

Short Communication

Intra-Annual Changes in Cetacean Occurrence in the Western Mediterranean Sea

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Submitted: 08 August 2016

Accepted: 29 August 2016

Published: 01 September 2016

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Keywords

- Cetaceans
- Mediterranean
- Spatio-Temporal Changes
- Monitoring

Abstract

Monitoring cetacean's variability in presence and distribution over their large, mostly pelagic, range is extremely challenging. This paper investigates, during one year period (October 2012 - September 2013), the seasonal variations in occurrence of cetacean species over three ecologically different sectors (Sardinian-Balearic Seas, Bonifacio Strait, Tyrrhenian Sea) of the Western Mediterranean Sea Region. Data was collected by repeated surveys carried out from ferries regularly running between Italy and Spain and contributing to the Fixed Line Transect Mediterranean Monitoring Network. Analyses were performed on a grid cell basis of 100 km², considered as statistical unit, on the Encounter Rate, calculated as sightings per km travelled on effort within each cell. Seasonal Encounter Rates of all cetaceans and of the six most sighted species were calculated within each sector and compared (Kolmogorov-Smirnov test). Almost 500 sightings of eight resident cetacean species of the Mediterranean Sea were recorded over 21,051 km of effort. Results showed high seasonal variations in cetacean presence and distribution in all the three investigated sectors, with general higher occurrence in spring compared to summer. Outcomes support the need for multi-annual studies to better understand the environmental and biological processes involved. The implementation of this systematic research can contribute to enhance the knowledge on poorly investigated areas and seasons, providing useful information to assess the effectiveness of conservation measures.

ABBREVIATIONS

SPAMI: Specially Protected Areas of Mediterranean Importance; ER: Encounter Rate

INTRODUCTION

The Mediterranean Sea hosts a considerable cetacean diversity with ten species living permanently in the basin [1], even if current knowledge about distribution and habitat use of many of them is still limited [2]. Cetaceans are long-living animals belonging to different trophic guilds, from filter feeders to top predators; some of them have a broad range of distribution, performing seasonal movements within the Mediterranean basin. Species distribution is determined by a combination of spatial and temporal processes [3], which include ecological features, physiographic, oceanographic and biotic, and anthropogenic factors [4]. Over the last 20 years, several studies reported changes in the oceanographic parameters in the

Mediterranean Sea [5-7], influencing food chains and which may result in potential changes of cetaceans ranges and distribution [8,9]. Many human activities can also affect cetacean behaviour over time, leading to changes in abundance and distribution [10-15 among others]. Thus, monitoring cetacean presence and distribution can be considered an effective tool for detecting early signs of noteworthy variations in the marine environment that could consequently require conservation measures, management and mitigation efforts [16,17].

On the other hand, studying cetacean presence and distribution over their large, mostly pelagic, range is extremely challenging [4,18] and few studies have been conducted during the entire year-round cycle, but confined to limited areas or using different methodologies [e.g. 19-21]. Moreover, results from studies not covering simultaneously the entire range of distribution can be affected by the animals' small-scale movements, migration or seasonality. At fine scale, habitat

use can also differ in time and space, according to the relative influence of both fixed and variable environmental features in different biological conditions and life history stages [22]. Depth, for example, can play different roles according to areas. Fin whale *Balaenoptera physalus* is observed in deep waters in the Ligurian Sea [23,24] while it is recorded in shallow waters around Lampedusa island [25-27] due to different feeding strategies in the two areas [27]. As well, striped dolphin *Stenella coeruleoalba* is a widely distributed oceanic species, but its opportunistic feeding behaviour may lead to irregular presence according to variations in prey's availability [19, 21, 23]. Thus, uncertainty over species year-round movements exists so far and knowledge in remote high sea areas is lacking.

Systematic studies are appropriate to account for the variability in species distribution and occurrence over different areas, even for understanding the interactive role of anthropogenic, environmental and biological processes [4]. In our study, we present the results of the first year of continuous survey effort across different habitats of the Western Mediterranean Sea Region, providing an overview on the intra-annual changes in occurrence of cetacean species, with the aim to set the stage for future consistent investigations on spatio-temporal relationships over a large scale. This work can also give baseline information about cetacean distribution over a wide marine region, which is useful within the European legislative framework for the assessment of environmental status of marine waters (e.g. Marine Strategy Framework Directive) [28].

MATERIALS AND METHODS

Study area

Data was collected along a trans-border line transect, about 810 km long, running from Civitavecchia (Italy) to Barcelona (Spain), through the Western Mediterranean Sea Region. The transect was divided in three sectors, corresponding, proceeding eastwards, to the Sardinian-Balearic Seas, the Bonifacio Strait (from north of Capo Falcone, Sardinia, to the eastern 200 m isobath) and the Tyrrhenian Sea (Figure 1).

The three marine sectors are characterised by a wide range of topographic and ecological conditions where eight cetacean species regularly living in the Mediterranean Sea can be observed [19,20,29]: fin whale, striped dolphin, bottlenose dolphin *Tursiops truncatus*, sperm whale *Physeter macrocephalus*, Risso's dolphin *Grampus griseus*, Cuvier's beaked whale *Ziphius cavirostris*, common dolphin *Delphinus delphis*, long-finned pilot whale *Globicephala melas*. The continental shelf is wider along the Balearic and Tyrrhenian coasts than in the Sardinian Sea, while almost all the Bonifacio Strait sector is located in neritic habitat. Steep slopes are present in the Sardinian Sea, leading to the abyssal plateau in the middle of the western basin (around 2700 m deep). Canyons and ridges are instead defining complex bottom topography in the central Tyrrhenian Sea, where important upwelling/down-welling phenomena occur [30].

From a conservation point of view, this route encompasses waters outside the south-eastern and western borders of the Pelagos Sanctuary marine protected area (Figure 1), while the Bonifacio Strait is the southern portion of the Sanctuary, also

recognised, along the Corsican coast, as one of the Specially Protected Areas of Mediterranean Importance (SPAMI) [31].

Field method

A year-round monitoring program was conducted along the trans-border fixed line transect from Italy to Spain. This is part of the Fixed Line Transect Mediterranean Monitoring Network, which extends the same methodology to a systematic research across several marine regions [32], using ferries as platforms of observation for dedicated surveys [4,17].

The transect is surveyed four to eight times per month, and for this study we considered data from the first year (October 2012 to September 2013), collected from two twin ferries travelling at a mean speed of 24 knots. Two to four dedicated Marine Mammal Observers, with at least one expert supervisor, were located on the two sides of the ships' bridge (28 m high), conducting observational scans with the naked eye and binoculars (8×42 magnification), covering a total of 270° of visual range ahead of the ferry. During each cetacean sighting, ship's location was marked with a handheld GPS, and information on the species, group size and behaviour were noted. Information regarding changes of route, vessel speed, weather conditions was also recorded, considering the "on effort" period only the surveys performed in favourable conditions, maintaining equal probability for cetacean detection (Beaufort scale < 4, good visibility) [29,33]. Maximum range considered for cetacean sightings was of approximately 4 km from the ship, as only big whales could be detected at a further distance.

Data analysis

One year of data, covering all the four seasons, was analysed in this study. Analyses were performed on a grid cell basis of 10×10 km resolution, each one considered as statistical unit, using the programme ArcGIS10.1 with the open source Geospatial Modelling Environment application. The abundance index was calculated as number of sightings (n) per km travelled on effort (L) within each cell (Encounter Rate, $ER = n / L$). To avoid bias due to low effort values, we set minimal sampling effort criteria for each cell on the basis of preliminary exploratory data analyses on ER and Z-score. We found that the variance of mean ER did not appreciably change with > 10 km effort per grid cell, so only cells with more than 10 km of surveys were selected for the analyses (total processed area = 63,700 km²).

Univariate analysis was used to assess, in the three investigated sectors, seasonal occurrence of all cetacean species pooled together and the most sighted ones. Comparisons were conducted using the non-parametric statistical Kolmogorov-Smirnov test (KS), testing the hypothesis of equivalence between datasets in the different seasons. Statistical analyses were performed using the programme PAST 2.17 [34].

RESULTS

Species presence and composition

During the one year of monitoring, 496 cetacean sightings were recorded over 21,051 km travelled on effort. The Sardinian-Balearic Seas accounted for more than 70% of total surveyed area and the other two sectors presented comparable effort

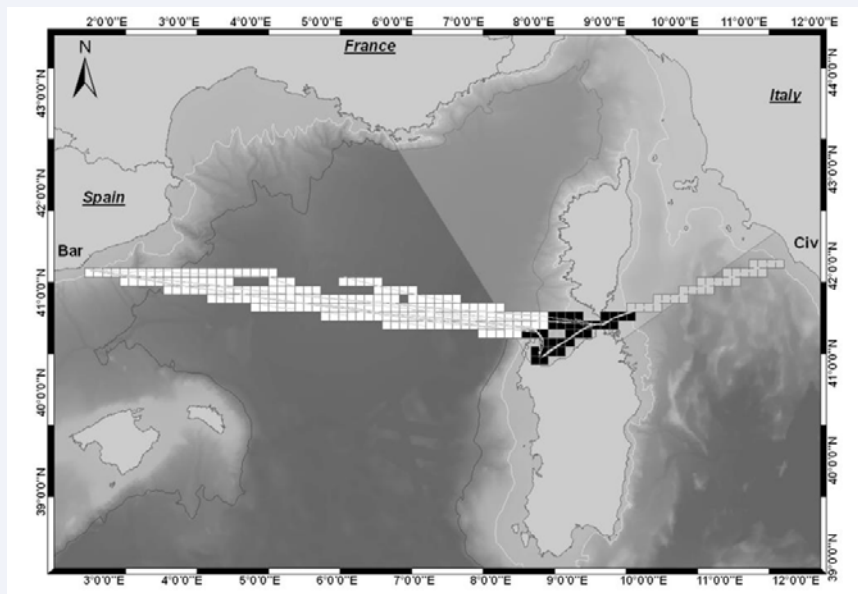


Figure 1 Study area: the monitored transect between Italy (Civitavecchia) and Spain (Barcelona) with the effort tracks and the 10x10 km grid cells used for the analysis, divided in three sectors: Sardinian-Balearic Seas (white cells), Bonifacio Strait (black cells) and Tyrrhenian Sea (grey cells). Pelagos Sanctuary marine protected area is displayed in light grey. Bathymetric profile of -200 m (light grey) and -2000 m (dark grey) are shown.

(Table 1). Eight cetacean species were observed (384 sightings with successful identification) with the highest percentage of fin whale and striped dolphin, representing respectively 36% and 32% of total sightings, followed by bottlenose dolphin, sperm whale and others. Common dolphin and long-finned pilot whale were sighted only once, so they were excluded from specific analysis.

The highest species richness was found in all seasons in the Sardinian-Balearic Seas, with particular presence of fin whale, striped dolphin and sperm whale. In the Bonifacio Strait bottlenose dolphin was the most observed species, but also fin whale and striped dolphin were recorded. In the Tyrrhenian Sea fin whale and striped dolphin were the most common species and the highest species richness was recorded in summer for the occasional presence of sperm whale, Risso's dolphin and Cuvier's beaked whale (Table 1).

Spatio-temporal occurrence

Pooling together data of all cetacean sightings all through the monitored transect, the highest ER value was recorded in Spring ($ER = 0.023 \pm 0.002$) and the lowest in Summer ($ER = 0.007 \pm 0.001$), reflecting the different occurrence and distribution of records (Figure 2).

Results for the three studied sectors highlighted seasonal variations in cetacean occurrence, as reported in Table 2. In the Sardinian-Balearic Seas, Spring showed the highest ER, significantly different (KS test, $p < 0.0001$) from all the other seasons. Significant decrease of ER value was found in this sector between Autumn and Summer ($p < 0.001$). In the Bonifacio Strait the highest ER was recorded in Winter ($p \leq 0.005$) while no differences were found among the other seasons. In the Tyrrhenian Sea, the highest ER was recorded in Spring, not statistically different from Summer and Autumn, while the value

for Winter was significantly lower compared to the other seasons ($p < 0.05$).

Species distribution

Looking at the species presence, we observed variability among sectors and seasonal distribution (Table 1, 2). Fin whale highly concentrated in the Bonifacio Strait in Winter and was observed all through the Sardinian-Balearic Seas in Spring; high ERs were also reported for Bonifacio Strait in Autumn, Sardinian-Balearic Seas in Autumn and Summer and Tyrrhenian Sea in Summer, showing more localised distributions (Figure 3). Striped dolphin was mainly recorded in Spring and Summer along the whole transect while, in the other seasons, most of the sightings occurred in the Sardinian-Balearic Seas. Few encounters were reported in Winter in the Bonifacio Strait and in the Tyrrhenian Sea and none in Autumn in these sectors (Figure 4). Bottlenose dolphin was largely observed in the Bonifacio Strait in Autumn, Spring and Summer but it was also spotted in the high sea area of the Sardinian-Balearic Seas in Spring and Summer (Table 1). Squid-eating species showed a more scattered distribution, generally related to open sea areas deeper than 2000 m. They were mostly seen in the central part of the Sardinian-Balearic Seas, especially in Autumn and Winter (respectively Risso's dolphin and sperm whale), while in Spring and Summer all species were distributed throughout the transect, with sperm whale and Cuvier's beaked whale observed also in the Tyrrhenian Sea. None of these species was sighted in the Bonifacio Strait (Table 1).

DISCUSSION

Many studies point out the need for systematic research to monitor highly mobile, wide-range, pelagic cetacean species, especially if the aim of the research is to explore the relationships among environmental, anthropogenic and biological factors or to use cetaceans as indicators of marine environment changes

Table 1: General data of surveys conducted along the transect from Italy (Civitavecchia) and Spain (Barcelona) between October 2012 and September 2013.

	Seasons	N cells	cells >10 km	Tot km	Bp	Sc	Tt	Pm	Gg	Zc	Dd	Gm
Sardinian-	Autumn	82	73	2035	19	8	-	-	1	-	-	-
Balearic Seas	Winter	119	97	2367.6	9	11	-	2	1	-	-	1
	Spring	142	124	5453.4	64	62	4	1	4	1	1	-
	Summer	115	105	5370.6	48	45	3	8	3	1	-	-
	Total	142	-	15226.6	140	126	7	11	9	2	1	1
Bonifacio Strait	Autumn	13	10	294.8	2	-	2	-	-	-	-	-
	Winter	18	14	485.8	19	1	-	-	-	-	-	-
	Spring	25	19	775.3	-	3	2	-	-	-	-	-
	Summer	31	22	1172.5	1	4	4	-	-	-	-	-
	Total	31	-	2728.4	22	8	8					
Tyrrhenian Sea	Autumn	15	12	249.5	1	-	-	-	-	-	-	-
	Winter	24	18	423.3	-	1	-	-	-	-	-	-
	Spring	26	21	930.5	6	10	-	1	-	-	-	-
	Summer	26	22	1493.1	11	16	-	1	1	1	-	-
	Total	26	-	3096.4	18	27		2	1	1		

Abbreviations: Total Number Of Grid Cells (N Cells) And Cells Selected For The Analyses (Cells >10 Km Of Effort); Total Survey Effort (Tot Km) And Number Of Identified Cetacean Sightings. Species: Fin Whale (Bp); Striped Dolphin (Sc); Bottlenose Dolphin (Tt); Sperm Whale (Pm); Risso's Dolphin (Gg); Cuvier's Beaked Whale (Zc); Common Dolphin (Dd); Long-Finned Pilot Whale (Gm).

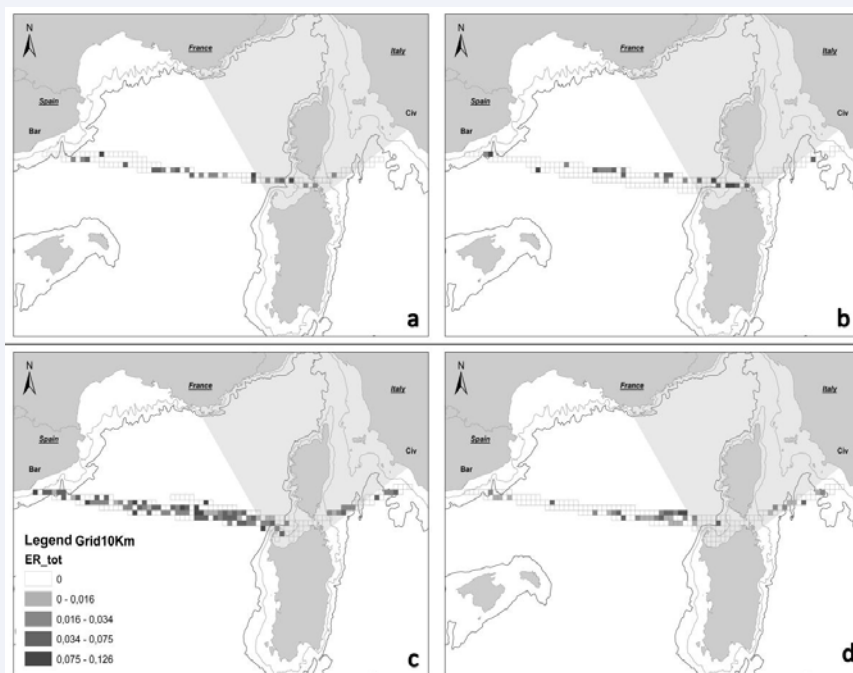


Figure 2 Seasonal Encounter Rates (ER) along the monitored transect between Italy (Civitavecchia) and Spain (Barcelona): sightings of cetaceans per km travelled on effort in good weather conditions within a 10x10 km grid cell. a = Autumn, b = Winter, c = Spring, d = Summer. Pelagos Sanctuary marine protected area is displayed in light grey. Bathymetric profile of -200 m (light grey) and -1000 m (dark grey) are shown.

[4,17]. However, for those species performing migratory movements, knowledge on seasonal patterns is lacking so far and sources of variability, especially in poorly known areas and seasons, are still unclear. This research allowed the continuous and homogeneous data collection across different habitats, high sea and coastal areas, representing a baseline for longer term

study, which is among the purposes of the monitoring network [32].

Looking at one year of data on cetacean presence in three ecologically different basins, our study revealed the high variability occurring in species presence and composition in this portion of the Western Mediterranean Sea. As expected,

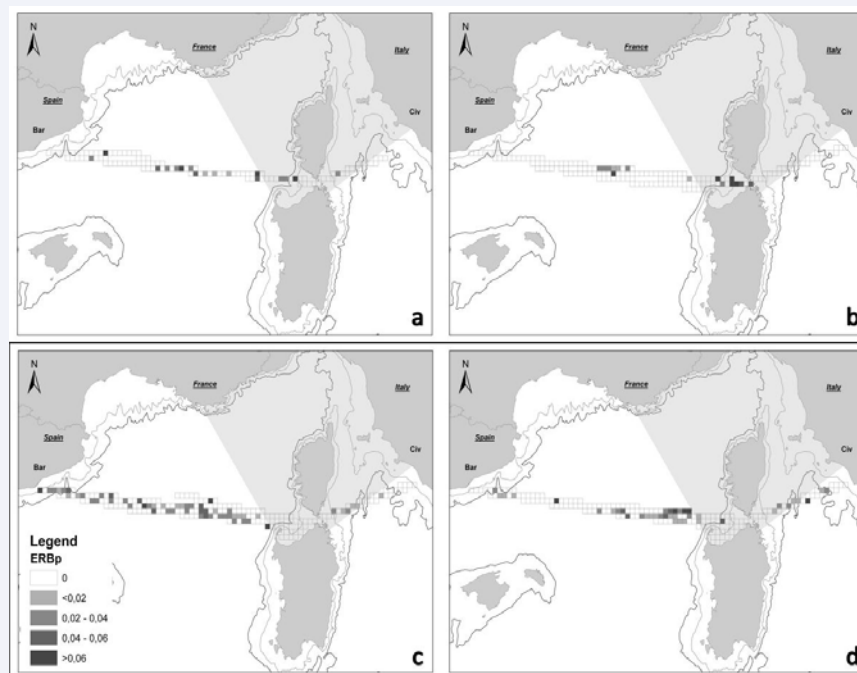


Figure 3 Seasonal Encounter Rates (ER) of fin whale along the monitored transect between Italy (Civitavecchia) and Spain (Barcelona): sightings of fin whale per km travelled on effort in good weather conditions within a 10x10 km grid cell. a = Autumn, b = Winter, c = Spring, d = Summer. Pelagos Sanctuary marine protected area is displayed in light grey. Bathymetric profile of -200 m (light grey) and -1000 m (dark grey) are shown.

Table 2: Encounter Rate and standard error of cetacean species and for each season in the three investigated sectors.

	Seasons	All species		Bp		Sc		Tt		Pm		Gg		Zc	
		ER	SE	ER	SE	ER	SE	ER	SE	ER	SE	ER	SE	ER	SE
Sardinian-	Autumn	0.013	0.003	0.009	0.002	0.003	0.001	-		-		0.001	0.001	-	
Balearic Seas	Winter	0.010	0.003	0.003	0.001	0.006	0.002	-		0.000	0.000	0.000	0.000	-	
	Spring	0.024	0.002	0.012	0.002	0.011	0.002	0.001	0.000	0.000	0.000	0.001	0.000	0.000	0.000
	Summer	0.008	0.002	0.008	0.002	0.009	0.002	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000
Bonifacio	Autumn	0.015	0.01	0.010	0.010	-		0.005	0.003	-		-		-	
Strait	Winter	0.042	0.02	0.041	0.017	0.001	0.001	-		-		-		-	
	Spring	0.012	0.008	-		0.010	0.010	0.003	0.002	-		-		-	
	Summer	0.002	0.002	0.002	0.002	0.004	0.002	0.003	0.001	-		-		-	
Tyrrhenian	Autumn	0.003	0.003	0.003	0.003	-		-		-		-		-	
Sea	Winter	0.002	0.002	-		0.002	0.002	-		-		-		-	
	Spring	0.015	0.004	0.005	0.002	0.008	0.002	-		0.001	0.001	-		-	
	Summer	0.008	0.003	0.008	0.003	0.008	0.003	-		0.000	0.000	0.000	0.000	0.001	0.001

Abbreviations: Encounter Rate = number of sightings / km on effort (\pm Standard Error) for all species pooled together and the six most sighted species: fin whale (Bp), striped dolphin (Sc); bottlenose dolphin (Tt); sperm whale (Pm); Risso's dolphin (Gg); Cuvier's beaked whale (Zc).

differences were recorded between areas featuring high sea processes (Sardinian-Balearic and Tyrrhenian Seas) and the coastal region of the Bonifacio Strait, with Spring as the peak season in terms of cetacean presence in both high sea sectors, as opposed to the Bonifacio Strait where Winter was the season with most sightings. Nevertheless, differences were also found between the two high sea sectors, with more pronounced seasonal variations within the Tyrrhenian Sea than in the Sardinian-Balearic Seas, also depending on the wider coverage of the latter.

Results also revealed variations in terms of species richness and composition among seasons and areas, reflecting the main ecological differences among these basins.

In the Sardinian-Balearic Seas, species composition was in general homogeneous through the year, with overall higher species richness. In fact, even less frequent species (i.e. squid-eaters) were observed in this sector in almost all seasons, while they were sighted in the Tyrrhenian Sea only during Spring and Summer. The seasonal peak of cetacean presence was Spring,

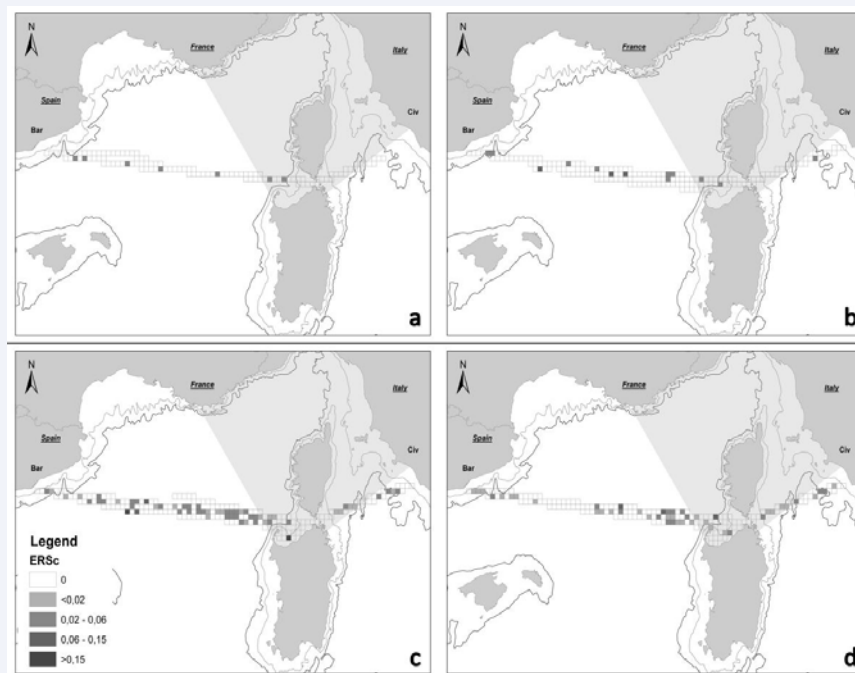


Figure 4 Seasonal Encounter Rates (ER) of striped dolphin along the monitored transect between Italy (Civitavecchia) and Spain (Barcelona): sightings of striped dolphin per km travelled on effort in good weather conditions within a 10x10 km grid cell. a = Autumn, b = Winter, c = Spring, d = Summer. Pelagos Sanctuary marine protected area is displayed in light grey. Bathymetric profile of -200 m (light grey) and -1000 m (dark grey) are shown.

in accordance with Gomez De Segura et al.[19], while just north of this sector, in the Ligurian-Provençal basin, Summer is recognised to be the season of highest cetacean presence [35,36], indicating possible transit movements across the Sardinian Sea. Moreover, the lowest occurrence of cetaceans recorded during Winter supports the idea of a general dispersion pattern, mostly southwards, during this season [2,20,35].

In the Bonifacio Strait, in addition to the expected bottlenose dolphin, our analysis showed that even pelagic species can characterise continental waters in some seasons, as the case for striped dolphin during Spring, or fin whale during Winter. The main finding was the notable presence recorded during Autumn-Winter of fin whale, a species regionally listed as vulnerable in the IUCN Red List [37]. This region is recognised as area of special ecological significance [31] and was recently designated as Particularly Sensitive Sea Area, establishing strict mitigation measures such as ships' routing, reporting and pilotage for the protection of the environment [38]. The considerable presence of fin whale, frequently sighted in pair of adult and juvenile, led to the hypothesis of a possible, even if occasional, use of the Bonifacio Strait as wintering ground [39], so that further research would be helpful for confirming this supposition. Besides, this information on the presence of the species, especially if supported by successive years of data, underlines the need for additional mitigation measures towards specific risks, such as ship strikes, considered one of the main threats for fin whales [40].

In the Tyrrhenian Sea the seasonal variations observed were wide: lowest ERs and species richness resulted for Autumn and Winter when only one sighting of, respectively, fin whale and

striped dolphin was recorded. The significant presence of fin whale in Spring and Summer in the central Tyrrhenian Sea, with its absence in Winter, is in line with the hypothesis of a diverse use of the basin both as transit and opportunistic summer feeding ground suggested by other studies [29,41]. During Spring and Summer we also reported the highest species richness in this sector: if this was confirmed through future research effort, it would sustain the necessity of conservation measures especially focused in these seasons, given also the concurrent increase of the maritime traffic pressure in these periods of the year [15,42].

CONCLUSION

Overall results of this study showed marked intra-annual changes in cetacean occurrence in the whole study area, with differences among sectors that could reflect a variable use by the species. Many studies usually distinguish data between high sea and continental areas, to highlight habitat preferences [19,43-45]. Our findings suggest a more complex and flexible use of high sea and continental areas by typical pelagic and coastal species, linked to seasons and to the individual plasticity. In fact, different spatial and temporal scales of interaction exist and need to be caught by adaptive sampling strategies [20]. In this work, fixed transects covering a broad area with high sampling intensity resulted effective in describing seasonal variations in cetacean occurrence. Indeed, our results confirm the importance of conducting studies through the intermediate seasons (Spring and Autumn); however, the addition of a wider network of surveys and the combination with other techniques, like satellite tracking, can surely cover larger portions of the distribution range of these animals and enhance the knowledge on their large movement

patterns, especially in high sea [20]. Finally, given the evidence of inter-annual variability in habitat use showed by many studies [33,46-48], further investigation at multi-annual scale is surely needed for a better understanding of the environmental and biological processes involved. From a conservation point of view, results endorse the need for a continuous research effort in order to intercept the distribution dynamics of cetacean populations and to better assess the adequacy of conservation measures.

ACKNOWLEDGEMENT

We are thankful to all Grimaldi Lines Ferries staff for their kind assistance to the researchers onboard during the surveys, as well as Cristina Berardi, Silvia Manzini, Stefania Refice, Pamela Trisolino and all the volunteers and students who contributed in the monitoring. We also thank the anonymous reviewers for their valuable comments.

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Cite this article

Arcangeli A, Campana I, Di Clemente J, Paraboschi M, Crosti R (2016) Intra-Annual Changes in Cetacean Occurrence in the Western Mediterranean Sea. *Ann Mar Biol Res* 3(1): 1014.