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ORIGINAL PAPER

Spatio-temporal analysis of cetacean strandings and bycatch in a UK fisheries hotspot

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Abstract Marine vertebrate strandings data can provide insights into the long-term dynamics of cetacean populations, and the threats they face. We investigate whether the spatio-temporal patterns of cetacean strandings around Cornwall, SW Britain, have changed in the past century. Analysis of strandings from 1911 to 2006 ($n = 2{,}257$) show that, since the mid-1970s, the relative frequency of strandings of common dolphins (*Delphinus delphis*), harbour porpoises (*Phocoena phocoena*) and pilot whales (*Globicephala melas*) has increased significantly. Seasonal peaks in strandings frequencies are apparent, between December and March for harbour porpoises and common dolphins, and between November and January for pilot whales. There were significant positive trends in the number of common dolphin and harbour porpoise strandings, as a proportion of total strandings, over time. Strandings of common dolphins, porpoises and all other species occur more frequently on the south coast of Cornwall. A total of 415 cetaceans were subject to full veterinary necropsy to determine cause of death, between 1990 and 2006, and 253 (61%) of these individuals were determined to have died due to bycatch in fishing gear. Analyses of industrialised fishing pressure in UK waters show the seas around Cornwall to be one of the

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most heavily fished areas of the UK. We suggest a number of factors that could be responsible for the recent increases in cetacean strandings in southwest UK waters in recent years, including survey effort, as well as abundance and range shifts that are potentially linked with climate change. Although detectable levels of bycatch rate have not increased over time, fisheries interactions are in significant part responsible for mortality patterns and are worthy of more detailed investigation.

Keywords Cetacean communities · Climate change · Conservation · Dolphin · Porpoise · Whale

Introduction

Fisheries bycatch of non-target marine vertebrates is of global concern, impacting a wide range of taxa (Silvani et al. 1999; Norman 2000; Hays et al. 2003; Lewison et al. 2004; Read et al. 2006; Chilvers in press; Zeeberg et al. 2006). Hundreds of thousands of marine mammals are estimated to be captured every year, and this is thought to be having significant effects on the demography of many populations of cetaceans (Read et al. 2006; Karamanlidis et al. in press). Although interactions between cetaceans and fisheries have occurred for centuries, they are occurring with increasing frequency as fishing intensity increases, new areas are fished and methods become more industrialised (DeMaster et al. 2001). Assessing levels of bycatch so that mitigation can be instigated is difficult. Although fisheries observer programmes offer the potential for spatially explicit, effort-corrected and gear-specific estimates of capture and mortality levels (e.g. Tregenza et al. 1997; Morizur et al. 1999; Lewison et al. 2004; Baker and Wise 2005; Carranza et al. 2006), they are logistically difficult and expensive. Strandings data offer potential insights into incidence of bycatch (Shoop and Ruckdeschel 1982; Kuiken et al. 1994b; Kirkwood et al. 1997; Rogan et al. 2001; Kemper et al. 2005).

Patterns of marine vertebrate strandings are subject to a range of influences which can affect the resultant availability of carcasses for post-mortem. Spatially, oceanography and coastal topography have been shown to influence the occurrence of strandings (Brabyn and McLean 1992; Hart et al. 2006). Evans et al. (2005) linked periodical variability in cetacean strandings to large-scale climate events, resulting from long-term and large-scale shifts in sea-pressure gradients. Long-term climate change is thought to affect the composition and structure of ecological communities (Lemoine and Boehning-Gaese 2003; Genner et al. 2004; MacLeod et al. 2005) and as local conditions change, species' ranges may shift and new community compositions may arise. Nonetheless, when appropriately caveated, spatio-temporal patterns across wide scales, which arise from hundreds of validated strandings records collected over many decades, are likely to be instructive and offer insights into mortality patterns (Evans and Hammond 2004; Hart et al. 2006; Kemper et al. 2005; Tomás et al. in press).

Cetaceans may strand alive for a number of putative reasons including behavioural tendencies of particular species to follow a leader (Odell et al. 1980), disorientation caused by geographical anomalies in the earth's magnetic field (Kirschvink et al. 1986) and acoustical 'dead zones', areas of coast where echolocation signals are distorted (Sundaram et al. 2005). Individuals found dead on the coast will have been subject to a range of mortality factors both natural and anthropogenic such as bycatch in fisheries (Kirkwood et al. 1997; Siebert et al. 2006), which can in many cases be revealed by detailed veterinary post-mortem. Recent studies on stranded cetaceans have also highlighted significant associations between elevated levels of environmental contaminants and infectious diseases (Kuiken et al. 1994a; Jepson et al. 1999, 2005; Bennett et al. 2001), and between exposure to sonar and the gas-bubble lesions which result (Jepson et al. 2003).

UK waters are known to support a diversity of cetacean species, consisting of both permanent residents and migratory populations (Reid et al. 2003). Strandings have long been a source of popular and scientific interest and have been well documented (Dudok van Heel 1966; Dailey and Walker 1978), with data in the UK having received greater scrutiny since the country's accession to the ASCOBANS (Agreement on the conservation of Small Cetaceans of the Baltic And North Seas) treaty in 1993, and the establishment of a strandings reporting scheme and a project investigating cause of death of these strandings (Jepson 2005). Additionally, in response to the 1992 Convention on Biological Diversity, the UK launched the Biodiversity Action Plan which included a 'grouped plan for small dolphins' (http://www.ukbap.org.uk/). The aims of this BAP for the six small dolphin species occurring regularly in UK waters included a commitment to research cetacean-fisheries conflicts. Within the UK, the coasts of Cornwall and the Isles of Scilly consistently receive the largest share of UK cetacean strandings (Jepson 2005; Sabin et al. 2003). In this study, we set out to undertake a detailed spatio-temporal analysis of the strandings of cetaceans around the coast of Cornwall and the Isles of Scilly, between 1911 and 2006, elaborating phenology of incidence and longitudinal changes in species composition. We integrated these data with the results of veterinary necropsy reports of cetaceans and data on industrial fishing effort around the region, to offer additional insights into the relative importance of fisheries bycatch as a source of mortality.

Methods

The study area is shown in Fig. 1. Data used comprised records of cetaceans stranded in Cornwall and the Isles of Scilly, collated by the Cornwall Wildlife Trust Marine Strandings Network (MSN) and housed at the Environmental Records Centre for Cornwall and the Isles of Scilly (ERCCIS). Data result from reports from naturalists and members of the public, and have been subject to varying levels of verification. We systematically compared strandings records over a 96-year period between 1911 and 2006. This temporal range was selected as records before 1910 were more infrequent and less detailed. Year-on-year and monthly patterns were investigated for all cetacean data and on a species-by species basis. Number of stranded individuals was used as the sampling unit. Reported species identification was assumed to be correct unless the identification was reported as questionable. Thus all records of 'cetacean', 'baleen whale', 'dolphin' or 'small cetacean' were discarded from single-species analyses. Results of post-mortem investigations of all cetaceans subject to necropsy within the study area ($n = 415$) were available for all years between 1990 and 2006. Selection of carcasses for necropsy was non-random and was based on carcass condition, logistics and the total number of animals already examined in a given month.

Spatial analyses

Initial screening of the database involved cross-checking grid references, where given, against the described location of the stranding. In order to investigate spatial patterns in strandings, a 20 km (linearly spaced in x and y) grid was placed over the coastline of the study area. We investigated the number of strandings of common dolphins (*Delphinus delphis*), harbour porpoises (*Phocoena phocoena*) and all other species collectively, falling within each grid square, corrected for length of coastline within each square (the coastline was resolved to a 100 m interval, and smoothed across the mouths of rivers).

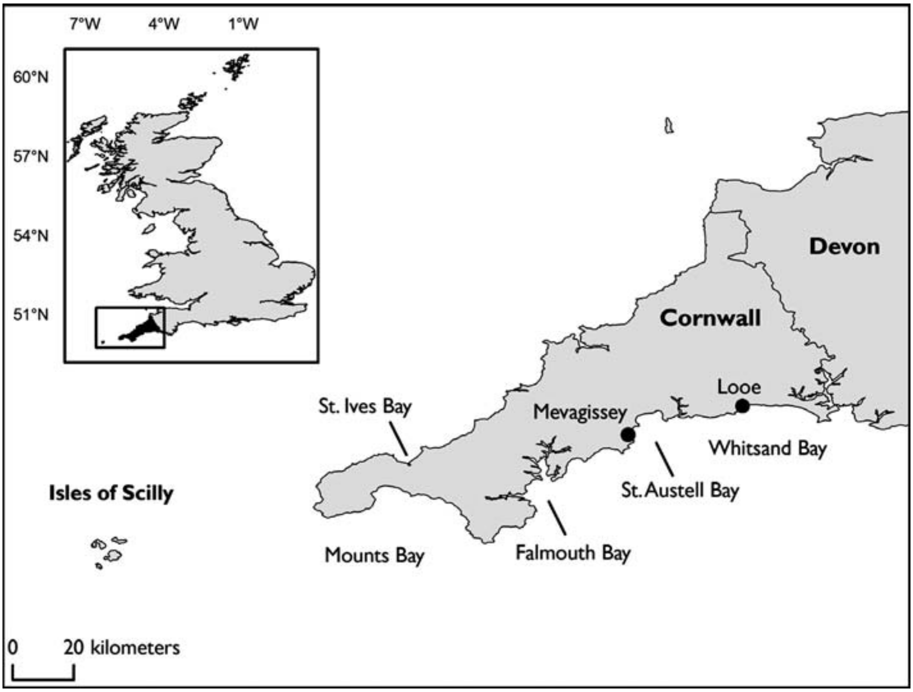

Fig. 1 The study area covering Cornwall, south-west UK, used to investigate changes in the incidence of stranded cetaceans over a 96-year period. This study area included the north and south coasts of the Cornish peninsula, and the Isles of Scilly

In order to assess levels of fishing pressure in the study area relative to those around the rest of the UK, data from the UK Government Vessel Monitoring System (DEFRA) was processed as follows. Two-hourly positions from the raw VMS data were identified for each individual vessel. For any one vessel, these points were then sorted by time, and the start and end positions of each fishing trip made were established. The hourly speed (in knots) of the vessel was calculated for each fishing trip, and the positions where the vessel was travelling at speeds of greater than two knots and less than six knots were selected. A spatial grid was produced with counts of the number of these positions, for all vessels, for the entire dataset (2000–2004). The count at each position on the grid was divided by 5 to get an annual mean. For records from 2000 to 2003, data for all vessels >24 m in length were used, whilst for 2004, data for all vessels >18 m were used. For further details see Witt and Godley (2007).

Results

Long-term patterns

A total of 2,257 stranded cetaceans were recorded between 1911 and 2006. This comprised records for 16 species: 862 common dolphins, 482 harbour porpoises, 125 pilot whales (including one mass stranding of 50 animals in Penzance, 1911); 38 bottlenose dolphins (*Tursiops truncatus*), 36 striped dolphins (*Stenella coeruleoalba*), 31 Risso's dolphins

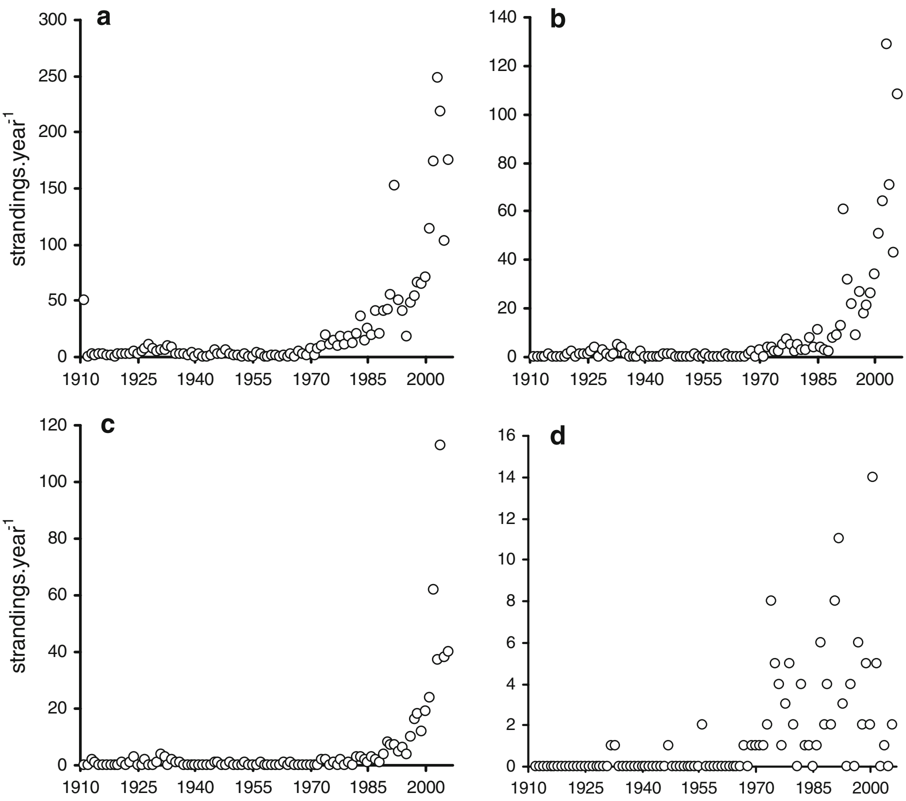

Fig. 2 (**a**) Total number of cetacean strandings of all species (including unspecified 'cetacean', 'dolphin' or 'baleen whale' records) per year in Cornwall, from 1911 to 2006 (No data for years 1912, 1919, 1940, 1942, 1943, 1952, 1954, 1955, 1958, 1959, 1962, 1964, 1966). By species: (**b**) Total number of common dolphin strandings per year, (**c**) harbour porpoises, (**d**) pilot whales (the single mass-stranding event in 1911 of 50 pilot whales has been removed from Fig. 2d in order to better view the overall pattern for the whole time period). Species (**e**)–(**h**) (bottlenose dolphins, striped dolphins, Risso's dolphins and minke whales, respectively) stranded in a minority of years and had annual totals of five strandings or less. For completeness, these data are presented as online Fig. S1. Note differing scales on *y*-axis

(*Grampus griseus*) and 20 minke whales (*Balaenoptera acutorostrata*) (Fig. 2; Fig. S1). In addition to these commonly recorded species, there are records of white-beaked dolphins (*Lagenorhynchus albirostris*; 8 records) and white-sided dolphins (*L. acutus*; 10), fin whales (*Balaenoptera physalus*; 7), sperm whales (*Physeter macrocephalus*; 5), Cuvier's beaked whale (*Ziphius cavirostris*; 4), Sowerby's beaked whale (*Mesoplodon bidens*; 4), killer whales (*Orcinus orca*; 4), sei whales (*Balaenoptera borealis*; 2), and northern bottlenose whales (*Hyperoodon ampullatus*; 1), as well as the unspecified categories 'dolphin species', 'baleen whale', small cetacean', 'small toothed cetacean' and 'cetacean'.

The annual stranding rates for all cetaceans, common dolphins, porpoises and pilot whales are shown in Fig. 2. There has been a dramatic rise in the number of reports of cetacean strandings per year, from the early 1980s onwards. In particular, common dolphin strandings increased from 34 in 2000 to a maximum of 129 in 2003 (Fig. 2b), and harbour porpoise strandings from 19 in 2000 to 113 in 2004 (Fig. 2c). Strandings rates were lower in 2005, in comparison to the previous 4 years. This lower number of strandings was due to reduced numbers of both common dolphins and harbour porpoises (43 and 38, respectively, in 2005). Numbers of unidentified cetaceans varied considerably from year to year but also started to increase from the 1980s onwards.

Seasonal patterns

A distinct seasonality is evident in strandings of all cetaceans, common dolphins, harbour porpoises and pilot whales (Fig. 3a–d), with most strandings occurring between December and March/April. It is worthy of note that this peak does not coincide with the summer period when recreational coastal use is highest and lends support to the exhaustive year-round nature of the recording and recovery effort.

Species composition

Changes in the patterns of occurrence of the two most abundant species, the harbour porpoise and the common dolphin, were investigated between 1973 (the year from which there were 10 or more strandings per year) and 2006. As a preliminary analysis, a generalised linear model (GLM) with logit link and quasibinomial errors was fitted to the data since, a priori, some overdispersion might have been expected in the data. The preliminary quasibinomial GLM found no evidence of overdispersion (dispersion parameters of 1.002

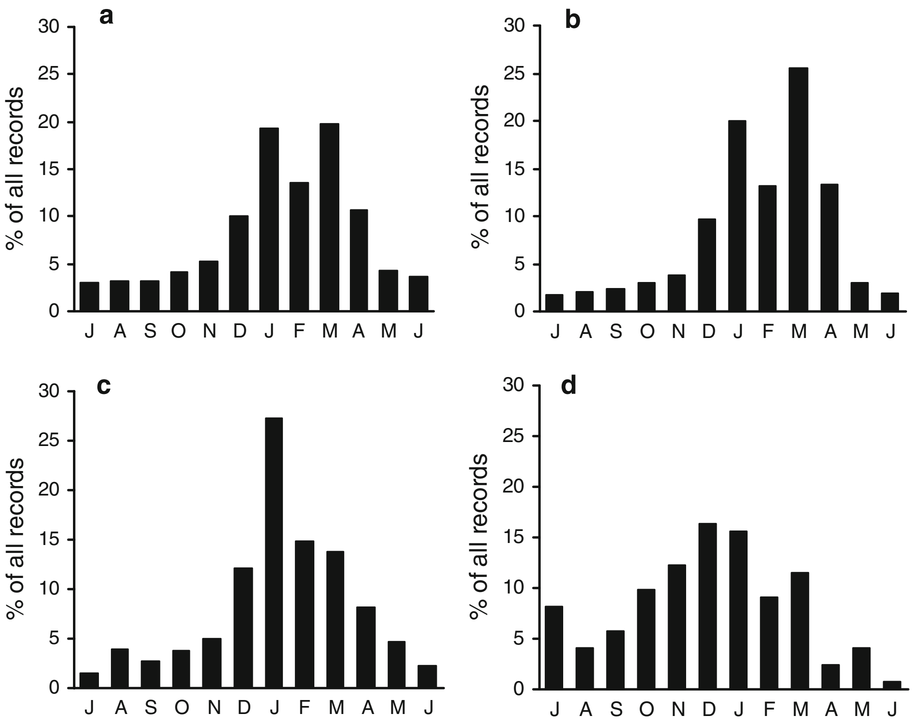

Fig. 3 Proportion of all stranding records, 1911–2006, in each month of the year (starting in July). (**a**) All cetacean species (including unidentified cetaceans; records of 2,257 animals), (**b**) common dolphins ($N = 862$), (**c**) harbour porpoises ($N = 482$), (**d**) pilot whales ($N = 124$, 1911 mass stranding removed from data)

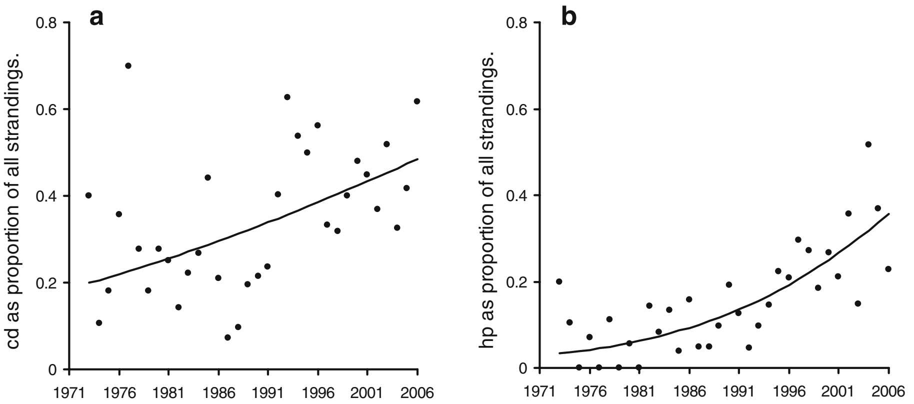

Fig. 4 Single-species strandings as a proportion of total cetacean strandings per year, from 1973 to 2006, for (**a**) common dolphins ($Z = 6.705$, $P = 2.01 \times 10^{-11}$) and (**b**) harbour porpoises ($Z = 9.408$, $P < 2 \times 10^{-16}$). Raw data (points) and fitted values from binomial model (line)

for common dolphins and 1.025 for harbour porpoises), justifying the use of a binomial model. A GLM with logit link and binomial errors was thus used to model any temporal trend in the contributions of common dolphins and harbour porpoises to overall strandings rates, using the programme R (R Development Team). The GLM found significant positive trends in the number of each species as a proportion of total strandings. Figure 4 shows the fitted values from these models, for common dolphins (Fig. 4a) and harbour porpoises (Fig. 4b).

Spatial patterns

When controlling for the length of coastline, more strandings occurred on the south coast than on the north coast of Cornwall (Fig. 5). Harbour porpoise strandings occurred mainly in Mount's Bay and to a lesser extent, around the St. Austell Bay area (Fig. 5a). Common dolphin strandings occurred all along the south coast, with concentrations apparent in Mount's Bay, Falmouth Bay and Looe Bay-Whitsand Bay, and a small concentration in St. Ives Bay on the north coast (Fig. 5b). Strandings of all other species were clearly concentrated along the south coast, primarily in Mount's Bay and Looe Bay-Whitsand Bay (Fig. 5c). The concentration of harbour porpoise and common dolphin strandings, on the south coast of Cornwall during the early part of the year, may be at least in part due to the prevailing south-westerly winds in these months and regional wind-induced surface currents (Witt et al. 2006).

Necropsy data

Of the 415 cetaceans from Cornwall subject to full veterinary necropsy between 1990 and 2006 (24% of all strandings over this period, including 239 common dolphins, 142 harbour porpoises, 21 striped dolphins, 5 pilot whales and 5 bottlenose dolphins), 67% of common dolphins and 61% of harbour porpoises were determined to have died as a result of being bycaught in fisheries. These diagnoses were made based on criteria presented in Kuiken et al. (1994a, 1996). Bycatch was by far the most prevalent cause of death (61% of all necropsies; Table 1). There is a distinct peak in proportion of harbour porpoises and common

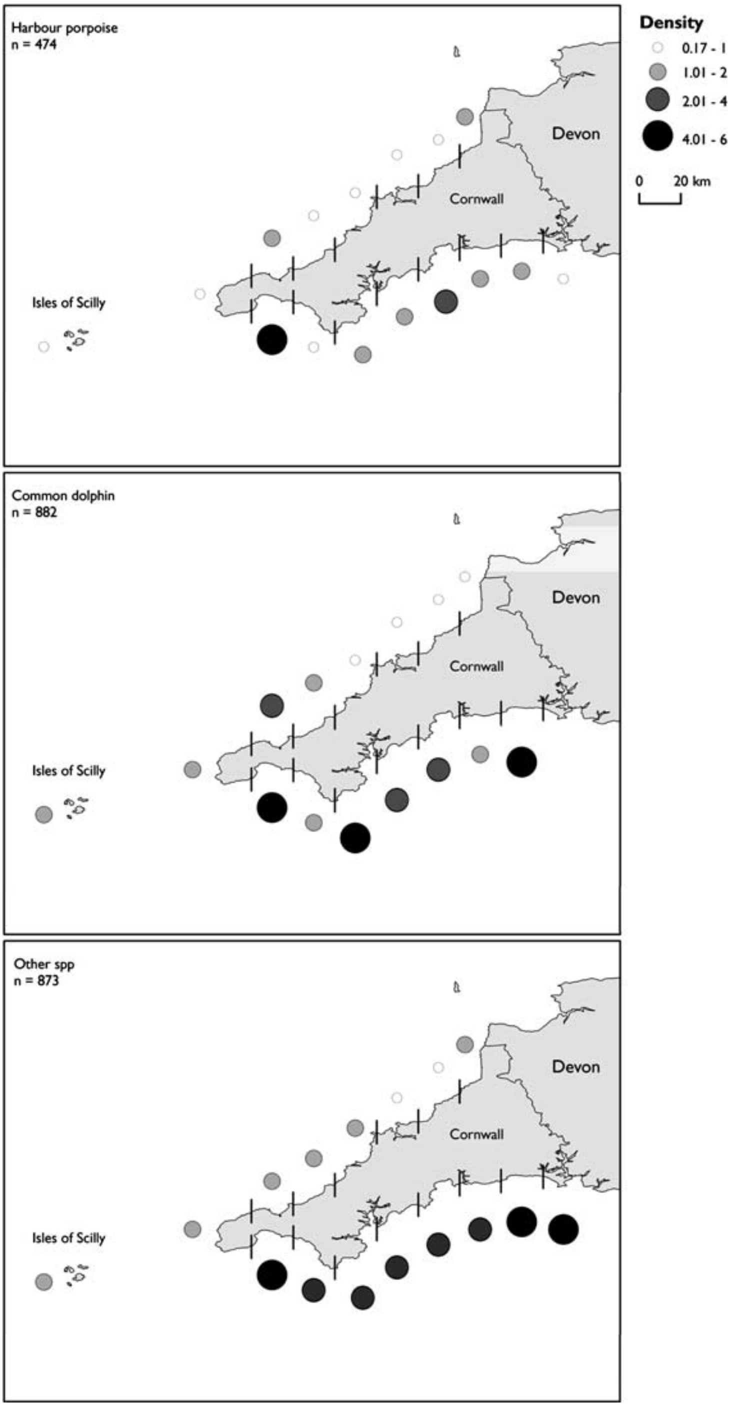

Fig. 5 Maps of density of strandings per kilometre of coastline for (**a**) harbour porpoises, (**b**) common dolphins and (**c**) all other species. All records 1911–2006 (excluding at-sea records, *n* = 29)

Table 1 Causes of death of all cetaceans taken for post-mortem analysis at the Institute of Zoology, London, 1990–2006 ($n = 415$)

Cause of death	Common dolphins		Harbour porpoises		Other		Total
	n	%	*n*	%	*n*	%	
Physical trauma							
Bycatch	159	67	86	61	8	26	253
Bottlenose dolphin attack	0	0	8	6	0	0	8
Other	4	2	6	4	3	9	13
Other pathologies							
Pneumonia	3	1	12	8	1	3	16
Gastropathy and/or enteropathy	4	2	4	3	0	0	8
Starvation	4	2	3	2	2	6	9
Gas embolism	3	1	0	0	0	0	3
Others (e.g. Peritonitus, uterine rupture)	8	3	5	4	2	6	15
Live stranding	4	2	1	1	1	3	6
Not established	50	21	17	12	17	50	84

Percentages are for each species category

dolphins subject to bycatch between December and March, which corresponds with the seasonal peak in total strandings frequencies for these two species (Fig. 6).

As numbers of harbour porpoise and common dolphin strandings have clearly increased since 1990, and especially since 1999, so have numbers of necropsies of these species (Fig. 7). Perhaps surprisingly, there was no clear temporal pattern in the proportion of cause of death of either species attributable to bycatch (Fig. 7) with annual values ranging from 0–84% (mean 56%) in harbour porpoises and 0–91% (mean 61%) in common dolphins. In the majority of years, however, bycatch was by far the most frequently diagnosed cause of death. For common dolphins, cause of death was indeterminable in 20% of carcasses necropsied between 1990 and 2006. For harbour porpoises, this figure was much lower (12%) and the second most common cause of death was pneumonia (parasitic, bacterial or mycotic). In recent years, a number of harbour porpoises stranding in the southwest have been killed by bottlenose dolphins, a phenomenon which previously was recorded only in Wales and Scotland. This was particularly apparent in 2006, when five such cases were documented. The high proportion of necropsied strandings attributable to bycatch is somewhat startling and given that Cornwall is an established hotspot for cetacean stranding in the UK (Sabin et al. 2003), it is of interest to contextualise these findings with fishing

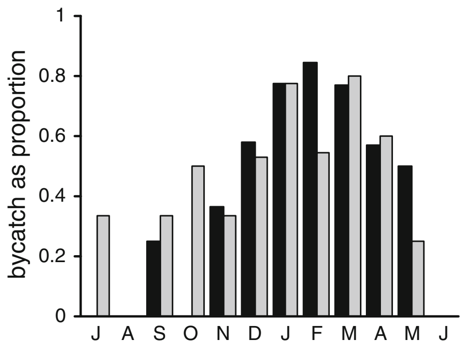

Fig. 6 Proportion of all necropsied common dolphins (black bars; $n = 237$*) and harbour porpoises (grey bars; $n = 142$) for which cause of death was determined to be bycatch, monthly, 1990–2006, for all months in which $n > 1$ (*239 common dolphins necropsied in total, but exact date not available for four records of bycaught individuals)

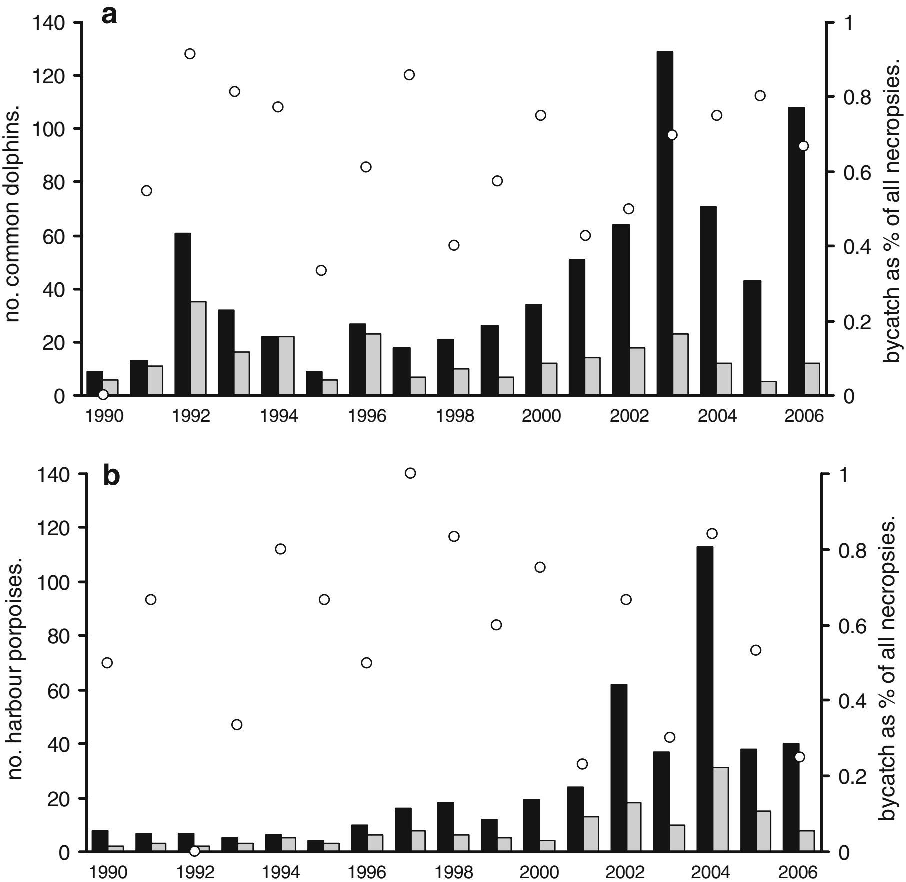

Fig. 7 Number of strandings (black bars), number of necropsies (grey bars) and confirmed cases of bycatch as a proportion of all necropsies (points), 1990–2006. (**a**) Common dolphins, (**b**) harbour porpoises

effort. The recent advent of vessel monitoring systems in commercial, predominantly offshore fisheries offers an insight. When we look at a rastor of UK industrialised fishing effort (2000–2004; Fig. 8) we can see that the waters around the SW Peninsula are indeed one of two major hotspots of fishing effort in UK waters, comparable with that around the Northern Coasts of Scotland and the Northern Isles for intensity.

Discussion

Concern regarding the status of marine vertebrates has resulted in the growth of public data recording schemes for strandings supported by government sponsored investigations into the causes of mortality (e.g. Shoop and Ruckdeschel 1982; Godley et al. 1998; Jepson et al. 1999; Rogan et al. 2001). Our analyses of a long-term dataset, comprising 96 years of public records, have identified strong seasonal and decadal trends that provide significant insight into patterns of strandings of cetaceans in the waters around Cornwall, highlighting

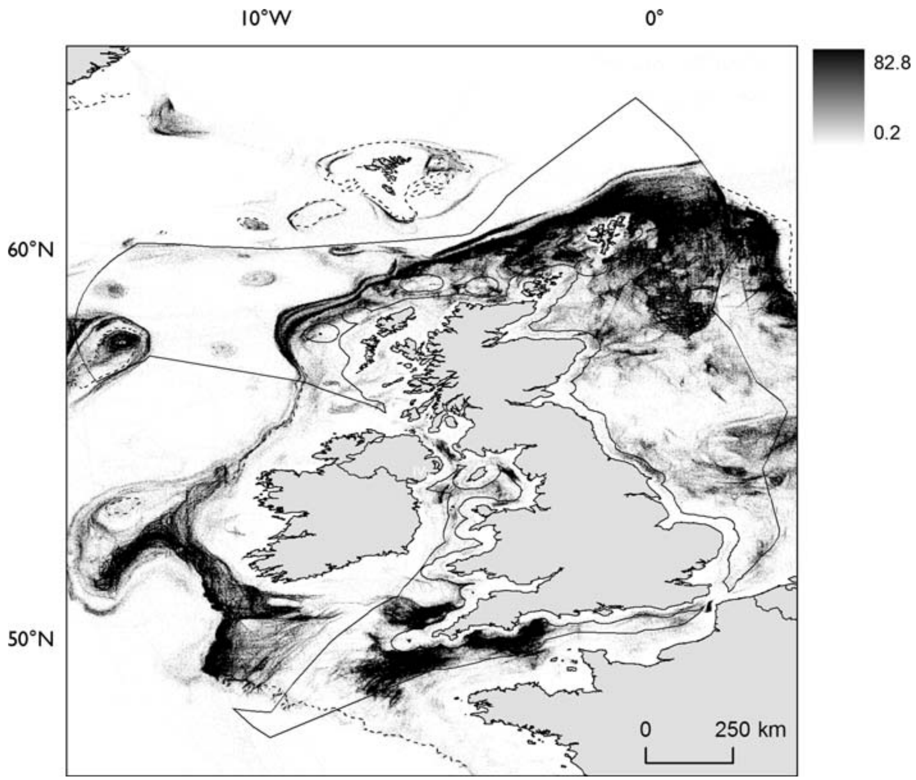

Fig. 8 Mean annual spatial distribution of fisheries activity (2000–2004) derived from VMS records using a simple speed filter (≥2 and ≤6.5 knots). The colour scale indicates the mean annual number of VMS derived data points within 9 km^2 pixels, solid line circumscribes the UK declared fishing zone, broken line is 200 m depth contour

possible changes in cetacean distribution and abundance, as well as significant levels of fisheries bycatch which warrant further investigation.

There has been a dramatic increase in the number of stranding reports since 1970. The increase in the 1970s and 1980s may, to an extent, have been due to an increasing awareness and effort by the public to report strandings, but particularly since 1990, during which time the strandings network has run a cohesive and efficient programme, these data may also indicate an increase in strandings and possibly, an increase in mortality in the region. The increase in strandings rates is attributable to growing numbers of strandings of multiple species; however, the trend is most dramatic for common dolphins and harbour porpoises, the two most regionally abundant species. The common dolphin is found throughout the world's warm-temperate and tropical waters, and is the most numerous offshore cetacean species in the temperate north-east Atlantic and Mediterranean (Reid et al. 2003; Cañadas and Hammond 2008). The harbour porpoise occurs primarily in temperate waters of the North Pacific and North Atlantic, mainly but not exclusively over the continental shelves of these regions (Reid et al. 2003) and is the most abundant marine mammal in the north-western European shelf waters (Hammond et al. 2002; MacLeod 2006). Long-finned pilot whales, the third most frequently stranding species, occur in the temperate and sub-arctic regions of the North Atlantic and are commonly sighted along the continental shelf-edge, southwest of the UK and Ireland, and north of Scotland (Reid et al. 2003). It is worthy of note that the increase in strandings of these species in recent decades cannot be linked to a decrease in the number of individuals not identified to species level, since this number has also risen since the 1980s.

Our data suggest several possible reasons for an increase in strandings rates. Given the presence of an industrialised fishing hotspot around the Southwestern Approaches and the prevailing high level of mortality attributed to bycatch, demonstrated by necropsy data gathered in recent years, it is clear that bycatch and associated mortality is contributing to the overall number of strandings and potentially their resultant spatial patterns. Bycatch in fisheries is considered to be one of the major issues for the management of at least some cetacean species in Europe (Evans and Hammond 2004), such as the harbour porpoise. Since the early 1980s, the relative frequency of stranding has increased for all cetacean species, and in recent years, involves hundreds of common dolphins, harbour porpoises and pilot whales annually, over a relatively short (376 km) length of coastline. This coincides with the emergence of mid-water trawl fisheries in this area, for species such as bass (*Dicentrarchus labrax*) and mackerel (*Scomber scombrus*) (Morizur et al. 1995). Although there is a paucity of observer generated bycatch data in UK fisheries, the one fishery which has received some attention is pair trawling for bass. Northridge et al. (2007) estimated that, between 2005 and 2006, around 460–730 porpoises and 410–610 common dolphins were killed in pelagic trawl and static net fisheries in ICES sub-division VII, which encompasses the Celtic Sea, the English Channel and the Irish Sea. The authors suggest that, in isolation, these levels of bycatch do not present a major conservation threat to porpoise and common dolphin populations which number in the hundreds of thousands in this region. However, bycatch resulting from numerous other European fisheries, particularly those using gill or tangle nets (Tregenza et al. 1997), also impacts these biological populations and thus, the true impact of fisheries interactions is likely greater.

Nonetheless, between 1990 and 2006, our analyses of necropsy reports showed no clear increase in proportion of bycaught animals, despite the overall increase in strandings and in numbers of post-mortems carried out. This suggests that, whilst fisheries are clearly having an impact in the region, this effect, pro rata, is not worsening in comparison with other causes of death. Jepson (2005) suggests that factors such as increased coastal vigilance and a change in distribution and abundance of common dolphins and harbour porpoises have likely contributed significantly to the increase in numbers of strandings of these species in the southwest, in recent years. A shift in the range of a cetacean population could cause an increase in strandings through a number of different mechanisms. If cetacean distribution moved closer to shore, a greater proportion of dead or dying animals would reach the shore to be recorded as strandings. If distribution shifted in such a way that cetacean habitat and key fishing areas overlapped, cetacean captures would increase and more strandings would result. Increased levels of strandings could also be due to an increase in population size. Evidence from conspecific populations elsewhere (eg. Teilmann and Dietz 1998; Bearzi et al. 2005) suggest that populations in these regions are decreasing. However, comparing extensive aerial-survey based abundance estimates for harbour porpoises in 1994 and 2005 around the UK (Hammond et al. 2007), the SCANS II survey found that porpoise abundance had doubled in the southern areas (encompassing our study area) whilst correspondingly, in the northern areas, abundance had halved. It has been suggested that this may be due to a shift in prey distribution (Hammond et al. 2007). Whatever the reason, these data suggest the possibility of a greater density of porpoises around the southwest of the UK in recent years, which seems a likely contributing factor to the increase in strandings of this species.

MacLeod et al. (2005) documented an increase in abundance of common dolphins in the waters of north-west Scotland in the previous decade, which the authors linked to the effects of climate change facilitating the northward movement of warm-water species. If this is indeed the case, then common dolphin abundance in Cornish waters may also have increased as conditions become more favourable, which in turn may lead to a greater number of, if not proportionally more, fishery interactions, as well as mortalities attributable to other causes. Likewise, MacLeod et al. (2005) documented an increase in harbour porpoise strandings between 1998 and 2003, compared with 1992–1997; a pattern which also appears in the data from Cornwall and the Isles of Scilly. Striped dolphins appeared in our dataset as one record each in 1939 and 1975, followed by regular records from 1984 onwards. The striped dolphin is considered a tropical species, with northernmost limits in the Atlantic around the UK. Sightings and strandings of this species have increased around Scottish coasts in the past two decades, despite having never been recorded in this area prior to 1988 (MacLeod et al. 2005). Whether this represents a range shift for this species, increased levels of reporting or simply greater levels of stranding due to bycatch, is not possible to ascertain.

The reduction in stranding rates in the most recent years (2004–2006) has been largely due to fewer strandings of common dolphins and harbour porpoises in these years. In December 2004, pelagic pair trawling for bass was banned within 12 nautical miles of the coast of southwest England (The South-West Territorial Waters (Prohibition of Pair Trawling) Order 2004), in order to reduce bycatch of small cetaceans. However, this legislation only applied to UK vessels and many vessels from other European states continue to fish these waters (DEFRA 2003, 2004). In addition, it is possible that this legislation served to intensify fishing effort offshore rather than reducing overall effort (De Santo and Jones 2007). Bycatch offshore may be less detectable, as carcasses are less likely to reach the coast and be recorded. It is interesting to note, however anecdotal, that in the recent years when harbour porpoise strandings have been lower (2003, 2005 and 2006), the proportion of strandings attributable to bycatch has also dropped, whilst this is not the case for common dolphins. Harbour porpoises are more often found in coastal waters than common dolphins, thus this recent trend may be connected to the 2004 ban of inshore pair trawling.

In contrast to effort-corrected surveys including those from ship-based fisheries observers (Tregenza et al. 1997; Berrow et al. 1998; Morizur et al. 1999; Silvani et al. 1999; López et al. 2003), data from public recording schemes are potentially biased at several levels including inter-annual, seasonal and spatial variation in recording effort (Witt et al. 2006, 2007). In addition, stochastic variability in stranding can result from interacting spatial and temporal factors involving regional geography, oceanography and climate (Collet and Mison 1995; Wright 2005; Hart et al. 2006). Notwithstanding, we have rigorously filtered and analysed these data to provide strong evidence that the rate of cetacean strandings on the coasts of Cornwall and the Isles of Scilly has increased in recent decades. Bycatch is a major cause of death for cetaceans, and there is strong evidence to suggest that fishery interactions in UK waters, possibly combined with a range shift or increase in local relative abundance, contribute significantly to the high levels of strandings which have been observed around the study area. Such levels of detected cetacean mortality, given that they might represent a small proportion of those actually impacted, is a matter of grave concern. With such impacts, whether further increased or sustained at current levels, the viability of these populations may be compromised. Jepson (2005) suggested that the harbour porpoises of the Celtic Sea may be a genetically and spatially isolated stock, which may thus be particularly vulnerable to regional decline. Even if current levels of bycatch are sustainable, the ethical issue of the death of hundreds of small cetaceans every year, as a result of fishing activities, is one which needs to be addressed. Our findings highlight the need for much more detailed information on at-sea distribution of cetaceans, fisheries and the magnitude of interactions between them, particularly in the Western Approaches and the Celtic Sea.

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