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Cetacean presence and distribution and relationship with environmental and anthropogenic parameters in central western Mediterranean Sea, using data from network of fixed sampling transects using ferry as platform of research

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Introduction

Of the cetacean species residing with populations in the Mediterranean basin, one has a coastal habitat (bottlenose dolphin, *Tursiops truncatus*), while all the others have mainly pelagic habitats (striped dolphin, *Stenella coeruleoalba*; fin whale, *Balaenoptera physalus*; sperm whale, *Physetus macrocephalus*; Cuvier's beaked whale, *Ziphius cavirostris*; common dolphin, *Delphinus delphis*; Risso's dolphin, *Grampus griseus*; long finned pilot whale, *Globicephala melas*).

Cetacean species are under threat by many pressures, such as climate change, pollution, interactions with human activities, prey depletion. A large legislative framework for the protection of the species and/or the marine biodiversity (e.g. CITES, 1973; Bern Convention, 1979; Bonn Convention, 1979 and the ACCOBAMS Agreement, 2001; SPA/BIO protocol, 1995, under the Barcelona Convention, 1976; Convention on Biological Diversity, 1992; Habitat Directive, 1992; Marine Strategy Framework Directive, 2008) asks for information on cetacean species, their interaction with environmental and anthropogenic parameters, and the monitoring of the status of populations for conservative purposes.

Despite these requirements, knowledge is still lacking mainly due to biological characteristics of the species and their environment: cetaceans are mostly wide ranging pelagic species, not homogenously distributed, mostly showing seasonality, and have an evident behavioral plasticity that adds significant variability to general patterns.

During the last few decades, an increasing amount of research has enhanced knowledge about cetacean populations living in the Mediterranean basin with most of them focusing on the highly productive area of the Pelagos Sanctuary and the summer season. Nevertheless, surveys are often conducted with different methodologies, and the limited spatial or temporal scales cause difficulties with data comparison, so many aspects about species seasonal movements and habitat use still remain unclear, and information is especially needed in remote high sea areas during the whole year.

In 2007, a research project was renewed, on the basis of a method already used in the early '90s by Marini et al. (1996), using ferries as platforms of observation for systematic research along sampling fixed transects. To date, more than twenty organizations are networking to collect consistent data about cetaceans along ten fixed transects distributed across the Mediterranean basin (Fixed Line Transect Mediterranean monitoring Network, Arcangeli et al. 2013). The method allows systematic monitoring with high frequency in remote high sea

areas even during seasons when data are generally scarce and also collects a lot of data on the more rare species.
This PhD project is intended to contribute to improving our knowledge about cetaceans' presence and distribution and their relationship with environmental and anthropogenic parameters in the western Mediterranean basin, using some of the data coming from the Fixed Line Transect Mediterranean monitoring Network with a particular focus on the medium Western Mediterranean latitudes still scarcely explored (between Civitavecchia-Latium, Italy, Bonifacio Strait and Barcelona-Spain). The PhD focus on five main issues, which can add information about some of the main gaps in our knowledge: 1) the spatio-temporal variability of cetacean species, especially in remote still largely unexplored areas of medium Mediterranean latitudes (Ch.1. Analysis of the spatio-temporal variability of cetacean species with a particular focus on the yearly round fixed transects between Civitavecchia and Barcelona): 2) the migration pattern of fin whale in the Mediterranean basin (Ch.2. Contributing to enhancing the knowledge about migration patterns for fin whale (*Balaenoptera physalus*) and relationship with physiographic variables, remote sensing data, and anthropogenic factors); 3) the rare and elusive Cuvier's beaked whale species (Ch.3. Studying the presence of Cuvier's beaked whale - *Ziphius cavirostris*- in the central Tyrrhenian Sea); 4) the impact of maritime traffic on cetaceans (Ch.4. Studying the impact of maritime traffic on cetaceans along the main shipping routes); 5) effectiveness of the monitoring methodology (Ch. 5. Assessment of the fixed line transects method for being used for legislative and conservation purposes).

PhD Thesis Structure

For each of the aim of the PhD one or more article/s has been published in ISI indexed journals during the three years of the PhD, or is just submitted. Therefore the chapters, except Introduction and General conclusion, are organized in paragraphs corresponding to the published articles, each with a distinct sequence in number of figures and tables. An image of the first page of the published article is added at the beginning of the paragraph.

References

Arcangeli A., Castelli A., Marini L., Moulins A., B. Paliaga B., Tepsich P., Tringali M., 2013. A cooperative programme for cetacean monitoring over the Mediterranean sea: the example of the Fixed

Transects Monitoring Network. *Biol. Mar. Mediterr.*, 20 (1): 254-255.

Marini, L., Consiglio, C., Angradi, A. M., Catalano, B., Finoia M.G., Sanna, A., Valentini, T., Villetti, G. (1996). Distribution, abundance and seasonality of cetaceans sighted during scheduled ferry crossings in the central Tyrrhenian Sea: 1989–1992. Italian Journal of Zoology, 63(4), 381-388.

CH. 1 Analysis of the spatio-temporal variability of cetacean species, with particular focus on the yearly round fixed transect between Civitavecchia and Barcelona

Santoro R., Sperone E., Pellegrino G., Giglio G., Tripepi S., Tringali M.L., Arcangeli A. (2015) Summer Distribution, Relative abundance and encounter rates of Cetaceans in the Mediterranean Waters off Southern Italy (Western Ionian Sea and Southern Tyrrhenian Sea). Mediterranean Marine Science. doi:10.12681/mms.1007.

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Research Article

Summer Distribution, Relative Abundance and Encounter Rates of Cetaceans in the Mediterranean Waters off Southern Italy (Western Ionian Sea and Southern Tyrrhenian Sea)

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Abstract

During the summers of 2010 and 2011, weekly cetacean surveys were undertaken in "passing mode", using ferries as platforms of opportunity, along the "fixed line transect" between Catania and Civitavecchia (southern Italy). Of the 20 species of cetaceans confirmed for the Mediterranean Sea, eight were sighted within the survey period, of which seven species represented by Mediterranean subpopulations (*Balaenoptera physalus, Physeter macrocephalus, Stenella coeruleoalba, Delphinus delphis, Grampus griseus, Tursiops truncatus* and *Ziphius cavirostris*) and one is considered a visitor (*Steno bredanensis*). A total of 220 sightings were effected during 2010 and a total of 240 sightings in 2011. The most frequently recorded species was *S. coeruleoalba*. By the comparing the data from the two sampling seasons, a significant increase of *D. delphis* sightings and a decrease of sightings of *B. physalus* and *P. macrocephalus* were observed. While all the other species were observed in both sampling seasons, *Z. cavirostris* and *Steno bredanensis* were observed only during 2011. The presence of mixed groups of odontocetes was also documented: groups composed of pairs of species were *S. coeruleoalba* and *D. delphis*, *S. coeruleoalba* and *T. truncatus*, and *S. coeruleoalba* and *G. griseus*. The results of this research add useful information on cetacean species in a very poorly known area and highlight the need to standardize large-scale and long-term monitoring programs in order to detect variation in presence, abundance and distribution of cetaceans populations and understand the effect of anthropogenic factors.

Keywords: Cetaceans, distribution, relative abundance, central Mediterranean Sea, mixed groups.

Introduction

Cetacean fauna in the Mediterranean Sea can be considered as a group of the north Atlantic fauna. Of the approximately 20 species of cetaceans that have been cited in the Mediterranean Sea, only eight are considered Mediterranean subpopulations (Reeves & Notarbartolo di Sciara, 2006): *Balaenoptera physalus* (fin whale), *Physeter macrocephalus* (sperm whale), *Ziphius cavirostris* (Cuvier's beaked whale), *Globicephala melas* (pilot whale), *Grampus griseus* (Risso's dolphin), *Delphinus delphis* (common dolphin), *Stenella coeruleoalba* (stripped dolphin) and *Tursiops truncatus* (bottlenose dolphin), while *Steno bredanensis* (rough-toothed dolphin) is considered only an occasional species for the Mediterranean Sea. All cetaceans are long-lived vertebrates located in the highest levels of the marine trophic webs; they are also characterized by a very low reproductive rate and are thus particularly vulnerable to threats deriving from human activities, especially in the semi-enclosed basin of the Mediterranean Sea that supports a high human density in the coastal zones. As has been demonstrated for the short-beaked common dolphin (*Delphinus delphis*) and other cetaceans (Bearzi *et al.*, 2003; Bellante *et al.*, 2012; Fossi *et al.*, 2013), these threats may lead to declining populations of some Mediterranean species. Therefore, it is necessary to implement conservation measures especially in this basin. Information on spatial and temporal variations in cetacean abundance, as well as other taxa, is essential to determine both whether management actions are necessary and to assess the effectiveness of any actions that are taken (Evans & Hammond, 2004). Obtaining abundance estimates is, then, a priority in order to assess the status of the different cetacean species in the Mediterranean Sea and to evaluate the impact that human threats may have on these populations. Monitoring cetacean presence, and distribution and migration patterns is an effective indicator to detect environmental changes and habitat degradation and to recommend appropriate conservation planning. However, distribution and abundance data on cetaceans, particularly those occurring predominantly offshore, are generally difficult to collect (Notarbartolo di Sciara *et al.*, 1993; Kiszka *et al.*, 2007). The cost of dedicated surveys on chartered research ves-

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census of cetaceans, their distributions and sighting frequency in the Mediterranean. In 2007 the Accademia del Leviatano in partnership with ISPRA (Istituto Superiore per la Protezione e Ricerca Ambientale, Italy) resurrected the project, under the same protocol and the same supervision. In 2008 this project became organic and systematic monitoring of cetaceans in all the western Mediterranean across five transects began: Catania – Civitavecchia; Civitavecchia – Golfo Aranci; Livorno – Bastia; Savona – Bastia; Nizza – Calvi.
In this paper the results of weekly observations during the summers 2010 and 2011 are presented, along the western Ionian and the southern Tyrrhenian seas, in the ferry transect between Catania (Sicily) and Civitavecchia (Lazio). The main goal of this study was to provide preliminary information on the presence, the distribution, the encounter rates, and habitat characteristics of cetaceans in the central-southern Tyrrhenian and western Ionian seas. We focused our attention also on the presence of mixed groups. These results could be used for further conservation applications for cetacean Mediterranean populations.

Materials and Methods

Study area

The survey area covers three different marine geo- graphical regions: western Ionian Sea, Messina Strait and southern Tyrrhenian Sea (Fig. 1). Calabria, together with Sicily and the Tunisian coast, divides the Mediterranean Sea into western and eastern parts, often characterized by different biological communities (Nicolaidou *et al.*, 2012; Sperone *et al.*, 2012; Bilecenoglu *et al.*, 2013). The Tyrrhenian side of the study area lies in the western Mediterranean, while the Ionian side lies in the eastern Mediterranean. The Ionian Sea is included among the Sicilian, Calabrian and Apulian coasts on the western side, and Albanian and Greek coasts on the eastern side. The Ionian continental shelf is not particularly wide, and the depth along the Sicilian coast drops suddenly and reaches -2000 m within few miles from the coast. The backdrop is bumpy and irregular, often characterized by canyon formations. In particular, the Gulf of Catania is characterized by important upwellings that develop interesting and delicate ecosystems. The Messina Strait is very important from a geological and an oceanographic point of view, because together with the Sicily-Tunisian Ridge it is one of the two conjunction points between the western and eastern basins of the Mediterranean Sea. The sea floor of this basin could be considered a mount-like formation and its top is named “Sella” (from -80 to -120 m under sea level). Sella Mountain divides the strait into two parts: the northern side lies in the Tyrrhenian and it has gentle slopes, reaching -2000 m bathymetric near the Aeolian islands; the southern side lies in the Ionian and it has steep slopes, quickly reaching -500 m near Messina. The two basins have different chemical and physical characteristics of the sea water and give origin to particular tides and currents. The Tyrrhenian Sea is located on the west Italian coast, encompassing Sicily, Sardinia and Corsica. The continental slope is well-developed along the western Sicilian, Campanian, Sardinian and Corsican coasts, while along the Calabrian and northern Sicilian coasts it is almost absent with considerable depths reached near the coastline. The abyssal plane within 3000 m under the sea level is located in the central-southern part of the basins, but it is often interrupted by mountains like the Marsili volcano and the Mavilov mount.

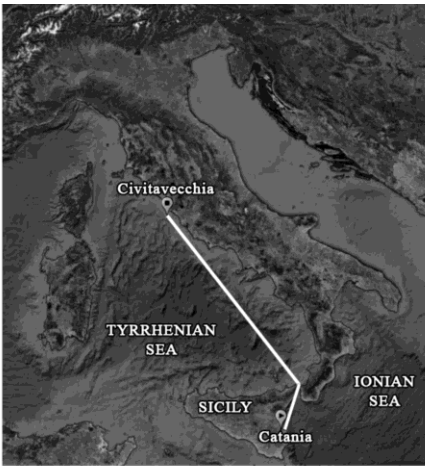

Fig. 1: Location of the study area.

Data collection

Between July and October 2010 and July and September 2011, weekly observation were undertaken in “passing mode”, using ferries as platforms of opportunity for dedicated surveys (see Donovan, 2005), along the “fixed line transect” between Catania harbor (Sicily, 37.50 N; 15.50 E) and Civitavecchia harbor (Lazio, 42.08 N; 11.8 E). The stretch is 358.5 nautical miles (nm) of which 120-170 were covered during night time and 210-230 nm during the day time. Cruising speed was approximately 20 knots and the average time of runs was approximately 19 hours. Two observers were located on the two sides of the command deck of the ferry, each observer focused primarily on an 90° arc ahead of the ship and continuously scanned area by naked eye and occasionally with binoculars (according to Marini *et al.*, 1996 and Arcangeli *et al.*, 2013). Observations were undertaken under fine weather condition (Beaufort wind- strength ≤ 3) during the day time. At the moment of sighting, data on species, group size, swim direction, distance between the detected group and the track line were collected on dedicated data sheets. Sighting bearings were measured using an angle board and distances were estimated with the aid of measuring stick. Sighting positions were also recorded using the GPS (Global Positioning System) of the ship. Environmental data were noted every hour. Sightings were reported on geo-referenced map using Google Earth soft- ware. Where species identification could not be confirmed, sightings were placed as unidentified small cetaceans (NISC) or unidentified big cetaceans (NIBC). According to Cañadas et al. (2002), 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.

Data analysis

All collected data were organized using MS Excel, in the Ketos Database. Presence, relative abundance and distribution of the species were all analyzed. However, due to variation in visibility during the survey, observations were not continuous and differed according to the run. For this reason and due to the fact that along the transect sighting could be considered an event and not a state, the relative abundance was measured using En- counter Rate (ER): i.e., numbers of sightings per hour of observation (Evans & Hammond, 2004; Wall *et al.*, 2006). Data from the two investigated periods were compared with the Mann–Whitney (MW) test. To test whether differences occurred in inter-annual and intra- annual observations, yearly and monthly analyses were performed only on the most commonly sighted species, i.e., *S. coeruleoalba*, *D. delphis* and *T. truncatus*.

Results

Of the 20 species of cetaceans regularly present in the Mediterranean sea, eight were sighted within the survey period: seven species represented by Mediterranean subpopulations (*B. physalus*, *P. macrocephalus, S. coeruleoalba, D. delphis, G. griseus, T. truncatus* and *Z. cavirostris*) and one was considered only as occasional (*S. bredanensis*). A total of 220 sightings were made during 2010 and 240 sightings in 2011. The sightings distribution for all species is given in Figure 2. The seasonal Encounter Rate for summer 2010 was 0.94 ± 0.60, while for summer 2011 was 1.11 ± 0.94. From both seasons the most frequent species seen was *S. coeruleoalba*, which represented 34% of sightings of 2010 and the 48% of 2011. The overall sighting relative frequencies and numbers of sightings observed are given in Table 1. In 30% of the sightings, species could not be determined. While all the other species were observed in both sampling sea- sons, *Z. cavirostris* (two individuals) and *Steno bredanensis* (five individuals) were observed only during 2011 near the Pontine Islands. By comparison of the data from the two sampling seasons, a significant increase of *D. delphis* sightings could be observed: only 37 individuals were encountered in 2010, but 289 individuals in 2011 (x^2_{Yates} = 112,69; df = 1; P< 0.0001). On the other hand, a decrease in sightings of *B. physalus* and *P. macrocephalus* was observed: in fact, in 2011 both species were sighted just once. During the two sampling seasons many groups of mixed species were observed (Fig. 3). The most frequent association was that between *S. coeruleoalba* and *D. delphis* with two sightings in 2010 and five in 2011. In the case of associations between *S. coeruleoalba* and *G. griseus* and between *S. coeruleoalba* and *T. truncatus*, only one sighting was registered for each year.

Cetacean sightings frequency reflects regional differences, so the entire study area may be subdivided into two distinct categories: regions where the overall cetacean sightings frequency is high (Campanian-Latium sea; Aeolian sea- Strait of Messina -Gulf of Catania) and regions in which is low (southern Tyrrhenian sea). In this latter region only *S. coeruleoalba* and *D. delphis* were observed, while all the other species were sighted in the regions with high frequency.

For *B. physalus* a decrease was registered in the numbers of sightings, indeed, the ER is 0.02 in 2010 and only 0.01 in 2011. Sightings were recorded along the continental slope, near

Civitavecchia harbor, Pontino archipelago and in the Strait of Messina. Even for *P. macrocephalus* a decrease of sightings and abundance were recorded: in the 2010 seasonal ER was 0.04 with 8 individuals, while in 2011 it was only 0.01, with one sighted specimen. All the sightings were recorded in the area with the highest frequency of sightings, corresponding to the location of the continental slope. An increase of frequency of sightings for *S. coeruleoalba* was recorded: the seasonal ER was 0.34 in 2010 and 0.56 in 2011. In both years the higher monthly values were observed in July and in September. Sightings of this species were all recorded in deep water. An increase of frequency of *D. delphis* was observed in the two years of investigation: the seasonal ER was 0.03 in 2010 and 0.11 in 2011. All sightings were recorded beyond the continental slope, in deep waters between the Aeolian arch and the Pontino archipelago. *Tursiops truncatus s*easonal ER values were 0.03 in 2010 and 0.05 in 2011 while the abundance of this species was approximately the same: in fact, 64 individuals were counted in 2010 and 68 in 2011, and all sightings were recorded along the continental platform. For *G. griseus* a decrease in frequency and abundance was recorded. Only one sighting with three individuals was recorded in 2011 summer, in spite of the seven sightings of 2010 with a total 41 individuals. Seasonal ER values were 0.05 for the 2010 and 0.01 for 2011. Most sightings were recorded along the Sicilian continental platform.

Table 1. Overall sighting encounter rates, numbers of sightings, and number of specimens for each species.

Species	**2010**	**2011**	**2010**	**2011**
Balaenoptera physalus	0,02	0,01	7	2
Physeter macrocephalus	0,04	0,01	6	1
Stenella coeruleoalba	0,34	0,56	74	94
Delphinus delphis	0,03	0,11	4	15
Grampus griseus	0,05	0,01	7	1
Tursiops truncatus	0,03	0,05	9	8
Steno bredanensis	0	0,01	0	1
Ziphius cavirostris	0	0,01	0	1

Group size descriptive statistics are shown in Table 2. In 2010 the species with the greatest mean group size (20.08) was *S.coeruleoalba*.

D. delphis had the second largest mean group size (9.25), followed by *T. truncatus* (7.1) and *G. griseus* (5.85). The two largest species, *B. physalus* and *P. macrocephalus*, had a mean group size of 1.43 and 1.3 respectively. In 2011 the species with the greatest mean group size was *D. delphis* (19.86). *Stenella coeruleoalba* had the second largest mean group size (14.87), followed by *T. truncatus* (8.5) and *G. griseus* (3). The two largest species, *B. physalus* and *P. macrocephalus*, had a mean group size of 1.

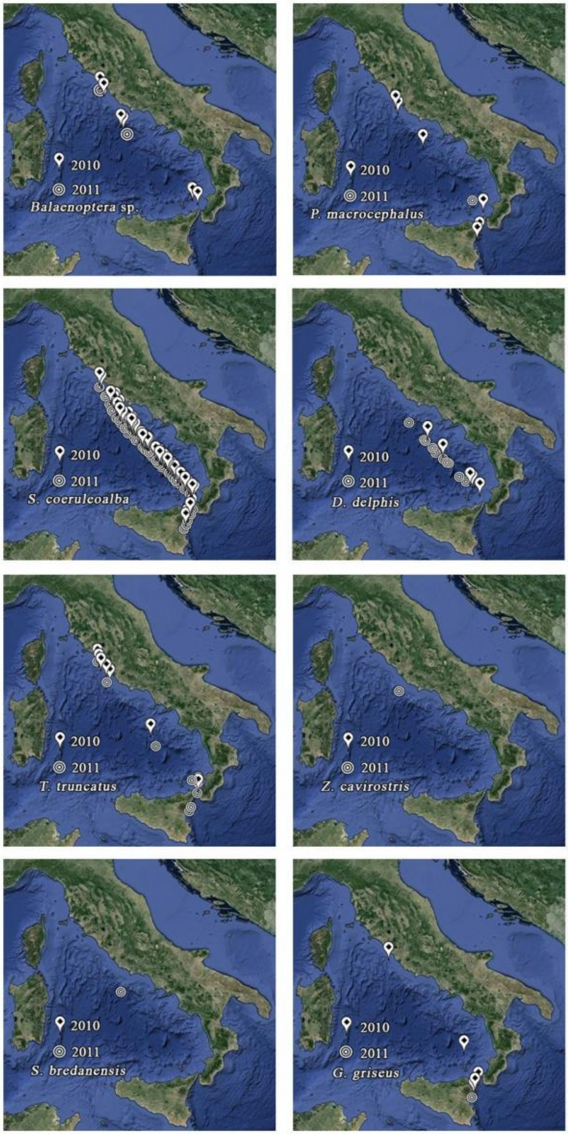

Fig. 2: Sightings of cetaceans in the study area during the study periods.

Fig. 3: Sightings of mixed groups.

Table 2. Group size statistics.

Species	Mean group size	
	2010	**2011**
Balaenoptera physalus	1.43	1.00
Physeter macrocephalus	1.30	1.00
Stenella coeruleoalba	20.08	14.87
Delphinus delphis	9.25	19.86
Grampus griseus	5.85	3.00
Tursiops truncatus	7.10	8.50
Steno bredanensis	0	5.00
Ziphius cavirostris	0	2.00

Discussion

This work represents the first attempt to compare the distribution and relative abundance of cetaceans between two regions of the sea surrounding southern Italy. Data analysis underlined some differences in the abundance of species and within their area of distribution, probably in relation to the sea bed characteristics, the chemical and physical water parameters, the vessel traffic and the trophic availability

(Hui, 1979). The observed sightings and frequencies of cetacean species warrant discussions on their significance.

The sightings of *B. physalus* were mainly located in the central-northern part of the transect along the continental slope: this distribution could be related to the detection of a new feeding zone in the central Tyrrhenian Sea (Arcangeli *et al.*, 2014) where the species seems to concentrate during summer. On the other hand, the sightings of *B. physalus* in the area of the Strait of Messina confirmed the importance of this area as seasonal feeding ground and for the migration patterns of this species through different marine geographical regions in the Mediterranean (Aissi *et al.*, 2008). The absence of sightings in the southern part of the transect could be linked to a different seasonal use of this area but more investigation is needed to confirm this data.

Physeter macrocephalus is the most pelagic of the odontocetes (Notarbartolo di Sciara *et al.*, 1993): in fact, this species was sighted only in pelagic waters, where its preys (mesopelagic squids) are common. The low number of sightings for this species could be linked to a general decrease of the species in the Mediterranean basin where it is listed as Endangered by the IUCN Red List criteria (Notarbartolo di Sciara, 2013) and by the fact that visual surveys can, in general, affect the sighting's probability for long-diving species such as the sperm whale.

Stenella coeruleoalba was the most frequently re- corded and abundant species, confirming the general pattern described for the Mediterranean Sea (Notarbartolo di Sciara *et al.*, 1993; Gomez de Segura *et al.*, 2006; Panigada *et al.*, 2011). These sightings were all recorded in the deep waters of the transect between the Aeolian Arc and the Latium continental shelf: this confirmed that *S. coeruleoalba* is an almost exclusively pelagic species (Forcada *et al.*, 1994). Most sightings were recorded along the Sicilian coast, between Messina and Catania, in relationship with the high trophic availability of the area, as a consequence of the local upwelling currents.

Delphinus delphis is considered extremely rare in Mediterranean, with some relict groups in the south- eastern Tyrrhenian around the Cuma canyon (Bearzi *et al.*, 2003), but we documented the presence and an increment of sightings and abundance of the species along the transect investigated. Sightings were all recorded along the deeper waters between the Messina Strait and Civitavecchia, in accordance with the habits of *D. delphis* recorded in the western Mediterranean and in the

Alboran Sea (Cañadas *et al.*, 2002; Cañadas & Hammond, 2008). *Tursiops truncatus* was sighted mainly in neritic water, along the continental shelf near Civitavecchia and Catania and in the Strait of Messina, agreeing well with the species' coastal habits already documented for the Mediterranean (Notarbartolo di Sciara *et al.*, 1993). In 2010 we recorded only one sighting of *T. truncatus* in deep waters, along the continental slope, confirming the observations of Notarbartolo di Sciara *et al.* (1993) that the species can be rarely observed also in pelagic waters. Most of sightings of *G. griseus* were recorded in the Catania Gulf, along continental shelf, where coastline and continental slope are closer, in relationship with their prey habits (Bearzi *et al.*, 2011).

Interesting, the only sighting of *Z. cavirostris* was recorded in 2011 in the Latium pelagic waters, in the area that is known to host the species since the beginning of the 1990s (Marini *et al*., 1996) and where its presence has been confirmed in recent years (Arcangeli *et al*., 2012). *Steno bredanensis* is considered an accidental species in the Mediterranean (Notarbartolo di Sciara, 1994): for this reason the sighting of the five specimens in the pelagic waters off Latium should be considered an interesting datum. During our surveys, the presence of mixed groups of odontocetes were documented: groups composed of *Scoeruleoalba* and *D. delphis*, of *S. coeruleoalba* and *truncatus*, and of *S. coeruleoalba* and *G. griseus* were recorded. Mixed groups of *S. coeruleoalba* and *D. delphis* were known in the western tropical Pacific Ocean (Reilly, 1990) and this aggregation was explained as a consequence of the similar habitat shared by both species. In the Mediterranean, the association between *S. coeruleoalba* and *D. delphis* are common only in the Alboran Sea and in the Gulf of Corinth (Frantzis & Herzing, 2002). In particular, in the Alboran Sea, 17% of *D. delphis* sightings were recorded in association with *S. coeruleoalba* (Garcìa *et al.*, 2000). Frantzis & Herzing (2002) documented that *D. delphis* sightings in mixed groups represented approximately 25% of all sightings of this species in the Pontine archipelago, an area in which the species abundance is lower than in the Alboran Sea. Very little is known about the associations between *S. coeruleoalba* / *T. truncatus* and *S. coeruleoalba* / *G. griseus*, so that this could be a potential indication of particular conditions in the area that deserve further investigation.

The results of this research add useful information on cetacean species in a very poorly known area and highlight the need to standardize large-scale and long-term monitoring programs in order to detect variation in presence, abundance and distribution of cetacean populations and to understand the effect of anthropogenic factors. If used as a standardized protocol, ferries could be an efficient and low cost platform of observation for longer and larger cetacean monitoring programs.

References

Aissi, M., Celona, A., Comparetti, G., Mangano, R., Wurtz, M. *et al.*, 2008. Large-scale seasonal distribution of fin whales (*Balaenoptera physalus*) in the central Mediterranean Sea. *Journal of the Marine Biological Association of the United Kingdom*, 88 (6), 1253-1261.

Arcangeli, A., Marini, L., Crosti, R., 2012. Changes in ceta- cean presence, relative abundance and distribution over 20 years along a trans-regional fixed line transect in the Central Tyrrhenian Sea. *Marine Ecology*, 34 (2013), 112-121.

Arcangeli, A., Castelli, A., Marini, L., Moulin, A., Paliaga, B. *et al.*, 2013. A cooperative program for studying and monitoring cetacean in Mediterranean Sea. *Biologia Marina Mediterranea*, 20 (1), 254-255.

Arcangeli, A., Orasi, A., Carcassi, S., Crosti, C., 2014. Exploring thermal and trophic preference of *Balaenoptera physalus* in the Central Tyrrhenian Sea: a new summer feeding ground? *Marine Biology*, 161, 427-436.

Bearzi, G., Reeves, R.R., Notarbartolo di Sciara, G., Politi, E., Cañadas, A. *et al.*, 2003. Ecology, status and conservation of Common Dolphins *Delphinus delphis* in the Mediterranean Sea. *Mammal Review*, 33, 224-252.

Bearzi, G., Reeves, R.R., Remonato, E., Pierantonio, N., Airoldi, S., 2011. Risso’s dolphin *Grampus griseus* in the Mediterranean Sea. *Mammalian Biology*, 76, 385-400.

Bellante, A., Sprovieri, M., Buscaino, G., Buffa, G., Di Ste- fano, V. *et al.*, 2012. Stranded cetaceans as indicators of mercury pollution in the Mediterranean Sea. *Italian Jour- nal of Zoology*, 79 (1), 151-160.

Berrow, S.D., Whooley, P., Ferriss, S., 2001. *Irish Whale and Dolphin Group cetacean sighting schemes: development of a system to record sightings of cetaceans (whales, dolphins and porpoises) in Irish waters*. Final report to the Heritage Council (Ireland), Kilkenny, pp. 34.

Bilecenoglu, M., Alfaya, J.E.F., Azzurro, E., Baldacconi, R., Boyaci, Y.Ö. *et al.*, 2013. New Mediterranean Biodiversity Records (December 2013). *Mediterranean Marine Science*, 14 (2), 463-480.

Brereton, T., Williams, A.D., Williams, R., 2000. A low-cost method to determine bathypelagic and seasonal occupancy of fin whale *Balaenoptera physalus* in the Bay of Biscay.

p. 14-18. *European Research on Cetaceans – 14.* Evans,

P.G.H. (Ed.). European Cetacean Society, Rome, Italy. Cañadas, A., Hammond, P., 2008. Abundance and habitat prefer-

ences of the short-breaks common dolphin *Delphinus delphis* in the southwestern Mediterranean: implications for conservation. *Endangered Species Research*, 4, 309-33.

Cañadas, A., Sagarminada, R., Garcia-Tiscar, S., 2002. Cetacean distribution related with depth and slope in the Mediterranean waters off southern Spain. *Deep sea Research*, 49 (11), 2053-2073.

Donovan, G., 2005. Cetaceans: can we manage to conserve them? The role of long-term monitoring. *Long-term Monitoring: Why, What, Where, When & How?*. Solbé, J. (Ed). Sherkin Island Marine Station, Sherkin Island, Co. Cork, Ireland 226 pp.

Evans, P.G.H., Hammond P., 2004. Monitoring cetaceans in European waters. *Mammal Review*, 34 (1), 131-156.

Forcada, J., Aguilar, A., Hammond, P.S., Pastor, X., Aguilar, R., 1994. Distribution and number of striped dolphins in the western Mediterranean Sea after the 1990 epizootic outbreak. *Marine Mammal Science*, 10, 137-150.

Fossi, M.C., Panti, C., Marsili, L., Maltese, S., Spinsanti, G. *et al.*, 2013. The Pelagos Sanctuary for Mediterranean marine mammals: Marine Protected Area (MPA) or marine polluted area? The case study of the striped dolphin (*Stenella coeruleoalba*). *Marine Pollution Bulletin*, 70 (1- 2), 64-72.

Frantzis, A., Herzing, D.L., 2002. Mixed-species associations of striped dolphins (*Stenella coeruleoalba*), short-beaked common dolphins (*Delphinus delphis*), and Risso's dolphin (*Grampus *griseus*) in the Gulf of Corinth (Greece, Mediterranean Sea). *Aquatic Mammals*, 28 (2), 188-197.

Garcìa, S., Knouse, D., Sagarminaga, R., Cañadas, A., 2000. An insight on the biological significance of mixed groups of common dolphins (*Delphinus delphis*) and striped dolphins (*Stenella coeruleoalba*) in the Alboran Sea. In: *Proceedings of the 14th Annual Conference of the European Cetacean Society*. Cork, Ireland, 2–6 April 2000. European Cetacean Society, Cambridge, England.

Gomez de Segura, A., Crespo, E.A., Pedraza, S.N., Hammond, P.S., Raga, J. A., 2006. Abundance of small cetaceans in waters of the central Spanish (Mediterranean). *Marine Biology*, 150, 149-160.

Hui, C.A., 1979. Undersea topography and distribution of dolphins of the genus *Delphinus* in the southern California Bight. *Journal of Mammology*, 60, 521-527.

Kiszka, J., Macleod, K., Van Canneyt, O., Walker, D., Ridoux, V., 2007. Distribution, encounter rates, and habitat charac- teristics of toothed cetaceans in the Bay of Biscay and adjacent waters from platform-of-opportunity data. *Journal of Marine Science*, 64, 1033-1043.

MacLeod, C.D., Bannon, S.M., Brereton, T., Wall D., 2007. Using passenger ferries to study seasonal pattern of minke whale occurrence in northwest Europe. pp.32-37. In: *European Research on Cetaceans - 21 Proc. 21st Annual Meeting of the European Cetacean Society Donostia*, 22 April 2007. San Sebastian, Spain.

Marini, L., Consiglio, C., Angradi, A.M., Catalano, B., Sanna, A., Valentini, T. *et al.*, 1996. Distribution, abundance and seasonality of cetaceans sighted during scheduled ferry crossing in the central Tyrrhenian Sea: 1989-1992. *Italian Journal of Zoology*, 63, 381-388.

Nicolaidou, A., Alongi, G., Aydogan, O., Catra, M., Cavas,L. *et al.*, 2012. New Mediterranean Biodiversity Records (June 2012). *Mediterranean Marine Science*, 13 (1), 162- 174.

Northridge, S.P., Tasker, M.L., Webb, A., Williams, J.M., 1995. Distribution and relative abundance of harbour porpoises (*Phocoena phocoena* L.), white-beaked dolphins (*Lagenorhynchus albirostris* Gray), and minke whales (*Balaenoptera acutorostrata* Lacepède) around the British Isles. *ICES Journal of Marine Science*, 52, 55-66. Notarbartolo di Sciara, G., Demma, M., 1994.

Guida dei Mammiferi marini del Mediterraneo. Franco Muzzio Editore, Padova, 264 pp.

Notarbartolo Di Sciara, G., Venturino, M.C., Zanardelli, M., Bearzi, G., Borsani, F.J. *et al.*, 1993. Cetaceans in the central Mediterranean Sea: distribution and sighting frequencies. *Bollettino di Zoologia*, 60, 131-138.

Notarbartolo di Sciara, G., 2013. Sperm whales, *Physeter macrocephalus,* in the Mediterranean Sea: a summary of status, threats, and conservation recommendations. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 24 (Suppl.1), 4-10.

O'Cadhla, O., Mackey, M., Aguilar de Soto, N., Rogan, E., Connolly, N., 2004. *Cetaceans and seabirds of Ireland's Atlantic margin. Volume II*Cetacean distribution and abundance*. Report on research carried out under the Irish Infrastructure Programme (PIP): Rockall Studies Group (RSG) projects 98/6 and 00/13, Porcupine Studies Group project P00/15 and Offshore Support Group (OSG) project 99/38. Cork. Coastal and Marine Resources Centre, University College.

Panigada, S., Lauriano, G., Burt, L., Pierantonio, N., Donovan, G., 2011. Monitoring Winter and Summer Abundance of Cetaceans in the Pelagos Sanctuary (Northwestern Mediterranean Sea) Through Aerial Surveys. *PLOS ONE*, 6 (7), e22878.

Pollock, C., Reid, J.B., Webb, A., Tasker, M.L., 1997. *The distribution of seabirds and cetaceans in the waters around Ireland.* Joint Nature Conservation Committee Report no.267. Peterborough (UK). 167 pp

Reeves R.R., Notarbartolo di Sciara G., 2006. *The status and distribution of cetaceans in the Black Sea and Mediterranean Sea*. IUCN Centre for Mediterranean Cooletarion, Malaga, Spain. 137 pp.

Reid, J.B., Evans, P.G.H., Northridge, S.P., 2003. *Atlas of cetacean distribution in north-west European waters*.. Joint Nature Conservation Committee. Peterborough (UK) , 75 pp.

Reilly, S.B., 1990. Seasonal changes in distribution and habitat differences among dolphins in the eastern tropical Pacific. *Marine Ecology Progress Series*, 66, 1-11.

Sperone, E., Parise, G., Leone, A., Milazzo, C., Circosta, V. *et al.*, 2012. Spatiotemporal patterns of distribution of large predatory sharks in Calabria (central Mediterranean, southern Italy). *Acta Adriatica*, 53 (1), 13-24.

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 (2), 135-142.

Arcangeli A., Campana I. (submitted) Spatio-temporal variability of cetacean species along a sampling transect between Barcelona and Civitavecchia in the Western Mediterranean Sea Region

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1

Summary
During the last few decades, an increasing amount of research enhanced knowledge about cetacean populations living in the Mediterranean, but the limited spatial or temporal resolutions cause difficulties in data comparison so that many aspects about species seasonal movements and habitat use still remain unclear, especially in remote high sea areas and throughout the whole year. A sampling transect encompassing almost longitudinally a large portion of the Western Mediterranean Sea Region, from Barcelona (Spain) to Civitavecchia (Italy), was monitored twice/four times a month for three years. Data was collected following the "ISPRA monitoring protocol using ferry as platform of observation for systematic research". The transect was divided into three subareas (Sardinian-Balearic, Bonifacio, Tyrrhenian) and spatio-temporal analyses were performed using 5x5km grid cell as statistical unit. Four species out of the eight regularly present in the Mediterranean Sea were recorded more frequently (fin whale, striped dolphin, sperm whale and bottlenose dolphin). Variability was detected at season, subarea and species level. The study confirmed seasonal cycles for fin whale, and striped dolphin in the Sardinian-Balearic basin, with peaks of occurrence recorded in spring and summer in the two high sea basins, and drops in presences detected during winter and autumn, most likely consistent with a dispersing pattern towards southern Mediterranean areas. Inter-annual fluctuations were mostly detected in fin whale, with small group/individual flexibility determining an even more complex pattern of distributions. From a conservation point of view, the study highlighted some hot spots of cetacean presence that, especially in spring/summer, require increased consideration due to the combined effect of the highest species diversity, abundance, significance of hot spots and presence of juveniles. The significant variability detected points out the importance of continuous monitoring with consistent methodology in remote high sea areas all year round to support conservation efforts.

Introduction

During the last few decades, an increasing amount of research has enhanced knowledge about cetacean populations living in the Mediterranean basin with most of them focusing on the highly productive area of the Pelagos Sanctuary for the Conservation of Mediterranean Marine Mammals (north-western Mediterranean, Notarbartolo di Sciara et al., 2008) and the summer season (e.g. Azzellino et al., 2008; Panigada et al., 2008; Gnone et al., 2011; Fiori et

al., 2014; Tepsich et al. 2014, Cominelli et al., 2015). Nevertheless, surveys are often conducted with different methodologies and the limited spatial or temporal resolutions cause difficulties in data comparison: cetacean are wide-ranging species, so many aspects about their seasonal movements and habitat use still remain unclear, and information is especially lacking in remote high sea areas throughout the whole year (Evans and Hammond, 2004; Notarbartolo di Sciara and Birkun 2010; Fujioka and Halpin 2014; Pace et al., 2015). Species distribution is in fact determined by a combination of processes which include ecological features and anthropogenic factors. Systematic studies are appropriate to account for the variability in species distribution and occurrence over different areas, even for understanding the interactive role of the different processes involved (Evans and Hammond, 2004; Fujioka and Halpin 2014). There is also an increasing need for information on marine biodiversity for management planning, which requires to assess the overlap with human impacts in order to evaluate protection efforts and support further conservation measures (Halpern et al., 2008; Hamilton et al., 2010; Coll et al., 2012).
This study was designed to improve knowledge about year-round cetaceans' presence in a large, poorly known, area at the borders of the Pelagos Sanctuary. A long trans-regional transect crossing the Sardinian-Balearic basin, the Bonifacio Strait and central Tyrrhenian Sea was systematically surveyed for three years allowing consistent data collection and comparisons of the spatio-temporal occurrence of all eight cetacean species known to be regularly present in the Mediterranean Sea (Notarbartolo di Sciara and Birkun, 2010). This research allowed to deliver seasonal distribution of cetacean species over a wide range, highlighting differences among three ecologically distinguished subareas; secondly, it aimed to identify hot spots of cetaceans' presence, useful to support the implementation of conservation measures even in pelagic areas.

Materials and methods

Study area

The monitored sampling transect encompasses almost longitudinally a large portion of the Western Mediterranean Sea Region from Barcelona (Spain) to Civitavecchia (Italy) crossing the Balearic Sea, the southern portion of the Gulf of Lion, the Sardinian Sea, the Bonifacio Strait, and the central Tyrrhenian Sea. For the purpose of this study, the area was divided into three subareas: two large basins (Sardinian-Balearic and central Tyrrhenian) and a central portion from north of C. Falcone to the point of intersection of the surveyed transects with the 200m bathymetry. While the first two are mainly pelagic high sea areas, the third subarea is included between the Sardinia and Corsica islands and is mainly influenced by the continental part of the Bonifacio Bouche and, in the western part, by the Asinara Gulf and the Castelsardo Canyon just north (Fig. 1). The entire Bonifacio subarea falls inside the Pelagos Sanctuary. Each subarea has distinct oceanographic signatures, so the synoptic and systematic data collection in these different sea regions allowed consistent comparisons on spatio-temporal occurrences of all cetacean species within different habitat types distinguished by different physical and oceanographic processes.

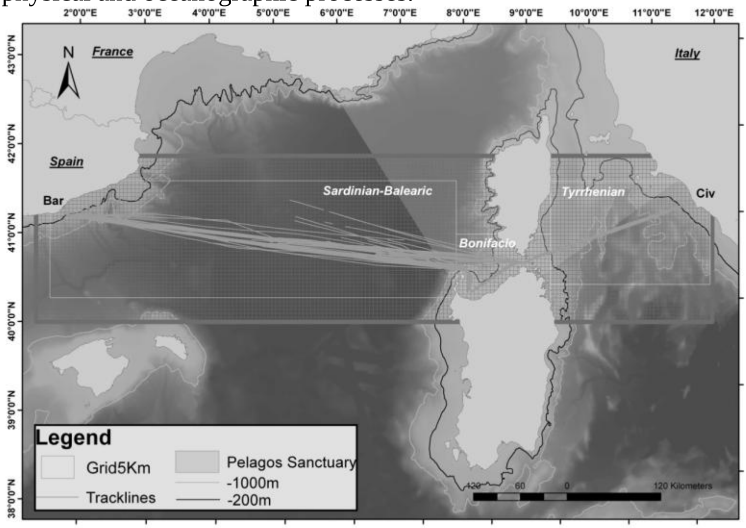


Fig. 1. Study Area showing the three subareas (Sardinian-Balearic, Bonifacio, Tyrrhenian), the tracklines of effort, and the grid cell of 5x5 Km used for the analyses. The light grey area is the Pelagos Sanctuary.

Data collection

Data was collected along sampling transects following the "ISPRA monitoring protocol using ferry as platform of observation for systematic research" (ISPRA, 2012), which set the condition for data collection in order to maintain equal probability of detecting species under the "on effort" state (e.g. range of weather conditions ≤3 Beaufort scale, experience of observers, angle and height of observation, range of speed and type of ferry). Monitoring was conducted all year round from two twin ferries of the Grimaldi Lines Company with a frequency of at least five surveys per season (considering that each survey monitored the entire study area with an outbound and a return transect). The data collection started in June 2012, but for the purpose of this study, the dataset considered goes from October 2012 to September 2015 for a total of three entire years.

During the study period, a total of 58741 km were travelled on effort. The highest effort carried out in the Sardinian-Balearic (Table1) was due to the fact that this is the largest subarea, and that the general good weather conditions during the spring and summer seasons allowed longer daily observations along the entire subarea. The maps of seasonal effort per cell (Fig. 2) show the distribution of survey effort along the whole study area.

Tab.1. Total effort (Km and # of monitored cells) and effort per cell with minimum effort value ≥10Km.

	Tot cells		**Cells >10Km of effort**		
	# Km effort	**# cell**	**# Km effort**	**# cell**	**# sight**
Sardinian-Balearic	**40.308**	**1.745**	**36.451**	**904**	**895**
Autumn	6.998	337	6.093	144	123
Winter	7.565	454	6.269	165	83
Spring	13.465	574	12.242	306	413
Summer	12.280	380	11.845	289	276
Bonifacio	**8.278**	**296**	**7.909**	**206**	**94**
Autumn	1.341	44	1.308	37	23
Winter	1.435	66	1.355	48	28
Spring	2.619	104	2.470	63	25
Summer	2.881	82	2.775	58	18
Tyrrhenian	**10.154**	**254**	**9.934**	**185**	**235**
Autumn	1.609	64	1.539	43	31
Winter	1.590	56	1.544	40	40
Spring	3.372	71	3.303	53	80
Summer	3.582	63	3.547	49	84

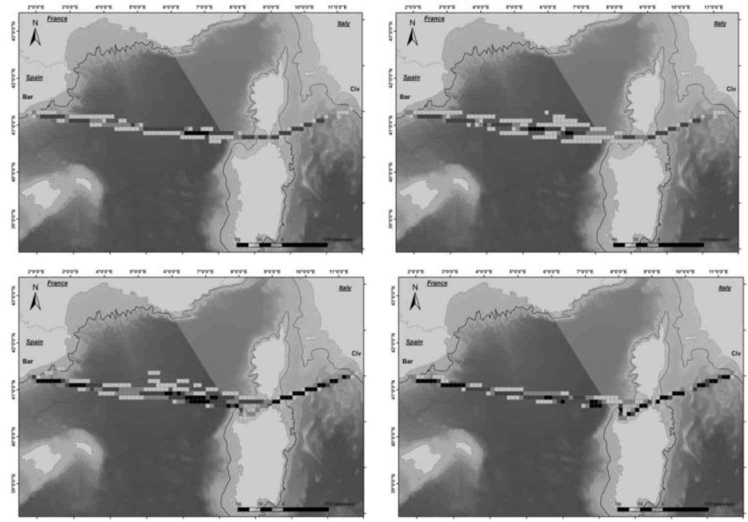


Fig.2 Distribution of effort during Autumn (top left), Winter (top right), Spring (bottom left), Summer (bottom right). The light grey area is the Pelagos Sanctuary.

Data analysis

Species diversity, encounter rate, and distribution

The diversity of species was investigated for each subarea/season as species presence and richness (i.e. the list and number of different species detected) and as the percentage composition (i.e. number of sightings of a species to the total number of sightings of all species). The Shannon diversity index –H- (which increases as both the richness and the evenness of the community increase) was used to characterize species diversity for the cetacean community, while the Shannon evenness (which assumes values between 0 and 1 with 1 being complete evenness) was used to measure the equality of individuals. The diversity indices were used temporally to compare the four seasons and spatially to compare the Sardinian-Balearic and central Tyrrhenian basins, while the Bonifacio Strait was excluded due to oceanographic features that can host smaller number of species.

Intra-specific composition was analysed by means of group size, defined as the number of individuals observed at a distance of a few body lengths, and the presence of juveniles within the detected groups. A juvenile was considered as an individual with less than half the length of other animal/s in the group and generally spotted in close contact and with synchronous movements to one adult.

An abundance index was used to statistically compare differences in cetacean occurrences in space and time. The study area was divided on a grid cell basis of 5x5 km (Fig. 1) as this value allowed a compromise among the range of observational effective strip (half) width and the potential bias due to a high number of cells with zero values or due to a high spatial correlation among adjacent cells. Each cell was used as a statistical unit and, for each of the investigated time periods, only the cells crossed at least by one trackline of effort were selected from the entire grid.

For each cell, the number of km travelled on effort and the number of sightings per each species were then calculated. The abundance index was estimated as number of sightings (N) per 10 km travelled on effort (e) per each grid cell (encounter rate, ER=N/e). To account for potential bias due to an uneven effort, a minimal sampling effort criteria was set: on the basis of preliminary exploratory data analysis of ER and Z-score values related to effort, it was found that the variance of the ERs does not appreciably change with >10 km of effort per cell. So, out of the total 2295 grid cells encompassed on effort, only 1295 cells with the minimum effort value of 10 km per cell were used for the analyses (Table 1, Fig. 2). Within this subset, the total number of sightings was 1224.

For each cell, values were assigned corresponding to the Y and X coordinates of the central point, the subarea, the season, the year, the total number of km travelled on effort, the total number of sightings, the sightings of each species, and the abundance indexes calculated for all species pooled together and for the species singularly. All analyses were performed with ArcGIS 10.1 and the open access software Geospatial Modeling Environment (GME, Beyer, 2012) coupled with R for statistical analysis (R Core Team, 2013).

Univariate analysis was performed on the abundance indexes stratifying the data per year, subarea, and season, and differences were tested with the non-parametric Kruskall-Wallis test (KW) comparison with the Bonferroni correction and the post-hoc pair-wise Mann-Whitney U test (MW) to test the hypothesis of equal medians among and between population samples. A multivariate ordination technique

(Correspondence Analysis, CA) was then applied to help represent relationships among samples and variables relationships in the low-dimensional space: a contingency table of categorical data was used for the analysis with the ER of the species as a response variable and the 3 subareas x 4 seasons as explanatory variables. Preliminary exploratory data analysis, univariate, multivariate analyses and statistical tests were performed with the software Past 2.17 (Hammer et al., 2001).

Hot/cold spot analysis

Spatial data were preliminary tested to highlight whether the pattern of cluster/dispersal data exist using the Average Nearest Neighbor and the Morans I index with the spatial analysis tools in ArcGIS 10.1. The abundance index per cell was used for displaying the areas of different categories of abundance, and for the subset of data with clustered patterns, the Getis-Ord Gi* analysis (Getis and Ord, 1992) was used to identify the locations of statistically significant hot spots and cold spots. The Gi* analysis produces Z scores and P values: high Z score and small P value indicate a significant hot spot while a low negative Z score and small P value indicate a significant cold spot. Hot spots were thus considered as areas where cells with high relative abundance values were spatially clustered. For this study, only highest (or lowest) Z score values (>2.58 or <-2.58 Std.Dev.) were used for displaying the more intense hot/cold clusters. As the purpose of this study was to verify areas/seasons of particular importance for the significant presence of cetaceans as whole taxon, the analysis was conducted only by pooling all data together, while analyses at species level and on the persistence of hot spots during the years where beyond the purpose of the present study.

Results

Species presence and composition

All eight cetacean species residing within the Mediterranean basin were recorded in the study area with five species sighted in all three subareas (*Balaenoptera physalus*, Bp; *Stenella coeruleoalba*, Sc; *Physeter macrocephalus*, Pm; *Tursiops truncatus*, Tt; *Ziphius cavirostris*, Zc). The highest species richness was generally recorded in the Sardinian-Balearic subarea during the spring season (Table1) due to the detection of the other species: *Grampus griseus* (Gg), *Delphinus delphis* (Dd) and *Globicephala melas* (Gm). Sightings of mixed species were also recorded, mostly represented by the association of striped dolphin with bottlenose dolphin or common dolphin or fin whale; in one occasion, an association between bottlenose dolphin and Risso's dolphin was observed.

Tab. 2. Total number # of sightings per species per area / season

	Bp	Sc	Pm	Tt	Zc	Gg	Dd	Gm	ScBp	ScTt	ScDd	GgTt
Sardinian-Balearic												
Autumn	42	44	6	3	2	2	1				1	
Winter	19	41	5	1				1				
Spring	161	167	3	10	3	6	4	1	2	1		
Summer	85	104	17	7	1	6						
Bonifacio												
Autumn	8	8		5	1							
Winter	25	1		2								
Spring	1	7	2	9								
Summer	3	8		6								
Tyrrhenian												
Autumn	3	21										
Winter	1	23	1									
Spring	25	29	2	2	3		1					1
Summer	21	40	2		6	1					1	

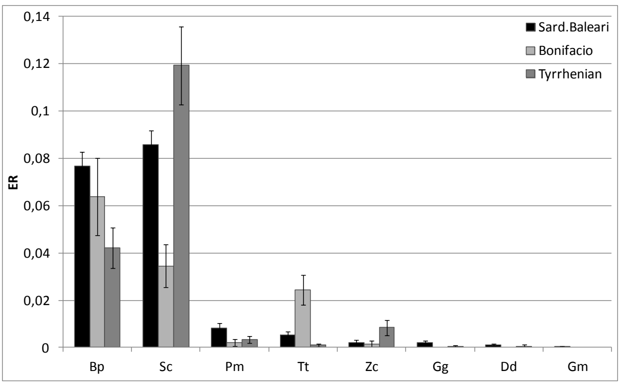


Fig.2. Index of abundance (ER=sightings per 10 Km travelled on effort) of the sighted species recorded in the three investigated subareas

The highest values of the abundance index were reported only for fin whale and striped dolphin in all the subareas, while sperm whale, bottlenose dolphin and Cuvier's beaked whale showed relatively higher ERs only in one of the three subareas (Pm: Sardinian-Balearic, Tt: Bonifacio, Zc: Tyrrhenian) (Fig. 2). All the other species where rarely recorded.

The output of the diversity indices showed that the Sardinian-Balearic had a slightly higher species diversity compared to the Tyrrhenian basins, and that spring and summer were the seasons when a much higher diversity occurred (Table 3).

Tab. 3 Shannon diversity index and Shannon evenness index in the Sardinian-Balearic and central Tyrrhenian basins and during the four seasons

	Shannon diversity index	Shannon evenness index
Basin		
Sardinian-Balearic	0,79	0,36
Central Tyrrhenian	0,63	0,32
Season		
Winter	0,12	0,18
Autumn	0,16	0,10
Spring	0,80	0,45
Summer	0,79	0,38

Group size and presence of juvenile

The most numerous groups were generally recorded in the Sardinian-Balearic subarea for all species except Cuvier's beaked whale which showed higher group sizes in the Tyrrhenian subarea (Table 4).

Juveniles were recorded during all the seasons with a predominant presence in spring, both in terms of total number of juveniles, as well as the percentage of sightings with juvenile presences (Fig. 3). In most cases, juveniles were recorded in striped dolphin groups, followed by cases in pairs of adult and juvenile fin whales or in bottlenose dolphin pods. Juveniles of sperm whales and Risso's dolphins were also documented. In one case, a group of eleven long finned pilot whales were sighted with a young juvenile in the Sardinian Sea.

Tab. 4. Group size and the number of individuals per species in the three subareas (SB: Sardinian-Balearic; Bon: Bonifacio; Ty: Tyrrhenian).

	S.coeruleoalba			***B.physalus***			***P.macrocephalus***			***T.truncatus***		
	SB	**Bon**	**Ty**	**SB**	**Bon**	**Ty**	**SB**	**Bon**	**Ty**	**SB**	**Bon**	**Ty**
N	354	28	113	308	37	51	30	5	5	19	23	2
Min	1	1	1	1	1	1	1	1	1	1	1	1
Max	70	25	35	12	4	4	7	2	2	30	10	8
Mean	7,5	6,6	5,3	1,5	1,5	1,3	1,6	1,2	1,2	6,4	3,7	4,5
SE	0,44	1,16	0,49	0,06	0,13	0,09	0,22	0,20	0,20	1,54	0,56	3,50
Ind. tot	2666	185	600	452	54	68	47	6	6	122	84	9

	Z.cavirostris		***D.delphis***		***G.griseus***		***G.melas***
	SB	**Ty**	**SB**	**Ty**	**SB**	**Ty**	**SB**
N	7	9	4	1	14	1	2
Min	1	1	2		1		3
Max	1	4	15		12		11
Mean	1,0	2,0	6,8	4,0	3,9	7,0	7,0
SE	0,00	0,37	2,87		0,84		4,00
Ind. tot	7	18	27	4	54	7	14

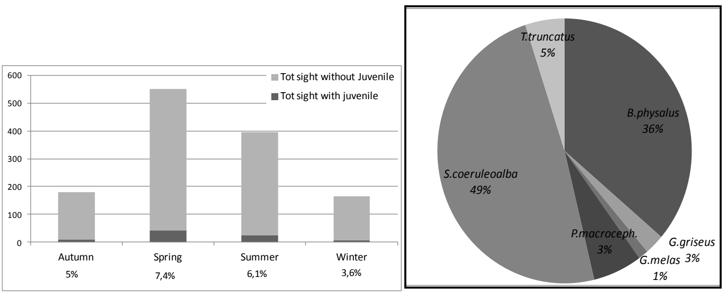


Fig. 3. Total sightings with and without juveniles, and the percentage of sightings with juveniles (left). Percentage of juveniles per species' sightings (right).

Spatio-temporal variability

Looking at pooled data from the whole transect, no significant inter-annual differences in abundance indexes were recorded for all species (KW, $p>0.5$) being only fin whale significantly different between the first ($ER=0.085\pm0.01$ SE) and the second investigated years ($ER=0.049\pm0.006$ SE) (MW, $p<0.05$).

Stratifying data for the three investigated subareas and the more sighted species (Bp, Sc, Pm, Tt), results showed no significant differences among the three investigated years except for fin whale in the Sardinian-Balearic and Bonifacio subareas (KW, $p<0.01$). For these cases, data were further stratified per season in order to highlight the year/s of seasonal significant differences in the three subareas:

- in the Sardinian-Balearic, the lowest significant abundance of fin whale was recorded during spring of the second year (2014) (KW and MW, $p<0.01$);
- in the Bonifacio, a significant highest abundance of fin whale was recorded during the winter of the first year (2013) (KW and MW, $p<0.01$);

Looking at seasonality for all data pooled (species and subareas), the highest ER was recorded during the spring while the lowest was in winter (MW, $p<0.05$), likely driven by the significant difference in abundance of fin whale ($ER_{Spring}=0.1\pm0.013$ SE; $ER_{Winter}=0.05\pm0.012$ SE; MW, $p<0.05$). Considering the three investigated subareas separately (Fig. 4):

- in the Sardinian-Balearic, the significant highest abundance for all species pooled together was recorded in spring, probably driven by the significant highest abundance of fin whale and striped dolphin (spring $\neq$ autumn and winter; KW and MW, $p<0.01$),while the lowest abundance was recorded in winter ($winter_{fin\ whale} \neq$ autumn, spring and summer; KW and MW, $p<0.01$);
- in Bonifacio, fin whale showed a significant seasonality with a maximum abundance in winter ($\neq$ spring and summer; KW and MW, $p<0.01$) driven by the highest ER of the first year;
- in the Tyrrhenian, a significant seasonality was found for fin whale with maximum ERs in spring and summer, opposed to winter (KW and MW, $p<0.01$).

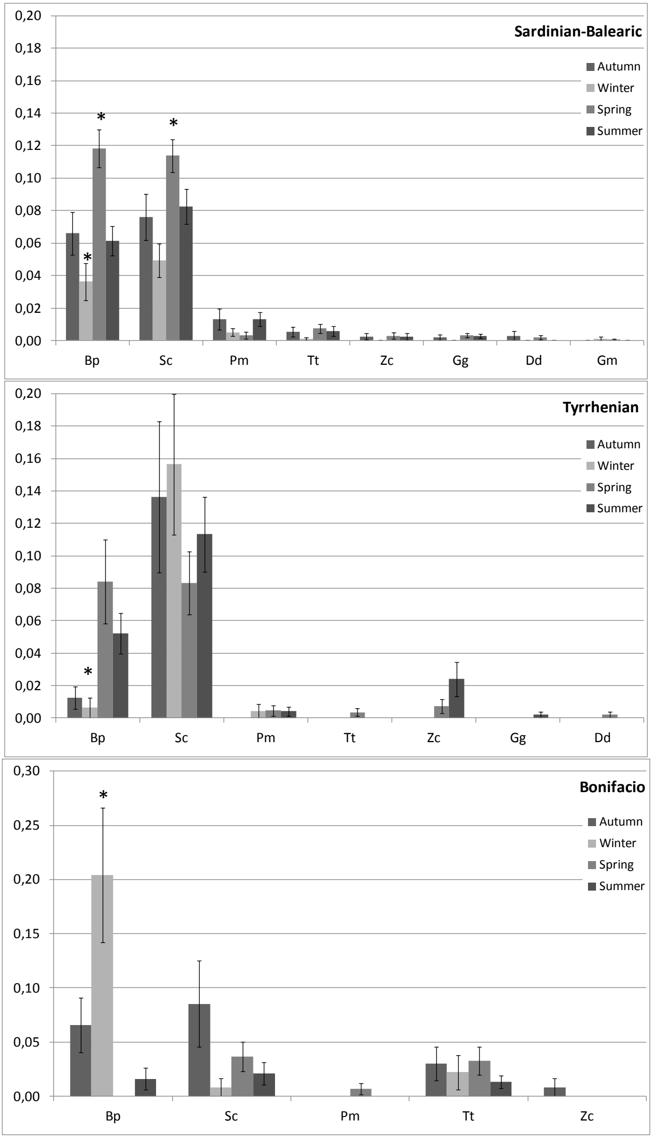
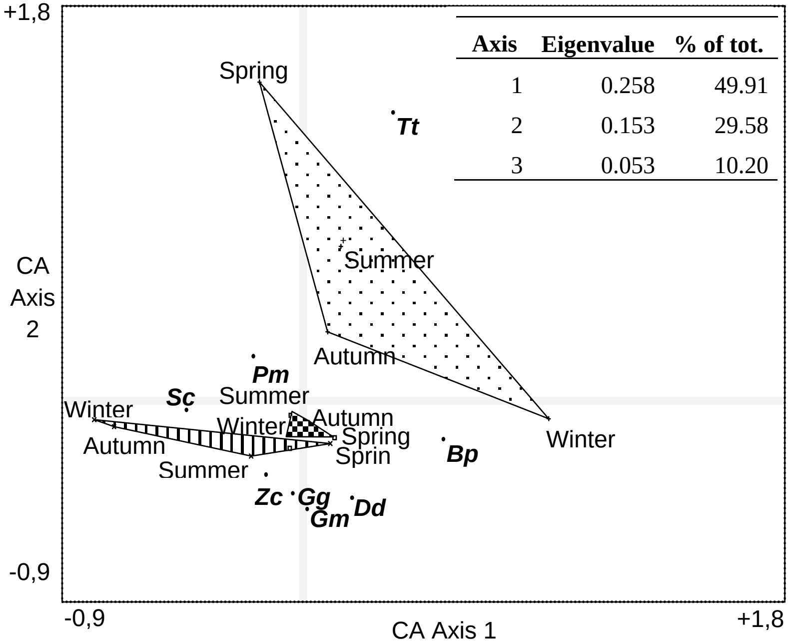


Fig. 4. Seasonal index of abundance (Encounter Rate, ER = sightings/10Km on effort ±St.Err.) of the sighted species (Bp: *B.physalus*; Sc: *S.coeruleoalba*; Pm: *P.macrocephalus*; Tt: *T.truncatus*).



Axis	Eigenvalue	% of tot.
1	0.258	49.91
2	0.153	29.58
3	0.053	10.20

Fig. 5. Results of the Correspondence analysis on the seasonal abundance index. Dotted: Bonifacio; Lines: Tyrrhenian; Squared: Sardinian-Balearic. In the table the contribute of the axes.

Results of the correspondence analysis confirmed outcomes of the statistical analysis helping visualise the relationships among species and all subareas/seasons in a synoptic view. Almost 80% of total variance was explained by the first two axes (more than 90% when including the third axis) (Fig. 5). To the first axis it mainly contributes the association between fin whale and winter in the Bonifacio subarea (and, to a lesser extent, to spring in the other two subareas) as opposed to striped dolphin and winter/autumn in the Tyrrhenian. The second axis shows the association between bottlenose dolphin and spring (plus summer and autumn) in the Bonifacio subarea and, conversely, the cluster of the less common pelagic species (Zc, Gg, Dd, Gm) mostly related to spring/summer in the Sardinian-Balearic and Tyrrhenian subareas, with a close association between Cuvier’s beaked whale and summer in Tyrrhenian Sea (confirmed as a main contributor to the third axis). In general, seasonality was more accentuated in the Tyrrhenian subarea than in the Sardinian-Balearic one, with only spring/summer being more similar between the two basins.

Hot/cold spot analysis

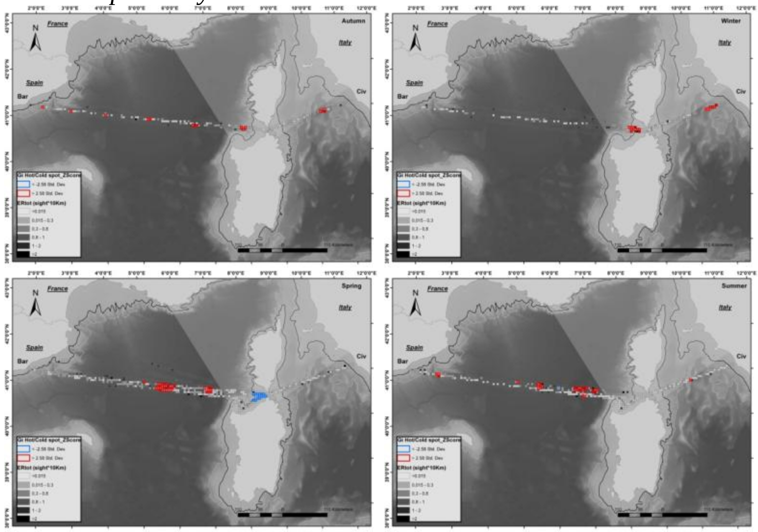


Fig. 6. Maps of the seasonal abundance index (ER=sightings/10Km on effort) and significant hot/cold spots individuated by the Gi* analysis (in red). Autumn: top left; winter: top right; spring: bottom left; summer: bottom right. The light grey is the Pelagos Sanctuary.

The distribution of the cetaceans' abundance showed variations during the different seasons: during autumn, several hot spots were found dispersed along the whole surveyed transect; in winter, a hot spot of fin whale emerged in the Bonifacio area and another one in the eastern part of the Tyrrhenian Sea; in spring and summer, hot spots concentrated mostly in the central-eastern part of the Sardinian-Balearic Seas, and in spring, a relatively large cold spot was detected in the Bonifacio Strait.

Discusssion

Many studies pointed out the need for consistent and extensive long-term programs to understand patterns of cetacean occurrences, to monitor their status over time and as a first step to investigate their relationships with environmental and anthropogenic factors (Evans and Hammond 2004; Fujioka and Halpin 2014). Results of these three continuous years of consistent surveys introduced new insights into the occurrence of cetaceans in a largely unexplored portion of the Western Mediterranean Sea Region.

All eight cetacean species known to have resident populations all around the Mediterranean basin were detected, but the study confirmed the highest occurrence only of fin whale and striped dolphin, followed by sperm whale and the more coastal bottlenose dolphin, while the other pelagic species were sighted more rarely.

Notwithstanding the difficulties on gathering information about more rare pelagic species, the sampling design of this study allowed us to deliver some interesting information also on these species. Sperm whale, Risso's dolphin, common dolphin and long-finned pilot whale were mainly detected in the Sardinian-Balearic basin, possibly due to the highest effort being undertaken in this subarea; as well, their confirmed presence even in the Tyrrhenian Sea, where long-finned pilot whale was not detected, is in line with previous data in this area (Marini et al., 1996; Arcangeli et al., 2013b). Moreover, results confirmed the importance of the central Tyrrhenian Sea for Cuvier's beaked whale as already highlighted by other researches (Gannier, 2011, Arcangeli et al., 2015): the species was in fact detected during all seasons in the Sardinian-Balearic basin, but the highest encounter rate and biggest group size were recorded during spring/summer in the central Tyrrhenian Sea.

Results in the Bonifacio subarea were mainly driven by the predominant continental habitat of the central and eastern parts: bottlenose dolphin was primarily recorded in this area, while striped dolphin, sperm whale and Cuvier's beaked whale were observed in the western deeper parts. A significant highest occurrence of fin whale was documented inside the Bonifacio Strait in winter 2013 but it was not registered in the two successive years, indicating a variability that could be linked to demography, life stage, and/or group/individual preference.

Looking at the two large pelagic basins, the Sardinian-Balearic Seas had slightly higher species richness and diversity than the Tyrrhenian Sea, with spring/summer being the richest seasons with the highest diversity and encounter rates in both areas. The study confirmed seasonal cycles for fin whale and striped dolphin, with peaks of occurrence recorded in spring and summer in both pelagic basins, and drops in presences detected during winter and autumn. Both species are known to concentrate during summer in high latitudes (i.e. Pelagos Sanctuary) for feeding purposes with minimum occurrence recorded in winter (Panigada et al., 2011). In the medium western-Mediterranean latitudes of the present study most of the significant seasonal variability was

driven by fin whale: in the central Tyrrhenian Sea, the summer presence was recently associated with feeding (Arcangeli et al., 2014) while in the Sardinian-Balearic, the decreased number of encounters recorded from spring to summer in two out of three of the investigated years is more consistent with an hypothesis of intermediate concentrations of individuals in medium latitudes in spring followed by northern movement during summer, probably towards more productive areas (De Segura et al., 2006; Laran and Drouot-Dulau 2007; Cotté et al., 2009). During autumn and winter, the lowest occurrence recorded in both Sardinian-Balearic and Tyrrhenian basins is most likely consistent with a dispersing pattern towards more southern Mediterranean areas (Marini et al., 1996; Laran and Drouot-Dulau 2007; Cotté et al., 2009). However, while the seasonal movement surely involves most fin whales, sightings were recorded all year round along the surveyed transect, in accordance with the year-round presence of specimens recorded in other studies in the Corso-Ligurian-Provencal basin (Notarbartolo et al., 2003) and in the Tyrrhenian Sea (Marini et al, 1996). Individual remaining in the same area throughout the seasons, as well as individual differences in movement patterns, were highlighted by several telemetry studies (Cottè et al., 2011; Panigada et al., 2015). The occurrence of fin whales wintering in the Bonifacio Strait in 2013 (min. of 13 animals, Arcangeli et al., 2013a) further confirms that small group/individual flexibility could determine a more complex pattern with seasonal and inter-annual fluctuations in distributions and that many factors can act like drivers, such as gender differences (e.g. females remain in feeding areas throughout winter as is the case for humpback whale, Brown et al., 1995), life stage, site fidelity, or others.
Striped dolphin followed the same pattern of fin whale in the Sardinian-Balearic areas, likely driven by feeding purpose as well; no clear seasonality was instead recorded in the central Tyrrhenian sea, indicating a more stable presence of the species throughout the year, as already reported by Marini et al. (1996).
A general spring-concentrated and autumn-dispersal pattern was shown in particular in the Sardinian-Balearic Seas and is coherent with the theory of a relationship between the pattern of distribution of cetaceans with the pattern of productivity (autumn/winter-dispersal, spring/summer-concentrate). Significant hot spots were mainly concentrated in the central-eastern part of the Sardinian-Balearic basin (spring/summer) and the eastern Tyrrhenian Sea (autumn/winter), while they were more dispersed during autumn (and not detected during winter) in the Sardinian-Balearic basin.

As highlighted by other studies (e.g. Gannier, 2002; Monestiez, 2006; Druon et al., 2012; Arcangeli et al., 2014), differences can occur from one year to others, adding more variables into the general seasonal process. Inter-annual variability was confirmed by this study especially for fin whale in the Sardinian-Balearic, with lowest significant abundance recorded during spring 2014 followed by a peak during summer.

Spring was confirmed to be the season with highest occurrence of juveniles, which is probably related to the prevalence of offspring in this season. Juveniles were recorded in all the monitored areas and were observed in six out of the eight sighted species (with the exception of Cuvier's beaked whale and common dolphin). Of the two sightings of long-finned pilot whale in the Sardinian Sea, the one recorded in April 2015 documented a large pod of eleven individuals in close contact each other with an offspring spy hopping within the pod.

Despite the growing concern for the protection of cetacean species and the emergent data rising from cetacean research, significant gaps still limit the comprehension of the seasonal cycle and movement/distribution of species, especially in remote high sea areas and throughout the entire seasonal cycle. Results of this study helped fill some gaps in a large portion of remote high sea areas of medium latitudes in the western Mediterranean basin during all seasons.

From a conservation point of view, the study highlighted some hot spots that, especially in spring/summer, require increased consideration due to the combined effects of the highest species diversity, abundance, significance of hot spots and presence of juveniles. Currently only 4% of the Mediterranean Sea is in Marine Protected Areas, most of it represented by the large area of the Pelagos Sanctuary, which only partially include the functional diversity of marine ecosystems (Pace et al., 2015); thus, given its high biodiversity, significant amount of effort is still required to protect and manage this basin richness (Coll et al., 2012). On the other hand, a plethora of anthropogenic factors is providing growing pressures towards marine environment at different levels and scale (Halpern et al., 2008; Coll et al., 2012) and identifying such ecologically important areas through continuous monitoring is complementary for the implementation of conservation measures in pelagic areas.

References

Arcangeli A., Campana I., Carcassi S., Casella E., Cracas F., Fabiano F., Ottaviani D., Manca Zeinchen M., Addis A., Crosti R. (2013a).

Seasonal sighting of *Balaenoptera physalus* the Bonifacio Strait (Santuario PELAGOS). Biol. Mar. Mediterr. 20 (1): 252-253.
Arcangeli, A., Campana, I., Marini, L., & MacLeod, C. D. (2015). Long-term presence and habitat use of Cuvier's beaked whale (*Ziphius cavirostris*) in the Central Tyrrhenian Sea. Marine Ecology (DOI 10.111/maec.12272)
Arcangeli, A., Marini, L., & Crosti, R. (2013b). Changes in cetacean presence, relative abundance and distribution over 20 years along a trans-regional fixed line transect in the Central Tyrrhenian Sea. Marine Ecology, 34(1), 112-121.
Arcangeli, A., Orasi, A., Carcassi, S. P., & Crosti, R. (2014). Exploring thermal and trophic preference of Balaenoptera physalus in the central Tyrrhenian Sea: a new summer feeding ground?. Marine biology, 161(2), 427-436.
Beyer, H.L. (2012). Geospatial Modelling Environment (Version 0.7.2.1). (software). URL: http://www.spatialecology.com/gme. for Education and Data Analysis. Palaeontologia Electronica 4(1): 9pp.
Brown, M. R., Corkeron, P. J., Hale, P. T., Schultz, K. W., & Bryden, M. M. (1995). Evidence for a sex-segregated migration in the humpback whale (*Megaptera novaeangliae*). Proceedings of the Royal Society of London B: Biological Sciences, 259(1355), 229-234.
Coll, M., Piroddi, C., Albouy, C., Ben Rais Lasram, F., Cheung, W. W., Christensen, V., ... & Pauly, D. (2012). The Mediterranean Sea under siege: spatial overlap between marine biodiversity, cumulative threats and marine reserves. Global Ecology and Biogeography, 21(4), 465-480.
Cotté C, Guinet C, Taupier-Letage I, Mate B, Petiau E (2009) Scale-dependent habitat use by a large free-ranging predator, the Mediterranean fin whale. Deep Sea Res Pt I 56(5):801-811
Cotté, C., d'Ovidio, F., Chaigneau, A., Lévy, M., Taupier-Letage, I., Mate, B., & Guinet, C. (2011). Scale dependent interactions of Mediterranean whales with marine dynamics. Limnology and Oceanography, 56(1), 219-232.
De Segura AG, Crespo EA, Pedraza SN, Hammond PS, Raga JA (2006) Abundance of small cetaceans in waters of the central Spanish Mediterranean. Mar Biol 150(1):149-160
Druon, J. N., Panigada, S., David, L., Gannier, A., Mayol, P., Arcangeli, A., ... & Gauffier, P. (2012). Potential feeding habitat of fin whales in the western Mediterranean Sea: an environmental niche model. Marine Ecology Progress Series, 464, 289-306.

Evans PGH, Hammond P (2004) Monitoring cetaceans in European waters. Mammal Rev 34:131-156

Fujioka E, Halpin PN (2014) Spatio-temporal assessments of biodiversity in the high seas. Endang Spec Res 24:181-190

Gannier, A. (2011). Using existing data and focused surveys to highlight Cuvier's beaked whales favourable areas: A case study in the central Tyrrhenian Sea. Marine pollution bulletin, 63(1), 10-17.

Getis, A., Ord, J.K., 1992. The analysis of spatial association by use of distance statistics. Geographical Analysis 24, <http://onlinelibrary.wiley.com/doi/10.1111/j.1538-4632.1992.tb00261.x/pdf> (article first published online: 03.09.10).

Halpern, B.S.,Walbridge, S., Selkoe, K.A., Kappel, C.V.,Micheli, F., D'Agrosa, C., Bruno, J.F., Casey, K.S., Ebert, C., Fox, H.E., Fujita, R., Heinemann, D., Lenihan, H.S., Madin, E.M.P., Perry, M.T., Selig, E.R., Spalding, M., Steneck, R. &Watson, R. (2008) A global map of human impact on marine ecosystems. Science, 319, 948–952.

Hamilton, S.L., Caselle, J.E., Malone, D.P. & Carr, M.H. (2010) Incorporating biogeography into evaluations of the Channel Islands marine reserve network. Proceedings of the National Academy of Sciences USA, 107, 18272–18277.

Hammer, Ø., Harper, D.A.T., and P. D. Ryan, 2001. PAST: Paleontological Statistics Software Package for education and data analysis. Palaeontologia Electronica, 4(1), 9 pp

ISPRA, 2012. Fixed line transect using ferries as platform of observation monitoring protocol. Technical annex at the Agreement for the activities of 'Fixed line transect using ferries as platform of observation for monitoring cetacean populations' of the 11/12/2012.

Laran, S., & Drouot-Dulau, V. (2007). Seasonal variation of striped dolphins, fin-and sperm whales' abundance in the Ligurian Sea (Mediterranean Sea). Journal of the Marine Biological Association of the United Kingdom, 87(01), 345-352.

Marini, L., Consiglio, C., Angradi, A. M., Catalano, B., Finoia M.G., Sanna, A., Valentini, T., Villetti, G. (1996). Distribution, abundance and seasonality of cetaceans sighted during scheduled ferry crossings in the central Tyrrhenian Sea: 1989–1992. Italian Journal of Zoology, 63(4), 381-388.

Monestiez, P., Dubroca, L., Bonnin, E., Durbec, J. P., & Guinet, C. (2006). Geostatistical modelling of spatial distribution of Balaenoptera physalus in the Northwestern Mediterranean Sea from sparse count data and heterogeneous observation efforts. Ecological Modelling, 193(3), 615-628.

Notarbartolo di Sciara, G., Zanardelli, M., Jahoda, M., Panigada, S., & Airoldi, S. (2003). The fin whale *Balaenoptera physalus* (L. 1758) in the Mediterranean Sea. Mammal Review, 33(2), 105-150.

Notarbartolo di Sciara, G., Agardy, T., Hyrenbach, D., Scovazzi, T., Van Klaveren, P., 2008. The Pelagos sanctuary for Mediterranean marine mammals. Aquatic Conservation: Marine and Freshwater Ecosystems 18, 367−391.

Notarbartolo di Sciara G, Birkun AJr (2010) Conserving whales, dolphins and porpoises in the Mediterranean and Black Sea: an ACCOBAMS status report. ACCOBAMS, Monaco, 212 pp.

Pace DS, Tizzi R, Mussi B (2015) Cetaceans Value and Conservation in the Mediterranean Sea. J Biodivers Endanger Species S1:004. doi:10.4172/2332-2543.S1.004

Panigada, S., Lauriano, G., Burt, L., Pierantonio, N., & Donovan, G. (2011). Monitoring winter and summer abundance of cetaceans in the Pelagos Sanctuary (northwestern Mediterranean Sea) through aerial surveys. PloS one, 6(7), e22878.

R Core Team (2013). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/

CH. 2 Ecology of *Balaenoptera physalus*: migration pattern and relationship with physiographic variables, remote sensing data and anthropogenic factor.

Arcangeli A., Orasi A., Carcassi S., Crosti C. (2014). Exploring thermal and trophic preference of *Balaenoptera physalus* in the Central Tyrrhenian Sea: a new summer feeding ground? Mar Biol 161: 427–436.

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ORIGINAL PAPER

Exploring thermal and trophic preference of *Balaenoptera physalus* in the central Tyrrhenian Sea: a new summer feeding ground?

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Abstract In the 1990s, the central Tyrrhenian Sea was regarded as a transit region for fin whales' (*Balaenoptera physalus*) summer migration. In recent years, a much higher presence of fin whales during the entire summer season was reported in the region. The hypothesis that the central Tyrrhenian Sea may have become a summer feeding ground was tested gathering data from summer presence of whales in the region (40–42.5°N; 9–13°E) and investigating whether it might be related to sea surface temperature and chlorophyll-a concentration, considered as proxies of food availability. Results showed that whales always aggregate in the more productive portions of the investigated area; the general productivity of the area, however, did not directly influence the frequency of occurrence of whales. We concluded that the complex dynamics of the balance between feeding activities and avoiding pressures may have led fin whales to use the region as an opportunistic feeding ground.

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Introduction

The fin whale (*Balaenoptera physalus*) is the most common large baleen whale species in the Mediterranean Sea and the only one with a resident population in the basin (Bérubé et al. 1998).

The Corso-Ligurian-Provençal basin is considered its primary summer feeding ground, mainly due to the presence of a frontal system in the area which provides a high level of primary production (Forcada et al. 1995; Notarbartolo di Sciara et al. 2003). The protection of this productive feeding area was the main reason for the establishment of the International Pelagos Sanctuary for the protection of marine mammals in 2001 (Notarbartolo di Sciara et al. 2008).

The Tyrrhenian Sea by contrast has been regarded as an area of intermediate value for fin whales; the abundance of whales was found to be lower than in the Corso-Ligurian-Provençal basin, possibly due to the lower productivity of its waters (Notarbartolo di Sciara et al. 2003). Marini et al. (1997) reported the presence of fin whales in the central Tyrrhenian Sea throughout the year, with peaks in April–May and September–October. This is in line with the transit of whales during their migration to and from their northern summer feeding ground. Other researchers have also found evidence of whale migration through the central Tyrrhenian Sea (Nascetti and Notarbartolo di Sciara 1996).

However, in recent years, a much higher occurrence of fin whales, three times that of the early 1990s, was reported during the entire summer season in the central Tyrrhenian Sea (Arcangeli et al. 2008; Arcangeli et al. 2012). Such an increase was not reported in other studies conducted in other regions of the Mediterranean basin (Gannier 2002; Aissi et al. 2008; Castellote et al. 2011); conversely, a decrease in fin whale was reported in the Pelagos Sanctuary

Summary
In the 1990s, the central Tyrrhenian Sea was regarded as a transit region for fin whales' (*Balaenoptera physalus*) summer migration. In recent years, a much higher presence of fin whales during the entire summer season was reported in the region. The hypothesis that the central Tyrrhenian Sea may have become a summer feeding ground was tested gathering data from summer presence of whales in the region (40–42.5°N; 9–13°E) and investigating whether it might be related to sea surface temperature and chlorophyll-a concentration, considered as proxies of food availability. Results showed that whales always aggregate in the more productive portions of the investigated area; the general productivity of the area, however, did not directly influence the frequency of occurrence of whales. We concluded that the complex dynamics of the balance between feeding activities and avoiding pressures may have led fin whales to use the region as an opportunistic feeding ground.

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al. 2012). Such an increase was not reported in other studies conducted in other regions of the Mediterranean basin (Gannier 2002, Aissi et al. 2008, Castellote et al. 2011); conversely, a decrease in fin whale was reported in the Pelagos Sanctuary (Panigada 2005; Lauriano 2008). In particular, Panigada et al. (2011) suggested a drop ("perhaps by a factor of six") in summer density and abundance in the Pelagos Sanctuary since the early 1990s. The two possible causes of this declining trend were suggested as (1) an absolute decline in the population of fin whales or (2) a change in their distribution, being mainly linked to anthropogenic factors (e.g. ship strike, vessel noise, the effect of contaminants and climate change).

Although several studies have been conducted on the fin whale population in the Mediterranean basin, little is known about its secondary or occasional feeding grounds and migration routes.

The availability of prey is one of the main factors determining the distribution, abundance and migration of cetaceans (Learmonth et al. 2006). Changes in the distribution of key prey species can result in changes in the geographical range and habitat preference of cetaceans (Evans 1971; Wells et al. 1990). This is especially true in the context of climate change, which is reported to have caused alterations in oceanographic parameters (IPCC 2007) in the past decade. These alterations have been linked to changes in cetacean range (MacLeod 2009), distribution and migration timing (Azzellino et al. 2008; Gambaiani et al. 2009; Simmons and Eliott 2009). Many anthropogenic factors are also known to influence the Mediterranean fin whale population (Reeves and Notarbartolo 2006) and could determine changes in the ecology of the species.

Sea Surface Temperature is a good predictor of chlorophyll (Irwin and Finkel 2008) and phytoplankton biomass (Volpe et al. 2012), especially in areas with wide seasonal fluctuation (Bouman et al. 2005). Chlorophyll is also widely treated as a good indicator of phytoplankton bloom, directly related to the consequent bloom of zooplankton, the main food source of baleen whale species. For this reason, chlorophyll, as a proxy of phytoplankton biomass, has often been correlated with the distribution of whales (Barale et al. 2002; Littaye et al. 2004; Laran. and Gannier 2008; Cotté et al. 2009; Hlista et al. 2009).

Our study aims to test the hypothesis that the higher occurrence of fin whales in the central Tyrrhenian Sea in recent years is related to the availability of food, suggesting that the region is no longer just a migration route but has now been used also as a summer feeding ground. Using the same fixed line transect, monitored with the same methodology of Marini et al. (1997), the study investigated the summer frequency of occurrence and distribution pattern of fin whales in the central Tyrrhenian Sea from 2007 to 2011. It compared the occurrence and distribution of whales with the pattern of Sea Surface Temperature (SST) and the density of chlorophyll-a (Chl), used as proxies for the availability of food.

There is a need for a deeper understanding of whale distribution and migration patterns in order to plan effective conservation measures, as required by legislation (e.g. the Habitat and Marine Strategy Framework Directives). Exploring the changes that have taken place over 20 years in the strategic ecological corridor of the central Tyrrhenian Sea, this study adds important information to enhance the understanding of whale migration patterns in this region of the western Mediterranean basin.

Materials and methods

Study area

The study area is located in the central Tyrrhenian Sea, just off the southeastern border of the Pelagos Sanctuary. The study area (Fig.1) is the area at sea between Civitavecchia (Central Italian peninsula) and Golfo Aranci (northern Sardinia) (40°N-42.5°N; 9°E-13°E) where data on SST and Chl concentrations were acquired. Inside the study area, cetacean surveys were conducted along the fixed line transect that runs from the port of Civitavecchia to the port of Golfo Aranci. This includes several habitats, among them shelf, shelf-edge, seamount and deep sea.

In the study area, sea currents are influenced by the Tyrrhenian cyclonic circulation and by the eastward jet-like force generated by the wind blowing from the Boniface Strait, especially in summer. This force determines important quasi-stationary gyres (Boniface gyre) which enhance the vertical component of motion in the sea (Astraldi e Gasparini 1994). This process determines a semistationary localized area of relative high productivity east of Bonifacio Strait (Barale et al. 2008). Further east of the Boniface gyres, another surface and intermediate cyclonic eddy is found along the coast of the Italian peninsula, while a small anticyclonic eddy is found between the two principal structures (Vetrano et al. 2010). The sea surface temperature is subject to typical seasonal variations. A trend of increasing temperature and salinity in the intermediate and deep layer has been documented in the region since the late 1980s (Gasparini et al. 2005) and this process has been speeding up since the late 1990s (Schroeder et al. 2006).

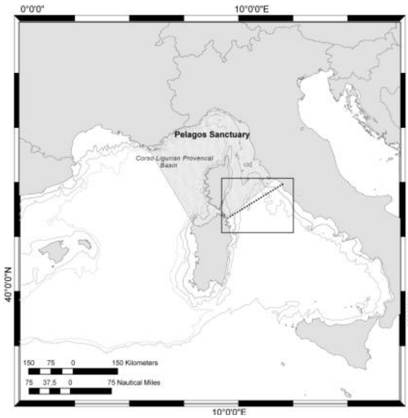

Fig. 1 Box indicates the Study Area with the transect inside (dotted line). The striped area shows the Pelagos Sanctuary with the Corso Ligurian Provencal Basin in the western part.

Sightings data

Observations were made using ferries as observation platforms along a fixed line transect of 220 km length in the central Tyrrhenian Sea (Civitavecchia, Central Italian peninsula-Golfo Aranci, northern Sardinia).

Fixed line transects are individual routes which are set in advance and which can be repeatedly surveyed, allowing populations to be estimated with narrower confidence intervals (Taylor et al. 2007). Fixed transects are particularly useful for studying temporal aspects of species biology and changes in status (e.g. changes in range, distribution, abundance, habitat use) (MacLeod et al. 2008). The method is also used to study the relationship between population parameters and anthropogenic factors (e.g. maritime traffic, Crosti et al.2011). Indeed, with fixed physiographic variables (i.e. depth, distance from coast, bathymetry, slope), fixed line transects allow better investigation of the relationship between changes in cetacean abundance and distribution, and changes in the environmental parameters such as SST and Chl.

From 2007 to 2011, the fixed transect in the central Tyrrhenian Sea was monitored twice a week during summer months (early June to end of September). Trained and expert observers were used in the study to avoid bias due to differences in sighting rate or species identification. At least two observers were positioned on the command deck, one on the port and one on the starboard side. They alternatively used the naked eye and binoculars to search for cetaceans in a 270° arc ahead of the vessel. Data were collected in passing mode (Wall 2006) and the ‘on effort’ period was considered only under good weather conditions (Beaufort ≤ 3). For each sighting, the GPS position, time, angle of the sighting, distance to the sighting, species, group size, presence of juveniles and general behavior was recorded.

Remote sensing data

Remote sensing data at a resolution of 4x4 km were used to establish the chlorophyll-a concentration (Chl) and the Sea Surface Temperature (SST), recorded both in the study area and at the positions where whales were sighted along the transect.

SST and Chl concentration data used in this study were acquired from the Moderate-resolution Imaging Spectroradiometer (MODIS) sensors aboard NASA satellites. These sensors were designed to provide a wide variety of information about land, oceanic and atmospheric conditions. MODIS L3 binned data and standard mapped images of Chl concentration and SST at a 4x4 km resolution were downloaded from: http://oceancolor.gsfc.nasa.gov. To avoid major source of error due to solar heating, only night-time values of SST were used in the study.

Daily, monthly and seasonal binned data for both parameters in the positions where whales were sighted were initially evaluated to assess which temporal range was more convenient for the study. Outcomes showed that daily data provide a more realistic value, but much information is missing or uncorrected due to sources of error in the radiometric determination and/or sensor failures (row cancelled effect, noise). At the same time, seasonal series are too smooth and it is not possible to evaluate the periodic variations which would clarify the fluctuation in the presence of cetaceans. Moreover, a preliminary evaluation found that daily and monthly series were highly correlated ($\rho = 0.82$). In addition, from a biological point of view, monthly data comprise the gap between phytoplankton bloom and the availability of main whales’ prey species (i.e. *Meganyctiphanes norvegica*, Orsi Relini and Giordano 1992) considered in the order of two weeks (Colella and Santoleri 2006). For these reasons the monthly values for each parameter (SST and Chl both in the study area and in the sighting positions) were used for the analyses.

Statistical analysis

Two levels of analysis were performed to investigate whether the presence of whales was related to the availability of food.

1) We investigated if more whales were sighted in the central Tyrrhenian sea transect when more food was available in the area. We used as an indicator the monthly and yearly relative abundance of whale in relation to the monthly and yearly absolute values of Chl (and SST).
2) We explored if, regardless of the number of whales detected, their distribution was related to the portions of the study area where the relative maximum availability of food was present. For this analysis we used as an indicator the pattern of whale sightings distribution in relation to the spatial distribution of Chl (and SST) values.

Frequency of occurrence and remote sensing data
Data acquired from each transect were considered to be the statistical unit. The Spearman rank correlation was calculated to verify the independency of sightings. The correlation between outbound and return transects was also compared with the autocorrelation of outbounds (and returns), assuming that the values of autocorrelation at the minimum time distance of a week were independent. The results of correlation and autocorrelation evidenced independency of the statistical units. An abundance index (Encounter Rate, ER) was assessed as frequency of whales sightings' occurrence calculated as sightings per unit of space travelled (ER = number of sightings x 10^{-1} km travelled on effort). Yearly (2008-2011) and monthly (June-September) differences in ER were compared with the non-parametric Kruskal-Wallis test. As a post-hoc test between each pair, the Mann-Whitney test, was performed. Pearson correlation was used to test the correlation among monthly ER and SST and Chl values.

Distribution and remote sensing data
Geographical data were analyzed by performing a spatial analysis with a GIS program (software ArcMAP 9.2). The Kernel smoother for point pattern analysis of occurrence-only data was used (Hengl 2009), after testing for independency of the dataset, to map higher density areas of species distribution (smoothing application = adaptive; smoothing factor = h_cv; volume level = 0.70).
Pearson correlation and scatter analysis were performed to test the linear relationship between SST and Chl data at the whale sighting positions.
To examine the relationship between the distribution of whales and chlorophyll availability, a first qualitative comparison was performed, overlapping Chl monthly images of the study area and the monthly distribution of sightings.
Range of values of Chl (and SST) differed monthly and from year to

year so that a quantitative comparison was not possible using the absolute values. For this reasons, a quantitative comparison was performed between the percentage distribution of monthly Chl and SST values detected in the study area and the distribution of values detected at the whale sighting positions. Chl and SST monthly values available in the study area were divided into classes and the same was done with parameter values extracted at the sighting positions. Percentages for each class were calculated and histograms of monthly percentage values of Chl and SST of the all study area were cross-referenced with the monthly percentage values of Chl and SST extracted in the position of sightings. Mean monthly deviation between highest frequencies in Chl concentration values detected at the sightings positions and Chl concentration detected in the study area was calculated as absolute value and as relative mean percentage variation of higher frequencies, as: [((Chl concentration in sightings positions–Chl in study area) · (Chl concentration in study area)$^{-1}$) ·100]. The same procedure was applied to the SST data.

Results

Relative abundance and remote sensing data

In this paper we used data gathered from 154 transects, resulting in a total of 613 cetacean sightings recorded over a total of 27935 km (Table 1). Of the six species identified, fin whale presented the most prevalent findings. It was the most sighted species (N= 233) during the last four years of the study and accounted for 38% of total sightings.

Table 1 Total effort and fin whale sightings along the transect Civitavecchia-G.Aranci from 2007 to 2011 during the summer season (start of June to the end of September)

Years	**Period**	**Tot. # of runs**	**Tot. # of hours on effort**	**Tot. # of km on effort**	**Tot. # of whale sightings**
2007	03/06-29/09	30	142.19	4476.76	24
2008	15/06-28/09	27	105.83	4517.88	40
2009	05/06-27/09	34	142.15	6897.46	72
2010	05/06-26/09	32	138.02	6364.61	48
2011	01/06-25/09	31	125.02	5678.60	49

The whale abundance index (ER) showed no significant difference among the five years (Kruskal-Wallis test, $H_4 = 6.90$, $P = 0.16$); the post-hoc test showed, however, a significant difference (Mann-Whitney test, $P<0.05$) between 2007 and 2009 (Fig. 2).

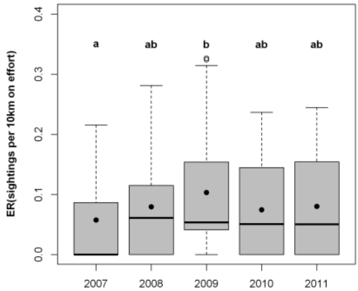

Fig. 2 Boxplots of yearly Encounter Rate = sightings of fin whale $x10^{-1}$ km travelled on effort in good weather condition (Beaufort≤3) ± SE. Black dot = mean. No significant difference among the five years (Kruskal-Wallis test, P = 0.16). Mean with different letters are significantly different (Mann-Whitney test, P < 0.05). a = ab ; b = b; a ≠ b.

Monthly ERs showed significant difference (Kruskal-Wallis test, H_3 = 11.07, $P<0.05$) among the four summer months with maximum values in June and August (the highest value of ER was recorded in August 2009) (Fig. 3).

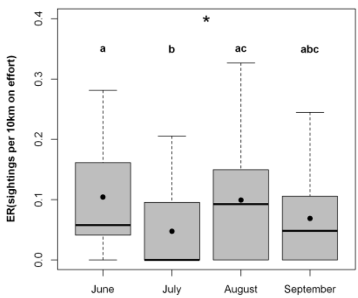

Fig. 3 Boxplots of monthly Encounter Rate = sightings of fin whale $x10^{-1}$ km travelled on effort in good weather condition (Beaufort≤3) ± SE. Black dot = mean. Asterisk (∗) = significant difference among the four

months (Kruskal-Wallis test, $P < 0.05$). Mean with different letters are significantly different (Mann-Whitney test, $P < 0.05$): a = ac = abc; b = abc; ac = abc; a ≠ b; b ≠ ac.

The monthly average of SST and Chl values in the study area from 2007 to 2011 (Fig. 4) showed an inverse trend of the two parameters. Monthly mean temperatures in the study area showed a maximum in August, except in 2010 when the maximum values were detected in July. Inversely, values of Chl showed minimum values in August except in July 2010.
No significant correlation was detected during the study period between monthly ER and Chl absolute values (Pearson correlation, $\rho = -0.029$, $P < 0.05$) or ER and SST values (Pearson correlation, $\rho = 0.047$, $P < 0.05$).

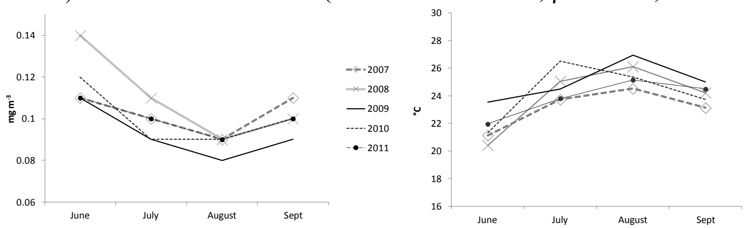

Fig. 4 Monthly mean values of Chlorophyll (Chl) on the left and Sea Surface Temperature (SST) on the right in the Study Area from 2007 to 2011derived from MODIS Aqua.

Distribution and remote sensing data

Whale distribution, processed with Kernel analysis (Fig. 5) showed that sightings are not uniformly distributed along the all transects, being concentrated in specific zones. A core area was located approximately 20 nautical miles northeast of the Sardinian coast. The size, as well as the level of fragmentation, of this core area varied among the years. In 2010, an additional area of high frequency sightings was detected closer to the coast of the central Italian peninsula.
Pearson correlations and scatter analysis of monthly distribution values of SST and Chl in the position where sightings occurred showed that SST was generally negatively correlated with chlorophyll (Pearson correlation, $\rho = -0.66$, $P < 0.05$).

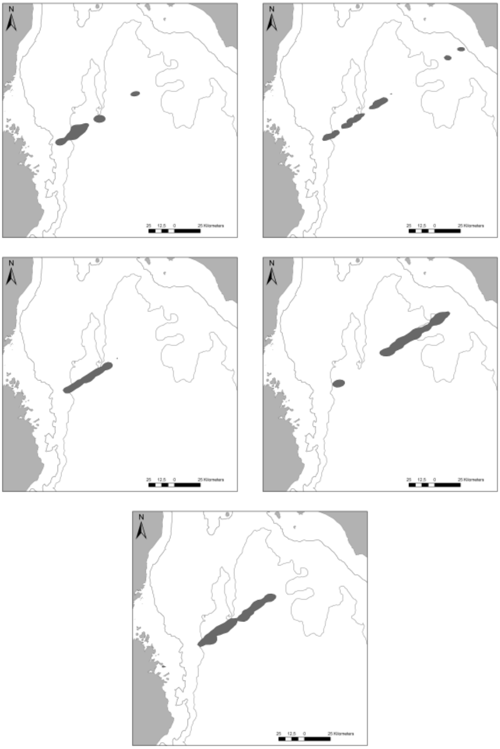

Fig. 5 Preferential areas of distribution for fin whale obtained through Kernel analysis from 2007 to 2011 (filled areas) (Kernel parameter: h_bcv2; volume level = 0.70). Bathymetric profiles of the depth (-200m and -1000m) in solid lines.

Fig. 6 illustrates qualitatively the distribution of sightings with respect to remote sensing Chl data (mg m^{-3}) in the study area. Chl images show a relatively high productivity area in the northeastern part of Sardinia, even with differences in terms of Chl concentration and extension. A general correspondence between higher values of Chl concentration and higher density of whale sightings is detected in the core area off the northeastern Sardinian coasts. By contrast, when the central Tyrrhenian Sea was poorer in primary production, the presence of the species was spread wider across the transect (i.e. June 2009). A broader distribution of whales over all transects can be associated both with low values of

Chl along the transect (i.e. June 2009) or to a wide distribution of Chl (June 2010).

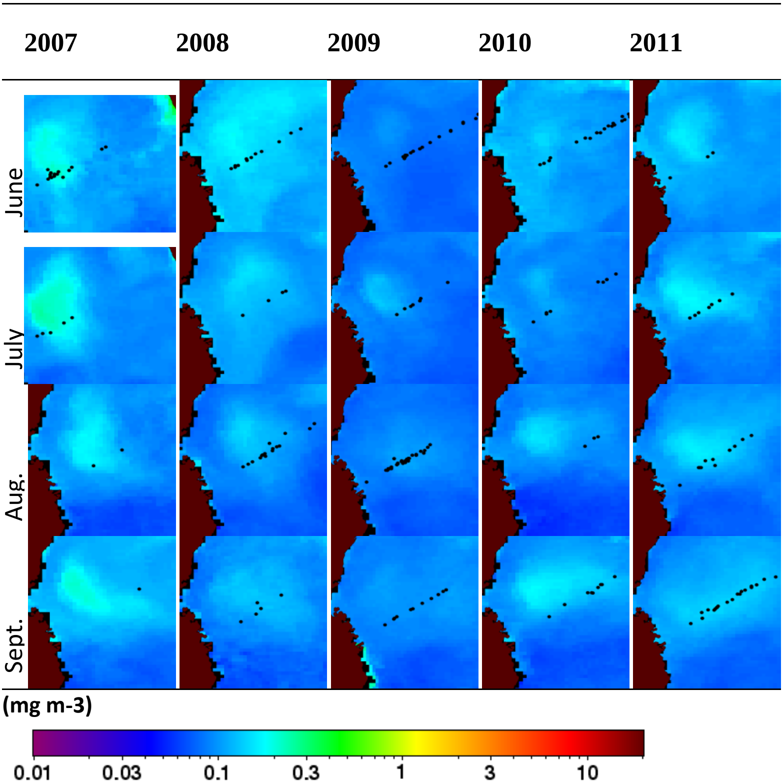

Fig. 6 The background images show the spatial representation of monthly mean Chlorophyll (Chl) concentration in mg m^{-3} (scale bar ranges from 0 to 3 mg m^{-3}) in the study area derived from MODIS Aqua. In foreground the distribution of monthly sightings (black dots) along the monitored transect.

Quantitative comparison across years and months between Chl and SST values detected in the study area and Chl and SST values detected in the sightings positions are shown by the histograms in Fig. 7 (displayed as example only 2010). Distribution of frequency values of Chl detected in the sighting positions are always in the right part of the distribution of frequency Chl values in the study area, indicating that whales were

mainly sighted in the portions of the study area with maximum relative values of Chl. Indeed, the mean monthly deviation between the highest frequencies in Chl values detected in the sighting positions and in the study area was +0.06 mgm^{-3}, which corresponds to an absolute deviation of +76%. The deviation was positive in 100% of cases, meaning that whales were always sighted in zones with highest relative values of Chl.
The position of fin whale sightings and their relations to SST revealed a preference for colder waters (Fig.7). Mean monthly deviation between highest frequencies in the SST detected in the sighting positions and in all study areas was -1.03°C, which corresponds to -4% as absolute deviation. The deviation was negative or nil in 100% of cases. These results are in line with the negative correlation between SST and Chl monthly distribution values.

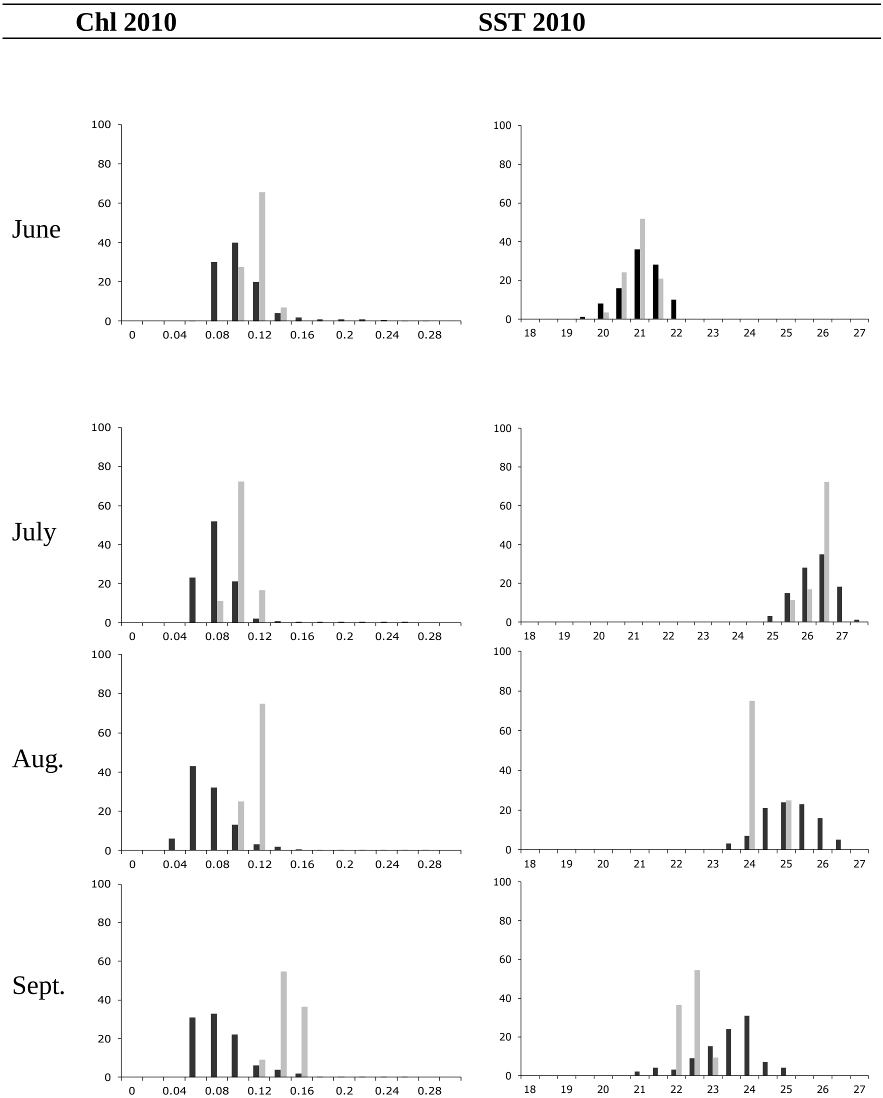

Fig. 7 Percentage frequency distribution of monthly Chlorophyll (Chl) (left) and Sea Surface Temperature (SST) (right) values detected in the study area (black) and at the whale sighting positions (grey) in 2010.

Discussion and conclusions

During the five years of the study (2007-2011) the fin whale was one of the most frequent cetacean species detected in the central Tyrrhenian Sea during the summer season. Comparing results with a previous study in the 1990s, along the same transect monitored with the same methodology, the species was three times more frequent in the latter period. Moreover, the temporal distribution and habitat preference showed a radical difference between the two periods, suggesting a change in the habitat use (Arcangeli et al. 2012). Using SST and Chl data derived from remote sensing as proxy of food availability, the outcome of our study shows that, during the 2007-2011 period, trophic preference drove whales' distribution in the central Tyrrhenian Sea.

The relationship between the distribution of sightings and SST and chlorophyll was evident throughout the study period. The whales concentrated in zones with lower SST and relatively higher Chl values. The same correlation was found even in 2010, when the maximum values of Chl were seen in July instead of August, and spread more to the east in the study area.

During the five years of the study, the range of Chl mean values in the all study area was in line with the general 'oligotrophic' condition typical of the Mediterranean Sea in summer season (Barale et al. 2008), with highest frequencies of Chl mean values in the order of 0.08-0.01 mg m^{-3}. However, summer composite SST and Chl images from 2007 to 2011 confirmed the presence of a colder and relatively high productivity area off the north-eastern coast of Sardinia, in coincidence with the Bonifacio gyre. The productivity of this area is due to the favorable oceanographic conditions driven by the encounter of the Tyrrhenian cyclonic stream with the current forced by the prevailing north-westerly wind from the Boniface Strait that enhances the vertical component of motion in the sea (Astraldi and Gasparini 1994*).* Fin whales always aggregated in the zones where the relative maximum of Chl and minimum of SST were detected. Indeed, the highest percentage of whale sightings occurred in the small portions of the study area with higher relative values of Chl, with a percentage variation of +76% in respect to the Chl values registered in the largest portion of the study area. Similar and inverse was the distribution of higher frequencies of SST values: lowest values of SST were found in the sighting positions with mean monthly variations in respect to the SST values registered in the largest portion of the study area of -1.3°C (-4%).

Results of this study showed that fin whale distribution in the 2007-2011 period was mainly driven by feeding purposes, in line with the hypothesis that the area is being recently used as a feeding ground. This is also supported by direct reports of whales feeding in the area in 2010 (Magnone et al. 2011). The findings suggest a marked change in the use of the area from the early 1990s, when the area was primarily used as a transit zone (Marini et al. 1997).

The decreasing abundance of fin whale recorded during the last 15 years in the Pelagos Sanctuary during summer (Panigada 2005; Lauriano 2008; Panigada et al. 2011) was attributed by Panigada et al. (2011) to various possible causes, such as the increasing impact of vessel traffic or the indirect effects of pollution, climate change or synergistic effects of some or all of these factors. Some of these causes may have led to a decline in the population or, on the other hand, to a shift in the summer distribution of fin whale. Our results support the hypothesis that, in recent years, more fin whales have been spending more time in the central Tyrrhenian Sea for feeding purposes instead of just moving through this area as in the early 1990s. Consequently, a partial shift in the summer distribution of whales seems a likelier scenario.

Many factors can influence fin whale distribution. The long-term effects of various pressures (e.g., vessel traffic, military exercises, seismic surveys and so on) may have forced the species to avoid more affected areas. Crosti et al. (2011) for example recorded the negative effect of maritime traffic in deep-sea waters on cetaceans and showed that when sightings occurred traffic was significantly lower. Moreover, there has been a trend of increasing temperature and salinity in the deep and intermediate level in the central Tyrrhenian Sea during the last few decades (Gasparini et al. 2005; Schroeder et al. 2006) and changes have been recorded over the Mediterranean basin (e.g. Barale et al. in 2008 reported a decreasing trend of Chl indicator of about 20% for the entire Mediterranean basin between 1998 to 2003). Changing oceanographic factors may also play a role in determining the availability of prey or the timing of migrations.

As a further element, our study showed that monthly and inter-annual variability in frequency of occurrence of whales in the study area was not directly related to the Chl or SST values. In some cases, higher encounter rates of fin whale were recorded during the months when the mean values of Chl in the area were lower (i.e. August 2009).

A summer inter-annual variability in the distribution of fin whales was also reported in the Pelagos Sanctuary (Gannier 2002; Panigada et al. 2005; Monestiez et al. 2006) and was predicted over the northwestern Mediterranean basin (Laran and Gannier 2008). A very high year-to-year variation in potential feeding habitat size and locations (40% to 50%)

from 2000 to 2010 was also shown by a habitat model for fin whale across the entire Mediterranean basin (Druon et al. 2012). Moreover, the size of blooming area in the north-western Mediterranean basin is known to be subject to inter-annual variability (Barale et al. 2008), as well as the productivity of the overall Mediterranean basin.

Cotté (2009) suggested two possible scale-dependent foraging strategies of fin whale in summer: animals can exhibit a large-scale site fidelity for the persistent area of krill habitat (i.e. the Corso Ligurian Provencal area) while, at the mesoscale, they can search for the most concentrated, relatively small, food areas, characterized by high dynamism in terms of oceanographic processes. The relatively high productive area eastern of Bonifacio Strait in the central Tyrrhenian Sea can be considered at this latest scale and different opportunistic feeding strategies can drive a year-to-year variability in the summer presence of whales.

In conclusion, the spatial distribution of whales seems to be a dynamic and complex system affected by many factors. Results of the study show that, from 2007 to 2011, Chl and SST, considered as proxies of food availability, directly determined whale distribution in our study area in the central Tyrrhenian Sea (Figs. 6 and 7), although they did not directly influence the yearly and monthly frequency of occurrence of fin whales in the study area (Figs. 2, 3, 4). Our findings suggest that the central Tyrrhenian Sea is now used as an opportunistic summer feeding ground so that, in general, more whales are detected in the area during the entire summer season compared to the early 1990s.

Whales may be apportioning their distribution opportunistically at a Mediterranean basin scale, based on a combination of where food is found and where anthropogenic pressures are less likely to affect the whales' activity. Regular, consistent, long-term and large-scale monitoring programs are surely the needed bases to better understand the effect of environmental and anthropogenic factors and to support effective and adaptive measures for the conservation of the species.

References

Aissi M., Celona A., Comparetto G., Mangano R., Wurtz M., Moulin A. (2008) Large-scale seasonal distribution of fin whales (*Balaenoptera physalus*) in the central Mediterranean Sea. J Mar Biol Assoc UK 88 (6);1253-1261.

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. Eur Res Cetaceans 22:5pp.

Arcangeli A , Marini L, Crosti R (2012) Changes in cetacean presence, relative abundance and distribution over 20 years along a trans-regional fixed line transect in the central Tyrrhenian Sea. Mar EcolDOI:10.1111/maec.12006.

Astraldi M, Gasparini GP (1994)The Seasonal Characteristics of the Circulation in the Tyrrhenian Sea. In Seasonal and interannual variability of the Western Mediterranean Sea. Coastal Estuarine Stud 46:115-134.

Azzellino A, Gaspari SA, Airoldi S, Lanfredi C (2008) Biological consequences of global warming: does sea surface temperature affect cetacean distribution in the western LigurianSea? J Mar Biol Assoc UK88(6):1145–1152.

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 Sens Environ 112:3300–3313.

Barale V, Panigada S, Zanardelli M (2002) Habitat preferences of fin whales (*Balaenoptera physalus*) in the northwestern Mediterranean Sea: a comparison between in situ and remote sensing data. 7th International Conference on Remote Sensing for Marine and Coastal Environments, Miami, Florida, 20-22 May 2002.

Bérubé M, Aguilar A, Dendanto D, Larsen F, Notarbartolo di Sciara G, Sears R, Sigurjonsson J. (1998) Population genetic structure of North Atlantic, Mediterranean Sea and Sea of Cortez fin whales, *Balaenoptera physalus* (Linnaeus 1758): analysis of mitochondrial and nuclear loci. Mol Ecol 7:585–599.

Bouman H, Platt T, Sathyendranath S, Stuart V (2005) Dependence of light-satured photosynthesis on temperature and community structure. Deep-Sea Res I 52:1284-1299.

Castellote M., Clark CW, Lammers MO (2011) Fin whale (*Balaenoptera physalus*) population identity in the western Mediterranean Sea. Mar Mam Sci 28(2):325-344.

Colella S, Santoleri R (2006) Variabilità interannuale della produzione primaria nel Mar Mediterraneo: 8 anni di osservazioni SeaWiFS. Clima e cambiamenti climatici: le attività del CNR, 525-528.

Cotté C, Guinet C, Taupier-Letage I, Mate B, Petiau E (2009) Scale-dependent habitat use by a large free-ranging predator, the Mediterranean fin whale. Deep-Sea Res I 56:801–811.

Crosti R, Arcangeli A, Moulins A, Tepsich P, Tringali M (2011) Cetacean and maritime traffic in deep sea waters. A relation to avoid? Biol. Mar. Mediterr 18(1):178-179.

Druon JN, Panigada S, David L, Gannier A, Mayol P, Arcangeli A, Cañadas A, Di Méglio N, Gauffier P.(2012) Potential feeding habitat of fin whale in the Western Mediterranean Sea. Mar Ecol Prog Ser 464:289–306.

Evans WE (1971) Orientation behavior of delphinids: radio telemetric studies. Ann NY Acad Sci 188:142–160.

Forcada J, Notarbartolo di Sciara G, Fabbri F (1995)Abundance of fin whales and striped dolphins summering in the Corso-Ligurian Basin. Mammalia 59:127–140.

Gambaiani DD, Mayol P, Isaac SJ, Simmonds MP (2009) Potential impacts of climate change and greenhouse gas emissions on Mediterranean marine ecosystems and cetaceans. J Mar Biol Assoc UK 89(1):179–201.

Gannier A (2002) Summer distribution of fin whales (*Balaenoptera physalus*) in the northwestern Mediterranean Marine Mammals Sanctuary. Rev Ecol - Terre Vie 57:135–150.

Gasparini GP, 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 Res 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.

Hengl T (2009) A Practical Guide to Geostatistical Mapping. 2009 Tomislav Hengl.

Hlista BL, Sosik HM, Martin Traykovski1 LV, Kenney RD, Moore MJ (2009) Seasonal and interannual correlations between right-whale distribution and calving success and chlorophyll concentrations in the Gulf of Maine, USA. Mar Ecol Prog Ser 394:289–302.

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

Irwin AJ, Finkel ZV (2008) Mining a Sea of Data: Deducing the Environmental Controls of Ocean Chlorophyll. PLoS ONE 3(11): e3836. doi:10.1371/journal.pone.0003836.

Laran S, Gannier A (2008) Spatial and temporal prediction of fin whale distribution in the northwestern Mediterranean Sea. – ICES J Mar Sci 65:1260–1269.
Lauriano G (2008) Censimento cetacei nel Santuario Pelagos Greenpeace Italia e ISPRA (ex ICRAM). Relazione finale. ISPRA.
Learmonth JA, Macleod CD, Santos MB, Pierce GJ, Crick HQP, Robinson RA (2006) Potential effects of climate change on marine mammals. Oceanogr Mar Biol: Annu Rev 44: 431–464.
Littaye A, Gannier A, Laran S, Wilson JPF (2004) The relationship between summer aggregation of fin whales and satellite-derived environmental conditions in the northwestern Mediterranean Sea. Remote Sens Environ 90:44–52.
MacLeod CD (2009) Global climate change, range changes and potential implications for the conservation of marine cetaceans: a review and synthesis. Endang Species Res 7:125–136.
MacLeod CD, Brereton T, Martin C (2008) Changes in the occurrence of common dolphins, striped dolphins and harbour porpoises in the English Channel and Bay of Biscay. J Mar Biol Assoc UK 89(5):1059–1065.
Magnone F, Trainito E, Picollo V, De Lazzari A, Fozzi A, Napolitano E, Vitale S (2011) Observation of the feeding behaviour of fin whales (*Balaenoptera physalus*) along the northeastern coast of Sardinia, Mediterranean Sea. Biol. Mar. Mediterr 18(1):186-187.
Marini L, Consiglio C, Angradi AM, Catalano B, Sanna A, Valentini T, Finoia MG, Villetti G (1997) Distribution, abundance and seasonality of cetaceans sighted during scheduled ferry crossings in the central Tyrrhenian Sea: 1989-1992. Ital J Zool 63:381-388.
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
Monestiez P, Dubroca L, Bonnin E, Durbec JP, Guinet C (2006) Geostatistical modelling of spatial distribution of *Balaenoptera physalus* in the Northwestern Mediterranean Sea from sparse count data and heterogeneous observation efforts. Ecol Model 193:615–628.
Nascetti D, Notarbartolo di Sciara G (1996) A fin whale and sperm whale sighting programme undertaken by the Italian Navy in the Central Mediterranean Sea. Eur Res Cet 10:150-153.
Notarbartolo di Sciara G, Agardy T, Hyrenbach D, Scovazzi T, Van Klaveren P (2008) The Pelagos Sanctuary for Mediterranean marine mammals. Aquatic Conserv: Mar Freshwat Ecosyst 18:367–391.

Notarbartolo di Sciara G, Zanardelli M, Jahoda M, Panigada S, Airoldi S (2003) The fin whale *Balaenoptera physalus* (L. 1758) in the Mediterranean Sea. Mamm Rev 33:105-150.

Orsi Relini L, Giordano A (1992) Summer feeding of the fin whale, *Balaenoptera physalus*, in the Liguro–Provenc¸al basin. Eur Res Cet 6:138–141.

Panigada S, Lauriano G, Burt L, Pierantonio N, Donovan G (2011) Monitoring winter and summer abundance of cetaceans in the Pelagos Sanctuary (Northwestern Mediterranean Sea) through aerial surveys. PLoS ONE 6(7): e22878. Doi: 10.1371/journal.pone.0022878.

Panigada S, Notarbartolo di Sciara G, Zanardelli Panigada M, Airoldi S, Borsani JF, Jahoda M (2005) Fin whales (*Balaenoptera physalus*) summering in the Ligurian Sea: distribution, encounter rate, mean group size and relation to physiographic variables. J. Cetacean Res. Manage 7(2):137–145.

Reeves R, Notarbartolo di Sciara G (compilers and editors) (2006) The status and distribution of cetaceans in the Black Sea and Mediterranean Sea. IUCN Centre for Mediterranean Cooperation, Malaga, Spain. 137 pp.

Schroder K, Gasparini GP, Tangherlini M, Astraldi M (2006) Deep and intermediate water in the western Mediterranean under the influence of the Eastern Mediterranean Transient. Geophys Res Lett 33:L21607, doi: 10.1029/2006GL027121.

Simmonds MP, Eliott WJ (2009) Climate change and cetaceans: concern and recent developments. J Mar Biol Assoc UK 89(1):203–210.

Taylor BL, Martinez M, Gerrodette T, Barlow J (2007) Lessons from monitoring trendsin abundance of marine mammals. Mar Mamm Sci 23(1):157–175.

UNEP-MAP-RAC/SPA (2010a). Identification of potential sites in open seas including the deep sea that may satisfy SPAMI criteria. T. Ed. RAC/SPA, Tunis: 24pp.

UNEP-MAP-RAC/SPA (2010b). Overview of scientific findings and criteria relevant to identifying SPAMIs in the Mediterranean open seas, including the deep sea. By Notarbartolo di Sciara, G. and Agardy, T. Ed. RAC/SPA, Tunis: 71pp.

Vetrano A, Napolitano E, Iacono R, Schroeder K, Gasparini GP (2010) Tyrrhenian Sea circulation and water mass fluxes in spring 2004: Observations and model results. J geophys res 115, C06023, doi:10.1029/2009JC005680.

Volpe G, Nardelli BB, Cipollini P, Santoleri R, Robinson IS (2012) Seasonal to interannual phytoplankton response to physical processes in the Mediterranean Sea from satellite observations. Remote Sens Environ 117:223-235Wall D, O’Brien J, Meade J, Allen BM (2006) Summer distribution and relative abundance of cetaceans off the west coast of Ireland. Biology and environment: proceedings of the Royal Irish Academy 106B(2):135 142.

Wells RS, Hansen LJ, Baldridge A, Dohl TP, Kelly DL, Defran RH (1990) Northward extension of the range of bottlenose dolphins along the California coast. In Leatherwood S and Reeves RR (eds) The bottlenose dolphin. San Diego: Academic Press, pp. 421–431.

Arcangeli A., Campana I., Carcassi S., Casella E., Cracas F., Fabiano F., Ottaviani D., Manca Zeinchen M., Addis A., Crosti R. (2013). Seasonal sighting of *Balaenoptera physalus* the Bonifacio Strait (Santuario PELAGOS). Biol. Mar. Mediterr. 20 (1): 252-253.

Biol. Mar. Mediterr. (2013), 20 (1): 252-253

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AVVISTAMENTI STAGIONALI DI *BALAENOPTERA PHYSALUS* NELLE BOCCHE DI BONIFACIO (SANTUARIO PELAGOS)

SEASONAL SIGHTINGS OF BALAENOPTERA PHYSALUS *IN THE BONIFACIO STRAIT (PELAGOS SANCTUARY)*

***Abstract** - A cetacean systematic monitoring programme crossing the Bonifacio Strait started in June 2012. Surveys are conducted regularly 2/4 time a month yearly round using ferry as platform of observation. Fin whales (*Balaenoptera physalus*) were detected each month, with differences on sighting distribution across seasons. Preliminary results showed that encounter rate is higher in winter (0.203 sigthing/km) compared to summer (0.039 sigthings/km) with most of the sightings distributed inside the area of the Strait.*

***Key-words:** fin whale, distribution, Bonifacio Strait, Pelagos Sanctuary, wintering ground.*

Introduzione - L'area delle Bocche di Bonifacio è stata individuata come importante area ecologica, per la cui protezione è stato istituito il Parco marino Internazionale delle Bocche di Bonifacio. L'area è inclusa nel Santuario Internazionale Pelagos per la protezione dei cetacei e comprende parte del Parco Nazionale della Maddalena. Nel 2011, per mitigare l'effetto del traffico marittimo internazionale, è stata istituita nell'area una PSSA (IMO-Area Marittima Particolarmente Sensibile). Nonostante le basse profondità, alcune precedenti segnalazioni, incluso un monitoraggio lungo il transetto S. Teresa di Gallura-Bonifacio nelle estati 2011/2012, indicano la presenza nell'area di *Balaenoptera physalus*. Pertanto, da giugno 2012 è stato attivato un monitoraggio sistematico dell'area. I primi risultati sono riportati nel presente studio.

Materiali e metodi - Da 2 a 4 rilevamenti sistematici vengono condotti mensilmente lungo l'asse Est-Ovest che attraversa le Bocche di Bonifacio nel corso di tutto l'anno. In particolare, l'area analizzata nel presente studio è il tratto di mare fra Corsica e Sardegna e le aree immediatamente adiacenti, ad est e ad ovest dello stretto, rispettivamente in Tirreno centrale e Mar di Sardegna (Fig. 1). Le osservazioni sono condotte da avvistatori esperti dalle alette laterali del ponte di comando di traghetti di linea in condizioni omogenee di velocità e altezza del punto di osservazione. L'attività di rilevamento viene effettuata secondo un protocollo standard (Protocollo ISPRA, ISPRA, 2012) e solo in condizioni meteo favorevoli (Beaufort≤3); durante gli avvistamenti vengono registrati tutti i dati relativi alle specie, compresa distanza e angolo di avvistamento, ed i dati ambientali.

Risultati - Da giugno 2012 sono stati compiuti 42 rilevamenti di cui 24 in primavera/estate (giugno-settembre), 8 in autunno (ottobre-dicembre) e 10 in inverno (gennaio-marzo). Nell'area di studio sono stati percorsi un totale di 4.398 km in osservazione ed effettuati 49 avvistamenti di *B. physalus*. La balenottera è stata avvistata nell'arco di tutti i mesi di studio con differenze nella frequenza e distribuzione degli avvistamenti. Il tasso d'incontro (ER=avvistamenti*10 km^{-1} *on*

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Introduction
The area of the Strait of Bonifacio has been identified as an important ecological area, for whose protection was established the International Marine Park of the Strait of Bonifacio. The area is included in the International Pelagos Sanctuary for the protection of cetaceans and includes part of the National Park of La Maddalena. In 2011, to mitigate the effect of international maritime traffic, a PSSA (Particularly Sensitive Sea Area - IMO) was established for the area. Despite the low depth, some previous surveys, including a monitoring along the transect S. Teresa di Gallura-Bonifacio in the summers 2011/2012, recorded the presence of *Balaenoptera physalus* in the area. Therefore, in June 2012 was launched a systematic monitoring of the area. The first results are reported in this study.

Materials and Methods
From 2 to 4 systematic surveys were conducted each month along the east-west axis that crosses the Strait of Bonifacio throughout the year. In particular, the area analyzed in the present study is the part of sea between Corsica and Sardinia and the areas immediately adjacent to the east and to the west of the Strait, respectively, in the Central Tyrrhenian and Sardinian Sea (Fig. 1). The observations were conducted by expert observers from the side wings of the bridge of the ferry lines with comparable speed and height of the observation point. Monitoring activities were conducted according to a standard protocol (Protocol ISPRA, 2012) and only in favorable weather conditions (Beaufort ≤ 3) during the sightings were recorded all the data on the species, including the sight distance and angle, and environmental data.

Results
From June 2012 were undertaken 42 survey runs of which 24 in the spring/summer (June to September), 8 in the fall (October-December)

and 10 in the winter (January- March). In the study area were conducted a total of 4,398 km on effort and made 49 sightings of *B. physalus*. The whales were spotted in all the months of the study period with differences in the frequency and distribution of the sightings. The recorded encounter rate (ER= sightings*10 km-1 on effort) was highest in winter (0.232), followed by autumn (0.109) and spring/summer (0.063). The distribution of sightings over the seasons (Fig. 1) shows the presence of the species in spring/summer in the most western part of the Sardinian sea, at bathymetric > 2000 m. In winter, the distribution of sightings is rather prevalent in the inner area of Bonifacio on bathymetric <200 m. In autumn, the distribution appears to be intermediate between the previous two extremes. It has been estimated a minimum number of 13 animals in the area inside the Strait of Bonifacio on the basis of the maximum number of animals recorded along a single survey (13/03/2013) so to exclude the possibility of a recount of the same animal

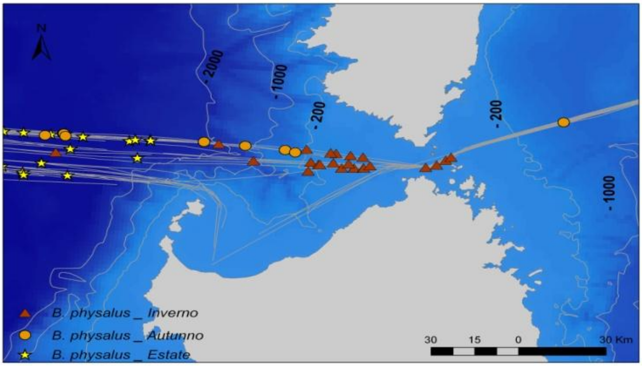

Fig. 1 The study area; in grey the track on effort with the sighting points; yellow stars spring/summer, orange circles autumn, red triangles winter.

Conclusion

The first results of this study showed the importance of the Strait of Bonifacio for *B. physalus*. Particularly important is the indication from the presence of the species inside the Strait in the winter, since it allows to hypothesize a possible use of the area as a wintering ground. Continuing this systematic study in the coming years, extended also to neighboring areas such as the Central Tyrrhenian and the Sardinian and the Balearic Islands seas, will allow to have more useful data in order to validate the information that emerged from this study. If confirmed, the results of the study could have important implications for the conservation and the needed measures for the protection of the species.

Bibliografia

ISPRA 2012. Fixed line transect using ferries as platform of observation monitoring protocol. Allegato tecnico della convenzione quadro per lo svolgimento di attivita' di '*Fixed line transect using ferries as platform of observation for monitoring cetacean populations'*

CH. 3 Presence of *Ziphius cavirostris* in central Tyrrhenian Sea

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ORIGINAL ARTICLE

Long-term presence and habitat use of Cuvier's beaked whale (*Ziphius cavirostris*) in the Central Tyrrhenian Sea

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Conservation; habitat suitability; long-term; Mediterranean Sea; site fidelity; Ziphius cavirostris.

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Abstract

Cuvier's beaked whale (*Ziphius cavirostris*, G. Cuvier 1823) is a poorly known species and many international agreements have asked for a better understanding of its biology for conservation purposes. In the present study, systematic cetacean surveys were carried out from ferries along a trans-regional fixed transect in the Central Tyrrhenian Sea (Civitavecchia, Latium – Golfo Aranci, Sardinia), just outside the southeastern border of the Pelagos Sanctuary. This research provided long-term, consistent data on Cuvier's beaked whale during two research periods (1990–1992 and 2007–2011). The objective of the research was to compare the presence, distribution and habitat use of Cuvier's beaked whale between the two investigated periods. Summer data (June–September) from the two periods were compared in terms of frequency of sightings, group size and spatial distribution related to the main ecogeographical features. A presence-absence model (generalized additive modelling) was performed to predict habitat suitability in the two study periods. The results highlight long-term site fidelity of Cuvier's beaked whale in the Central Tyrrhenian Sea with encounter rates comparable to the ones reported for other key areas. Separate suitability models based on 1990s and 2000s data appeared to work for each individual time period but differences were evident between the two periods, indicating changes in habitat selection over time. Our findings of the study appear to expand the definition of suitable beaked whale habitat and underline how the temporal scale of the analysis can affect the results in habitat studies. Moreover, this research highlights the importance of the Central Tyrrhenian Sea marine region for Cuvier's beaked whale and the ability of continuous monitoring to identify changes in cetacean frequency and distribution, necessary for adaptive conservation management approaches.

Introduction

The Mediterranean Sea hosts one regular ziphiid species, the Cuvier's beaked whale (*Ziphius cavirostris*, G. Cuvier 1823) (Notarbartolo di Sciara & Birkun 2010), the most cosmopolitan of all of the beaked whale species (MacLeod *et al.* 2006; Allen *et al.* 2012). Globally, the species is listed as Least Concern by IUCN (Taylor *et al.* 2008), although the Mediterranean sub-population is listed as Data Deficient (Cañadas 2012). Beaked whales are difficult to detect and identify at sea mainly because of their elusive behaviour (Barlow *et al.* 2006); thus, they are poorly known and most information comes from stranding data (Podestà *et al.* 2006; Holcer *et al.* 2007; Öztürk *et al.* 2011). Mass stranding events have been related to navy sonar and seismic exploration (*e.g.* Frantzis 1998,

Summary
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thus, they are poorly known and most information comes from stranding data (Podestà *et al.* 2006; Holcer *et al.* 2007; Öztürk *et al.* 2011). Mass stranding events have been related to navy sonar and seismic exploration (*e.g.* Frantzis 1998, 2004; Tyack *et al.* 2006, 2011; Filadelfo *et al.* 2009), which are considered major threats to Cuvier's beaked whale in the Mediterranean basin (Cañadas 2012). Other potential threats are the occasional risk of entanglement in gillnets (Reeves *et al.* 2013), ingestion of plastic debris (Allen *et al.* 2012; Cañadas 2012), ship noise (Aguilar Soto *et al.* 2006) and contamination by heavy metals (Storelli *et al.* 1999; Frodello *et al.* 2002). Several field campaigns in the Mediterranean have investigated some aspects of the ecology, distribution and habitat use of free-ranging individuals (Cañadas *et al.* 2002; Moulins *et al.* 2007; Rosso *et al.* 2007; Azzellino *et al.* 2008; Gannier & Epinat 2008; Tepsich *et al.* 2014) and an initiative for modelling high-use areas for Cuvier's beaked whale was undertaken under the Agreement on the Conservation of Cetaceans in the Black Sea, Mediterranean Sea and Contiguous Atlantic Area (ACCOBAMS) Ziphius initiative (Cañadas *et al.* 2011). Nevertheless, more information is needed and many documents under the ACCOBAMS agreement, as well as other EU Directives and national legislation, ask for a better understanding of the biology of this species for conservation purposes. According to the literature, the species is distributed in several key areas (Cañadas 2012), especially over and around canyons in the Eastern Ligurian Sea, the Alboran Sea and off Southwestern Crete. The same areas, based on evidence of threats and potential impact on the species, have also been recognized as important areas for conservation (MacLeod & Mitchell 2006). Other areas of distribution were recently recognized by analysing data on strandings in the Southern Adriatic Sea (Holcer *et al.* 2007) and in Israeli and Palestinian waters (Podestà *et al.* 2006; Kerem *et al.* 2012). Furthermore, based on regional scale (Marini *et al.* 1992; Gannier & Epinat 2008) and large-scale studies, Gannier (2011) confirmed the importance of the Central Tyrrhenian Sea as a favourable habitat for the Cuvier's beaked whale, in addition to the key areas listed by MacLeod & Mitchell (2006).

In the early 1990s, the first monitoring project on cetaceans took place in the Central Tyrrhenian Sea (Marini *et al.* 1996) along a fixed line transect (FLT) using the ferries running between

Civitavecchia (Latium, Italy) and Golfo Aranci (Sardinia, Italy) as research platforms. In 2007 the research restarted along this FLT with the same protocol. Testing for the presence of cetaceans along the same transect over a 20-year time span, Arcangeli *et al.* (2013b) showed the regular occurrence of Cuvier's beaked whales in the area.

Different studies have reported changes in oceanographic parameters in the Mediterranean Sea over the last 20 years (Fuda *et al.* 2002; Rixen *et al.* 2005; Schröder *et al.* 2006, 2010), influencing food availability and resulting in potential changes of cetacean ranges and distributions (Gambaiani *et al.* 2009; MacLeod 2009). For *Balenoptera physalus* as an example, the FLT continuous monitoring in the Central Tyrrhenian Sea during 1990– 1992 and 2007–2011 revealed a long-term change in habitat use and a direct correlation of inter-annual and intra-annual variability in chlorophyll concentration with the change in distribution of the species to be shown (Arcangeli *et al.* 2014). Comparison of the habitat selection of Cuvier's beaked whales over such a long period in an area characterized by complex bathymetry such as the Central Tyrrhenian Sea could enhance knowledge of the relationships between Cuvier's beaked whales' presence and habitat features, adding information on the definition of the species' favourable areas.

In this paper, we discuss Cuvier's beaked whale distribution in the Central Tyrrhenian Sea in relation to different environmental features that are known to have important influences on the biological processes of this species. Using data from the two research periods (1990– 1992 and 2007–2011), the objectives of the study were to describe the habitat preferences of Cuvier's beaked whale over a long time period and obtain information that will be useful for driving further action on the conservation of this species (Hooker *et al.* 1999; Cañadas *et al.* 2002; Azzellino *et al.* 2008).

Material and Methods

Study area

Systematic surveys were conducted along a trans-regional fixed line transect in the Central Tyrrhenian Sea between Civitavecchia (Latium, Central Italian peninsula) and Golfo Aranci (Sardinia): the transect is about 220 km long and crosses several habitat types, such as continental shelf, slope, offshore waters with canyons, abyssal plain and sea mountains (Fig. 1). The 200-m isobaths run almost parallel along the coastlines of both Latium and Sardinia: the continental shelf is quite extended along the eastern side of the basin, with a ridge coming out from the wide shelf of Tuscany and crossing the study area southward. Along Sardinia the shelf is reduced and the water depth reaches 1000 m at about 15 km away from the coastline. The abyssal plain is found at around – 1500 m depth and volcanic seamounts rise up to 600/ 800 m. Steep slopes are also present, defining a complex bottom topography.

Deep waters rich in nutrients reach the study area from the Eastern Mediterranean Sea and the Ligurian Sea, flowing towards the Gibraltar Strait. Surface circulation is instead influenced by the Atlantic current coming into the Tyrrhenian Sea from the south, generating a cyclonic gyre off the Sardinian coast; this is also maintained by the year-round jet wind blowing eastward from the Strait of Bonifacio, which enhances the vertical mixing of the water masses, inducing divergence and important upwelling/downwelling phenomena (Astraldi & Gasparini 1994). Summer upwelling was also described along the coast of Latium by Marullo *et al.* (1994) because of water stratification. A trend of increasing temperature and salinity in the intermediate and deep layer has been documented in the region since the late 1980s (Gasparini *et al.* 2005) and this process has been speeding up since the late 1990s (Schröder *et al.* 2006).

From a conservation point of view, the Central Tyrrhenian Sea was recently recognized 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). In spite of its importance for conservation, this region falls just outside the southeastern boundary of the Pelagos Sanctuary and is exposed to heavy threats for cetaceans, such as high nautical traffic pressure, which increases in summer months (Vaes & Druon 2013), active navy sonar and seismic exploration (Cañadas 2012).

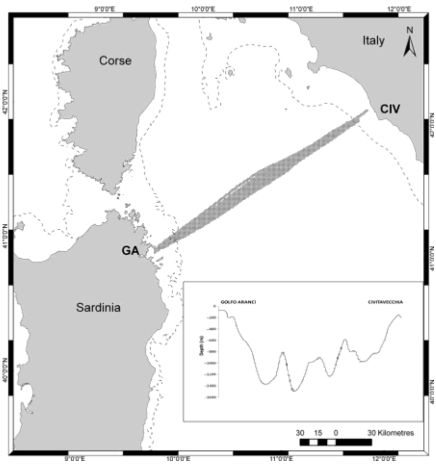

Fig. 1. Study area. In grey the area of the surveyed transects between Civitavecchia (CIV, central Italian peninsula) and Golfo Aranci (GA, Sardinia). Dotted line identifies the 200 m isobath. Bottom right: bathymetric profile of the transect

Field methods

Fixed line transects are routes set in advance, which can be repeatedly surveyed using any vessel that regularly travels along the same route. The use of ferries as observation platforms for dedicated surveys (*sensu* Donovan 2005) was first applied in the early 1990s along a fixed transect in the Tyrrhenian Sea (Marini *et al.* 1996) and, from 2007, along a network of fixed routes in the Mediterranean Sea (Arcangeli *et al.* 2013a). The method is particularly useful to monitor systematically long-term changes in cetacean occurrence through different habitat types, including open sea regions, because biases owing to spatial heterogeneity or to small sample sizes are minimized.

In this study, a fixed line transect in the Central Tyrrhenian Sea running from Civitavecchia to Golfo Aranci was surveyed almost twice a week from the beginning of June until the end of September during two research periods (from 1990 to 1992 and from 2007 to 2011). The same protocol was applied during the two periods to assure the consistency of the data collected, taking into account the meteorological conditions (observations carried out at Beaufort wind force state $\leq$3), speed and type of ferries (same type of ferries with range of mean speed 17–23 knots), experience of observers (only appropriately experienced and trained observers used in the programmes). At least two dedicated Marine Mammal Observers were located on each ship's command deck, conducting observational scans by the naked eye and binoculars (8 9 42 magnification), covering a 270° of visual range ahead of the ferry. Information regarding the route, speed and weather conditions were recorded at the beginning and at the end of the effort and each time a change occurred. During sightings, information about the time, ship's position, radial angle to the sighting, surface behaviour, direction of swimming, distance from the ship and group size of the species were recorded. A group was defined as more than one individual seen at the same time within few body lengths one to the other (Moulins *et al.* 2007).

Data analysis

Only data collected during the same season (from the end of May to the end of September) in both research periods (1990s: 1990–1992, 90 surveys; 2000s: 2007–2011, 160 surveys) were taken into account for the analysis.

Depth, slope, aspect northing and easting (facing direction of slope) and distance from the 200-m isobath were chosen for the analysis as these are usually considered the most important ecogeographical variables (EGVs) for predicting Cuvier's beaked whale presence (*e.g.* Cañadas *et al.* 2002; Moulins *et al.* 2007; Azzellino *et al.* 2008; MacLeod *et al.* 2008; Tepsich *et al.* 2014; Fig. 2). A depth map at 1-km^2 resolution was created from isobaths of the study area and slope and aspect maps were then derived from it using the Spatial Analyst tools in ARCMAP 10.1. The aspect parameter was converted into two linear components to be included in the analysis: aspect easting (sine of the aspect value) and aspect northing (cosine of the aspect value). Distance from the 200-m isobath (D200) was chosen because it was considered to be more descriptive than 'distance from shore' for deep-diving species and in order to avoid bias resulting from the variable extension of the continental shelf (Hooker *et al.* 1999; Praca *et al.* 2009). Thus, in order to gain data also on the continental shelf for the predictive maps (even if no sightings occurred there) the distance was considered both towards the coast and towards the open sea, with negative values assigned in continental shelf.

Spatial analysis was performed on a grid of 1 9 1 km resolution, this being the finest available scale for the EGV data (Claridge 2006; Hall *et al.* 2010; Gannier 2011). EGV values were extracted for the central point of each grid cell of the study area. The cell effort was calculated as the length travelled on effort for each cell in a total of almost 2000 km^2 of surveyed area.

Whale sighting data

Each ferry trip was considered as an independent statistical unit. Independency of the dataset was tested using the Spearman rank correlation and the autocorrelation test, assuming that the data between two successive outbound (or return) surveys, which had a minimum time interval of a week, were independent (Arcangeli *et al.* 2013b). Sightings per unit of effort (SPUE) was measured as the number of sightings per 100 km surveyed in good weather conditions (Evans & Hammond 2004; Wall *et al.* 2006).

Non-parametric statistical analyses (Kruskal–Wallis test and post-hoc Mann–Whitney test between each pair) were used to compare monthly and yearly variations in SPUE and group size between the two research periods. Analyses were performed using the program PAST 2.17 (Hammer *et al.* 2001).

Spatial analysis was studied using a Geographic Information System (ARCMAP 10.1 and Geospatial Modelling Environment) combining data from all months and years within the same research period. The distributions of sightings in the two research periods were first investigated using the Kernel smoother for point pattern analysis of occurrence-only data (Hengl 2009) to map areas of higher densities of sightings.

Habitat suitability analysis

Habitat preferences were first investigated for each variable in each time period separately. Values of each variable were extracted for the cetacean sightings positions and along the monitored transect as mean cell values. The range of values for each variable was divided into classes and the percentage frequency distribution of values in the sighting positions in the 1990s and in the 2000s were compared by graph and when possible by Chi-squared test, with the expected values along the monitored transect.

A species distribution model was then performed in order to account for any possible interactions between variables. A presence-absence model (generalized additive modelling, GAM; Hastie & Tibshirani 1990) was chosen to assess Cuvier's beaked whale habitat preferences as recommended by Praca *et al.* (2009) for data that are systematically recorded, collected within the same protocol and with an equal distribution effort across the investigated area. GAM was also chosen because it does not make any prior assumptions about the relationships and shape of the relationship between habitat features and species distribution (linear, sigmoidal *etc.*) and it is more flexible than other models (Guisan *et al.* 2002; Redfern *et al.* 2006; Hall *et al.* 2010).Within each considered period, a subset of absence cells was randomly selected amongst those with highest effort values along the transect, to prevent false absence bias, (>50 km, MacLeod *et al.* 2008; Arcangeli *et al.* 2013b). Moreover, to avoid bias because of a large number of cells with ‘zero’, a number of absence cells almost three times higher than the number of presence cells was selected for the analysis (Smith2010). To check the representativeness of the selected cells we: repeated the selection a number of times to check the consistency of the results;

1 checked for each parameter the similarity of data distribution of the all data and the subset with a Kolmogorov–Smirnov test;

2 performed the GAM analysis with a different number of selected cells to check the predictions coming from the different models.

Independency of the EGVs was tested before they were included in the analysis. The percentage of deviance explained and Akaike’s information criterion (AIC) step- wise selection criteria were the main criteria used to test for the accuracy of the models. The predictive abilities of the models were successively validated using an independent data set of Cuvier’s beaked whale sightings and related survey effort that intersected the study area (surveys along the fixed line transects of Livorno-Golfo Aranci and Civitavecchia-Barcelona within the ISPRA monitoring network, Arcangeli *et al.* 2013a). In addition, we cross-validated the distributions predicted from each study period with data coming from the other period, in order to verify whether or not we obtained a better validation using contemporary data. Model analysis and validation were performed using R3.0.1 software (R Core Team 2013).

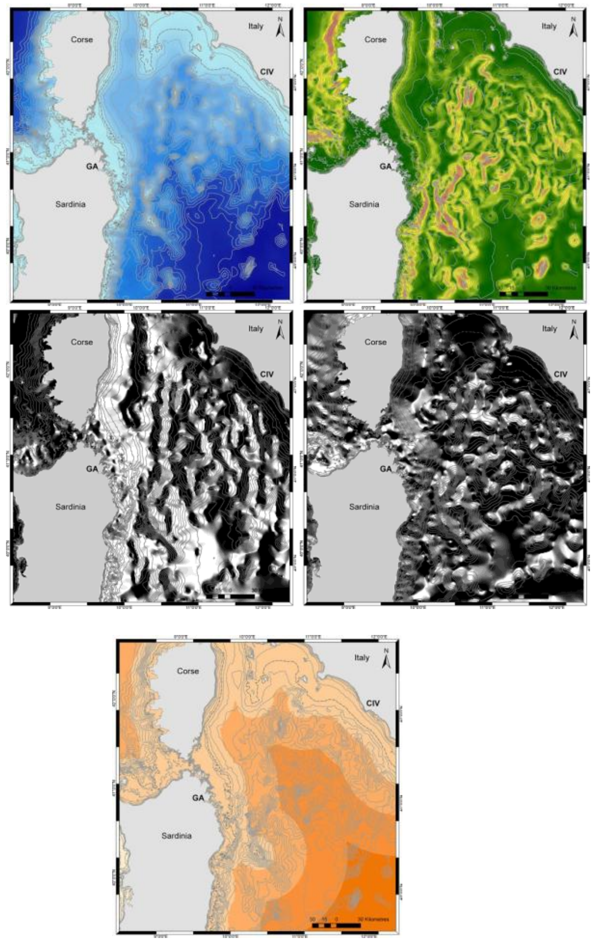

Fig. 2. Maps of the ecogeographical variables. Depth and Slope (top left and right), Aspect Easting and Northing (centre), Distance from 200 m isobath (down right). Dotted line identifies the 200 m isobath.

Results

Whale sighting data

The general results of the monitoring conducted during the two study periods are shown in Table 1. *Ziphius cavi- rostris* was recorded in each of the 8 years of the research, resulting in 3% of total cetacean sightings in the 1990s (n = 8) and 5% in the 2000s (n = 26).

Although all monitoring was conducted in conditions with a Beaufort scale of under 3, no detailed information on the sea state is available for the first investigated period. All Cuvier's beaked whale sightings during 2007–2010 occurred in Beaufort sea states of between 0 and 1. In 2011, three out of nine sightings were in Beaufort sea states equal to 2 and no sightings occurred in higher sea states.

SPUE showed different values, with a slight although not statistically significant increase during the latter survey period ($SPUE_{1990s} \pm SE = 0.043 \pm 0.02$; $SPUE_{2000s} \pm SE = 0.081 \pm 0.02$; Mann–Whitney test, $N_{1990s} = 90$, $N_{2000s} = 160$, $P > 0.05$).

Statistical comparison was performed within each research period to verify whether inter-annual variability occurred: in both the 1990s and 2000s no significant differences in SPUE between years were found (Mann– Whitney test, $P > 0.05$), indicating fairly consistent presence of the species in the study area.

The mean group size seen in the 1990s was1.75 ± 0.16, slightly lower than in the 2000s (1.88 ± 0.24) but the difference was not statistically significant (Mann–Whitney test, $P > 0.05$). During the last research period, 81% of sightings consisted of groups of one or two individuals whereas in 2009 60% of recorded groups were composed of four or give animals. In 2010 groups of two or three animals were observed breaching.

Spatial distribution

The distribution of sightings was studied in the surveyed cells during the two research periods (Fig. 3) and kernel analysis was performed to identify the high sighting density areas (Fig. 4): in the 1990s two main areas were identified at 30–45 km away from the continental shelf whereas in the 2000s three different hot-spots were observed, only partially overlapping with the previously recognized areas as the sightings were more dispersed along the transect.

Habitat suitability analysis

The observed distribution of animals was investigated in relation to each variable in order to highlight habitat preferences. Mean depth values recorded in the sightings locations were similar during the two research periods, according to a bathymetric affinity for medium–high depths (mean 1990s = –1131 ± 75 m; mean 2000s = – 989 ± 41 m). In the 2000s the distribution frequency of sightings differed significantly from the expected values (Chi-squared test, $P < 0.05$), with a peak for the 800–1000 m class, whereas in the 1990s two maximum, higher than the expected values, were recorded for the 1000–1200 m and 1200–1400 m classes (Fig. 5).

Table 1. Whole dataset: study periods and general results of surveys along the fixed line transect in central Tyrrhenian Sea (Civitavecchia - Golfo Aranci, Italy).

Study period	Years	Years	Frequency of surveys	km of effort	No. of species	Total sight	CBW sight
1990s	1990–	June–	4–8 per	16,750	7	344	8
2000s	2007–	June–	4–8 per	28,874	8	640	26

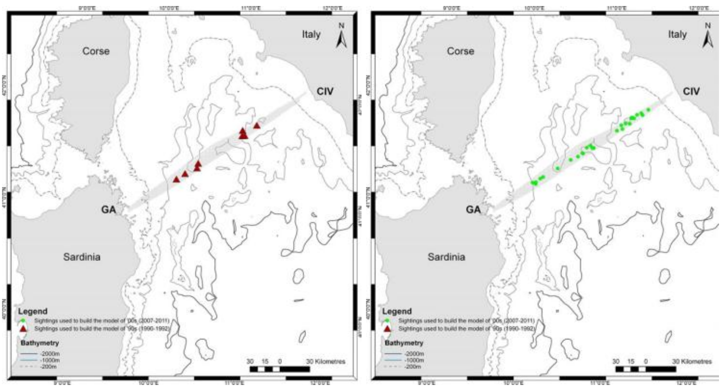

Fig. 3. Surveyed cells (in grey) and sighting locations for the 1990s (red triangles, left) and the 2000s (green dots, right).

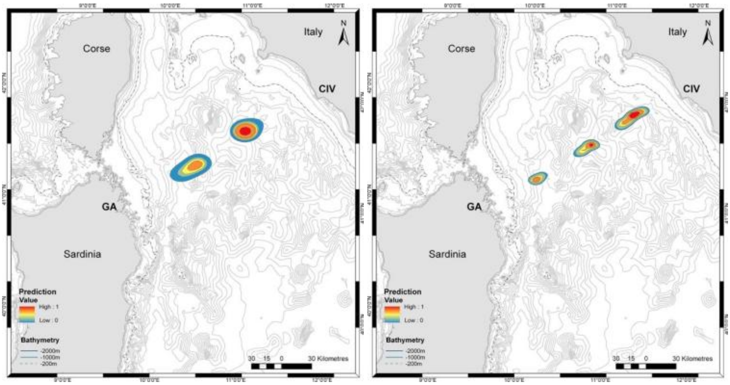

Fig. 4. Distribution of sightings in the 1990s (left) and in the 2000s (right) (Kernel parameters: adaptive Kernel; volume level = 0.70; smoothing factor, h = bcv2).

The distribution frequencies of sightings showed a marked difference between the two periods with respect to slope: mean slope was higher in the 1990s (77.35 ± 16.4 $m \cdot km^{-1}$) than in the 2000s (30.04 ± 3.5 $m \cdot km^{-1}$) and, whereas in the latter period the animals' distribution appeared consistent with the frequency of values in the study area, in the 1990s Cuvier's beaked whale sightings concentrated with more than 40% of cases in the highest classes (90– 120 $m \cdot km^{-1}$ class), much higher than the expected frequency (Chi-squared test, $P < 0.05$; Fig. 5).

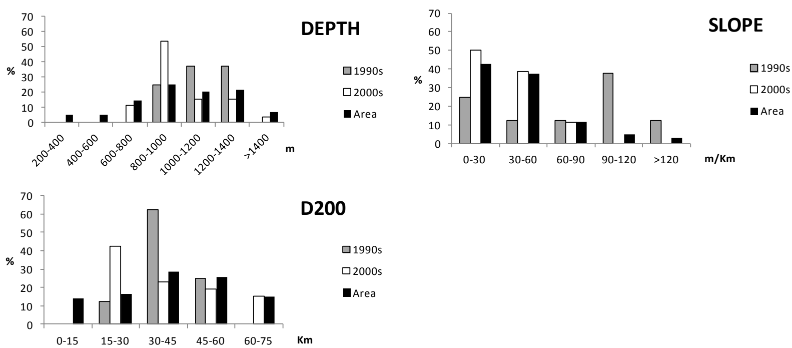

Fig. 5. Percentage distribution of CBW sighting locations in the two study periods and monitored points along the transect for Depth, Slope, Distance from the 200 m isobath.

Cuvier's beaked whale observations occurred at different ranges of distances from the 200-m isobath: in the 1990s a higher percentage of observations than expected was recorded in the 30–45 km class, whereas in the 2000s a more variable frequency distribution was observed, with a higher percentage than expected for the class 15–30 km. The absolute minimum and maximum distances were both recorded in the 2000s (15 and 70 km), which is consistent with the greater distribution of sightings found in the kernel analysis (Figs 4 and 5).

Pooling the effects of all variables together, the results of the GAM analyses performed on the 1990s and 2000s datasets separately (Table 2) indicated that in the 1990s, only slope had a slight influence on beaked whale presence ($P < 0.1$), whereas in the 2000s, both D200 and Aspect E strongly influenced habitat selection ($P < 0.001$ and <0.05, respectively).

Based on the percentage of deviance explained ($Dev.Expl._{1990s}$ = 49.7%; $Dev.Expl._{2000s}$ = 29.7%), AIC and the results check, both models account for a suitable predictive ability.

Table 2. Generalized additive modelling results.

	Intercept	D200	Slope	Depth	AspectN	AspectE	Dev.expl.	AIC
1990s *(N=38*	**.**		**.**				49.7%	34.433
2000s *(N=126)*	***	**				*	29.7%	108.85

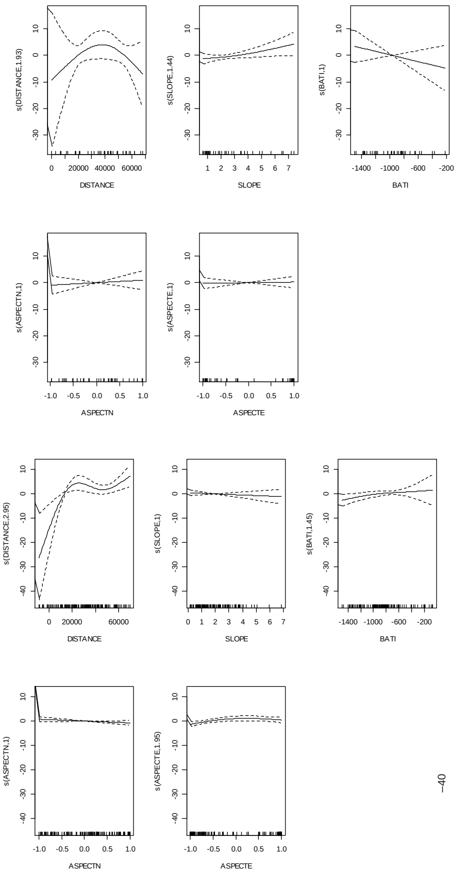

Fig. 6. Plots of EGVs for the species distribution model based on 1990s data (left) and 2000s data (right).

Plots of EGVs illustrated the non-linear relationship between species distribution and habitat features (*e.g.* distance from the 200-m isobath) and the differences in this relationship between the two investigated periods (Fig. 6). The revised prediction models based on the 1990s and 2000s data showed that changes occurred in the predicted most suitable habitat between the two investigated periods (Fig. 7).

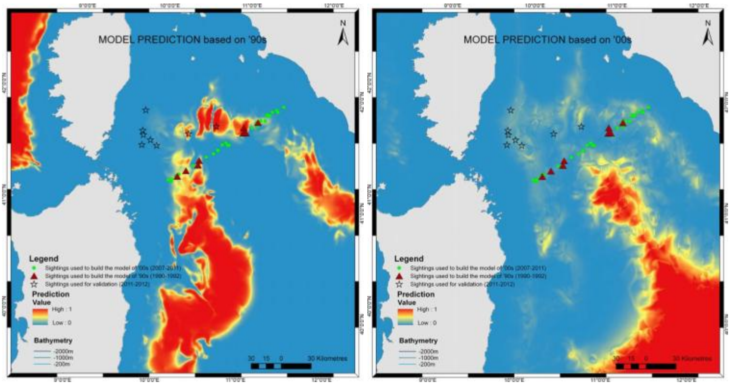

Fig. 7. Model predictions based on the 1990s data (left) and on the 2000s data (right). Scale bar from low predictive values (blue) to high predictive values (red). CBW sighting positions are indicated as red triangles (1990s), green dots (2000s) and stars (sightings used for the validation).

A positive relationship was found between the probability of occurrence of Cuvier's beaked whale predicted from the model and the presence or absence of the species in the independent data set used for validation (Fig. 8a and b). The relationship was statistically significant only for the prediction based on the 2000s data ($P = 0.0064$). By contrast, no relationship was found between the probability of occurrence of Cuvier's beaked whale predicted from the model based on the 2000s data and the presence or absence of Cuvier's beaked whale in the 1990s and *vice versa* (Fig. 8c and d; $P > 0.05$).
Based on the high percentage of deviance explained (49.7%), the model built on the 1990s data seemed to work well, despite the small number of Cuvier's beaked whale sightings and although no independent data set was available for that period. The 2000s data performed a suitable model, which was also validated against an inde- pendent data set. The results also showed that the 2000s data did not fit the predicted habitat based on the 1990s data and, similarly, the predicted habitat based on the 2000s data did not fit the 1990s data

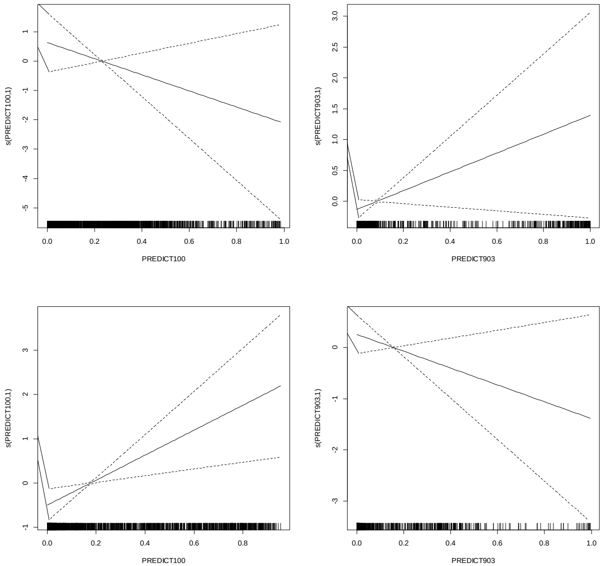

Fig. 8. Validation plots. Prediction based on 2000s data *versus* independent dataset (P- value = 0.0064) (a), prediction based on 1990s data *versus* independent dataset (P- value = 0.095) (b), prediction based on 2000s data *versus* 1990s data (P-value = 0.17) (c), prediction based on 1990s data *versus* 2000s data (P-value = 0.12) (d).

Discussion

This study confirms the presence, amongst other cetaceans, of Cuvier's beaked whales in the Central Tyrrhenian Sea. The species was recorded over a 20-year time span and the constant presence during the investigated periods (1990–1992, 2007–2011) gives an indication of the long-term site fidelity of the species in the area, as reported for other regions (cf. Allen *et al.* 2012).

The percentage of Cuvier's beaked whale sightings with respect to the total sightings of all cetacean species was higher during the latter study period (2000s) and, although not statistically significant, the sighting rate (SPUE) was almost twice than that of the 1990s. Comparing our results with those obtained for CBW in other research studies in the Tyrrhenian Sea, Gannier & Epinat (2008) obtained a SPUE simi- lar to the one of our last period (0.081 for the Southern Tyrrhenian; 0.102 for Northern Tyrrhenian), pooling data from 1996 and 2007 in different seasons. Marini *et al.* (1996), within the same research of the present study in the 1990s, but combining data from all seasons, reported a lower SPUE of 0.02. In the Ligurian Sea, Gannier & Epinat (2008) reported a much lower SPUE (0.013) whereas Moulins *et al.* (2007) reported higher sighting rates, in the range of 0.1–0.6 sightings/100 km, for optimal slopes, surveying Cuvier's beaked whale's most favorable habitat with a sampling design optimized for the species.

Looking at the effect of weather conditions on the detectability of the species, Marini *et al.* (1992) reported that all sightings in the 1990s period were recorded in conditions with a Beaufort scale of <2. In the 2000s all sightings were also recorded in conditions with a Beaufort scale of <2 and no sightings ever occurred in a higher sea state, confirming how the detectability of this species changes with weather conditions (Barlow *et al.* 2006).

Mean group sizes in the 1990s and in the 2000s were consistent with the one observed for the whole Mediterranean basin (1.80 ± 1.18, Gannier & Epinat 2008).

The distribution of sightings illustrated that a change occurred during the two investigated periods, with wider range of habitat and different hot-spots occupied by Cuvier's beaked whales during the latter period compared with the 1990s. According to the literature, beaked whales are distributed in medium–deep waters and steep slopes, albeit within a large range of habitats, all over the world (MacLeod *et al.* 2006). The geographical complexity of the Tyrrhenian Sea offers a variety of suitable areas for the species; the fine scale of the present study allowed us to identify habitat use over a long time span and analyses preferences in relation to different physiographical features. Mean depth was constant during the two research periods (around -1000 m): both studies considered for comparison (Moulins *et al.* 2007; Gannier & Epinat 2008) reported greater values of depth (-1369 ± 498 m and -1544 ± 489 m, respectively). In the GAM analyses, depth was not a significant variable, confirming that other features defined habitat suitability for Cuvier's beaked whale in this complex area. Slope classes were used differently during the two periods, much steep during the 1990s than in the 2000s. Habitat selection seemed to be determined by the highest classes of slope exclusively in the 1990s, resulting the only significant variable in the GAM analysis. This feature was also found to discriminate the habitat suitability in other models for Cuvier's beaked whale (Ferguson *et al.* 2006; Praca *et al.* 2009; Smith 2010) although the presence of the species in different slope classes was recently revealed in the Ligurian Sea, from where Tepsich *et al.* (2014) reported the existence of a second type of habitat not closely related to steep canyon axes. Distance from the 200-m isobath was instead the most significant variable in the 2000s in the present study, along with the aspect easting. During this period, a variable distribution of distance was observed, within 15–70 km from the continental shelf, in line with the broader spatial range of sightings.

Both suitability models for the 1990s and 2000s data appeared to work for each individual time period; the best predictive power obtained for the model of the 1990s was probably because of the lower number of sightings distributed in relatively restricted areas. Differences were evident in the areas of greatest habitat suitability predicted by the two models. Therefore, both the raw data and predicted distributions showed marked differences in the presence of Cuvier's beaked whale in relation to habitat features between the 1990s and the 2000s. Given the consistency of the sampling design of this study, this difference cannot be the result of different spatial or seasonal coverage or by low temporal resolution of the surveys, which could have made the results influenced by causality, especially for a rare and elusive species such as Cuvier's beaked whale. Therefore, from a methodological point of view, the results indicate that great care must be taken when pooling together data over a long period of time or when transferring the predictions of models from one time period to another.

Fluctuations in Cuvier's beaked whale distribution were also identified in the Bay of Biscay by Smith (2010) although in this area the species always selected the same habitat characteristics. By contrast, in our study we found evidence for changes in Cuvier's beaked whale habitat selection over time.

Many factors could have induced these changes. The results highlighted the higher percentage of Cuvier's beaked whale in species composition, the higher sighting rate and a wider distribution of Cuvier's beaked whale during the latest period compared with the 1990s. These features point out a possible increase in the Cuvier's beaked whale population size in the study area between the two research periods. The presence of more animals in the area would lead to extend the distribution of the species towards new available habitats and, in fact, we noticed a broader range of environmental features in the 2000s, identifying wider suitable habitats in the model.

The driving forces behind these changes remain unclear. However, two possibilities exist that would be worthy of further investigation.

First, climate-induced variations in prey distribution and marine circulation could have affected Cuvier’s beaked whale distribution (cf. MacLeod 2009). In this respect, increasing temperatures and salinities have been registered in the Central Tyrrhenian Sea since the late 1980s (Gasparini *et al.* 2005; Schröder *et al.* 2006) and were indicated as possible signs of ecological modifications that could have driven the summer increase and the changes in habitat use of fin whales in the area in recent years (Arcangeli *et al.* 2014). Secondly, anthropogenic activities that mostly affect deep-diving species (nautical traffic, geo- logical investigation or military exercise) could also have influenced Cuvier’s beaked whale presence in the study area. The development of the maritime transport net- work in the area in the last 20 years has been documented (Bultrini *et al.* 2009), as the growth of the main port of the Central Tyrrhenian Sea (Civitavecchia), making it plausible that the marine traffic in the area has increased.

Regardless of the possible mechanisms for the observed changes in spatial distribution, the long-term site fidelity and the relatively high, increasing, presence (as well as the year-round presence, Marini *et al.* 1996) of Cuvier’s beaked whale in the Central Tyrrhenian Sea highlight the importance of this marine region for the species; in the meantime, these results ask for further in-depth investigation to understand if the recorded changes in habitat use can be linked to a population increase or to a negative response to pressures that could force the species to move towards different habitats.

Conservation implications

In terms of conservation of the Cuvier’s beaked whale, our results appear to expand the definition of what is considered to be suitable habitat for this species and indicate that the temporal scale of the analysis can consider- ably affect the interpretation of results from beaked whale habitat studies. Thus, great care must be taken when working with historical Cuvier’s beaked whale data sets, especially those collected over relatively short time periods and when using them as the basis for current or future management decisions based on spatial distributions. Any management plan for this species needs to be assessed at a small scale (Allen *et al.* 2012) and be ready to be adapted over time.

This study confirms the importance of long-term and continuous monitoring, which can not only increase the ecological understanding of cetacean species but may also be able to identify shifts in patterns of habitat use and therefore in spatial distributions. The sampling design utilized in this study appears to be able in delivering information at fine scale, suitable to be extended also outside the surveyed transect and to be a reliable survey programme to improve knowledge about distribution, relative abundance, trend and habitat use of the species over time. Indeed, the ability to detect and keep track of any changes occurring in these factors is important to predicting the responses of cetaceans to future environ- mental changes and to figure out how the ranges of species might change. This is a fundamental step for progressing dynamic conservation management approaches in changing environment scenarios.

References

Aguilar Soto N., Johnson M., Madsen P.T., Tyack P.L., Bocconcelli A., Borsani J.F. (2006) Does intense ship noise disrupt foraging in deep-diving Cuvier's beaked whales (*Ziphius cavirostris*)? *Marine Mammal Science*, 22, 690–699.

Allen B.M., Brownell R.L., Mead J.G. (2012) Species Review of Cuvier's Beaked Whale, *Ziphius cavirostris*. Reports of International Whaling Commission: 8 pp.

Arcangeli A., Castelli A., Marini L., Moulin A., Paliaga B., Tepsich P., Tringali M. (2013a) A cooperative program for studying and monitoring cetacean in Mediterranean Sea. *Biologia Marina Mediterranea*, 20, 254–255.

Arcangeli A., Marini L., Crosti R. (2013b) Changes in cetacean presence, relative abundance and distribution over 20 years along a trans-regional fixed line transect in the Central Tyrrhenian Sea. *Marine Ecology*, 34, 112–121.

Arcangeli A., Orasi A., Carcassi S.P., Crosti R. (2014) Exploring thermal and trophic preference of *Balaenoptera physalus* in the central Tyrrhenian Sea: a new summer feeding ground? *Marine Biology*, 161, 427–436.

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

Azzellino A., Gaspari S., Airoldi S., Nani B. (2008) Habitat use and preferences of cetaceans along the continental slope and the adjacent pelagic waters in the western Ligurian Sea.
Deep Sea Research I, 55, 296–323.

Barlow J., Ferguson M.C., Perrin W.F., Ballance L., Gerrodette T., Joyce G., MacLeod C.D., Mullin K., Palka D.L., Waring
G. (2006) Abundance and densities of beaked and bottlenose whales (family Ziphiidae). *Journal of Cetacean Research and Management*, 7, 263–270.

Bultrini M., Faticanti M., Leonardi A. (2009) Traffico marittimo e gestione ambientale nelle principali aree portuali nazionali. ISPRA Report 95/2009: 177 pp.

Cañadas A. (2012) *Ziphius cavirostris* (Mediterranean subpopulation). In: IUCN Red List of Threatened Species. Version 2013.2. www.iucnredlist.org. Downloaded on 19
May 2014.

Cañadas A., Sagarminaga R., Garcia-Tiscar S. (2002) Cetacean distribution related with depth and slope in the Mediterranean waters off southern Spain. *Deep Sea Research I*, 49, 2053–2073.

Cañadas A., Fortuna C., Pulcini M., Lauriano G., Bearzi G., Cotte C., Raga J.A., Panigada S., Politi E., Rendell B-Nagy A., Pastor X., Frantzis A., Mussi B. (2011) Accobams collaborative effort to map high-use areas by beaked whales in the Mediterranean. Document presented to the Scientific Committee of the International Whaling Commission.
Paper SC/63/SM10.

Claridge D.E. (2006) Fine-scale distribution and habitat selection of beaked whales. M.Sc. thesis, University of Aberdeen, UK.

Donovan G. (2005) Cetaceans: can we manage to conserve them? The role of long-term monitoring. In: Solbe J. (Eds), *Long Term Monitoring. Why, What, Where, When and How?* Sherkin Island Marine Station, Cork, Ireland: 161–174.

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

Ferguson M.C., Barlow J., Reilly S.B., Gerrodette T. (2006) Predicting Cuvier's (*Ziphius cavirostris*) and Mesoplodon beaked whale population density from habitat characteristics in the eastern tropical Pacific Ocean. *Journal of Cetacean Research and Management*, 7, 287–299.

Filadelfo R., Mintz J., Michlovich E., D'Amico A., Tyack P.L., Ketten D.R. (2009) Correlating military sonar use with beaked whale mass strandings: what do the historical data show? Aquatic Mammals, 35, 435–444.

Frantzis A. (1998) Does acoustic testing strand whales? Nature,392, 29.
Frantzis A. (2004) The first mass-stranding that was associated with the use of active sonar (Kyparissiakos Gulf, Greece, 1996). ECS Newsletter, 42, 14–20.
Frodello J.P., Viale D., Marchand B. (2002) Metal levels in a Cuvier's beaked whale (Ziphius cavirostris) found stranded on a Mediterranean Coast, Corsica. Bulletin of Environmental Contamination and Toxicology, 69, 662–666.
Fuda J.L., Etiope G., Millot C., Favali P., Calcara M., Smriglio G., Boschi E. (2002) Warming, salting and origin of the Tyrrhenian Deep Water. *Geophysical Research Letters*, 29, 4-1–4-4.
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 favourable 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, 1145–1151.
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, 52, 915–935.
Guisan A., Edwards T.C. Jr, Hastie T. (2002) Generalized linear and generalized additive models in studies of species distributions: setting the scene. *Ecological Modelling*, 157, 89–100.
Hall K., MacLeod C.D., Mandleberg L., Schweder-Goad C.M., Bannon S.M., Pierce G.J. (2010) Do abundance–occupancy relationships exist in cetaceans? *Journal of the Marine Biological Association of the United Kingdom*, 90, 1571–1581.
Hammer Ø., Harper D.A.T., Ryan P.D. (2001) PAST: Paleontological Statistics software package for education and data analysis. *Palaeontologia Electronica*, 4, 9 pp.
Hastie T.J., Tibshirani R.J. (1990) *Generalized Additive Models*. Chapman & Hall, London, UK: 340 pp.

Hengl T. (2009) *A practical guide to geostatistical mapping*. University of Amsterdam, Amsterdam: 291 pp.
Holcer D., Notarbartolo di Sciara G., Fortuna C.M., Lazar B., Onofri V. (2007) Occurrence of Cuvier's beaked whales in the southern Adriatic Sea: evidence of an important Mediterranean habitat. *Journal of the Marine Biological Association of the United Kingdom*, 87, 359–362.
Hooker S.K., Whitehead H., Gowans S. (1999) Marine Protected Area design and the spatial and temporal distribution of cetaceans in a submarine canyon.*Conservation Biology*, 13, 592–602.
Kerem D., Hadar N., Goffman O., Scheinin A., Kent R., Boisseau O., Schattner U. (2012) Update on the cetacean fauna of the Mediterranean Levantine basin. *The Open Marine Biology Journal*, 6, 6–27.
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., Mitchell G. (2006) Key areas for beaked whales worldwide. *Journal of Cetacean Research and Management*, 7, 309–322.
MacLeod C.D., Perrin W.F., Pitman R., Barlow J., Balance L., D'Amico A., Gerrodette I., Joyce G., Mullin K.D., Palka D.L., Waring G.T. (2006) Known and inferred distributions of beaked whale species (Cetacea: Ziphiidae). *Journal of Cetacean Research and Management*, 7, 271–286.
MacLeod C.D., Mandleberg L., Schweder C., Bannon S.M., Pierce G.J. (2008) A comparison of approaches for modelling the occurrence of marine animals. *Hydrobiologia*, 612, 21–32.
Marini L., Consiglio C., Angradi A.M., Sanna A. (1992) Four sightings of Ziphiidae (Cetacea, Odontoceti) in the central Tyrrhenian Sea. *Italian Journal of Zoology*, 4, 85–89.
Marini L., Consiglio C., Angradi A.M., Catalano B., Finoia M.G., Villetti G., Sanna A. (1996) Distribution and seasonality of cetaceans sighted during scheduled ferry transects in Central Tyrrhenian Sea: 1989–1992. *Italian Journal of Zoology*, 63, 381–388.
Marullo S., Santoleri R., Bignami F. (1994) The surface characteristics of the Tyrrhenian Sea: historical satellite data analysis. *Coastal and Estuarine Studies*, 46, 135–154.
Moulins A., Rosso M., Nani B., Wü rtz M. (2007) Aspects of the distribution of Cuvier's beaked whale (*Ziphius cavirostris*) in

relation to topographic features in the Pelagos Sanctuary (northwestern Mediterranean Sea). *Journal of the Marine Biological Association of the United Kingdom*, 87, 177–186.

Notarbartolo di Sciara G., Birkun A. Jr (2010) *Conserving whales, dolphins and porpoises in the Mediterranean and Black Sea: an ACCOBAMS status report*. ACCOBAMS, Monaco: 212 pp.

Öztürk A.A., Tonay A.M., Dede A. (2011) Strandings of the beaked whales, Risso's dolphins, and a minke whale on the Turkish coast of the Eastern Mediterranean Sea. *Journal of the Black Sea/Mediterranean Environment*, 17, 269–274.

Podestà M., D'Amico A., Pavan G., Drougas A., Komnenou A., Portunato N. (2006) A review of Cuvier's beaked whale strandings in the Mediterranean Sea. *Journal of Cetacean Research and Management*, 7, 251–261.

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 Core Team (2013) *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria: 482 pp.

Redfern J.V., Ferguson M.C., Becker E.A., Hyrenbach K.D., Good C., Barlow J., Kaschner K., Baumgartner M.F., Forney K.A., Ballance L.T., Fauchald P., Halpin P., Hamazaki T., Pershing A.J., Qian S.S., Read A., Reilly S.B., Torres L., Werner F. (2006) Techniques for cetacean–habitat modeling. *Marine Ecology Progress Series*, 310, 271–295.

Reeves R.R., McClellan K., Werner T.B. (2013) Marine mamml bycatch in gillnet and other entangling net fisheries, 1990 to 2011. *Endangered Species Research*, 20, 71–97.

Rixen M., Beckers J.M., Levitus S., Antonov J., Boyer T., Maillard C., Fichaut M., Balopoulos E., Iona S., Dooley H., Garcia M.J., Manca B., Giorgetti A., Manzella G., Mikhailov N., Pinardi N., Zavatarelli M. (2005) The Western Mediterranean Deep Water: a proxy for climate change. *Geophysical Research Letters*, 32, L12608.

Rosso M., Moulins A., Ballardini M., Gelsomino F., Wurtz M. (2007) Preliminary estimation of the population size of Cuvier's beaked whales (*Ziphius cavirostris*) in the northern Ligurian Sea. *Rapport Commission Internationale Mer Méditerranée*, 38, 582.

Schröder 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, L21607.
Schröder K., Josey S.A., Herrmann M., Grignon L., Gasparini G.P., Bryden H.L. (2010) Abrupt warming and salting of the Western Mediterranean Deep Water after 2005: atmospheric forcings and lateral advection. *Journal of Geophysical Research*, 115, C08029.
Smith J. (2010) The ecology of Cuvier's beaked whale, *Ziphius cavirostris* (Cetacea: Ziphiidae), in the Bay of Biscay. Ph.D. thesis, University of Southampton, Southampton, UK.
Storelli M.M., Zizzo N., Marcotrigiano G.O. (1999) Heavy metals and methylmercury in tissues of Risso's dolphin (*Grampus griseus*) and Cuvier's beaked whale (*Ziphius cavirostris*) stranded in Italy (South Adriatic Sea). *Bulletin of Environmental Contamination and Toxicology*, 63, 703–710.
Taylor B.L., Baird R., Barlow J., Dawson S.M., Ford J., Mead J.G., Notarbartolo di Sciara G., Wade P., Pitman R.L. (2008) *Ziphius cavirostris*. In: IUCN 2013. IUCN Red List of Threatened Species. Version 2013.2. www.iucnredlist.org. Downloaded on 19 May 2014.
Tepsich P., Rosso M., Halpin P.N., Moulins A. (2014) Habitat preferences of two deep-diving cetacean species in the northern Ligurian Sea. Marine Ecology Progress Series, 508, 247–260.
Tyack P.L., Johnson M., Aguilar Soto N., Sturlese A., Madsen P.T. (2006) Extreme diving of beaked whales. The Journal of Experimental Biology, 209, 4238–4253.
Tyack P.L., Zimmer W.M.X., Moretti D., Southall B.L., Claridge D.E., Durban J.W., Clark C.W., D'Amico A., DiMarzio N., Jarvis S., McCarthy E., Morrissey R., Ward J., Boyd I.L. (2011) Beaked Whale respond to simulated and actual navy sonar. *PLoS One*, 6, e17009.
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 pp.
Vaes T., Druon J.N. (2013) *Mapping of potential risk of ship strike with fin whales in the Western Mediterranean Sea*. JRC Institute for Protection and Security of the Citizen, Luxembourg: 28 pp.
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.

CH. 4 Study of the impact of maritime traffic on cetacean along the main shipping routes

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Cetacean response to summer maritime traffic in the Western Mediterranean Sea

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ABSTRACT

Maritime traffic is one of many anthropogenic pressures threatening the marine environment. This study was specifically designed to investigate the relationship between vessels presence and cetacean sightings in the high sea areas of the Western Mediterranean Sea region. We recorded and compared the total number of vessels in the presence and absence of cetacean sightings using data gathered during the summer season (2009–2013) along six fixed transects repeatedly surveyed. In locations with cetacean sightings (N = 2667), nautical traffic was significantly lower, by 20%, compared to random locations where no sightings occurred (N = 1226): all cetacean species, except bottlenose dolphin, were generally observed in locations with lower vessel abundance. In different areas the species showed variable results likely influenced by a combination of biological and local environmental factors. The approach of this research helped create, for the first time, a wide vision of the different responses of animals towards a common pressure.

1. Introduction

Cetacean populations nowadays are facing several threats including habitat loss, depletion of resources and interactions with fisheries (Notarbartolo di Sciara and Birkun, 2010). Human disturbance is also represented by ship transport which may affect the marine environment through shipping lanes, collisions and underwater noise and pollution, as indicated in the reference list adopted by the EU Habitats Directive (EC, 1992) (respectively D03.02, G05.11, H06.01, H03 codes). Vessel presence can have a direct disturbance on cetaceans causing long-term changes in distribution (Bejder et al., 2006a; Arcangeli et al., 2015), short-term changes in behaviour in fin whales (Jahoda et al., 2003; Castellote et al., 2012), bottlenose dolphins (Bejder et al., 2006b; Arcangeli and Crosti, 2009) and beaked whales (Aguilar et al., 2006; Tyack et al., 2011), or direct physical injuries due to collisions. Ship strikes are, in fact, reported all over the world and the size and speed of boats seems to be directly related to the severity of the wounds on the animals (Laist et al., 2001; Silber et al., 2010). Additionally, different types of vessels could be implicated in the accidents (Ritter, 2012). The Mediterranean Sea is among the world's busiest waterways and shipping traffic is continuously growing along with the concern for its potential impacts on marine fauna (Notarbartolo di Sciara and Birkun, 2010; Geijer and Jones, 2015). The intensity of traffic is expected to increase over the next few years due to the application of the EU program on "Motorways of the Sea" as alternative to land transport (EC, 2004) and summer months are generally the busiest in terms of naval traffic, especially for the transit of cruise ships and passenger ferries

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Summary
Maritime traffic is one of many anthropogenic pressures threatening the marine environment. This study was specifically designed to investigate the relationship between vessels presence and cetacean sightings in the high sea areas of the Western Mediterranean sea region. We recorded and compared the total number of vessels in the presence and absence of cetacean sightings using data gathered during the summer season (2009-2013) along six fixed transects repeatedly surveyed. In locations with cetacean sightings (N=2667), nautical traffic was significantly lower, by 20%, compared to random locations where no sightings occurred (N=1226): all cetacean species, except bottlenose dolphin, were generally observed in locations with lower vessel abundance. In different areas the species showed variable results likely influenced by a combination of biological and local environmental factors. The approach of this research helped create, for the first time, a wide vision of the different responses of animals towards a common pressure.

Introduction
Cetacean populations nowadays are facing several threats including habitat loss, depletion of resources and interactions with fisheries (Notarbartolo di Sciara and Birkun, 2010). Human disturbance is also represented by ship transport which may affect the marine environment through shipping lanes, collisions and underwater noise and pollution, as indicated in the reference list adopted by the EU Habitats Directive (1992) (respectively D03.02, G05.11, H06.01, H03 codes). Vessel presence can have a direct disturbance on cetaceans causing long-term changes in distribution (Bejder et al., 2006a; Arcangeli et al., 2015), short-term changes in behaviour in fin whales (Jahoda et al., 2003; Castellote et al., 2012), bottlenose dolphins (Bejder et al., 2006b; Arcangeli and Crosti, 2009) and beaked whales (Aguilar et al., 2006; Tyack et al., 2011), or direct physical injuries due to collisions. Ship strikes are, in fact, reported all over the world and the size and speed of boats seems to be directly related to the severity of the wounds on the animals (Laist et al., 2001; Silber et al., 2010). Additionally, different types of vessels could be implicated in the accidents (Ritter, 2012). The Mediterranean Sea is among the world's busiest waterways and shipping traffic is continuously growing along with the concern for its potential impacts on marine fauna (Notarbartolo di Sciara and Birkun, 2010; Geijer and Jones, 2015). The intensity of traffic is expected to increase over the next few years due to the application of the EU program on “Motorways of the Sea” as alternative to land transport (EC, 2004) and

summer months are generally the busiest in terms of naval traffic, especially for the transit of cruise ships and passenger ferries connecting tourist destinations (Notarbartolo di Sciara et al., 2008; David et al., 2011; Vaes and Druon, 2013). The main shipping routes often overlap with critical cetacean habitats, so potential conservation/mitigation measures are under discussion at different scientific and political levels, but critical decision making information is still lacking. Cetaceans are wide-ranging animals, mostly pelagic, that perform seasonal movements within almost the whole basin. Indeed, seasonal as well as annual variations in presence and distribution of cetacean species were detected by several studies in different areas of the Mediterranean (Gannier, 2002; Monestiez et al., 2006; Laran and Gannier 2008; Panigada et al., 2011; Arcangeli et al., 2014a; Arcangeli et al., 2014b) and are generally linked to a variable and synergistic effect of different ecological and anthropogenic driving forces. Human impacts on the marine environment are mostly studied in relation to coastal activities, such as ports, fishing, and pleasure boat traffic (Notarbartolo di Sciara and Birkun, 2010) but very little is reported, especially through direct observations, on high sea areas. Therefore, while a wide and multi-species scale approach is needed to provide conservation/mitigation measures towards this threat at the international level (Geijer and Jones, 2015), data remains extremely scarce and quantitative measures on the effects of maritime traffic on different cetacean species in open seas is missing.

This study was specifically designed to investigate the relationship between maritime traffic and cetacean sightings in high sea waters along some of the main shipping routes in the Western Mediterranean Sea. Data was gathered from a large dataset coming from an international network that, since 2007, systematically samples several transects along the main shipping routes (Arcangeli et al., 2014c) with the purpose of monitoring cetacean populations and their relationship with environmental features and anthropogenic factors, such as maritime traffic and marine litter (Crosti et al., 2011; Arcangeli et al., 2015). This research program provided standardised large-scale data and also recorded information in the high seas where long-term studies are otherwise difficult to conduct. For this study, we collected real-time data on vessel and cetacean sightings during summer months. By recording the total number of ships visible at eyesight from the observation platform both during cetacean sightings and in locations randomly sampled all throughout the monitored transects where animals were not sighted, we aimed to determine if the overall intensity of maritime traffic statistically differed between presence and absence of cetacean sightings. As a consequence of traffic disturbance animals could leave the areas with more vessels with short or large displacements (resulting in true absences) or change diving activity (i.e. longer diving could result in more pseudo-absences) (David, 2002). Thus we hypothesised that a lower number of ships would be recorded where cetacean sightings occurred with respect to the number of vessels observed in the absence of sightings. Once this was tested at different geographical scales, we aimed to also investigate whether different species showed heterogeneous responses to traffic intensity. Finally, we discuss the effect of disturbances in areas of particular relevance, such as the Pelagos Sanctuary, to verify the necessity of additional conservation efforts.

Materials and methods

Study area

This research is focused in high sea areas, because most of the Mediterranean cetacean species are mainly pelagic and there is a general lack of information in these areas. Surveys were conducted along six fixed transects within the main shipping routes connecting Italy, France and Spain (Fig. 1): Toulon-Ajaccio (TOU), Nice-Calvì (NIZ), Savona-Bastia (SAV), Livorno-Golfo Aranci (LIGA), Civitavecchia-Golfo Aranci (CIV) and Civitavecchia-Barcelona (divided in an eastern, EBAR, and in a western section, WBAR). These transects cross, respectively, the Ligurian-Provençal basin, the northern and central Tyrrhenian Sea and the Sardinian and Balearic Seas. These marine regions are characterised by a broad range of topographic and ecological conditions: the continental shelf is wide in the Tyrrhenian and Balearic Seas and less extended along the Ligurian and French coasts, while steep slopes and canyons define a complex sea bottom topography in the areas crossed by TOU, SAV and especially the CIV transects. Waters reach maximum depths in the Balearic Sea and in the abyssal plateau of the Ligurian Sea (around 2700 m deep).
All eight cetacean species regularly occurring in the Mediterranean Sea can be found within all of the study area (Notarbartolo di Sciara and Birkun, 2010): fin whale *Balaenoptera physalus,* striped dolphin *Stenella coeruleoalba,* sperm whale *Physeter macrocephalus,* Cuvier's beaked whale *Ziphius cavirostris,* bottlenose dolphin *Tursiops truncatus,* Risso's dolphin *Grampus griseus,* common dolphin *Delphinus delphis* and long-finned pilot whale *Globicephala melas*.

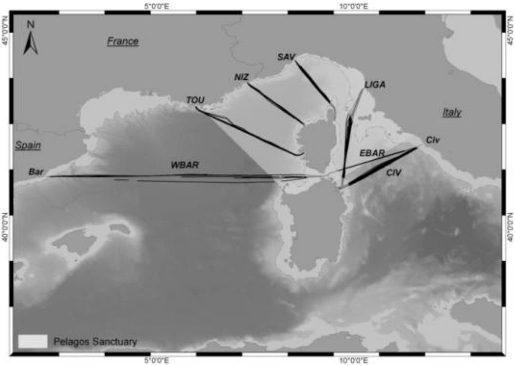

Figure 1. Study area. Transects sampled between 2009 and 2013: Toulon-Ajaccio (TOU), Nice-Calvì (NIZ), Savona-Bastia (SAV), Livorno-Golfo Aranci (LIGA), Civitavecchia-Golfo Aranci (CIV), Eastern Civitavecchia-Barcelona (EBAR), Western Civitavecchia-Barcelona (WBAR). The Pelagos Sanctuary (light gray area) and the -200 m bathymetric contour are shown in the map.

Two Special Protected Areas of Mediterranean Importance (SPAMI, UNEP, 2010) are crossed by the studied transects (Fig. 1): the Bonifacio Strait, mostly falling within continental waters and the Pelagos Sanctuary, the largest and the only SPAMI established in high sea areas and under international agreement. This latter area is characterised by high levels of primary productivity providing suitable habitats for the breeding and foraging needs of many cetacean species. On the other hand, it is subject to high levels of human pressures due to the presence of coastal cities, ports and tourist destinations (Notarbartolo di Sciara et al., 2008).

Data collection

The transects were repeatedly surveyed between 2009 and 2013 (Table 1). Consistency of datasets throughout the different areas and research periods was guaranteed by the application of a common protocol for data collection, the experience of the observers and by using research platforms with similar characteristics (deck height, speed). Outbound and return surveys were performed weekly along each transect using ferries (19-25 knots) as observation platforms, where trained observers followed the network data collection protocol to provide standardised records (for further details see Arcangeli et al., 2014a). The effort for both cetaceans and visual ship observations was carried out in favourable weather conditions (Beaufort scale≤3). A sampling protocol was specifically designed in order to provide real-time information on maritime traffic in the presence and absence of cetacean sightings and was applied to all transects during the surveys: scan sampling to count all vessels longer than 5 meters and visible by eyesight all around the ferry was performed each time a cetacean sighting occurred (record in presence of cetacean sightings; presence dataset); additionally, scan sampling of vessels was conducted in random locations all throughout the transects when animals were not sighted (absence or pseudo-absence) starting at a random time interval after the effort began and repeating the count approximately every hour (random record in absence of cetacean sightings; absence/random dataset). In order to avoid pseudo-replication, a minimum interval of 15 minutes was defined between presence and absence records. As surveys were performed from a vessel, the research platform was not included in the ships counts and not considered a source of error in the comparison as it was constant in both datasets. To account for seasonality and to investigate the season with highest intensity of traffic, only surveys carried out between June and September were used for this study.

Data analysis

As the focus of the research was in high sea areas, we selected only maritime traffic records taken offshore and thus considered the portions of all transects falling outside the 200 m isobath (portions in black in Fig. 1). Geographical distribution was studied using ArcGIS 10.1.

The two datasets in the presence and absence of sightings (Table 1) were compared to test the null hypothesis that the number of ships doesn't differ between them. Two geographic scales were investigated: at marine sub-region level, pooling data from all transects together and at single transect scale to highlight if differences exist among different sea areas. Under this spatial differentiation, comparisons were performed both combining data from all species together and at a single species level in order to test for species-specific effects. At single transect scale, all transects were studied singularly except EBAR, which was grouped together with CIV as a single dataset (CIV+EBAR) given their close proximity (Fig. 1). Testing at a single species level, the absence datasets were built gathering data only from the transects where the species under study were sighted.

Table 1. Datasets used in the study. N absence: number of records of vessel counts in the absence of cetacean sightings; N presence: number

of records of vessel counts in the presence of cetacean sightings. Transects: Toulon-Ajaccio (TOU), Nice-Calvì (NIZ), Savona-Bastia (SAV), Livorno-Golfo Aranci (LIGA), Civitavecchia-Golfo Aranci (CIV), Eastern Civitavecchia-Barcelona (EBAR), Western Civitavecchia-Barcelona (WBAR). Species: fin whale (Bp), striped dolphin (Sc), sperm whale (Pm), Cuvier's beaked whale (Zc), bottlenose dolphin (Tt), Risso's dolphin (Gg), common dolphin (Dd), long-finned pilot whale (Gm).

TRANSECTS	**YEAR**	**#surveys**	**N absence**	**N presence**	**SP.RECORDED**
TOU	2011	14	57	117	Bp, Sc, Pm, Gm
NIZ	2009	28	58	156	Bp, Sc, Pm, Zc, Tt, Gg, Dd, Gm
	2010	32	62	132	
	2011	30	63	258	
	2012	29	65	330	
	2013	27	52	275	
SAV	2009	32	27	92	Bp, Sc, Pm, Zc, Tt, Gg, Gm
	2010	33	58	130	
	2011	33	81	67	
	2012	29	63	141	
	2013	32	58	189	
LIGA	2011	27	27	54	Bp, Sc, Pm, Zc, Tt, Dd
	2013	29	65	75	
CIV	2009	36	102	132	Bp, Sc, Pm, Zc, Tt, Gg
	2010	34	96	108	
	2011	31	122	133	
EBAR	2012	22*	9	5	Bp, Sc, Pm, Zc, Tt, Gg
	2013	26°	18	35	
WBAR	2012	22*	69	33	Bp, Sc, Pm, Zc, Tt, Gg, Dd
	2013	26°	74	205	
TOTAL		***524***	***1226***	***2667***	***8***

*° Data of Civitavecchia-Barcelona were collected during the same surveys, then divided into EBAR and WBAR.

To study the relationship between maritime traffic and cetacean sightings, we calculated the mean percentage difference between the number of vessels recorded in the sighting locations ($\overline{\ }_{pres}$) and those recorded randomly in the absence of sightings ($\overline{\ }_{abs}$) as : [($\overline{\ }_{pres}$ - $\overline{\ }_{abs}$) / $\overline{\ }_{abs}$]*100. The non-parametric Kolmogorov-Smirnov test (KS) was used to compare the two datasets. Only datasets with a minimum of 10 records were used for statistical analysis.
To consider the influence of the intensity of traffic, we also used as indicators of real-time vessel abundance the number of ships randomly and uniformly recorded all throughout the surveyed transects in the absence of cetacean sightings. The Kolmogorov-Smirnov test with the Bonferroni correction for multiple comparisons was used to test for differences between the transects. Transects were then grouped on the basis of statistical results and 95th percentiles. All the analyses were performed using PAST 2.17 software (Hammer et al., 2001).

Results

During the study period, 95962 km were surveyed along six transects and the presence of eight cetacean species was recorded: fin whale, striped dolphin and sperm whale were sighted in all transects, Cuvier's beaked whale and bottlenose dolphin were in five, while Risso's dolphin, common dolphin and pilot whale sightings were more scattered (see Table 1).

Analysis at a marine sub-region level

The first analysis on the whole dataset showed that, in locations with cetacean sightings, the number of vessels recorded was 20% lower than the number of vessels recorded in the absence of sightings with a significant difference in the frequency distribution of the two datasets (KS tests, $p \leq 0.001$; Table 2).
At a species level for the three most frequently sighted species, a lower number of vessels was recorded in sighting locations compared to data randomly collected where cetaceans were not sighted: the differences observed were -18% for fin whale, -20% for striped dolphin, and -2% for sperm whale, and they all were statistically significant ($p \leq 0.001$). Cuvier's beaked whale was observed with a significantly lower number of ships compared to the number of ships recorded in absence of sightings (-29%; $p<0.0001$). No significant difference was detected for bottlenose dolphin. The other species were observed in only a few transects and with a very patchy distribution. For Risso's dolphin, a

significantly lower number of vessels in sighting locations was recorded (-43%; p<0.01). Additionally, common dolphin and pilot whale were observed in locations with a lower number of ships (respectively -48% and -44%) but these differences were not statistically significant, probably as a consequence of the low number of sightings. Given the small presence dataset for these three last species, investigation at a single transect level was not performed.

Table 2. Percentage differences in the number of vessels counted in the presence and absence of cetacean sightings at regional, species and single transect levels: number of records in each dataset (presence and absence), percentage differences and Kolmogorov-Smirnov test results (p KS; ns = not significant).

					Species					All
Transects		**Bp**	**Sc**	**Pm**	**Zc**	**Tt**	**Gg**	**Dd**	**Gm**	**species**
All trans.	*presence*	924	1294	94	54	42	17	11	15	2667
	absence	1226	1226	1226	1169	1169	1077	535	644	1226
	% difference	-18%	-20%	-2%	-29%	-2%	-43%	-48.2%	-44.2%	-20%
	p KS	**0.001**	**0.0**	**0.000**	**0.00**	ns	**0.002**	ns	ns	**0.000**
TOU	*presence*	41	37	12	0	0	0	0	1	117
	absence	57	57	57						57
	% difference	-83%		-79%						-47%
	p KS	**0.002**	ns	**0.021**					-	0.059
NIZ	*presence*	475	591	43	5	14	3	9	9	1151
	absence	300	300	300		300				300
	% difference	0%	-19%							-11%
	p KS	**0.00**	**0.0**	ns	-	ns	-	-	-	**0.000**
SAV	*presence*	139	417	21	22	10	3	0	5	619
	absence	287	287	287	287	287				287
	% difference	-35%	-32%							-31%
	p KS	**0.000**	ns	ns	ns	ns	-		-	**0.013**
LIGA	*presence*	18	86	6	2	9	0	1	0	129
	absence	92	92							92
	% difference	-46%	-55%							-49%
	p KS	**0.00**	**0.0**	-	-	-		-		**0.000**

CIV+ EBAR	*presence*	161	95	3	22	5	5	0	0	413
	absence	347	347		347					347
	% difference	-10%	-39%		-36%					-22%
	p KS	**0.00**	**0.0**	-	**0.001**	-	-			0.069
W BAR	*presence*	90	68	9	3	4	6	1	0	238
	absence	143	143							143
	% difference	-12%	-26%							-11%
	p KS	**0.055**	**0.00**	-	-	-	-	-		**0.000**

Analysis at a single transect level

Looking at the single transects (Table 2), results showed that the number of ships recorded during cetacean sightings was lower in all areas, with a percentage difference ranging from -11% to -49%, which was significant for four out of six transects (p≤0.01). The highest differences between the presence and absence/random datasets were recorded in LIGA (-49%; p<0.001) and TOU (-47%; p=0.059), while minimum differences were observed in NIZ and WBAR (-11%; p<0.001).

By stratifying the data at a single species level along each transect, statistical analysis was feasible only in some cases (see Table 2). In locations with fin whale sightings (six transects), the number of vessels was significantly lower than in the absence of sightings in all the surveyed transects (p≤0.05) with the exception of NIZ. The percentage difference changed among transects: it was higher along TOU (-83%) and LIGA (-46%), intermediate along SAV (-35%) and lower along CIV+EBAR and WBAR (-10% and -12% respectively). Along NIZ, no difference in mean number of ships in the presence and absence of fin whale sightings was observed. During striped dolphin sightings (six transects), a lower number of ships compared to random locations was recorded; in all transects except TOU and SAV, significant differences were recorded (p<0.001) with percentages ranging between -19% (NIZ) and -55% (LIGA). For sperm whale (three transects), the only significant difference was recorded along TOU (p<0.05) where the amount of vessels counted during sightings was 79% lower than in locations where animals were not sighted. Conversely, along NIZ and SAV, no statistical differences were detected. In the two transects where data was sufficient to test Cuvier's beaked whale, no significant difference emerged along SAV, while a difference was significant in CIV+EBAR (p<0.001) with a mean of 36% fewer vessels during sightings with respect to locations where cetaceans were not observed.

No significant differences were detected between the number of vessels in the presence and absence of bottlenose dolphin sightings both along NIZ and SAV.

Analysis on the influence of traffic intensity

We investigated real-time vessel abundance by comparing the absence/random datasets: the results showed significant differences between the transects (KS test with Bonferroni correction $p \leq 0.003$, Table 3) except for NIZ-SAV and TOU-LIGA. Transects were then grouped, by also considering the values of the 95th percentiles, in areas of low traffic (CIV+EBAR and WBAR), medium traffic (NIZ and SAV) and high traffic (TOU and LIGA).

Table 3. Analysis of traffic intensity measured on the absence/random datasets (number of vessels counted in random locations in the absence of cetacean sightings) along the six transects. N: number of records in each dataset; results of Kolmogorov-Smirnov test between each pair (Bonferroni correction, significant values for $p \leq 0.003$) and 95th percentile values.

Transects absence/random datasets	NIZ	SAV	LIGA	CIV+EBAR	WBAR	95th percentile
TOU (N=57)	**0.003**	**0.002**	0.010	**0.000**	**0.000**	52.8
NIZ (N=300)	-	0.342	**0,000**	**0.000**	**0.000**	10
SAV (N=287)		-	**0.000**	**0.002**	**0.000**	9.7
LIGA (N=92)			-	**0.000**	**0.000**	10.45
CIV+EBAR (N=347)				-	**0.000**	4
WBAR (N=143)					-	3

On the basis of these groups of transects, we considered the percentage difference between the numbers of ships in the presence and absence of cetacean sightings in the different traffic areas (Table 4). Fin whale showed results fairly in line with traffic intensity: the highest negative difference was detected in high traffic areas, while minimum values emerged in low traffic areas. The only exception was reported in NIZ where no difference in mean values was observed. For striped dolphin, we recorded a general difference in the datasets with respect to the levels of traffic: the highest negative difference was recorded in LIGA, while it was lower in the other transects. Results for sperm whale pointed out a major mean negative difference of vessel numbers in sighting locations compared to random locations in a high traffic transect (TOU). Conversely, the greatest difference for Cuvier's beaked whale was reported in a low traffic transect (CIV+EBAR). Bottlenose dolphin showed similar results only in medium traffic areas.

Table 4. Traffic intensity and cetacean species. For each transect: 95th percentile values of the absence datasets (number of vessels counted in random locations in the absence of cetacean sightings). For each species: percentage differences between the number of vessels counted in the presence and absence of cetacean sightings (ns = not significant). Species: fin whale (Bp), striped dolphin (Sc), sperm whale (Pm), Cuvier's beaked whale (Zc), bottlenose dolphin (Tt).

		Absence/Random	**Bp**	**Sc**	**Pm**	**Zc**	**Tt**
HIGH TRAFFIC	*% difference*	**TOU**	-83%	ns	-79%	-	-
	95th percentile	52.8					
	% difference	**LIGA**	-46%	-55%	-	-	-
	95th percentile	10.45					
MEDIUM TRAFFIC	*% difference*	**NIZ**	0%	-19%	ns	-	ns
	95th percentile	10					
	% difference	**SAV**	-35%	ns	ns	ns	ns
	95th percentile	9.7					
LOW TRAFFIC	*% difference*	**CIV+EBAR**	-10%	-39%	-	-36%	-
	95th percentile	4					
	% difference	**WBAR**	-12%	-26%	-	-	-
	95th percentile	3					

Discussion

Maritime traffic is one of the main recognised threats that affects cetacean populations (Notarbartolo di Sciara and Birkun, 2010). Shipping can have direct and indirect effects on species, causing reactions at an individual level (e.g. short-term changes in behaviour) or at a population level (e.g. long-term changes in distribution or in migration timing) (David, 2002). Direct physical injuries due to collisions are reported all over the world and, according to Panigada et al. (2006) and Carrillo and Ritter (2010), are known to occur recurrently in the Mediterranean basin. However, direct information on the effect of this potential threat on cetacean species in high sea areas is still lacking.

General results of this study showed that in high sea areas during summer months, vessel abundance was significantly lower in correspondence with cetacean sightings. Notably, the large amount of data of this study is consistent in showing a lower number of ships where cetacean sightings occurred with respect to the number of vessels observed in locations randomly sampled all throughout the transects. This difference emerged at all analysed levels (i.e. all species, single species, all transects, single transect), being also statistically significant in most of the cases, indicating not accidental results.

The monitored transects are along some of the main shipping routes covering large and variable regions with different traffic intensity and different degrees of habitat suitability for cetaceans. Additionally, cetacean presence and distribution varies with the species and varies annually, and total sightings during the whole study period were recorded almost all throughout the surveyed transects. Thus, our data provided representative and synoptic information on the variability of cetacean and shipping distribution in the areas crossed.

Excluding that the observed pattern is due to an active displacement by the ships in cetacean presence, our results might have been enhanced in some cases by an independent segregation among rich areas for cetaceans and main shipping routes. On the other hand, in particular where and when high traffic areas overlap with cetacean favourable areas, it is likely that our findings represent a negative response of the animals towards vessel presence, even if the study design doesn’t allow to test if a direct cause-effect relationship exists. For example, animals could tend to avoid more impacted portions with small-scale displacements by looking for patches with relatively fewer vessels, or perform larger scale changes in distribution to occupy low traffic areas. Furthermore, as an alternative short-term response to disturbance, some species could also increase diving activity where intense traffic occurs (more pseudo-absence), resulting in both cases in a lower number of vessels in locations of sightings. Information on maritime traffic intensity (David et al., 2011; Vaes and Druon, 2013; AIS data from Marinetraffic.com), in coherence with our data, identifies two main regions of high traffic: the Ligurian-Provençal basin and the northern

Tyrrhenian Sea in opposition to the Sardinian and Balearic Seas covering the widest range of this study. The intensity of the response of cetaceans appeared rather related to the intensity of traffic, but with relevant differences among areas and species. This suggests that several factors are probably involved in defining the priorities of each species which are likely dependent upon a combination of specific ecological needs and local environmental conditions.

Fin whale showed negative responses generally related to traffic intensity with the only exception occurring in NIZ in the central part of the Ligurian Sea. This exception could be driven by ecological reasons as the area is known to be a favourable summer feeding ground where the species is present for primary feeding reasons (Forcada et al., 1996; Notarbartolo di Sciara et al., 2008; Druon et al., 2012) and turns out in a coexistence with traffic pressure or, as suggested by David (2002), in a sort of "familiarity" with naval traffic for this area.

Interestingly, striped dolphin also showed negative responses in many of the transects, even without a clear relationship with traffic intensity. Striped dolphin is the most frequent species observed within our study, is known to be common in the study area in the summer (Gannier, 2005; Azzellino et al., 2008; Panigada et al., 2011; Arcangeli et al., 2014b) and is often sighted approaching ships (Angradi et al., 1993; Marini et al., 1996). However, possibly due to their high mobility skills and opportunistic behaviour, these animals can probably actively distribute along the transects in patches with a relatively lower presence of vessels. The negative response to traffic was indeed recorded in all areas except for TOU and SAV where, perhaps, feeding priority could have brought the animals, as with fin whales in NIZ, to also occupy portions with high traffic impacts.

Results on sperm whale and Cuvier's beaked whale showed different responses to nautical traffic depending upon the transects analysed. In the Ligurian Sea, the number of ships recorded in the presence and absence of sightings was not different for both species. This can probably be related to the availability of suitable habitats: in this basin, sperm and Cuvier's beaked whale have their feeding grounds and preferred habitats linked to the slopes and submarine canyons (MacLeod and Mitchell, 2004; Moulins et al., 2007; Azzellino et al., 2008; Tepsich et al., 2014) which are confined in very specific areas and are in some cases very close to the coast and ports. Therefore, the species' typical niches seem to overlap with quite heavy traffic areas. Conversely, both species showed a negative response towards traffic in the other two transects where they were recorded (i.e. CIV+EBAR in the central

Tyrrhenian Sea for Cuvier's beaked whale; TOU in the Provençal basin for sperm whale). Sperm whales are generalist feeders in the Mediterranean Sea which explains their wide distribution over both continental and offshore waters (Gannier et al., 2002). The complex system of coastal upwelling, vertical mixing, and westward drift of the Provençal basin induces a wide dispersal of resources (Millot, 1987) that potentially allow sperm whales to move through the TOU transect in portions with fewer ships. Cuvier's beaked whales are indeed a more specialised animals with a more residential behaviour and high fidelity to areas with well-defined characteristics (Moulins et al., 2007; Tepsich et al., 2014). However in the central Tyrrhenian Sea, the availability of diverse roughly suitable habitats in this complex bathymetry could have allowed Cuvier's beaked whales to modify its range in order to exploit less disturbed portions. This interpretation is coherent with one of the hypotheses formulated for explaining the change in habitat use recorded in this region during recent years compared to beginning of the '90s (Arcangeli et al., 2015).

Bottlenose dolphin was the only species showing no response towards nautical traffic. Being a coastal species, it is surely more used to sharing its typical habitat with maritime traffic so that, when sighted offshore, it responds differently compared to pelagic species. This result doesn't mean that animals are not disturbed by vessels. Most likely, the species is generally unable to change habitat preference by moving away from coastal areas and uses playing other behavioural responses to balance human disturbance (e.g. Janik and Thompson, 1996; Novacek et al., 2001; Bejder et al., 2006b; Arcangeli and Crosti, 2009; Papale et al., 2012; La Manna et al., 2013). These kinds of short-term alterations, even at individual level, may also arise in other species where we found a correspondence with the high presence of ships and animals (deep-sea divers and fin whales in the Ligurian Sea and striped dolphins in TOU and SAV). However, these compensative behaviours of tolerance influence activity budgets and energetic demands and may be ineffective when the disturbance is prolonged over time, leading to negative effects at population level (Jahoda et al., 2003; Bejder et al., 2006a; Williams et al., 2006).

Pelagos Sanctuary

The four transects crossing the Pelagos Sanctuary revealed different situations in terms of naval traffic and species responses. In the central part of the protected area (NIZ and SAV), we recorded medium traffic levels and minor differences in terms of the abundance of vessels for many species (sperm and fin whales in NIZ, striped dolphin, sperm and Cuvier's beaked whales in SAV). In this basin, they exploit well-known feeding grounds (Azzellino et al., 2008; Tepsich et al., 2014), but evidently do so under traffic pressure. The south-eastern part of the Sanctuary (LIGA) is a narrow and partially pelagic area where nautical routes are also compelled and thus high trafficked. We recorded negative responses by fin whale and striped dolphin which supports the hypothesis of traffic disturbance on these species. Additionally, this area is probably used by fin whale more for latitudinal displacements (as suggested by Marini et al., 1996) than for specific habitat requirements, which allows the species to move in the less disturbed portions. In the western region of the Sanctuary where the greatest shipping movements were registered (TOU), large whales are sighted in the less impacted locations. This is likely due to the dispersed resources available through the complex water circulation of this basin (Millot, 1987; Gannier et al., 2002) that potentially allow the animals to use portions with fewer ships. On the basis of these results, it is evident that the variability of both ecological aspects and potential threats within a large pelagic basin call for an integrated study, also outside the limit of the protected area, to improve the effectiveness of the management plans for the area (Notarbartolo di Sciara et al., 2008).

Conclusions

Based on a wide dataset, outcomes of the study showed that, during the summer months, all cetacean species of pelagic habitats are generally observed in locations with relatively lower vessel abundance. The consistent results obtained, regardless the species and the area analysed, cannot be easily explained by just considering a segregation among high density areas for vessels and for cetaceans. This suggests that a negative response of the animals towards vessel presence exists, in coherence with information gathered from literature, even without demonstrating a direct cause-effect relationship. The intensity of animals' responses varies from area to area and it is probably determined by a combination of factors in relationship with ecological priorities linked to the species and the intensity of the pressures. In fact, most exceptions in our results are found where the species have well-known ecological requirements, as is the case for Cuvier's beaked whale and sperm whale in the central Pelagos Sanctuary where the suitable habitats are very confined, or for fin whale that concentrate during the summer in the Ligurian Sea (and, to a lesser extent, in the central Tyrrhenian Sea) for essential feeding needs that have a high priority compared to the costs of disturbance by maritime traffic.

The approach of this research helped to have for the first time a wide vision of the different responses of animals towards a common pressure. Potential conservation/mitigation measures to limit the impact nautical traffic on cetaceans are under discussion and vary according to the disturbance and ship categories; in particular, to avoid ship strikes, recommendations have already been suggested, including spatial planning to reduce overlap between shipping routes and important areas for single/multiple species (Firestone, 2009; David et al., 2011; Redfern et al., 2013), the use of an effective early warning system to highlight risk zones (Panigada et al., 2006), increasing awareness among crews or placing dedicated look-outs on fast-moving vessels (Carrillo and Ritter, 2010; David et al., 2011) and implementing speed restrictions (Laist et al., 2001; Firestone, 2009; Silber et al., 2010).

Outcomes of this study showed that the overlap between the intensity of traffic and hotspots for main cetacean species is not enough for the definition of risky areas and also depends on the balance among prior biological needs of the species, habitat characteristics and intensity of the pressure; so caution must be taken when applying information obtained from one situation to others. Moreover, as also indicated by Gill et al. (2001), the intensity of the response of a species to disturbance is not a direct indication of its vulnerability: a stronger response may in fact indicate the possibility that the animals can change areas by moving to less impacted regions, still featuring adequate ecological conditions. Conversely, animals living under pressure can reduce the disturbance by applying short-term behavioural changes, but probably having negative effects over a longer period. In any case, the presence of high shipping activities may lead to changes in the local cetacean populations over time.

More information is also needed on cetaceans' response towards the different types of nautical pressures including responses to different vessel categories and responses in other seasons when species are in different biological conditions. This would enhance the knowledge on the potential impacts and drive the definition of effective conservation/mitigation measures. Additionally, long-term and large-scale studies are crucial for detecting variations in cetacean distribution and abundance and can help to monitor the effects of potential conservation actions over time.

References

Aguilar Soto, N., Johnson, M., Madsen, P.T., Tyack, P.L., Bocconcelli, A., Borsani, J.F., 2006. Does intense ship noise disrupt foraging in deep-diving Cuvier's beaked whale (*Ziphius cavirostris*)? Marine Mammal Science 22, 690-699.

Angradi, A.M., Consiglio, C., Marini, L., 1993. Behaviour of striped dolphins (*Stenella coeruleoalba*) in the central Tyrrhenian Sea in relation to commercial ships. European Research on Cetaceans 7, 77-79.

Arcangeli, A., Crosti, R., 2009. The short-term impact of dolphin-watching on the behaviour of bottlenose dolphins (*Tursiops truncatus*) in Western Australia. Journal of Marine Animals and Their Ecology 2(1), 3-9.

Arcangeli, A., Orasi, A., Carcassi, S.P., Crosti, R., 2014a. Exploring thermal and trophic preference of *Balaenoptera physalus* in the central Tyrrhenian Sea: a new summer feeding ground? Marine Biology 161, 427–436.

Arcangeli A., Cominelli S., David l., Di-Méglio N., Moulins A., Mayol P., Marini L., Rosso M., Tepsich P., 2014b. Seasonal monitoring of cetaceans and validation of the system REPCET in terms of monitoring. Scientific Report Port-Cros natl. Park 28, 37-48.

Arcangeli, A., Aissi, M., Aragno, P., Atzori, F., Azzolin, M., Baccetti, N., Campana, I., Castelli, A., Cerri, F., Crosti, R., David, L., Di-Méglio, N., Frau, F., Lippi, S., Luperini, C., Maffucci, F., Marini, L., Moulins, A., Paraboschi, M., Pellegrino, G., Ruvolo, A., Tepsich, P., Tringali, M., 2014c. Cetaceans, marine birds, sea turtles, marine traffic and floating marine litter: potential of a synoptic multi-disciplinary data collection in the Western Mediterranean marine region. Biologia Marina Mediterranea 21(1), 366-368.

Arcangeli, A., Campana, I., Marini, L., MacLeod, C.D., 2015. Long-term presence and habitat use of Cuvier's beaked whale (*Ziphius cavirostris*) in the central Tyrrhenian Sea. Marine Ecology (in press).

Azzellino, A., Gaspari, S., Airoldi, S., Nani, B., 2008. Habitat use and preferences of cetaceans along the continental slope and the adjacent pelagic waters in the western Ligurian Sea. Deep-Sea Research I 55, 296–323.

Bejder, L., Samuels, A., Whitehead, H., Gales, N., Mann, J., Connor, R., Heithaus, M., Watson-Capps, J., Flaherty, C., Krützen, M., 2006a. Decline in relative abundance of bottlenose dolphins exposed to long-term disturbance. Conservation Biology 20(6), 1791–1798.

Bejder, L., Samuels, A., Whitehead, H., Gales, N., 2006b. Interpreting short-term behavioural responses within a longitudinal perspective. Animal Behaviour 72, 1149-1158.
Carrillo, M., Ritter, F., 2010. Increasing numbers of ship strikes in the Canary Islands: proposals for immediate action to reduce risk of vessel-whale collisions. Journal of Cetacean Research and Management 11(2), 131-138.
Castellote, M., Clark, C.W., Lammers, M., 2012. Acoustic and behavioural changes by fin whales (*Balaenoptera physalus*) in response to shipping and airgun noise. Biological Conservation 147, 115–122.
Crosti, R., Arcangeli, A., Moulins, A., Tepsich, P., Tringali, M., 2011. Cetacean and maritime traffic in deep sea waters, a relation to avoid? Biologia Marina Mediterranea 18(1), 178-179.
David L., 2002. Disturbance due to the intensity of sea traffic, in: Notarbartolo di Sciara, G. (Ed.), Cetaceans of the Mediterranean and Black seas, state of knowledge and conservation strategies. A report to the Interim Secretariat of ACCOBAMS, pp. 108-127.
David, L., Alleaume, S., Guinet, C., 2011. Evaluation of the potential of collision between fin whales and maritime traffic in the north-western Mediterranean Sea in summer, and mitigation solutions. Journal of Marine Animals and Their Ecology 4(1), 17-28.
Druon, J.N., Panigada, S., David, L., Gannier, A., Mayol, P., Arcangeli, A., Cañadas, A., Laran, S., Di-Méglio, N., Gauffier, P., 2012. Potential feeding habitat of fin whales in the western Mediterranean Sea: an environmental niche model. Marine Ecology Progress Series 464, 289-306.
EC, 1992. Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora. Commission of the European Communities, Brussels.
EC, 2004. Motorways of the Sea, Implementation through Article 12a TEN-T. Consultation document dated 30 July 2004. Commission of the European Communities, Brussels.
Firestone, J., 2009. Policy considerations and measures to reduce the likelihood of vessel collisions with great whales. Boston College Environmental Affairs Law Review 36, 389-400.
Forcada, J., Aguilar, A., Hammond, P., Pastor, X., Aguilar, R., 1996. Distribution and abundance of fin whales (*Balaenoptera physalus*) in the western Mediterranean sea during the summer. Journal of Zoology 238, 23−34.

Gannier, A., 2002. Summer distribution of fin whales (*Balaenoptera physalus*) in the north-western Mediterranean Marine Mammals Sanctuary. Revue d'Ecologie (Terre et Vie) 57, 135–150.

Gannier, A., 2005. Summer distribution and relative abundance of delphinids in the Mediterranean Sea. Revue d'Ecologie (Terre et Vie) 60(3), 223-238.

Gannier, A., Drouot, V., Goold, J.C., 2002. Distribution and relative abundance of sperm whales in the Mediterranean Sea. Marine Ecology Progress Series 243, 281–293.

Geijer, C.K., Jones, P.J., 2015. A network approach to migratory whale conservation: are MPAs the way forward or do all roads lead to the IMO? Marine Policy 51, 1–12.

Gill, J.A., Norris, K., Sutherland, W.J., 2001. Why behavioural responses may not reflect the population consequences of human disturbance. Biological Conservation 97, 265-268.

Hammer, Ø., Harper, D.A.T., Ryan, P.D., 2001. PAST: Paleontological statistics software package for education and data analysis. Palaeontologia Electronica 4(1), 9pp.

Jahoda, M., Lafortuna, C.L., Biassoni, N., Almirante, C., Azzellino, A., Panigada, S., Zanardelli, M., Notarbartolo di Sciara, G., 2003. Mediterranean fin whale's (*Balaenoptera physalus*) response to small vessels and biopsy sampling assessed through passive tracking and timing of respiration. Marine Mammal Science 19(1), 96-110.

Janik, V.M., Thompson, P., 1996. Changes in surfacing patterns of bottlenose dolphin in response to boat traffic. Marine Mammal Science 12(4), 597-602.

Laist, D.W., Knowlton, A.R., Mead, J.G., Collet, A.S., Podestà, M., 2001. Collisions between ships and whales. Marine Mammal Science 17(1), 35-75.

La Manna, G., Manghi, M., Pavan, G., Lo Mascolo, F., Sarà, G., 2013. Behavioural strategy of common bottlenose dolphins (*Tursiops truncatus*) in response to different kinds of boats in the waters of Lampedusa Island (Italy). Aquatic Conservation: Marine and Freshwater Ecosystems 23, 745–757.

Laran, S., Gannier, A., 2008. Spatial and temporal prediction of fin whale distribution in the north-western Mediterranean Sea. ICES Journal of Marine Science 65, 1260–1269.

MacLeod, C.D., Mitchell, G., 2006. Key areas for beaked whales worldwide. Journal of Cetacean

Research and Management 7, 309–322.

Marinetraffic.com, 2014. Live ship maps, AIS vessel traffic and position http://www.marinetraffic.com/ais/

Marini, L., Consiglio, C., Angradi, A.M., Catalano, B., Sanna, A., Valentini, T., Finoia, M.G., Villetti, G., 1996. 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.

Millot, C., 1987. Circulation in Western Mediterranean Sea. Oceanologica Acta 10(2), 143–150.

Monestiez, P., Dubroca, L., Bonnin, E., Durbec, J.P., Guinet, C., 2006. Geostatistical modelling of spatial distribution of *Balaenoptera physalus* in the North-western Mediterranean Sea from sparse count data and heterogeneous observation efforts. Ecological Modelling 193, 615–628.

Moulins, A., Rosso, M., Nani, B., Wurtz, M., 2007. Aspects of the distribution of Cuvier's beaked whale (*Ziphius cavirostris*) in relation to topographic features in the Pelagos Sanctuary (northwestern Mediterranean Sea). Journal of the Marine Biological Association of the United Kingdom 87, 177–186.

Notarbartolo di Sciara, G., Agardy, T., Hyrenbach, D., Scovazzi, T., Van Klaveren, P., 2008. The Pelagos sanctuary for Mediterranean marine mammals. Aquatic Conservation: Marine and Freshwater Ecosystems 18, 367−391.

Notarbartolo di Sciara, G., Birkun, A.Jr., 2010. Conserving whales, dolphins and porpoises in the Mediterranean and Black Sea: an ACCOBAMS status report. ACCOBAMS, Monaco.

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

Panigada, S., Pesante, G., Zanardelli, M., Capoulade, F., Gannier, A., Weinrich, M.T., 2006. Mediterranean fin whales at risk from fatal ship strikes. Marine Pollution Bulletin 52, 1287–1298.

Panigada, S., Lauriano, G., Burt, L., Pierantonio, N., Donovan, G., 2011. Monitoring winter and summer abundance of cetaceans in the Pelagos Sanctuary (northwestern Mediterranean Sea) through aerial surveys. PLoS ONE 6(7), e22878. doi:10.1371/journal.pone.0022878

Papale, E., Azzolin, M., Giacoma, C., 2012. Vessel traffic affects bottlenose dolphin (Tursiops truncatus) behaviour in waters surrounding Lampedusa Island, south Italy. Journal of the Marine Biological Association of the United Kingdom 92(8), 1877-1885.

Redfern, J.V., McKenna, M.F., Moore, T.J., Calambokidis, J., Deangelis, M.L., Becker, E.A., Barlow, J., Forney, K.A., Fiedler, P.C., Chivers, S.J., 2013. Assessing the risk of ships striking large whales in marine spatial planning. Conservation Biology 27(2), 292-302.

Ritter, F., 2012. Collisions of sailing vessels with cetaceans worldwide: first insights into a seemingly growing problem. Journal of Cetacean Research and Management 12(1), 119-127.

Silber, G.K., Slutsky, J., Bettridge, S., 2010. Hydrodynamics of a ship/whale collision. Journal of Experimental Marine Biology and Ecology 391(1), 10-19.

Tepsich, P., Rosso, M., Halpin, P.N., Moulins, A., 2014. Habitat preferences of two deep-diving cetacean species in the northern Ligurian Sea. Marine Ecology Progress Series 508, 247–260.

Tyack, P.L., Zimmer, W.M.X., Moretti, D., Southall, B.L., Claridge, D.E., Durban, J.W., Clark, C.W., D’Amico, A., Di Marzio, N., Jarvis, S., McCarthy, E., Morrissey, R., Ward, J., Boyd, I.L., 2011. Beaked whales respond to simulated and actual navy sonar. PLoS ONE 6(3), e17009. doi:10.1371/journal.pone.0017009

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.

Vaes, T., Druon, J.N., 2013. Mapping of potential risk of ship strike with fin whales in the Western Mediterranean Sea. JRC Institute for Protection and Security of the Citizen, Luxembourg.

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

CH. 5 Assessment of the fixed line transects method for being used for legislative and conservation purposes.

Arcangeli A., Aissi M., Aragno P., Atzori F., Azzolin M., Baccetti N., Campana I., Castelli A., Cerri F., Cinti F., Crosti R., David L., Di Meglio N., Frau F., Lippi S., Luperini S., Maffucci F., Marini L., Moulins A., Paraboschi M., Pellegrino G., Ruvolo A., Tepsich P., Tringali M. (2014). Cetacean, marine birds, sea turtle, marine traffic and floated marine litter: potential of a synoptic multi-disciplinary data collection in the Western Mediterranean Marine Region. Biol.Mar.Med. 21 (1): 366-368.

Biol. Mar. Mediterr. (2014), 21 (1): 366-368

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CETACEI, UCCELLI PELAGICI, TARTARUGHE MARINE, TRAFFICO MARITTIMO E RIFIUTI MARINI GALLEGGIANTI: POTENZIALITÀ DI UNA RACCOLTA DATI SINOTTICA MULTIDISCIPLINARE NELLA REGIONE MARINA DEL MEDITERRANEO OCCIDENTALE

CETACEANS, MARINE BIRDS, SEA TURTLES, MARINE TRAFFIC AND FLOATED MARINE LITTER: POTENTIAL OF A SYNOPTIC MULTI-DISCIPLINARY DATA COLLECTION IN THE WESTERN MEDITERRANEAN MARINE REGION

***Abstract** - Ecology studies and nowadays legislative framework ask for an ecosystem based approach in order to understand and manage the environmental complexity for conservation purpose. An interdisciplinary approach for collecting data on different taxa and potential pressures are experimented in the Mediterranean Sea by a network of scientific organizations. Preliminary results show the potential for a better understanding of key and sensitive (high risk) areas for biodiversity.*

***Key-words:** cetaceans, marine traffic, marine litter, multidisciplinary monitoring, Mediterranean region.*

Introduzione - Il quadro normativo in materia di conservazione dell'ambiente marino sottolinea la necessità di un approccio ecosistemico per gestire in maniera efficace le complesse interazioni fra componenti ambientali ed antropiche. La rete di monitoraggio su transetti fissi che utilizza i traghetti come piattaforma di osservazione è stata realizzata a partire dal 2007 per il monitoraggio dei cetacei. Nel tempo è stata sfruttata l'opportunità di una raccolta dati sinoptica su diversi taxa (cetacei, uccelli e tartarughe marine) e di alcune fra le principali pressioni che hanno un impatto sulla biodiversità marina (traffico marittimo, *macro-litter* galleggiante).

Materiali e metodi - Osservatori dedicati si imbarcano 2-4 volte al mese effettuando le osservazioni dal ponte comando dei traghetti di linea. Il monitoraggio dei cetacei viene effettuato secondo il protocollo ISPRA (Arcangeli, 2010). Il monitoraggio degli uccelli marini viene realizzato dagli osservatori del COT (Centro Ornitologico Toscano) lungo la tratta Livorno-Bastia secondo il protocollo ESAS (European Seabirds at Sea, Camphuysen e Garthe, 2004). Il monitoraggio del *macro-litter* galleggiante viene realizzato secondo il protocollo sperimentale definito da Università di Pisa, Accademia del Leviatano e ISPRA che prevede la registrazione di tutti gli oggetti maggiori di 25 cm registrati da un osservatore dedicato all'interno di una striscia impostata a priori ≤100 m di larghezza a lato nave, con Beaufort ≤2 (Luperini *et al.*, 2013). Questo protocollo è stato validato, in collaborazione con la Stazione Zoologica Anton Dohrn di Napoli, anche per il monitoraggio delle tartarughe marine.

Summary
Ecology studies and nowadays legislative framework ask for an ecosystem based approach in order to understand and manage the environmental complexity for conservation purpose. An interdisciplinary approach for collecting data on different taxa and potential pressures are experimented in the Mediterranean Sea by a network of scientific organizations. Preliminary results show the potential for a better understanding of key and sensitive (high risk) areas for biodiversity.

Introduction
The regulatory framework for the conservation of marine environment calls for the need for an ecosystem approach to effectively manage the interactions between both environment and anthropogenic components. The monitoring network of fixed transects, using ferries as a platform of observation, started in 2007 exclusively for the monitoring of cetaceans. Over time it has been increased the opportunity to undertake synoptic data collection on different taxa (e.g.cetaceans, birds and turtles) and on some of the main anthropogenic pressures that impact marine biodiversity (i.e. maritime traffic, floating macro-litter) in the Western Mediterranean Sea Region.

Materials and methods
Dedicated observers embark 2-4 times a month undertaking visual surveys from the command deck of ferry lines. Monitoring of cetaceans is undertaken according to the ISPRA protocol (Arcangeli, 2010) while monitoring of sea birds is undertaken by the observers of the COT (Centro Ornitologico Toscano) along the Livorno-Bastia according to the ESAS (European Seabirds at Sea) protocol (Camphuysen 2004). The monitoring of floating macro-litter is undertaken according to the experimental protocol designed by Pisa University, Accademia del Leviatano and ISPRA with a dedicated observer that records all objects larger than 20/25 cm within a strip set up "a priori" ≤100m wide, with Beaufort ≤2, with the strict assumption that any floating object larger than 20/25 cm passing in the strip is undoubtedly seen (Luperini et al., 2013); this protocol has been validated, also for the monitoring of sea turtles in collaboration with the Zoological Station Anton Dohrn.

Results
In 2014 the network monitored cetaceans along more than 1,700 nautical miles of transects distributed in the Weastern Mediterranean sea Region (Fig. 1). Monitoring of seabirds and cetaceans was undertaken

simultaneously along the Livorno-Bastia (34 detections, December 2009-December 2012). Preliminary results showed a different distribution of pelagic birds and cetaceans according to the area: the coastal area between 5 and 15 nautical miles from Livorno is preferred by bottlenose dolphin, yelkouan shearwater and scopoli' shearwater; important for striped dolphin, bottlenose dolphin and scopoli' shearwater are also the deep waters along the continental shelf north east of the island of Capraia; in pelagic areas between Capraia and Corsica occur mainly striped dolphin, yelkouan shearwater and yellow-legged gull.

Although valuation of findings based on data for *Caretta caretta* are still at a preliminary stage, they suggest an uneven distribution of the species in the Western and Central Mediterranean with a frequency of occurence much higher in the Sardinia Channel compared to higher latitudes (e.g. Civitavecchia and Barcelona). The monitoring of macro-litter floating was made on a trial along 3 routes. Preliminary results on the Civitavecchia-Barcelona showed the importance of the joint monitoring of cetaceans and marine macro-litter highlighting some risk areas with high concentrations of floating plastic and presence of squid eater species (the latter species are at greater risk of plastic ingestion) especially in the Central Tyrrhenian Sea, off the continental shelf just west of the Strait of Bonifacio and in the areas of continental slope east of the Spanish coast.

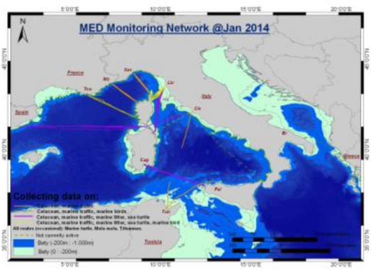

Fig.1 - Type of data collected (green: cetaceans, marine traffic,marine birds; pink: cetaceans, marine traffic, marine-litter, sea turtles; yellow: cetaceans, marine traffic, marine –litter, sea turtle, sea birds)

Conclusions

Given the need for information on a large scale and long-term both on different components of marine biodiversity and on potential impacts of pressures, the monitoring network, with dedicated observers on board of ferries, is as an effective tool to get synoptic information on several umbrella species and their main threats.

References

Arcangeli A. (2010) - ISPRA cetacean monitoring network along fixed transect. Biol. Mar. Mediterr., 17 (1): 400-401.

Camphuysen K., Garthe S. (2004) - Recording foraging seabirds at sea standardised recording and coding of foraging behaviour and multi-species foraging associations. Atlantic Seabirds 6 (1).

Luperini C., Arcangeli A., Castelli A. (2013) - Composition, spatial distribution and source of floating marine macro litter, in the Tuscan-Corsica marine ecosystem in the Pelagos Sanctuary, monitored along a transborder transect.

Arcangeli A., Azzolin M., Campana I., Castelli A, Luperini C., Marini L., Paraboschi M., Pellegrino G., Ruvolo A., Tringali M., Vetrugno A., Crosti R. Cetaceans at risk by plastic debris: a protocol for simultaneous monitoring of marine litter and marine mega-fauna. First results from the FLT Mediterranean monitoring network. Biol.Mar.Med (in press).

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CETACEI E PLASTICA: PRIMI RISULTATI DELLA RETE MEDITERRANEA DI MONITORAGGIO

CETACEANS AT RISK BY PLASTIC DEBRIS: FIRST RESULTS FROM THE FIXED LINE TRANSECT MEDITERRANEAN MONITORING NETWORK

Abstract *–Marine plastic debris is one of the main threat affecting cetaceans and other macro-fauna. A specific protocol was adapted by the Mediterranean network that monitors cetaceans using ferries as platform of observation allowing a complementary data collection on marine macro-litter. Since 2013, the protocol was applied along 5 fixed transects (2700 km monitored year-round) between Italy, France, Spain, Tunisia and Greece. Plastic was the main component of the marine litter, with highest density in Summer (2,53±0,5 items/km²); Kernel analysis revealed variation in distribution of plastic debris and the overlap with squid-eating species distribution.*

Key-words: *Cetacean, plastic debris, Mediterranean Sea.*

Introduction - Among cetaceans, toothed species are mostly affected by ingestion of plastic litter that can be confused with potential preys. Despite the legislative framework still few data are available in the Mediterranean basin on marine macro-litter and there is a lack of knowledge on sensitive areas where the potential damage to the biota is greater. Based on methodologies in use by international programs for monitoring of marine debris, a specific protocol was adopted by the FLT Mediterranean network (Arcangeli *et al.*, 2013) allowing a complementary data collection on marine mega-fauna and plastic debris (H03.03 Habitats Directive threats code). Preliminary results along the Civitavecchia-Barcelona transect allowed to detect risky areas due to the overlap of high plastic density and squid-eaters records.

Materials and methods - An experienced observer is positioned on one side of the vessel and makes the observation by the naked eye, using binoculars to confirm the sighting of debris bigger than 20-25 cm. Data are recorded on a handheld GPS (effort track and marked points) and on data sheets. At the beginning of the survey the width of the monitored strip is defined *a priori* (up to a maximum of 100m) based on the type of platform of observation, height, sea state (≤2 on the Beaufort scale) and visibility, assuming that all litter larger than 20-25 cm is detected. For each sighting, composition, source, buoyancy, dimensions are recorded. Within the strip, sea turtles and other macro-fauna is also recorded. Since 2013, the protocol was applied along 5 transects of the FLT Med Mon Network running between Italy, France, Spain, Tunisia and Greece (Fig. 1).

Summary
Marine plastic debris is one of the main threat affecting cetaceans and other macro-fauna. A specific protocol was adapted by the Mediterranean network that monitors cetaceans using ferries as platform of observation allowing a complementary data collection on marine macro-litter. Since 2013, the protocol was applied along 5 fixed transects (2700 km monitored year-round) between Italy, France, Spain, Tunisia and Greece. Plastic was the main component of the marine litter, with highest density in Summer (2,53±0,5 items/km^2); Kernel analysis revealed variation in distribution of plastic debris and the overlap with squid-eating species distribution.

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Results

The Civitavecchia-Barcelona transect was repeatedly surveyed from Sept. 2013 to Sept. 2014 along 22932 km on effort for cetacean monitoring (57 runs) and 3556 km for macro-litter monitoring (40 runs) (Fig. 1). We recorded 34 sightings of squid-eaters (10 *Z. cavirostris, Zc*; 21 *P. macrocephalus, Pm*; 3 *G. griseus, Gg*) and 774 items of litter (70% of plastic). The proportion of plastic items was higher in Autumn and Summer (>72%), lower in the others (<68%); plastic density was also significantly different throughout the year (Kruskal-Wallis p<0,05), rising from 0,58±0,2 items/km^2 (Autumn) to 2,53±0,5 items/km^2 (Summer). Kernel analysis revealed variation in distribution of plastic debris, highlighting areas of higher density in central Tyrrhenian Sea, Strait of Bonifacio and Spanish continental shelf (Fig. 1). Overlap of seasonal distribution of plastic and squid-eating species exposed some sensitive areas: central Tyrrhenian Sea for *Zc* (Spring/Summer), Sardinian Sea for *Pm* (Summer) and *Zc* (Autumn), along the Spanish shelf for *Gg* (Spring/Summer) and *Pm* (Winter/Summer).

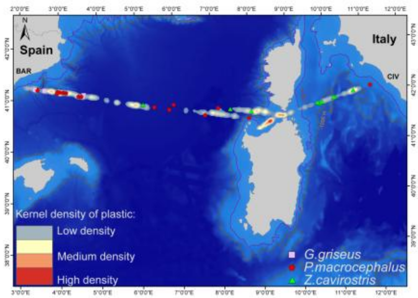

Fig. 1 Kernel density of plastic.

Conclusions

Results of the study highlight the importance of gathering simultaneous information on mega-fauna and potential threat at multi-annual scale necessary to confirm patterns. The information collected within this network, covering a wide area during all the seasons, will definitely be an important step to identify sensitive areas needing focused mitigation measures.

References

Arcangeli a., castelli a., marini l., moulins a., paliaga b., tepsich p., tringali m. (2013) - A cooperative programme for cetacean monitoring over the Mediterranean Sea: the example of the fixed transects monitoring network. Biol. Mar. Mediterr., 20 (1), 254-255.

M.F. Cinti , F. Atzori, F. Frau , S. Corrias , S. Lippi, R. Ghiani, S. Donati [1], A. Arcangeli[2,3] Monitoring marine species (Cetacean, Sea Turtle) in the Sardinia Channel connecting Marine Protected Areas Biol. Mar. Mediterr. (2014), 21 (1): 371-372

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M.F. Cinti, F. Atzori, F. Frau, S. Corrias, S. Lippi,
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MONITORAGGIO DELLE SPECIE MARINE (CETACEI, TARTARUGHE MARINE) NEL CANALE DI SARDEGNA ATTRAVERSO UNA RETE DI AREE MARINE PROTETTE

MONITORING MARINE SPECIES (CETACEAN, SEA TURTLE) IN THE SARDINIA CHANNEL CONNECTING MARINE PROTECTED AREAS

***Abstract** - Despite the ecological importance of the Sardinia Channel, between Sardinia and Sicily, little information is available on the marine species living or migrating in these waters. A monitoring programme was conducted between the two Marine Protected Areas at the two border of the channel (Capo Carbonara and Egadi MPAs) during summer 2013. Results highlight the importance of the area, especially for some migratory cetacean species, e.g.* Physeter macrocephalus *and sea turtles. The programme also constitute an example of connection between Marine Protected Areas to enhance the knowledge at a broader scale so to be used for conservation purposes.*

***Key-words:** marine parks, migratory species, biodiversity, high seas.*

Introduzione - Uno dei principali obiettivi istituzionali delle Aree Marine Protette è quello di mantenere la biodiversità, focalizzando l'attenzione non solo entro i confini dell'area protetta, ma anche nelle aree limitrofe. La stessa Strategia Marina prevede che vengano adottate misure di protezione spaziale che contribuiscano ad istituire reti coerenti e rappresentative di zone marine protette. L'Area Marina Protetta di Capo Carbonara (AMPCC), all'interno del network di monitoraggio coordinato da ISPRA nel Mediterraneo (Arcangeli, 2010), ha attivato uno studio nel Canale di Sardegna, fra l'AMPCC e l'AMP Isole Egadi. Ad oggi infatti, nonostante l'importanza strategica di questo tratto di mare, sono disponibili poche informazioni sulla presenza e distribuzione di cetacei e tartarughe marine al di fuori delle acque costiere.

Materiali e metodi - Il monitoraggio è stato condotto nel periodo compreso tra giugno e ottobre 2013, con osservatori esperti presenti sul ponte di comando del traghetto Dymonios della società di navigazione Tirrenia CIN. Per la raccolta dei dati è stato applicato il protocollo redatto dall'ISPRA "*Fixed line transect using ferries as platform of observation*" (ISPRA, 2012) attraverso osservazioni visive su transetto lineare coincidente con la tratta Cagliari-Trapani. Durante la navigazione sono stati registrati sistematicamente: dati meteo-marini, di origine antropica (traffico marittimo, rifiuti marini), presenza di cetacei, tartarughe e altre specie marine di interesse (*Mobula mobular, Thunnus* spp.). Sono stati elaborati il tasso di incontro (ER=avvistamenti/100 Km on effort) e la dimensione media del gruppo per ciascuna specie; l'analisi spaziale è stata eseguita in ArcGIS 10.1. applicando il metodo di Kernel, con celle della griglia pari a 5×5 Km.

Summary
Despite the ecological importance of the Sardinia Channel, between Sardinia and Sicily,little information is available on the marine species living or migrating in these waters. A monitoring programme was conducted between the two Marine Protected Areas at the two border of the channel (Capo Carbonara and Egadi MPAs) during summer 2013. Results highlight the importance of the area, especially for some migratory cetacean species, e.g. *P.macrocephalus* and sea turtles. The programme also constitute an example of connection between Marine Protected Areas to enhance the knowledge at a broader scale so to be used for conservation purposes.

Introduction
One of the main purpose for the establishment of MPAs is the conservation of the biodiversity, focusing not only within the legislative boundaries of the area but also in the adjacent zones. One of the Italian targets of the MSFD to reach the GES for Biodiversity, for example, is the increase of a well connected systems of marine protected areas. Taking this into consideration, the Capo Carbonara MPA, within the Mediterranean monitoring network coordinated by ISPRA (Arcangeli, 2010), started a research in the Sardinian Channel between Capo Carbonara (in Sardinia) and Isole Egadi (in Sicily) MPAs. Nowadays, in fact, notwithstanding the strategic importance of the Channel for the conservation of biodiversity, just few are the information available on presence of cetaceans and turtles off coastal waters.

Materials and methods
The monitoring was undertaken between June and October 2013, with expert observers located on the command deck of the Dymonios ferry of the Tirrenia CIN shipping company. Data were acquired according to the ISPRA protocol “Fixed line transect using ferries as platform of observation” (ISPRA, 2012) with visual surveys along the transect Cagliari (Sardinia) –Trapani (Sicily). During navigation were systematically recorded: meteo, anthropogenic factors (i.e. maritime traffic and marine litter), presence of cetaceans and turtles and other species of interest (e.g. *M.mobular*, *Thunnus* spp.). Encounter rate (ER=sightings/100km on effort) and average group size were produced; Kernel Density Estimation (KDE) and spatial analysis on a 5x5km cell grid were performed.

Results
The transect was repeatedly sampled 14 times, 1,257 NM, in good weather conditions, were systematically monitored with a total ER of

1,41±0,39 sightings per 100 km of survey. Preliminary results confirm the presence of striped dolphin (*S.coeruleoalba*) (ER=0,54±0,17), sperm whale (*P.macrocephalus*) (ER=0,15±0,12), bottlenose dolphin (*T.truncatus*) (ER=0,1±0,05); also scattered sightings of Risso's Dolphin (*G.griseus*) and short-beaked common dolphin (*D.delphis*) occurred. Interestingly, fin whale was never sighted. Striped dolphin average group size was 13,2 individuals with most of the sightings occurring in the complex bathymetry in the southern eastern area of the Channel. Sperm whale sightings occurred on the steep areas south of the Capo Carbonara MPA, where in June 2013 a pod of six individuals with a calf was recorded. Bottlenose dolphin was sighted in small groups (average=2,67) nearby the coastlines of both Regions. Important findings were the high frequency of occurrence of the marine turtle *C.caretta* (ER=4,7±0,14) recorded along all the transect and some sporadic sightings of *T.thynnus* and *M.mobular*.

Conclusions

Results show that the cetacean encounter rate values along the sample transect in the Sardinian Channel in the summer season are similar to the ones recorded for the same season in the Pelagos Sanctuary (Arcangeli et al., 2013). Noteworthy, during the 2013 survey period, was the presence of a sperm whale family group, the absence of fin whale sightings and the high frequency of occurrence of *C.caretta*. Overall results confirm the importance of the study area and of the research to increase the knowledge of the marine biodiversity in the area.

References

ARCANGELI A. (2010) - Rete ISPRA di monitoraggio dei cetacei da transetto fisso in Tirreno e Mar Ligure. *Biol. Mar. Mediterr.*, **17** (1): 400-401.

Arcangeli A., David L., Di Meglio N., Moulins A., Mayol P., Marini L., Rosso M., Tepsich P., Castelli A., Paliaga P., Tringali M. (2013) - Meeting the needs for conservation: a network of cetacean monitoring in the Mediterranean Sea. *Rapp. Comm. int. Mer Medit.,* **40**: 609.

ISPRA (2012) - *Fixed line transect using ferries as platform of observation monitoring protocol*. Allegato tecnico della convenzione quadro per lo svolgimento di attivita di '*Fixed line transect using ferries as platform of observation for monitoring cetacean populations*': 11 pp.

Arcangeli A, Fixed Line Transect MED Monitoring Network. Extended abstract of the presentation at the ECMC WS on "Developing analytical protocols to assess trends in cetacean populations from structured surveillance data collected on ferries". ECS WS 22 March 2015.

Summary

Cetaceans are wide-ranging long-lived mobile marine species, living mostly in pelagic waters. Threats can have an impact at individuals level as well as on population size and/or distribution. Consistent long-term large-scale population monitoring is therefore needed for defining and monitoring the effectiveness of conservation measures. Nevertheless, monitoring programmes deal with limited resources, affecting repeatability and spatial extent of surveys, and with consistency among data collected. A collaborative programme based on a standard protocol was established in the Mediterranean sea since 2007. Almost 20 scientific organisations and 5 ferry companies are involved in the programme, monitoring all cetacean species along fixed transects using ferries as research platform. Since the beginning, the programme increased from almost 300km up to a network of almost 3700 km of fixed transects distributed in the all Mediterranean basin and monitored on a monthly basis (1-4 surveys/month) mostly along the entire year. A key point of the project is the shared protocol that define the experience of observers, the parameters for effort, the datasheets, the use of instruments and some specific definitions for collecting consistent data. Other key points of the programme regard the training to new routes/organizations, the validation process and a periodical exchange of experiences. Moreover, the synergistic data collection on other macro-fauna (e.g. sea turtle, sea birds etc) and potential threats (i.e. maritime traffic, marine macro litter) established within the network, enhanced the ability of this sustainable, multidisciplinary monitoring programme for better contributing to the understanding of the marine ecosystem complexity.

Introduction

All cetacean species are protected by an international legislative framework that requires the initial evaluation and information on trends of cetacean range, populations and habitats to assess their conservation status and the effect of potential pressures in order to plan effective conservation measures. Population monitoring is therefore a key pillar to

early detection of any significant change that require a definition or re-definition of conservation efforts.
The use of platform of opportunity to conduct systematic cetacean research is recently increasing, providing a valuable option for scientific data collection (see Hupman et al. 2014 for a review) and a cost effective method for long-term monitoring. Moreover, for modelling cetacean habitat purpose, data collected from opportunistic vessels are considered equivalent to data collected from dedicated research vessels, if collected under an adequate research protocol (Redfern et al., 2006) .
To contribute to legislative requirement, a collaborative programme was established since 2007 in the Mediterranean Sea to monitor cetacean species along trans-border fixed transects using ferries as research platform (Fixed Line Transect Mediterranean Monitoring Network programme, FLT Med Net. Arcangeli 2010; Arcangeli et al., 2013). At date, almost 3700 km of fixed line transects are surveyed on a monthly basis, mostly along the entire year, by about twenty scientific organizations in collaboration with five ferry companies (Fig.1). The network includes some scientific organizations directly responsible for the monitoring and others involved for the definition of the protocol, data analysis or tutoring of students.

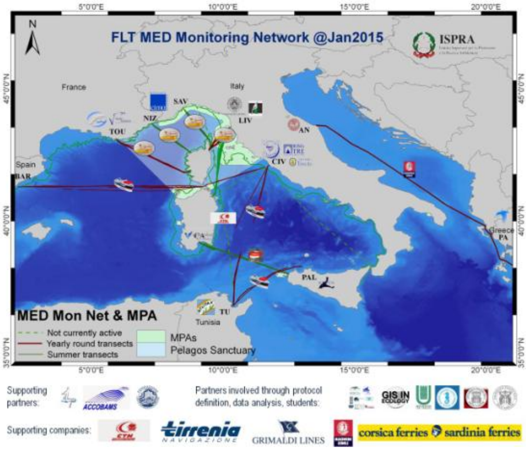

Fig. 1. Fixed transects and partnership. In red the transects monitored during the all year; in green the transect monitored from beginning of June to the end of September. The scientific organizations directly involved in the data collection are: ISPRA, Accademia del Leviatano, AMP Capo Carbonara, Atutax, CIMA Research Foundation, EcoOcean Institute, Gaia Research Institute, Ketos, Univ. of Pisa, Univ. of Roma

Tre, Univ. of Turin, Univ. of Tuscia. The ferry companies collaborating in the programme are: Corsica-Sardinia Ferry, CTN, Grimaldi lines, Minoan, Tirrenia.

Surveys

At date, systematic monitoring of cetaceans is performed on board of a predetermined range of ferry types along ten fixed routes (sampling transects), distributed within the Mediterranean basin (Fig.1). The temporal resolution is of one to four surveys per month.

Main constrains in the use of ferries as research platform refer to data that cannot be collected in passing mode without approaching the animals, such as high quality photos for photoID analyses, behavioural data, tissue sampling etc. Other kind of constrains, commonly described for the use of platforms of opportunity, are easily overcome setting in advance an appropriate and well defined surveys methodology with a research question specifically tailored to the limitations of the specific research platform.

Consistency over the FLT Med network is guaranteed by a shared protocol that define in detail the experience of observers, the parameters for the effort, the datasheets, the use of instruments such as the dedicated handheld GPS and other specific definitions. The training for new routes/organizations, the validation process and a periodical exchange of experiences among the partners contribute in maintaining coherence and high quality of data.

Main assumption of the method is that the detectability of the species doesn’t change through time and space so, preliminary analyses were undertaken to avoid possible bias due to the type of platform, speed, experience of the observers, meteorological conditions and distance from the ship. Possible source of bias and the correction made in the protocol is shown in Table 1.

Table 1: potential bias investigated and correction made in the protocol of the FTL Med Net

Possible bias	Correction
Density gradient	Transect design perpendicular to any density gradient (e.g. migration of fin whale) for most of the transects
Meteorological condition	Change with sea state : effort only under Beaufort scale ≤3 (≤2 for *Ziphius cavirostris*)
Speed, type of ferries	No significant changes were detected in sighting rates within a range of speed (17-27kn) and type of ferries (e.g. deck high 12-20m): same grouping of ferries are used in the programme.

Experience of observers	We detected a 50% of difference in sighting rates between experienced and un-experienced observers: consequently only appropriately experienced and trained observers are used in the programme. The experience is assessed by a senior observer taking into consideration the personal characteristics, previews experiences, number of surveys already done (specifically on ferries) and number of different species and in different conditions already sighted by the on training observer.
Distance	Detection probability changes due to distance, species, sea state so an estimate of effective strip width is undertaken for single species/type of ferry. It is however considered constant among time and space.
Distance estimate	A preliminary training is performed to the observers to estimate distance using fixed point at a known distance in order to calculate the personal error in the use of different method to measure distance.
Recount of animals	Angle of observation 130° ahead each side; the correlation between outbound and return transects is compared with the autocorrelation of outbound (and returns), assuming that the values of autocorrelation at the minimum time distance of a week are independent
Species and group identification	Can change with the experience of the observers: only experienced observers are used in the program and photo are taken to confirm species identification and group size.
Responsive movement of species	Limited by the range of speed of the vessels and the angle of observation
Typing and transcription errors	Use of dedicated application; validation by an independent expert after data collection.

Moreover, three specific protocols were established within the programme for synoptic multidisciplinary monitoring of macro-fauna (e.g. sea turtle, sea birds etc) and two of the main potential threats (i.e. maritime traffic, marine macro litter), allowing to contribute to the requirement of the legislative framework and to the understanding of the marine ecosystem complexity (Arcangeli et al., 2014).

Analyses

To monitor changes in population size for many conservation purposes, it may not be necessary to have absolute population estimates, especially if the species is highly mobile and distributed heterogeneously spatially and/or temporally. Instead, changes in population size can be inferred from trends in an index that is itself related to abundance; such methods are used in many other taxa to measure population trends (Battersby and Greenwood, 2004; Vorisek et al., 2008). As well, an understanding of the cause of significant changes is also needed and can be obtained in part by relating the distribution and abundance of the species to environmental and/or anthropogenic factors.

Data coming from the FLT Med Net programme are analysed on a spatial basis, using as statistical unit a grid-cell of appropriate resolution or using each transect as the statistical unit: correlation and autocorrelation analyses are performed before using data.

At date, analyses were performed for delivering large scale cetaceans distribution and trends, long term comparison on cetacean presence and habitat use, studying the relationship between cetaceans and environmental parameters (Arcangeli et al., 2012; Arcangeli et al., 2014) and for modeling species' suitable habitat (e.g. potential feeding habitat for fin whale, Druon et al., 2014; changes in suitable habitat for *Ziphius cavirostris*, Arcangeli et al., 2015).

The first analyses on the multidisciplinary data collection on cetacean, marco-fauna and potential threats, delivered useful information on the relationship between cetaceans and maritime traffic (Crosti et al. 2011; Campana et al., 2015) and highlighted potential risky areas due to the overlap between sensitive species, such as squid eaters and sea turtle, and high density of plastic debris (Arcangeli et al., in press).

Discussion

Outcomes of the first nine years of the FLT programme in the Mediterranean basin highlighted some important aspects to be taken into account for applying the methodology for long-term monitoring of cetaceans for conservation purposes: primarily the importance of a detailed and shared protocol in combination with dedicated applications for helping in the data collection and in the validation process; then, the need of a periodical review of the protocol and the programme for strengthening the cooperation within the partners, redefine priorities and enhance the quality of the programme as whole.

At date, outcomes of the FLT Med Net programme showed the ability of the methodology to highlight changes in cetacean distribution, habitat use (through modeling) and abundance (through index of abundance) over time. Significant changes were already recorded in some key areas and it will be continuously monitored over time by the network to deliver information needed for conservation purposes. Moreover, the method demonstrate to be able to highlight changes also for rare and elusive species such as the Cuvier's beaked whale, contributing to filling the gap on less known species. Furthermore, the spatial prevision performed on Cuvier's beaked whale using data from a single transect were validated also through independent datasets (Arcangeli et al., 2015), demonstrating the potential of the surveyed transect to be representative of wider area.

Lastly, early results demonstrate also the potential of the multidisciplinary data collection from ferries to deliver information on marine biodiversity and to contribute to the risk assessment through contemporary data collection on biota and some of the main potential pressures and threats.

References

Arcangeli A (2010) ISPRA Cetacean Monitoring Network along Fixed Transect. Biol. Mar. Mediterr., 17(1): 400-401.

Arcangeli A., Aissi M., Aragno P., Atzori F., Azzolin M., Baccetti N., Campana I., Castelli A., Cerri F., Cinti F., Crosti R., David L., Di Meglio N., Frau F., Lippi S., Luperini S., Maffucci F., Marini L., Moulins A., Paraboschi M., Pellegrino G., Ruvolo A., Tepsich P., Tringali M. (2014). Cetacean, marine birds, sea turtle, marine traffic and floated marine litter: potential of a synioptic multi-disciplinary data collection in the Western Mediterranean Marine Region. Biol.Mar.Med. 21 (1): 366-368.

Arcangeli A., Azzolin M., Campana I., Castelli A., Luperini C., Marini L., Paraboschi M., Pellegrino G., Ruvolo A., Tringali M., Vetrugno A., Crosti R. Cetaceans at risk by plastic debris: a protocol for simultaneous monitoring of marine litter and marine mega-fauna. First results from the FLT Mediterranean monitoring Network. Biol.Mar.Med. in press.

Arcangeli A., Campana I., Marini L., MacLeod C.D. (2015) Long-term presence and habitat use of Cuvier's beaked whale (*Ziphius cavirostris*) in the central Tyrrhenian Sea. Marine Ecology. doi: 10.1111/maec.12272.

Arcangeli A., Castelli A., Marini L., Moulin A., Paliaga B., Tepsich P., Tringali M. (2013). A cooperative program for studying and monitoring cetacean in Mediterranean Sea. Biol.Mar.Med. 20 (1): 254-255.

Arcangeli A., Marini L., Crosti R. (2012). Changes in cetacean presence, relative abundance and distribution over 20 years along a trans-regional fixed line transect in the Central Tyrrhenian Sea. Marine Ecology 34 (1).

Arcangeli A., Orasi A., Carcassi S., Crosti C. (2014). Exploring thermal and trophic preference of *Balaenoptera physalus* in the Central Tyrrhenian Sea: a new summer feeding ground? Mar Biol 161:427–436.

Battersby JE, Greewood JJD (2004). Monitoring terrestrial mammals in the UK: Past, present and future, using lessons from the bird world. Mammal Review 34, 3–29.

Campana I., Crosti R., Angeletti D., Carosso L., David L., Di-Méglio N., Moulins A., Rosso M., Tepsich P., Arcangeli A. Cetacean response to summer maritime traffic in the western Mediterranean Sea. Marine Environmental Research: 109: 1-8.

Crosti R., Arcangeli, A., Moulins, A., Tepsich, P., Tringali, M. (2011) Cetacean and maritime traffic in deep sea waters. A relation to avoid? Biol. Mar. Mediterr., 18(1): 178-179.

Druon JN, Panigada S, David L, Gannier A, Mayol P, Arcangeli A, Cañadas A, Di Méglio N, Gauffier P. (2012). Potential feeding habitat of fin whale in the Western Mediterranean Sea. Mar Ecol Prog Ser. 464: 289–306.

Hupman, K., Visser, I. N., Martinez, E., & Stockin, K. A. (2014). Using platforms of opportunity to determine the occurrence and group characteristics of orca (Orcinus orca) in the Hauraki Gulf, New Zealand. New Zealand Journal of Marine and Freshwater Research, (ahead-of-print), 1-18.

Redfern, J. V., Ferguson, M. C., Becker, E. A., Hyrenbach, K. D., Good, C. P., Barlow, J., Werner, F. E. (2006). Techniques for cetacean–habitat modeling.

Vorisek P., Klvanova A., Wotton S., Gregory R.D. (editors), 2008. A best practice guide for wild bird monitoring schemes. JAVA Trebon.

General conclusions

The Mediterranean basin is a marine biodiversity hot spot, and cetaceans are key ecosystem components. They are long living species, who occupy different trophic levels in the food chain, ranging mostly within the entire basin, and interacting with many different ecological and anthropogenic parameters. For these reasons cetaceans are considered good indicators of environmental status, and are included in a large legislative framework. However, despite the legislative requirements, the increasing research activities and the public interest due to the emphatic characteristic of these species, still our knowledge is lacking.
Using some of the data collected within the Fixed Line Transect Mediterranean monitoring Network, this PhD project contributed to improve information about some of the main gaps in our knowledge.
1) Spatio-temporal variability of cetacean species was detected at many levels in the medium latitudes of the western Mediterranean basin and the southern Tyrrhenian seas (Ch.1). Only three species were recorded more frequently (fin whale, striped dolphin and bottlenose dolphin) while concern must be given to the others. Among the more rare species, of particular importance resulted the central Tyrrhenian for Cuvier's beaked whale and the southern Tyrrhenian for common dolphin. Seasonality was detected in particular in fin whale, but was also detected in striped dolphin, especially in the Sardinian-Balearic. Differences among years were found in the short term (Ch.1) and were remarkable also in the long term, especially for fin whale (Ch. 2.1) and Cuvier's beaked whale (Ch. 3) in the central Tyrrhenian sea.
2) Within the Mediterranean Sea, the Corso-Ligurian-Provencal basin is considered a primary summer feeding ground for fin whale (Notarbartolo di Sciara et al., 2003), and migratory movements between northern summer feeding area and southern wintering grounds where firstly recognized in the early '90s through seasonal bipolar pattern in the central Tyrrhenian sea (Marini et al., 1996). The study in the medium western-Mediterranean latitudes (Ch.1.2) confirmed seasonal cycles for fin whale, with peaks of occurrence recorded in spring and summer in the Sardinian-Balearic and in the Tyrrhenian basins, and drops in presences detected during winter and autumn. But the long term comparative study in the central Tyrrhenian sea (Ch. 2.1), revealed that changes in the habitat use of fin whale can occur, as this area was recently used more as opportunistic summer feeding grounds than a corridor for transit. Instead, in the Sardinian-Balearic (Ch.1.2), the decreasing number of encounters recorded from spring to summer in

two out of three of the investigated years, is more consistent with an hypothesis of intermediate concentrations of individuals in medium latitudes in spring followed by an even northern movement during summer, probably towards more productive areas. During autumn and winter (Ch.1.2), the lowest occurrence recorded in both Sardinian-Balearic and Tyrrhenian basins is most likely consistent with a dispersing pattern towards more southern Mediterranean areas. However, while the seasonal movement surely involves most fin whales, sightings were recorded all year round along the surveyed transect (Ch. 1.2), in accordance with a year-round presence of specimens recorded in other studies (e.g. Marini et al, 1996; Notarbartolo et al., 2003; Cottè et al., 2011). The occurrence of fin whales wintering in the Bonifacio Strait in 2013 (min. of 13 animals, Ch. 2.2) further confirms that small group/individual flexibility could determine a more complex pattern with seasonal and inter-annual fluctuations in distributions, and that many factors can act like drivers, such as gender differences, life stage or site fidelity.

3) Despite difficulties on gathering data on Cuvier's beaked whale, the species was regularly recorded in the Sardinian-Balearic basin during recent years (Ch. 1.2), and data on the central Tyrrhenian sea demonstrate long term site fidelity (Ch. 3). However, the recorded changes in habitat use in this latter area could indicate both the need for expanding the definition of what is considerable suitable for the species, and/or a warning about possible effect of pressures that should force the species to move to less suitable habitat.

4) The study on the relationship between cetaceans and maritime traffic (Ch. 4) showed that summer maritime traffic influence all pelagic cetacean species, with different level of negative responses likely determined by a combination of environmental and biological factors, and the intensity of the pressure. Moreover, the negative response toward summer traffic recorded for Cuvier's beaked whale in the central Tyrrhenian sea, support the hypothesis (Ch. 3) of a change in habitat use from beginning of the '90s to recent years due to a modification in order to exploit less disturbed portions. Similar consideration for fin whale support the hypothesis of a shift in the summer distribution toward southern opportunistic feeding areas due to a differentiate effect of maritime traffic pressure (Ch. 2.3).

5) The method demonstrates to be suitable and sustainable for long term and large scale monitoring programme on all cetacean species, allowing to collect a great amount of consistent data also in remote high sea areas all year round, and on the more rare species as well.

Changes were detected over time in cetaceans' distributions (Ch.1), habitat use (through modelling) (Ch.3), and abundance (through index of abundance) (Ch. 1-5). The significant variability detected points out the need for continuous monitoring with consistent methodology at the scale of the range of species, in order to apply adaptive conservation management approach. Moreover, the long term changes in habitat use detected both in fin whale (Ch. 2.3) and in the rare and elusive Cuvier's beaked whale (Ch.3), indicate that the temporal scale of the analysis can considerably affect the interpretation of results, so that the large amount of data is necessary to apply these methods at appropriate resolution. From a conservation point of view, the recorded variability warns about the possible effects of pressures on species and helps in filling some gaps on less known species.

The spatial prevision performed on Cuvier's beaked whale (Ch. 3) using data from a single transect, and validated also through independent datasets, demonstrates that the sampled transect can be representative of broader areas and, consequently, that the network of more sampled transects could potentially be useful on delivering information at basin wide scale.

Lastly, first results on multidisciplinary data collection (Ch. 4 & 5) attested the capability of the methodology in delivering information on biota and some of the main potential threats, contributing to continuous risk assessment across areas with different levels of protection.

Cotté, C., d'Ovidio, F., Chaigneau, A., Lévy, M., Taupier-Letage, I., Mate, B., & Guinet, C. (2011). Scale dependent interactions of Mediterranean whales with marine dynamics. Limnology and Oceanography, 56(1), 219-232.

Marini, L., Consiglio, C., Angradi, A. M., Catalano, B., Finoia M.G., Sanna, A., Valentini, T., Villetti, G. (1996). Distribution, abundance and seasonality of cetaceans sighted during scheduled ferry crossings in the central Tyrrhenian Sea: 1989–1992. Italian Journal of Zoology, 63(4), 381-388.

Notarbartolo di Sciara, G., Zanardelli, M., Jahoda, M., Panigada, S., & Airoldi, S. (2003). The fin whale *Balaenoptera physalus* (L. 1758) in the Mediterranean Sea. Mammal Review, 33(2), 105-150.

List of publications and communications

ISI indexed journal

1. **Arcangeli** A., Orasi A., Carcassi S., Crosti C. (2014). Exploring thermal and trophic preference of *Balaenoptera physalus* in the Central Tyrrhenian Sea: a new summer feeding ground? Mar Biol 161:427–436.
2. **Arcangeli** A., Campana I., Marini L., MacLeod C.D. (2015) Long-term presence and habitat use of Cuvier's beaked whale (*Ziphius cavirostris*) in the central Tyrrhenian Sea. Marine Ecology. doi: 10.1111/maec.12272.
3. Campana I., Crosti R., Angeletti D., Carosso L., David L., Moulins A., Tepsich P., **Arcangeli** A. (2015) Cetacean response to summer maritime traffic in the western Mediterranean Sea. Marine Environmental Research: 109: 1-8.
4. **Arcangeli** A., Azzolin M., Campana I., Castelli A, Luperini C., Marini L., Paraboschi M., Pellegrino G., Ruvolo A., Tringali M., Vetrugno A., Crosti R. Cetaceans at risk by plastic debris: a protocol for simultaneous monitoring of marine litter and marine mega-fauna. First results from the FLT Mediterranean monitoring network. Biol.Mar.Med (in press)
5. Santoro R., Sperone E., Pellegrino G., Giglio G., Tripepi S., Tringali M.L., **Arcangeli** A.. (2015) Summer Distribution, Relative abundance and encounter rates of Cetaceans in the Mediterranean Waters off Southern Italy (Western Ionian Sea and Southern Tyrrhenian Sea). Mediterranean Marine Science. doi:10.12681/mms.1007
6. **Arcangeli** A., Campana I., Bologna M.A.. Spatio-temporal variability of cetacean species along a sampling transect between Civitavecchia and Barcelona in the Western Mediterranean Sea Region (submitted).
7. **Arcangeli** A., Scardi M. A machine learning approach to explore fin whale favorable habitat in the Western Mediterranean Marine Region. (in prep).

Conference papers/published abstract

2013

- Campana I., **Arcangeli** A., Carcassi S., Casella E., Cracas F. Cetacean diversity across the Mediterranean Sea: first results from a new fixed-line transect from Tyrrhenian to Balearic Seas. 26°

Conferenza dell'European Cetacean Society. April 2013. Setubal, Portugal.

- Luperini C., Castelli A., **Arcangeli** A. (2013) Composition, spatial distribution and source of floating marine macro litter, in the Northern Tuscan-Corsica marine ecosystem in the Pelagos Sanctuary, monitored along a trans-border transect. Presented at the Conference " Biology and ecotoxicology of large marine vertebrates and seabirds: potential sentinels of good environmental status of marine environment, implication on European Marine Strategy Framework Directive" Siena 5 - 6 giugno 2013.

2014

- **Arcangeli** A, Campana I., Paraboschi M., Cerri F., Berardi C., Carcassi S., Di Clemente J., Luperini C., Refice S., Trisolino P., Crosti R. Monitoring cetacean outside the borders of the Pelagos Sanctuary: seasonal variability in cetacean presence along a cross-border fixed transect in the Western Mediterranean Marine Region and implication for conservation purposes. 27° European Cetacean Society Conference. April 2014. Liége, Belgium.
- Campana I., **Arcangeli** A., Paraboschi M., Marini L., Luperini C., Cerri F. Changing point of view: fin whale breaching in the Western Mediterranean Sea. 27° European Cetacean Society Conference. April 2014. Liége, Belgium.
- Atzori F., Frau F., Cinti M. F., Corrias S., Lippi S., Paliaga B., **Arcangeli** A. The role of Marine Protected Areas for monitoring marine species: the example of Capo Carbonara MPA in the Sardinia channel. 27° European Cetacean Society Conference. April 2014. Liége, Belgium.
- **Arcangeli** A., Aissi M., Aragno P., Atzori F., Azzolin M., Baccetti N., Campana I., Castelli A., Cerri F., Cinti F., Crosti R., David L., Di Meglio N., Frau F., Lippi S., Luperini S., Maffucci F., Marini L., Moulins A., Paraboschi M., Pellegrino G., Ruvolo A., Tepsich P., Tringali M. Cetacean, marine birds, sea turtle, marine traffic and floated marine litter: potential of a synioptic multi-disciplinary data collection in the western mediterranean marine region. 45° Congresso S.I.B.M 2014.
- Cinti M.F., Atzori F., Frau F., Corrias S., Lippi S., Ghiani R., Donati S., **Arcangeli** A. Monitoring marine species (cetacean, sea turtle) in the Sardinian channel Connecting Marine Protected Areas. 45° Congresso S.I.B.M 2014.

- **Arcangeli** A, Aissi M., Atzori F., Azzolin M., Baccetti N., Campana I., Castelli A., Cerri F., Cinti F., Crosti R., David L., Di Meglio N., Frau F., Luperini C., Maffucci F., Marini L., Moulins A., Paraboschi M., Pellegrino G., Ruvolo A., Tepsich P., Tringali M., 2014. Synoptic data collection on Cetacean, Marine birds, Sea turtle, Marine traffic, Marine litter: a multidisciplinary collaboration in Mediterranean sea. 3rd International Marine Conservation Congress. Glasgow.

2015

- **Arcangeli** A, Fixed Line Transect MED Monitoring Network. Presented at the ECMC WS on "Developing analytical protocols to assess trends in cetacean populations from structured surveillance data collected on ferries". 29th Annual Conference of European Cetacean Society. 22 March 2015.
- **Arcangeli** A, Campana I., Paraboschi M., Di Clemente J., Vetrugno A., Maffuci F., Crosti R. Plastic debris and mega-fauna (cetaceans and sea turtle) in the central western Mediterranean Marine Region: synoptic multidisciplinary monitoring as tool for addressing one of the major threats in the marine ecosystem. 29th Annual Conference of European Cetacean Society. 23-25 March 2015.
- Maffucci F. , Aissi M., Atzori F., Azzolin M., Campana I., Castelli A., Cerri F., Cinti F., Crosti R., David L., Di Meglio N., Frau F., Giacoma C., Hochscheid S. Luperini C., Marini L., Monaco C., Moulins A., Paraboschi M., Pellegrino G., Rosso M., Ruvolo A., Tepsich P., Tringali M., **Arcangeli** A. (2015). Ferries as platform of opportunity for regular monitoring sea turtle distribution in the Mediterranean sea. 35th Annual Symposium on Sea Turtle Biology and Conservation.
- **Arcangeli** A., Azzolin M., Campana I., Castelli A., Giacoma C., Luperini C., Marini L., Paraboschi M., Pellegrino G., Ruvolo A., Tringali M., Vetrugno A., Crosti R., 2015. Cetaceans at risk by plastic debris: first results from the Fixed Line Transect Mediterranean Monitoring Network. 46° Congresso della Società Italiana di Biologia Marina. Roma, 10-12 giugno 2015

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