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ORIGINAL ARTICLE

Assessing the relationship between cetacean strandings (*Tursiops truncatus* and *Stenella coeruleoalba*) and fishery pressure indicators in Sicily (Mediterranean Sea) within the framework of the EU Habitats Directive

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Abstract Cetacean strandings are a constant phenomenon that occurs on coastlines; mortality is related to several factors but commercial fishing is considered one of the main pressures, in the Mediterranean, that can impact small cetacean species such as common bottlenose dolphin (*Tursiops truncatus*) and striped dolphin (*Stenella coeruleoalba*). Since all eight species of cetaceans residing in the Mediterranean Sea are listed in the Habitats Directive, there is a legislative and management need to survey and report their conservation status every 6 years. The aim of this study was to assess the relationship, in Sicily, between strandings of two species and the fishery capacity, using records from 1995 to 2012. Positions and densities of all the strandings were compared with values of engine power from all the fishing vessels registered in 48 Sicilian ports. In addition, the relationship between strandings and the wild population at sea was investigated. Results showed that trends of fishing capacity and strandings both decreased, with a strong positive association. Trends were also confirmed when data were grouped into "6-year periods" or into different geographical sub-areas. Strandings were clustered near ports with higher fishing capacities; *S. coeruleoalba* records were distributed more homogenously along the coastline compared to *T. truncatus*, whose strandings were mostly distributed on the southern coastline, where the fishing capacity of bottom otter trawls was greater. The ratio between the two cetacean species was similar both for strandings and at-sea populations. Results show that fishing capacity is a pertinent indicator of pressure/threat to small cetacean species, and stranding records could complement at-sea data to assess population status within the framework of EU Directives.

Keywords Fishing capacity · Drift nets · Fishing gear · Fleet Register

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Introduction

All eight species of cetaceans known to reside in the Mediterranean region (Notarbartolo di Sciara 2002—*See* Table 2 in "Results") are considered in the EU Habitats Directive as species of community interest and in need of strict protection. The Directive calls on member states to undertake inventory of surveillance on the conservation status of the species ensuring that incidental capture and killing does not have a significant negative impact. Every 6 years, member states are required to write a report on the implementation of the measures, the main results of surveillance, the conservation status of the species, which includes data on range, population, and anthropogenic pressures.

The main anthropogenic pressures that can cause direct cetacean deaths due to injury are by-catch in fisheries—Habitat Directive code F02 (Pace et al. 2015), and to a lesser extent, collisions with vessels along shipping lanes—D03.02 (Campana et al. 2015), ingestion of macroplastics—H03.03 (Baulch and Perry 2014), and recently, according to several authors, seismic exploration airgun blasts—H06.05 (Castellote and Llorens 2016). In addition, high levels of contaminants—H03.02 (Fossi et al. 2004) can lead to immune system suppression, which can increase susceptibility to diseases such as morbillivirus and toxoplasmosis (Aguilar and

Borrell 1994); in general, sickness can make the animals more prone to all types of pressures.

When a cetacean's life comes to an end, whether from natural or anthropogenic causes, it is likely that the body will decompose or be scavenged at sea without landing along the coastline. The possibility that the dead body would land ashore is likely due to a series of factors such as the distance from the coast, winds, and currents; in addition, species population density and presence of a "recording network" are important factors that can influence the number of stranding records (Hooker et al. 1997, Siebert et al. 2006, Pikesley et al. 2012). Disposal of stranded carcasses follows complex and expensive procedures.

The population and management relevance of stranding data is, at present, uncertain both due to the absence of real population estimates that could be used for comparisons and due to the opportunistic nature of the recordings; stranding data, however, could be a good source of information when survey effort at sea is scarce (d'Astore et al. 2008). On the other hand, when data coming from hundreds of validated strandings, collected over many decades from an efficient stranding network, are appropriately taken into consideration, spatio-temporal patterns across a region can offer insight into mortality patterns (Leeney et al. 2008). In this case, the information is functional both for population data and future prospective data, which most importantly are parameters used to evaluate the conservation status of the species according to the Habitats Directive.

Periodic single stranding events are usually the result of a death caused by age or by injury while frequent single stranding events concentrated in a short time period are instead usually caused by population outbreak (such as the ones due to infectious agents). Multiple strandings are instead rare events, occurring when more than a few animals strand altogether, and several factors (*e.g.*, climate and oceanographic variation, navigational errors, anthropogenic noise, earthquakes) can, presumably, play a role in these events (Bradshaw et al. 2006).

In the Italian seas alone, it has been calculated that more than 80% of the stranding events that occurred between 1986 and 1990, for which the cause of death was established, resulted from by-catch in drift nets (Cagnolaro and Notarbartolo di Sciara 1992). Also, sea turtle strandings have strongly been related to by-catch in the Mediterranean: according to a 14-year study period (Tomás et al. 2008), in fact, more than half of the loggerhead turtle (*Caretta caretta*) strandings were a result of human activities such as fisheries.

By-catch in fisheries is considered to be one of the major issues for the management and conservation of small cetacean species in Europe (Evans and Hammond 2004) and, during the last few decades, by-catch was recognized to be one of the major causes impacting cetacean populations in the Atlantic (Osinga et al. 2008) and in the Mediterranean (Bearzi 2002). Worldwide, interactions between cetaceans and fisheries are increasing as fishing pressure increases due to more industrialized fishing methods (DeMaster et al. 2001).

In the Mediterranean in general, most incidental captures involve common bottlenose dolphins (*Tursiops truncatus—T.t.*) and striped dolphins (*S. coeruleoalba—S.c.*) (Di Natale and Notarbartolo di Sciara 1994; Northridge and Hofman 1999). Pelagic drift nets (banned from EU waters since 2002 via Council Regulation 894/1997 and the Council Regulation 1239/1998 when intended for capturing highly migratory species such as swordfish and tunafish) are the most dangerous nets, not only for sperm whales and striped dolphins (Fortuna et al. 2007) but also for Cuvier's beaked whale, common bottlenose dolphins, and common dolphins (IWC 1994). Coastal bottom gillnets, on the other hand, cause incidental trappings of common bottlenose dolphins and common dolphins: several incidental catches were reported in the Mediterranean (UNEP 1998, Díaz López 2006), and according to the IWC (1994) report, both common bottlenose dolphins and striped dolphins can be trapped in this type of net. By-catch in purse seines mainly affects small cetaceans such as common bottlenose dolphins and striped dolphins (Magnaghi and Podestà 1987; Di Natale 1990, UNEP/IUCN 1994, Aïssi 2014). Records of by-catch in longlines are known for both common bottlenose dolphins and striped dolphins (Bearzi 2002). By-catch in trawl nets could occur both for common bottlenose dolphins and striped dolphins (Bearzi 2002) which, although are believed to be aware of nets (Fertl and Leatherwood 1997), could become entangled in them while foraging adjacently. In the Mediterranean, a high mortality of common bottlenose dolphins has been reported in bottom trawl nets off the coast of Israel (Goffman et al. 2001 in Bearzi 2002); Duguy et al. (1983) reported striped, common, and common bottlenose dolphins and a few fin whales incidentally caught by trawlers off France and Italy. In Spain, by-catch mortality for common dolphins and common bottlenose dolphins was reported to be the highest for trawls and set gillnets (Goetz et al. 2014). In general, the common bottlenose dolphin is the most often documented cetacean species feeding in association with trawls (Fertl and Leatherwood 1997). In the Adriatic Sea, for example, in a study on by-catch during pair trawling, while both the presence of common bottlenose dolphins and striped dolphins was documented, only the former was sighted interacting with the fishing operation, following trawlers during tows, entering the net, and swimming around the cod-end (the part of the trawl where fish are retained) during the final part of hauling operations (Fortuna et al. 2010). In the Central Tyrrhenian Sea, the interaction between common bottlenose dolphins and trawlers was reported in several other studies (Marini et al. 1995, Silvani et al. 1999).

Also, intentional killing by fisheries is considered to have a high impact on cetaceans (Bearzi 2002; Moore et al. 2013); dolphins, especially the common bottlenose, are in fact considered a "pest" by fishermen in many parts of the Mediterranean and are blamed for the destruction of nets when preying on trapped fish (Tudela et al. 2005). Studies conducted by the University of Barcelona, in the Balearic Islands (from 1992 to 1995), indicated that about 30 common bottlenose dolphins were dying annually as a result of direct killing by fishermen in retaliation for depredation on nets (Silvani et al. 1992). In most of the Mediterranean countries, the frequency of intentional killings declined over the years due in part to protective legislation (Bearzi et al. 2008), targeted kills, however, still occur in certain areas (*e.g.* Tudela et al. 2005; Gazo et al. 2008).

In general, it should be considered that available data on by-catch, to properly assess and successively manage the impacts on cetacean species, is still lacking in the Mediterranean. Consequently, the real impact could be much greater, especially considering the pressure of the fishing fleet in both coastal and pelagic waters.

The Sicilian fishing fleet represents by far the largest regional fleet in Italy, both in terms of the number of vessels and total capacity (Popescu 2010). Based on the available published literature, Table 1 shows the rank of impact of the fishing gear on common bottlenose and striped dolphin populations.

The aim of this paper is to assess whether values, trends, and distributions of cetacean stranding records, in particular those of common bottlenose and striped dolphins, are associated with fleet fishing capacity, port distributions, and population data in Sicily (from 1995 to 2012).

These findings will have important management application, via EU legislation, for the relationship between fishery pressures/threats to cetaceans.

Table 1 Effect of fishing gear (in *bracket* Habitats Directive pressure code) including intentional killings of *Tursiops truncatus* and *Stenella coeruleoalba* in the Mediterranean Sea based on literature, in particular, Di Natale and Notarbartolo di Sciara (1994), Bearzi (2002), Tudela et al. (2005), and Pace et al. (2015). Impact rank: *H* high, *M* medium, *L* low, *N* nil

Gear/species	*Tursiops truncatus*	*Stenella coeruleoalba*
Boat dredges (DRB) (F02.02.05)	N	N
Drift nets (GND) (F02.02.02)	M	H
Set gillnets (GNS) (F02.01.02)	H	L
Handlines and polelines (LHM) (F02.01)	L	L
Set longlines (LLS) (F02.01.03)	L	L
Trolling lines (LTL) (F02.01.04	L	L
Bottom otter trawls (OTB) (F02.02.01)	H	M
Purse seines (PS) (F02.02.04)	L	L (M)

Materials and methods

Time period

The time period considered in this study was from 1995 to 2012. This 18-year time period was chosen for the following reasons: it allowed evaluation of a trend for the three "6-year periods" (1995–2000, 2001–2006, 2007–2012) in order to frame the study within the requirements of Article 17 of the Habitat Directive. In addition, the period was considered suitable for the aim of this study as it considered a time window in which there were no records of "cetacean unusual mortality events" (WGMMUME 2006) such the ones recorded in 1991, due to dolphin morbillivirus (DMV) die off (Bortolotto et al. 1992, Aguilar and Raga 1993, Valsecchi et al. 2004), and in 2013, when DMV and other infectious agents contributed to mortality events (Casalone et al. 2014); these events would in fact increase the number of strandings not directly related to fishery pressure. Moreover, according to Pyenson (2011), cetacean stranding sampling greater than 10 years generally enhanced the completeness of the strandings records (death assemblage).

Fleet capacity records

Data of fishing capacities were all gathered from the Fleet Register which is the EU Community Register within which all the fishing vessels flying the flag of a member state have to be registered in accordance with community legislation and are based on the various national registers (for Italy ALP Archivio Licenze Pesca).

In Sicily, there are 48 ports, all spread along the coastline, to which fishing vessels have to register in accordance with Article 15 of Council Regulation 2371/2002 (*See* Fig. 9 in "Results").

Fishing capacity (quantified using parameters such as the number of vessels, engine power, and gross tonnage) is a useful indicator with robust information particularly because: it is comparable both in time and space, the data source is reliable, temporal series are complete, and data are validated by the State Fishery Authority (for Italy MiPAAF). Moreover, it is simple and easy to interpret, it is strictly connected to anthropogenic activities, it has good geographical coverage, and the data (including updates) is easy to access. Data on fishing effort, such as days at sea, were not available for the whole time period, or were too aggregated to return spatial information and consequently could not be used for the aim of this study. For similar reasons, fishing mortality was considered to not be a pertinent indicator for the aim of our study, also considering that this indicator was developed mainly to assess fish stock exploitation. In addition, according to Piroddi et al. (2015), in the Mediterranean country statistical reports of catch and effort are often unreliable and actual catches are often underestimated.

From the Register, it was also possible to gather separated information for each vessel of fishing capacity per LOA (length over board) and also capacity for each type of main fishing gear.

The Sicilian fishing fleet currently (2012) comprises 2979 registered vessels and represents by far the largest regional fleet in Italy, both in terms of the number of vessels (23.4% of the national fleet) and the total capacity (30.7% of the gross tonnage and 24% of the engine power of the national fleet).

Seeing the nearly perfect positive association between the fishing capacity parameters in the investigated time space (Fig. 1), engine power (measured in kW) was the only parameter used in this study as an indicator of fishing capacity, as it was better correlated with the other two parameters (number (*N*) of vessels measured in units and gross tonnage measured in tonnes—t) according to the Pearson correlation coefficient ("*r*" values were 0.98 and 0.96, respectively).

The fishing gear most commonly used by the Sicilian fishing fleet, with regard to vessel engine power, was bottom otter trawls (55%), followed by purse seines (24%), and set longlines (17.5%). All the others, including drift nets and set gillnets, account for less than 5% (Fig. 2).

Cetacean records

Both cetacean stranding and wild population at-sea data were output from the webGIS of the Osservatorio sulla Biodiversità della Regione Sicilia (ORBS) biodiversity observatory, the Sicily Region focal point of the Italian National Network for Biodiversity.

Data of cetacean strandings were input into the ORBS webGIS mostly from the "Monitoring on Cetacean Stranding on the Italian Coast" database, a project of the CIBRA (Interdisciplinary Center for Bioacoustics and Environmental Research) of Pavia University (Pavan et al. 2013) funded, among others, by the Italian Environmental Ministry; the database also incorporates historical information acquired from the Centro Studi Cetacei stranding network. Input data were also gathered from the "Geocetus database" (a GIS for the collection of data on stranding along the Italian coastline) and from direct reports to the ISPRA Institute, the technical and scientific headquarters in Palermo, of the local offices of the Italian Coast Guard.

All the available information on records of cetacean populations at sea, for the Sicilian Region, was gathered from published literature or online databases such as the OBIS-SEAMAP, to which several research bodies contribute.

Stranding records

The species considered for this study are *T. truncatus* (*T.t.*, a species with a coastal distribution in inshore waters on the continental shelf) and *S. coeruleoalba* (*S.c.*, a species with a pelagic distribution in offshore waters beyond the continental shelf). Both species suffer incidental mortality from fisheries, according to both the Habitat Directive Reporting Article 17 for Italy (code F02 high-importance ranking Genovesi et al. 2014) and the IUCN Red List Assessment for the Mediterranean Sub-population Region (code A2d, Bearzi et al. 2012; Aguilar and Gaspari 2012). The two species were selected, because they are common in the region, have different distribution ranges, both suffer from fishing pressures, and have many stranding records ($N = 46$ and $N = 128$, respectively) for the considered period to allow statistical analysis.

In the investigated region, mass stranding events have never been reported, and most of the animals were individual specimens, already found dead on the shore.

Post mortem examination, which provides valuable information for the management, and mitigation of human impacts (Moore et al. 2013), was, however, not taken into consideration as the main aim of the study was to assess if abundance and distribution of strandings were related to the fishing

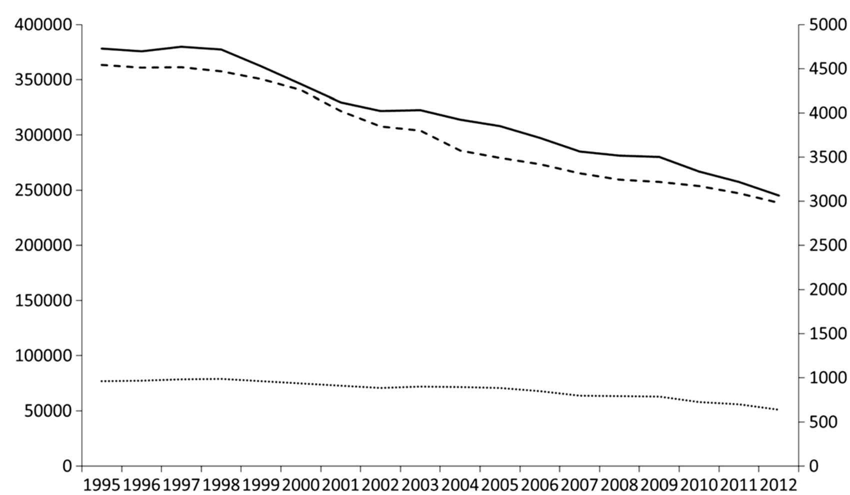

Fig. 1 Annual trends in fishing capacity parameters such as engine power measured in kW (*solid line*), gross tonnage measured in t (*dotted line*), both refer to the *left vertical axis*, and numbers of vessels measured in units (*dashed line*), refer to the *right vertical axis*

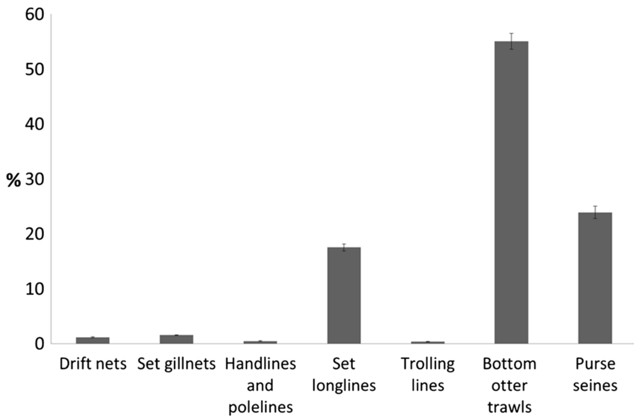

Fig. 2 Percentage of main fishing gear for all ports in Sicily, yearly mean, fleet capacity quantified in kW for the period 1995–2012

capacity; in addition, especially in the early time period, the cause of mortality had been only assessed for only a few animals.

Population at-sea data

In order to assess the capability of stranding data to be able to give appropriate information on population density at sea, both stranding numbers and the abundance at sea should be properly computed. In Sicily, due to the efficiency of the strandings network since the 1980s (Borri et al. 1997), it is likely that most of the stranded animals were recorded, also due to the fact that the coastline morphology, the enduring of the carcass, and the yearly presence of people on the coast would favor "citizen" reports; on the other hand, yearly data on abundance and distribution are strongly biased by the research effort undertaken. Regardless of the effort at sea, however, it can be assumed that the yearly ratio between sightings of *T.t.* and *S.c.* would not be influenced by the effort as long as research was undertaken both in inshore and offshore waters.

From the ORBS webGIS, we obtained the number of *T.t.* and *S.c.* sightings (the number of specimens were not always available) in the investigated period (Table 3); we then multiplied the number of sightings by the mean group size of the species. Mean group size was obtained from a recent published study undertaken in the region (Santoro et al. 2015).

According to Pyenson (2011), cetacean strandings can reflect the relative abundance of living communities for coastlines of great extent. The great extent of the Sicilian coast line would act as a "skim" for cetacean dead bodies floating not too far from the coast.

The region

The location of Sicily, surrounded by the southern Tyrrhenian Sea, the Sicily channel/Tunisian plateau, and the Ionian Sea, places the island in the middle of the Mediterranean Sea, with a length of coastline of about 1500 km. The Sicilian waters are divided into three FAO-GFCM geographical sub-areas (GSAs), respectively: 10 "northern Sicily" (coastline without islands, approx. 460 km, with islands 620 km); 16 "southern Sicily" (coastline without islands, approx. 460 km, with islands 690 km); and 19 "eastern Sicily" (coastline without islands, approx. 200 km, with islands 250 km). The sub-areas represent three different areas, homogeneous within them for oceanographic, biological and fishing parameters exposed to similar currents (Béranger et al. 2004) and winds (Pierini and Simioli 1998), which originate a circulation surface pattern with prevalent more or less steady path along the coastline from west for GSAs 10 and 16 and for south for GSA 19 (Lermusiaux and Robinson 2001, Ismail et al. 2012).

Trend and association analyses

Trends of fisheries capacities and of strandings were compared: chronologically, for the entire 18-year period and for the three 6-year periods; and spatially, for all of Sicily and for the three GSAs separately.

Measures of the strength of the association between yearly fishery capacity and strandings for all 18 years for all the regions were undertaken using a Pearson correlation analysis r. The correlation tested the strength of the association between strandings and yearly values of the total fishery capacity, capacity per fishing gear, and capacity per fleet with LOA smaller or bigger than 12 m (the latter with the intention to separate, supposedly, inshore from offshore fishing boats).

In order to assess the strong impact on *T.t.* by trawl and set gillnet fisheries (*See* Table 1), the number and distribution of *T.t.* strandings were compared for each GSA and for the whole study time period with capacity values for the above fishing gears and their percentage value with respect to total fishing gear per GSA.

The ratio between *T.t.* and *S.c.* specimens estimated from sightings was compared with the ratio between *T.t.* and *S.c.* recorded from strandings using a 2 × 2 contingency table. The Fisher's exact test (two-tailed P values), which calculates the probability of getting the observed numbers under the null hypothesis that the ratios are the same, was used.

Spatial analysis

In order to assess whether strandings showed a random or clustered pattern, both the nearest neighbor analysis, based on the average distance from each stranding to its nearest neighbor, and the Moran's I index, which measures spatial autocorrelation based on feature locations, were calculated.

Following this pattern of analysis, to display the existence of spatial patterns for strandings, the kernel density estimation (KDE) and the Gi* hotspot analysis were completed. KDE provides a way to distribute individual counts over the study area to better visually understand the distribution, while the

Gi* hotspot analysis provides a way to identify statistically significant clustering for events with a count field (Hall 2014).

For the KDE, the percent volume contour, which represents the boundary of the area that contains a percentage of the volume of a probable density distribution, was set at 50%. KDE was overlapped with position and total fishing capacity (in kW) of the 48 ports for the whole period in order to visually assess spatial relationships among the two distributions.

Hot spot analysis uses vectors to identify the locations of statistically significant hot spots and cold spots in data. Through the Getis-Ord Gi* statistic, it is possible to return both *Z* score and *P* value in order to identify areas where the numbers of strandings were above average. A high *Z* score and a small *P* value for a feature indicate a significant hot spot. In this study, we set the *Z* score for the hotspot above 1.65.

The fishing capacity of ports located within proximity of the stranding hotspots was compared with the fishing capacity of all the other ports with above median values of the total engine power (Lampedusa was excluded due to the relatively small coastal extension and consequently limited stranding capacity of the coast). Comparisons were made on the relationship between total engine powers of the total fleet and were limited to fishing gear with medium/high impacts such as GND, GNS, and OTB (*See* Table 1).

Spatial analysis was performed using ArcGIS 10.1 using the spatial analysis tools.

Results

In the investigated period, a total of 213 cetacean strandings occurred for the eight species: more than 80% of the strandings involved *T.t.* and *S.c.* (Table 2).

Trend and association analyses

During the 18 years of investigation, the fishing capacity of the Sicilian fleet decreased (with similar trends for all the fishing gear except drift nets GND), and the relationship between the yearly values of total fishing capacity and strandings of *T.t.* and *S.c.* for all Regions showed similar trends (Fig. 3).

Trends were also similar when data were compared for the three 6-year periods for all of Sicily (Fig. 4).

Both the fishing capacity (Fig. 5) and strandings of the two cetacean species (Figs. 6 and 7) showed a decreasing trend when split into the three GSAs and into the three 6-year periods.

Results from the Pearson's correlation analysis *r* are shown in Table 3.

Overall, results highlight a strong positive association between strandings of both species and the total yearly values of fishing capacity. For *S.c.*, there was a strong positive strength of association for all the different types of fishing gears except for drift nets (weak negative) and set gillnets (moderate positive). For *T.t.*, the strength of association was moderate and strongly positive except for drift nets (null) and set gillnets (weakly positive). In particular, however, considering data only from 2002, trends between drift nets and strandings are similar, and the strength of association is moderately positive.

For both species, a strong positive strength of association was also assessed with vessels with LOA <12 mt (*T.t.* = 0.75, *S.c.* = 0.76); for vessels with LOA >12 mt, instead, it was assessed as a moderately positive strength of association with *T.t.* (0.64) and a strong positive with *S.c.* (0.73).

P values for all of the two tested variables between pressure capacity and species stranding was always <0.001, rejecting the idea that the correlation was due to random sampling.

While strandings of *S.c.* were distributed in all three GSAs (with a minimum of 20 in GSA 16), most of the strandings

Table 2 Total and percentage of strandings for the eight species of cetacean residents in the Mediterranean Sea. Number of sightings of populations at sea (data gathered from the ORBS webGIS), and the mean group size from Santoro et al. (2015)

		% stranded	No. of sightings of population at sea	Mean group size population at sea
Tursiops truncatus	Common bottlenose dolphin	21.6	82	7.8
Stenella coeruleoalba	Striped dolphin	60.1	94	17.5
Balaenoptera physalus	Fin whale	1.4		
Physeter macrocephalus	Sperm whale	4.2		
Delphinus delphis	Common dolphin	6.1		
Grampus griseus	Risso's dolphin	1.4		
Globicephala melas	Long-finned pilot whale	0.9		
Ziphius cavirostris	Cuvier's beaked whale	4.2		
Total *N*		213		

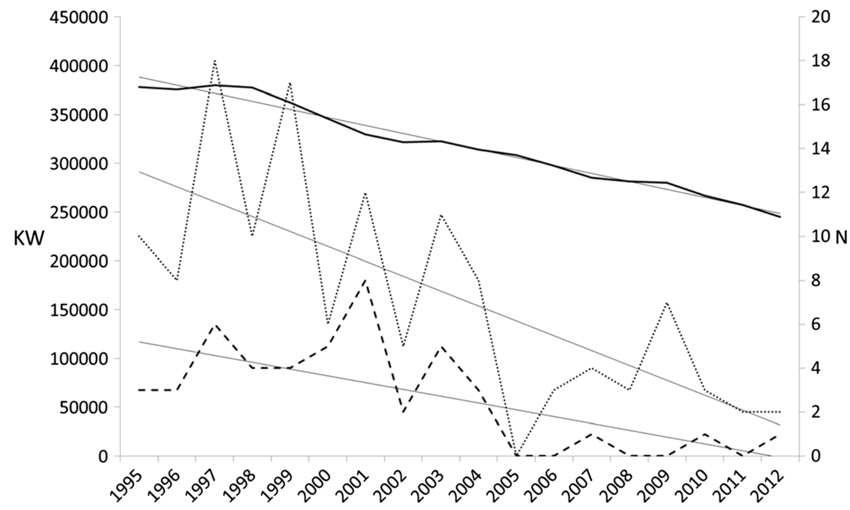

Fig. 3 Yearly values and trend lines of fishing capacity quantified as engine power and measured in kW (*solid line*) refer to the *left vertical axis*; *Tursiops truncatus* (*dashed line*) and *Stenella coeruleoalba* (*dotted line*) number of strandings refers to the *right vertical axis*

(over 85%) of *T.t.* were concentrated in GSA 16 southern Sicily (Fig. 7). The fishing capacity of set gillnets was equivalent in the three GSAs, with relative low values for fishing capacity (mean 29,500 kW, Fig. 2), while the fishing capacity of bottom otter trawls was much higher within GSA 16 accounting for 82% (=2,583,075 kW) of the entire Sicilian fleet. Percentage values of the ratio between set gillnets + bottom otter trawls / total fishing gear showed values of 80% for GSA 16, 34% for GSA 10, and 15% for GSA 19.

Fisher's exact test yield was $P = 0.73$, showing that the ratio between *T.t.* and *S.c.* specimens of populations sighted at sea and the ratio between *T.t.* and *S.c.* recorded from strandings were similar.

Pattern analysis

The nearest neighbor analysis, given the Z score of −18.51 and a P value <0.0001 and a ratio of the observed distance divided by the expected distance of 0.262, suggests that there is a less than 1% likelihood that the clustered pattern could be the result of random chance.

Similarly, the Moran's index, given the Z score of 2.44 a P value < 0.012 and a value of 0.073, suggests that there is less than 5% likelihood that the clustered pattern could be the result of random chance.

The KDE (Fig. 8) visually suggests the stranding probable density distribution by highlighting high-density areas in close proximity to ports with high-fishing capacities; 50% of the strandings, in fact, are located in four areas: Mazara del Vallo, between Mazara del Vallo and Sciacca, between Palermo and Termini Imerese, and Cefalù.

The Gi* hotspot analysis located statistically significant hotspots (Fig. 9), where strandings were above average (with a Z score over 1.65). Hotspots were located nearby the ports of Mazara del Vallo, Palermo, Porto Empedocle, Catania, and Porticello.

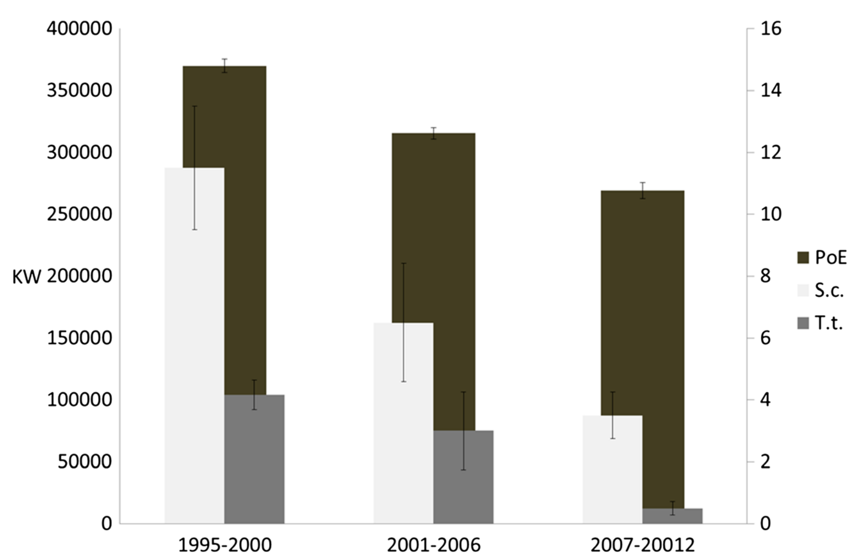

Fig. 4 Values, aggregated for the 6-year periods, of fishing capacity quantified in engine power engine (*PoE*) and measured in kW (refer to *left vertical axes*); and the number of strandings for *Stenella coeruleoalba* (*S.c.*) and *Tursiops truncatus* (*T.t.*) (refer to *right vertical axes*)

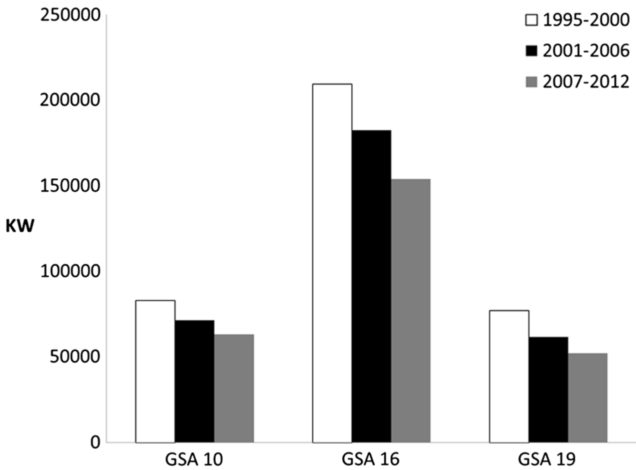

Fig. 5 Values of fishing capacity quantified in engine power and measured in kW, aggregated for the 6-year periods and for the three FAO geographical sub-areas (*GSAs*) occurring in Sicily

The five strandings hotspots (Fig. 9) were located nearby five ports which have above mean fishing capacity values (*N* = 14 ports of the 48 considered). When values of fishing capacity of these five ports were compared with values of the other ports with above median values of fishing capacity (*N* = 19), results showed that the percentage of medium-/high-impact gear (GND, GNS, OTB) on total fishing gear was more than 80% for the five ports; while for the ports above the median, it was only 46%. Mean values of total gear were, for the five ports, three times bigger than the ports that had above the median values of fishing capacity.

Discussion

Article 17 of the Habitats Directive requires, for the assessment of the conservation status of species in need of strict protection, not only population data but also the trends of related pressures and threats (Evans and Arvela 2011). At present, however, the conservation status of cetacean species regularly present in Italy is stated for the period 2007–2012 as "unknown" (Genovesi et al. 2014). Failing to assess the conservation status of cetacean species can lead to reductions in both measures to restore the species to "favorable conservation status" and also programs attempting to mitigate pressures and threats.

Several studies, other than the ones already mentioned in the "Introduction," showed a relationship between fishing pressure and strandings: in south-west Sicily, from 1999 to 2008, most of the *T. truncatus* strandings were linked to interactions with fisheries (Bellante et al. 2008); in the nearby region of Puglia in Italy, more than 15% of small stranded cetaceans had injuries resulting from nets and longlines (Troncone et al. 1990). In Cornwall in 1992, a great increase of strandings of small cetaceans such as *Delphinus delphis* were found with the presence of net marks, and this was associated with the occurrence of a great stock of mackerel in the region; according to Simmonds (1997), overlap between the fishery fleets and dolphin distributions would have presumably increased by-catch. Similarly, on the French coast, an increase of strandings from 1989 to 1991 was associated with interactions with fisheries as there were signs of net marks on the bodies (Duguy and Wisdorf 1988). Still in Cornwall, Leeney et al. (2008) assessed that by-catch was contributing to the overall number of strandings; following veterinary necropsy, 61% of strandings between 1990 and 2006 were determined to have died due to by-catch in fishing gear.

The main intent of this study was to assess the relationship between indicators of fishery pressure, such as the engine power of the registered fleet and stranding records, in order to frame the study within of the EU Habitats Directive.

In the Sicilian Region, the values of stranded cetaceans, in particular *T. truncatus* and *S. coeruleoalba*, and fleet capacity,

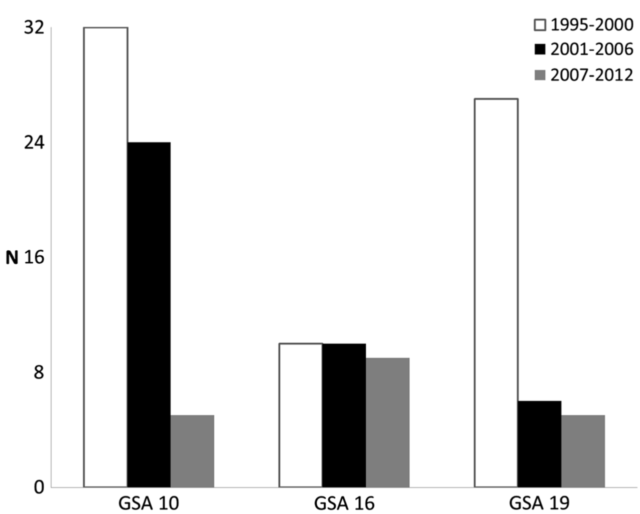

Fig. 6 Numbers of *Stenella coeruleoalba* strandings aggregated for the 6-year periods and for the three FAO geographical sub-areas (*GSAs*) occurring in Sicily

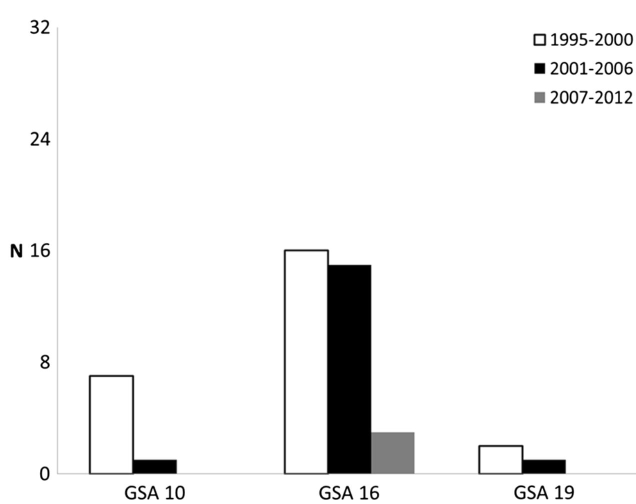

Fig. 7 Numbers of *Tursiops truncatus* strandings aggregated for the 6-year periods and for the three FAO geographical sub-areas (*GSAs*) occurring in Sicily

Table 3 Pearson's correlation coefficient *r* table between the two cetacean species and total fishing capacity, fishing capacity per fishing gear, and per LOA. *P* was always <0.001 between the two tested variables

	Total	Drift nets	Set gillnets	Handlines and polelines	Set longlines	Trolling lines	Bottom otter trawls	Purse seines	<12 mt	>12 mt
T. truncatus	0.70	−0.03	0.39	0.72	0.64	0.70	0.67	0.68	0.75	0.65
S. coeruleoalba	0.74	−0.29	0.57	0.72	0.73	0.71	0.73	0.74	0.76	0.73

a pertinent indicator of fishery pressure, revealed a similar downward trend both for data aggregated together for the whole region or when uncombined for the three Sicilian FAO-GFCM GSAs, or for the three 6-year periods. Bottom otter trawls, purse seines, and set longlines are the most commonly used fishing gear, with more than 95% of the engine power capacity and was positively correlated with the strandings.

Unexpectedly, both trends and the relationship between strandings and drift nets were unrelated, notwithstanding the fact that drift nets have always been considered to be a major concern for cetacean by-catch (Tudela et al. 2005; Cornax et al. 2006; EJF 2007). Following the specific United Nations General Assembly resolutions (UNGA 1991), which called for a moratorium on large-scale pelagic drift net fishing on the high seas, in fact, there was a reduction in mortality due to drift nets (Reeves et al. 2013). The reason could be due to the fact that the annual trend, from 1995 to 2012, of the fishing capacity of vessels using drift nets as the main fishing gear (which has an inverted V shape with the peak in 2002—the year when a total ban on drift nets when intended for the capture of highly migratory species came into force and control increased) may have been affected by incorrect declarations for the Register. However, since 1992, while the stowing on board or use of drift nets whose individual or total size was more than 2.5 km was prohibited in EU waters by Council Regulation 345/1992, illegal drift net activity, mainly targeting swordfish (*Xiphias gladius*), was still undergone by the fleets of Spain, Italy, and Morocco causing high-by-catch mortalities (Silvani et al. 1999; Tudela et al. 2005, Cornax et al. 2006). Due to the importance of the swordfish and tuna fishery industry, fishing vessels would have not declared the retention of these drift nets on board. As a matter of fact, the Court of Justice of the European Union, following EU inspections undertaken from 1992 to 2003, which showed several established infringements, declared that Italy (Case 249/08 2009) failed to control, inspect, and survey in a satisfactory manner fishing activities within its territory regarding the retention and use of drift nets on board (Caddell 2010). However, during the summer fishing season of 2003, a ministerial decree 27/03/2003 allowed the use of set nets for all fishermen that previously used drift nets (called locally spadara and/or ferrettara) and also allowing the possibility to catch the species included in the annex of the Council

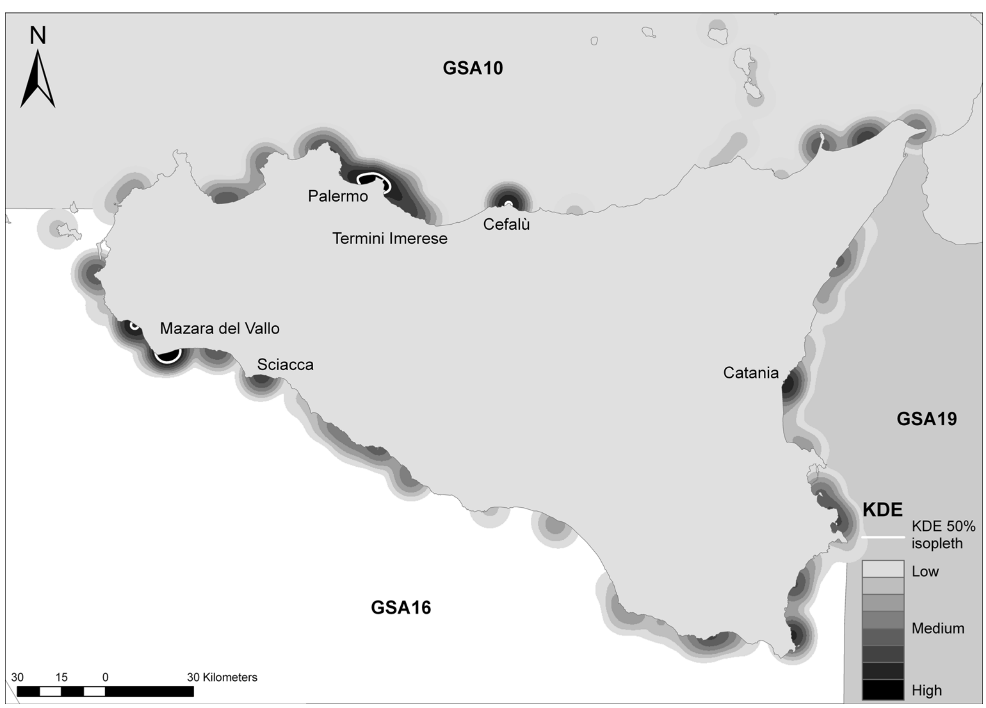

Fig. 8 Kernel density estimation showing where 50% of the strandings occurred. *Circle size* refers to the 50% isopleth

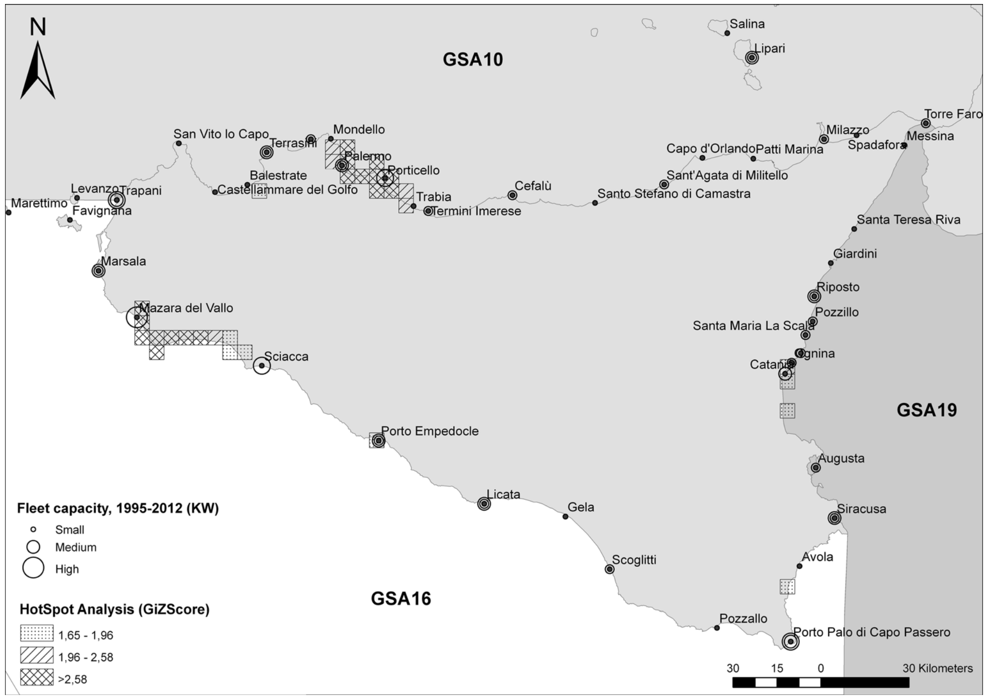

Fig. 9 Hotspot analysis showing areas where the number of strandings is above average (*Z* score). *Circle size* refers to kW relative value for the fishing capacity of the 48 ports in Sicily

Regulation 1239/98 with these nets. The application of this decree was a way to circumvent the drift net ban via set net use. In our study, when we considered drift net and stranding data, from 2002, trends were similar with a positive correlation. In Italy, one of the major causes of illegal/unreported catches (IUUF) is the continuous use of prohibited drift nets by the Sicily Region fleet, which contributed for 31% of the estimated unreported catches from the illegal drift net fishing fleet, during the 1992–2010 period (Piroddi et al. 2015).

Results of the relationship between strandings and the length of the vessels' LOA (intending that vessel with LOA <12 mt would presumably fish more in coastal waters) showed that while striped dolphins showed a strong positive correlation with both lengths, common bottlenose dolphins showed a strong positive correlation with vessels smaller than 12 m.

The different relationships could be easily explained for common bottlenose dolphins which have a, more or less, strictly coastal distribution, and by the fact that the pelagic striped dolphin can come close to shore (Bearzi et al. 2011), reaching the near shore waters, especially where areas of deep water are found close to the coast for foraging (Gannier and David 1997; Gannier 1999).

In our study, the spatial analysis highlighted both that strandings are clustered nearby ports with big fishing capacities and the fact that most of the common bottlenose dolphin strandings occurred in GSA 16 southern Sicily. Deep analysis showed how patterns of strandings were also related to the fishing gear. In particular, otter bottom trawlers registered in ports nearby the high-density strandings areas have both total and relative values of OTB (bottom otter trawls) much greater than the average. Similarly, for GSA 16 where OTB accounts for more than 80% of the Sicilian fleet, this type of fishing gear could be responsible for the by-catch of common bottlenose dolphins. In particular, for common bottlenose dolphins, in fact, OTB has a strong impact as animals are entangled in the nets and sometimes are intentionally killed; the species, in fact, is blamed by the fishermen both for stealing fish and damaging nets.

Our study also showed that values of strandings could give information of cetacean population density at sea, and this was supported by the finding that the ratio between common bottlenose dolphins and striped dolphins for the stranded records and for the estimated number of individuals sighted at sea was similar. At present, the ecological relevance of stranding data is uncertain mostly because the geographical origin of a sample is not accessible and their statistical strength is disputed as sampling is mostly opportunistic in nature. It is commonly admitted that stranded animals represent a minimum measure of at-sea mortality (Epperly et al. 1996). Thus, stranding data are often considered as non-representative of populations or communities at sea, mostly due to the lack of sampling strategies (Epperly et al. 1996; Siebert et al. 2006).

On the other hand, several studies showed a relationship between stranding data and the population at sea; worldwide, Pyenson (2011) revealed a strong and significant correlation between the relative abundance of living and dead (stranded) animals. Peltier et al. (2012) mapped tagged cetacean carcasses (by-caught in fisheries) and showed an association between stranded sites and the location of release, confirming how stranding numbers represent only a small fraction of cetaceans dead at sea.

Similarly, according to Leeney et al. (2008) in Cornwall, the higher number of harbor porpoise strandings on the southern coasts, compared to the northern coast, was related to higher densities of cetaceans in the southern areas compared to the northern ones. As a matter of fact, both the International Whaling Commission Scientific Committee (IWC 2010) and various agreements under the Convention for Migratory Species (ACCOBAMS Resolution 4.16) encourage the scientific use of stranding data, due to their increasing availability in many countries.

Generally, both fishing activities and cetacean population densities have a direct effect on the number of strandings, especially in the presence of an appropriate stranding network.

Castège et al. (2013), for example, showed that among temporal patterns of cetacean density at sea, stranded individuals and fishing activities impacting sea mammals are similar; the number of stranded cetaceans, however, was significantly correlated to at-sea encounter rates more than to fisheries.

Overall, this study showed a strong correlation, without implying direct causation, between fishing capacity and cetacean strandings, likely sustaining the idea that fishing pressure, and in particular OTB, is one of the main pressures/threats for cetaceans even if it needs to be taken into, particularly in GSA 16, the fact that part of the registered fleet (*i.e.* Mazara del Vallo) undertakes fishing activities well offshore.

Relationships were assessed both in time (when aggregated in the 18 years or split into the three 6-year periods) and in space (when aggregated for all of Sicily or split into the three GSAs). In addition, limited to the ratio striped dolphin/common bottlenose dolphin, our study found a strong relationship between estimated cetacean populations at sea and strandings. In the future, this type of investigation needs to be expanded over a larger area, for example the Marine Strategies marine sub-areas (Article 4 Directive 2008/56/EC), in order to also include other important fishery fleets, for instance the ones registered in the nearby region of Calabria in Italy (*e.g.*, Bagnara port).

These findings are of great importance for evaluating both pressures/threats and for population estimates under the requirements of the Habitats Directive.

Indeed, for the next Article 17 report on the "conservation status" of the species (for the 6-year period from 2013 to 2018), it is important to consider the possibility of using data from fishery capacities as a pertinent indicator of fishing pressure/threat, and data from the stranding network to fulfill both the requirements of assessing the magnitude of incidental killings and for complementing population estimate gathered from shipping surveys. Both the fishing capacity and the stranding data can easily be aggregated into the 6-year periods required by the Habitats Directive process trends (also in the long term) and can be more easily reported (for reporting under Article 17), and thus provide important, and valid, information on cetacean conservation status despite there being data gaps.

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