performed on geographical data using Kernel analysis to map the distribution of sightings. Logistic regression (GLM) was performed to compare habitat preference. Total encounter rate in the 1990s (ER = 0.59 ± CI 0.08) was significantly lower ($P < 0.01$) compared with the 2000s (ER = 0.94 ± CI 0.15). The same seven out of eight species known for their regular presence in the Mediterranean Sea were sighted in both the investigated periods. The most common species were striped dolphin (*Stenella coeruleoalba*), fin whale (*Balaenoptera physalus)* and common bottlenose dolphin (*Tursiops truncatus*). Neither the pilot whale nor any other rare or occasional species were sighted during the 6 years of the study. Despite the time span, no dramatic changes were observed for any species, bar fin whale, in terms of distribution, relative abundance, group size or habitat preference. Sightings of fin whale have surprisingly increased (+300%, $P< 0.001$), and their spatial and temporal distribution and habitat preference showed a radical difference between the two periods. The 2000s surveys confirmed the existence of high density areas of cetaceans, especially of fin whale, and the consequent necessity of specific legislative acts for cetacean conservation.

Introduction

Long-term monitoring of cetacean presence, relative abundance and distribution is essential to promptly detect variation that can be related to changes in the environmental factors, providing evidence to improve conservation and adaptive management of marine ecosystems (Evans & Hammond 2004; Donovan 2005). The assessment of trends in distribution and abundance of cetacean population over time is a key pillar to fulfill the requirement of the EU legislative frameworks on biodiversity such as the Habitat Directive (1992) and, specifically, the Marine Strategy Framework Directive (2008).

The cost of research and lack of methodological consistency have been the main problems in the development of long-term monitoring programs of cetacean populations (Oakley *et al.* 2003; Donovan 2005). Due to their low costs, standard routes, speed and height of the observation point, ferries are efficient and cost-effective platforms for long-term monitoring programs of cetaceans (Kiszka *et al.* 2007). Ferries allow for repetitive surveys along a fixed transect which can be conducted regularly throughout progressive years, thus providing information on long-term patterns within a particular area of interest (MacLeod *et al.* 2008). This method has been accepted by the Joint Nature Conservation Committee for regular conservation assessments of cetaceans in the UK (Brereton *et al.* in press). It has also been used to assess the impact of maritime traffic in deep sea waters (Crosti *et al.* 2011).

From 1989 to 1991, dedicated surveys along a fixed-transect in the Central Tyrrhenian Sea were carried out twice a week using passenger ferries as research platforms. The collected data provided new information about some species and their distribution in the region (Marini *et al.* 1997). In 2007, the research restarted in the same area, under the same protocol and supervision of the same investigators (Arcangeli *et al.* 2008), giving the opportunity to compare consistent data over a long period.

The study was conducted in the Central Tyrrhenian Sea, in a strategic area just beyond the southeastern border of the Pelagos Sanctuary. This is considered an ecological corridor within whale migration patterns in the Central Mediterranean Sea (Marini *et al.* 1997) and has been identified as a favorable area for Cuvier's beaked whale (*Ziphius cavirostris*) (Gannier 2011). The Central Tyrrhenian Sea is considered a priority conservation area and has been proposed as a Specially Protected Area of Mediterranean Importance under the protocol on Special Protected Areas and Biological Diversity in the context of the Barcelona Convention (UNEP 2010). Moreover, the Italian Government recently established an 'Ecological Protection Zone' (D.P.R. 209/2011) within the Tyrrhenian Sea, boosting conservation measures extending national jurisdiction beyond country boundaries.

During the last two decades (from 1988 to 2006) changes in temperature and salinity trends at deep and intermediate levels were documented in the Central Tyrrhenian Sea, with clear accelerations observed since the 1990s (Gasparini *et al.* 2005; Schroder *et al.* 2006). General changes have also been seen across the Mediterranean basin (IPCC 2007; Barale *et al.* 2008; EEA 2008). This situation may have led to changes in the oceanographic features which drive prey availability and, consequently, cetacean range and distribution (Gambaiani *et al.* 2009; MacLeod 2009; Simmonds & Eliott 2009). In addition, the increasing intensity of some pressures, including maritime traffic (Abdulla & Linden 2008), may have had an impact on species size and distribution.

The research aimed to assess whether any changes occurred in the pattern of cetacean occurrence over this 20-year period along the representative transect in Central Tyrrhenian Sea. In particular, the research aimed to identify any changes in species presence and composition, relative abundance, distribution, and relation to environmental variables.

This paper presents the results of one of the longest quantitative comparisons on temporal differences of cetacean species in the Mediterranean Sea.

Material and Methods

Study area

Systematic surveys were conducted along a trans-regional fixed line transect in the Central Tyrrhenian Sea between Civitavecchia (CIV, Central Italian peninsula) and Golfo Aranci (GA, Sardinia). The transect is almost 118.5 nautical miles long and crosses several cetacean habitats, such as shelf, shelf-edge, deep sea and canyons. The transect runs almost perpendicular to coasts, to any expected density gradient, and across the direction of whale migration, as suggested by Evans & Hammond (2004).

The currents in the study area are influenced by the Tyrrhenian cyclonic circulation and the eastward jet-like force generated by the wind blowing from the Strait of Bonifacio. This force determines important quasi-stationary gyres (Boniface gyre), which enhance the vertical motion of the sea (Astraldi & Gasparini 1994).

Data collection

Two series of 3 years of seasonal monitoring, from early June to the end of September, were compared: 1990–92 (1990s) *versus* 2007–2009 (2000s). During the investigated periods, surveys were conducted twice a week in 'passing mode' (Wall *et al.* 2006), using ferries as observation platforms for dedicated surveys (Donovan 2005). The 'on effort' period was considered only under fine weather and sea conditions (Beaufort scale ≤ 3).

Two or three dedicated and expert cetacean observers were located on both sides of the ferry command deck, 15–18 m above sea level. Each observer focused primarily on a 130° arc ahead of the ship and continuously scanned the area with the naked eye plus an occasional scan with binoculars. Binoculars and some photographs were used to confirm sightings and to assess species and group size. Group size was considered to be a group of animals seen at the same time, showing similar behavioral characteristics and <1000 m from each other (Canadas *et al.* 2005).

Data analysis

Each ferry run (survey) was considered an independent statistical unit. The Spearman coefficient correlation between outbound and return, and autocorrelation between weekly runs in the same direction, were undertaken to assess independency of the dataset. An autocorrelation index was set as the critical value, as it was assumed that the data between two successive outbounds (or returns) at the minimum time distance of a week were independent.

Due to variation in visibility during the survey and changes in the sea state, the 'on effort' period was not continuous and differed according to the run. For this reason and due to the fact that, along the transect, a sighting could be considered an event more than a state (Martin & Bateson 1993), relative abundance was measured as encounter rate (ER = number of sightings per hour spent 'on effort') (Evans & Hammond 2004; Wall *et al.* 2006).

The two analysed periods were each grouped in 3 years of monitoring. Data from 90 weekly runs undertaken in the 1990s (1990, 1991 and 1992) were compared with data obtained from 95 runs in the 2000s (2007, 2008 and 2009) (Table 1). We primarily analysed whether differences occurred in species presence, ER and mean group size during the two investigated periods. Data were compared with the Kruskal–Wallis (KW) test and Mann–Whitney (MW) as a post hoc test between pairs. Yearly and monthly analyses, to test whether differences occurred in inter-annual and intra-annual variability, were performed only on the more commonly sighted frequent species. The data analysis package PAST (Hammer *et al.* 2001) was used.

Geographical data were interrogated by performing spatial analysis with a GIS program (software ARCGIS 9.3). The Kernel smoother for point pattern analysis of occurrence-only data (Hengl 2009) was used, after testing for independency of the dataset, to map higher density areas of species distribution assessed over 70% of the sightings (smoothing factor = h_{cv}; volume level = 0.70).

Table 1. Total effort and sightings during the two investigated periods

Years	Period	Total no. of runs	Total no. of hours in good weather conditions	Total no. of sightings
1990	30 May–21 Sept.	35	238	155
1991	19 May–11 Sept.	23	152	89
1992	25 May–26 Sept.	32	212	100
2007	26 May–29 Sept.	32	152	113
2008	15 June–27 Sept.	27	107	91
2009	29 May–27 Sept.	36	148	172
Total 1990–1992		90	603	344
Total 2007– 2009		95	406	376

Habitat preference

To be able to compare changes in habitat preference over the time period, logistic regression such as generalized linear model (GLM) was performed on the main ecogeographical variables (EGVs). According to Praca *et al.* (2009), presence–absence methods such as GLM are recommended for modeling habitat suitability of cetaceans, especially when, as in our case, data are systematically recorded, collected within the same protocol, and the observation effort is significant and equally distributed across the investigated area. Depth, slope, aspect (slope direction) and distance from the coast were chosen as EGVs, while chlorophyll *a* (Chl-*a*) and sea surface temperature (SST) were not considered due to the lack of satellite-derived data in the early 1990s.

Binary logistics regression with the logit link function was performed for the three most sighted species (striped dolphin, fin whale and common bottlenose dolphin) and the AIC (Akaike information criterion) was used to account for the accuracy of the model. The statistical software R Development Core Team (2005) was used for the analysis.

The research area was divided into cells of 1 × 1 km and, for each investigated period, only the cells which intercepted at least one track line 'on effort' were selected for further analysis. The mean 'cell effort' values were calculated as the number of km travelled within each cell (Fig. 1). The values for the central point of each cell were obtained for each EVG. The seabed aspect values were converted from a circular variable (degree) into two components: sine (aspect easting, E) and cosine (aspect northing, N).

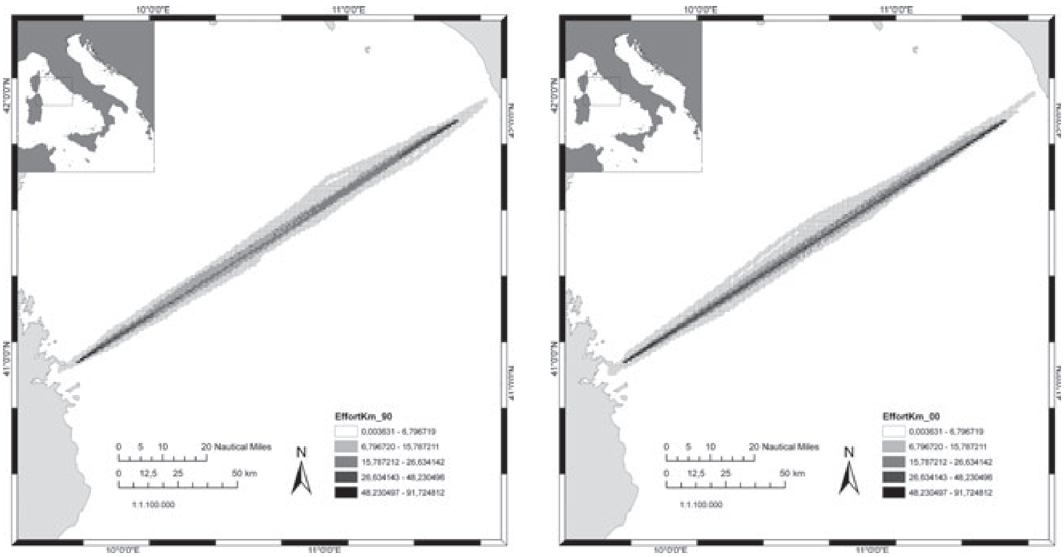

Fig. 1. Map showing number of grid cells surveyed within the study area: 'cell effort' is calculated as number of km surveyed in good weather conditions per cell of 1 × 1 km (period 1990–92 on left and 2007–2009 on right).

The presence data were compared with absence (pseudo absence) data. Presence cells were defined as cells, on the survey track, where one or more sightings occurred (value of 1), whereas absence cells were defined as cells where no sighting occurred (value of 0). To reduce the bias of false absence data (animals present but not detected) and considering the large number of cells with zero, cells with no sightings, twice the number of cells with presence, were selected among those with higher effort. This resulted in a greater mean effort for absence cells compared with presence cells (Table 2).

Results

'On effort' differences were recorded over the two investigated periods, mainly due to differences in the weather and sea conditions. In the 1990s, 344 sightings of seven cetacean species (ER = 0.59 ± CI 0.08 sightings per hour) were recorded, compared with 376 sightings (ER = 0.94 ± CI 0.15) of the same species in the 2000s (MW $P < 0.01$) (Table 1). In both investigated periods the most commonly sighted species were striped dolphin (*Stenella coeruleoalba*), fin whale (*Balaenoptera physalus)* and common bottlenose dolphin (*Tursiops truncatus*) (Fig. 2). The results showed a surprising increase in ER of fin whale (+300%, MW $P < 0.001$) whereas ER of the other commonly sighted species such as striped dolphin, common bottlenose dolphin and Cuvier's beaked whale (*Ziphius cavirostris*), showed no significant difference. In both periods, sperm whale (*Physeter macrocephalus)*, common dolphins (*Delphinus delphis*) and Risso's dolphin (*Grampus griseus*) were spotted only sporadically. Long-finned pilot whale (*Globicephala melas*) was not sighted either in the 1990s or in the 2000s.

Sightings of fin whale did not show any important inter-annual difference in the 1990s (mean ER = 0.088 ± 0.014), but differences in inter-annual ERs were detected in the 2000s (KW $P < 0.01$) with the lowest values detected in 2007 (ER = 0.18 ± 0.033) and the highest ER detected in 2009 (ER = 0.53 ± 0.083). Other species did not show any major inter-annual difference.

Over the years (Fig. 3), total cetacean ER was similar among the different months in the 1990s, whereas in the 2000s it showed two maxima in June and August, mostly determined by fin whale sightings. In fact, fin whale showed a relative higher ER at the beginning and end of the season (June and September) in the 1990s, whereas in the recent years the species has shown significantly higher ERs in June and August (KW $P < 0.01$). By contrast, sightings of striped dolphin did not show any significant intra-annual difference in ER between the investigated periods.

The mean group size (Fig. 4) was almost the same for all species in both investigated periods. Only common bottlenose dolphins were spotted in smaller groups during recent years compared with the past.

The output of the Kernel analysis for fin whale (Fig. 5) showed a significant change in distribution, being more concentrated in the central-western side of the transect during the 2000s compared with the 1990s triennium. Both periods confirm the importance for the species of the area between 20 and 50 nautical miles northeast of Sardinia.

Table 2. Presence data compared with absence (pseudo absence) data.

			Cell effort		GLM		
	EGVs	Mean value EGVs	Presence	Absence	Estimate	P	AIC
S. coeruleoalba 1990s	Intercept		13.2 ± 0.7	22.5 ± 0.5	−1.44E+00	***	860.11
	Depth (m)	−1021 ± 24			2.36E-04		
	Slope (°)	2.31 ± 0.12			6.69E-04		
	Aspect N (cos)	−0.09			−6.43E-02		
	Aspect E (sin)	0.004			1.18E-03		
	Dist-coast (m)	59,240 ± 1518			1.02E-06		
S. coeruleoalba 2000s	Intercept		16.4 ± 1.2	30.1 ± 0.8	−1.81E+03	***	564.50
	Depth (m)	−1041 ± 29			−8.78E-04		
	Slope (°)	2.32 ± 0.14			2.12E-01		
	Aspect N (cos)	−0.24			−9.48E-02	***	
	Aspect E (sin)	−0.019			1.35E-02		
	Dist-coast (m)	61,938 ± 1867			−2.70E-06		
B. physalus 1990s	Intercept		17.8 ± 1.7	34.7 ± 1.3	−3.79E+00	***	174.95
	Depth (m)	−1012 ± 49			2.57E-03		
	Slope (°)	2.20 ± 0.26			−4.40E-02		
	Aspect N (cos)	−0.18			−1.80E-01		
	Aspect E (sin)	−0.006			3.53E-01		
	Dist-coast (m)	57,589 ± 3074			1.21E-04	***	
B. physalus 2000s	Intercept		21.0 ± 1.1	37.2 ± 1	−2.36E+00	***	458.02
	Depth (m)	−1066 ± 36			−1.69E-03	***	
	Slope (°)	2.43 ± 0.11			8.39E-02		
	Aspect N (cos)	−0.232			−7.85E-01	***	
	Aspect E (sin)	0.153			4.15E-01	*	
	Dist-coast (m)	60,099 ± 1420			−1.59E-06		
T. truncatus 1990s	Intercept		12.5 ± 2.9	48.5 ± 2.3	1.99E+00	*	63.61
	Depth (m)	−55 ± 2			1.28E-03	*	
	Slope (°)	0.29 ± 0.03			−7.72E+00		
	Aspect N (cos)	−0.010			6.26E-01		
	Aspect E (sin)	0.828			2.13E+00	*	
	Dist-coast (m)	25,670 ± 4803			1.53E-05		
T. truncatus 2000s	Intercept		21.4 ± 5.1	61.4 ± 1.8	−2.16E+00	**	75.21
	Depth (m)	−429 ± 108			3.37E-03		
	Slope (°)	1.894 ± 0.51			−3.56E-01		
	Aspect N (cos)	0.045			−1.61E-02		
	Aspect E (sin)	0.762			2.09E+00	**	
	Dist-coast (m)	29,758 ± 7197			9.55E-05		

1990s = 1989–1991; 2000s = 2007–2010; cell effort = number of sightings per km travelled within each cell.
***$P < 0.001$; **$P < 0.01$; *$P \leq 0.05$.

The same analysis conducted on the other most sighted pelagic species, striped dolphin (Fig. 6), did not show such a remarkable change. Striped dolphin were distributed along all the pelagic areas of the transect, with a slight preference for the western side during more recent years.

The common bottlenose dolphin was sighted mostly along the Sardinian continental shelf in both the investigated periods (Fig. 7). Interestingly, some sightings occurred in deep sea waters in both periods, albeit in different positions: more on the eastern side of the transect in the 1990s, and concentrated in the high density area northeast of Sardinia in the 2000s.

Habitat preference

The results of the generalized linear model are shown in Table 2. The GLM P-values indicate that for striped dolphin in the 1990s, no EGVs showed any association with the sightings, whereas in the 2000s, only aspect N had a strong influence on the preference of the habitat.

Compared to the 2000s, the common bottlenose dolphin distribution in the 1990s was influenced by depth, and not only in the aspect E. However, it should be noted that the numbers of sightings of this species were relatively small during both the investigated periods and so it was not possible to assess habitat preferences.

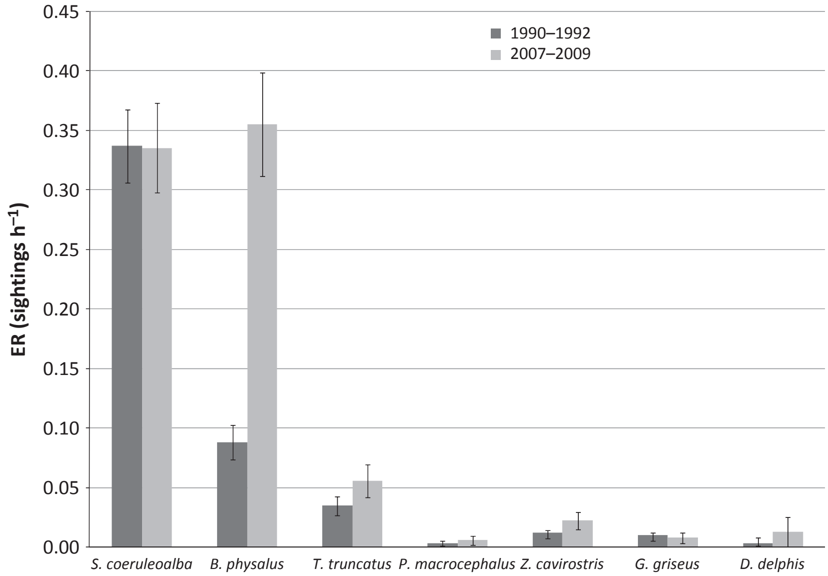

Fig. 2. Mean values of species encounter rate measured as ER = sightings per hour 'on effort' ± SE. N = number of sightings, N_{Sc90s} = 187; $N_{Sc2000s}$ = 134; N_{Bp90s} = 54; $N_{Bp2000s}$ = 142; N_{Tt90s} = 21; $N_{Tt2000s}$ = 21; N_{Pm90s} = 2; $N_{Pm2000s}$ = 2; N_{Zc90s} = 8; $N_{Zc2000s}$ = 9; N_{Gg90s} = 5; $N_{Gg2000s}$ = 3; N_{Dd90s} = 2; $N_{Dd2000s}$ = 2).

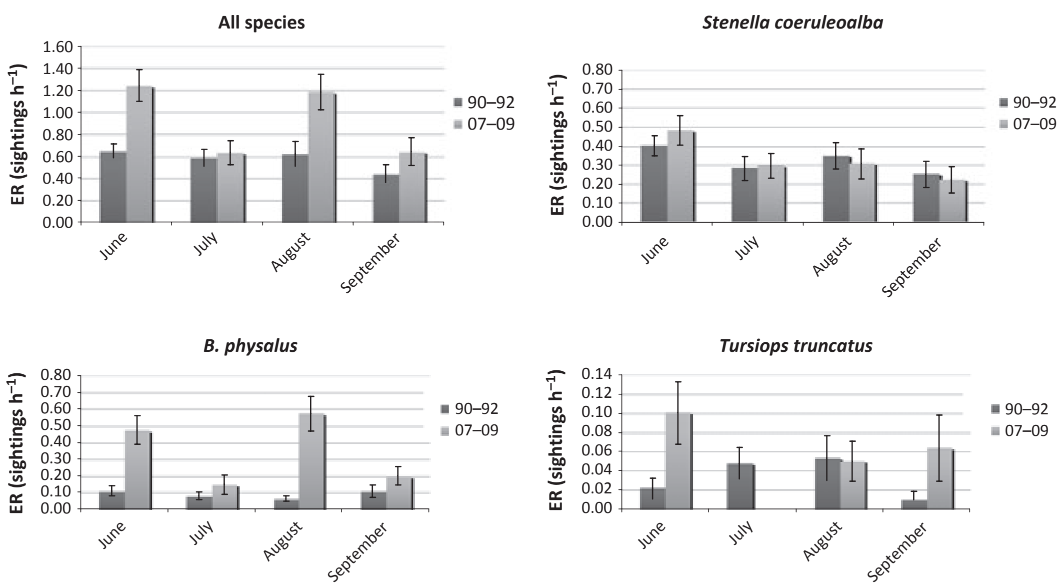

Fig. 3. Monthly ER = sightings per hour 'on effort' ± SE.

Fin whale showed greater differences in the association between EGVs and animal distribution over the 20 years. In fact, whereas in the 1990s only the distance from the coast could predict the presence of the species, in the 2000s, depth and other aspects were the variables strongly influencing the distribution of the species in the study area.

Discussion

Dedicated monitoring along the fixed line transect using ferries as observation platforms was confirmed to be a reliable and cost-effective method, enabling the collection of consistent data over a long period of time. Moreover, with fixed geographical variables, the detected changes in sightings cannot be due to spatial heterogeneity and can consequently be related to biological or ecological processes.

The same seven of eight species known to be sighted regularly in the Mediterranean Sea were sighted in the Central Tyrrhenian Sea in both the investigated periods. Neither the pilot whale nor any other rare or occasional species were sighted over the 6 years of the study.

For all species, bar the fin whale, distribution, relative abundance and group size revealed no dramatic changes during this extended period. In fact, sightings of fin

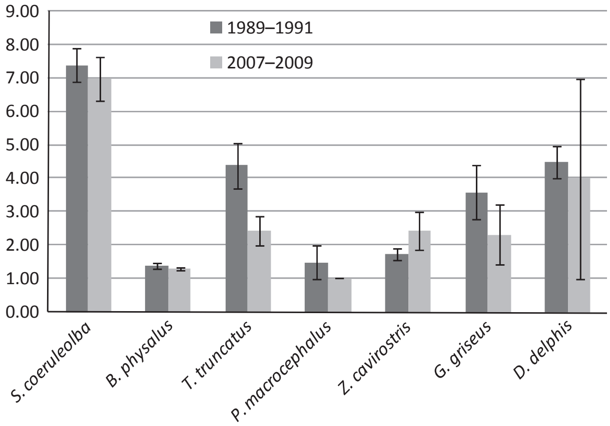

Fig. 4. Mean group size ± SE of sighted species during the two investigated periods.

whale have increased surprisingly, and their spatial distribution showed a radical difference between the two periods. Moreover, fin whale was frequently sighted during the middle of the summer season (August) during recent years, whereas it was mostly sighted at the beginning and end of the season in the 1990s. This result highlights a change in the migration timing of the species and/or in the use of the Central Tyrrhenian Sea area, which was considered a migration route by Marini *et al.* (1997) in the 1990s.

The results in habitat preference over the two investigated periods demonstrated that significant differences occurred exclusively for fin whale; over the 20-year period, this species was clearly driven by different geographical variables (mainly distance from the nearest coastline in the 1990s and depth and aspect E in the 2000s).

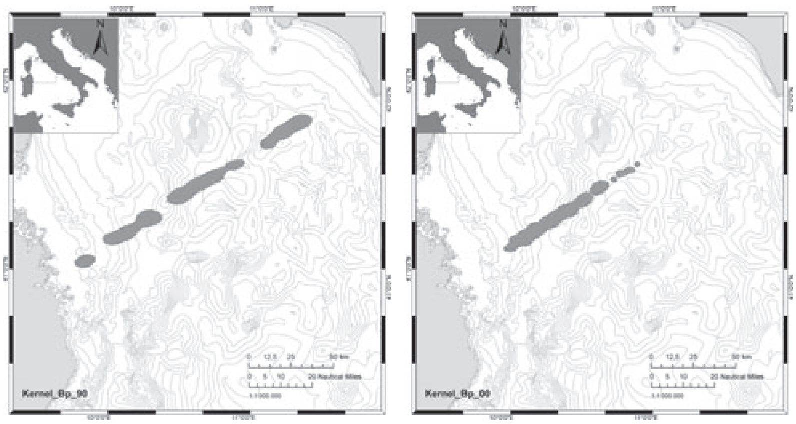

Fig. 5. Distribution of fin whale sightings compared: on the left, the uniform distribution recorded during 1990s (90) and, on the right, the hot spot observed in 2000s (00). Kernel parameters: volume level = 0.70 (k70).

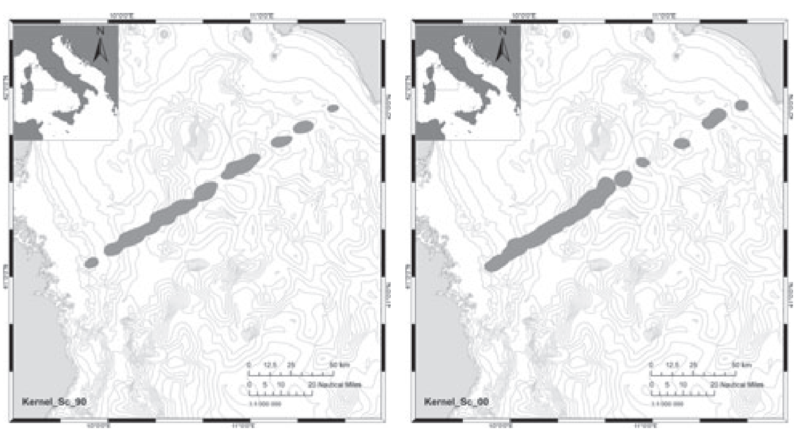

Fig. 6. Distribution of striped dolphin sightings compared: on the left, the distribution recorded during 1990s (90) and, on the right, the hot spot observed in 2000s (00). Kernel parameters: volume level = 0.70 (k70).

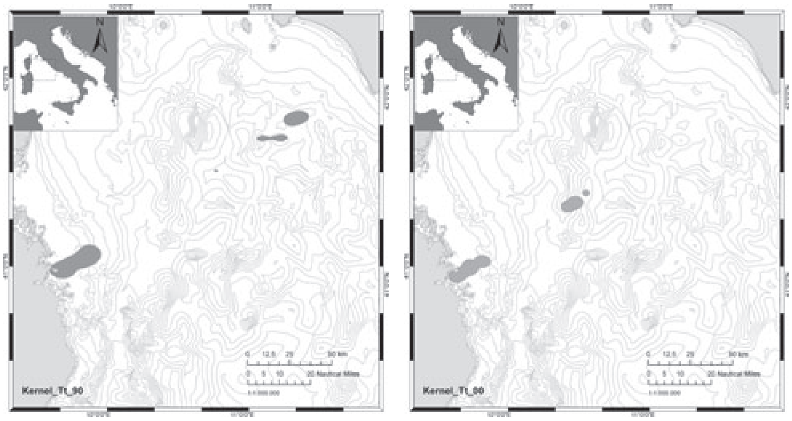

Fig. 7. Distribution of common bottlenose dolphin sightings compared: on the left, the distribution recorded during 1990s (90) and, on the right, the hot spot observed in 2000s (00). Kernel parameters: volume level = 0.70 (k70).

Since the early 1990s, significant changes have occurred in the thermohaline circulation, with increasing temperature and salinity in the intermediate and particularly the deep water layer (Gasparini *et al.* 2005). This process has increased since the late 1990s (Schroder *et al.* 2006) and the resulting environmental effects could bring occasional but intense concentration in food availability in some areas, with significant variations between years (Druon *et al.* 2012). Although a comparison on environmental parameters such as sea temperature and chlorophyll is not possible due to a lack of data relative to the first period, further analysis related exclusively to the 2000s period (Arcangeli *et al.* in prep.) suggests the existence of a relatively high productive area coinciding with the highest occurrence of fin whale. This temporary availability, as well as changes noted at the Mediterranean basin scale, could help in the understanding of the different ERs and spatial distribution observed during the present study.

Striped dolphin populations did not show any significant differences in either space or time. Although a morbillivirus epizootic heavily affected striped dolphin populations in the Mediterranean Sea in 1990 (Di Guardo *et al.* 1992; Aguilar & Raga 1993) and, to a lesser extent, in 2007 (Raga *et al.* 2008; Di Guardo *et al.* 2011), there does not seem to be any clear consequence of the infection in this area, as the number and size of sighted schools remained relatively unchanged across both periods.

Surveys intercepted the bottlenose dolphin coastal habitat for only a short period, as the transect ran perpendicular to the coast line. However, results highlight the efficacy of the method to monitor the occasional presence of this species in deep sea waters. This presence was confirmed in both the investigated periods. Differences were detected in the distribution of the sightings: toward the Central Italian peninsula coast in the 1990s and further west (toward Northeast Sardinia) during recent years, coinciding with the relatively high density area detected for fin whales. The increased presence of bottlenose dolphin in the northeastern area of Sardinia is coherent with results of Díaz López *et al.* (2005), which evidenced that frequency of sightings of bottlenose dolphin in the area of Golfo Aranci increased dramatically from 1991 to 2004 due to the realization of a fish farm in 1995.

Sightings of Cuvier's beaked whale were less frequent than sightings of the above-mentioned species, in line also with the known elusive behavior of the species. However, Cuvier's beaked whale showed a clear preference for the Central Tyrrhenian Sea during all investigated years, confirming the importance of the area already hypothesized by other authors (Gannier & Epinat 2008; Gannier 2011).

Sightings of other cetacean species were extremely rare and in some cases surprisingly low. This fuels concern for Risso's dolphin, long-finned pilot whale and common dolphin, which were also rarely sighted along the other transects monitored with a similar methodology in the Central-western Mediterranean Sea (Arcangeli *et al.* 2010).

The low encounter rate of sperm whale may be attributed to the long dive behavior of the species. This can lead to an underestimation of the relative abundance of this species when using visual instead of acoustic methodologies (Mussi *et al.* 2005; Pavan *et al.* 2006). However, the comparison of encounter rates recorded in the other monitored transects using the same methodology reveals a minor presence of this species in this area during the summer months (Arcangeli *et al.* 2010).

In management terms, our results underline the importance of the Central Tyrrhenian Sea for all cetacean species, especially for fin whale. We therefore recommend the enforcement of conservation measures in the area, supporting the institution of a SPAMI (UNEP 2010) or the enlargement of the Pelagos Sanctuary and the adoption of other measures to be undertaken, for example, by maritime companies to reduce the risk of collisions between large whales and large vessels in cetacean high density areas.

It should be noted that as of 1 January 2012 the entire Tyrrhenian Sea (including the Ligurian Sea) has been declared an 'Ecological Protection Zone' (ZPE) by the Italian Government (within the UNCLOS agreement) by specific decree of the President of the Republic (D.P.R. 209/2011). The entire region of the North-West Mediterranean Sea, also beyond country boundaries, is now subject to the legislative framework of Italian and EU laws and of international agreements of which Italy is a contracting party (including the Bern Convention and ACCOBAMS). EU directive 2005/33/EC on the sulfur content of marine fuel, for example, now applies across this region and in international waters. However, despite references in the decree to the protection of marine mammals, no specific executive act has yet been announced to reduce the impacts on cetaceans (*e.g.* measures to reduce the risk of ship strike along the main shipping routes).

Acknowledgements

We would like to thank all Sardinia-Corsica Ferries staff for their kind assistance and the many researchers who contributed to the monitoring. The authors are grateful to Arianna Orasi (ISPRA), Daniela Ottaviani, Ilaria Campana (Accademia del Leviatano) and Judith Fisher for their support; to Fabio Faraone of CONFITARMA for counsel on the effect of the ZPE decree for the shipping industry. Fondazione CARICIV partially financed the monitoring program. Finally, we thank the Atlantic Research Coalition for the continuous feedback and the anonymous referees for their very constructive comments on the manuscript.

References

Abdulla A., Linden O. (eds) (2008) *Maritime traffic effects on biodiversity in the Mediterranean Sea: Review of impacts, priority areas and mitigation measures*. IUCN Centre for Mediterranean Cooperation, Malaga: 184.

Aguilar A., Raga A. (1993) The Striped Dolphin epizootic in the Mediterranean Sea. *Ambio*, **22**, 524–528.

Arcangeli A., Crosti R., Marini L., Poggi A., Poldi A., Pulcini M., Safontas C., Sdringola S., Ukmar E. (2008) Monitoring cetacean populations over 15 years in Central Tyrrhenian Sea using a non-dedicated ferry as a observation platform. *European Research on Cetaceans*, **22**, 5pp.

Arcangeli A., Muzi E., Tepsich P., Carcassi S., Castelli A., Crosti R., Di Vincenzo M., Magliozzi C., Marini L., Poggi A., Poldi A., Pulcini M., Ricci , S. , Safontas , C. , Sdringola S., Ukmar E. (2010) Large scale cetacean monitoring from passenger ferries in Italy. Networking summer 2008 surveys. *European Research on Cetaceans*, **23**, 1–6.

Astraldi M., Gasparini G.P. (1994) The seasonal characteristics of the circulation in the Tyrrhenian Sea. *Coastal and Estuarine Studies*, **46**, 115–134.

Barale V., Jaquet J.-M., Ndiaye M. (2008) Algal blooming patterns and anomalies in the Mediterranean Sea as derived from the SeaWiFS data set (1998–2003). *Remote Sensing of Environment*, **112**, 3300–3313.

Brereton T., MacLeod C.M., Macleod K., Wall D., Bannon S., Benson C., Cermeño C., Curtis D., Gall A., Osinga N., Smith D., Zanderink F., Pinn E. (in press) Development of distribution and abundance indices and trends for cetacean using the Atlantic Research (ARC) dataset. JNCC Report.

Canadas A., Sagarminaga R., De Stephanis R., Urquiola E., Hammond P.S. (2005) Habitat preference modelling as a conservation tool: proposals for marine protected areas for cetaceans in southern Spanish waters. *Aquatic Conservation: Marine Freshwater Ecosystems*, **15**, 495–521.

Crosti R., Arcangeli A., Moulins A., Tepsich P., Tringali M. (2011) Cetacean and maritime traffic in deep sea waters. A relation to avoid?. *Biology Marine Mediterranean*, **18**, 178–179.

Di Guardo G., Agrimi U., Amaddeo D., McAliskey M., Kennedy S. (1992) Morbillivirus infection in a striped dolphin (*Stenella coeruleoalba*) from the coast of Italy. *Veterinary Record*, **130**, 579–580.

Di Guardo G., Cocumelli C., Scholl F., Di Francesco C.E., Speranza R., Pennelli M., Eleni C. (2011) Morbilliviral encephalitis in a striped dolphin (*Stenella coeruleoalba*) calf from Italy. *Diseases of Aquatic Organisms*, **95**, 247–251.

Díaz López B., Marini L., Polo F. (2005) The impact of a fish farm on a Bottlenose dolphin population in the Mediterranean Sea. *Thalassas*, **21**, 53–58.

Donovan G. (2005) Cetaceans: can we manage to conserve them? The role of long-term monitoring. In: Long term monitoring. Why, what, where, when and how? Proceedings conference 'The importance of the Long Term Monitoring of the Environment'. Ireland, (J. Solbè ed.).

D.P.R. 209 2011 27 ottobre Regolamento recante istituzione di Zone di protezione ecologica del Mediterraneo nord-occidentale, del Mar Ligure e del Mar Tirreno. Available at: http://www.normattiva.it/uri-res/N2Ls?urn:nir:stato:decreto.legge:2011-10-27;209.

Druon J.N., Panigada S., David L., Gannier A., Mayol P., Arcangeli A., Cañadas A., Laran S., Di Méglio N., Gauffier P. (2012) Feeding habitat of fin whales in the western Mediterranean Sea: an environmental niche model. *Marine Ecology-Progress Series*, **464**, 289–306.

EEA (2008) *Impacts of Europe's changing climate 2008 indicator based assessment*. European Environment Agency, Copenhagen.

Evans P.G.H., Hammond P. (2004) Monitoring cetaceans in European waters. *Mammal Review*, **34**, 131–156.

Gambaiani D.D., Mayol P., Isaac S.J., Simmonds M.P. (2009) Potential impacts of climate change and greenhouse gas emissions on Mediterranean marine ecosystems and cetaceans. *Journal of the Marine Biological Association of the United Kingdom*, **89**, 179–201.

Gannier A. (2011) Using existing data and focused surveys to highlight Cuvier's beaked whales favorable areas: A case study in the central Tyrrhenian Sea. *Marine Pollution Bulletin*, **63**, 10–17.

Gannier A., Epinat J. (2008) Cuvier's beaked whale distribution in the Mediterranean Sea: results from small boat surveys 1996–2007. *Journal of the Marine Biological Association of the United Kingdom*, **88**, 1245–1251.

Gasparini G.P., Ortona A., Budillon G., Astraldi M., Sansone E. (2005) The effect of the eastern Mediterranean transient on the hydrographic characteristics in the Strait of Sicily and in the Tyrrhenian sea. *Deep-Sea Research I*, **52**, 915–935.

Habitat Directive (1992) Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31992L0043:EN:NOT

Hammer Ø., Harper D.A.T., Rya P.D. (2001) PAST: paleontological statistics software package for education and data analysis. *Palaeontologia Electronica*, **4**, 9pp.

Hengl T. (2009) *A Practical Guide to Geostatistical Mapping*. University of Amsterdam, Amsterdam: 291.

IPCC (2007) Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. In: Parry M.L., Canziani O.F., Palutikof J. P., van der Linden P.J., Hanson C.E. (Eds), *Climate Change 2007: Impacts, Adaptation and Vulnerability*. Cambridge University Press, Cambridge: 976.

Kiszka J., MacLeod K., van Canneyt O., Walker D., Ridoux V. (2007) Distribution, encounter rates, and habitat characteristics of toothed cetaceans in the Bay of Biscay and adjacent waters from platform-of-opportunity data. *ICES Journal of Marine Science*, **64**, 1033–1043.

MacLeod C.D. (2009) Global climate change, range changes and potential implications for the conservation of marine cetaceans: a review and synthesis. *Endangered Species Research*, **7**, 125–136.

MacLeod C.D., Brereton T., Martin C. (2008) Changes in the occurrence of common dolphins, striped dolphins and harbor porpoises in the English Channel and Bay of Biscay. *Journal of the Marine Biological Association of the United Kingdom*, **89**, 1059–1065.

Marine Strategy Framework Directive (2008) (2008/56/EC) Available at: http://ec.europa.eu/environment/marine/eu-coast-and-marine-policy/marine-strategy-framework-directive/index_en.htm.

Marini L., Consiglio C., Angradi A.M., Catalano B., Sanna A., Valentini T., Finoia M.G., Villetti G. (1997) Distribution, abundance and seasonality of cetaceans sighted during scheduled ferry crossings in the central Tyrrhenian Sea: 1989–1992. *Italian Journal of Zoology*, **63**, 381–388.

Martin P., Bateson P. (1993) *Measuring Behaviour: An Introductory Guide*. Cambridge University Press, Cambridge: 187.

Mussi B., Miragliuolo A., Pace D.S. (2005) Acoustic behaviour of sperm whales nursery groups in the waters of Ischia, Italy. *European Research on Cetaceans*, **19**, 3pp.

Oakley K.L., Thomas L.P., Fancy S.G. (2003) Guidelines for long-term monitoring protocols. *Wildlife Society Bulletin*, **31**, 1000–1003.

Pavan G., Cosentino G., Musumeci M., Speziale F. (2006) Continuous real-time monitoring with a deep underwater acoustic station. Noise spectral and biological sounds from the NEMO Test Site. IWC. SC/58/E19, 1-4.

Praca E., Gannier A., Das K., Laran S. (2009) Modelling the habitat suitability of cetaceans: example of the sperm whale in the northwestern Mediterranean Sea. *Deep-Sea Research I*, **56**, 648–657.

R Development Core Team (2005) *A Language and Environment for Statistical Computing Foundation for Statistical Computing*. R Development Core Team, Vienna, Austria.

Raga J.A., Banyard A., Domingo M., Corteyn M., Van Bressem M.F., Fernández M., Aznar F.J., Barrett T. (2008) Dolphin morbillivirus epizootic resurgence, Mediterranean Sea. *Emerging Infectious Diseases*, **14**, 471–473.

Schroder K., Gasparini G.P., Tangherlini M., Astraldi M. (2006) Deep and intermediate water in the western Mediterranean under the influence of the Eastern Mediterranean Transient. *Geophysical Research Letters*, **33**, 1–6.

Simmonds M.P., Eliott W.J. (2009) Climate change and cetaceans: concern and recent developments. *Journal of the Marine Biological Association of the United Kingdom*, **89**, 203–210.

UNEP-MAP-RAC/SPA (2010) *Identification of Potential Sites in Open Seas Including the Deep Sea that May Satisfy SPAMI Criteria*. T. Ed. RAC/SPA, Tunis: 26.

Wall D., O'Brien J., Meade J., Allen B.M. (2006) Summer distribution and relative abundance of cetaceans off the west coast of Ireland. *Biology and environment: Proceedings of the Royal Irish Academy*, **106B**, 135–142.