CHAPTER FOUR

Cuvier's Beaked Whale, *Ziphius cavirostris*, Distribution and Occurrence in the Mediterranean Sea: High-Use Areas and Conservation Threats

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Abstract

Cuvier's beaked whale (*Ziphius cavirostris* G. Cuvier, 1823) is the only beaked whale species commonly found in the Mediterranean Sea. Until recently, species presence in this area was only inferred from stranding events. Dedicated cetacean surveys have increased our knowledge of the distribution of Cuvier's beaked whales, even though many areas still remain unexplored. Here, we present an updated analysis of available sighting and stranding data, focusing on the atypical mass strandings that have occurred in the Mediterranean Sea since 1963. We describe in detail the five more recent events (2006–14), highlighting their relationship with naval exercises that used mid-frequency active sonar. The distribution of the species is apparently characterized by areas of high density where animals seem to be relatively abundant, including the Alborán Sea, Ligurian Sea, Central Tyrrhenian Sea, southern Adriatic Sea and the Hellenic Trench, but other such areas may exist where little or no survey work has been conducted. Population size has been estimated for the Alborán and Ligurian seas. Habitat modelling studies for those areas, confirmed the species preference for the continental slope and its particular association with submarine canyons, as has also been found to be the case in other areas of the world. The application of results from habitat modelling to areas different from their calibration sites is proposed as a management tool for minimizing the potential impacts of human activities at sea. Military sonar is known worldwide as a threat for this species and is suggested to be a major threat for Cuvier's beaked whale in the Mediterranean Sea.

1. INTRODUCTION

Cuvier's beaked whale (*Ziphius cavirostris* G. Cuvier, 1823) is one of the best known species of the family Ziphiidae, and has a cosmopolitan distribution in all oceans, with the exception of very high-latitude polar regions of both hemispheres (MacLeod et al., 2006). Cuvier's beaked whales occur in deep waters (>200 m) and are often found over the continental slope, apparently frequenting slope areas with a steep seafloor (Taylor et al., 2008). The elusive behaviour of this medium-sized odontocete, with short surfacing durations and inconspicuous blows, as well as its offshore distribution, have made the species very difficult to study at sea (Heyning, 1989). During the last decade, field research conducted with data logging tags (Johnson and Tyack, 2003) characterized these animals as extreme divers, since they can routinely dive deeper than 1 km for an hour or more (Baird et al., 2006; Tyack et al., 2006). The mammalian dive record has recently been reported by Schorr et al. (2014) for a Cuvier's beaked whale tagged off the Southern California coast that reached a depth of 2992 m with a dive duration of 137.5 min (both new mammalian dive records).

Fig. 1 An adult male Cuvier's beaked whale (*Ziphius cavirostris*) breaching in the Ligurian Sea (ID 31308071 CIMA RF database). Note the presence of erupted teeth extending beyond the rostrum and dense scarring along the anterior part of the animal. *Photograph: M. Rosso, CIMA Research Foundation.*

Cuvier's beaked whale is the only beaked whale species commonly found in the Mediterranean Sea (Fig. 1). A few other species (*Mesoplodon* spp.) are reported occasionally as rare sightings or strandings (Notarbartolo di Sciara and Birkun, 2010; Podestà et al., 2005). In the past, Cuvier's beaked whale presence in the region has mainly been inferred via stranding data (Podestà et al., 2006). Over the last 30 years, however, dedicated cetacean surveys have greatly increased our knowledge on the distribution of this species, despite the fact that survey effort has not covered the entire Mediterranean Basin and many areas remain unexplored (Cañadas, 2012). Occurrence of Cuvier's beaked whale has been confirmed for the entire Mediterranean Basin, from the Western Mediterranean (Alborán Sea) to the far eastern part of the Levantine Sea. Species distribution is apparently characterized by areas of high density, where individuals seem to be relatively abundant, such as in the Alborán Sea, Ligurian Sea, Central Tyrrhenian Sea, South Adriatic Sea and the Hellenic Trench (Cañadas et al., 2013).

In the Ligurian Sea, Cuvier's beaked whale diving and foraging behaviour has been investigated using archival DTag technology (Aguilar de Soto et al., 2006; Johnson et al., 2004). Dive profiles were characterized by a series of shallow dives, lasting no more than 22 min and reaching a maximum depth of 425 m, followed by deep dives to a maximum depth of 1888 m with a maximum duration of 85 min (Tyack et al., 2006; Zimmer et al., 2005). A recent study in the Ligurian Sea used photo-identification techniques based on natural markings and found that notches, large scars, scrapes and other markings

(some the result of inter/intraspecific aggression) are long-lasting marks that may be used for future studies, including mark-recapture studies to provide estimates of abundance for this species (Rosso et al., 2011).

Cuvier's beaked whales are suction feeders, frequently preying upon deep-sea cephalopods, but also occasionally feed on fish and crustaceans (MacLeod et al., 2003). Feeding habits in the Mediterranean Sea have been described based on stomach contents of specimens from Spanish waters (Blanco and Raga, 2000), the Ligurian Sea (Orsi Relini and Garibaldi, 2005), the Tyrrhenian Sea (Carlini et al., 1992; Pedà et al., 2015; Podestà and Meotti, 1991), the southern Adriatic Sea (Kovačić et al., 2010) and the Ionian Sea (Garibaldi et al., 2015; Lefkaditou and Poulopoulos, 1998). These results confirm that in the Mediterranean, deep-sea squids (primarily histioteuthids) represent the main prey for this species, although in a single case mesopelagic fish was found to be a significant part of the stomach contents (Garibaldi et al., 2015). Woodside et al. (2006) suggested that seafloor gouge marks on mud volcanoes observed during geological surveys in the eastern Mediterranean Sea (at depths of 1700–2100 m) could have been made by Cuvier's beaked whales during foraging dives.

Habitat preference of beaked whales has been investigated worldwide (Baumgartner et al., 2001; Davis et al., 1998, 2002; Ferguson et al., 2006; MacLeod, 2000; MacLeod and D'Amico, 2006; MacLeod and Mitchell, 2006; Mannocci et al., 2011; Waring et al., 2001). Most studies reported a clear relationship with the topographic features of the sea bottom (Baumgartner et al., 2001; Davis et al., 1998, 2002; Ferguson et al., 2006; Mannocci et al., 2011; Waring et al., 2001), with beaked whales regularly observed over the continental slope in waters up to 2000 m of depth (Hamazaky, 2002; Hooker et al., 2002; MacLeod and Zuur, 2005; MacLeod et al., 2006; Waring et al., 2001) and near submarine canyons (Wimmer and Whitehead, 2004). This is consistent with findings for Cuvier's beaked whales in the Mediterranean Sea where the species has also been found to be associated with the continental slope, and in particular, with submarine canyon areas (Azzellino et al., 2008, 2011, 2012; Cañadas and Vázquez, 2014; Cañadas et al., 2002; Coomber, 2016; D'Amico et al., 2003; Moulins et al., 2007; Tepsich et al., 2014). Indeed, the species' habitat preferences are mainly driven by its diet. The main high-density areas, where habitat preferences of this species have been studied in the Mediterranean Sea, are the Genoa Canyon in the Ligurian Sea, located within the Pelagos Sanctuary for Mediterranean Marine Mammals (the largest Mediterranean Marine Protected Area, MPA, encompassing an area

between southeastern France, Monaco, northwestern Italy, Northern Sardinia and surrounding Corsica and the Tuscan Archipelago), the Alborán Sea and the Hellenic Trench. MacLeod and Mitchell (2006) classified these three areas as Cuvier's beaked whale 'key areas' in the Mediterranean Sea. However, the records of species occurrence and the geographical complexity of some additional areas, such as the Tyrrhenian Sea (Arcangeli et al., 2015; Gannier, 2011) and the southern Adriatic Sea (Holcer et al., 2007), suggest that potential areas of key habitat and high Cuvier's beaked whales density may exist in other regions of the Mediterranean Sea.

In a worldwide molecular genetic analysis of the species, a high degree of differentiation was observed between Atlantic Cuvier's beaked whales and the Mediterranean population (Dalebout et al., 2005). Moreover, haplotype diversity was lower in the Mediterranean Sea than in other regions investigated, suggesting that this population may be isolated and relatively small (Dalebout et al., 2005).

Globally, the species is assessed as being of Least Concern on the International Union for the Conservation of Nature (IUCN) Red List (Taylor et al., 2008), while the Mediterranean sub-population is classified as Data Deficient (Cañadas, 2012), and a proposal to change the current listing to Vulnerable is currently under review. This proposal is prompted by the multiple mass strandings of Cuvier's beaked whales that occurred in the basin during the past five decades, causing the death of at least 100 animals, and demonstrated to have been related to naval exercises using mid-frequency active sonar (ACCOBAMS, 2016; Frantzis, 1998, 2015; Podestà et al., 2006) (see Section 2.2).

Here we review and synthesize information on distribution, abundance and habitat of Cuvier's beaked whale in the Mediterranean Sea. We begin with a review of recent Cuvier's beaked whale strandings, including records of single strandings and a description of recent atypical mass stranding events. Next, we outline what is known about the distribution of Cuvier's beaked whales in the Mediterranean, describing the known areas of high density, and including information on apparently preferred habitat in the Mediterranean Sea—the Alborán Sea, Ligurian Sea, Central Tyrrhenian Sea, southern Adriatic Sea and the Hellenic Trench. We include a discussion of the results of a recent collaborative effort implemented by the Agreement on the Conservation of Cetaceans in the Black Sea, Mediterranean Sea and Contiguous Atlantic Area (ACCOBAMS) to map areas of high use by beaked whales in the Mediterranean region. Major anthropogenic threats affecting the species in the Mediterranean are highlighted, demonstrating

that urgent conservation measures are needed to ensure the protection of the Cuvier's beaked whales in the Mediterranean Sea.

2. STRANDINGS OF CUVIER'S BEAKED WHALES IN THE MEDITERRANEAN REGION

2.1 The Importance of Strandings for Understanding Cuvier's Beaked Whale Ecology

Comparisons of stranding data with sighting data have demonstrated that stranding records can be a good indicator of species composition at sea and can sometimes be used to infer species distribution (Maldini et al., 2005; Peltier and Ridoux, 2015; Peltier et al., 2012; Pyenson, 2010, 2011).

Effort for the collection of stranded marine mammals along Mediterranean coasts is extremely variable, but very few stranding networks are organized at a national level (these include France, Israel, Italy, Croatia, and to a lesser extent, Greece and Spain), and many areas are managed by local institutions that have limited geographical coverage. Coastal topography presents another difficulty, including areas that are inaccessible, and the expanse of small islands cannot be carefully monitored for stranded animals (e.g. Greece).

Podestà et al. (2006) reviewed Cuvier's beaked whale strandings in the Mediterranean Sea from the first stranding record in 1803 to 2003. A total of 316 stranded individuals were reported from Albania, Algeria, Croatia, Egypt, France, Greece, Israel, Italy, Malta, Spain and Turkey. Countries with a higher number of strandings included Italy (118), Greece (86), Spain (38) and France (34) (atypical mass stranding events were also reported for these countries).

To update stranding records for the Mediterranean coasts, we reviewed the literature and searched for unpublished records (2004–15). Strandings included single individuals and mass strandings of multiple individuals, including some for which there was no exact number. Therefore, an approximate total of 100 Cuvier's beaked whales were found stranded in Algeria, Croatia, France, Greece, Israel, Italy, Lebanon, Malta, Spain, Syria, Turkey (Arbelo et al., 2008; Banca Dati Italiana Spiaggiamenti, 2015; Dalton, 2006; Dhermain, 2012; Dhermain et al., 2011, 2015; Gomerčić et al., 2006; Gozalbes-Aparicio and Raga, 2015; Holcer et al., 2007; Kerem et al., 2012; Medaces, 2015; Öztürk et al., 2011; S. Muscat, Marine Rescue Team, Malta, personal communication, 23 June 2011). Strandings had previously been reported from each of these countries (see Podestà et al.,

2006), with the exceptions of Lebanon and Syria. In both cases, a single stranding was reported, one in 2008 for Lebanon and one in 2005 for Syria (Akkaya Bas et al., 2016). We also found two previously unreported strandings in Cyprus, dating 2001 and 2002 (S. Michaelidis, Department of Fishery and Marine Research, Cyprus, personal communication, 11 February 2016), adding this country to the range of known strandings for this species in the Mediterranean region.

Geographic distribution of Cuvier's beaked whale strandings from 1803 to 2015 indicates the presence of the species in the entire Mediterranean Basin (Fig. 2), including in the more eastern areas where recent at sea research supports the stranding data (Akkaya Bas et al., 2016; Kerem et al., 2012; Öztürk et al., 2011). The majority of the strandings are reported along the coasts of Spain, France, Italy (excluding the northern and central Adriatic Sea) and Greece, where monitoring effort is generally higher. Stranding rate for single animal strandings in these areas is generally only a few cases per year.

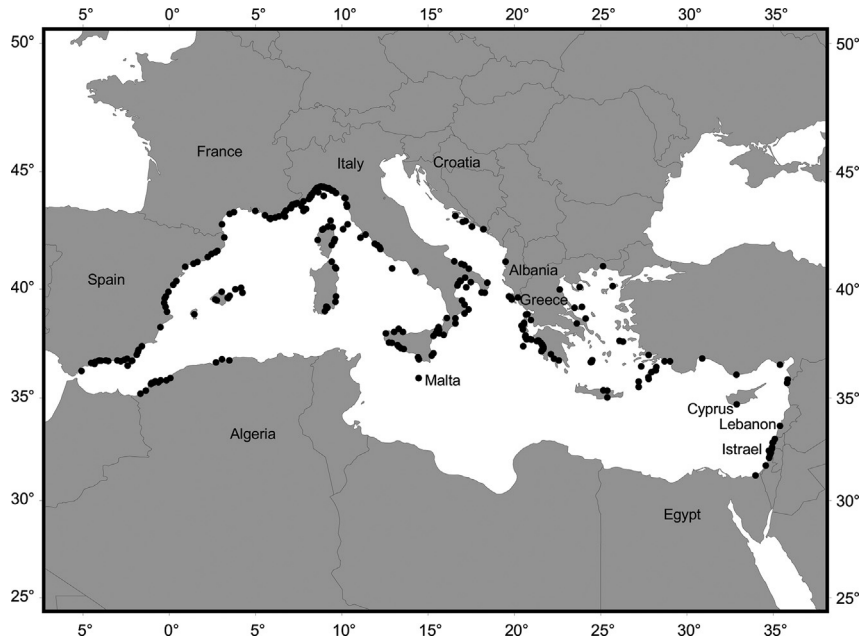

Fig. 2 Distribution of Cuvier's beaked whale (*Ziphius cavirostris*) strandings recorded in the Mediterranean Sea from 1803 to 2015.

Cuvier's beaked whales in the Mediterranean Sea, as well as in other areas of the world, have also been involved in atypical mass strandings, as described in detail with updated information in the following section.

2.2 Atypical Mass Strandings

Frantzis (1998) defined an atypical mass stranding as one that involves two, or usually more, individuals and refers to an unusual temporal and spatial distribution of stranded cetaceans, as opposed to typical mass strandings known, for example, from pilot whales (*Globicephala* spp.) and false killer whales (*Pseudorca crassidens*) (Geraci and Lounsbury, 1993). The cetaceans involved in an atypical mass stranding may belong to one or more species that strand during a relatively short period of time (one or few days) at nearby, but separate locations, sometimes along many kilometres of coastline. Beaked whales have been reported to be particularly prone to atypical mass strandings, which have been reported for ziphiids in different areas of the world and have almost always been shown to have occurred in coincidence with naval exercises, when military data were available (e.g. Greece in 1996, 1997, 2011 and 2014; Bahamas in 2000; Canary Islands in 1985, 1986, 1988, 1989, 2002 and 2004: Frantzis, 1998, 2004, 2015; Balcomb and Claridge, 2001; Martín, 2002; Martín et al., 2004).

Podestà et al. (2006) reported that at least 12 atypical mass stranding events, totalling a minimum of 80 Cuvier's beaked whales, occurred in Italy (Liguria and Calabria), France (Corsica) and Greece, between 1963 and 1999. The first reported atypical mass stranding of Cuvier's beaked whales in the Mediterranean region occurred in 1963 along the Ligurian coasts of Northern Italy. In that year, three mass strandings were reported in three different time periods: the end of January to the beginning of February, May and November (involving 5, 15 and 15 specimens, respectively). The May 1963 stranding occurred over more than 70 km of Ligurian coastline and was originally described as a single stranding event (Tortonese, 1963). Littardi et al. (2004) reviewed the available information on military activity in the area during the early 1960s and found a temporal link between the strandings and the presence of military ships in the area. Some stranded animals in that May 1963 event were dead of gunshot wounds and others were still alive, and were described as having clear signs of 'sickness' (Littardi et al., 2004; Tortonese, 1963).

Between 2006 and 2015, five atypical mass strandings of Cuvier's beaked whales occurred along the Mediterranean coasts of Spain, Italy and Greece, totalling a minimum of 28 individuals (Table 1; Fig. 3). Here, we briefly summarize these five events.

Table 1 Atypical Mass Strandings of Cuvier's Beaked Whales (*Ziphius cavirostris*) Recorded Between 2006 and 2014 Along the Coasts of the Mediterranean Sea

ID	Date	Location(s)	Number of Animals	Sex (Age Class)	Length (m)	Naval Activity in the Region
A	26 January 2006	Almeria, Spain	4	2 juvenile females, 2 adult males	Unknown	NATO Active Sonar Training, 25–26 January 2006 (DON, 2008; see also ACCOBAMS, 2016)
B	11 April 2006	Messina, Italy	4–5	2 females	4.8; 5.5	Unknown
C	8 February 2011	Siracusa, Italy	2–3	1 female	5.05	NATO Exercise *Proud Manta*, 4–17 February 2011
D	30 November to 19 December 2011	Corfu, Greece, Crotone, Italy	12	1 female	5.38	Military exercise *Mare Aperto/Amphex* 2011 (Italy), 28 November to 5 December 2011
E	1–6 April 2014	Crete, Greece	6–10	1 female (pregnant)	Unknown	Military exercise *Noble Dina* 2014 (Greece, Israel, USA), 26 March to 10 April 2014

ID, identifier shown in Fig. 3. Sex, age class and length data of individuals are included where known.

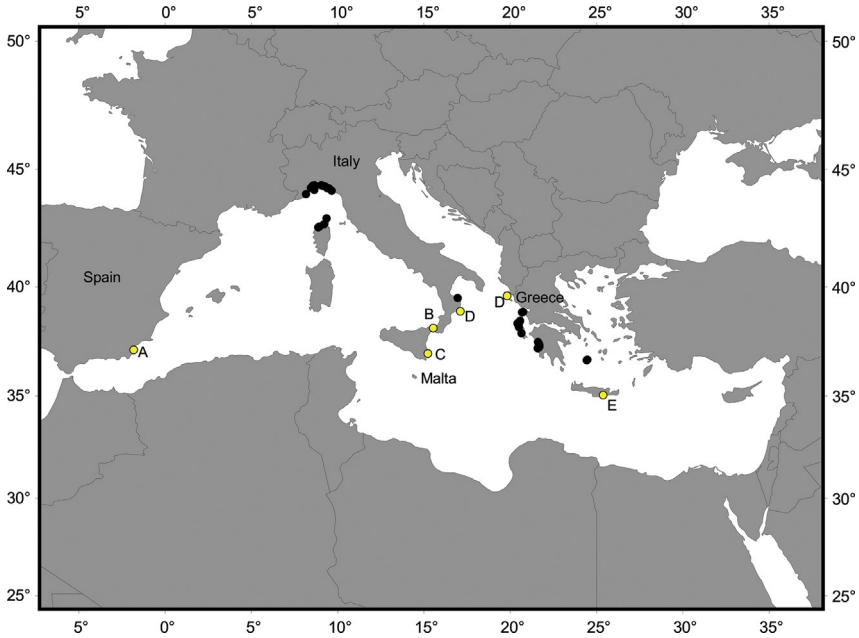

Fig. 3 Distribution of Cuvier's beaked whale (*Ziphius cavirostris*) atypical mass stranding events (three or more animals) in the Mediterranean Sea (*black dots*: 1963–2004 events; *yellow dots*: 2006–14 events).

On 26 January 2006, an atypical mass stranding of four Cuvier's beaked whales (two juvenile females and two adult males) occurred on the southern coast of Almeria, Spain (Arbelo et al., 2008). Two individuals were already dead, and two were still alive but died soon after being found. The two live animals were reported to show signs of illness. All animals appeared to be in good body condition. Necropsy documented gas bubble-associated lesions and fat emboli in the vessels and parenchyma of organs, and these were similar to previous findings from mass strandings associated with naval military exercises (Arbelo et al., 2008; Dalton, 2006). Military activity occurred in the region from 25 to 26 January 2006, when seven North Atlantic Treaty Organization (NATO) surface ships and a Spanish submarine conducted active sonar training within 93 km of the stranding site (DON, 2008; see ACCOBAMS, 2016).

Another atypical mass stranding was reported close to Messina, Sicily, Italy, on 11 April 2006 (Cozzi et al., 2011). Three Cuvier's beaked whales stranded alive 10 km south of Messina and subsequently floated back to sea. A fourth female individual stranded alive, 1 km south of Messina, and died

soon after. Fat emboli were detected in alveolar vessels of this animal (Cozzi et al., 2011), suggesting gas and fat embolic syndrome, the pathological condition in beaked whales associated to the exposure to mid-frequency military sonar (Fernández et al., 2004, 2005). On 20 April 2006, a 5.5 m long female Cuvier's beaked whale was found dead (in an advanced state of decomposition) 20 km south of Messina, in Alì Terme. No data were recorded for the three beaked whales live stranded on 11 April; thus it is uncertain whether this animal was a part of that mass stranding event.

On 8 February 2011, two Cuvier's beaked whales stranded alive in Fontane Bianche, 13 km south of Siracusa, Sicily, on the Ionian coast, and were towed to open waters by the Coast Guard (Cozzi et al., 2011). On 9 February, one of these two animals (recognizable by the numerous scars and marks on the body) stranded alive in the same area. The animal (5.05 m long, probably a female, as no protruding teeth were present in the lower jaw) was constantly trying to head toward shore, and there were signs of repeated scrapes (loss of the superficial layers of the skin) from the rocky shoreline. Copepods, *Pennella* spp., were observed all over the body. The animal was towed (once more) to open waters and was released approximately 6 km off Capo Murro di Porco. Once released from the tow gears, the animal spontaneously swam away and was no longer sighted (Cozzi et al., 2011). One month later, on 15 March 2011, a dead Cuvier's beaked whale was found stranded in Eraclea Minoa, Agrigento, in an advanced state of decomposition. From 4 to 17 February 2011, the *Proud Manta* exercise, which consisted of 'intense Anti-Submarine warfare activity', was conducted by NATO in the Ionian Sea region and, at the time, was reported to be the largest annual event of this type ever conducted by the Alliance, including 10 NATO nations with six submarines, 19 aircraft (including ship-borne helicopters) and eight surface ships.[1]

From 30 November to 19 December 2011, a total of 12 Cuvier's beaked whales stranded on the coasts of Greece and southern Italy. Ten Cuvier's beaked whales stranded along 23 km of coast of the western island of Corfu, Greece, and two stranded 240 km away on the southern Italian coast of Calabria, in Irto, Crotone. Necropsies on two of the specimens stranded in Greece indicated a gas and fat embolic pathology (A. Fernández, University of Las Palmas de Gran Canaria, personal communication, 4 June 2012; see also Bernaldo de Quirós et al., 2012; Fernández et al., 2005). Analysis of gas amount and gas composition in one whale revealed a condition

[1] See www.dvidshub.net/news/printable/65852.

compatible with decompression sickness (DCS) (A. Fernández, University of Las Palmas de Gran Canaria, personal communication, 4 June 2012; see also Bernaldo de Quirós et al., 2012). No inflammatory or neoplastic processes were noted, and no pathogens were identified as responsible for the pathology. An animal that stranded and died in Italy (on 1 December 2011) had fat emboli of the inner ear and peri-auricular vascular plexus (S. Mazzariol, Cetacean Emergency Response Team, University of Padua, personal communication, 7 March 2016). The Italian naval exercise *Mare Aperto/Amphex* 2011 was being conducted in the Ionian Sea and southern Adriatic Sea (Gulf of Taranto, from the Ionian coast of Calabria to approximately 130 km west of Corfu) from 28 November to 5 December, and involved anti-submarine warfare including 13 ships and two submarines.[2]

On 1 April 2014 another atypical mass stranding of Cuvier's beaked whales occurred along the southern coast of the island of Crete, Greece (Frantzis, 2015). Several strandings of one, two and three live animals were reported along nearly 70 km of coast (Fig. 4). Two of these whales died, and the remaining whales were refloated to the open sea (but stranded again). In the following days (2, 5 and 6 April), three whales single stranded dead in the

Fig. 4 Two live Cuvier's beaked whales (*Ziphius cavirostris*) that stranded on the southern coast of Crete, Greece, in an atypical mass stranding event during April 2014. This stranding, involving from six to 10 Cuvier's beaked whales, occurred during the large-scale anti-submarine military exercise, *Noble Dina*, which was conducted in the Eastern Mediterranean Sea from 26 March to 10 April. See Frantzis (2015). *Photograph Copyright: L. Aggelopoulos, Pelagos Cetacean Research Institute.*

[2] See www.marina.difesa.it/conosciamoci/notizie/Pagine/20111205_amphex.aspx.

same area. Subsequent analysis of photographs taken during the different strandings suggested that a minimum of six and a maximum of 10 animals were involved in the mass stranding (Frantzis, 2015). A trilateral military exercise, *Noble Dina* 2014, involving surface and air defence (including two guided-missile destroyer ships, a replenishment oiler and P-3 aircraft), with anti-submarine and mine-swept channel exercises, was conducted by Greek, Israeli and United States navies from 26 March to 10 April in the Eastern Mediterranean Sea.[3]

3. DISTRIBUTION, ABUNDANCE AND HABITAT PREFERENCES OF CUVIER'S BEAKED WHALES IN THE MEDITERRANEAN SEA

A collaborative initiative, supported by ACCOBAMS, used Cuvier's beaked whale sighting data to describe the species' habitat distribution in the Mediterranean Sea. Data were obtained from a total of 420,050 km of survey effort, in good to moderate searching conditions (Beaufort 3 or less), yielding 456 sightings of Cuvier's beaked whale including 1036 individuals, and covering a time span of 21 years, from 1990 to 2010 (Cañadas et al., 2013). Habitat modelling incorporated grid of cells with a resolution of 0.2 degree (22.2×22.2 km; 494 km^2), and a number of geographical and environmental covariates were associated with each grid cell. Data were modelled by using the Generalized Additive Model (see Cañadas et al., 2013).

Results of habitat modelling highlighted three areas with the highest relative density (more than 40%) of Cuvier's beaked whale: (1) the Alborán Sea, (2) the northern Ligurian Sea and (3) the Hellenic Trench (and the area north of Crete). In addition, the northwestern Tyrrhenian Sea, the southern Adriatic Sea and some areas to the north of the Balearic Islands and south of Sicily showed relatively high predicted densities (around 40%) compared to the rest of the Mediterranean Sea. Model results highlighted an interesting area in the far east of the Mediterranean Sea, off the coast of Syria, where there has not been survey coverage, but where there was a relatively high prediction (>40%) of Cuvier's beaked whale preferred habitat. This area should be surveyed to confirm the presence of Cuvier's beaked whale. The model did not identify any habitat along the African coast, but this could be due to the use of latitude as a covariate in the model, together with the lack of survey effort (and observations) in the area (Cañadas et al., 2013).

[3] See www.navy.mil/submit/display.asp?story_id=80259.

Here, we describe information on Cuvier's beaked whale distribution, abundance and habitat preference based on the above-mentioned modelling effort and the available literature. In particular, we focus on known Cuvier's beaked whale high-density areas including the Alborán Sea, the Ligurian Sea, the central Tyrrhenian Sea, the southern Adriatic Sea and the Hellenic Trench, while noting other areas of possible importance.

3.1 Distribution

Despite increased knowledge resulting from dedicated sighting surveys conducted in the Mediterranean Sea, knowledge gaps regarding the distribution of Cuvier's beaked whale still exist, especially for the southern part of the Basin. Thus, strandings of this species can provide useful distribution data. Even though stranding sites may be strongly influenced by multiple factors, including surface current movements and coastal topography, these sites can provide useful information for the inference areas of Cuvier's beaked whale occurrence beyond known areas for the species. The distribution of stranding and sighting data is shown in Fig. 5.

Data from strandings and sightings seem to confirm that Cuvier's beaked whales occur at high densities in some regions (e.g. Alborán Sea, Genoa Canyon area, Central Tyrrhenian Sea, southern Adriatic Sea, Hellenic Trench), while in other areas only occasional strandings are reported. These occasional strandings may be indicative of additional habitat for the species. While Cuvier's beaked whale distribution appears to be characterized by high-use areas (Fig. 6) where animals seem to be relatively abundant, we note that these areas are those in which more research effort has been undertaken.

3.1.1 Alborán Sea

In the Alborán Sea, Cuvier's beaked whales have been regularly observed in the last 20 years during dedicated cetacean surveys conducted since the early 1990s (Cañadas et al., 2002, 2005) that highlighted the presence of the species in an area with borders that coincide with the 1000 m isobath. The data suggest that the Alborán Sea has one of the world's highest densities for this species, and Cañadas and Vázquez (2014) have recently proposed to increase protection in the region. There are no stranding or sighting records from the Strait of Gibraltar at the western most region of the Alborán Sea (Cañadas et al., 2005).

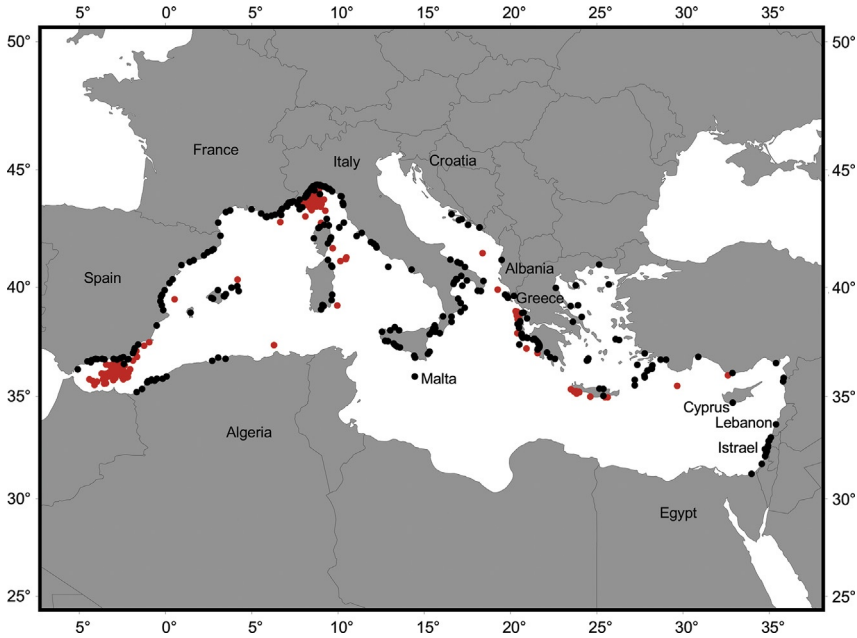

Fig. 5 Distribution of strandings and sightings of Cuvier's beaked whale (*Ziphius cavirostris*) in the Mediterranean Sea (*black dots*: strandings; *red dots*: sightings). *Sightings data from Cañadas, A., B-Nagy, A., Bearzi, G., Cotte, C., Fortuna, C., Frantzis, A., Gannier, A., Laran, S., Lauriano, G., Lewis, T., Moulins, A., Mussi, B., Pastor, X., Politi, E., Pulcini, M., Raga, J.A., Rendell, L., 2013. ACCOBAMS collaborative effort to map high-use areas by beaked whales in the Mediterranean, Monaco, p. 24.*

3.1.2 Ligurian Sea

Another Mediterranean area where cetacean surveys have been conducted since the late 1980s is the Pelagos Sanctuary, in which Cuvier's beaked whales have been sighted especially in waters over and around canyons (Azzellino et al. 2008, 2011, 2012; D'Amico et al., 2003). In particular, the Genoa Canyon area has been identified as a high-density area for Cuvier's beaked whales (MacLeod and Mitchell, 2006; Moulins et al., 2007; Tepsich et al., 2014).

3.1.3 Central Tyrrhenian Sea

Systematic cetacean surveys conducted from ferries in the Central Tyrrhenian Sea, south of the Pelagos Sanctuary, between the Italian Peninsula and the islands of Corsica and Sardinia during two different time periods (1990–92; 2007–11), documented the occurrence of Cuvier's beaked whales and indicated site fidelity in the area (Arcangeli et al., 2015;

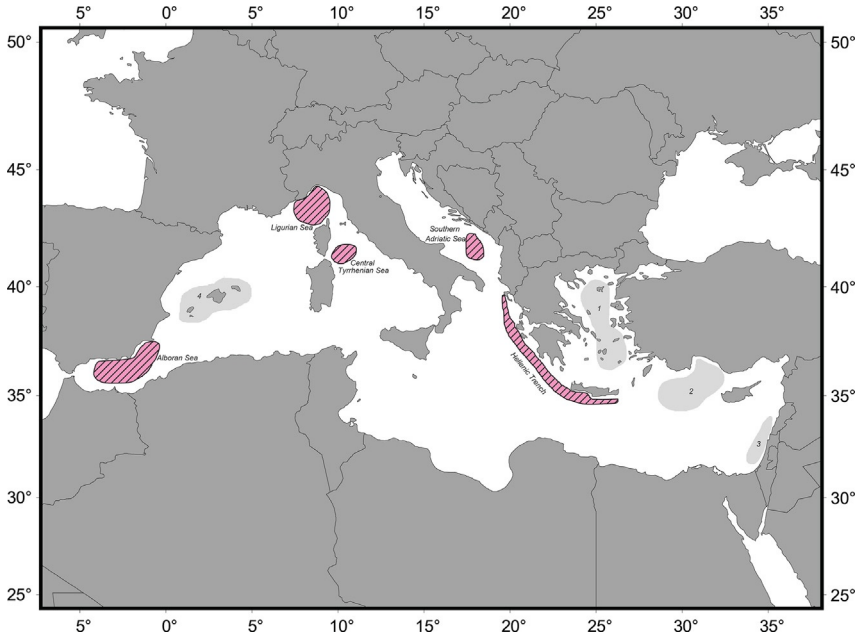

Fig. 6 High-density areas of Cuvier's beaked whale (*Ziphius cavirostris*) occurrence in the Mediterranean Sea (*purple/stripes*). Other possible high-use areas are shown in *grey* (1. Greek waters; 2. Greek–Turkish waters; 3. Levantine Sea; 4. Balearic area).

Marini et al., 1992). Sightings in the same region were also reported by Gannier (2011, 2015), based on small vessel surveys.

3.1.4 Southern Adriatic Sea

Cuvier's beaked whale presence in the southern Adriatic Sea is supported by recent stranding and sighting data reported from the Italian and Croatian coasts (Gomerčić et al., 2006; Holcer et al., 2007). Aerial surveys in the area confirmed the presence of the species in correspondence to a deep, wide depression (>1000 m depth), along the northeastern part of the South Adriatic Basin (Holcer et al., 2014).

Five sightings were recently reported by Bräger et al. (2014) in Albanian and northern Greek waters (north of the island of Corfu). Groups of two and three individuals were observed during the encounters, with a cow–calf pair present in two of the five encounters.

These observations suggest the possibility that the southern Adriatic high-density area might represent a continuum with the Hellenic Trench area.

3.1.5 Hellenic Trench

Cuvier's beaked whales have been observed in Greek seas all along the Hellenic Trench, from northwestern Corfu to east Rodos Island. The areas with the highest number of sightings are south of Crete and west to Lefkada (Frantzis et al., 2003; Pelagos Cetacean Research Institute, unpublished data).

3.1.6 Other Areas of the Mediterranean Sea

Cuvier's beaked whale observations are available for Greek waters (Fig. 6) over all the steep depressions of the Aegean Plateau (northern Aegean Trench from northern Sporades to north of Limnos Island, Ikarion Sea, South Milos Island, west and northwest of Karpathos Island and in the North Cretan Sea) (Frantzis et al., 2003; Pelagos Cetacean Research Institute, unpublished data).

Recent sighting data from the Levantine Sea (Fig. 6) suggest a regular presence of the species in the area, where the Anaximander seamounts, Antalya Canyon and Adana Trough could be areas of particular importance for the species (Frantzis, 2009; Frantzis et al., 2003). More recently, a survey carried out in Turkish waters of the Levantine Sea confirmed the presence of Cuvier's beaked whales in the Antalya Bay (Akkaya Bas et al., 2016).

Results from dedicated surveys conducted in the Levantine Sea in the past decades reported occasional Cuvier's beaked whale sightings off the Israeli and Turkish coasts (Fig. 6) (Kerem et al., 2012).

Sightings have also been reported for the Balearic Sea region (Fig. 6) (Gannier and Epinat, 2008), suggesting the occurrence of this species in the area, although recent dedicated surveys did not confirm this (Cañadas et al. 2013).

3.2 Abundance

There are no estimates of total abundance for Cuvier's beaked whale in the Mediterranean Sea. There are subregional estimates for only two areas, the Alborán Sea and the Ligurian Sea.

3.2.1 Alborán Sea

Research in the Alborán Sea, including spatial modelling based on a detection function with data from 1992 to 2009, yielded an abundance estimate of 429 individuals (CV = 0.22; 95% CI = 334–557) (Cañadas and Vázquez, 2014). Density estimates from line transect surveys are usually subject to 'availability bias' due to animals not always being available for detection while within detectable range (Buckland et al., 2004), and to 'perception bias' due to

observers failing to detect animals even though they are available (Buckland et al., 1993), both causing a negative bias. Deep diving species such as beaked whales are even more subject to such negative bias. To account for this, a correction for availability bias was included in the estimate of Cuvier's beaked whale abundance in the Alborán Sea (Cañadas and Vázquez, 2014).

Based on the modelling of these data, the Alborán Sea presents one of the highest densities of Cuvier's beaked whales in the world, together with Hawaii and the California Current (Barlow et al., 2006; Cañadas and Vázquez, 2014).

3.2.2 Ligurian Sea

A long-term photo-identification study was carried out in the Ligurian Sea to ascertain reliable identification features such as colour patterns and natural marking of Cuvier's beaked whales (Coomber et al., 2016; Rosso, 2010; Rosso et al., 2011). The population analysed in the Genoa Canyon region was found to be generally well and reliably marked along the visible flank (right side and left side), and although 96% of individuals were marked, only 71% of the population was considered reliably marked over multiple years.

Estimates of population size and size trends were calculated separately for left and right side identifications using different models available in the POPAN module of SOCPROG 2.4 (Whitehead, 2009). The '*mortality*' model was the best fit (Table 2). This model estimates that the population of reliably marked individuals was on average composed of 71 (for right side identifications) and 68 individuals (for left side identifications). Results indicated that a small number of Cuvier's beaked whales inhabited the pelagic waters of the Genoa Canyon between 2002 and 2008. The estimated total population size (N_{total}) of Cuvier's beaked whales in the Genoa Canyon was around 100 individuals: 98 individuals for the right side dataset (CV = 0.10; 95% CI ranged = 81–116) and 95 individuals for the left side dataset (CV = 0.09; 95% CI = 79–112).

Because there were no previous estimates of abundance, it is impossible to assess whether the population size has been stable, increasing or decreasing. However, the *mortality + trend* model showed a negative, but not significant, trend (Table 2). It is possible that the population might still be recovering from atypical mass strandings that have occurred since the early 1960s wherein at least 35 individuals (around one-third of the current population size) have stranded in the area (Podestà et al., 2006; Tortonese, 1963; see Section 2.2).

Table 2 Abundance Estimates of Population Size for Cuvier's Beaked Whales (*Ziphius cavirostris*) in the Ligurian Sea

Right Side Sample	θ	**SE**	N_{marked}	**SE**	N_{total}	**SE**	**95% CI**	**Trend (%)**	**95% CI**	**AICc**
Population (n = 82)	*0.73*	*0.16*								
Closed			87	4	119	7	103–136			380
Mortality			71	7	98	10	81–116			375
Mortality + trend			73	9	100	13	75–136	−3	−15–7	377
Reimmigration			71	9	98	13	66–114			377
Reimmigration + mortality			69	7	95	10	77–115			379
Left Side Sample	θ	**SE**	N_{marked}	**SE**	N_{total}	**SE**	**95% CI**	**Trend (%)**	**95% CI**	**AICc**
Population (n = 82)	*0.72*	*0.18*								
Closed			89	4	113	6	96–133			395
Mortality			68	6	95	9	79–112			383
Mortality + trend			71	8	99	12	82–132	−3	−15–6	385
Reimmigration			67	8	93	12	64–113			385
Reimmigration + mortality			65	7	90	10	74–113			387

Results include right and left side identifications. θ, proportion of identifiable animals; N_{marked}, estimate of reliably marked individuals; N_{total}, estimate of total population size; *AICc*, Akaike Information Criterion value. Models are (i) closed: this model assumes a closed population, whose size is estimated by maximum likelihood; (ii) mortality: this assumes a population of constant size, where mortality (which may include permanent emigration) is balanced by birth (which may include immigration); (iii) mortality + trend: this assumes a population growing or declining at a constant rate; (iv) reimmigration: this is the model in which members of a closed population move from (emigration rate) and into (reimmigration rate) a study area; (v) reimmigration + mortality: this is model 'reimmigration' with the exception that mortality (which may include permanent emigration from the total population) is balanced by birth (which may include immigration).

Modified from Rosso, M., 2010. Population size, residency patterns and energy demand of Cuvier's beaked whales (Ziphius cavirostris) in the north western Mediterranean sea. PhD thesis, University of Basilicata, Potenza, Italy.

Considering that no past or present abundance estimate is available for the entire range of the Mediterranean Cuvier's beaked whale population, and that abundance data are available only for limited areas within the region, inference regarding the total number of Cuvier's beaked whales in the Mediterranean Sea is currently impossible. Considering the fundamental conservation importance of such knowledge, it seems recommendable that all efforts be invested in obtaining it.

3.3 Habitat

3.3.1 Alborán Sea

Habitat modelling was performed for the Alborán Sea, to identify the important habitats for Cuvier's beaked whales in the area (Cañadas and Vázquez, 2014). Data used for these analysis came from two sources: (a) data collected during summers 2008–09 on board the NATO research vessel *NRV Alliance* during the research surveys Sirena08 and Med09, and (b) data collected during surveys carried out by the Non-Governmental Organization, Alnitak, on board three vessels: *Toftevaag* (1992–2010), *Thomas Donagh* (2009) and the Fisheries Patrol boat of the General Secretariat of Maritime Fisheries (2003–09) (see Cañadas and Vázquez, 2014). Highest Cuvier's beaked whale density was associated with the area over 500 m depth, and especially around 1000 m or deeper waters, which is the most suitable habitat for this species that is rarely found in shallower waters. In comparison with the available information, the Alborán Sea is clearly a very important area for Cuvier's beaked whale within the Atlantic and Mediterranean system, with one of the highest densities recorded (mean density of 0.0054 animals/km^2, CV = 22%). Habitat modelling results have been used as key tool to design a proposal for the designation of a 'Critical Area' (Fig. 7), or MPA, by the Spanish government, and as the basis for a Cuvier's beaked whale Management Plan (Cañadas and Vázquez, 2014).

3.3.2 Ligurian Sea

Cuvier's beaked whale habitat preference has been widely investigated in the northern part of the Pelagos Sanctuary, based on a sighting dataset deriving from dedicated ship-based surveys (Azzellino et al., 2008, 2011, 2012; Coomber, 2016; D'Amico et al., 2003; Gannier and Epinat, 2008; Moulins et al., 2007, 2008; Tepsich et al., 2014).

Dedicated surveys conducted between 2000 and 2006 in the northern part of the Pelagos Sanctuary reported higher Cuvier's beaked whale

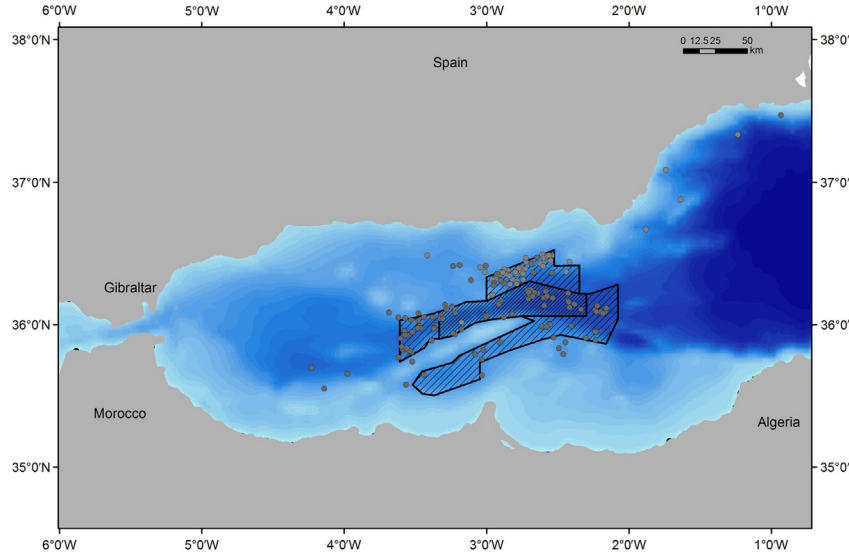

Fig. 7 'Critical Area' proposed by Cañadas and Vázquez (2014) in the Alborán Sea to be used for management measures for the protection of Cuvier's beaked whales (*Ziphius cavirostris*).

sighting frequency in deep waters (between 1000 and 2000 m) within a mid-closed basin with its boundary limited by the 1000 m isobath (Moulins et al., 2007). The majority of sightings were located between a depth of 756 and 1389 m, but the encounter rate was highest between 1389 and 2021 m (Moulins et al., 2007).

Cuvier's beaked whale habitat preferences have been modelled primarily through the use of topographic descriptors, and studies highlighted a strong habitat preference for the upper and lower slopes along the Ligurian–Provençal coast, at depths ranging from 1000 to 2500 m (Azzellino et al., 2008; Moulins et al., 2007). A strong preference was also found for areas with complex topography such as canyons and seamounts (Azzellino et al., 2012; Gannier and Epinat, 2008; Moulins et al., 2007, 2008). Core habitat area was identified in the Genoa Valley, within the Genoa Canyon axis, as well as in the small half-basin with gentle slope located off western coast of Liguria (D'Amico et al., 2003; Moulins et al., 2007, 2008). The Genoa Canyon is the largest and northern-most canyon of the Western Mediterranean Sea. It is 20–30 km across and 60 km long at its 1000 m isobath. This canyon starts about 6 km from the Port of Genoa, which is one of the main commercial harbours in the Mediterranean Basin. As

evidenced by Moulins et al. (2008), species presence is also regular around a seamount located at the mouth of the Genoa Canyon. Recently, Tepsich et al. (2014) noted the importance of the deeper portion of the Ligurian Basin, confirming the existence of additional habitat for this species in deeper waters not closely related to peculiar topographic structures. In addition, dynamic predictors, such as remotely sensed physical oceanographic parameters and modelled biogeochemical and physical parameters, have also been used to investigate Cuvier's beaked whale habitat preference in the Gulf of Genoa (Azzellino et al., 2011; Coomber, 2016; Lanfredi, 2014). Results suggest that dynamic predictors may act as proxy for macroscale features (i.e. upwelling/downwelling motion) that indirectly delineate beaked whale habitat in the area.

3.3.3 Hellenic Trench

Information regarding range and habitat of Cuvier's beaked whale in Greek waters (Ionian and Aegean seas and Sea of Crete), including in the Hellenic Trench area, comes from dedicated surveys conducted from 1991 to 2015 (79 Cuvier's beaked whale sightings) and secondarily from the 147 strandings in the region (see Frantzis, 2009). Seventy of the sightings were recorded along the Hellenic Trench (especially along southwest Crete and west of Lefkada Island), where search effort has been much greater than that in the Aegean Sea (Frantzis, 2009). In Greek waters, Cuvier's beaked whales occurred mainly over the continental slope. They were less frequently observed in the pelagic waters of the region. The mean water depth for 63 Cuvier's beaked whale sightings made along the Hellenic Trench was 1066 m (range 491–2279 m; sd = 343), and mean distance from the coast was 8.6 km (range 2.1–26.5 km; sd = 6.1). These values should only be considered representative for Cuvier's beaked whales along the slope or above the Aegean plateau, since there are no available sightings over the abyssal plains.

3.4 Cuvier's Beaked Whale Habitat Model Transferability and Potential for Improvement

Cuvier's beaked whale habitat models may provide predictions about the range of the species in areas of the Mediterranean Sea where its distribution is not well known, and this could be useful to support species conservation in the region.

Although many models with different statistical approaches have been used to predict the presence or absence of sensitive species, in very few

instances have such models been evaluated for their transferability to areas different from their calibration sites. Azzellino et al. (2011) evaluated the transferability of habitat predictions for Cuvier's beaked whales deriving from a model developed for the Ligurian Sea area. Data used for this modelling exercise came from the Ligurian Sea Sirena 02 survey, and model evaluation benefited from data collected in Alborán Sea Sirena 08 survey (see Section 3.3.1). The Ligurian Sea dataset was used for the model calibration, and then the Alborán Sea dataset was used to evaluate the Ligurian Sea models. The presence/absence classification performances of the models developed in the Ligurian Sea were evaluated using both dynamic (i.e. remote-sensed chlorophyll *a*) and static (i.e. sea bottom topographic features) predictors. Accuracy was slightly lower when using dynamic predictors with respect to static predictors (i.e. 73% vs 87%). However, despite differences in accuracy, the two models showed good agreement (Fig. 8). A prediction map of presence and absence cells based on the Ligurian Sea models was produced for the '*a priori*' evaluation of the Alborán Sea area. Model accuracy was evaluated by overlaying the Cuvier's beaked whale observations (both visual and acoustic) collected in the field. Model predictions, based on either chlorophyll or bathymetry features, were surprisingly comparable in both the study areas (Azzellino et al., 2011). Results indicated that *a priori* predictions were significantly correlated with Cuvier's beaked whale sightings in the Alborán Sea (evaluation area), although, as expected, the model overall accuracy was much lower than the accuracy estimated for the Ligurian Sea (calibration area). Moreover, based on the fact that model high-risk predictions (i.e. higher presence probability of a species sensitive to anthropogenic impact) were found no more than 7–8 km from the closest beaked whale sighting and significantly closer to visual sightings or acoustic detections than the cells predicted as low risk, this distance was proposed as a spatial uncertainty factor to be attributed to the *a priori* predictions. Considering such a spatial uncertainty factor, the *a priori* predictions can be considered robust enough to support knowledge-based decisions for determining the ranking of priority areas that may be sensitive to anthropogenic impact within a region (Azzellino et al., 2011).

Azzellino et al. (2011) demonstrated that human activity impact risk maps can be drawn based on *a priori* predictions of this kind (Fig. 9) and used as knowledge-based support for minimizing the potential impacts induced by human activities at sea.

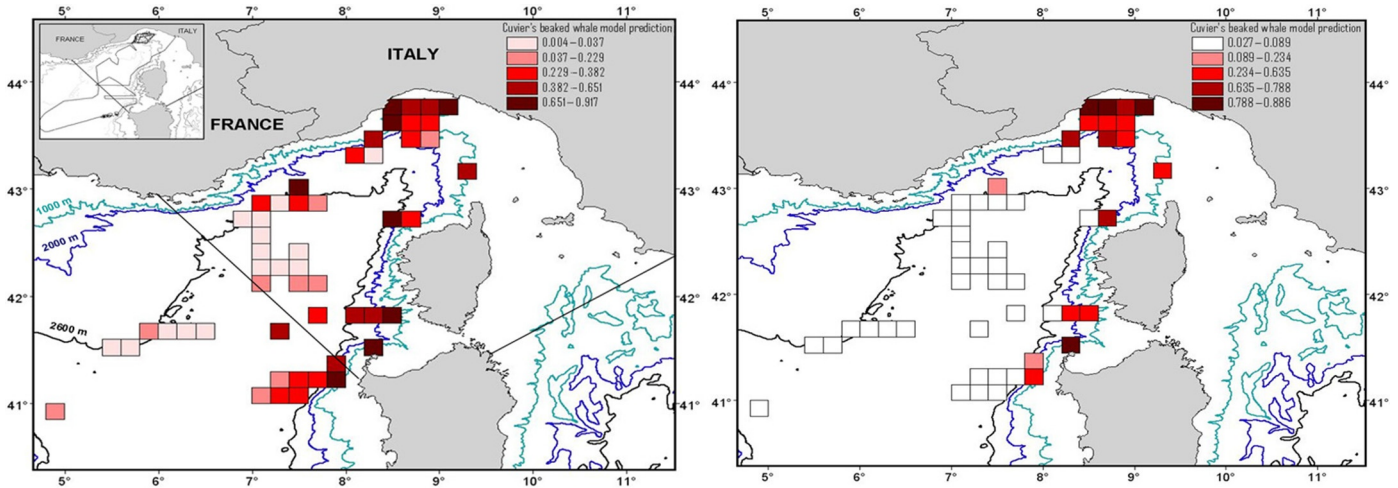

Fig. 8 Cuvier's beaked whale (*Ziphius cavirostris*) presence probability predictions for Ligurian Sea Basin according to the bathymetry model (*right*) and chlorophyll model (*left*). The Pelagos Sanctuary boundaries are also shown (Azzellino et al., 2011).

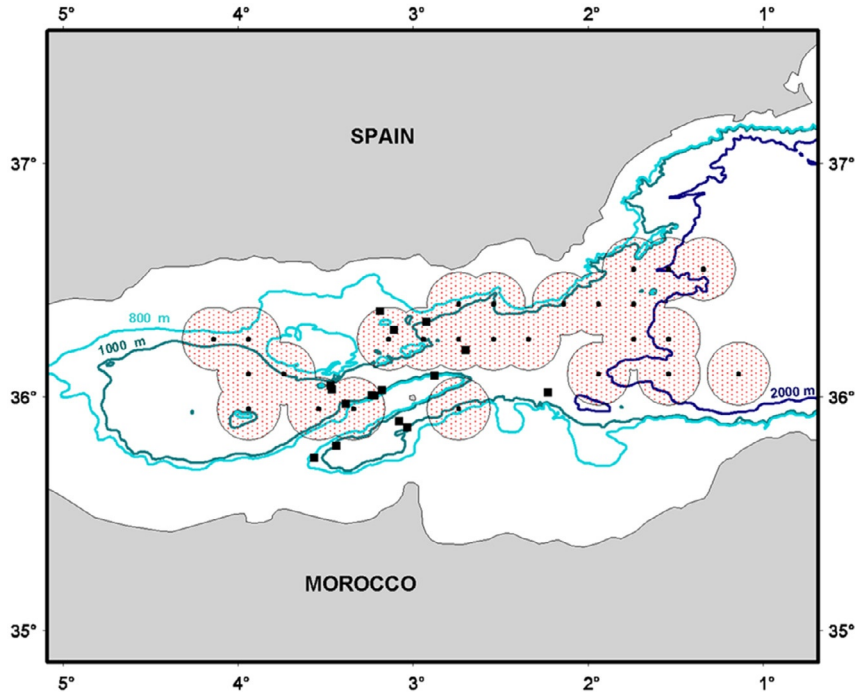

Fig. 9 Risk prediction map for the Alborán Sea area (Azzellino et al., 2011). Cuvier's beaked whale (*Ziphius cavirostris*) observations are also shown as *dark full squares*.

4. THREATS

Cuvier's beaked whales in the Mediterranean Sea are likely impacted by many threats linked to human presence in the semi-enclosed basin, but few studies have quantified the problems affecting this population. Conclusive necropsies (e.g. those described in Section 2.2) are rare for the species in this region, largely due to the rarity of strandings and the difficulty of expeditiously recovering newly stranded specimens (more often found in an advanced state of decomposition). Known threats include bycatch in fishing activities, ingestion of plastics, possible chemical contamination and anthropogenic noise.

Only scattered information concerning Cuvier's beaked whale fisheries interactions is available in the scientific literature. In the past (prior to the driftnet ban of 2002), occasional bycatch in pelagic driftnets was reported from Spanish, French and Italian waters (Banca Dati Italiana Spiaggiamenti, 2015; Cañadas, 2012; Podestà and Magnaghi, 1989). Rosso et al. (2011)

reported one specimen photographed in the Ligurian Sea with a linear amputation of the dorsal fin, suggesting that it could have been the result of entanglement in fishing gear, such as monofilament lines used in the local sword fish fishery. Intentional captures in French and Spanish waters have also been reported (Northridge, 1994).

Plastic debris has been found in the stomachs of some stranded animals (Cañadas, 2012; Gomerčić et al., 2006; Podestà and Meotti, 1991), and in some cases was considered a possible cause of death (Cagnolaro et al., 1986; Frantzis, 2009; Holcer et al., 2003).

No information exists on the actual impact of chemical contaminants on Mediterranean Cuvier's beaked whale survival. High concentrations of mercury, selenium and cadmium have been detected for Cuvier's beaked whales from the Ligurian Sea (Capelli et al., 2008). Ecotoxicological status of Cuvier's beaked whales was recently investigated by Baini et al. (2016). Cytochrome P450 (CYP1A1 and CYP2B isoforms) were used as biomarkers of exposure to anthropogenic contaminants. Protein expression was evaluated using biopsy samples of tissue from free ranging Cuvier's beaked whales from the Ligurian Sea. Protein expression seemed to be linked to age and sex. This method may provide a useful means of assessing ecotoxicological status for this species in the future.

4.1 Anthropogenic Noise

4.1.1 Military Sonar Activity

One of the main threats affecting the Cuvier's beaked whale population in the Mediterranean Sea, is anthropogenic noise resulting from military activities as is highlighted by the atypical mass strandings that have occurred since 1963 (see Section 2.2). Gas bubble-associated lesions and fat embolism in the vessels and parenchyma of vital organs were described by Jepson et al. (2003) and by Fernández et al. (2004, 2005) in beaked whales found stranded in the Canary Islands, evidencing a DCS similar to that in human divers. The syndrome was suggested to have been induced by exposure to mid-frequency sonar signals, and the strandings were temporally and spatially coincident with naval exercises employing this acoustic source (Cox et al., 2006; D'Amico et al., 2009; Martín et al., 2004). Recent analyses of sperm whale (*Physeter macrocephalus*) and beaked whale diving physiology (Fahlman et al., 2014; Hooker et al., 2012; Tyack et al., 2006; Zimmer and Tyack, 2007) suggest altered behaviour of these species in response to naval sonar could increase the risk of gas bubble embolism. Changes in dive time and consequent variation in physiological parameters could

explain the DCS symptoms found in beaked whales stranded in atypical mass events. Cuvier's beaked whale atypical mass strandings that occurred in the Mediterranean Sea region prior to 2006 have been correlated with naval activity (Filadelfo et al., 2009; Frantzis, 1998, 2015; Podestà et al., 2006). Based on pathology from the five recent mass stranding events of 2006–14, the most likely cause of death was naval activities in the areas (ACCOBAMS, 2016; Arbelo et al., 2008; Bernaldo de Quirós et al., 2012; Cozzi et al., 2011; Dalton, 2006; DON, 2008; A. Frantzis, unpublished data; A. Fernández, University of Las Palmas de Gran Canarias, S. Mazzariol, University of Padua, Italy, personal communication, 7 March 2016) (see Section 2.2). During these five recent events a total of at least 28 animals were found stranded, mainly concentrated in the South of Italy and Greece, where similar atypical mass strandings had already occurred for this species in the past (Podestà et al., 2006). Furthermore, the total number of animals that died without reaching the coasts may have been much higher than the number of reported strandings. Large portions of both the Western and Eastern Mediterranean, including some areas that are known Cuvier's beaked whale high-use areas, have been affected by military activities, including naval exercises using low- and mid-frequency active sonar and underwater and surface detonations (ACCOBAMS, 2016; DON, 2008) (see Section 2.2). Mortality is the most significant impact to these whales, but response to nonlethal acoustic exposure can also be expressed by avoidance, and can cause disruption of foraging behaviour (New et al., 2013; Tyack et al., 2011), and alterations in dive profiles, that could affect metabolism and reduce individual fitness (DeRuiter et al., 2013).

As a result of these concerns regarding cetacean exposure to anthropogenic noise resulting from military activity, ACCOBAMS (2013) strongly recommended that, during naval exercises using sonar or underwater explosions, there should be absolute avoidance within an approximate 90 km buffer zone around all areas that have been designated as 'Areas of Special Concern for Beaked Whales' in the Mediterranean Sea (see Fig. 7) (ACCOBAMS, 2013). This did not prevent military activities from occurring in one such area only one year later, when *Noble Dina* was temporally and spatially connected to the atypical mass stranding event in the Hellenic Trench off Crete in 2014 (Frantzis, 2015; see Section 2.2).

While abundance estimates and trends remain unknown for the global Mediterranean Sea population, the impact of mortalities occurring during atypical mass strandings could be significant. For example, for Cuvier's

beaked whales in the Hellenic Trench area, a decrease in sightings and strandings (with no reduction in search effort) during the last two decades has been reported (Frantzis, 2009).

4.1.2 Seismic Activity

Another source of anthropogenic noise that could be a threat to Cuvier's beaked whales in the Mediterranean Sea is oil and gas exploration through seismic surveys. A recent overview of high impact areas for noise in the Mediterranean demonstrated that the entire basin is heavily impacted by seismic surveys, with 830 active areas surveyed in the past 10 years (ACCOBAMS, 2016). Main areas of exploration were concentrated in the Gulf of Valencia, Alborán Sea, Strait of Sicily, Ionian Sea, Levantine Sea and Adriatic Sea. The Adriatic Sea has more than 130 different gas and oil extraction installations that represent an additional possible threat to the marine fauna of this semi-enclosed basin (Holcer et al., 2014). Two Cuvier's beaked whale stranding events (four whales in the Galapagos islands in 2000, and two whales in the Gulf of California in 2002) have been cautiously linked to seismic pulses (Gentry, 2002; Gordon et al., 2003; Malakoff, 2002). Considering the apparently heightened sensitivity of Cuvier's beaked whale to acoustic noise such as the military sonar, the extensive use of air guns could have a cumulative impact and in some cases may be exacerbated by the overlapping of Cuvier's beaked whale high-use areas (e.g. Alborán Sea, Ligurian Sea, Central Tyrrhenian Sea, southern Adriatic Sea, and the Hellenic Trench) with the main areas of seismic exploration.

4.1.3 Maritime Traffic

Little is known about the effects of maritime traffic and ship noise on Cuvier's beaked whales. Changes in Cuvier's beaked whale dive and foraging behaviour in response to ship noise have been reported in the Ligurian Sea (Aguilar de Soto et al., 2006). Behavioural reactions to vessel noise were also observed for Blainville's beaked whales (*Mesoplodon densirostris*) in the Tongue of the Ocean, Bahamas (Pirotta et al., 2012). The main commercial harbours of the Ligurian Sea are located within the Pelagos Sanctuary, which, as a consequence, is a crossing for all main commercial routes in the area. Marine traffic and noise pollution in this region have some of the highest levels within the entire Mediterranean Basin (Coomber, 2016; LMIU, 2008). Accordingly, the potential impact of maritime traffic

(including frequent naval traffic) on the species habitat should be considered as a possible threat affecting the Cuvier's beaked whale population.

No evidence of ship collision or injury due to propellers in the Mediterranean Sea has been reported for Cuvier's beaked whales. Recently, the Secretariat of the Pelagos Sanctuary Agreement funded a project dedicated to determining the potential impact of shipping and its associated noise on Cuvier's beaked whale distribution in the Ligurian Sea (Azzellino et al., 2016). The potential species response to the naval traffic density, inferred from Automatic Identification System (AIS) data, and the related generated noise (inferred from a simulation model) was analysed (Azzellino et al., 2016). The study highlighted the close association of Cuvier's beaked whale preferred habitat with areas of intense naval traffic. Moreover, Cuvier's beaked whales avoided zones with a higher than average density of naval traffic. Another analysis focused on the Genoa Canyon area (considered to be optimal beaked whale habitat) and found that Cuvier's beaked whales preferentially avoided zones with a higher density of naval traffic than the zonal average (Azzellino et al., 2016). Similarly, Coomber (2016) used Generalized Additive Mixed Models to examine the effects of maritime shipping traffic in the Genoa Canyon and found that the level of shipping had a negative linear correlation with sighting rates of Cuvier's beaked whales.

5. CONCLUSION AND RECOMMENDATIONS

Genetic analysis has indicated a high degree of differentiation from the Atlantic population (Dalebout et al., 2005) and suggests that Cuvier's beaked whales in the Mediterranean Sea should be considered as a separate Evolutionarily Significant Unit, distinct from other populations. Moreover, we suggest that Cuvier's beaked whales in the Mediterranean Sea should be designated as Vulnerable or Threatened on the IUCN Red List.

Military activities, seismic exploration and ship noise all represent major threats to Cuvier's beaked whales in the Mediterranean Sea, especially in areas where the species occurs in high densities, and maritime traffic is particularly intense, such as the Genoa Canyon area in the Pelagos Sanctuary. Research in the Genoa Canyon has shown that the species attempts to avoid areas with high shipping density (Azzellino et al., 2016), and there is some evidence of a possible association of Cuvier's beaked whale strandings with seismic explorations (Gordon et al., 2003). Mitigation measures should be applied in the Pelagos Sanctuary, and in other Cuvier's beaked whale high-density areas, to alleviate the impact of maritime traffic and anthropogenic

noise. Furthermore, application of mitigation measures to restrict military exercises can provide a successful tool for reducing the impact of noise on this species, in particular by restricting such operations from occurring in its preferred habitat. Indeed, the effectiveness of such spatial mitigation has apparently been successful for the Canary Islands (an area where atypical mass strandings had previously occurred in relation to military exercises), where no atypical mass stranding of beaked whales has been recorded since 2004, after a moratorium of military activities using sonar was declared there (Fernández et al., 2012).

Urgent conservation measures need to be applied to ensure the protection of Cuvier's beaked whale in the Mediterranean Sea. Important Cuvier's beaked whale habitats, including the Alborán Sea, Ligurian Sea, Tyrrhenian Sea, southern Adriatic Sea, Hellenic Trench and likely other less studied areas (e.g. the Levantine Sea), have a high conservation value for beaked whales in the Mediterranean and, therefore, are worthy of conservation actions. Major efforts should be undertaken to fill the current knowledge gaps regarding distribution, population size and trends and anthropogenic disturbances of Cuvier's beaked whale in the Mediterranean region. Results from predictive habitat models may be used as a basis for better designing survey effort in unsurveyed areas. Similarly, research on stranded specimens should be better organized with a standardized protocol and collection of samples implemented all along the Mediterranean coasts. Research to gain a better understanding of the effects of other anthropogenic pressures on Cuvier's beaked whales should also be pursued. Detailed analyses investigating the causes for mortality in stranded Cuvier's beaked whales will be useful to properly assess the impacts of the threats potentially affecting the population in the Mediterranean Basin, and to implement the appropriate mitigation measures. Moreover, management measures are urgently needed to restrict military activities within and around Cuvier's beaked whale high-density areas in the Mediterranean Sea.

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REFERENCES

ACCOBAMS, 2013. In: Report of the Fifth Meeting of the Parties to Accobams. Tangier, 5–8 November 2013, p. 152.

ACCOBAMS, 2016. Overview of the noise hotspots in the ACCOBAMS area part I—Mediterranean Sea: Final report by Maglio, A., Pavan, G., Castellote, M., Frey, S. 45 pp. http://dx.doi.org/10.13140/RG.2.1.2574.8560.

Aguilar de 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*? Mar. Mamm. Sci. 22, 690–699.

Akkaya Bas, A., Lagoa, G.C., Atchoi, E., 2016. New records of Cuvier's beaked whales (*Ziphius cavirostris*) from the Turkish Levantine Sea. Turk. J. Zool. 40, 454–460. http://dx.doi.org/10.3906/zoo-1509-19.

Arbelo, M., Bernaldo de Quirós, Y., Sierra, E., Méndez, M., Godinho, A., Ramírez, G., Caballero, M.J., Fernandez, A., 2008. Atypical beaked whale mass stranding in Almeria's coast: pathological study. Int. J. Anim. Sound Rec. 17 (10), 295–297.

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. Mar. Ecol. 37, 269–282. http://dx.doi.org/10.1111/maec.12272.

Azzellino, A., Airoldi, S., Gaspari, S., Nani, B., 2008. Habitat use of cetaceans along the Continental Slope and adjacent waters in the Western Ligurian Sea. Deep Sea Res. I 55, 296–323.

Azzellino, A., Lanfredi, C., D'Amico, A., Pavan, G., Podestà, M., Haun, J., 2011. Risk mapping for sensitive species to underwater anthropogenic sound emissions: model development and validation in two Mediterranean areas. Mar. Poll. Bull. 63, 56–70.

Azzellino, A., Panigada, S., Lanfredi, C., Zanardelli, M., Airoldi, S., Notarbartolo di Sciara, G., 2012. Predictive habitat models for managing marine areas: spatial and temporal distribution of marine mammals within the Pelagos Sanctuary (Northwestern Mediterranean Sea). Ocean Coast. Manag. 67, 63–74.

Azzellino, A., David, L., Di Meglio, N., Labach, H., Origné, L., Amar, D., Agliati, P.O., Coomber, F., Rosso, M., Tepisich, P., Moulins, A., 2016. Noise impact on sperm whale (*P. macrocephalus*) and Cuvier's beaked whale (*Z. cavirostris*), estimated from the marine traffic: Final report. p. 140. Convention PELAGOS Sanctuary No. 2014-01.

Baini, M., Fossi, M.C., Panti, C., Marsili, L., Coomber, F., Tepsich, P., Moulins, A., Rosso, M., 2016. Cytochrome P450 1A1 and 2B protein expression as biomarker for the first assessment of the ecotoxicological status of Cuvier's beaked (*Ziphius cavirostris*) in the NW Mediterranean sea. In: 30th Annual Conference of the European Cetacean Society, 14–16 March 2016, Madeira.

Baird, R.W., Webster, D.L., McSweeney, D.J., Ligon, A.D., Schorr, G.S., Barlow, J., 2006. Diving behavior and ecology of Cuvier's (*Ziphius cavirostris*) and Blainville's (*Mesoplodon densirostris*) beaked whales in Hawaii. Can. J. Zool. 84, 1120–1128.

Balcomb III, K.C., Claridge, D.E., 2001. A mass stranding of cetaceans caused by naval sonar in the Bahamas. Bahamas J. Sci. 2, 2–12.

Banca Dati Italiana Spiaggiamenti, 2015. Available at: http://mammiferimarini.unipv.it (accessed 30 January 2016).

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). J. Cetacean Res. Manag. 7 (3), 263–270.

Baumgartner, M.F., Mullin, K.D., May, L.N., Leming, T.D., 2001. Cetaceans habitats in the northern Gulf of Mexico. Fish. Bull. 99, 219–239.

Bernaldo de Quirós, Y., Gonzales-Diaz, O., Arbelo, M., Sierra, E., Sacchini, S., Fernández, A., 2012. Decompression versus decomposition: distribution, quantity and gas composition of bubbles in stranded marine mammals. Front. Aquat. Physiol. 3, 177. http://dx.doi.org/10.3389/fphys.2012.00177.

Blanco, C., Raga, J.A., 2000. Cephalopod prey of two *Ziphius cavirostris* (Cetacea) stranded on the western Mediterranean coast. J. Mar. Biol. Assoc. U. K. 80, 381–382.

Bräger, S., Kopcsányi, T., Bräger, Z., 2014. First sightings of living Cuvier's beaked whales (*Ziphius cavirostris*) in Albanian waters. Mar. Biodiv. 44, 553–557.

Buckland, S.T., Anderson, R., Burnham, K.P., Laake, J.L., 1993. Distance Sampling: Estimating Abundance of Biological Populations. Chapman and Hall, London. Available from: http://www.ruwpa.st-and.ac.uk/distance.

Buckland, S.T., Anderson, R., Burnham, K.P., Laake, J.L., Borchers, D.L., Thomas, L., 2004. Advance Distance Sampling. Examining Abundance of Biological Populations. Oxford University Press, Oxford, UK.

Cagnolaro, L., Cozzi, B., Magnaghi, L., Podestà, M., Poggi, R., Tangerini, P., 1986. Su 18 cetacei spiaggiati sulle coste italiane dal 1981 al 1985: rilevamento biometrico ed osservazioni necroscopiche (Mammalia Cetacea). Atti Soc. Ital. Sci. Nat. Museo Civ. Stor. Nat. Milano 127, 79–106 (in Italian).

Cañadas, A., 2012. *Ziphius cavirostris* (Mediterranean subpopulation). In: The IUCN Red List of Threatened Species 2012. e.T16381144A16382769, http://dx.doi.org/10.2305/IUCN.UK.2012-1.RLTS.T16381144A16382769.en.

Cañadas, A., Vázquez, J.A., 2014. Conserving Cuvier's beaked whales in the Alborán Sea (SW Mediterranean): identification of high density areas to be avoided by intense man-made sound. Biol. Conserv. 178, 155–162.

Cañadas, A., Sagarminaga, R., García-Tiscar, S., 2002. Cetacean distribution related with depth and slope in the Mediterranean waters off southern Spain. Deep Sea Res. I 49 (11), 2053–2073.

Cañadas, A., Sagarminaga, R., de Stephanis, R., Urquiola, E., Hammond, P.S., 2005. Habitat preference modelling as a conservation tool: proposal of marine protected areas for cetaceans in Southern Spain. Aquat. Conserv. 15, 495–521.

Cañadas, A., B-Nagy, A., Bearzi, G., Cotte, C., Fortuna, C., Frantzis, A., Gannier, A., Laran, S., Lauriano, G., Lewis, T., Moulins, A., Mussi, B., Pastor, X., Politi, E., Pulcini, M., Raga, J.A., Rendell, L., 2013. ACCOBAMS collaborative effort to map high-use areas by beaked whales in the Mediterranean, Monaco. p. 24.

Capelli, R., Das, K., De Pellegrini, R., Drava, G., Lepoint, G., Miglio, C., Minganti, V., Poggi, R., 2008. Distribution of trace elements in organs of six species of cetaceans from the Ligurian Sea (Mediterranean), and the relationship with stable carbon and nitrogen ratios. Sci. Total Environ. 390, 569–578.

Carlini, R., Pulcini, M., Wurtz, M., 1992. Cephalopods from the stomachs of Cuvier's beaked whale (*Ziphius cavirostris* Cuvier, 1823) stranded at Fiumicino, Central Tyrrhenian Sea. Eur. Res. Cetaceans 6, 190–191.

Coomber, F., 2016. Ecological impact assessment of maritime traffic and its associated noise pollution on Cuvier's beaked whales (*Ziphius cavirostris* Cuvier, 1823) in the Pelagos Sanctuary. PhD thesis, University of Genoa, Italy.

Coomber, F., Moulins, A., Tepsich, P., Rosso, M., 2016. Sexing free-ranging adult Cuvier's beaked whales (Ziphius cavirostris) using natural marking thresholds and pigmentation patterns. J. Mammal. 97, 879–890. http://dx.doi.org/10.1093/jmammal/gyw033.

Cox, T.M., Ragen, T.J., Read, A.J., Vos, E., Baird, R.W., Balcomb, K., Barlow, J., Caldwell, J., Cranford, T., Crum, L., D'Amico, A., D'Spain, G., Fernández, A., Finneran, J., Gentry, R., Gerth, W., Gulland, F., Hildebrand, J., Houser, D., Hullar, T., Jepson, P.D., Ketten, D., MacLeod, C.D., Miller, P., Moore, S., Mountain, D., Palka, D., Ponganis, P., Rommel, S., Rowles, T., Taylor, B., Tyack, P., Wartzok, D., Gisiner, R., Mead, J., Benner, L., 2006. Understanding the impacts of anthropogenic sound on beaked whales. J. Cetacean Res. Manag. 7 (3), 177–187.

Cozzi, B., Podestà, M., Mazzariol, S., 2011. Strandings of beaked whales in the Italian waters: a perspective of 25 years. Document presented to the Scientific Committee of the International Whaling Commission. Paper SC/63/SM5.

D'Amico, A., Bergamasco, A., Zanasca, P., Carniel, E., Portunato, N., Teloni, V., Mori, C., Barbanti, R., 2003. Qualitative correlation of marine mammals with physical and biological parameters in the Ligurian Sea. IEEE J. Ocean. Eng. 28 (1), 29–43.

D'Amico, A., Gisiner, R.C., Ketten, D.R., Hammock, J.A., Johnson, C., Tyack, P.L., Mead, J., 2009. Beaked whale strandings and naval exercises. Aquat. Mamm. 35 (4), 452–472.

Dalebout, M.L., Robertson, K.M., Frantzis, A., Engelhaupt, D., Mignucci, A.A., Rosario-Delestre, R.J., Baker, C.S., 2005. Worldwide structure of mtDNA diversity among Cuvier's beaked whales (*Ziphius cavirostris*): implications for threatened populations. Mol. Ecol. 14, 3353–3371.

Dalton, R., 2006. More whale strandings are linked to sonar. Nature 440, 593. http://dx.doi.org/10.1038/440593.

Davis, R.W., Fargion, G.S., May, N., Leming, T.D., Baumgartner, M.F., 1998. Physical habitat of cetaceans along the continental slope in the north-central and western Gulf of Mexico. Mar. Mamm. Sci. 14 (3), 490–507.

Davis, R.W., Ortega-Ortiz, J.G., Ribic, C.A., Evans, W.E., Biggs, D.C., Ressler, P.H., Cady, R.B., Leben, R.R., Mullin, K.D., Wursig, B., 2002. Cetacean habitat in the northern oceanic Gulf of Mexico. Deep Sea Res. I 49, 121–142.

DeRuiter, S.L., Southall, B.L., Calambokidis, J., Zimmer, W.M.X., Sadykova, D., Falcone, E.A., Friedlaender, A.S., Joseph, J.E., Moretti, D., Schorr, G.S., Thomas, L., Tyack, P.L., 2013. First direct measurements of behavioural responses by Cuvier's beaked whales to mid-frequency active sonar. Biol. Lett. 9, 20130223. http://dx.doi.org/10.1098/rsbl.2013.0223.

Dhermain, F., 2012. Réseau Echouage Méditerranéen Suivi des échouages sur les côtes méditerranéennes françaises. Années 2009–2012: Rapport GECEM/GIS3M, contract 10-058-83400 pour le Parc national de Port-Cros. GECEM Publ., Marseille, pp. 1–140.

Dhermain, F., Dupraz, F., Dupont, L., Keck, N., Godenir, J., Cesarini, C., Wafo, E., 2011. Recensement des échouages de cétacés sur les côtes françaises de Méditerranée. Années 2005–2009. Sci. Rep. Port-Cros Natl. Park Fr. 25, 121–141.

Dhermain, F., Astruc, G., Cesarini, C., Dupont, L., Dupraz, F., Godenir, J., Keck, N., Labach, H., Wafo, E., 2015. Recensement des échouages de cétacés sur les côtes françaises de Méditerranée, entre 2010 et 2012. Sci. Rep. Port-Cros Natl. Park 29, 103–126.

DON, 2008. Final Atlantic Fleet Active Sonar Training Environmental Impact Statement/Overseas Environmental Impact Statement. United States Department of the Navy, Norfolk, VA.

Fahlman, A., Tyack, P.L., Miller, P.J.O., Kvadsheim, P.H., 2014. How man-made interference might cause gas bubble emboli in deep diving whales. Front. Physiol. 5 (13), 1–6.

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. J. Cetacean Res. Manag. 7 (3), 287–299.

Fernández, A., Arbelo, M., Deaville, R., Patterson, I.A.P., Castro, P., Baker, J.R., Degollada, E., Ross, H.M., Herraez, P., Pocknell, A.M., Rodriguez, F., Howie, F.E., Espinosa, A., Reid, R.J., Jaber, J.R., Martin, V., Cunninghan, A.A., Jepson, P.D., 2004. Beaked whales, sonar and decompression sickness. Nature 10, 1038.

Fernández, A., Edwards, J.F., Rodríguea, F., Espinosa de los Monteros, A., Herráez, P., Castro, P., Jaber, J.R., Martin, V., Arbelo, M., 2005. "Gas and Fat Embolic Syndrome" involving a mass stranding of beaked whales (Family *Ziphiidae*) exposed to anthropogenic sonar signals. Vet. Pathol. 42, 446–457.

Fernández, A., Sierra, E., Martín, E., Méndez, M., Sacchinni, S., Bernaldo de Quirós, Y., Andrada, M., Rivero, M., Quesada, O., Tejedor, M., Arbelo, M., 2012. Last "atypical" beaked whales mass stranding in the Canary Islands (July, 2004). J. Marine Sci. Res. Dev. 2, 107. http://dx.doi.org/10.4172/2155-9910.1000107.

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? Aquat. Mamm. 35 (4), 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). In: Proceedings of the Workshop: "Active Sonar and Cetaceans", pp. 14–20. 8 March 2003, Las Palmas, Gran Canaria. ECS Newsletter 42 (special issue).

Frantzis, A., 2009. Cetaceans in Greece: present status of knowledge. Initiative for the Conservation of Cetaceans in Greece, Athens, Greece. 94 pp.

Frantzis, A., 2015. Short report on the mass stranding of Cuvier's beaked whales that occurred on the 1st of April 2014 in South Crete, Greece, during naval exercises. FINS 6 (1), 10–11.

Frantzis, A., Alexiadou, P., Paximadis, G., Politi, E., Gannier, A., Corsini-Foka, M., 2003. Current knowledge of the cetacean fauna of the Greek Seas. J. Cetacean Res. Manag. 5, 219–232.

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. Mar. Poll. Bull. 63 (1–4), 10–17.

Gannier, A., 2015. Cuvier's beaked whale (*Ziphius cavirostris*) diving behavior as obtained by visual observation methods and consequences in terms of visual detection during surveys. Sci. Rep. Port-Cros Natl. Park 29, 127–134.

Gannier, A., Epinat, J., 2008. Cuvier's beaked whale distribution in the Mediterranean Sea: results from small boat surveys 1996–2007. J. Mar. Biol. Assoc. U. K. 88 (6), 1245–1251.

Garibaldi, F., Cataldini, G., Insacco, G., Podestà, M., Garibaldi, F., Cataldini, G., Insacco, G., Podestà, M., 2015. Stomach contents of Cuvier's beaked whales, *Ziphius cavirostris*, stranded in Southern Italy. In: 29th Annual Conference of the European Cetacean Society, March, Malta.

Gentry, R.L., 2002. Mass stranding of beaked whales in the Galapagos islands, April 2000. Available at: http://www.nmfs.noaa.gov/pr/pdfs/health/galapagos_stranding.pdf.

Geraci, J.R., Lounsbury, V., 1993. Marine Mammals Ashore. A Field Guide for Strandings. Texas A.M. Sea Grant Publications, Galveston, TX.

Gomerčić, H., Đuras Gomerčić, M., Gomerčić, T., Lucić, H., Dalebout, M., Galov, A., Škrtić, D., Ćurković, S., Vuković, S., Huber, Đ., 2006. Biological aspects of Cuvier's beaked whale (*Ziphius cavirostris*) recorded in the Croatian part of the Adriatic Sea. Eur. J. Wildl. Res. 52, 182–187.

Gordon, J., Gillespie, D., Potter, J., Frantzis, A., Simmonds, M.P., Swift, R., Thompson, D., 2003. A review of the effects of seismic surveys on marine mammals. Mar. Tech. Soc. J. 37 (4), 16–34.

Gozalbes-Aparicio, P., Raga, J.A., 2015. Progress report 2014 on the Mediterranean database of cetacean strandings. p. 44. Contract RAC/SPA, No. 24/2013/RAC/SPA.

Hamazaky, T., 2002. Spatiotemporal prediction models of North Atlantic Ocean (from Cape Hatteras, North Carolina, U.S.A. to Nova Scotia, Canada) cetacean habitats in the mid-western. Mar. Mamm. Sci. 18 (4), 920–939.

Heyning, J.E., 1989. Cuvier's beaked whale, *Ziphius cavirostris* G. Cuvier, 1823. In: - Ridgway, S.H., Harrison, R. (Eds.), Handbook of Marine Mammals, vol. 4. Academic Press, London, pp. 289–308.

Holcer, D., Notarbartolo di Sciara, G., Fortuna, C.M., Onofri, V., Lazar, B., Tvrtkovic, N., 2003. The occurrence of Cuvier's beaked whale (*Ziphius cavirostris*) in Croatian Adriatic waters: historical and recent findings. In: Besendorfer, V., Kopjar, N. (Eds.), Proceedings of the 8th Croatian Biological Congress, Zagreb, pp. 255–256.

Holcer, D., Notarbartolo di Sciara, G., Fortuna, C.M., Lazar, B., Onofri, V., 2007. Occurrence of Cuvier's beaked whale in the Southern Adriatic Sea evidence of an important Mediterranean habitat. J. Mar. Biol. Assoc. U. K. 87, 359–362.

Holcer, D., Fortuna, C.M., Mackelworth, P., 2014. Important areas for conservation of cetaceans, sea turtles and giant devil rays in the Adriatic Sea: summary of existing knowledge: UNEP/MAP-RAC/SPA Internal report. Contract No. 08/RAC/SPA_2013 MedOpenSeas, 67 pp.

Hooker, S.K., Whitehead, H., Gowans, S., Baird, R.W., 2002. Fluctuations in distribution and patterns of individual range use of northern bottlenose whales. Mar. Ecol. Prog. Ser. 225, 287–297.

Hooker, S.K., Fahlman, A., Moore, M.J., Aguilar De Soto, N., Bernaldo De Quiros, Y., Brubakk, A.O., Costa, D.P., Costidis, A.M., Dennison, S., Falke, K.J., Fernandez, A., Ferrigno, M., Fitz-Clarke, J.R., Garner, M.M., Houser, D.S., Jepson, P.D., Ketten, D.R., Kvadsheim, P.H., Madsen, P.T., Pollock, N.W., Rotstein, D.S., Rowles, T.K., Simmons, S.E., Van Bonn, W., Weathersby, P.K., Weise, M.J., Williams, T.M., Tyack, P.L., 2012. Deadly diving? Physiological and behavioural management of decompression stress in diving mammals. Proc. R. Soc. Lond. B Biol. Sci. 279, 1041–1050. http://dx.doi.org/10.1098/rspb.2011.2088.

Jepson, P.D., Arbelo, M., Deaville, R., Patterson, I.A.P., Castro, P., Baker, J.R., Degollada, E., Ross, H.M., Herráez, P., Pocknell, A.M., Rodríguez, F., Howiell, F.E., Espinosa, A., Reid, R.J., Jaber, J.R., Martin, V., Cunningham, A.A., Fernández, A., 2003. Gas bubble lesions in stranded cetaceans: was sonar responsible for a spate of whale deaths after an Atlantic military exercise? Nature 425, 575–576.

Johnson, M., Tyack, P.L., 2003. A digital acoustic recording tag for measuring the response of wild marine mammals to sound. IEEE J. Ocean. Eng. 28, 3–12.

Johnson, M., Madsen, P.T., Zimmer, W.M.X., Aguilar de Soto, N., Tyack, P.L., 2004. Beaked whales echolocate on prey. Proc. R. Soc. Lond. Ser. B 271, S383–S386.

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. Open Mar. Biol. J. 6, 6–27.

Kovačić, I., Gomerčić, M.D., Gomerčić, H., Lucić, H., Gomerčić, T., 2010. Stomach contents of two Cuvier's beaked whales (*Ziphius cavirostris*) stranded in the Adriatic Sea. Mar. Biodiv. Rec. 3, e19. http://dx.doi.org/10.1017/S1755267210000059.

Lanfredi, C., 2014. Risk assessment of underwater sounds emissions: impact on marine environment. PhD thesis, Politecnico di Milano, Environmental Engineering Department, Milano, Italy.

Lefkaditou, E., Poulopoulos, Y., 1998. Cephalopod remains in the stomach-content of beaked whales, *Ziphius cavirostris* (Cuvier, 1823), from the Ionian Sea. Rapp. Comm. Int. Mer Medit. 35, 460–461.

Littardi, V., Rosso, M., Wurtz, M., 2004. Enquêtes historiques (1900–1966) sur les échouages de *Ziphius cavirostris* G. Cuvier, en Mer Ligure. Rapp. Comm. Int. Mer Médit. 37, 388.

LMIU (Lloyd's Marine Intelligence Unit), 2008. Study of Maritime Traffic Flows in the Mediterranean Sea. Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC), Valletta.
MacLeod, C.D., 2000. Distribution of beaked whales of the genus *Mesoplodon* in the North Atlantic (Order: Cetacea, Family: Ziphiidae). Mammal Rev. 30, 1–8.
MacLeod, C.D., D'Amico, A., 2006. A review of knowledge about behavior and ecology of beaked whales in relation to assessing and mitigating potential impacts from anthropogenic noise. J. Cetacean Res. Manag. 7 (3), 211–221.
MacLeod, C.D., Mitchell, G., 2006. Known key areas for beaked whales around the world. J. Cetacean Res. Manag. 7 (3), 309–322.
MacLeod, C.D., Zuur, A.F., 2005. Habitat utilisation by Blainville's beaked whales off Great Abaco, Northern Bahamas, in relation to seabed topography. Mar. Biol. 174, 1–11.
MacLeod, C.D., Santos, M.B., Pierce, G.J., 2003. Review of data on diets of beaked whales: evidence of niche separation and geographic segregation. J. Mar. Biol. Assoc. U. K. 83, 651–665.
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). J. Cetacean Res. Manag. 7, 271–286.
Malakoff, D., 2002. Suit ties whale deaths to research cruise. Science 298, 722–723.
Maldini, D., Mazzucca, L., Atkinson, S., 2005. Odontocete stranding patterns in the main Hawaiian islands (1937-2002): how do they compare with live animal surveys? Pac. Sci. 59 (1), 55–67.
Mannocci, L., Dorémus, G., Kiszka, J., Laran, S., Martinez, L., Van Canneyt, O., Ridoux, V., 2011. Habitat preferences of Ziphiids: an analysis of physiographic variables associated to beaked whales sightings in French temperate and tropical waters. International Whaling Commission, SC/63/SM12, 15 pp.
Marini, L., Consiglio, C., Angradi, A.M., Sanna, A., 1992. Four sightings of Ziphiidae (Cetacea, Odontoceti) in the central Tyrrhenian Sea. Ital. J. Zool. 4, 85–89.
Martín Martel, V., 2002. Especial varamiento de cetáceos–Viceconsejería de Medio Ambiente. Government of the Canary Islands, Gran Canaria. www.gobcan.es/medioambiente/varamientos.
Martín, V., Servidio, A., García, S., 2004. Mass strandings of beaked whales in the Canary Islands. In: Evans, P., Miller, L. (Eds.), Proceedings of the Workshop on Active Sonar and Cetaceans Held at the European Cetacean Society Held at the 17th Annual Conference Las Palmas, Gran Canaria, pp. 33–36. 8 March 2003. ECS Newsletter 42.
MEDACES, 2015. Mar. Zoology Unit, University of Valencia, Available at: http://medaces.uv.es/ (accessed 31 December 2015).
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 (north-western Mediterranean Sea). J. Mar. Biol. Assoc. U. K. 87, 177–186.
Moulins, A., Rosso, M., Ballardini, M., Würtz, M., 2008. Partitioning of the Pelagos Sanctuary (north-western Mediterranean Sea) into hotspots and coldspots of cetacean distributions. J. Mar. Biol. Assoc. U. K. 88, 1273–1281.
New, L.F., Moretti, D.J., Hooker, S.K., Costa, D.P., Simmons, S.E., 2013. Using energetic models to investigate the survival and reproduction of beaked whales (family Ziphiidae). PLoS One 8 (7), e68725. http://dx.doi.org/10.1371/journal.pone.0068725.
Northridge, S.P., 1994. World review of interactions between marine mammals and fisheries. Fisheries Technical paper 251, Food and Agriculture Organization of the United Nations, Rome.

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

Orsi Relini, L., Garibaldi, F., 2005. Diversità dei cefalopodi mesopelagici del santuario dei cetacei in base a campionamenti diretti e osservazioni sull'alimentazione dello zifio, *Ziphius cavirostris*. Biol. Mar. Medit. 12 (1), 106–115.

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. J. Black Sea/Mediterranean Env. 17 (3), 269–274.

Pedà, C., Battaglia, P., Scuderi, A., Voliani, A., Mancusi, C., Andaloro, F., Romeo, T., 2015. Cephalopod prey in the stomach contents of odontocete cetaceans stranded in the western Mediterranean Sea. Mar. Biol. Res. 11, 593–602. http://dx.doi.org/10.1080/17451000.2014.966724.

Peltier, H., Ridoux, V., 2015. Marine megavertebrates adrift: a framework for the interpretation of stranding data in perspective of the European Marine Strategy Framework Directive and other regional agreements. Environ. Sci. Pol. 54, 240–247.

Peltier, H., Dabin, W., Daniel, P., Van Canneyt, O., Dorémus, G., Huona, M., Ridoux, V., 2012. The significance of stranding data as indicators of cetacean populations at sea: modelling the drift of cetacean carcasses. Ecol. Indic. 18, 278–290.

Pirotta, E., Milor, R., Quick, N., Moretti, D., Di Marzio, N., Tyack, P., Boyd, I., Hastie, G., 2012. Vessel noise affects beaked whale behavior: results of a dedicated acoustic response study. PLoS One 7 (8), e42535. http://dx.doi.org/10.1371/journal.pone.0042535.

Podestà, M., Magnaghi, L., 1989. Unusual number of cetacean by-catches in the Ligurian Sea. Eur. Res. Cetaceans 3, 67–70.

Podestà, M., Meotti, C., 1991. The stomach contents of a Cuvier's beaked whale *Ziphius cavirostris* and Risso's dolphin *Grampus griseus* stranded in Italy. Eur. Res. Cetaceans 5, 58–61.

Podestà, M., Cagnolaro, L., Cozzi, B., 2005. First record of a stranded Gervais' beaked whale, *Mesoplodon europaeus* (Gervais, 1855), in the Mediterranean waters. Atti Soc. Ital. Sci. Nat. Museo Civ. Stor. Nat. Milano 146 (I), 109–116.

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. J. Cetacean Res. Manag. 7 (3), 251–261.

Pyenson, N.D., 2010. Carcasses on the coastline: measuring the ecological fidelity of the cetacean stranding record in the eastern North Pacific Ocean. Paleobiology 36, 453–480.

Pyenson, N.D., 2011. The high fidelity of the cetacean stranding record: insights into measuring diversity by integrating taphonomy and macroecology. Proc. R. Soc. B 278, 3608–3616.

Rosso, M., 2010. Population size, residency patterns and energy demand of Cuvier's beaked whales (*Ziphius cavirostris*) in the north western Mediterranean sea. PhD thesis, University of Basilicata, Potenza, Italy.

Rosso, M., Ballardini, M., Moulins, A., Würtz, M., 2011. Natural markings of Cuvier's beaked whale *Ziphius cavirostris* in the Mediterranean Sea. Afr. J. Mar. Sci. 33 (1), 45–57.

Schorr, G.S., Falcone, E.A., Moretti, D.J., Andrews, R.D., 2014. First long-term behavioral records from Cuvier's beaked whales (*Ziphius cavirostris*) reveal record-breaking dives. PLoS One 9 (3), e92633. http://dx.doi.org/10.1371/journal.pone.0092633.

Taylor, B.L., Baird, R., Barlow, J., Dawson, S.M., Ford, J., Mead, J.G., NotarbartolodiSciara, G., Wade, P., Pitman, R.L., 2008. *Ziphius cavirostris*. In: The IUCN Red List of Threatened Species. e.T23211A9429826.

Tepsich, P., Rosso, M., Halpin, P.N., Moulins, A., 2014. Habitat preferences of two deep-diving cetacean species in the northern Ligurian Sea. Mar. Ecol. Prog. Ser. 508, 247–260.

Tortonese, E., 1963. Insolita comparsa di cetacei (*Ziphius cavirostris* G. Cuv.) nel golfo di Genova. Natura 54, 120–122 (in Italian).
Tyack, P.L., Johnson, M., Aguilar Soto, N., Sturlese, A., Madsen, P.T., 2006. Extreme diving of beaked whales. J. Exp. Biol. 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 whales respond to simulated and actual navy sonar. PLoS One 6 (3), e17009. http://dx.doi.org/10.1371/journal.pone.0017009.
Waring, G.T., Hamazaki, T., Sheenan, D., Wood, G., Baker, S., 2001. Characterization of beaked whale (Ziphiidae) and sperm whale (*Physeter macrocephalus*) summer habitat in shelf-edge and deeper waters off the northeast US. Mar. Mamm. Sci. 17 (4), 703–717.
Whitehead, H., 2009. SOCPROG programs: analyzing animal social structures. Behav. Ecol. Sociobiol. 63, 765–778.
Wimmer, T., Whitehead, H., 2004. Movements and distribution of northern bottlenose whales, *Hyperoodon ampullatus*, on the Scotian Slope and in adjacent waters. Can. J. Zool. 82, 1782–1794.
Woodside, J.M., David, L., Frantzis, A., Hooker, S.K., 2006. Gouge marks on deep-sea mud volcanoes in the eastern Mediterranean: caused by Cuvier's beaked whales? Deep Sea Res. I 53, 1762–1771.
Zimmer, W.M.X., Tyack, P.L., 2007. Repetitive shallow dives pose decompression risk in deep-diving beaked whales. Mar. Mamm. Sci. 23 (4), 888–925.
Zimmer, W.M.X., Johnson, M.P., Madsen, P.T., Tyack, P.L., 2005. Echolocation clicks of free-ranging Cuvier's beaked whales (*Ziphius cavirostris*). J. Acoust. Soc. Am. 117 (6), 3919–3927.