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Marine megavertebrates of Cornwall and the Isles of Scilly: relative abundance and distribution

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We document patterns of distribution and relative abundance of marine megavertebrate fauna around Cornwall and the Isles of Scilly from a combination of aerial and boat-based surveying. Between January 2006 and November 2007, 20 aerial surveys were undertaken, comprising over 40 hours of on-effort flying time. In April to October of these years, 27 effort-corrected ferry surveys were also conducted from a passenger ferry travelling between Cornwall and the Isles of Scilly. Opportunistic sightings were also logged by the crew members of the ferry and another vessel travelling regularly along the same route on 155 days. Ten megavertebrate species were sighted: basking sharks Cetorhinus maximus*, sunfish* Mola mola*, common dolphins* Delphinus delphis*, harbour porpoise* Phocoena phocoena*, grey seals* Halichoerus grypus*, Risso's dolphins* Grampus griseus*, bottlenose dolphins* Tursiops truncatus*, minke whales* Balaenoptera acutorostrata*, long-finned pilot whales* Globicephala melas *and killer whale* Orcinus orca*. During aerial surveys, 206 sighting events of seven species were made, compared with 145 sighting events of eight species during ferry surveys and 293 sighting events of 10 species from opportunistic ship-board data collection efforts. Seasonal and spatial patterns in species occurrence were evident. Basking sharks were the most commonly-sighted species in the region and were relatively abundant throughout the estimated 5 km-wide strip of coastal waters covered by the aerial surveys, during spring and summer. Ferry surveys and opportunistic vessel-based sightings data confirmed that the distribution of surface-feeding aggregations of this species was largely around the coasts. Despite the limited scope of this study, it has provided valuable baseline data, and possible insights into the marine biodiversity of the region.*

Keywords: basking shark, harbour porpoise, common dolphin, bottlenose dolphin, grey seal, sun fish, Risso's dolphin, aerial survey, Celtic Sea

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INTRODUCTION

A diversity of marine megavertebrate species inhabits UK coastal waters either year-round or seasonally. Those that can be observed at the surface include numerous species of cetaceans (Reid *et al.*, 2003), seals (e.g. SCOS, 2008), marine turtles (Houghton *et al.*, 2006a; Witt *et al.*, 2007a, b) and at least two large fish species: the basking shark *Cetorhinus maximus* (Bloomfield & Solandt, 2007) and the sunfish *Mola mola* (Sims & Southall, 2002; Houghton *et al.*, 2006b). Knowledge about the ecology and distribution of these species varies by taxon.

Distribution and abundance of coastal cetaceans are well documented in some regions of specific interest around the UK, especially Scottish waters (e.g. Tregenza, 1992; Leaper *et al.*, 1997; Evans *et al.*, 2003; Hastie *et al.*, 2003; MacLeod *et al.*, 2008; Pierpoint, 2008; Weir *et al.*, 2008; Simon *et al.*, 2010). The SCANS and SCANS II surveys documented cetacean abundance throughout UK waters (Hammond *et al.*, 2002; Hammond, 2006). Additionally, strandings records have provided recent insight into the cetacean species present in UK waters and the threats they may face (MacLeod *et al.*, 2005; Leeney *et al.*, 2008). The seas around Cornwall appear to host regionally important habitat for cetaceans, as well as significant fishery activity (Witt & Godley, 2007), but there is a lack of understanding of the spatio-temporal habitat use by various species, although analysis of public sightings data is affording preliminary insights (Pikesley *et al.*, 2011). Cetaceans strand more commonly on the coasts of Cornwall than anywhere else in England and Wales (2257 individuals between 1911 and 2006, comprising 16 species; Jepson, 2005; Leeney *et al.*, 2008) and high levels of porpoise and common dolphin mortality have been documented from fisheries in the Celtic Sea, the English Channel and the Irish Sea (Northridge *et al.*, 2007). Tregenza (1992), using a quantitative retrospective survey method, estimated a 90% decline in the number of small cetaceans sighted from the Cornish coast between the 1940s and the 1990s.

Representing over half of the world's population, grey seals in the UK have been, and continue to be well documented (e.g. SCOS, 2008). The grey seal is the most commonly-sighted

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marine mammal in Cornwall and the Isles of Scilly, from land, and is a year-round resident in these waters (e.g. Summers, 1974; Leeney *et al.*, 2010).

The basking shark is the world's second largest fish. It is a highly migratory species, exhibiting seasonal peaks in abundance at least in parts of its range; however, the localized movements of basking shark populations are still poorly understood. Basking shark stocks have been depleted in the past by fisheries exploitation (e.g. Kunzlik, 1988) and the International Union for the Conservation of Nature (IUCN) lists basking sharks as globally 'vulnerable' and the north-east Atlantic sub-populations as 'endangered' (IUCN, 2011). Despite these concerns, the status of this species, both worldwide and at a national level in the UK, is poorly described due to a lack of reliable estimates of population size and distribution (Southall *et al.*, 2005). The north-east Atlantic provides both feeding and overwintering habitats for basking sharks (Sims *et al.*, 2003). Most studies of basking sharks to date, both in the UK and overseas, have focused on the tagging and tracking of individual sharks (Southall *et al.*, 2006; Gore *et al.*, 2008; Skomal *et al.*, 2009). Sightings of this species during aerial surveys for other species have led to abundance estimates for Atlantic Canada (Campana *et al.*, 2008) and the coast of California (Squire, 1990), but this has not yet been undertaken around the UK. The south-west peninsula of the UK, including Cornwall and the Isles of Scilly, is known to host seasonal aggregations of basking sharks (Southall *et al.*, 2005), although the relative importance of the stocks in this region is difficult to assess given the lack of both local and global population estimates (Skomal *et al.*, 2009).

There is a lack of information relating to the biology and behaviour of sunfish (Cartamil & Lowe, 2004; Sims *et al.*, 2009), although they are known to occur as by-catch at relatively high levels in some commercial fisheries targeting other species (e.g. Silvani *et al.*, 1999). Sunfish inhabit subtropical to temperate pelagic waters throughout the world (Wheeler, 1969), and are most commonly sighted in UK waters in the summer months (Sims & Southall, 2002; Houghton *et al.*, 2006b). Of the marine turtle species, leatherbacks (*Dermochelys coriacea*) occur regularly, whilst loggerheads (*Caretta caretta*) and Kemp's ridleys (*Lepidochelys kempii*) are occasionally recorded in the region (Witt *et al.*, 2007a, b).

Data on the spatial ecology of all of these species in UK waters are limited, particularly for the south-west. Given concerns regarding the effects of industrial (Silvani *et al.*, 1999; Lewison *et al.*, 2004; Petersen, 2005) and artisanal (Soykan *et al.*, 2008) fisheries by-catch on marine megavertebrates, potential climate change impacts (e.g. MacLeod *et al.*, 2005; Perry *et al.*, 2005; Hawkes *et al.*, 2009; MacLeod, 2009; Witt *et al.*, 2010) and emerging issues such as industrial development of marine areas for renewable energy generation (Inger *et al.*, 2009), baseline data at a local level are needed. This study documents species occurrence and phenology in the region's inshore waters (<50 km from the coast) over a two year period and describes important baseline data for marine megavertebrates in the south-west of the UK.

MATERIALS AND METHODS

Aerial surveys

The study area of Cornwall and the Isles of Scilly (IoS) are found at the south-westernmost point of the UK (Figure 1).

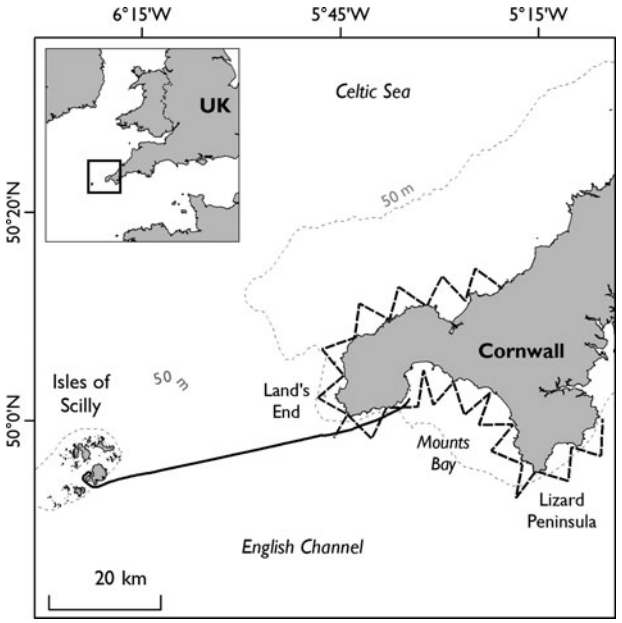

Fig. 1. Survey routes. Inset map of UK highlights study region; study area shown in detail. Aerial survey transect lines (dashed line) and ferry/cargo ship route (solid line) are shown.

Aerial surveys were flown around the western coast of Cornwall, on a near-monthly frequency (N = 20) in 2006 and 2007. Surveys were carried out from a Britten-Norman Islander (BN2 Islander) twin-engine aircraft with high-wing configuration. Survey legs were flown at approximately 200 m above sea level, at an average speed of 175 km.h^{-1} (94 knots) and surveys were only carried out in sea states of Beaufort 4 or less, with visibility of at least 10 km. Two surveyors in the front passenger seats recorded sea state and environmental conditions for each leg and reported any sightings to a scribe seated behind them. The aircraft was not equipped with bubble windows, thus each observer scanned an arc of approximately 90°, centred perpendicular to the track line, and focused their attention to within several hundred metres of the track line. Sightings were made with the naked eye only. For each sighting, time, position, species and number of individuals were recorded. The onshore–offshore survey route comprised 31 survey legs (Figure 1). These were flown starting offshore from Land's End (due to the proximity to the air field), surveying 11 legs along the north coast of Cornwall, then crossing the Cornish Peninsula and surveying a further 20 legs (and one transit leg). Each leg was approximately 6 km long, covering a survey area from the coast to roughly 5 km offshore. On-effort distance covered per flight was 187.6 km. One survey (September 2007) was only partly completed due to low visibility in parts of the study region.

Vessel surveys

'Constant effort' surveys, where observers were on watch for the whole route (64.1 km route with a journey time of ~2 hours 45 minutes each way), were undertaken twice a month, if conditions were suitable, on-board the 'Scillonian III', a passenger ferry which travels between Penzance, on the mainland, and the island of St Mary's, part of the IoS. This ferry operates between April and October only. One

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surveyor was stationed on each side of the bridge, 9 m above sea level. Observers scanned the area ahead and to 90° to the side of the vessel, scanning to the horizon but focusing on the area of water within 1 km of the vessel. Observers used the naked eye to scan and binoculars to confirm sightings and to aid species identification. Species and number of individuals were recorded for each sighting. At 15 minute intervals, the ship's position was noted. A similar route was followed by the vessel in both directions (and also by a second vessel—see below). Environmental data (sea state, swell height, precipitation and visibility) were also recorded. A complete ferry survey involved the recording of sightings on both the outward and returning legs, which always occurred on the same day (the east-to-west journey took place in the morning and the return trip in the afternoon). Most of the vessel surveys were carried out by the same two observers (R.H.L. & D.J.), with several surveys involving one of these observers and a trained volunteer.

Simple recording forms were also provided to the crew of the 'Scillonian III' and the cargo ship supplying the IoS, the 'Gry Maritha' (bridge height 7 m). No effort or environmental data were recorded, so these data provide only an overview of the seasonal and spatial patterns in diversity of species present and an approximate index of the frequency with which sightings occur. The majority of the sightings were made and logged by the officers on the bridge and one crew member (J.B.), all of whom had experience in identifying marine megavertebrates; a simple species identification guide and several reference books were also provided to them. This dataset, whilst not collected using constant effort methodology, nonetheless provides valuable and reliable additional data on species presence, particularly for the winter months when the passenger ferry ('Scillionian III') does not run.

Data analysis

All sightings were included in the distribution maps, regardless of whether they were made on-track (sightings made from transect lines) or not and in all sea states. Although surveys were always planned for days with calm sea conditions (sea state < Beaufort 3), during several of the aerial surveys, sea state and visibility conditions deteriorated to less than favourable. Sightings rates for small cetaceans such as the harbour porpoise have been shown to decrease dramatically in conditions above Beaufort sea state 2 (Palka, 1995; Teilmann, 1995); however, our dataset proved too limited to remove data collected in Beaufort 3 or above, thus we present all data here with the caveat that variability in sightings rates will be a result of other factors as well as seasonality. On-track, effort-corrected seasonal patterns in species abundance were investigated for the aerial survey dataset.

The constant-watch ferry survey dataset was too limited to allow robust analysis of phenology for many species (sightings rates graphs for basking shark, harbour porpoise and common dolphin have been included, for comparison). The larger, 'opportunistic' dataset from the ferry and cargo vessels (which could not be corrected for sea state since these data were not available) was corrected for effort using a simple measure of effort we have termed 'vessel days'—any day from which there was at least one sighting report from the 'Scillonian III' or the 'Gry Maritha'. Days when crew from both vessels recorded opportunistic sightings were considered separately, as the vessels usually travelled at different times.

RESULTS

A total of 19 complete and one incomplete aerial survey were flown between February 2006 and November 2007, representing 3697.1 km of survey effort (Table 1; Supplementary Table 2). Twenty-seven ferry surveys were carried out between April 2006 and October 2007, representing 3461.4 km of survey distance (Supplementary Table 3a). A total of 199 sighting events of seven species (plus seven sighting events of unidentified dolphins) were made on aerial surveys, 145 sighting events of eight species were made during ferry surveys and additionally, 293 sighting events comprising 10 species were recorded opportunistically by the crews of the vessels of opportunity on 155 vessel days (Supplementary Table 3b).

Cetaceans

HARBOUR PORPOISES

Sightings of porpoises during aerial surveys occurred almost exclusively along the south coast of Cornwall, around the

Table 1. Number of sighting events of each species (and number of individuals in parentheses) from the three platform types—aerial surveys (including sightings made 'off-track'), ferry surveys (both uncorrected for sea state) and vessels of opportunity (VO). Numbers of off-track aerial sightings are shown in square brackets.

Species	Aerial sightings (19 full and 1 partial surveys)	Ferry sightings (27 surveys)	VO sightings (155 'vessel days')	Total sightings
Basking shark	120 (194) [12]	30 (36)	79 (395)	228 (625)
Harbour porpoise	16 (19)	51 (106)	69 (245)	136 (370)
Common dolphin	13 (49) [1]	23 (186)	65 (793)	101 (1028)
Grey seal	15 (29)	20 (37)	5 (11)	41 (77)
Sunfish	27 (27) [1]	11 (11)	19 (21)	57 (59)
Risso's dolphin	6 (47) [1]	0	8 (26)	13 (73)
Bottlenose dolphin	2 (13)	1 (2)	18 (106)	21 (121)
Minke whale	0	1 (1)	25 (27)	26 (28)
Pilot whale	0	1 (1)	2 (2)	3 (3)
Killer whale	0	0	2 (2)	2 (2)
Unidentified dolphin	7 (9) [1]	7 (15)	1 (1)	8 (16)
Total	206 [16]	145	293	630

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Lizard peninsula and around Mount's Bay (Figure 2C). This species was sighted all along the vessel route, and was most numerous both along the south coast of Land's End and within a few kilometres of the IoS (Figure 3C). During aerial surveys, porpoises were sighted in April and from July to November (Supplementary Table 2). Sightings were always of individuals or pairs. Harbour porpoises were the most commonly-sighted species on the vessel route, with sightings occurring in most months, but particularly in late summer and autumn (Table 1; Supplementary Figures 5B & 7A). 3 sightings of 8 individuals (ferry surveys) and 3 sightings of 6 individuals (aerial) occurred in sea state 3, of a total of 106 and 19 individuals on ferry and aerial surveys respectively. There were no sightings in higher sea states.

COMMON DOLPHINS

Aerial survey sightings of common dolphins were more numerous along the south coast of Cornwall, especially around the Lizard peninsula (Figure 2D). This species was sighted all along the vessel route in most months of the year (Figure 3D). Opportunistic sightings rates were highest in autumn and winter months (Supplementary Figures 5C & 7B). Few common dolphin sightings were made during ferry surveys.

OTHER MARINE MAMMALS

Bottlenose dolphins were sighted only twice during aerial surveys (Figure 2C). There was one confirmed sighting of bottlenose dolphins during a ferry survey and this species was sighted opportunistically on 22 occasions. Sightings were dispersed along the vessel route, in both coastal and offshore waters (Figure 3E); all but one of these sightings comprised between one and 12 individuals; the other comprised 30 individuals. No seasonal pattern in sightings was apparent in either year (Supplementary Figure 7C).

Minke whales were sighted 26 times on the vessel route (25 times opportunistically and once during a ferry survey) along the vessel route, and were most commonly seen several kilometres east of the IoS (Figure 3F). Sightings were documented primarily in the summer and autumn months, although three sightings were documented in December 2006 (Supplementary Figure 7E). Sightings were generally of solitary individuals, occasionally of pairs.

Risso's dolphins were recorded opportunistically on eight occasions along the vessel route, with no apparent seasonality. Groups ranged from one to 10 individuals. Two groups were sighted on aerial surveys off Longships lighthouse, west of Land's End, in 2007 (Table 2; Figure 2D). A single pilot whale was sighted along the vessel route on two occasions, on a ferry survey in June 2006 and once, opportunistically, in September 2007. Both sightings occurred off the south-west corner of Land's End. A killer whale was sighted opportunistically from the ferry in June of 2006, and a second possible sighting of this species occurred in May of 2007. Both sightings occurred in offshore waters, roughly halfway between the mainland and the IoS. Marine turtles were not sighted during any of the surveys.

Individual grey seals were sighted on 15 occasions during aerial surveys on both the north and south coasts of Cornwall (Figure 2F). On the vessel route, grey seals were most commonly sighted while passing St Clement's Isle on the mainland and closer to the IoS (Figure 3G).

Basking sharks

Basking sharks were by far the most commonly sighted species on aerial surveys, and sightings occurred on both the north and south coasts of the Cornish peninsula. There is a marked difference between years in the distribution of sightings from aerial surveys, with a predominance of sightings on the north coast of Land's End in 2006, and sightings mostly occurring south-west of Land's End in 2007, as well as around the Lizard peninsula (Figure 2A, B). In both years, sightings along the vessel route were frequent along the southern coast of the Land's End peninsula, and out to approximately 10 kilometres offshore, after which they declined (Figure 3A, B). This contrasts with the sightings distributions of most other species, which were dispersed along the entire vessel route (Figure 3). Basking sharks were the second most commonly sighted species from vessel platforms (Table 1). Seasonality of sightings was broadly April–October with a suggestion of interannual variability in magnitude and seasonality (Supplementary Figures 5A & 6A,B; Supplementary Table 2); this pattern was clear in both the aerial and vessel-based datasets.

Sunfish

Sightings of sunfish from aerial surveys were distributed around the coastline (Figure 2E) in the summer months only. Sightings from vessel platforms were most numerous along the south-west coast of the Land's End peninsula (Figure 3H). In 2006, sunfish were numerous during aerial survey flights in July and August, with up to 19 individuals recorded on one survey, but only one individual was sighted in August of 2007 (Supplementary Table 2). Eleven sightings of sunfish were made during ferry surveys, exclusively during the summer months (May–October) of 2006 and 2007 (Figure 3H; Supplementary Figure 7D).

Hotspots

In order to assess overall patterns of abundance and species diversity in the study region, all sightings were combined and mapped within 25 km^2 grid cells (Figure 4). For both the aerial and vessel-based datasets, the importance of the two major peninsulas, in particular Land's End, as potential hotspots of abundance is clear (Figure 4A, C). There is also a suggestion that Land's End may support greatest species richness (Figure 4B, D).

DISCUSSION

Concern regarding the status of large marine vertebrates worldwide, and the commitment by Government to establish an ecologically coherent network of marine protected areas in UK waters, has resulted in an increased interest in documenting the distributional ranges and phenology of top predators, charismatic species and those which may be at particular risk from human activities in the marine environment. Data from aerial surveys and vessels of opportunity have been combined to provide evidence for patterns of distribution, and have provided preliminary information on seasonal patterns in abundance which requires more effort-related surveys to confirm. Leeney *et al.* (2008) documented 16 species of cetacean from

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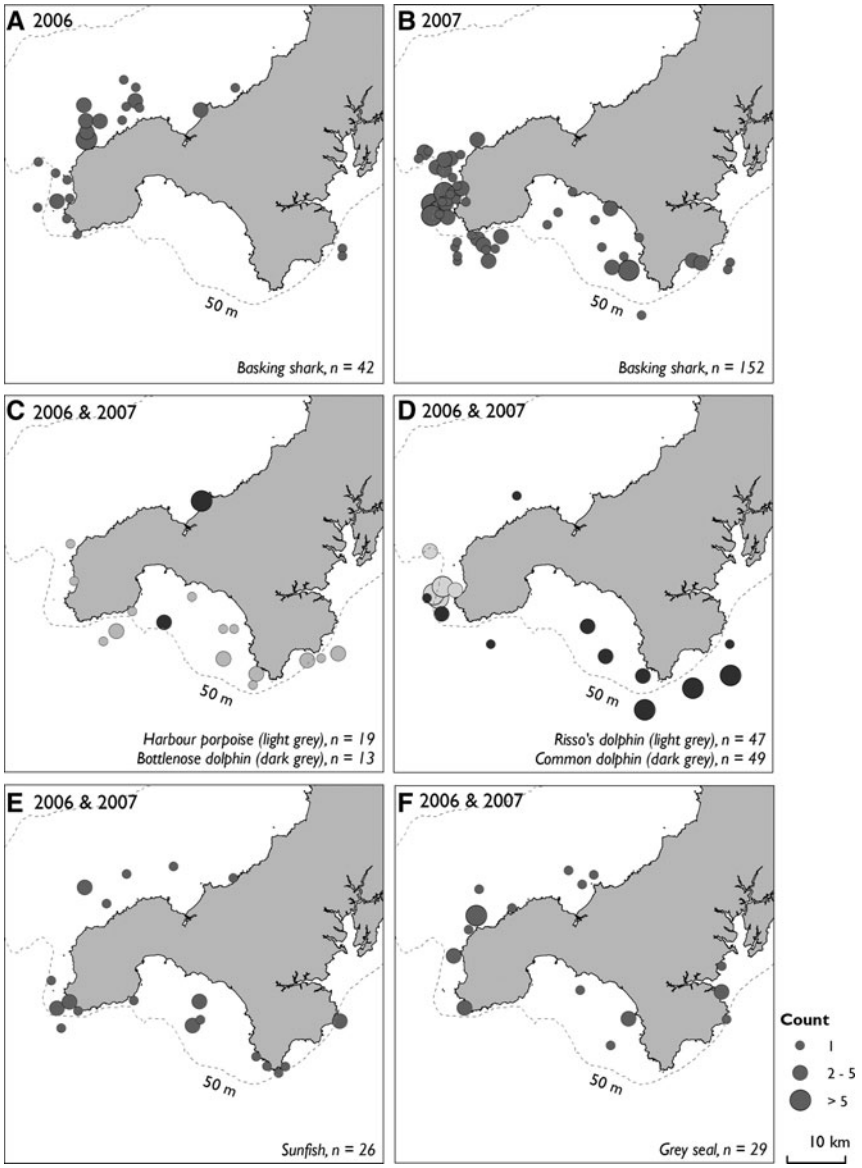

Fig. 2. Distribution of sightings from aerial surveys. Basking sharks in (A) 2006 and (B) 2007; (C) harbour porpoises and bottlenose dolphins; (D) Risso's dolphins and common dolphins; (E) sunfish; (F) grey seals. Symbols are scaled to represent total number of sightings in that region, regardless of sighting dates. For maps (C)–(F), 2006 and 2007 data sets are combined.

the strandings records of Cornwall and the IoS. The most commonly-stranding cetacean species are also those cetacean species which were sighted most often on aerial surveys and from vessels of opportunity. Basking sharks and harbour porpoises are clearly the most frequently-encountered marine megavertebrate species in this region, the former primarily in coastal waters, and the latter throughout the route between the mainland and the IoS.

Harbour porpoises and common dolphins are the two most commonly-sighted cetacean species in this region, likely the reason why they have been documented as the two most commonly-stranded species of small cetacean on the coast of Cornwall (Leeney *et al.*, 2008). Harbour porpoises were sighted in most months in which surveys were carried out, suggesting that they utilize this habitat throughout the year. Around the mainland, sightings of these two species occurred almost exclusively on the south coast of Cornwall, a pattern which is also mirrored in the strandings record. Leeney *et al.* (2008) suggested that the high level of strandings on the south coast may be due to the prevailing south-westerly winds in this region. However, this study indicates that these species may more frequently occur in the near coastal waters of the south of the Cornish peninsula where the edge of the coastal shelf is more proximate (Pikesley *et al.*, 2011), and these distributions may therefore also help to explain the documented stranding patterns.

It is interesting to note that although our surveys confirm they are relatively low in number, bottlenose dolphins are the cetacean species most frequently observed by the public (Pikesley *et al.*, 2011). This is likely because this species often comes close to shore, engages with boats and can be highly visible when active. Wood (1998) documented a seasonal pattern of residency in the local bottlenose dolphin population, moving from Cornwall into Welsh waters, indicating that they utilize a large home range. It is believed that most recent sightings of bottlenose dolphins in Cornish waters are

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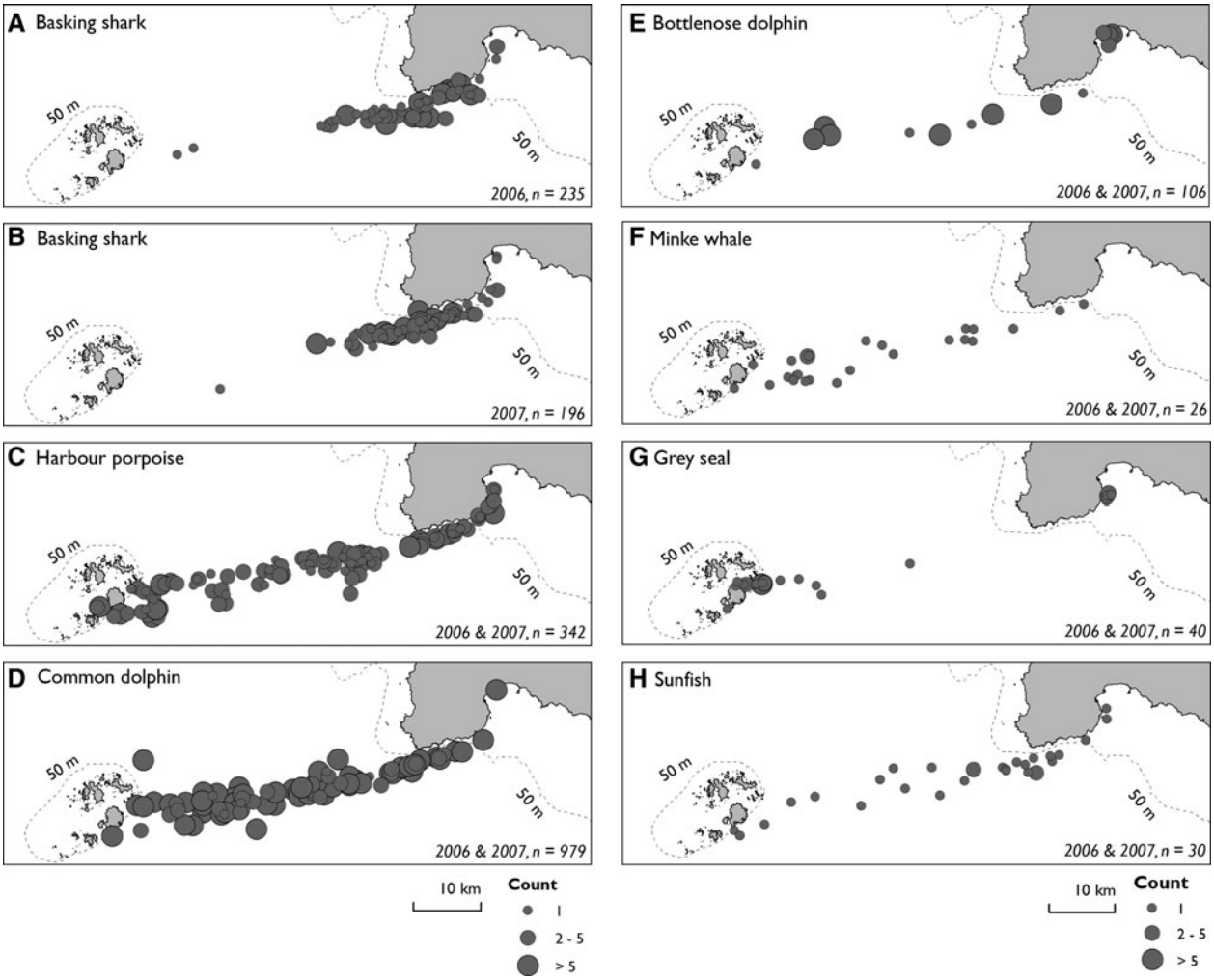

Fig. 3. Distribution of vessel-based sightings (ferry survey and opportunistic combined). (A) Basking sharks in (A) 2006 and (B) 2007; (C) harbour porpoises; (D) common dolphins; (E) bottlenose dolphins; (F) minke whales; (G) grey seals; (H) sunfish. Symbols are scaled according to number of individuals. For maps (C)–(H), 2006 and 2007 data sets are combined.

of the same, small group of individuals, which spends considerable periods of time in the south-west but may also utilize habitats further afield. Our data indicate that the species is not common or numerous in this region, thus suggesting a decline from historical levels, as Tregenza (1992) proposed was the case for several species of small cetaceans.

Minke whales were sighted along the vessel route, suggesting that they utilize both the coastal and offshore waters around Cornwall. Robinson *et al.* (2009) found that water depths of between 20 and 50 m were preferred by this species in the Moray Firth, Scotland. In contrast, our data show a distribution beyond the 50 m depth contour. Sightings of Risso's dolphins and pilot whales were sporadic and infrequent. The consistent, low-level occurrence of these species in the historical strandings records (Leeney *et al.*, 2008), and the occasional presence of sighting records for these species in our data, suggests that they do inhabit the region with some degree of regularity, but may often remain in offshore waters where they are less likely to be sighted. Indeed, Risso's dolphins are known to prefer deep-water habitats (e.g. Gomez de Segura *et al.*, 2008). Killer whales are occasionally reported from various locations around the UK and Ireland (e.g. Reid *et al.*, 2003; Ryan & Wilson, 2003), and the occasional sighting likely involves individuals transiting through offshore waters.

Aerial surveys detected higher basking shark abundance in 2007 than in 2006, whilst vessel data suggested a contrasting result. This may be in large part due to the different areas covered by the two survey methods; aerial surveys covered the coastal zone, whereas the vessel route included both coastal and offshore waters along the survey route. Indeed, the sightings distribution in 2007 shows large numbers of sightings along the west coast of the Land's End peninsula and around the Lizard peninsula, areas not covered by the vessel-based surveys. There is a clear difference in the coastal distribution of sharks between years, with considerably more sightings on south and west coastlines in 2007. Basking sharks are known to congregate along thermal fronts in coastal waters around the UK, during the summer months, where surface plankton is dense and they can feed efficiently (Sims *et al.*, 1997; Sims & Quayle, 1998; Sims *et al.*, 2003). The difference in distribution is thus presumably due to a difference in surface aggregations of prey. The later peak in basking shark abundance in the summer of 2007 is likely due in part to interannual variability in oceanographic conditions. These conditions may have delayed the onset of

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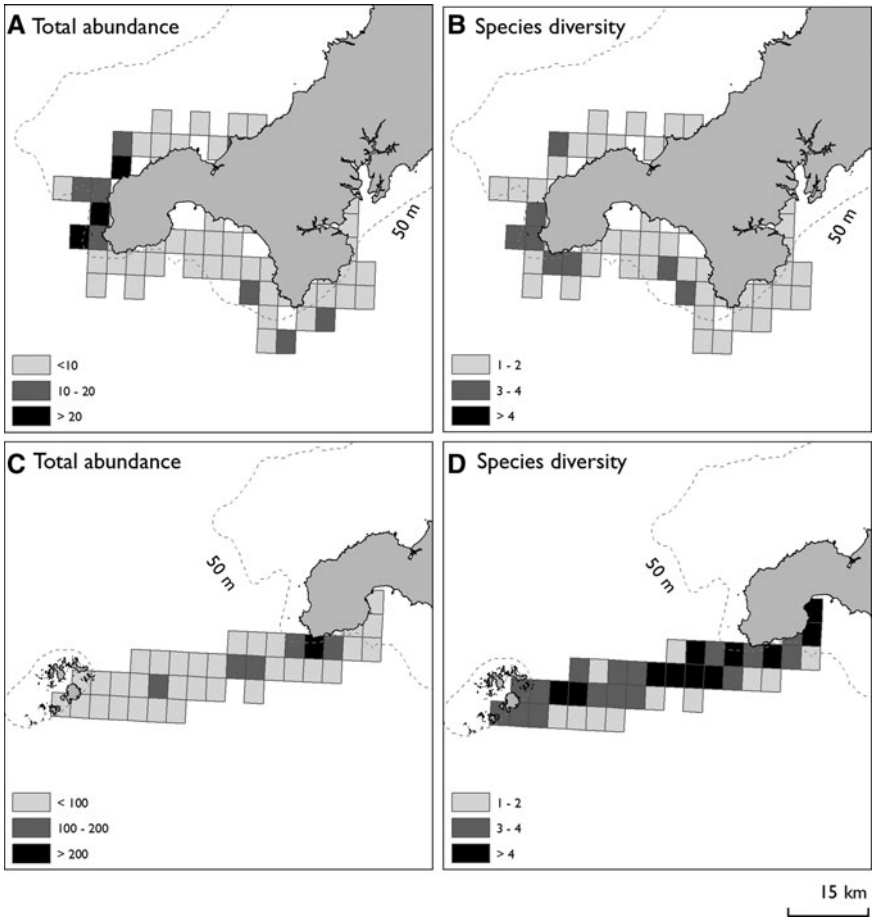

Fig. 4. Maps of total abundance and species diversity. (A) & (B) Aerial survey sightings data; (C) & (D) vessel sightings. 2006 and 2007 combined. Pixel area represents 25 km^2.

plankton productivity around the coast of Cornwall, which triggers surface feeding behaviour in basking sharks (Sims & Quayle, 1998; Sims *et al.*, 2003).

The distribution of basking shark sightings from vessel survey data also highlights the primarily coastal distribution of surface-feeding aggregations of this species. In contrast to most of the other megavertebrate species, sightings of which were distributed along the entire route, there is an evident cut-off to basking shark sightings at a distance of several kilometres off the coast of the mainland. Basking sharks have been documented to show a seasonal reduction in time spent near the surface, as their prey move away from surface waters (Shepard *et al.*, 2006). Likewise, Sims *et al.* (2005) highlighted the differences in time spent at the surface between basking sharks in shelf waters and those in deeper, well-stratified waters. They suggested that differing patterns of diel vertical migration in prey species caused significant differences in amount of 'basking' behaviour exhibited by basking sharks and thus, when basking sharks do not appear at the sea surface, their presence will go unrecorded (Southall *et al.*, 2005). This explains the seasonal 'appearance' of large numbers of basking sharks in coastal waters around Cornwall, and highlights the fact that the species may still be present in this region outside of the summer months, but may be utilizing deeper waters and will therefore not be detected by visual survey methods. Basking sharks satellite-tagged in coastal environments have been observed to move into shelf waters off the UK during the winter (Sims *et al.*, 2003). Such findings highlight the importance of tracking data, in addition to survey data, in adding to our understanding of the ecology and behaviour of such species. Aerial surveys can provide data on regions where basking sharks are engaging in surface-feeding behaviour, which places them at a higher risk of ship strike. Aerial survey counts can also provide a 'snapshot' minimum abundance estimate for basking sharks in any given region, which is surely valuable given that both the North Atlantic and North Pacific populations of this species are of unknown size, but thought to be declining (IUCN, 2011). Aerial surveys have recently been suggested as an effective means of establishing spatial changes in short-term whale shark population distribution (Rowat *et al.*, 2009), and may similarly be appropriate for assessing basking shark habitat use patterns, at least in areas where they are known to engage seasonally in surface behaviour.

A higher number of sunfish was sighted off Cornwall in 2006 than in 2007, which may have been due, at least in part, to lower water temperatures in the latter year. At higher latitudes, such as around the UK, sunfish are commonly sighted during the summer months (Sims & Southall, 2002; Houghton *et al.*, 2006b), a pattern which is apparent in our dataset. However, it is unclear whether this represents an arrival from other areas, or rather greater surface activity and visibility during these months (Sims *et al.*, 2009). Data from satellite-tagged sunfish have suggested that there may be a northward migration of sunfish in the spring, into higher latitudes, and a southward movement at the end of the summer

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(Sims *et al.*, 2009), perhaps as a result of the higher plankton productivity in these regions in the spring and summer.

Many studies have investigated the relationship between patterns of abundance and distribution of large marine vertebrates, such as cetaceans, and environmental features such as primary productivity, bathymetry and ocean fronts (e.g. Mendes *et al.*, 2002; MacLeod *et al.*, 2004; Pierpoint, 2008; Tetley *et al.*, 2008; Bost *et al.*, 2009; Robinson *et al.*, 2009). Our study area having largely been constrained within the coastal zone, bathymetry did not vary enough to warrant an analysis of its effect. Given that the data remain uncorrected for sea state and that sightings rates for most species are low, no detailed analysis of the effects of environmental factors on sightings rates was carried out, and we simply present the data as a baseline description for the region, from which future, more focused research questions can be developed for species of interest or concern. A long-term land-based study at Gwennap Head, at the southern point of Land's End (Wynn *et al.*, 2010), is examining the importance of bathymetry and tidal features in the abundance and distribution of various marine megavertebrate species. Findings from this study also support our suggestion that Land's End represents an important area for both density and diversity of species.

Although small numbers of live leatherback, loggerhead and unidentified species of marine turtles were recorded at sea within, or proximate to the study area during 2006 and 2007 (Penrose & Gander, 2007, 2008), no marine turtles were sighted during this study. However, aerial surveys are regularly used for detecting marine turtles at sea (e.g. Marsh & Saalfeld, 1989; Roos *et al.*, 2005), and thus it is likely that the methodologies used were suitable but that turtle abundance was very low in the study area. No sightings of aggregations of jellyfish such as barrel jellyfish *Rhizostoma octopus*, a key prey species for leatherback turtles, were made during surveys, which may explain the absence of turtles in the region (Houghton *et al.*, 2006a). Finally, the small number of seals sighted at-sea has been reported for completeness, but the methodologies used in this study were not entirely appropriate for assessing true seal abundance in the region. Leeney *et al.* (2010) describe a boat-based method for counting seals at haul-out sites, which has provided a better estimate of grey seal abundance and haul-out distribution along the coasts of Cornwall and the IoS.

CONCLUSIONS

From the two years of data presented here, it is evident that basking sharks and harbour porpoises are relatively numerous in the waters around the Cornish coast, and that the Land's End peninsula appears to be a hotspot for marine megavertebrate abundance. The vessel route revealed that many species of marine megafauna utilize both coastal and offshore waters between Cornwall and the IoS. Compared with 15 species of cetaceans recorded over a 20-year period, in a considerably larger region north and west of Scotland (Weir *et al.*, 2001), the reporting during this study of seven species from mainly coastal waters indicates that this area does provide important habitat, particularly for small cetacean species. Cetacean strandings around these coasts most commonly occur between December and April; this peak is most obvious for common dolphins, harbour porpoises and pilot whales (Leeney *et al.*, 2008). However, the ferry does not run between November and April, and aerial surveys were less frequent over the winter months. Future surveys should take this into account and every attempt should be made to collect data over the winter. Future studies should also attempt to cover a greater proportion of offshore waters, in order to assess whether the waters off Cornwall and the IoS provide important habitat for deep-water cetacean species.

The combination of data from aerial and vessel platforms has provided insight into the spatial and temporal patterns of distribution and abundance of many species, both in coastal and offshore waters at the south-western tip of the UK. Aerial surveys proved a time-efficient, if relatively costly, means of documenting these data for most species, but should be carried out more frequently if they are to document seasonal and inter-annual patterns. Basking sharks are not always detectable from vessels as they do not always break the water surface, thus aerial surveying appears to be an efficient means of surveying for this species in areas where they are utilizing near-surface waters. Using the ships travelling between Cornwall and the IoS as platforms of opportunity has proved an ideal means of collecting large volumes of data from this route, incorporating both coastal and offshore waters, and there is clearly power in this approach when data from multiple routes are integrated (e.g. MacLeod *et al.*, 2005).Whilst the data presented are in large part descriptive, they form a first step towards understanding the relative importance of Cornwall and the IoS for marine megavertebrates, and provide information which will feed into the planning of Marine Protected Areas in the UK. It will be essential to continue effort-based surveys in the region in order to detect future trends in abundance and distribution for species of interest.

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Supplementary materials and methods

The supplementary material referred to in this article can be found online at journals.cambridge.org/mbi

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