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Cuvier's beaked whale distribution in the Mediterranean Sea: results from small boat surveys 1996–2007

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*A total of 17,651 km of sailboat survey effort obtained with very good sighting conditions was pooled over the period 1995 to 2007 to provide an insight into Cuvier's beaked whales' (*Ziphius cavirostris*) distribution in the western and central Mediterranean Sea. Although only six confirmed sightings were obtained under such conditions, complementary sightings made a total of eleven confirmed records. Their distribution showed that only slope habitat, and its close proximity, was favourable to the species. In contrast to regions pointed out in the recent literature, such as the Alboran, Ligurian and Ionian Seas, it appeared that the Tyrrhenian Sea was likely to be an important area for Cuvier's beaked whales in the Mediterranean. Sighting rates of 0.1–0.25 sighting/100 km and sighting rates for individuals of 0.2–0.5 individual/100 km were obtained in favourable regions. When compared to sighting rates obtained on Risso's dolphins* Grampus griseus *during the same surveys, the Cuvier's beaked whale appeared to be quite a frequent species in its favoured habitats. The present study contributes a better knowledge of this poorly-known species, in the context of increasing and threatening anthropogenic noises.*

Keywords: survey; distribution; Cuvier's beaked whale; Mediterranean; ziphiids.

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INTRODUCTION

The determination of beaked whales distribution poses major problems because these medium-sized cetaceans are not visually conspicuous under most sea conditions (Barlow *et al.*, 2006), and can dive for up to 84 minutes during the day (Baird *et al.*, 2006; Tyack *et al.*, 2006). Contrary to the sperm whale *Physeter macrocephalus*, the Cuvier's beaked whale *Ziphius cavirostris* (as well as mesoplodonts) do not upon diving emit loud clicks in the human-auditory band, but start clicking at depths over several hundred metres, transmitting high frequency directional pulses (Johnson *et al.*, 2004; Zimmer *et al.*, 2005). Consequently, clicks are not easily received when using conventional multi-purpose towed array such as the 'IFAW-type', which have proven useful in small boat visual-acoustics distribution surveys (Gordon *et al.*, 2000; Gannier *et al.*, 2002; Lewis *et al.*, 2007). The Mediterranean Sea hosts one regular ziphiid species, the Cuvier's beaked whale (Duguy *et al.*, 1983), with three identified 'key areas', the Genoa Canyon, the eastern Alboran Sea and waters off western Greece (MacLeod & Mitchell, 2006): although the species is little reported during surveys, it is a common stranding case in all the Mediterranean (Podesta *et al.*, 2006). Several mass strandings have been recorded, some of them being officially related to the occurrence of military sonar exercises (Frantzis, 1998), others showing pathological signs of high intensity sound exposure, although not formally linked to naval manoeuvres occurring in the vicinity of stranding sites shortly before the grounding of specimens (Arbelo *et al.*, 2007). There are currently major re-equipment programmes in western navies. As long as the typology of ziphiid sonar-related mortalities is not fully understood, and adequate mitigation techniques are not implemented, the identification of beaked whale hot spots in the Mediterranean remains the only way to avoid further accidents (if one excepts a ban on active sonar use). The current effort to bring significant distribution results in the knowledge of bodies deploying powerful sound sources in the Mediterranean Sea, including (but not solely) the military active sonar users, is focused on modelling (Moulins *et al.*, 2007), while strandings also have brought interesting clues (Podesta *et al.*, 2006; Holcer *et al.*, 2007). However, to date, no attempt has been made to use effort-corrected visual survey data to increase our knowledge. In previous papers, we have used data collected during long-range small boat surveys to study the distribution of sperm and fin whales, and delphinids (Gannier *et al.*, 2002, 2003; Gannier, 2005). With increased data set and specific processing, the present study proposes a view on Cuvier's beaked whale distribution in the western and central Mediterranean Sea.

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MATERIALS AND METHODS

Survey area

We investigated the Mediterranean Sea between the Strait of Gibraltar (5°W) and Crete Island (25°E). From an oceanographic point of view, the Mediterranean Sea is formed by two main basins (Nielsen, 1912): (i) the western basin (from

Gibraltar to Sicily, including the Tyrrhenian Sea); and (ii) the eastern basin (regions east of Sicily). The Tyrrhenian Sea is commonly considered as a distinct entity, because it is semi-enclosed between the islands of Corsica and Sardinia, and mainland Italy, and separated from the rest of the western basin by a channel about 1500 m deep (Figure 1). It also features distinct bottom topography; contrary to the main western basin, the Ionian Sea and the Levantine basin, there are numerous seamounts in the Tyrrhenian Sea, some of them with depths ranging from over 3000 m to less than 500 m. We further divided these three major areas into a total of 11 regions, all encompassing areas of water deeper than 2000 m (the open sea habitat), and areas of continental slopes (200 m to 2000 m). From west to east, we defined the Alboran Sea, the southern Balearic region, the northern Balearic Sea, the Gulf of Lion, the Provençal basin, the Ligurian Sea, the western Corsican region, the western Sardinian region, the northern Tyrrhenian Sea, the southern Tyrrhenian Sea and the central Ionian Sea (Figure 1; Table 1). The slopes are often steep, such as off Provence, Minorca, south-eastern Spain, north-western Sardinia and Corsica, eastern Sicily and south-western Peloponnese. But in some cases, vast areas with intermediate depths (1000 m to 2000 m) make up a major proportion of a region, such as in the Alboran, northern Balearic and Tyrrhenian Seas.

Field methodology

Surveys dedicated to cetaceans were conducted during the summers from 1996 to 2007 with a 12 m motor-sailing boat, and using a consistent three-observer visual and acoustic combined search protocol. An 80 hp diesel engine allowed a mean speed of 11 km/h. The acoustic method will not be detailed here, since the bandwidth of the receiver (200 Hz – 20 kHz) was unable to reliably provide beaked whale data. Each of the surveys was organized between 15 June and 25 August. In 1996, a zigzag survey was dedicated to the Ligurian Sea (see Gannier, 1998 for details), while from 1997 to 2001, zigzag courses were predetermined with tracks aligned approximately 20 – 30° to the longitudinal axis of 'boxes with variable widths placed between two ports of call. In other cases (2002 to 2007), no precise sampling track was adopted, but sampling coverage was defined to include slope and open sea areas. A complementary data set obtained in 2001 during a motor-boat abundance survey in the Pelagos marine mammals sanctuary (Gannier, 2006) was used only for the habitat study, excluding the encounter rate estimates, because vessel characteristics did not allow the pooling of these data with those of the sailboat. The sampling strategy was random, disregarding the Cuvier's beaked whale guessed distribution (i.e. the effort was not focused on areas supposedly favourable to Cuvier's beaked whales), with the exception of one day in June 2007 when the survey route was directed to a seamount in the Ligurian Sea.

The basic crew ranged from five to seven persons, enabling three observers to be on duty, with an additional crew acting as a secretary (and acoustic listener), and individual observers rotating on a two-hourly basis. Visual sightings of all species were systematically noted on paper forms and later converted into a computer database. The survey routine was occasionally interrupted for sperm whale sightings, as this species was focal during a majority of surveys. The visual survey consisted of continuous, naked eye observation: one observer stood in front of the mast searching the $\pm 45^{\circ}$ sector ahead, two other observers, sitting on the roof, scanned the $30^{\circ}-90^{\circ}$ sectors on both sides of the centre line. Visual searching took place from half an hour after sunrise to half an hour before sunset, when the wind speed was lower than Beaufort 4. An index of sighting conditions was recorded every 20 min (Table 2): the index varied from zero to 6 (excellent) and was derived from wind speed, sea-state, residual swell and light conditions (Gannier, 2005). This index was used as a criterion to discard transect portions with poor sighting conditions from the analysis, instead of considering simply the wind force: the Mediterranean Sea state cannot be only described by a mere Beaufort sea state, since on many occasions the sighting conditions are affected by some sort of residual swell. When cetaceans were sighted various sighting parameters were recorded, e.g. distance and bearing to the boat, school size, and behaviour. Further data were

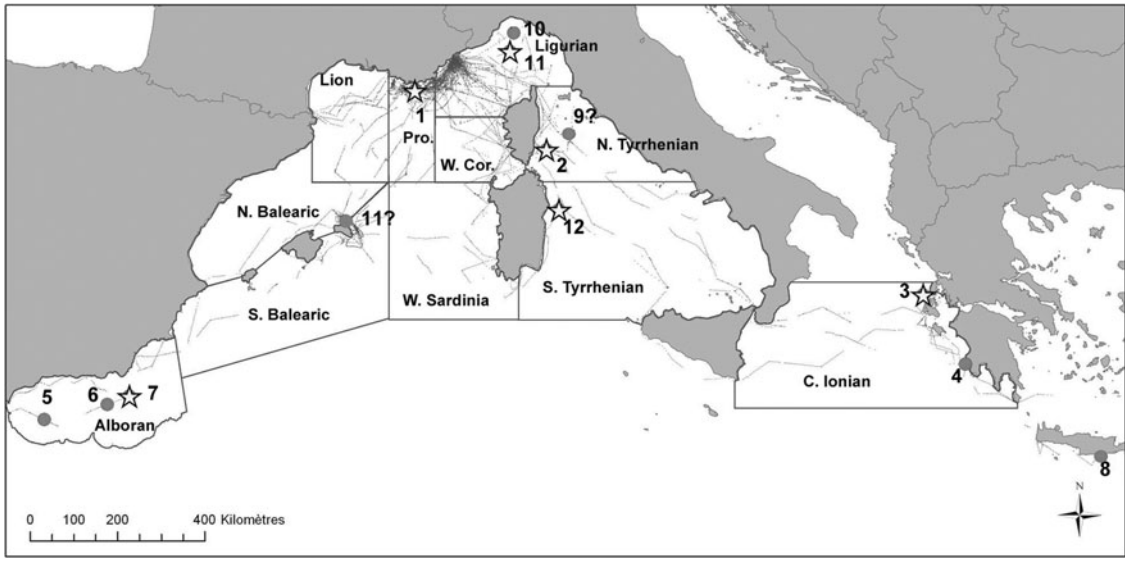

Fig. 1. Area of study, sampling effort and Cuvier's beaked whale sighting 1996 – 2007. Stars are for on-effort sightings with conditions 5 – 6, dots for other cases (see Table 3).

Table 1. Description of study area and effective effort (1996–2007). Area of 11 regions, total, open sea (depth >2000 m) and slope waters (200 m < z < 2000 m). Effective sampling effort, total, open sea and slope waters.

Region	Area (km²)	Slope area (km²)	Open sea area (km²)	Effective effort (km)	Effort slope (km)	Effort open sea (km)
Alboran Sea	63,368	42,025	15,141	413	283	77
Southern Balearic	104,920	28,298	65,385	1,071	665	81
Northern Balearic	65,381	35,925	10,924	587	409	28
Gulf of Lion	46,060	13,818	18,452	556	410	75
Provence	24,845	1,546	21,825	2,457	1,118	943
Ligurian Sea	47,039	16,476	22,470	7,844	3,848	3,494
Western Corsica	27,268	4,227	20,250	942	389	506
Western Sardinia	82,604	10,481	65,145	520	228	169
Northern Tyrrhenian	44,828	460	36,009	979	852	11
Southern Tyrrhenian	152,062	42,555	69,973	1,229	317	544
Central Ionian	145,183	20,465	107,701	1,053	279	366
Total				17,651	8,798	6,294

occasionally collected by nearing cetaceans. Whenever Cuvier's beaked whales were detected, they were tentatively approached to a 100 m distance, however, due to the particular diving habit of the species (still undiscovered by the time most surveys were carried out), such 'wait and see' opportunities were rarely successful.

Data analysis

Cuvier's beaked whale sightings were sorted into two categories of habitat: the open sea and continental slope. We analysed the data to provide average encounter rates for each region, by grouping data for slope and open sea habitats, and global estimates for the slope and open sea strata (by grouping all regions together). We also computed a sighting rate for individuals (SRI), an index which takes account of the school size and may be used as a substitute for relative abundance estimates when conditions do not permit the computing of an effective search width.

The data were exported to ArcGIS software, which was used for mapping the survey track and processing data for each geographical stratum. We created habitat strata for every region in the area of study, using the International Bathymetric chart of the Mediterranean depth contours provided by the GEBCO Atlas (British Oceanographic Data Centre, 2003). For mean encounter rate estimates, the survey track was divided into daily segments and legs covered in any particular years were pooled together to provide an average situation. Variances were estimated on the basis of one sample per survey day. Due to the poor sightability of Cuvier's beaked whales, only segments obtained with sighting conditions of 5 and 6, i.e. very good to excellent, were kept for these estimates (equivalent to Beaufort 0–2 conditions without residual swell and with good light, see Table 2).

RESULTS

Effort and sightings

The total effective effort (sighting conditions 5–6) during the study period amounted to 17651 km, with a maximum survey coverage in the Ligurian Sea (7844 km) and minimum coverage in the Alboran Sea (413 km), western Sardinia (520 km), the Gulf of Lion (556 km) and northern Balearic region (587 km). A majority of effort (49.8%) was devoted to the slope habitat, compared to the open sea (35.7%), the rest concerning the shelf habitat. Due to the regional topography, the continental slope was more sampled than the open sea in several areas, such as the northern Tyrrhenian, Balearic, and Alboran Seas, and Gulf of Lion (Table 1).

From a total of 832 cetacean sightings in sighting conditions 5–6, six were obtained on Cuvier's beaked whales and were available for the sighting rate analysis (Table 3). Five more records were used for the habitat results, because they were either made in sighting condition 4 (for three of them), or in a region outside the area of study (southern Crete), or in the Ligurian Sea during a motor-boat survey (one sighting). The school size varied between 1 (6 cases), 2 (4 cases) and 5 (one case), giving an average of 1.80 (SD = 1.18; N = 10), and sighting bottom depth averaged 1369 m (SD = 498; minimum = 390; maximum = 2150; N = 11). Radial distances of detection for Cuvier's beaked whale sightings averaged 694 m (SD = 302 m; N = 7), while they averaged 850 m (SD = 429 m; N = 17) for Risso's dolphins *Grampus griseus* during the same surveys; these medium-sized delphinids were observed in groups of 5–20 individuals (Gannier, 2005).

All sightings were obtained in the slope habitat, except one in the Ionian Sea which was located in the open sea stratum, although this was in a canyon area less than 2 km from the

Table 2. Sighting conditions index.

Wind speed (knots)	0,1	2–5	6–10	11–15	16–27	>27	over
Beaufort scale	**0**	**1–2**	**2–3**	**4**	**5–6**	**>6**	
Sighting condition index (swell < 0.5 m; good light)[1]	6	5	4	3	2	1	0
Sighting condition index (swell < 0.5 m; low light)	5	5	4	2	2	1	0
Sighting condition index (swell > 0.5 m; good light)	5	4	3	3	2	1	0
Sighting condition index (swell > 0.5 m; low light)	5	4	3	2	2	1	0

[1] good light applies to clear sky and sun ray incidence higher than 15°; swell applies to waves whose origin is away from sampling site.

Table 3. Cuvier's beaked whale sightings 1996–2007. Including those unconfirmed, those obtained with a motor-boat, or with sighting conditions lower than the standard for this study. The index number helps to locate every sighting on Figure 1.

Date	Latitude	Longitude	School size	Detection distance	Sight. conditions	Depth	Remarks	Index
10 July 1997	42°54	6°05 E	1	600	5	950		1
20 June 1998	41°41	9°47 E	2	1200	6	850	with juvenile	2
03 July 1998	38°33	20°22 E	2	450	6	2150	close to slope	3
12 July 1998	37°00	21°34 E	1	300	4	390		4
10 July 1999	35°45	4°21 W	1	150	4	1450		5
11 July 1999	36°06	2°34 W	1	500	4	1850		6
11 July 1999	36°17	1°57 W	2	500	5	1830		7
07 July 2000	34°56	25°29 E	1	400	6	1050	Crete	8
28 July 2001	41°58	10°26 E	2	4000	6	550 ?	unconfirmed	9
31 July 2001	44°06	8°50 E	1	1000	6	1500	motor-boat	10
18 July 2002	40°10	4°08 E	1	1500	4	150 ?	unconfirmed	11
24 July 2006	40°24	10°08 E	5	1200	5	1700	with juvenile	12
20 June 2007	43°46	8°43 E	2	400	5	1390	with juvenile	13

2000 m isobath (sighting number 3 in Figure 1). The sighting of 2006 in the southern Tyrrhenian Sea occurred in a submarine valley located between the main Sardinian slope and an extended seamount oriented parallel to the island coastline (number 12 in Figure 1). In spite of a very substantial effort in open sea, the encounter rate was close to zero in this stratum. In particular, the intense survey effort in the central Ligurian Sea, 7844 km, and in offshore parts of the Provençal region, 2457 km, resulted in no Cuvier's beaked whale sightings. Our survey effort was not detailed here for the continental shelf, but no Cuvier's beaked whale sighting was reported for this habitat.

Cuvier's beaked whales represented 0.72% of the total sightings, but amounted to 1.60% of the records obtained on the continental slope stratum (Table 4). This compared to global proportions of 1.68% for sightings of Risso's dolphins, and 7.69% for sightings of sperm whales (Table 4), a wide ranging species in the Mediterranean Sea for which the visual sighting was aided by a consistent acoustic sampling protocol.

Encounter rates

The Cuvier's beaked whales' mean sighting rate for the study area, excluding the continental shelf, was 0.040 gr./100 km: 0.057 gr./100 km for the slope habitat, and 0.016 for the open sea. This resulted in a sighting rate for individuals of 0.093 ind/100 km (SD = 0.617) in the area of study, with a much higher value for the continental slope habitat (0.136 ind/100 km; SD = 0.497) than for the open sea (0.032 ind/100 km; SD = 2.09).

Although the SRI estimates were imprecise due to very low detection rates, they showed wide variations between regions (Table 4): the highest SRI was obtained in the Alboran Sea (0.484 ind/100 km), but a high estimate (0.407) was also met in the southern Tyrrhenian Sea, and to a lesser extent in the northern Tyrrhenian and Ionian Seas (0.205 and 0.189 ind/100 km, respectively). Very high standard deviations did not allow any meaningful statistical comparisons between regions. Regions with a moderate SRI included Provence and the Ligurian Sea (Table 4); in the latter case it may be recalled that an additional sighting was obtained during a motor-boat survey and was not taken into account in the sighting rate calculation (sighting number 10 in Figure 1). All regions with zero values belonged to the main western basin, from the Gulf of Lion, north, to the southern Balearic and western Sardinia, south (Table 3). In the higher SRI regions, slope encounter rates reached 1.60 (southern

Table 4. Cuvier's beaked whale sightings, sighting rate and sighting rate for individuals for different regions (1996–2007). Sightings of sperm whale and Risso's dolphin are added as a comparison basis.

Region	Total number of sightings	Cuvier's beaked whale number of sightings	Cuvier's beaked whale number of individuals	Risso's dolphin number of sightings	Sperm whale number of sightings	Cuvier's sighting rate (gr./100 km)	Cuvier's SRI (ind/100 km)
Alboran Sea	13	1 (3)	2 (4)	1	0	0.242	0.484
Southern Balearic	33	0 (1*)	0 (1*)	2	11	0.0	0.0
Northern Balearic	25	0	0	1	5	0.0	0.0
Gulf of Lion	35	0	0	3	7	0.0	0.0
Provence	148	1	1	2	16	0.040	0.040
Ligurian Sea	436	1 (2)	2 (3)	4	18	0.013	0.026
Western Corsica	53	0	0	0	1	0.0	0.0
Western Sardinia	10	0	0	0	1	0.0	0.0
Northern Tyrrhenian	32	1 (2*)	2 (4*)	1	2	0.102	0.205
Southern Tyrrhenian	29	1	5	0	1	0.081	0.407
Central Ionian	18	1 (2)	2 (3)	0	2	0.095	0.189
Total	832	6 (13*)	14 (21*)	14	64	0.040	0.093

SRI, sighting rate for individuals.
Number in parentheses denotes the total of Cuvier's beaked whale observations, including those in sighting condition 4; *, superscript indicates unconfirmed sightings.

Tyrrhenian), 0.71 (Alboran), 0.55 (central Ionian) and 0.35 ind/100 km (northern Tyrrhenian).

DISCUSSION

General occurrence

Our results indicated that Cuvier's beaked whales were distributed in both the western and central Mediterranean Sea, although with different levels of occurrence: the Alboran, Tyrrhenian and Ionian Seas were more favourable than most regions of the western basin. The wide ranging nature of Cuvier's beaked whales in the Mediterranean has been reported in earlier accounts (Duguy *et al.*, 1983; Duguy, 1991) from strandings and opportunistic sightings; the authors pointed out that areas of occurrence included the Aegean Sea and Levantine basin, the Algerian and Spanish areas, the surroundings of Sicily and they stated that the Ligurian Sea was a favourable area. This distribution in the Mediterranean has also been confirmed by a recent summary of stranding records (Podestà *et al.*, 2006). By contrast, Cuvier's beaked whales were not reported from large scale conventional surveys in the western Mediterranean Sea (not including the Tyrrhenian Sea) (Forcada *et al.*, 1994, 1995). Notarbartolo di Sciara *et al.* (1993) did not observe the species in waters around Italy, in spite of frequent strandings, an absence already explained by the discrete surface behaviour of Cuvier's beaked whales; likewise, the species did not appear in records from our surveys in 1988–1994 (Gannier, 1995).

Habitat

MacLeod & D'Amico (2006) stated that the beaked whale habitat was to some extent determined by undersea topographical features, such as steep slopes and canyons, but that different species were present in deep abyssal waters, such as in the Eastern Tropical Pacific. The authors also pointed out that information on habitat preferences gathered in certain areas could not be applied in other regions without further research effort. Our study showed that all sightings were made in slope waters, with the exception of one group observed at a depth over 2150 m, very close to the eastern Ionian continental slope. In spite of an intense coverage, not a single sighting was obtained in the open sea away from the slope habitat. In the Gulf of Genoa, one of the key habitats in the Mediterranean Sea (MacLeod & Mitchell, 2006), modelling the results of Moulins *et al.* (2007), showed a sighting rate in the range 0.1–0.6 sight./100 km for optimal slopes, and in the range 0.5–0.8 sight./100 km for bottom depths between 750 and 2000 m. These figures are higher than our regional sighting rates (Table 4), but still in the same order of magnitude, and Moulins *et al.* (2007) surveyed the Cuvier's beaked whales' most favoured habitat in a key area, with a sighting protocol optimized for the species. Two of our sightings (one in the Ligurian Sea, one in the southern Tyrrhenian Sea) were made close to seamounts, which seems contradictory to one of the findings of Moulins *et al.* (2007) who discovered that in the Genoa canyon area, Cuvier's beaked whales were more likely to be observed in areas with a positive depth anomaly, i.e. locations where the bottom was deeper than the surrounding area. We did not observe Cuvier's beaked whales in featureless deep basins, such as the main western or central Ionian Sea, but rather in slope waters or in areas with contrasted topography.

Regional sighting rates

Four regions delivered Cuvier's beaked whale sighting rates higher than average, among which two, the northern and southern Tyrrhenian Sea were not listed in the beaked whale key areas by MacLeod & Mitchell (2006). In the northern Tyrrhenian Sea, Marini *et al.* (1992) reported four Cuvier's beaked whale sightings made from regular ferry surveys between Olbia (Sardinia) and Civitavecchia, a figure later corroborated by a global summary of observed cetaceans, reporting ten sightings of Cuvier's beaked whales, out of 851 sightings (Marini *et al.*, 1996), making a proportion of 1.2%. Our results and accounts of Marini *et al.* (1992, 1996) suggest this region might be favourable to the species. In the eastern Mediterranean, Frantzis *et al.* (2003) stated that the Cuvier's beaked whale was the fifth species in terms of sighting frequency in Greek seas (53 reports out of 821, making 6.3%), which is in agreement with our high sighting rate in the eastern Ionian slope region; they reported numerous sightings and strandings along the Hellenic Trench, and also strandings in the shallower Aegean Sea. North of the Strait of Taranto, in the southern Adriatic Sea, Holcer *et al.* (2007) pointed out that stranding events were relatively numerous in relation to the area extension and hypothesized this relatively deep area was possibly another relevant Cuvier's beaked whale habitat. Our highest SRI was found in the Alboran Sea (0.484 ind/100 km), where stranding reports are listed by Podesta *et al.* (2006), and also include the January 2006 mass stranding event (Arbelo *et al.*, 2007). We obtained our sightings in an area not covered by Canadas *et al.* (2002), who studied the ziphiid distribution from 33 sightings (out of a total of 1134, making 2.9%) in a slope habitat of the north-eastern Alboran Sea; this suggests that Cuvier's beaked whales are widely distributed in this regional sea.

We had only a moderate SRI in the Ligurian Sea (0.013 ind/100 km), which seems to be in contradiction to MacLeod & Mitchell (2006) and Moulins *et al.* (2007). In fact, our sightings (one in-effort, one off-effort) were located in the easternmost part (the Gulf of Genoa), an area not frequently covered by our surveys (Figure 1). No Cuvier's beaked whale sighting was reported in the deeper southern Ligurian Sea in spite of an intense survey coverage, where two other deep diving species, the long-finned pilot whale and the sperm whale, are regularly sighted (Gannier, 2005). This suggests that Cuvier's beaked whales are not wide ranging in the Ligurian Sea, but rather located around the north-eastern part of this region, as described by the effort-coupled distribution maps of Moulins *et al.* (2007). The Cuvier's beaked whales' absence from the Gulf of Lion seemed remarkable, since this area is much frequented by sperm whales (Gannier *et al.*, 2002). Although this absence of sighting might result from our moderate survey effort, we noticed that on 18 long term Cuvier's beaked whale stranding records along the French coastline, the Cuvier's beaked whales only appeared once along the Gulf of Lion shore (Dhermain, 2004). Most Cuvier's beaked whale strandings were recorded along the Provençal shore (9 events), a region where we sighted Cuvier's beaked whales once, or in Corsica, an island located right south of the Gulf of Genoa (7 events). Hence, the absence of Cuvier's beaked

whales from our records in the Gulf of Lion may indicate its true local scarcity.

The south of the western basin is mainly bordered by the Algerian coast, where Cuvier's beaked whale strandings are reported (Podesta *et al.*, 2006), mostly close to Oran and Algiers. The absence of Cuvier's beaked whale stranding reports from the eastern North African countries may owe more to the present status of stranding networks than to the actual occurrence of Cuvier's beaked whales along this 2000 km coastline (Podesta *et al.*, 2006). As a matter of fact, there are six stranding records reported from Israel by Podesta *et al.* (2006), in the easternmost part of the Mediterranean Sea.

Correcting the availability bias

Our sailboat survey effort of 17,651 km with very good sea conditions (equivalent to less than Beaufort 2) delivered only six certain Cuvier's beaked whale sightings (out of 832); by including sighting condition 4 (equivalent to Beaufort 3 with good light and no swell) we would increase the effort by 60% and add only three extra Cuvier's beaked whale sightings, supporting Barlow *et al.*'s (2006) statement on the sightability problems inherent to beaked whale surveys. The Cuvier's beaked whales represented a minor part of the sightings made during our surveys (0.72%), even if we restrain the comparison to the slope habitat (1.60%). Compared to Risso's dolphin, considered as 'secondary' in terms of sighting frequency (Gannier, 2005), the ratio of sighting rates is 1:2.3 in favour of the *Grampus*. However, when dealing with such a sighting rate comparison, one must account for the species availability to visual observers, and its detectability. The radial detection distances (694 m against 850 m) suggested that Cuvier's beaked whales were slightly less detectable during our surveys than Risso's dolphins, either a consequence of school size or surface behaviour, or both. The availability bias also causes under-reporting of beaked whales during surveys (Barlow *et al.*, 2006), due to the extensive dive duration of such species (Baird *et al.*, 2006; Tyack *et al.*, 2006); it was estimated at 0.07 for Cuvier's beaked whales for aerial surveys in Beaufort 0–2 conditions, i.e. only 7% of the Cuvier's beaked whales located close to the trackline would be detectable from the surface, on average. Barlow *et al.* (2006) reported an ealier estimate of $g(0) = 0.23$ for large vessel surveys with a 25x binocular searching protocol in Beaufort 0–2, meaning that 23% of the Cuvier's beaked whales would be detected on the trackline. The above figures for availability and perception biases would suggest that Cuvier's beaked whales were in fact more frequent during our surveys than Risso's dolphins, because their particular dive–surfacing pattern probably more than counterbalances the 1:2 ratio in estimated sighting rates. This intriguing point does not indicate that Cuvier's beaked whales could be more abundant than Risso's dolphins in the Mediterranean Sea, as the average school size of the latter is much higher (11.6, A. Gannier, unpublished data), but suggests that Cuvier's beaked whales would be more frequently reported than Risso's dolphins during surveys, if some device permitted their detection underwater. For example, sperm whale availability at the surface is about 20% in the Mediterranean, with an average dive duration of about 40 minutes and a surfacing time of 10 minutes (Drouot *et al.*, 2004; Watwood *et al.*, 2006), and we obtained 64 sperm whale sightings during our surveys (Table 4), partly because sperm whale sightings were aided by the systematic use of passive acoustic equipment.

CONCLUSION

Our study shows that Cuvier's beaked whales are not regularly distributed in the Mediterranean Sea, the species being apparently rare in deep abyssal basins and more common in areas where bottom topography is variable. Our results also suggest that the Tyrrhenian Sea may be an important habitat for the species. Once compared to other species of wide-ranging cetaceans in the Mediterranean, Cuvier's beaked whales appear to be more frequent than suggested by their low sighting rate. However, large regions of their possible distribution range in the Mediterranean remain insufficiently surveyed. As Cuvier's beaked whales are threatened by high-power sound sources, the need to determine precisely the species distribution is urgent, and this represents a very challenging task.

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