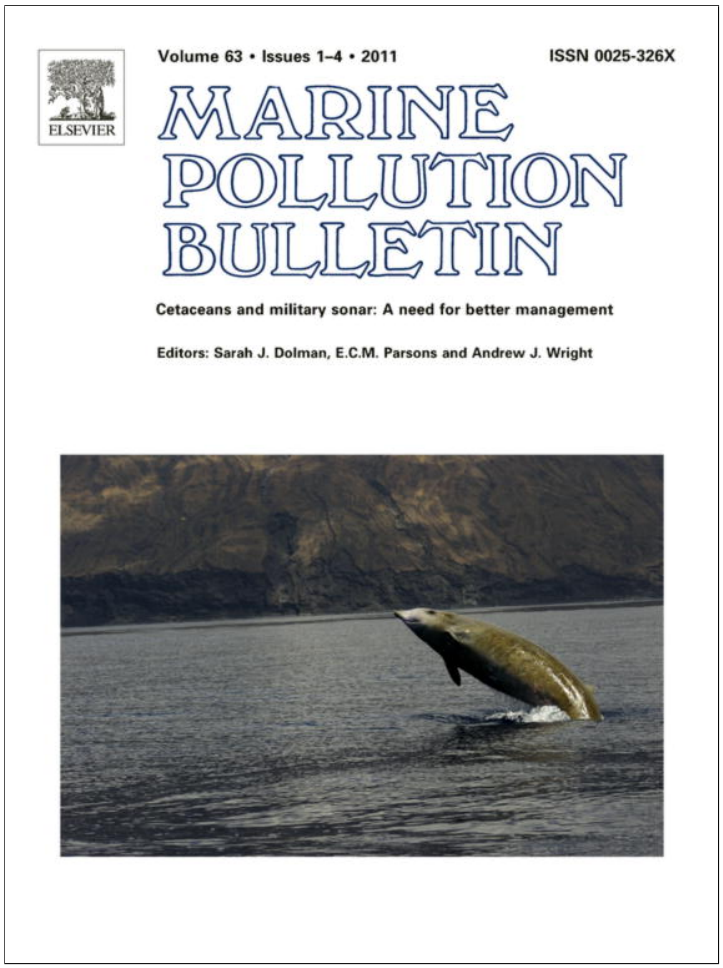

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Using existing data and focused surveys to highlight Cuvier's beaked whales favourable areas: A case study in the central Tyrrhenian Sea

Alexandre Gannier

Groupe de Recherche sur les Cétacés, BP 715, 06633 Antibes cedex, France

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ABSTRACT

This study focuses on the necessary elements to implement strategic mitigation in order to avoid Cuvier's beaked whale (CBW) strandings linked to intense sound sources, such as military active sonars, in the Mediterranean Sea. A careful review of stranding data and the analysis of existing survey results are required to highlight the main characters of the species regional distribution. Focused and repeated surveys are needed to confirm that possible favourable areas, such as the Balearic, Tyrrhenian or Aegean Seas, are really favourable CBW habitats. These surveys should be carried out with sea states 0 to 1 in order to minimize the risk of false absence data. Among the regions of interest, the central Tyrrhenian Sea was surveyed with a 12 m sailboat in 2007 and 2008. With 907 km of effective effort, a mean sighting rate of 1.9 CBW school/100 km was obtained, which is amongst the highest densities recorded in the Mediterranean.

1. Introduction

Cuvier's beaked whale (*Ziphius cavirostris*) is the most cosmopolitan ziphiid species (MacLeod et al., 2006) and is present in various habitat types such as continental slopes, fully oceanic regions and the surroundings of oceanic islands (MacLeod and D'Amico, 2006). It has been recorded in several atypical mass strandings which co-incided with naval activities involving powerful mid-frequency sonars (Frantzis, 1998; Evans and England, 2001; Fernandez et al., 2005; Arbelo et al., 2007). Atypical mass strandings, involving "more than two animals, stranding approximately simultaneously but not in the same location" (Parsons et al., 2008), have been documented on several occasions in the Mediterranean Sea (Podesta et al., 2006), including the widely known Kyparissiakos Gulf case in 1996 (Frantzis, 1998). Future active sonar systems will probably include sound sources as powerful as some existing assets, such as the US Navy's SQS-53C system. As the effectiveness of real-time at-sea mitigation remains to be documented, the avoidance of future sonar-linked CBW strandings in the Mediterranean relies on strategic mitigation. Strategic mitigation may be defined as the choice of a suitable exercise area and time to avoid impacting cetaceans, in particular beaked whales (Barlow and Gisiner, 2006; Dolman et al., 2009). It requires a specific processing of strandings, sightings, as well as other available data.

Beaked whales are difficult to detect at sea. The visual detection of Cuvier's beaked whales (CBWs) during sea surveys is affected by their extended diving durations (Mean = 58 min Tyack et al., 2006), an apparently small school size (2.3 in average, MacLeod and D'Amico, 2006), and surface behaviours that are often unconspicuous. The visual detection also decreases tremendously when wind and sea states are above beaufort two (Barlow et al., 2006). As a result, there are regions in the world where they remain difficult to visually detect most of the time. Acoustic detection at sea can only be achieved at short range, because they tend of only vocalise at depth, and because of the high frequency of their clicks (Zimmer et al., 2005). On average, CBWs in the Ligurian Sea click 56% of the time during their foraging dives (Tyack et al., 2006). In addition, strandings of CBWs are not frequent even in regions close to favourable habitats. For example, in the Bay of Biscay, CBWs have stranded on 30 occasions since 1990 on the French Atlantic shores (Van Canneyt et al., 2008), despite the year-round presence of CBWs within this region (Smith, 2010).

Strategic mitigation of CBW sonar-linked stranding risk appears a difficult task. In this respect, the Mediterranean Sea offers an interesting case study. Reliable long-term stranding networks exist in several countries (Podesta et al., 2006). In addition, three known CBW hot spots have been identified in the Mediterranean Sea. These are the Alboran Sea, the northern Ligurian Sea and the Hellenic Trench (MacLeod and Mitchell, 2006). In addition, habitat preferences for continental slopes have been identified in the north-eastern Alboran Sea (Canadas et al., 2002) and in the northern Ligurian Sea (Moulins et al., 2007). Dedicated surveys have been carried out with various boats over most of the western basin and part of the eastern basin (Notarbartolo di Sciara et al., 1993; Forcada et al., 1994, 1995; Sagarminaga and Canadas, 1996; Gannier, 1998, 2005; Boisseau et al., 2008). Survey results also include

E-mail address: a_o.gannier@club-internet.fr

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consistent seasonal data set at least in three regions where CBWs are present: the central Tyrrhenian Sea (Marini et al., 1996), the Ligurian Sea (Laran, 2005) and the southern Balearic Sea (Gomez de Segura et al., 2006).

I examined the existing information on CBW presence in the Mediterranean Sea, and focused my attention to an area which was not earmarked as a key area (MacLeod and Mitchell, 2006): the central Tyrrhenian Sea. Small boat survey effort was conducted in this region to determine whether it was a CBW hot spot or not. The study combined analysis of existing data and survey work, aiming to identify favourable CBW habitat, and could be adapted to other small and medium-sized beaked whale species, and to other regions.

2. Material and methods

2.1. Stranding data

Most of the existing information on CBW distribution In the Mediterranean Sea came from stranding data up until recently. A complete review of stranding cases in the Mediterranean Sea was provided by Podesta et al. (2006). Reliable stranding networks provided useful cues on the large scale distribution (a few hundred km) of the species, the only assumption being that dead animals most often come ashore close to the location of their death. We accessed three different data sets which had been assumed to be consistent since the early eighties:

- *Stranding data from Spain:* accessed through Medaces website (http://medaces.uv.es), with the authorization of J.A. Raga, previous data being also available in Castells and Mayo (1992)
- *Stranding data from France:* available from the annual stranding reports issued by GECEM (Dhermain, 2004) and CRMM (Réseau National d'Echouages)
- *Stranding data from Italy:* available from the annual stranding reports issued by Centro Study Cetacei (see references below), with recent accounts also accessible from the website (http://mamiferimarini.unipv.it)

Stranding records of each country were sorted in relation to their regional location. The results were used to draw large scale hypotheses regarding CBW distribution and habitat. In addition, these were compared to stranding results for Greece reported by Frantzis et al. (2003).

2.2. Existing survey data

CBW is listed among the common cetacean species in both basins of the Mediterranean Sea although it was not commonly observed at sea until the late nineties (Duguy et al., 1983): for example, Beaubrun (1995) listed only seven sightings of *Z. cavirostris* for the period 1972–1992, but locations were spread from the northern Aegean Sea to the western Alboran Sea. Dedicated cetacean surveys carried out from the early nineties relied principally on visual techniques (Notarbartolo di Sciara et al., 1993; Forcada et al., 1994; Gannier, 1995), with the exception of a survey in the Ligurian Sea (Gordon et al., 2000). Sightings were also obtained in different regions during longitudinal surveys, i.e. an intense coverage of restricted areas throughout several years, sometimes including all seasons: the central Tyrrhenian Sea was surveyed monthly from 1990 to 1992 by means of a regular ferry line between Olbia, Sardinia, and Civitavecchia, mainland Italy (Marini et al., 1996), the Gulf of Vera (southeastern Spain) was surveyed from 1992 to 1995 (Canadas and Sagarminaga, 1995; Sagarminaga and Canadas, 1996), the northern Alboran Sea was surveyed from 1999 onwards (Canadas et al., 2002), the north-eastern Ligurian Sea was surveyed in summer from 1996 to 1998 (Airoldi et al., 1999), the central Ligurian Sea was surveyed monthly from 2001 to 2003 using a motor boat between Antibes, mainland France, and Calvi, Corsica (Laran, 2005), the south-western Balearic Sea was surveyed monthly from 2000 to 2003 with aerial line transects (Gomez de Segura, 2006). A detailed review of the above literature enabled the identification of the main characters of the CBW distribution in the Mediterranean Sea, both on a large and a medium scales.

In addition, from 1995 to 2006, GREC surveys were carried out over a large part of the Mediterranean Sea, with a consistent sighting protocol including a 12 m motor sailboat and a stable core team of observers. CBW sighting rates were estimated from sighting data obtained with sea states $\leqslant 2$ (Gannier and Epinat, 2008), since regular and extensive US Government cetacean surveys had shown that beaked whales were difficult to detect in sea states greater than 2 (Barlow et al., 2006).

2.3. Focused survey

As some of the available literature suggested a consistent occurrence of CBWs in the central Tyrrhenian Sea, two surveys were focused on CBWs in the central Tyrrhenian Sea, during July 2007 and July–August 2008. The area of study was located between 40°30 N and 42 °N, in waters deeper than 500 m. It features a variable topography, with submarine valleys and ridges, seamounts and a bottom depth generally increasing from north to south (Fig. 1).

Surveys were conducted with a 12 m motor sailing boat, using a consistent three-observer visual search protocol combined to acoustic sampling (bandwidth limited to 24 kHz). Individual observers rotated on an hourly basis. Sampling effort was widely distributed in order to cover different CBW possible habitats. A 80 hp diesel engine allowed to cruise at a mean speed of five knots (2.5 m/s). The visual survey technique consisted of naked eye observation, and was adapted to improve the detection of CBWs: one observer stood in front of the mast searching the ±45° sector ahead, two other observers scanned the 30°–120° sectors on both sides of the boat, thus allowing the detection of CBWs surfacing in the rear sector. The crew included two highly experienced observers, one of them being permanently on duty, and volunteers having previously participated in at least one small boat survey. Barlow et al. (2006) calculated a 72% increase in beaked whale sighting rates for observers with over 12 month at sea experience, compared with first-time observers. Visual searching took place in sea states 0 or 1. When CBWs were detected, the distance and bearing to the boat were recorded. Data on behaviour and school structure were collected by closing whales (whenever possible) and included acoustic recordings. The detection of clicks was our criterion to assume that whales started a deep foraging dive, a signal to resume the surveying.

The physiographic variables used for the habitat description were bottom depth and slope, as derived from GEBCO Atlas (IOC-IHO-BODC, 2003). Sighting rates, relative abundances, mean school sizes and effective search width were computed with Distance 5.0 (Thomas et al., 2006). Daily survey tracks were taken as sample units to empirically estimate variances.

3. Results

3.1. Review of stranding results

For Spanish strandings, data were pooled into two shorelines, the Balearic Sea and Balearic Islands, and the Alboran Sea and its eastern approaches to Cape Denia (38.74°N, 0.24°E). In the Balearic

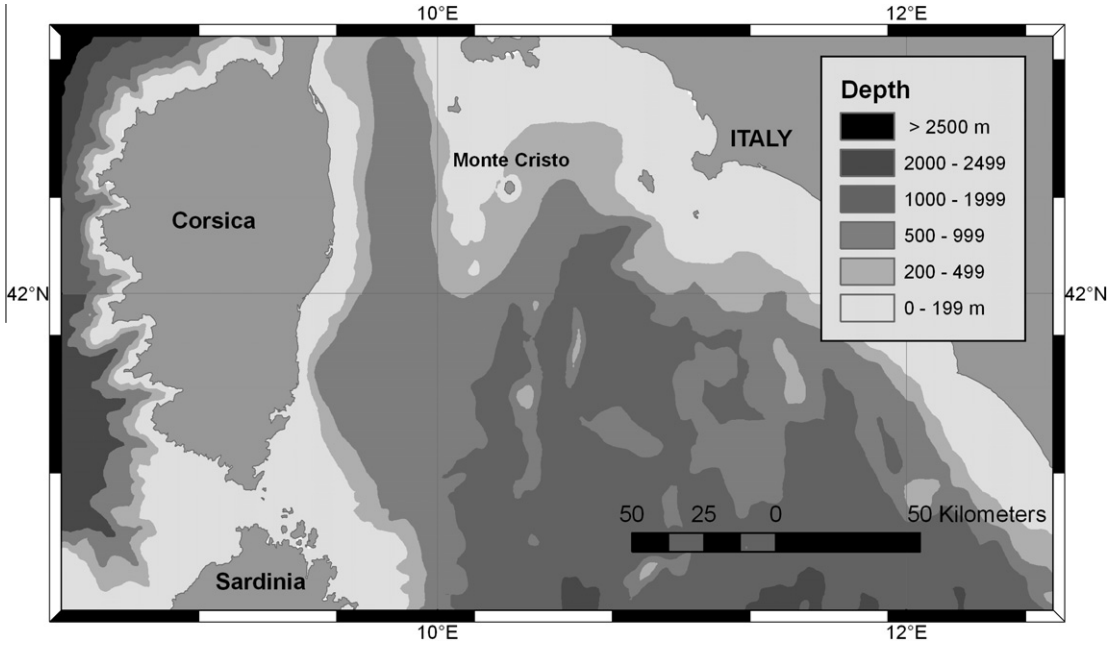

Fig. 1. Bottom depth in the northern and central Tyrrhenian Sea.

region, the stranding series was not regular, with one single case in the eighties, five during the nineties and seven cases from 2000 to 2008 (Table 1). In the southern Spain region, there was an average of eight strandings for each five-year period from 1996 to 2005, and 13 individuals stranded for 2006–2008 (Table 1). Frequent stranding areas were around Almeria (easten Alboran Sea), with 16 individuals of which four stranded in an "atypical" stranding in January 2006 (Arbelo et al., 2007), and a further three stranded within six days in 2007, and around Malaga (western Alboran Sea) with ten specimens. The mean stranding rate was 1.6 individual/year in the southern Spain region (excepting 2006–2008), against 0.6 individual/year since 1990 in the Balearic region.

For French coasts, CBW strandings totalled 21 individuals since 1971, including eight from 1970 to 1979, six from 1980 to 1989, two from 1990 to 1999, and five since 2000 (Table 2). Stranding cases were mainly reported on Var shores (11 specimens) and in northwestern Corsica (seven cases), none being reported on the Tyrrhenian shores of Corsica. The strandings were not regular along the shores of Var, with a rate of 0.4 individual/year from 1971 to 1990, and only three specimens stranded from 1991 to 2008. During the autumn of 1984, three CBWs stranded there over seven weeks. In northern Corsica, four specimens stranded over seven days in December 1974, three of them being found with bullets in their bodies.

Table 1
CBW strandings on Spanish shorelines (compiled from Castells and Mayo, 1992; Podesta et al., 2006, Medaces data-bases and Raga, personal communication).

Balearic region	N strandings	Alboran et southern Spain	N strandings
1960–1969	3		
1970–1979	7		
1980–1989	1	1996 to 2000	8
1990–1999	5	2001 to 2005	8
2000–2008	7	2006 to 2008	13[a]
Total	23		29[a]
Mean stranding rate since 1970	0.51	Mean stranding rate since 1996	1.92[b]

[a] Includes at least one atypical mass stranding in 2006.
[b] Average annual stranding rate excludes the 2006 atypical mass stranding.

Table 2
CBW strandings along French Mediterranan shore (compiled from Réseau National d'Echouages and Dhermain, 2004).

	Total	Var	NW Corsica	Other
1970–1979	8	3	4	1
1980–1989	6	5	0	1
1990–1999	2	1	1	0
2000–2008	5	2	2	1
Total	21	11	7	2
Mean stranding rate	0.55	0.28	0.18	0.05

Numerous stranding cases were reported along the Italian shores, with 58 individuals from 1987 to 2007 (Centro Studi Cetacei, 1988, 1990, 1991, 1992, 1994, 1995, 1996a,b, 1997a,b, 1998, 2000, 2001, 2002, 2003, 2004a,b, 2006), giving a mean stranding rate of 2.76 individuals/year. Stranding cases were more frequent in three regions (Table 3): 21 specimens were reported along Ionian shores, 14 along the shores of the northern and Tyrrhenian Sea (including eastern Sardinia), eight individuals along Ligurian shores. The frequent strandings in southeastern Italy (including eastern Sicily) suggested favourable CBW habitats in the northern Ionian Sea. The Tyrrhenian Sea, in particular its northern half, featured the second highest mean annual stranding rate (Table 3).

Along Greek shores, CBW was among the most frequently stranded cetaceans, with 73 individuals from 1991 to 2001 (Frantzis et al., 2003). However, among this total at least 23 individuals mass-stranded in relation to naval exercises in 1996 and 1997 (Frantzis, 2004; Podesta et al., 2006). Frantzis et al. (2003) confirmed the northern Ionian Sea as a favourable habitat, but also suggested other interesting sub-regions such as the northern and southern Aegean Sea, and the area close to Rhodes and Crete islands.

3.2. Information from existing survey results

Notarbartolo di Sciara et al. (1993) did not report CBW sighting in waters surrounding Italy and the Ligurian Sea, although they surveyed most coastal and slope waters with a total effective effort

Table 3
CBW strandings along regional shorelines of Italy (compiled from the Annuals Reports of Centro Studi Cetacei/Museo Civico de Storia Naturale de Milano 1988 to 2006, and CSC database).

	Total	Ligurian	Northern Tyrrhenian	Southern Tyrrhenian	Southern Sicily and Sardinia	Ionian	Southern Adriatic
1987–1991	12	0	7	4	1	0	0
1992–1996	20	3	3	1	1	11	1
1997–2001	12	4	2	1	1	4	0
2002–2006	11	0	2	0	3	5	1
2007	3	1	0	0	1	1	0
Total	58	8	14	6	7	21	2
Mean stranding rate	2.76	0.38	0.67	0.29	0.33	1.00	0.09

of 2453 h, and recorded 246 cetacean sightings. Forcada et al. (1994) surveyed the western basin, excluding the central and southern Tyrrhenian Sea, during the summer of 1991: some CBW sightings were recorded in the Alboran and Ligurian Seas (J. Forcada, pers.comm). Gannier (1995) did not observe CBWs during surveys held from 1988 to 1994 in various areas of the western Mediterranean, despite 969 cetacean sightings being recorded during 16,800 km of effort. Boisseau et al. (2008) reported two on-effort CBW sightings obtained during wide scale zig-zag sampling of various regions of the south-western and eastern Mediterranean Sea, including one in oceanic waters of the Levantine basin. Gannier and Epinat (2008) reported 13 sightings after 17,650 km of effort on the western and central Mediterranean Sea: favourable habitats were met in the Alboran, Tyrrhenian and Ionian Seas, CBWs being marginally present or absent in other regions (Table 4).

The scarcity of sightings provided by various extensive surveys might bring us to the conclusion that CBWs are not common in the surveyed waters. However, the poor detectability of the species has to be accounted for, whenever sea state exceeds 2 (Barlow et al., 2006), and a good proportion of the survey coverage may indeed pertain to the sea state 2 to 3 category. Such a poor sighting rate may also be related to the distribution pattern of CBWs in the Mediterranean Sea. That is, the distribution may be patchy, being restricted to a specific habitat type with no or few individuals wandering outside several hot spots. As a result, the true presence of CBWs in favourable areas could be missed unless there is a dense survey coverage with very good sea conditions.

Marini et al. (1996) reported ten CBW groups on a total of 851 sightings obtained during 42,000 km of effort in the central Tyrrhenian Sea: groups of one and two individuals were observed over depth of 1000–1800 m, throughout the study period, from December to August. Cañadas and Sagarminaga (1995) did not observe CBWs during three years of surveys in the Gulf of Vera, but the species was observed once, when they covered an area further west in the eastern Alboran Sea, in 1995 (Sagarminaga and Cañadas, 1996). Airoldi et al. (1999) observed 15 groups of CBWs over three years of surveys in the northern Ligurian Sea, totalling 8342 km of effort in good sea conditions. CBWs ranked third among 328 cetaceans sightings in the area and were more frequently reported than sperm whales. They were observed over mean water depths of 2012 m, and groups numbered 2.4 individuals on average. Laran (2005) did not observe CBWs in the central Ligurian Sea, after 7700 km of monthly transects and a total of 495 sightings. Gannier (1998) did not report CBWs in the southern Ligurian Sea and Provence slope waters, after 14,826 km of effective effort spread over eight years. In the south-western Balearic Sea, Gomez de Segura (2006) carried out monthly zig-zag surveys and obtained a total of 247 cetacean sightings over 20,200 km, including three groups of 1–4 CBWs, observed in waters 800–1200 m deep. Canadas et al. (2002) reported 33 sightings, among which CBWs, during regular surveys in the north-eastern Alboran Sea.

CBW sightings were also reported in isolated accounts published by experienced marine mammal observers. In the north-eastern Ionian Sea, the presence of CBWs was shown by Politi et al. (1992) and Pulcini and Angradi (1994) close to the Greek Ionian islands, with five sightings of three individuals on average obtained during the summer 1993. CBWs were sighted in water depth between 580 and 1060 m, with slopes ranging from 70 to 150 m/km. Carpentieri et al. (1994) observed CBWs during ferry crossings in the southern Aegean Sea, over water depths ranging from 1000 to 1500 m. In the straits of Sicily, Tringali et al. (2006) reported a group of five CBWs north of Linosa Island, an area with a submarine depression more than 1000 m deep.

To sum up, CBWs were regularly observed in five regions including three previously reported as key areas (MacLeod and Mitchell, 2006). The comparison of between Airoldi et al. (1999) and Laran (2005) shows that extensive surveys carried out in neighbouring areas can bring different results on CBW presence. Where CBWs are regularly sighted, as in Marini et al. (1996), they may be present in different seasons. This suggests that, in terms of strategic mitigation, CBW distribution in the Mediterranean Sea

Table 4
Sighting rates and frequencies of CBW in different regions of the Mediterranean Sea as obtained from the literature.

	Survey type	Sighting rate (school/100 km)	Sighting frequency (%)	Reference
Northern Ligurian Sea	w.-watching with dedicated obs.	0.18	4.6	Airoldi et al. (1999)
Central Ligurian Sea	Monthly boat transect	0.0	0	Laran (2005)
SW Balearic Sea	Monthly aircraft transect	0.01	1.2	Gomez de Segura (2006)
Central Tyrrhenian Sea	Monthly ferry crossing	0.02	1.2	Marini et al. (1996)
Southeastern Spain	Ecotourism with dedicated obs.	0.0	0.0	Canadas and Sagarminaga (1995)
Northwestern basin	Non-systematic dedicated sailboat	0.01–0.04	0.6	Gannier (2005) and Gannier and Epinat (2008)
Northern Tyrrhenian Sea	survey 1991–2006	0.10	15.3	
Southern Tyrrhenian Sea		0.0	0	
South-western basin		0.0	0	
Alboran Sea		0.24	6.8	
Central Ionian Sea		0.10	6.8	

should be considered on a medium or even small scale, rather than on a large one.

3.3. Focused survey results

The sampling effort in the northern/central Tyrrhenian Sea amounted to a total of 907 km with sea states 0–1 (Table 5). A total of 22 CBW sightings were obtained during survey tracks, among which three were secondary, i.e. collected in "standby mode" (Fig. 2). School sizes ranged from one to five, including 14 sightings of two to three individuals (Table 6), with a mean 2.5 (CV = 13.4%). Six schools included either a calf, with an estimated size about half that of the accompanying adult, or a juvenile, making a proportion of 13% of young individuals.

CBWs were observed in waters 1094 m deep on average (Table 6) and over moderate slopes (61 m/km on average), although the range was extended, with five sightings on slopes less than 25 m/km and three sightings on slopes over 100 m/km (Fig. 3). CBWs were observed in deeper waters in 2008 (1277 m, SD = 241) compared to 2007 (872 m, SD = 299). Both the shallow dives and the feeding dives were synchronous. On two occasions, groups of three and five whales were observed socializing at the surface, with conspicuous behaviours.

We obtained an average sighting rate of 1.88 sighting/100 km, and a relative abundance index of 4.7 individuals/100 km. The effective search half-width was estimated at 755 m (Table 7). The relative abundance indices were higher in 2007 compared with 2008, with respectively 5.7 and 3.8 individuals/100 km.

Table 5
Cuvier's beaked whale sampling effort in the northern–central Tyrrhenian Sea (2007, 2008).

Date	Sea state	Survey time	Effort km	CBW sightings
14-07-07	0	8h55–21h00	61	4
15-07-07	1	7h59–20h22	95	2
16-07-07	1	6h25–11h58	36	1
19-07-07	1	8h43–19h22	87	1
20-07-07	1	9h12–19h48	83	0
16-07-08	0	9h39–20h20	75	1
17-07-08	1	9h22–12h53	29	0
24-07-08	0	7h07–19h51	61	1
26-07-08	0	10h50–19h53	72	0
28-07-08	0	11h08–18h35	42	0
29-07-08	0	12h15–20h09	62	0
30-07-08	1	6h58–18h38	58	1
31-07-08	1	7h30–18h50	59	4
19-08-08	0	8h33–20h19	87	4
Total			907	19

4. Discussion

4.1. On useful criteria to select potentially favourable areas in the Mediterranean Sea

Barlow and Gisiner (2006) argued that a simple extrapolation of habitat preferences may not be efficient to identify regional CBW hot spots since the species has been shown to select different habitats in different areas world-wide. The existing literature, based on strandings and sightings enables to outline broad CBW habitat characteristics in the Mediterranean Sea: water depth is generally in excess of 700 m, but the abyssal depths are not favoured by the species. Bottom slope values can be variable and the nearby continental shelf can be narrow or quite wide such as in south-western Balearic Sea. The water mass can be oligotrophic (Hellenic Trench) or mesotrophic (northern Alboran Sea), and the sea surface temperature values range from the warmest regions, such as the Levantine basin, to seasonally cooler waters, such as in the Aegean and Ligurian Seas. This range of habitat properties is found in many regions of the Mediterranean Sea, hence the wide-spread stranding reports (Podesta et al., 2006).

Listing the potential favourable areas could be carried out by using basic criteria, as proposed by MacLeod and Mitchell (2006) for beaked whales key areas world-wide:

(a) areas where one or more beaked whale species have been regularly recorded at sea
(b) areas used during movements between two or more key areas identified in criterion (a)

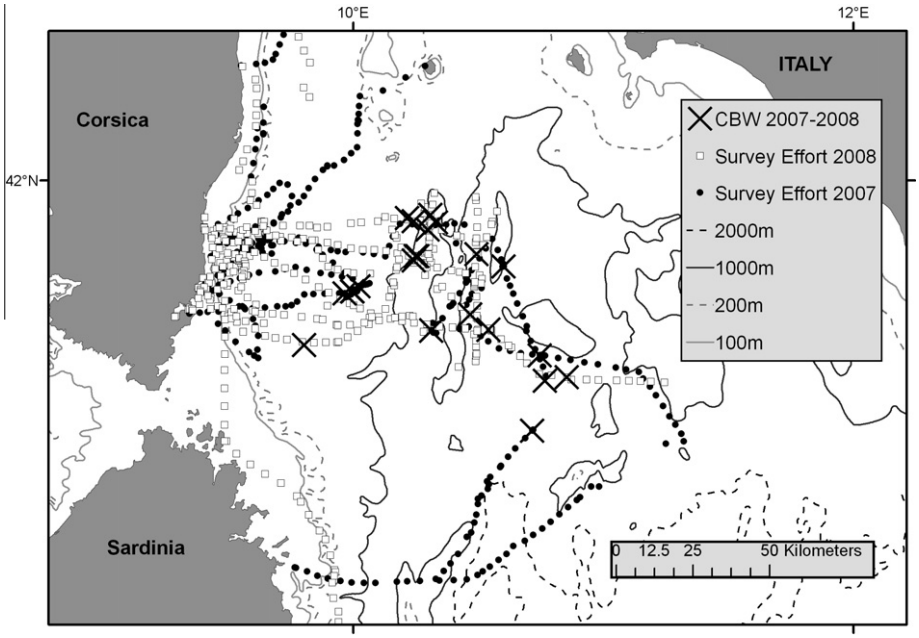

Fig. 2. Focused survey in the central Tyrrhenian Sea: effort and sightings in 2007 and 2008.

Table 6
Cuvier's beaked whale sightings 2007–2008 (on-effort and secondary).

	Sighting number	Date	Time	School size	Radial distance detection	Bottom depth	Remarks
(1)	107,054	14/07/07	1150	1	500	800	
(2)	107,056	14/07/07	1317	2	600	760	w.juvenile
(3)	107,057	14/07/07	1726	1	1200	800	
(4)	107,058	14/07/07	1759	2	1000	720	Secondary
(5)	107,060	14/07/07	1935	5	1100	800	w.juvenile
(6)	107,066	15/07/07	759	3	800	1190	w.calf
(7)	107,072	15/07/07	1416	3	800	750	
(8)	107,074	16/07/07	625	1	500	1600	
(9)	107,088	19/07/07	1405	3	1000	1100	
(10)	108,038	16/07/08	1558	1	150	1100	
(11)	108,053	24/07/08	1305	1	1500	1190	
(12)	108,054	24/07/08	1444	2	600	1100	w.juv./secondary
(13)	108,090	30/07/08	1509	3	500	1507	
(14)	108,095	31/07/08	840	1	2000	1094	
(15)	108,098	31/07/08	950	3	2000	1114	
(16)	108,099	31/07/08	1052	3	400	1132	
(17)	108,100	31/07/08	1332	1	1500	987	
(18)	108,101	31/07/08	1402	1	1500	876	Secondary
(19)	108,121	19/08/08	1227	2	100	1536	w.calf
(20)	108,122	19/08/08	1402	2	3000	1577	
(21)	108,126	19/08/08	1700	3	250	1487	w.juvenile
(22)	108,127	19/08/08	1819	2	1200	1517	

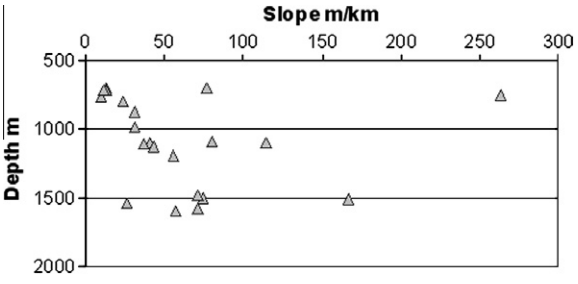

Fig. 3. Plots of bottom depth and slope of CBW sightings 2007/2008.

Table 7
Summary of relative abundance indice 2007–2008.

	2007	2008	2007–2008
L effort (km)	362	545	907
n primary sightings	8	11	19
S mean school size	2.62 (CV = 17%)	2.40 (CV = 9%)	2.50 (CV = 13%)
n/*L* sighting rate (/100 km)	2.2 (CV = 45%)	1.6 (CV = 36%)	1.88 (CV = 32%)
Relative abundance index (ind./100 km)	5.7 (CV = 48%)	3.8 (CV = 37%)	4.7 (CV = 35%)

(c) areas with a high diversity of beaked whales where 'high' means records of more than 25% of all beaked whale species and at least 50% of all beaked whale genera
(d) relatively small areas that cover a large portion, or all, of the known range of a species or isolated population

The third criterion can not be applied to the Mediterranean Sea, where *Z. cavirostris* is the only regularly occurring species of beaked whales (Mesoplodont strandings are very rare, and *Hyperoodon ampullatus* is occasional only in the Alboran Sea – Canadas and Sagarminaga, 1997).

The mean annual stranding rate may be used for a pre-selection of large scale CBW favourable areas, as already proposed by Holcer et al. (2007). Spanish records provide annual stranding rates of 1.92 in the Alboran area and 0.51 in the Balearic area, hence suggesting a CBW habitat in the latter region. For Italian records, the second highest stranding rate is in the northern/central Tyrrhenian Sea (0.67 stranding/year), compared to 1.0 found in the northern Ionian Sea, a reported key area (MacLeod and Mitchell, 2006).

The first criterion of MacLeod and Mitchell (2006) may be modified to take CBW sighting rate into account at a regional scale. However, sighting rates depend heavily on platform type and sea state, and comparisons may be biased by survey conditions met in different regions (Barlow et al., 2006). Also, observer experience is rarely detailed in studies and the importance of this factor has been emphasized. Instead of sighting rates, we propose to use the sighting frequency, defined as the proportion of CBW sightings on the total number of odontocete sightings obtained during the survey (n_{CBW}/n_{total}). Bigger survey vessels will generally lead to higher sighting rates whatever the species. Less favourable sea conditions will have a detrimental effect on the sighting rates of most odontocete species, hence not changing heavily every species sighting frequency. This criterion seems useful to compare regions in the Mediterranean Sea (Table 4).

4.2. On focused local surveys to confirm favourable habitats

During the survey in the Tyrrhenian Sea, a mean sighting rate of 1.9 CBW sighting/100 km was obtained, which is much higher compared to sighting rates of 0.1–0.24 reported by Gannier and Epinat (2008) for different regions (Table 4). Moulins et al. (2007) obtained sighting rates of 0.5–0.8 school/100 km in the Ligurian Sea. The focused surveys were carried out during two consecutive years, for which quite similar sighting rates were obtained (Table 7). Local variations of sighting rates could eventually result from large scale CBW movements between different favourable areas, such as the northern Ligurian Sea and this area of study, which are only 250 km apart. Movements of CBWs within the Mediterranean Sea have not been documented, but McSweeney et al. (2007) reported a degree of site fidelity for CBW off the Hawaii islands.

Differences in the sampling strategy probably contributed to the higher sighting rate obtained. Firstly, the area of study was specifically chosen from previous surveys results (including Marini et al., 1996) and searching was focused on a favourable bathymetric range, *i.e.* 500–2000 m depth. Secondly, optimal sea conditions were selected in agreement with Barlow et al. (2006): 28%, 40% and 32% of the effort were respectively obtained under 0, 1 and 2 sea

states. Thirdly, due to the specific sighting protocol, 32% of detections were obtained in the rear sector, increasing the sighting rate compared to a standard practice. Lastly, the option to interrupt survey effort whenever one CBW school was detected (sighting lasted 66 min on average), probably induced a positive bias on the sighting rates: once a favourable area had been reached, the successive stops to study behaviour tended to maintain the survey boat within the "hot spot". During usual distribution surveys, closing the cetaceans to determine behaviour would only be allowed for a short time.

The focused surveys detailed here confirmed that the central Tyrrhenian Sea was a CBW habitat, in addition to the key areas listed by MacLeod and Mitchell (2006). Other favourable habitats certainly exist in both basins of the Mediterranean Sea, including the Balearic Sea, the northern and southern Egean Seas, as well as other poorly documented regions.

5. Conclusion

The most effective mitigation to avoid sonar-related atypical strandings largely relies on the localisation of hot and cold spots. The present study showed that a small scale regional effort can be successfully used to document CBW presence in regions which have been previously earmarked from existing survey and stranding data. There are still undiscovered Cuvier's beaked whale habitats in the Mediterranean Sea.

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