

Review

Cetacean Strandings and Museum Collections: A Focus on Sicily Island Crossroads for Mediterranean Species

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Abstract: The study examined the extent of the cetacean strandings in Italy, with a particular focus on Sicily Island. The paper aimed to contribute to the description of a pattern that contemplates the “regular and rare” cetacean species passage along the Sicilian coast. The estimate of marine cetacean strandings was extrapolated from the National Strandings Data Bank (BDS—Banca Dati Spiaggiamenti) and evaluated according to a subdivision in three coastal subregions: the Tyrrhenian sub-basin (northern Sicilian coast), the Ionian sub-basin (eastern Sicilian coast), and the Channel of Sicily (southern Sicilian coast). Along the Italian coast, more than 4880 stranding events have been counted in the period 1990–2019. Most of these were recorded in five Italian regions: Apulia, Sicily, Sardinia, Tuscany, and Calabria. Approximately 15% of the recorded strandings in Italy occurred on the Sicilian coast. In Sicily Island, 725 stranded cetaceans were recorded in 709 stranding events, resulting in approximately 20 carcasses every year; the total number of specimens identified to species level was 539. The distribution along the Sicilian coast was the following: 312 recorded in the Tyrrhenian sub-basin, 193 in the Ionian sub-basin, and 220 in the Channel of Sicily. *Stenella coeruleoalba* was the species that can be considered as the stable record along the time-lapse investigated, and some rare species have been recorded as well. The role of Sicily Island as a *sentinel territory* of the cetacean distribution for the central Mediterranean Sea and as a region receiving a marine resource suitable for the scientific research and cetological museum collections is discussed herein.

Keywords: marine mammals; cetacean strandings; natural history museums; zoological collections; Mediterranean biodiversity



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1. Introduction

Natural history museums play an important role in zoological research and in the dissemination of scientific results to society, as well as in the enhancement of historical collections that mirror the past and current biodiversity of a region [1–3]. This is particularly valuable for cetacean collections [4,5] that preserve specimens which have been caught and specimens which have been stranded or died as a result of accidental captures in fishing gear (bycatch and entanglement) [6–8]. Some marine cetaceans in Italian museums, collected after stranding events, are remarkable for the Mediterranean Sea. An example is a specimen of the northern right whale, *Eubalaena glacialis*, a rare species for the basin, which stranded in Taranto in 1877 [9], and is presently exposed at the Zoological Museum of the University of Naples Federico II [10]. Two specimens of the Indo-Pacific rough-toothed dolphin, *Steno bredanensis*, recently considered a common species in the eastern

Mediterranean Sea [11], were stranded on the Sicilian coast in 2002 and now exhibited at the Civic Museum of Natural History of Comiso [12]. In addition, an exceptional skeleton of the dwarf sperm whale, *Kogia sima*, stranded near Foce Chiarore, Capalbio (Grosseto, Tuscany) in 1988 [13], which represents the first record for the Mediterranean, is shown at the Natural History Museum of the Accademia dei Fisiocritici of Siena.

Generally, cetaceans occupy a prominent position in museum exhibition halls and represent a great attraction to the public. They are considered *totem animals* [14] owing to their high emotional impact and because they function as precious documentary material useful for research and science dissemination. The abundant cetological heritage of Italian museums has been collected thanks to the work of scholars and taxidermists since the early 18th century [15] (see Supplement Document F1). The most important cetological collection in Italy in terms of the number of species and taxonomic diversity is now exhibited at the Natural History Museum of Calci (Pisa, Italy) where three species from Sicily Island are stored: a complete skeleton of a mounted sperm whale, *Physeter macrocephalus* (site collection Isola Grande—Marsala, Trapani, 1892); a skull and complete mounted skeleton of a Risso's dolphin, *Grampus griseus* (site collection Palermo 1881); and two skulls of the false killer whale, *Pseudorca crassidens* (date still unknown, previous 1900) [16].

The numerous specimens originating from Sicily and preserved in the Italian zoological collections, as well as the increasing scientific interest and public sensibility towards marine life by society led us to be aware of the extent of strandings along the coast of Sicily Island, the southernmost Italian region, in the view of offering a supporting document to whom have to manage strandings and plan a systematic collection of museum materials.

The present paper shows an assessment of the cetacean strandings that occurred in Sicily in the period 1990–2019 (Figure 1).

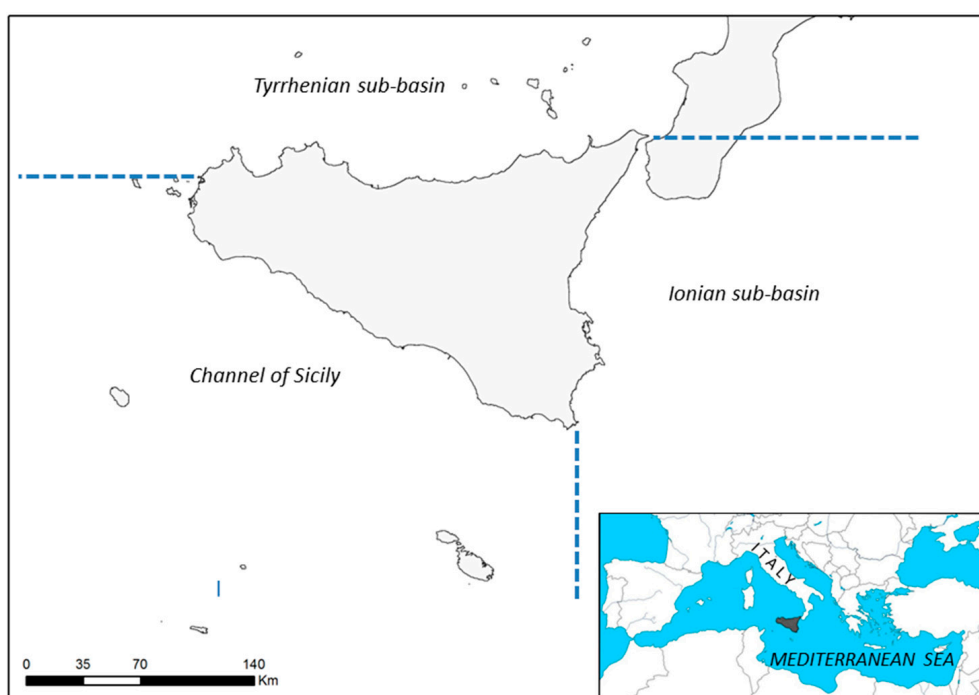


Figure 1. Map showing the partitioning of the Sicilian coast for the assessment of cetacean strandings: the Tyrrhenian sub-basin (northern Sicilian coast), the Ionian sub-basin (eastern Sicilian coast), and the Channel of Sicily (southern Sicilian coast). The insert indicates the position of Sicily Island in the Mediterranean Sea.

The data have been extracted from the National Strandings Data Bank (BDS—Banca Dati Spiaggiamenti) [17,18], and have been discussed in relation to the total stranding events along the Italian peninsula. The assessment was based on a coastal subdivision outlined in previous literature [19]; the Sicilian coast was partitioned into three sectors: the

Tyrrhenian sub-basin (the northern Sicilian coast), the Ionian sub-basin (the eastern Sicilian coast), and the Channel of Sicily (the southern Sicilian coast) (Figure 1).

Though the present paper reports the first description of spatial and temporal stranding records on the Italian coast, it does not deal with the impacts of humans on cetaceans or reasons for their mortality.

2. The National Strandings Data Bank (BDS—Banca Dati Spiaggiamenti)

The Italian research community benefits from organized information on the marine mammal strandings thanks to the National Strandings Data Bank [17,18]. The first Italian Strandings Network was created in 1986 at the Natural History Museum of Milan along with the Centro Studi Cetacei (CSC), a voluntary association of cetacean experts belonging to the Italian Society for Nature Sciences. Twenty years later, in 2006, the National Strandings Data Bank (BDS—Banca Dati Spiaggiamenti) was created and made available online by the University of Pavia and the Natural History Museum of Milan on behalf of the Italian Ministry of the Environment. The online data bank collects and validates strandings data to be made available to Governmental and Research Institutions as well as to the general public.

The BDS (<http://mammiferimarini.unipv.it> (accessed on 31 December 2020)) holds the records published by the Centro Studi Cetacei in the years 1986–2006, and since 2006, it has been updated in real-time with data sent by the Italian Strandings Network, which is managed by the Italian Ministry of the Environment and by the Ministry of Health. Currently, the initial reports of stranded animals are collected by the Coast Guard to be verified, validated, and transmitted to the competent territorial bodies and to the BDS. Any notice of stranded animals from citizens should be addressed to the Coast Guard.

The BDS also incorporates some historical data collected from a previous Cetacean Project, which was operative since 1975 and then merged into the CSC project. Data from Tuscany have, since 2007, been reported to the BDS directly by the regional network for the recovery of animals stranded along the Tuscan coast (Tuscan Observatory for Biodiversity—OTB) (L.R. n.30/2015, art. 11; Official Bulletin of the Tuscany Region n. 14 of 25 March 2015).

The scientific committee of the CSC also produced annual reports published by the Natural History Museum of Milan (Atti Soc. Ital. Sci. nat. Museo civ. Stor. Nat. Milano from I of 1986 to XXI of 2012; see Supplement Document F2).

In the period 1986 to 2019, 5571 stranding events were recorded in the BDS, totaling 6690 stranded animals, 4832 of which belong to 14 species and the rest were not identified. The records also include dead animals that were found entangled in fishing nets or on beaches and live animals that were caught in nets and then released.

The project National Stranding Data Bank (BDS) is within the frame of the activities recommended by ACCOBAMS (Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean and Contiguous Atlantic Area) and by the European Marine Strategy to monitor cetacean populations, the impacts of human activities, and the quality of the marine environment. The BDS is managed by the University of Pavia (CIBRA/Department of Earth and Environment Sciences) and by the Museum of Natural History of Milan (MSNM) in close coordination with the Mediterranean Marine Mammals Tissue Bank (BTMM <http://www.marinemammals.eu> (accessed on 31 December 2020)) and the Cetacean stranding Emergency Response Team (CERT) of the University of Padova, which was also established with a mandate by the Ministry of Environment.

3. The Study Area

The Mediterranean Sea covers an area of 2.5 million km². Twenty-one countries and three different continents—Africa, Asia, and Europe—are affected by its waters. The Mediterranean basin communicates with the Atlantic Ocean and the Indo-Pacific area, respectively, through the Strait of Gibraltar and the Suez Canal, which are corridors that guarantee the passage of different cetacean species, predominantly from the west and less

between the Mediterranean and the Red Sea, the latter arising for sporadic cases such as a specimen of *Sousa chinensis* [20].

From an oceanographical point of view, the Mediterranean Sea is divided into two macro-sectors: the western Mediterranean basin, which includes the Algerian-Provençal area and the Tyrrhenian, whose depth is no more than 3000 m in the northern Tyrrhenian; and the eastern Mediterranean basin, consisting of the Ionian, Aegean, and Levantine sub-basins, with a depth exceeding 5100 m in the Ionian area. The eastern Mediterranean basin is connected to the Black Sea through the straits of the Bosphorus and the Dardanelles. The Italian peninsula extends in the middle of the Mediterranean Sea and borders the two macro-sectors, connected by the Channel of Sicily (Figure 1).

Sicily Island is the southernmost region of Italy, has a coastline that is 1652 km long, 20% of the Italian coastal length, and overlooks three Mediterranean sub-basins (the Tyrrhenian, the Ionian Sea, the Channel of Sicily; Figure 1), each with peculiar oceanographical and ecological features.

Considering these aspects and its central position in the Mediterranean Sea, the study of marine mammals strandings in Sicily represents a topic of particular importance in the perspective of an effective network for both scientific research and museum enhancement. The position of Sicily is strategic, as its morphology makes the island a sort of *sentinel territory* for most marine species [21], due to the three portions of coast facing three different hydrographic and biogeographical provinces [22], i.e., the southern Tyrrhenian, along the northern coast, the Ionian, along the eastern coast, and the Channel of Sicily, along the southern coast.

The Tyrrhenian sub-basin is the deepest area in the western Mediterranean Sea [23]. It is characterized by complex bathymetry and plays an important role in the Mediterranean circulation because of several water masses flowing through [23]. The Atlantic Water (AW) enters the southern Tyrrhenian sub-basin in the upper layer of the water column (100–200 m thick); below the AW the Western Intermediate Water (WIW) is generated during the winter, while the West Mediterranean Deep Water (WMDW) flows at a greater depth. The complex dynamics and the presence of vortex and gyre structures are suitable conditions for vertical turbulence [24], resulting in favorable trophic conditions for cetaceans crossing the submarine canyons [25].

The Ionian Sea, the deepest regional area of the whole Mediterranean Sea, plays an important role in the intermediate and deep thermohaline cell of the Eastern Mediterranean conveyor belt. The Atlantic Water enters the Ionian, propagates towards the Levantine basin and bifurcates northward. Dense and oxygenated waters of Adriatic origin spread into the Ionian bottom layer, whilst the intermediate layer is influenced by salty and warm waters coming from the east [26]. Consequently, the Ionian circulation redistributes the different water masses rich in nutrients to adjacent seas. The Ionian continental shelf is very narrow, the depth along the eastern Sicilian coast drops suddenly reaching –2000 m within a few miles from the coastline, in contrast with the coastal seafloor morphology of the Channel of Sicily. The Ionian is characterized by significant upwellings that guarantee the regular sightings of six species: *Grampus griseus*, *Physeter macrocephalus*, *Balaenoptera physalus*, *Stenella coeruleoalba*, *Delphinus delphis*, and *Tursiops truncatus*, especially in the Gulf of Catania and in the strait of Messina [25,26].

The Channel of Sicily is a topographically complex region of the central Mediterranean comprising two sills: the depth of the eastern sill is about 540 m and that of the western is 530 m [27,28]. The maximum depth reaches 1700 m. The thermohaline circulation is mainly driven by an eastward flow of low-salinity Atlantic water (AW), bifurcating in the Atlantic Tunisian Current (ATC) and the Atlantic Ionian Stream (AIS), the last bordering the Sicilian coast. The AIS forces upwelling on the two shallow areas, the Adventure Bank and the Malta Plateau, influencing the concentration and distribution patterns of fish biomass, which is particularly favorable for the resident population of the common bottlenose dolphin, *Tursiops truncatus* [27–33].

The characteristics of the Mediterranean, in particular temperature and productivity (i.e., the presence of fish, macro-plankton, and cephalopods), affect the distribution of cetacean species [30,31]. Of the 78 known species, 22 have been recorded in the Mediterranean basin. The last species recorded in a recent stranding event is the first record of the Bryde's whale, *Balaenoptera edeni* (following nomenclature according to Kato and Perrin 2018 [34]), along the Egyptian coast [35].

The species of cetaceans observed in the Mediterranean Sea can be included into three categories [9,15,19,36]. Regular species, with resident populations, comprise 10 species including one belonging to the suborder Mysticeti (the fin whale, *Balaenoptera physalus*) and nine to suborder Odontoceti (the sperm whale, *Physeter macrocephalus*; the Cuvier's beaked whale, *Ziphius cavirostris*; the long-finned pilot whale, *Globicephala melas*; the Risso's dolphin, *Grampus griseus*; the common bottlenose dolphin, *Tursiops truncatus*; the striped dolphin, *Stenella coeruleoalba*; the short-beaked common dolphin, *Delphinus delphis*; and the Indo-Pacific rough-toothed dolphin, *Steno bredanensis*, which has only been observed in the Levantine Basin). Regarding *Steno bredanensis*, it is noteworthy to highlight that it has only recently been included as a regular species and maybe a relict population in the eastern basin [11]. The killer whale *Orcinus orca* can be also considered a regular species, resident in the Strait of Gibraltar whose population presence is widely verified by sightings [37]. Visitor species are named because of their Atlantic origin and have occasional appearances especially in the western Mediterranean basin (the false killer whale *Pseudorca crassidens*, the common minke whale *Balaenoptera acutorostrata*, and the humpback whale *Megaptera novaeangliae*). Vagrant species are those observed sporadically in different areas of the Mediterranean basin (the dwarf sperm whale *Kogia sima*, the northern bottlenose whale *Hyperoodon ampullatus*, the Blainville's beaked whale *Mesoplodon densirostris*, the Gervais' beaked whale *Mesoplodon europaeus*, the sei whale *Balaenoptera borealis*, the North Atlantic right whale *Eubalaena glacialis*, and the gray whale *Eschrichtius robustus*). Further, the Indo-Pacific humpback dolphin *Sousa chinensis* was included in a fourth category named alien species, the ones that moved towards the Mediterranean a few times following the opening of the Suez Canal (1869) (Morzer Bruyns, pers. comm. in Marchessaux, 1980) [19].

The conservation status of cetaceans in the Mediterranean is considered worrying by the IUCN (International Union for the Conservation of Nature), which draws up the "Red List of Threatened Species", the largest database of information on the conservation status of animal and plant species in all over the globe. Of the nine species of the Mediterranean cetaceans, *Ziphius cavirostris*, *Globicephala melas*, *Grampus griseus*, and *Steno bredanensis* fall into the "Data Deficient" category; *Stenella coeruleoalba*, *Balaenoptera physalus*, and *Tursiops truncatus* fall into the "Vulnerable" category; *Delphinus delphis* and *Physeter macrocephalus* are instead considered to be "Endangered" [38].

4. The Census

In this work, the number of stranding events occurring throughout the national maritime zone, as recorded by the National Strandings Data Bank, was examined to relate it to those occurring along the coast of Sicily. The period examined was between 1990 and 2019. The Data Bank (<http://mammiferimarini.unipv.it> (accessed on 31 December 2020)) was consulted on 31 December 2019; any current discrepancy might derive from updates inserted after the consultation. We first proceeded by observing all records in each Italian administrative region, including stranded carcasses and entangled specimens (see Supplement Figure S1).

Figure 2 shows the data relating to the number of stranding events and the number of specimens (as a single event can include more than one specimen) and the number of species stranded for each Italian region. It should be taken into account that the effort for monitoring and reporting of strandings in the past was not homogenous across years, although this did not limit an accurate evaluation of strandings. A total of 4889 stranding events and 4970 specimens were counted.

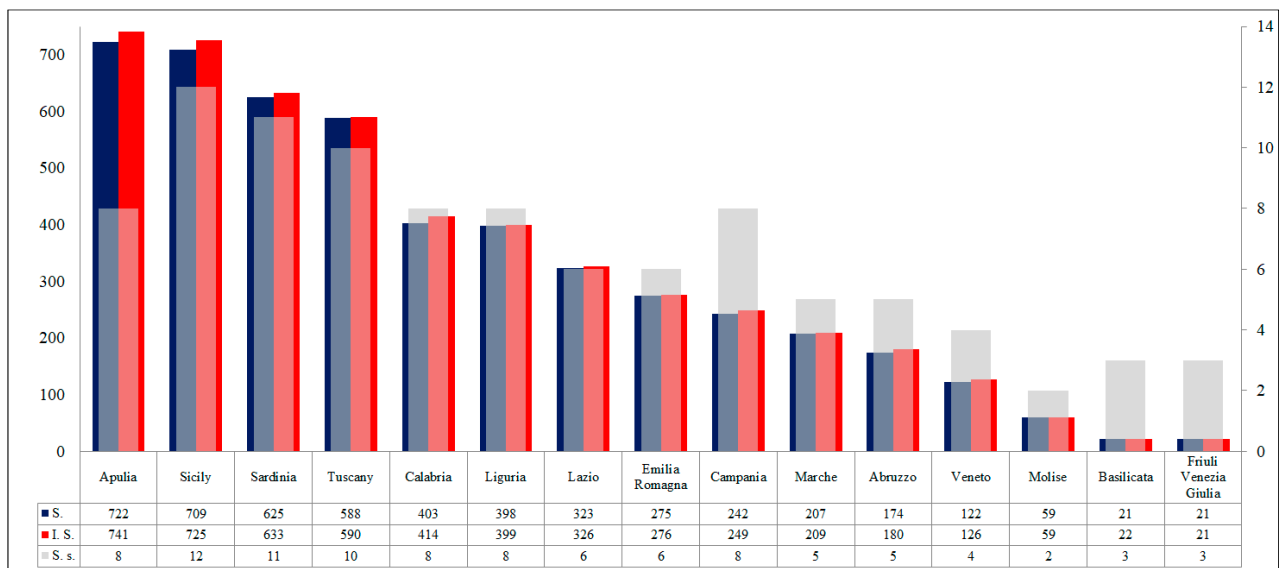


Figure 2. Number of stranding events (S.), the number of individuals stranded (I.S.), and the number of species stranded (S. s.) for each Italian region (see text for details and Supplement Figure S1 for map of the regions).

The extent of strandings appears proportionate to the length of the coastline per region (see Figure S1 in Supplementary material). Table 1 shows the number of specimens stranded, corresponding to the individuals stranded (I.S.) values of Figure 2, per species (1990–2019) in the different Italian regions.

Table 1. Number of specimens stranded, including entangled specimens (i.e., the I.S. in Figure 2) for each species (1990–2019) in the different Italian regions (Apu = Apulia; Sic = Sicily; Sar = Sardinia; Tus =Tuscany; Cal = Calabria; Lig = Liguria; Laz = Lazio; Emi = Emilia Romagna; Cam = Campania; Mar = Marche; Abr = Abruzzo; Ven = Veneto; Mol = Molise; Bas = Basilicata; Fri = Friuli Venezia Giulia) (see Supplemental Figure S1 for a map of the regions).

Species	Apu	Sic	Sar	Tus	Cal	Lig	Laz	Emi	Cam	Mar	Abr	Ven	Mol	Bas	Fri
<i>Balaenoptera acutorostrata</i> Lacépède, 1804		1	1	2		1			1						
<i>Balaenoptera physalus</i> (Linnaeus, 1758)	3	5	15	18	7	15	4	1	6	1					
<i>Delphinus delphis</i> Linnaeus, 1758	2	20	17	1				1	2	3	1	1			
<i>Globicephala melas</i> (Traill, 1809)	2	6	15	5	5	14									
<i>Grampus griseus</i> (G. Cuvier, 1812)	19	20	23	12	17	15	7	3	7	2	3	2			3
<i>Kogia sima</i> (Owen, 1866)		1							1						
<i>Megaptera novaeangliae</i> (Borowski, 1781)		1													
<i>Mesoplodon europaeus</i> (Gervasis, 1855)				1											
<i>Physeter macrocephalus</i> Linnaeus, 1758	10	45	29	9	18	4	16	1	14		7				
<i>Pseudorca crassidens</i> (Owen, 1846)			1		1										
<i>Stenella coeruleoalba</i> (Meyen, 1833)	318	335	282	292	267	240	185	12	129	4	29	9	5	11	2
<i>Steno bredanensis</i> (G. Cuvier, 1828)		6	1												
<i>Tursiops truncatus</i> (Montagu, 1821)	189	78	179	180	20	42	46	225	33	143	129	94	33	4	11
<i>Ziphius cavirostris</i> G. Cuvier, 1823	9	21	4	7	13	8	3							3	
Unidentified	189	186	66	63	66	60	65	33	56	56	11	20	21	4	5

The Italian regions where most of the strandings occurred are Apulia (Apu), Sicily (Sic), Sardinia (Sar), and Tuscany (Tus), counting respectively 722, 709, 625, and 588 stranding events, with, respectively, 741, 725, 633, and 590 specimens. The regions Molise (Mol), Basilicata (Bas), and Friuli Venezia Giulia (Fri) with the lowest coastline length showed a lower number of stranded cetaceans.

The common bottlenose dolphin, *Tursiops truncatus*, and the striped dolphin, *Stenella coeruleoalba*, are the most frequent species stranded in all regions. Sicily, compared to Apu, Sar, and Tus, has the lowest rate of strandings of *Tursiops truncatus*, and lists a greater variety of species along the coast, due to the *Balaenoptera acutorostrata*, *Kogia sima*, *Megaptera novaeangliae*, and *Steno bredanensis* occasional stranding events.

Regarding the two regions with the highest rate of strandings (Apu and Sic), important data concerns the Unidentified category, representing 25.5% and 25.6% of the total number of specimens recorded, respectively (Table 1).

This biological material, especially in Sicily, seems to be overlooked. An appropriate management program could retrieve it and contribute to increasing knowledge about cetacean distribution, increasing the valuable material for research and museum collections.

Sicily, occupying a central position in the Mediterranean, represents an area of transit of the more or less regular, sporadic, and vagrant species (Figure 3) whose presence and density is only documented through strandings, such as the dwarf sperm whale, *Kogia sima*, beached in Eraclea Minoa locality (AG) in June 2002 [39,40], the humpback whale, *Megaptera novaeangliae*, found entangled close to Siracusa and then released in 2004 [41], or the six specimens of the rough-toothed dolphin, *Steno bredanensis*, stranded along the Ionian coast of Sicily (RG) in April 2002, three of which died [40,42].



Figure 3. Some stranding events on the Sicilian coast: (a) *Stenella coeruleoalba*, striped dolphin, stranded in October 2018 (Triscina, Trapani); (b) *Physeter macrocephalus*, sperm whale, stranded in May 2019 (Capo Calavà, Gioiosa Marea, Messina); (c) *Grampus griseus*, Risso's dolphin, stranded in February 2020 (Milazzo, Messina); (d) *Tursiops truncatus*, common bottlenose dolphin, stranded in January 2021 (Palermo) (photos ©Andrea Calascibetta); (e) Necropsy procedure performed by a IZS and IAS-CNR Researchers Team for a specimen of *Balaenoptera physalus*, fin whale, stranded in September 2014 (Triscina di Selinunte, Trapani) (Photo © Giuseppa Buscaino, Bioacoustics Lab of CNR-IAS).

In addition to the reports of the aforementioned species, it is relevant to mention an old stranding event of false killer whales, *Pseudorca crassidens*, which occurred on the western Sicilian coast in 1877, before the analyzed period [43].

In the period 1990–2019, 725 specimens were counted along the Sicilian coastline (Figure 4). The greatest number of strandings (n = 106) occurred in the year 1991, which was due to a *Morbillivirus* infection [44]. The individuals concerned were two long-finned pilot whales, three sperm whales, 44 striped dolphins, five bottlenose dolphins, and 52 specimens that could not be identified as a result of decomposition. A decrease in numbers between 2005 and 2012 was probably due to lower efficiency in the monitoring of the region.

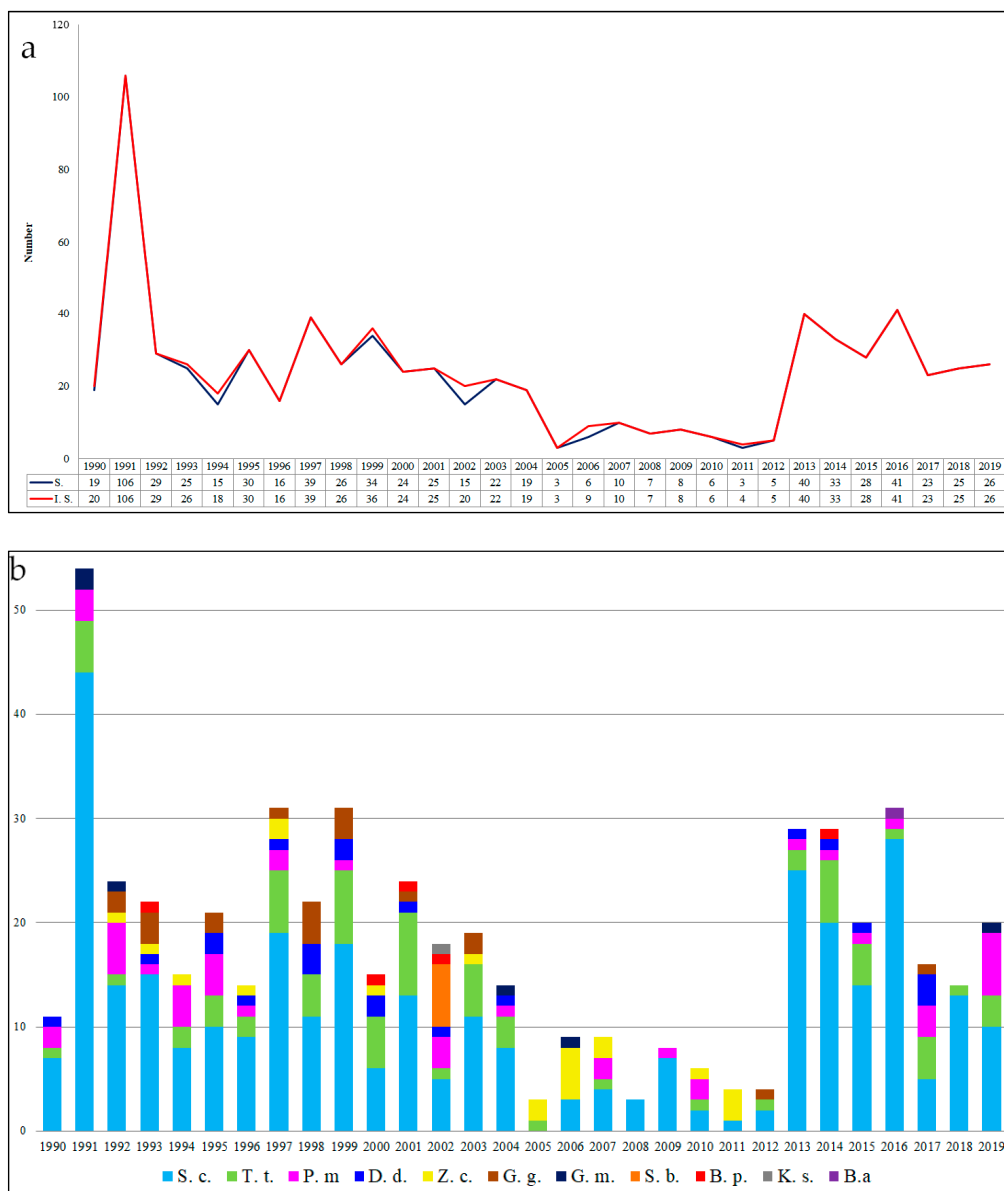


Figure 4. (a) Stranding frequency on Sicilian coast (1990–2019); S., Number of stranding events; I. S., number of stranded and entangled individuals; unidentified specimens included. (b) Number of stranded and entangled individuals for each species along the Sicilian coast per year (1990–2019). From the most to the less abundant S. c. = *Stenella coeruleoalba*; T. t. = *Tursiops truncatus*; P. m. = *Physeter macrocephalus*; D. d. = *Delphinus delphis*; Z. c. = *Ziphius cavirostris*; G. g. = *Grampus griseus*; G. m. = *Globicephala melas*; S. b. = *Steno bredanensis*; B. p. = *Balaenoptera physalus*; K. s. = *Kogia sima*; M. n. = *Megaptera novaeangliae*; B. a. = *Balaenoptera acutorostrata*; unidentified specimens not included.

On the whole, the annual average number of stranding events is 21, calculated by eliminating the maximum value ($n = 106$) and the minimum value ($n = 3$).

Stranding events showed a spatial pattern along the coast, as already detected in different seas [5–8], due to factors such as the seafloor morphology and the oceanographic characteristics. Table 2 shows the number of stranded individuals per sub-basin: Tyrrhenian, Ionian and Channel of Sicily. The most numerous strandings occurred in the Tyrrhenian sub-basin ($n = 312$), followed by the Channel of Sicily ($n = 220$), whereas the lowest number was scored in the Ionian sub-basin ($n = 193$).

Table 2. Number of stranded and entangled specimens for each species in the different Sicilian coastal areas (Tyrrhenian, Ionian, and Channel of Sicily).

Species	English Common Name	Italian Common Name	Tyrrhenian	Ionian	Channel of Sicily	Total
<i>Balaenoptera acutorostrata</i>	Common minke whale	Balenottera minore	1			1
<i>Balaenoptera physalus</i>	Fin whale	Balenottera comune	2		3	5
<i>Delphinus delphis</i>	Short-beaked common dolphin	Delfino comune	6	4	10	20
<i>Globicephala melas</i>	Long-finned pilot whale	Globicefalo	2		4	6
<i>Grampus griseus</i>	Risso's dolphin	Grampo	7	4	9	20
<i>Kogia sima</i>	Dwarf sperm whale	Cogia di Owen			1	1
<i>Megaptera novaeangliae</i> *	Humpback whale	Megattera		1		1
<i>Physeter macrocephalus</i>	Sperm whale	Capodoglio	31	4	10	45
<i>Stenella coeruleoalba</i>	Striped dolphin	Stenella striata	156	109	70	335
<i>Steno bredanensis</i> **	Rough-toothed dolphin	Steno			6	6
<i>Tursiops truncatus</i>	Common bottlenose dolphin	Tursiope	16	6	56	78
<i>Ziphius cavirostris</i>	Cuvier's beaked whale	Zifio	9	5	7	21
Unidentified			82	60	44	186
Total			312	193	220	725

* entangled and then released; ** all stranded and three released.

Figure 5 shows the different percentages of the species stranded in the different Sicilian coastal sectors. In particular, it should be noticed that in the Tyrrhenian sub-basin the most frequent species are the striped dolphin *Stenella coeruleoalba* (50%), the sperm whale *Physeter macrocephalus* (10%), and the common bottlenose dolphin *Tursiops truncatus* (5%); in the Ionian coast, the most frequent species are the striped dolphin *Stenella coeruleoalba* (56%), the common bottlenose dolphin *Tursiops truncatus*, and the Cuvier's beaked whale *Ziphius cavirostris* (3%); in the Channel of Sicily, the most frequent species are the striped dolphin *Stenella coeruleoalba* (32%), the common bottlenose dolphin *Tursiops truncatus* (25%), the fin whale *Balaenoptera physalus*, and the sperm whale *Physeter macrocephalus* (5%). Regarding the unidentified carcasses, 26% were in the first sector, 30% in the second, and finally 20% in the third, respectively.

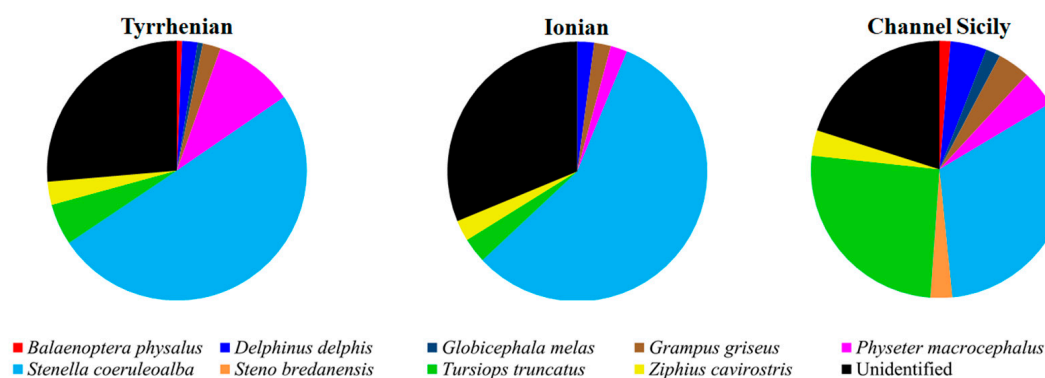


Figure 5. Percentage of carcasses of all stranded species during the period 1990–2019 (see Table 2) per each Sicilian coastal sub-area (Tyrrhenian, Ionian, and Channel of Sicily), unidentified specimens included, unique specimens excluded.

5. Sicily as a Crossroads for Cetaceans' Passage

The results highlight that the Tyrrhenian sub-basin, with 312 specimens, shows the highest number of stranded specimens, followed by the Channel of Sicily ($n = 220$) and the Ionian ($n = 193$); whereas the coast that receives the highest number of species is the Channel of Sicily (10 species), followed by the Tyrrhenian sub-basin (9 species) and the Ionian sub-basin (7 species).

On the Sicilian coast, 12 stranded species were counted of the 22 species of cetaceans that have been reported in the Mediterranean Sea. This data remarks the value of Sicily in common and rare cetacean species recruitment in the Mediterranean Sea and confirms the importance of the central position in the basin as a crossroads for cetacean passage.

Different factors, such as population density, the distance between the site of death and the coastline, the buoyancy of the carcasses, winds, and currents, can determine the number of stranding records. Considering the greatly extended coastline of the three Sicilian sub-areas, cetacean stranding records can reflect the relative abundance of living populations inhabiting the neighbouring areas [5,45] and could be a good source of information when survey efforts at sea are scarce or absent [8,46].

The cetacean stranding records can be moreover affected by variation in reporting rates by "citizen science" activities [8,30,47] and by the presence of a stranding network to collect and validate datasets [45,48].

The differences in abundance and the species diversity resulting in this study are correlated to different environmental and anthropogenic features. The three Sicilian coastal sub-areas show that different bathymetry, ecological characteristics, naval traffic density and fisheries influence the distribution, the behavior and the life safety of cetaceans. Our analysis confirms that *Stenella coeruleoalba* and *Tursiops truncatus* are the most commonly found species around Sicily [19,49], and similarly notes some differences in the distribution of them among the three sub-basins due to the environmental and anthropogenic features described above.

Regarding the *Stenella coeruleoalba* population, the number of strandings is the lowest in the Channel of Sicily sub-area; in this case, due to the large and shallow continental shelf, the populations live far from the coast and dead specimens can float offshore towards different areas of the Mediterranean. Regarding *Tursiops truncatus*, data indicate the Channel of Sicily as the sub-basin in which most specimens are stranded. This data is coherent with the nearshore habitat use of the common bottlenose dolphin [8,50]. The high number of stranded bottlenose dolphins adequately reflects previous studies of its population and interactions with industrial fishing activities [33,49].

Additionally, the distribution of the strandings is different regarding the sperm whale, *Physeter macrocephalus*, which strands more frequently on the Tyrrhenian coast. Previous literature reports the presence of this species in the Channel of Sicily, in the Ionian Sea [51] and in the Tyrrhenian Sea, commonly concentrated in canyon areas [52]. The present results show its strandings somehow infrequent along the eastern Sicilian coast, where the Ionian seafloor morphology characterized by a wide abyssal plain can limit risks of death.

It should be noticed that though the short-beaked common dolphin, *Delphinus delphis*, which was formerly very common and successively undergone a dramatic decline in abundance during the last few decades [19], shows very rare stranding events within the 30-year period, both in Italy and Sicily, if compared with other species like *Grampus griseus* or *Physeter macrocephalus*.

Finally, an interesting fact concerns the six records of *Steno bredanensis* stranded in the Sicilian Channel because the only sightings of this species have been made in the eastern Mediterranean [40,42] and in the Tyrrhenian sub-basin, in the Lazio (Laz) area [25].

6. The Cetological Collections in Sicily

From earlier literature (see Supplement Document F1), it emerges that Sicily is the seventh region in Italy with regard to the number of cetological collections (88 records), but it exhibits a small number of complete skeletons to the public.

The number of collected cetaceans in Sicily could have been higher if the local institutions would have been better organized in recovering carcasses.

Several Italian museums not located in Sicily store specimens (24) collected from the Sicilian coasts (in Milan [53]; Florence [54]; Pisa [16]; Genoa [55]; Padua [56]; Livorno [57]). The collections of cetaceans in Sicily are mainly osteological [12,14] and preserve a few specimens distributed in several exhibitions. The museum with the largest collection is the Civic Museum of Natural History of Comiso which stores 39 pieces obtained from specimens collected from 1991 to 2003 in Sicily. Among the specimens of considerable relevance, a complete and disjointed skeleton of the dwarf sperm whale, *Kogia sima*, the sole individual ever stranded in Sicily, and two skeletons of the rough-toothed dolphin, *Steno bredanensis* [12].

The Museum of Zoology “Pietro Doderlein” of the University of Palermo preserves the second most important cetological collection, albeit consisting of only 18 pieces (Figure 6a): two short-beaked common dolphins, *Delphinus delphis*, taxidermied; two common bottlenose dolphin, *Tursiops truncatus*, skulls; two Risso’s dolphin, *Grampus griseus*, skulls; one Cuvier’s beaked whale, *Ziphius cavirostris*, skull; one short-beaked common dolphin, *Delphinus delphis*, skull, and a partial skeleton. The specimens collected have a historical value, including a partial skeleton of a sperm whale, *Physeter macrocephalus*, that beached alive near the Stagnone of Marsala (TP) in December 1872, in a massive stranding event [58]. Other unexposed specimens are two fetuses of short-beaked common dolphins, *Delphinus delphis*, and two fin whale, *Balaenoptera physalus*, vertebrae.

Other Sicilian museums that house cetological collections are the Museo di Zoologia e Casa delle Farfalle of the University of Catania (4 specimens), the Museo della Fauna of the University of Messina (2 specimens), the Zoological Museum “F. Cambria” of the University of Messina (3 specimens), and the Acquario Civico in Messina (7 specimens) [12].

A cetological reconstruction laboratory established by the Institute of Anthropic Impact and Sustainability in Marine Environment of the National Research Council (CNR-IAS) at Capo Granitola (Sicily) collaborates with national and international experts with the aim to fill the skills gap on museological preparations and enhance and create a collection of skeletal systems of Mediterranean cetaceans, which is accessible to research and available for scientific dissemination. In the laboratory, several complete skeletons (*Balaenoptera physalus*, *Ziphius cavirostris*, *Tursiops truncatus*, two *Stenella coeruleoalba* specimens), *Delphinus delphis* (2 specimens) and incomplete skeletal and skulls are stored. Actually, one skeleton of *Physeter macrocephalus* (Figure 6b), one of *Stenella coeruleoalba* and one of *Grampus griseus* are included as part of a permanent exhibition of the “Observatory of terrestrial and marine Biodiversity of the Sicilian Region” (ORBS).

The extent of the cetological collections exhibited in Sicilian museums does not depend on a lack of available resources as the island is an area where numerous strandings occur. On the contrary, this is due to the loss of 93.5% of the specimens stranded in Sicily, which are not recovered by museums but instead discarded.

There are several reasons for this. First of all, there is an absence of some skills such as taxidermy due to the profession no longer being of interest for young people, the lack of financial resources dedicated to this field, and the limited interest of several public institutions. However, Sicily in recent years has received great consideration by the scientific authorities regarding the phenomenon of strandings and the recovery of the skeletons for museum purposes.

In September 2014 a 20 m-long fin whale, *Balaenoptera physalus*, a decomposed specimen, stranded close to Triscina di Selinunte, Castelvetrano (Trapani), whose analyses were managed by CNR-IAS and IZS (Istituto Zooprofilattico della Sicilia) researchers (Figure 3). The skeleton was extracted and is now preserved for research and scientific dissemination activities at the CNR-IAS of Capo Granitola (Gaspare Buffa *pers. comm.*). This stranding event is noteworthy as the fin whale is the largest species ever recorded along the island’s coast. It should be noticed that a mistake was reported in the BDS and a 12 m-long *Balaenoptera physalus* specimen was archived.

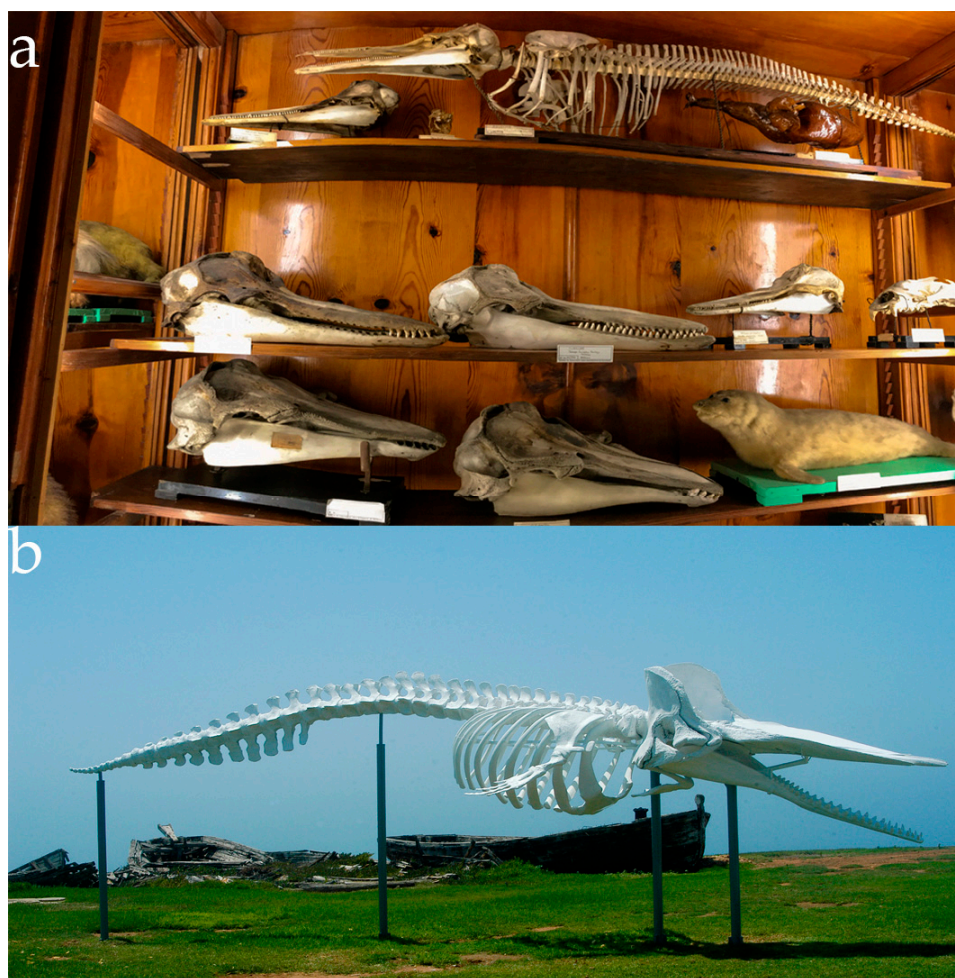


Figure 6. Examples of Sicilian cetological collections. **(a)** A view of the exhibition at the Museum of Zoology “P. Doderlein” of the University of Palermo. From above to below: *Delphinus delphis* skull, partial skeleton and anatomy apparatus; two *Tursiops truncatus* skulls, and a *Stenella coeruleoalba* skull; two *Grampus griseus* skulls. **(b)** The *Physeter macrocephalus* skeleton at the Institute of Anthropic Impact and Sustainability in marine Environment (CNR-IAS) section of Capo Granitola, Campobello di Mazara (Tp) (photos ©Andrea Calascibetta and © Gaspare Buffa).

In October 2016, an 8.4 m-long sperm whale, *Physeter macrocephalus*, stranded along the coast of Aspra (Palermo) was recovered by the task force of CERT (Cetacean Stranding Emergency Response Team-UNIPD) on behalf of the local authority to carry out the reconstruction of the skeleton (Sandro Mazzariol *pers.comm.*). In 2017, a stranded sperm whale was recovered by the Museo della Fauna (University of Messina) and exhibited at the Castle of Milazzo (Messina). Further, in February and May 2019, a long-finned pilot whale, *Globicephala melas*, stranded in Barcellona Pozzo di Gotto (Messina), and a sperm whale found in Cefalù (Palermo) were also recovered by the same museum (Filippo Spadola *pers.comm.*). Thus, an increasing interest in building a strandings network enables sharing skills and information and improving the samples collection.

7. Conclusions

In light of the aforementioned discussion, we can assert that Sicily is an island with a potential cetological resource that can integrate a museum heritage at a national and international scale. Under the sustainable development goals (SDGs) targeted by the United Nations [59] which include relevant topics on the protection and conservation of marine life, cetacean strandings can become a tool for the implementation of scientific dissemination programs if carcasses are adequately recovered and preserved. This paper

aims at promoting the establishment of a network for the management of strandings, the training of specialized personnel, and the collaboration among researchers to better improve knowledge about these marine mammals and the ocean environment.

Supplementary Materials: The following are available online at <https://www.mdpi.com/1424-2818/13/3/104/s1>, Figure S1: Italian strandings during 1990–2019. Map of Italian regions and a table with the number of strandings (S) and the number of individuals stranded (I. S.) for each Italian region. Coastline length has been obtained from the Istat portal (<https://www.istat.it/it/archivio/137341> (accessed on 31 December 2020)); Document F1: List of references reporting information about the inventory of the cetological collections in the Italian museums per region; Document F2: Annual reports published by the Natural History Museum of Milan (Atti Soc. Ital. Sci. nat. Museo civ. Stor. Nat. Milano from I of 1986 to XXI of 2012).

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