MARINE MAMMALS IN THE ENGLISH CHANNEL IN RELATION TO PROPOSED DREDGING SCHEME

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INTRODUCTION The cetacean fauna (whales, dolphins and porpoises) of the eastern Channel is poor, both in numbers of animals and diversity of species. Eleven cetacean species have been recorded along the coasts or in nearshore waters of the region since 1975. Of these, only two species (7% of the 27 UK species) are either present throughout the year or recorded annually as regular seasonal visitors to the region, and another three species occur on a more casual basis. No species is abundant, the most frequently observed in nearshore waters being the bottlenose dolphin *Tursiops truncatus* and in offshore waters, the common dolphin *Delphinus delphis*, whilst the harbour porpoise *Phocoena phocoena* is seen occasionally nearshore and the long-finned pilot whale *Globicephala melas* offshore, whilst there is some evidence that the minke whale *Balaenoptera acutorostrata* is occurring increasingly frequently in the western part region though only in very small numbers. The harbour porpoise and bottlenose dolphin are listed in Annex II of the EU Species & Habitats Directive as species whose conservation requires the designation of Special Areas of Conservation.

Other cetacean species recorded in the region include white-beaked dolphin *Lagenorhynchus albirostris*, Atlantic white-sided dolphin *Lagenorhynchus acutus*, striped dolphin *Stenella coeruleoalba*, Risso's dolphin *Grampus griseus*, humpback whale *Megaptera novaeangliae*, sei whale *B. borealis*, and fin whale *Balaenoptera physalus*, although some of these have been reported only as strandings, so the possibility exists that they died outside the region, and then drifted ashore helped by prevailing currents. For geographical comparisons of sightings rates for various cetacean species in UK waters, see Evans (1990a, 1992) and Northridge *et al.* (1995).

Of the two seal species resident in the British Isles, both the harbour seal *Phoca vitulina* and Atlantic grey seal *Halichoerus grypus* occur only casually in the region, their breeding grounds being some distance away.

STATUS & ECOLOGY The status, seasonal occurrence and ecology of the twelve species of marine mammal recorded in recent years in the region are given below:

a) REGULAR SPECIES

Bottlenose Dolphin (*Tursiops truncatus*) Worldwide distribution in tropical and temperate seas in both hemispheres.

International protection includes Appendix II of CMS Agreement on the Conservation of Migratory Species of Wild Animals (BONN Convention, 1983); Appendix II of BERN Convention on the Conservation of European Wildlife and Natural Habitats (applied to this species, from 1987); and Annex II of the EU Habitats Directive (1992) (prohibiting all forms of deliberate capture, killing or disturbance, especially during breeding, rearing or migration; bans the keeping, sale, or exchange of

such species; and requiring that member states monitor the incidental capture and killing of all cetaceans, and carries out research on conservation measures to prevent such accidents). Like all cetacean species, it is also listed on Annex IV Animal and Plant Species of Community Interest in Need of Strict Protection of the EU Habitats Directive (1992). It is listed on List C1 of Council Regulation and, since 1985, has been treated by the European Community as if it is on CITES Appendix II (trade controlled to prevent over-exploitation). Status listed by IUCN (1991) as insufficiently known. In the UK, it receives special protection in respect of particular methods of killing or taking under The Wildlife & Countryside Act (1981) and the Wildlife (Northern Ireland) Order (1985). One of the species for which the Agreement on the Conservation of Small Cetaceans in the Baltic and North Seas (ASCOBANS) (1992), applies.

Along the Atlantic seaboard of Europe, the species is locally fairly common nearshore off the coasts of Spain, Portugal, north-west France, western Ireland, north-east Scotland, in the Irish Sea, particularly Cardigan Bay and south-east Ireland, and in the Channel. All those localities receive influence from the Gulf Stream. The species also occurs offshore in the North Atlantic (often in association with long-finned pilot whales) as far north as the Faroe Islands. In coastal waters, bottlenose dolphins often favour river estuaries, headlands or sandbanks where there is unneven bottom relief and/or strong tidal currents (Lewis & Evans, 1993; Liret *et al*., 1994; Wilson *et al*., 1997).

Essentially an inshore species, in British and Irish waters the bottlenose dolphin is most frequently sighted within 10 km of land, although it also occurs in offshore waters, often associated with other cetaceans such as long-finned pilot whales. Bottlenose dolphins are present throughout the year in various bays in Western Ireland; in the Irish Sea (particularly Cardigan Bay); and the Moray Firth. Elsewhere in Britain, the species has been scarce in the central and southern North Sea, but it occurs seasonally along the south coast of England at particular localities (e.g. Durlston Head & Lyme Bay in Dorset, and Tor Bay in Devon). Bottlenose dolphins have been reported nearshore along the south coast of England in all months of the year, but particularly between March and September. Most sightings records come from the vicinity of the resorts of Littlehampton, Shoreham, Brighton and Eastbourne, but this probably reflects the greater effort in those areas. It is likely that the species occurs all along the coast in small numbers during the summer months, although there is a trend for individuals to be seen further eastwards as summer progresses (peaks in numbers occur off the Sussex coast between April and August with none seen between October and January), and to be confined mainly to west Cornwall in winter (Evans, 1992; Williams *et al.*, 1997). In the region under consideration, the species occurs most commonly at the western end at Durlston Head in Dorset and between Jersey in the Channel Islands and Normandy in France (Figure 1). At Durlston Head, distinct peaks in numbers of bottlenose dolphins occur between September and April, particularly around December - January and March - April. Off the coast of France, the population appears to be resident but with peaks in numbers between July and September. It has been rarely seen offshore, and photo-ID studies indicate no exchange of animals between the mainland English and French populations in Normandy (Liret *et al*., 1998).

In the UK, group sizes tend to increase in late summer when they may number tens of individuals, although in the Channel groups of 15 or more are uncommon. The species has an extended breeding season, but with births peaking between May and November (Evans 1980; Wilson, 1995). Bottlenose dolphins feed upon a variety of benthic (e.g. eels, flounder, dab, sole, turbot, haddock, hake, and cod) and midwater fish (e.g. salmon, trout, bass, mullet, herring, blue whiting) as well as marine invertebrates (cephalopods and shellfish).

The bottlenose dolphin makes a wide range of vocalisations. Echolocation clicks (used for orientation and foraging) are composed of intense short duration broadband clicks (40-130 kHz) (Au, 1993). Clicks are broadcast in episodic trains that can continue for the duration of a dive and culminate in buzzes and whines as targets are approached. Burst pulse vocalisations (barks, yelps

and donkey-like brays) may have a variety of social functions (0.2-16 kHz). Whistles are pure tone frequency modulated calls ranging from 2-20 kHz. Clicks and whistle vocalisations can be made simultaneously.

Common Dolphin (*Delphinus delphis*) Worldwide distribution in tropical, subtropical and temperate seas in both hemispheres.

International protection includes Appendix II of CMS Agreement on the Conservation of Migratory Species of Wild Animals (BONN Convention, 1983); Appendix II of BERN Convention on the Conservation of European Wildlife and Natural Habitats (applied to this species, from 1987); and Annex IV Animal and Plant Species of Community Interest in Need of Strict Protection of the EU Habitats Directive (1992). It is listed on List C1 of Council Regulation and since 1985, has been treated by the European Community as if it is on CITES Appendix II (trade controlled to prevent overexploitation). Status is listed by IUCN (1991) as insufficiently known. In the UK, it receives protection in respect of particular methods of killing or taking under The Wildlife & Countryside Act (1981) and the Wildlife (Northern Ireland) Order (1985). One of the species for which the Agreement on the Conservation of Small Cetaceans in the Baltic and North Seas (ASCOBANS) (1992), applies.

The common dolphin is widely distributed in the eastern North Atlantic, mainly in deeper waters from the Iberian Peninsula north to west Scotland. In British and Irish coastal waters, its distribution has a mainly western and southern component. It is common in the western approaches to the Channel and the southern Irish Sea, off the west coast of Ireland, and around the Inner Hebrides north to the Isle of Skye (Evans, 1992; Northridge *et al*., 1995). In some years, the species occurs further north and east, around Shetland and Orkney, and in the northern North Sea. It is generally rare in the southern North Sea and the eastern portion of the English Channel although it is a regular visitor west of a line drawn between Poole in Dorset and Normandy in France (Figure 2) where it occurs, mainly offshore, between March and May and betweeen July and December. A solitary common dolphin inhabited the Solent for a number of years during the 1990's.

The diet of the common dolphin includes a wide variety of fish and squid. Pelagic fish species are most common - blue whiting, mackerel, poor cod, hake, sardine, anchovy, silvery pout, scad, hake, and whiting, as well as small squid, octopus, cuttlefish, and crustaceans. The region is used both for feeding and breeding, with calves born mainly between June and September.

Vocalisations vary from whistles of 1-50 kHz frequency (mainly 6-12 kHz, max. source level 172 dB) to echolocation clicks which have not been adequately described but may reach 150 kHz (max. source levels 170 dB) at repetition rates of 30-200 clicks/sec. and pulsed calls such as "buzzes" and "barks" (Evans, 1973; Watkins, *pers. comm*.; Sturtivant *et al*., 1994; Moore & Ridgway, 1995). Clicks and whistles may be given simultaneously.

Harbour Porpoise (*Phocoena phocoena*) Distribution restricted to temperate and subarctic seas of the northern hemisphere.

International protection includes Appendix II of CMS Agreement on the Conservation of Migratory Species of Wild Animals (BONN Convention, 1983); Appendix II of BERN Convention on the Conservation of European Wildlife and Natural Habitats (applied to this species, from 1987); and Annex II of the EU Habitats Directive (1992) (prohibiting all forms of deliberate capture, killing or disturbance, especially during breeding, rearing or migration; banning the keeping, sale, or exchange of such species; and requiring that member states monitor the incidental capture and killing of all cetaceans, and carries out research on conservation measures to prevent such

accidents). Like all cetacean species, it is also listed on Annex IV Animal and Plant Species of Community Interest in Need of Strict Protection of the EU Habitats Directive (1992). It is listed on List C1 of Council Regulation and, since 1985, has been treated by the European Community as if it is on CITES Appendix II (trade controlled to prevent overexploitation). Status listed by IUCN (1991) as insufficiently known. In the UK, it receives special protection in respect of particular methods of killing or taking under The Wildlife & Countryside Act (1981) and the Wildlife (Northern Ireland) Order (1985). One of the species for which the Agreement on the Conservation of Small Cetaceans in the Baltic and North Seas (ASCOBANS) (1992), applies.

In the eastern North Atlantic, the harbour porpoise is widely distributed on the continental shelf from the Barents Sea south to the coast of France and Spain, although in the last thirty years it has become scarce in the southernmost North Sea, English Channel, and Bay of Biscay. Nevertheless, it is the commonest cetacean recorded in British and Irish waters, though most abundant along the south and west coasts of Ireland, western and northern Scotland including the Hebrides and Northern Isles, in East Scotland and Northeast England, and in some coastal areas within the Irish Sea (mainly off SW Wales). Only small numbers occur in Southwest England, and the species becomes scarce eastwards along the south coast of England, in the Thames estuary and off East Anglia. General declines were noted in coastal areas of the southern North Sea during the 1970's, extending and including some more northern and Atlantic sites during the early 1980's, with some indication of a reversal in this trend in the late 1980's to the present (Evans, 1992; Sea Watch unpubl. data).

The species is resident throughout the year in UK waters, although peak numbers nearshore tend to be recorded between July and September. In the Channel, the species is rare, occurring casually in nearshore waters mainly during March-May in the western portion and July-October further east. It is more common from Dorset westwards although it is regularly seen around Dungeness in Kent (Figure 3).

The main diet of porpoises is small fish (usually less than 40 cm length) such as young herring, sprats, sand-eels, whiting, saithe, and pollack, although particularly in winter months, prey such as dab, flounder, sole, and cod are taken. Breeding occurs mainly between May and August, with a peak in June, though some can be as early as March.

Harbour porpoises produce high-frequency sounds used for echolocation and communication, but do not make frequency-modulated whistles typical of many delphinids. The high frequency sounds are comprised entirely of click trains, produced in two narrow band frequency components, one weaker one of longer duration (c. 0.2 msec) at between 1-20 kHz (Schevill *et al.*, 1969; Goodson *et al*., 1995) and the other between 120-160 kHz (peaking around 125-130 kHz) of shorter duration (c. 0.02 msec) (Mohl & Andersen, 1973; Kamminga, 1990; Amundin, 1991; Goodson *et al.*, 1995). Repetition rates of pulses range between 0.5-1,000 clicks per sec (Amundin, 1991). Maximum source level is estimated at between 149 and 177 dB re 1µPa at 1 m (Akamatsu *et al*., 1992). The contexts in which these click trains are used are not well understood.

Long-finned pilot whale *Globicephala melas* Worldwide distribution in temperate and subpolar seas of both hemispheres.

International protection includes Appendix II of CMS Agreement on the Conservation of Migratory Species of Wild Animals (BONN Convention, 1983); Appendix II of BERN Convention on the Conservation of European Wildlife and Natural Habitats (applied to this species, from 1987); and Annex IV Animal and Plant Species of Community Interest in Need of Strict Protection of the EC Habitats Directive (1992). It is listed on List C1 of Council Regulation and, since 1985, has been treated by the European Community as if it is on CITES Appendix II (trade controlled to prevent

overexploitation). Status listed by IUCN (1991) as insufficiently known. In UK, it receives protection under The Wildlife & Countryside Act (1981) and the Wildlife (Northern Ireland) Order (1985). One of the species for which the Agreement on the Conservation of Small Cetaceans in the Baltic and North Seas (ASCOBANS) (1992), applies.

The species is common and widely distributed in deep North Atlantic waters, but seasonally enters coastal areas such as the Faroes, northern Scotland, western Ireland and the south-west Channel Approaches; it also occurs south to the Iberian Peninsula and is common in the Mediterranean. In the English Cannel it is found regularly mainly offshore from Dorset westwards, occurring only casually further east (Figure 3; Evans, 1992). Although recorded in all months of the years in the Channel, peaks in sightings (and numbers of individuals) occur between March and May and between August and December.

Sightings surveys in the eastern North Atlantic in the late 1980's (Buckland *et al.*, 1993) estimate the population at 778,000 (CV=0.295), but the difficulty of accurately estimating group size and distance of the centre of the group from survey vessels imposes serious limitations to the accuracy of such estimates whilst the area of coverage did not extend fully into UK waters.

The species usually occurs in deep temperate and subpolar waters (mainly 200-3,000m depth) seaward and along the edges of continental shelves where bottom relief is greatest, although it may venture on occasions into coastal waters entering fjords and bays.

Although there is no distinct breeding season, births in UK waters show a slight peak in late winter to early spring (January to March) (Evans, 1980; Martin *et al*., 1987). In the neighbouring Faroe Islands, births occur most frequently between July and September (Desportes *et al*., 1993; Martin & Rothery, 1993) although the differences may simply reflect inter-pod variation.

A highly social species, long-finned pilot whales are usually found in groups of 6-40 animals although pods can range to more than 1,000 individuals.

Cephalopods form the bulk of the prey in all dietary studies of this species, although a wide variety of fish have also been found (Sergeant, 1976; Desportes, 1985; Clarke, 1986; Overholtz & Waring, 1991; Desportes & Mouritson, 1993; Bernard & Reilly, 1999). Examination of the stomach contents of 857 pilot whales from the Faroes Islands revealed twelve genera of cephalopods, fifteen genera of fish, and three species of Crustacea (Desportes & Mouritson, 1993). The prey were mainly oceanic, mid-water pelagic shoaling species, and most of the squid were luminous. Two species of squid, *Todarodes sagittatus* and *Gonatus* sp., were the dominant prey, the former appearing to be the prefferred food.

When unavailable, other prey items including fish (mainly greater argentine *Argentina silas* and blue whiting *Micromesistius poutassou*) and shrimps (mainly *Pandalus montagui*) were taken. Fish were more important in summer, especially in the diet of males (although squid continued to make up the bulk of the food), whilst in winter, prey species diversity increased. The diet varied with reproductive status (e.g. fish were of very low importance in non-lactating mature females) and between years (*Todarodes* was much more important in some years compared with others).

Seasonal onshore movements of pilot whales in different areas have been correlated with the abundance of prey: the squid *Illex illecebrosus* off Newfoundland (Mitchell, 1975), the squid *Todarodes sagittatus* off the Faroes (Desportes & Mouritson, 1993), the squid *Loligo paei* and mackerel *Scomber scombrus* off the north-eastern United States (Payne & Heinemann, 1993); whilst Evans (1980) reported seasonal movements (and by-catches) associated with mackerel fisheries in South-west England.

b) OTHER SPECIES

Killer Whale or Orca (*Orcinus orca*) Worldwide distribution in tropical, temperate and polar seas in both hemispheres (with greatest abundance at higher latitudes).

International protection includes Appendix II of CMS Agreement on the Conservation of Migratory Species of Wild Animals (BONN Convention, 1983); Appendix II of BERN Convention on the Conservation of European Wildlife and Natural Habitats (applied to this species, from 1987); and Annex IV Animal and Plant Species of Community Interest in Need of Strict Protection of the EU Habitats Directive (1992). It is listed on List C1 of Council Regulation and since 1985, has been treated by the European Community as if it is on CITES Appendix II (trade controlled to prevent overexploitation). Status listed by IUCN (1991) as insufficiently known. In UK, it receives protection under The Wildlife & Countryside Act (1981) and the Wildlife (Northern Ireland) Order (1985). One of the species for which the Agreement on the Conservation of Small Cetaceans in the Baltic and North Seas (ASCOBANS) (1992), applies.

Although killer whale numbers in the North Atlantic appear to be greatest in subarctic and arctic waters, the distribution of the species extends south to the Caribbean, Azores, Madeira, Canaries and occasionally the western Mediterranean. It is widely distributed in the North Atlantic and in coastal northern European waters particularly around Iceland and western Norway. In UK, it is most common in northern and western Scotland, but rare in the Irish, central and southern North Seas, and the English Channel, with all six sightings in the latter region occurring betwen September and January (Evans, 1988, 1992).

Group size varies between 1 and 16, though usually between two and eight are seen, with groups (termed pods) having very stable membership. Breeding occurs between October and March, possibly mainly between October and December.

Vocalisations have been well studied and include a variety of whistles of variable duration mainly of 6-12 kHz frequency, a pulsed call primarily in the frequency range 1-6 kHz, and very short echolocation clicks mainly of 12-40 kHz (Hoelzel & Osborne, 1986; Bowles *et al*., 1988; Moore *et al*., 1988; Ford, 1989). Sterotyped, discrete calls have been found to vary between groups and appear to represent group-specific dialects (Ford & Fisher, 1982, 1983; Ford, 1984; Bowles *et al*., 1988; Ford, 1989, 1991; Strager, 1995).

Risso's Dolphin (*Grampus griseus*) Worldwide distribution in tropical and temperate seas in both hemispheres.

International protection includes Appendix II of CMS Agreement on the Conservation of Migratory Species of Wild Animals (BONN Convention, 1983); Appendix II of BERN Convention on the Conservation of European Wildlife and Natural Habitats (applied to this species, from 1987); and Annex IV Animal and Plant Species of Community Interest in Need of Strict Protection of the EU Habitats Directive (1992). It is listed on List C1 of Council Regulation and since 1985, has been treated by the European Community as if it is on CITES Appendix II (trade controlled to prevent overexploitation). Status listed by IUCN (1991) as insufficiently known. In the UK, it receives protection under The Wildlife & Countryside Act (1981) and the Wildlife (Northern Ireland) Order (1985). One of the species for which the Agreement on the Conservation of Small Cetaceans in the Baltic and North Seas (ASCOBANS) (1992), applies.

In the North Atlantic, it occurs from Newfoundland to the Lesser Antilles in the west; and from the Shetland Islands to the Mediterranean in the east. The species also occurs around oceanic islands

like the Azores, Canaries and Cape Verde Islands. The major populations in the UK occur in the Hebrides but the species is regular also in the Northern Isles, the Irish Sea, and off Western Ireland (Evans, 1992). It is rare or absent in the central and southern North Sea and eastern portion of the Channel. Elsewhere, it is present in Northwest France, the Bay of Biscay, around the Iberian Peninsula, and in the Mediterranean. The species is nowhere common but is seen most frequently in British waters between May and September, particularly the latter three months of July, August and September. In the eastern Channel, the greatest number of individuals occur early in the summer, in May.

Risso's dolphins feed mainly upon cephalopods (octopus, cuttlefish and small squid), and the area is important both for feeding and breeding (calving occurring mainly between April and September). Stomach content analysis of stranded animals indicate that octopus and cuttlefish are amongst important prey. Groups usually comprise 5-20 individuals although sometimes aggregations of 50-100 individuals have been recorded. Photo-ID studies indicate that groups can be stable over the longterm with individuals associating from one year to the next (Evans, 1987; Evans, unpubl. data).

Vocalisations include a variety of clicks, whistles, and pulsed calls. Whistles are rarely heard, but range over 2.5-20 kHz, usually 8-12 kHz, average duration 0.67 secs, and maximum source level of 170 dB re 1µPa @ 1 m (Watkins, *pers. comm*.). Clicks have peak frequency at 65 kHz and durations of 40-100 secs (Au, 1993). Click frequencies are between 0.2-over 100 kHz, with repetition rates of 4-200 per sec. Click-bursts last from 0.2-1.5 secs. Maximum source level is 175 dB re 1µPa @ 1 m (Watkins, *pers. comm*.). Eight different kinds of sounds in three main categories were recognised in Hebridean Risso's dolphins: clicks in discrete series (echolocation clicks, creaks, grunts) with repetition rates of 37-167 pulses per sec., fast sequences of pulses (buzzes, squeaks, squeals, moans) with high repetition rates of 187-3,750 pulses per sec, resulting in harmonics; and whistles of 9-13.2 kHz (Benoldi *et al*., 1997, 1998).

White-beaked Dolphin (*Lagenorhynchus albirostris*) Distribution restricted to temperate and subpolar seas of the North Atlantic.

International protection includes Appendix II of CMS Agreement on the Conservation of Migratory Species of Wild Animals (BONN Convention, 1983); Appendix II of BERN Convention on the Conservation of European Wildlife and Natural Habitats (applied to this species, from 1987); and Annex IV Animal and Plant Species of Community Interest in Need of Strict Protection of the EU Habitats Directive (1992). It is listed on List C1 of Council Regulation and since 1985, has been treated by the European Community as if it is on CITES Appendix II (trade controlled to prevent overexploitation). Status listed by IUCN (1991) as insufficiently known.

In the UK, it receives protection under The Wildlife & Countryside Act (1981) and the Wildlife (Northern Ireland) Order (1985). One of the species for which the Agreement on the Conservation of Small Cetaceans in the Baltic and North Seas (ASCOBANS) (1992), applies.

The distribution of the white-beaked dolphin extends northwards to central W Greenland, the Greenland Sea and the southern Barents Sea, and south to Newfoundland, Cape Cod and SW Ireland. It occurs over a large part of the northern European continental shelf and is common in British and Irish waters, with a similar distribution to the Atlantic white-sided dolphin though less pelagic and apparently more abundant at least in coastal waters. Its distribution is centred mainly upon the central and northern North Sea, but extending westwards to North and North-west Scotland, and southwards towards South-west Britain and Ireland (Evans, 1990, 1992; Northridge *et al*., 1995). It is occasionally observed in the western Channel east to Dorset and south to the Bay of Biscay, in the Irish Sea, and southernmost parts of the North Sea.

In UK waters, the species is most common between June and October) although it is present in northern Britain year-round (Evans, 1992; Northridge *et al.*, 1995). There are eleven records from the eastern Channel, with greatest numbers in March-April and between August and November (Evans, 1992; Sea Watch, unpubl. data).

White-beaked dolphins feed upon mackerel, herring, cod, poor-cod, sandeels, bib, whiting, haddock, and hake, as well as squid, octopus, and benthic crustaceans. The region is used both for feeding and breeding. They breed mainly between May and August, although some may occur also in September and October.

Vocalisations poorly known but include whistles of 6.5 to at least 15 kHz frequency (often around 8 kHz), with maximum source levels of 180 db re 1 µpa @ 1 m, and echolocation clicks of up to at least 325 kHz, with click bursts of 100-750 pulses per second, and maximum source levels of 207 db re 1 µpa @ 1 m (Watkins, *pers. comm*., Mitson & Morris, 1988; Mitson, 1990; Reeves *et al.*, 1999b).

Atlantic White-sided Dolphin (*Lagenorhynchus acutus*) Distribution restricted to temperate and subpolar seas of the North Atlantic.

International protection includes Appendix II of CMS Agreement on the Conservation of Migratory Species of Wild Animals (BONN Convention, 1983); Appendix II of BERN Convention on the Conservation of European Wildlife and Natural Habitats (applied to this species, from 1987); and Annex IV Animal and Plant Species of Community Interest in Need of Strict Protection of the EU Habitats Directive (1992). It is listed on List C1 of Council Regulation and, since 1985, has been treated by the European Community as if it is on CITES Appendix II (trade controlled to prevent overexploitation). Status listed by IUCN (1991) as insufficiently known. In UK, it receives protection under The Wildlife & Countryside Act (1981) and the Wildlife (Northern Ireland) Order (1985). One of the species for which the Agreement on the Conservation of Small Cetaceans in the Baltic and North Seas (ASCOBANS) (1992), applies.

This species is relatively abundant in mainly offshore waters from central West Greenland, Iceland and the southern Barents Sea south to Cape Cod (United States) and SW Ireland. In European waters, it is widely distributed mainly offshore from Iceland and the western Barents Sea south to the Bay of Biscay. It is less common on the continental shelf than on the slope and in deeper waters, and is more abundant north of 56^{o}N than south of this latitude. In coastal waters of Britain and Ireland, it is less commonly recorded than the closely related white-beaked dolphin, where its distribution is concentrated around the Hebrides, the Northern Isles and northern North Sea. It also occurs regularly off western Ireland, and in the southwest approaches to the Channel and in the central North Sea, but is rare in the southernmost North Sea, and Irish Sea, and absent from the Channel east of Dorset. Most sightings occur in UK waters in July and August, but four records from the Channel include two sightings in May, one in October and one in November, all of groups of six individuals or less.

The diet reflects its more oceanic ecology, with species like blue whiting, herring, mackerel, horse mackerel, cod, hake, and silvery pout being important. Squid are also taken. Breeding occurs between February and September, probably mainly between May and August.

Vocalisations include whistles of 7-16 kHz frequency, with mean peak frequencies of 8-12 kHz, and mean duration 0.5 sec, and broadband echolocation clicks at 0.2-180 kHz with peak frequencies of 60-80 kHz and single pulse duration 0.25-1 msec (Watkins, *pers comm.*).

Striped dolphin *Stenella coeruleoalba* Worldwide distribution, occurring in both hemispheres mainly in tropical, subtropical and warm temperate seas.

International protection includes Appendix II of CMS Agreement on the Conservation of Migratory Species of Wild Animals (BONN Convention, 1983); Appendix II of BERN Convention on the Conservation of European Wildlife and Natural Habitats (applied to this species, from 1987); and Annex IV Animal and Plant Species of Community Interest in Need of Strict Protection of the EC Habitats Directive (1992). It is listed on List C1 of Council Regulation and since 1985, has been treated by the European Community as if it is on CITES Appendix II (trade controlled to prevent overexploitation). Status listed by IUCN (1991) as insufficiently known. In UK, it receives protection under The Wildlife & Countryside Act (1981) and the Wildlife (Northern Ireland) Order (1985). One of the species for which the Agreement on the Conservation of Small Cetaceans in the Baltic and North Seas (ASCOBANS) (1992), applies.

In the eastern North Atlantic, striped dolphins occur mainly offshore west of the Iberian Peninsula and France, and in the Mediterranean. In UK waters the species is rare, recorded mainly from the South-west Approaches to the Channel and off southern Ireland, although occasional sightings and strandings have occurred as far north as Shetland, and the species has been seen off the continental shelf north to 62ºN (Evans, 1992). Of the handful of records in the Channel, most are strandings in the Channel Islands and along the south-west coast of England although one stranded dead in July 1990 in Brighton, East Sussex, another live-stranded in August 1993 at Christchurch Harbour, Hampshire, and a third at Gillingham in Kent in September 1999.

The only population estimate existing for the eastern North Atlantic is for an area of the continental shelf extending south-west of Ireland to France (excluding the Bay of Biscay) and north-west Spain, and westwards to 20ºW (Goujon *et al*., 1993). Most records nearshore to UK occur between July and December (Evans, 1990, 1992).

An oceanic warm water species, the striped dolphin tends to occur well beyond the continental shelf in depths of 1,000 m or more, although it will occcasionally come onto the shelf where it has been recorded in waters of 60 m depth or less.

Births take place mainly between July and September, although this can be variable and the breeding season quite extended.

A very sociable dolphin occurring in group sizes of hundreds or even thousands of individuals, although in European waters, group sizes of 6-60 individuals are most common. In British and Irish waters, however, most sightings are of single individuals or small groups of less than ten, often in mixed schools with common dolphin. Groups may show strong segregation by age, (for example entirely immature schools) with some evidence of segregation of sexes outside the breeding season (Kuiken *et al.*, 1994).

In the eastern North Atlantic, the striped dolphin feeds on a variety of meso- and benth-pelagic fish, including sprat *Sprattus sprattus*, blue whiting *Micromesistius poutassou*, *Trisopterus* spp., silvery pout *Gadiculus argenteus thori*, whiting *Merlangius merlangus*, hake *Merluccius merluccius*., scad *Trachurus trachurus*, bogue *Boops boops*, anchovy *Engraulis encrasicholus*, and gobies. Squid are also frequently taken, including *Chiroteuthis* spp., *Loligo* spp., *Histioteuthis reversa* and *H. bonnellii*, *Alloteuthis subulata*, *Todarodes sagittatus*, *Ancistroteuthis lichtensteini*, *Illex coindetii*, *Abraliopsis pferreri*, *Onychoteuthis banksii*, *Brachioteuthis riisei*, and *Heteroteuthis dispar*, and crustaceans such as *Pasiphaea multidentata* and *P. sivado* (Desportes, 1985, Wurtz & Meotti, 1991; Pulcini *et al*., 1992; Blanco *et al*., 1994; Berrow & Rogan, 1995; Santos, 1998).

Visual and acoustic surveys in the western Mediterranean indicate that striped dolphins may concentrate along the shelf edge (500-1,000 m depth) at night where feeding was deduced, and then move offshore during the day before returning to shallower waters after dusk (Gannier & David, 1997).

Minke Whale (*Balaenoptera acutorostrata*) Worldwide distribution in tropical, temperate and polar seas of both hemispheres. In the North Atlantic, the minke whale occurs from Baffin Bay in the west and the Greenland & Barents Seas in the east, south to the Lesser Antilles in the west and the Iberian Peninsula and Mediterranean in the east.

International protection includes Appendix II of CMS Agreement on the Conservation of Migratory Species of Wild Animals (BONN Convention, 1983); Appendix III (can be exploited so long as regulation keeps populations out of danger) of BERN Convention on the Conservation of European Wildlife and Natural Habitats (1982); and Annex IV Animal and Plant Species of Community Interest in Need of Strict Protection of the EU Habitats Directive (1992). It is listed on List C1 of Council Regulation and is treated by the European Community as if it is on CITES Appendix I (trade strictly controlled, and not for primarily commercial purposes, with exception of West Greenland); one of the species managed by the International Whaling Commission. Status listed by IUCN (1991) as vulnerable. In UK, it receives protection under The Wildlife & Countryside Act (1981) and the Wildlife (Northern Ireland) Order (1985).

The minke whale is widely distributed along the Atlantic seaboard of Britain and Ireland although it also occurs regularly in the northern and central North Sea as far south as the Yorkshire coast. It is seen in small numbers in the Irish Sea but is rare in the Channel and southernmost North Sea, as well as south of here in the Bay of Biscay. There is some indication of an increase since the 1980's, with populations concentrated in the northern North Sea, and around North and West Scotland, and sightings of individuals around Jersey and Guernsey north to the mid-Channel.

Most sightings occur in July-August although the species can be seen anytime between May and October, and at least small numbers remain in coastal waters year-round (Evans, 1980, 1992; Evans *et al.*, 1986; Northridge *et al*., 1995). In the autumn there appears to be a general offshore movement, possibly associated with breeding which occurs sometime between autumn and spring; however, breeding locations are unknown. There is no information on whether any more extensive migration takes place. Although most commonly seen singly or in loose groups of up to three, in Scotland in late summer, feeding aggregations numbering between 5 and 15 individuals may form.

Minke whales prey upon a variety of fish species, notably herring, sandeel, cod, haddock, saithe, as well as euphausiids and pteropods. Feeding occurs often in areas of upwelling or strong currents around headlands and small islands, primarily during the summer.

Vocalisations involve intense, low frequency, broadband (0.5-1 kHz bandwidth) and harmonic down-sweeps with maximum source level of 165 dB re 1 µPa. These include short broadband downsweeps (mainly 0.13-0.06 kHz lasting 200-300 msecs); 'grunts' (mainly between 0.08-0.14 kHz, but up to 2 kHz, lasting 165-320 msecs); and thumps (often downsweeps; mainly 0.1-0.2 kHz, lasting 50-70 msecs) (Schevill & Watkins, 1972; Winn & Perkins, 1976; Thompson *et al*., 1979; Edds, 1988).

Fin whale *Balaenoptera physalus* Worldwide distribution in mainly temperate and polar seas of both hemispheres.

International protection includes Appendix II of CMS Agreement on the Conservation of Migratory Species of Wild Animals (BONN Convention, 1983); Appendix III (can be exploited so long as regulation keeps populations out of danger) of BERN Convention on the Conservation of European Wildlife and Natural Habitats (1982); and Annex IV Animal and Plant Species of Community Interest in Need of Strict Protection of the EC Habitats Directive (1992). It is listed on List C1 of Council Regulation and is treated by the European Community as if it is on CITES Appendix I (trade strictly controlled, and not for primarily commercial purposes, with exception of West Greenland); one of species managed by the International Whaling Commission. Status listed by IUCN (1991) as vulnerable. In UK, it receives protection under The Wildlife & Countryside Act (1981) and the Wildlife (Northern Ireland) Order (1985).

In UK & Irish waters, fin whales are distributed mainly on the Atlantic seaboard along or beyond the continental shelf edge. The species occurs regularly in the Bay of Biscay, South-West Channel and south coast of Ireland, but further eastwards in the Channel proper, it is very rarely recorded (only one stranding)

No current estimates exist for the North Atlantic population as a whole, but recent sightings surveys indicate a total population numbering somewhere over 46,000 individuals, but still below its former size (Buckland *et al*., 1992; IWC, 1992).

Although most commonly recorded in deep waters (400-2,000 m depth) off the edge of the continental shelf, in some localities (e.g. lower Bay of Fundy) it can occur in shallow areas (less than 200 m depth). Appears to favour areas with high topographic variation, with underwater sills or ledges, upwellings and frontal zones between mixed and stratified waters with high zooplankton concentrations (Evans, 1990; Woodley & Gaskin, 1996; Relini *et al*., 1994, 1998).

Births occur mainly in winter. A comparatively non-social species, most sightings of fin whales are of singles or pairs of animals although they can form larger pods of 3-20 animals.

Fin whales feed mainly on planktonic crustacea (mainly euphausiids such as *Euphausia norvegica* but also copepods), but also take fish (e.g. herring *Clupea harengus*, capelin *Mallotus villosus*, sandeel *Ammodytes* spp., mackerel *Scomber scombrus*, and blue whiting *Micromisestius poutassou*), and cephalopods (Jonsgård, 1966; Mitchell, 1974; Kawamura, 1980; Sigurjónsson, 1995). A relationship between fin whale distribution and zooplankton abundance has been demonstrated in the western Mediterranean (Relini *et al*., 1998).

Sei whale *Balaenoptera borealis* Worldwide distribution in mainly temperate and polar seas of both hemispheres.

International protection includes Appendix II of CMS Agreement on the Conservation of Migratory Species of Wild Animals (BONN Convention, 1983); Appendix III (can be exploited so long as regulation keeps populations out of danger) of BERN Convention on the Conservation of European Wildlife and Natural Habitats (1982); and Annex IV Animal and Plant Species of Community Interest in Need of Strict Protection of the EC Habitats Directive (1992). It is listed on List C1 of Council Regulation and is treated by the European Community as if it is on CITES Appendix I (trade strictly controlled, and not for primarily commercial purposes, with exception of West Greenland); one of species managed by the International Whaling Commission. Status listed by IUCN (1991) as vulnerable. In UK, it receives protection under The Wildlife & Countryside Act (1981) and the Wildlife (Northern Ireland) Order (1985).

The species probably breeds in warm temperate and subtropical waters during winter months, and then migrates northwards to summer in cold temperate and polar seas. Summering populations are

concentrated in deep waters of the central North Atlantic north to Iceland. In the eastern North Atlantic, sei whales are thought to winter off North-west Africa, Spain and Portugal and in the Bay of Biscay, and then to migrate north to summering grounds off Shetland, the Faroes, Norway and Svalbard (Horwood, 1987; Evans, 1987, 1992; Stone *et al*., 1996, 1997; Williams *et al*., 1999). The species is rare in the North Sea and English Channel, with a sighting in the English Channel between Dover and Calais in January 1990.

No current estimates exist for the North Atlantic population, but recent sightings surveys indicate a population numbering 13,500+ individuals, with evidence of noticeable depletion of stocks from some of the former whaling grounds (Christensen *et al*., 1990; Joyce *et al*., 1990; Sigurjónsson, 1992, 1995; Cattenach *et al*., 1993).

Sei whales apparently favour pelagic, temperate deep waters between 500 m and 3,000 m depth. The species seems to have a more offshore distribution than fin whales or other balaenopterids (Horwood, 1987; Sigurjónsson, 1995). Births occur mainly in the winter months.

A relatively non-social species, sei whales are generally seen singly or in pairs, or otherwise in groups of up to five individuals. Larger aggregations up to 30 individuals have been recorded in feeding situations (Budylenko, 1977). Some segregation by age and reproductive status may take place, and in the Southern Ocean, pregnant females migrate first, whilst younger individuals tend not to occur at the highest latitudes (Gambell, 1985; Horwood, 1987).

Sei whales feed primarily on surface plankton (mainly copepods *Calanus* spp., but also euphausiids) which they capture by skimming and swallowing (Nemoto, 1959, 1962; Kawamura, 1974, 1980; Horwood, 1987), although small schooling fishes and squid form an important part of their diet in some areas (Tomilin, 1967; Rice, 1977; Nemoto & Kawamura, 1977; Kawamura, 1980).

Humpback whale *Megaptera novaeangliae* Worldwide distribution in tropical, temperate and polar seas of both hemispheres. As elsewhere, the North Atlantic population has been severely depleted by over-exploitation, although there are some signs of recovery since protection, at least in the Northwest Atlantic.

Photo-ID studies indicate the Northwest Atlantic population to number c. 10,600 individuals (95% CI: 9,300-12,100) (Smith *et al*., 1999), with an average annual rate of increase for the Gulf of Maine feeding stock of 6.5% (Barlow & Clapham, 1997). In the Northeast Atlantic, no estimate exists but Øien (1990) considers that the total population is probably much larger than previously thought, with concentrations mainly around Iceland and the Barents Sea.

In recent years, the number of sightings of humpbacks in UK waters has increased considerably, most coming from the Shetland Islands (where up to three individuals have been seen annually since 1992), the northern Irish Sea & Firth of Clyde (where one to two individuals are reported annually), and the southern Irish Sea, Celtic Sea, & western Channel east to Dorset (where two sightings have been reported involving two individuals, one in September 1988 off Portland Bill, Dorset and another in June 1992 between West Bay and Chesil Bay, Dorset) (Evans, 1996; Sea Watch, unpubl. data). Most sightings are between May and September. Small numbers have also been seen offshore mainly off the continental shelf west and north of Scotland.

International protection includes Appendix 1 (at present endangered and needing immediate protection) of CMS Agreement on the Conservation of Migratory Species of Wild Animals (BONN Convention, 1983); Appendix II (strictly protected endangered and vulnerable animals) of BERN Convention on the Conservation of European Wildlife and Natural Habitats (1982); and Annex IV Animal and Plant Species of Community Interest in Need of Strict Protection of the EC Habitats

Directive (1992). It is listed on List C1 of Council Regulation and is treated by the European Community as if it is on CITES Appendix I (trade strictly controlled, and not for primarily commercial purposes, with exception of West Greenland); one of species managed by the International Whaling Commission (completely protected since 1966). Status listed by IUCN (1991) as vulnerable. In UK, it receives protection under The Wildlife & Countryside Act (1981) and the Wildlife (Northern Ireland) Order (1985).

The species apparently favours waters over and along the edges of continental shelves, and around some oceanic islands (Whitehead, 1987). In winter, they mate and give birth over shallow banks (commonly 15-60 m depth) in tropical waters (Whitehead & Moore, 1982). In summer they tend to be coastal in habit, varying their localities depending upon local prey availability (Whitehead, 1987).

Births occur in the winter months, in the North Atlantic peaking in February on Silver Bank in the Caribbean (Whitehead, 1982). Humpbacks are usually seen singly or in pairs, and groups rarely exceed 4-5 animals unless in a feeding or breeding aggregation.

The diet is mainly small schooling fish (including sandeels *Ammodytes* spp., herring *Clupea harengus*, mackerel *Scomber scombrus*, capelin *Mallotus villosus*, pollack *Pollachius pollachius*, cod *Gadus morhua*, and anchovy *Engraulis encrasicolus*) and large zooplankton (mainly euphausiids, but also invertebrates such as mysids and copepods) (Tomilin, 1967; Nemoto, 1970; Kawamura, 1980; Frost & Lowry, 1981; Perkins *et al*., 1982; Kreiger & Wing, 1986; Winn & Reichley, 1985). Euphausiids tend to be taken in greater quantities in polar regions. The type and amount of fish taken varies regionally.

Harbour Seal (*Phoca vitulina*) Widely distributed throughout temperate and sub-arctic waters of the North Atlantic (and North Pacific).

In the Northeast Atlantic, the species occurs along the European mainland coast from northern France to northern Norway and the Kola peninsula, and through the Kattegat/Skagerrak and southern Baltic. It is common around the coasts of Ireland, Scotland, eastern England and Iceland but is rare in the central and eastern English Channel, where only one or two individuals are seen per year.

It is frequently seen in inshore waters and estuaries, hence its name, and is often to be observed hauled out close to areas with substantial human populations (e.g. in the Waddensea). Large concentrations occur in sheltered, shallow waters of the Wash, the Moray and Tay Firths in eastern Scotland and Waddensea where the large groups haul out on tidal mudflats and sandbanks. It is also abundant along sheltered rocky shores throughout its range, but especially in Shetland, Orkney, and the islands of the west coast of Scotland.

The eastern Atlantic population is estimated to number 72,000, with 29,500 in the UK (Reijnders *et al*., 1997). However, the latter figure is thought to be a minimum estimate and telemetry data gives a tentative estimate for UK of around 46,000 (Thompson & Harwood, 1990). In 1988, an epidemic of Phocine Distemper Virus killed large numbers in the North Sea, but most populations have recovered rapidly and are now at or above their 1987 levels (Reijnders *et al*., 1997).

Pupping occurs between May and July in mid June (Harkonen and Heide-Jørgensen, 1990). Harbour seals are inshore foragers, and usually forage less than 50km from their haulout sites (Thompson & miller, 1990; Thompson *et al.*, 1991; Thompson, 1993). There may be small scale seasonal shifts in distribution involving moves of 10-20 km (Thompson, 1989) between foraging areas used during

breeding and those during the winter. In spring and summer, harbour seals may forage 50-100 km offshore, but rarely enter the English Channel.

A wide variety of fish are taken as well as cephalopods, gastropods and crustaceans. Gadoid fish (particularly whiting and saithe) and clupeoid fish appear to be particularly important, although in the southern North Sea, flounders were the commonest species taken.

Atlantic Grey Seal (*Halichoerus grypus*) Occurs throughout temperate waters of the North Atlantic.

In the Northeast Atlantic the species breeds in the British Isles, Iceland, Faroe Islands and along the northwest coasts of mainland Europe from the Kola Peninsula in Russia to France. In the UK, grey seals breed in Shetland, Orkney, North Rona, Outer and Inner Hebrides, on the north and northeast coasts of the Scottish mainland and on the Isle of May (Fife), Farne Islands (Northumberland) and Donna Nook (Lincs) on the North Sea coast. Smaller populations are located in south-west Britain in Wales, Cornwall and the Scilly Islands, and there are small breeding groups off the northwest and south coasts of Ireland. Several small breeding groups have recently been established in the German and Dutch Waddensea and France. The species in rare in the English Channel east of Dorset with only casual records occurring (less than one per year).

Approximately 40% of the world population of the grey seal breeds on 37 widely dispersed sites around the British Isles, with the majority breeding in Orkney, the Outer and Inner Hebrides, North Rona, the Isle of May and the Farne Islands. The total British grey seal population in 1994 was estimated at 108,500; 99,300 seals were asociated with breeding sites in Scotland and 9,200 with sites in England and Wales. Although pup production was apparently affected by the phocine distemper epidemic in 1988, the population continues to increase throughout its range.

Pupping occurs between September and January, with the majority of pups born during October and November at the large British colonies. Outside the breeding season, grey seals may be found in groups throughout the Western Isles, along the west and north coasts of Scotland, throughout the Orkney and Shetland Islands and at various points down the east coast as far as the Wash and East Anglian coast.

Like harbour seals, grey seals are generalist fish feeders with cephalopods and crustaceans taken occasionally. In the North Sea, sandeels, Lemon/Dover sole, and other flatfish are mainly eaten, whereas cod and sandeels predominate in those around the Farne Islands and Isle of May, and sandeels, saithe and cod in Orkney.

EFFECTS OF ANTHROPOGENIC SOUND UPON CETACEANS

Sound characteristics produced by human activities Animals such as cetaceans which live entirely within an aquatic environment rely heavily on sound both to acquire information about their environment and for communication (Evans, 1987; Richardson *et al*., 1995). Additional sounds may therefore cause disruptions to the lives of cetaceans, distracting, annoying or even frightening them, as well as providing the potential for causing behavioural and physiological upset.

Since the industrial era, humans have developed a number of highly intense sources of sound (Ross, 1976; Urick, 1983, 1986). Indeed, Ross (1976) estimated that between 1950 and 1975, ambient noise had risen by 10 dB in areas where shipping noise dominates, and he predicted it would rise a further 5 dB by the end of the 20th century as shipping traffic increased. The more powerful the engine that a vessel possesses, the greater the amount of sound (at least at low frequencies) it will

produce. Supertankers, in particular, produce sound intensities of between 187 dB (at 50 Hz) and 232 dB (at 2 Hz) re 1 µPa, at very low (particularly <10 Hz) frequencies (Cybulski, 1977; Leggat, *et al.*, 1981).

Besides propeller and engine sound generated by vessels during commercial, military and recreational activities, surface vessels and submarines employ active sonar which uses sonic or ultrasonic waves to locate submerged objects, at the same time introducing brief, high-intensity pulses into the marine environment that sometimes may be transmitted over great distances. Source levels of sound are c. 200-250 dB re 1 µPa at frequencies up to 200 kHz. High resolution sidescan sonar (generally below 14 kHz) is also used in geophysical seismic surveys particularly during oil and gas exploration, along with lower resolution explosive techniques (airguns, sleeve exploders, etc) mainly at frequencies below 500 Hz (Richardson *et al.*, 1995; Evans & Nice, 1996).

Most of the sounds generated from maritime activities referred to above (with the exception of sonar) are produced at frequencies lower than 1 kHz. However, when a surface vessel travels at high speed, the propeller may cavitate and produce much higher frequency sound (between 2 and 20 kHz) (Evans *et al.*, 1992). Measurements of various small craft (up to 15 m length, 240 hp engine) indicated source levels ranging from 100-125 dB re µPa at 2 kHz and 60-105 dB re µPa at 20 kHz. Cavitation is also more likely to occur when the propeller is damaged.

Cetacean Sound Production and Hearing The auditory sensitivities of porpoises, dolphins and the smaller toothed whales are greatest at very high frequencies - between 10 and 150 kHz, with a hearing threshold of about 40 dB at those frequencies, increasing to around 100 dB at 1 kHz and 120 dB at 100 Hz, at least for those species for which data are available (Richardson *et al.*, 1995). Although there is no quantitative information on the auditory sensitivities of baleen whales (such as the minke whale), results of recent investigations suggest that greatest hearing sensitivities occur between 100 Hz and 5 kHz, on the assumption that whales will hear approximately over the same frequency range as the sounds they produce. Using this argument, we would expect minke whales to be most sensitive to frequencies of between 60-140 Hz.

The sounds produced by toothed whales and dolphins may conveniently be divided into: (1) pure tone whistles generally in the frequency range 500 Hz - 20 kHz, used mainly for communication; and (2) pulsed sounds or clicks varying from 500 Hz to 150 kHz, used mainly for echolocation. Source levels for both types of sound are estimated usually to be between 150 and 200 decibels, although pulsed sounds for non-echolocatory purposes may be produced at source levels of 115 dB, mainly in the frequency range below 20 kHz. Most of these measurements were made in captivity and it should be noted that animals can modify their sound production (particularly its intensity) in confined situations, and indeed do so also in open water.

The sounds produced by baleen whales may be classified into four types: (1) low-frequency moans, typically with frequencies of 12-500 Hz and of 0.4 to 36 seconds duration; (2) gruntlike thumps and knocks with most sound energy concentrated between 40 and 200 Hz; (3) chirps, cries and whistles at frequencies between 1 and 10 kHz; and (4) clicks or pulses at frequencies up to 20-30 kHz and lasting from 0.5 to 5 msec. Sound source levels range between 150 and 200 decibels, at frequencies of 500 Hz or less.

To summarise, most toothed whales, dolphins and porpoises can hear sounds over a wide range of frequencies from 75 Hz to 150 kHz, with greatest sensitivity around 20 kHz (although low frequency hearing has not been fully investigated), whereas the hearing of baleen whales probably ranges from frequencies of 10 Hz to 10 kHz, with greatest sensitivity usually below 1 kHz (this is based on sound production levels since no audiograms exist). Major differences in hearing between

baleen and toothed whales are further supported by anatomical differences between the hearing organs of these two groups.

Sounds generated within the hearing range of cetacean species tend to elicit specific responses: the animal or animals move away from the sound source; they increase their dive times, remaining underwater for longer periods (possibly as a result of a rapid flee response; and social groups may bunch together. Sometimes, a cetacean species can shift the sound frequency at which it is communicating, and thus avoid or at least reduce interference with human made sounds. Longterm effects upon survival and reproduction of cetaceans have scarcely ever been demonstrated. However, because of the extreme difficulty of distinguishing from other anthropogenic factors and natural environmental changes, it is almost impossible to say whether these occur.

In general, all vessels produce noise in the same ways (Richardson *et al*., 1995). Propeller cavitation produces most of the broadband noise, with dominant tones arising from the propeller blade rate. Propellers create more noise if damaged, operating asynchronously, or operating without nozzles. Propulsion and auxiliary machinery can also radiate significant noise. Radiated noise is roughly related to ship size, speed, and mode of operation. Large ships tend to be noisier than small ones, and ships underway with a full load produce more noise than unladen vessels. Noise also increases with ship speed. Large vessels tend to produce sounds of c. 180-190 dB re 1 µPa at 1 metre for sound frequencies of 30-60 Hz (Richardson *et al*., 1995: 116; Evans, 1996). As noted above, the size of the propeller affects the dominant frequencies at which sound is generated. Strong broadband components caused by propeller cavitation were centred at 40-50 Hz for a vessel with a propeller 6.3 m in diameter, and near 100 Hz for another with a 9-m propeller. Although such sounds will be heard by any cetacean species, there is greatest overlap with the frequencies used by baleen whales, but since none of these occur more than casually in this region, it is unlikely that serious disturbance will be caused.

Whereas local conditions of propagation will affect the actual sound levels that cetaceans are exposed to from any particular vessel, as a general rule behavioural avoidance tends to occur at sound levels of 160-170 dB re 1 µPa at 1 metre in the frequency range of greatest sensitivity to the species (Evans & Nice, 1996). For comparison, ambient noise in the ocean tends to be c. 60-100 dB re 1 µPa at 1 metre (usually nearer to the upper value of 100 dB) (Richardson *et al*., 1995: 88-98).

Assuming spherical spreading of sound according to the equation STL (sound transmission loss) = 20 log R + linear range term, where R = range (a reasonable assumption in this area), the zone of negative influence (resulting in direct avoidance) is unlikely to be more than 100 metres from the vessel, although there is potential for acoustic masking at distances of a few kilometres.

The most likely impact of the proposed dredging activities in the Channel will be through sound disturbance and local habitat modification. Source levels for explosions at 60 m depth gave peak values of 267 dB re 1 µPa at 1 metre for 0.5 kg TNT, 271 dB for 2 kg TNT, and 279 dB for 20 kg TNT (Richardson *et al*., 1995: 156-157), likely to cause physical hearing damage at distances of up to one kilometre, and behavioural avoidance to c. 10 km. Dredging activities produce sounds varying from 172-185 dB re 1 µPa at 1 metre over the broadband range 45 Hz to 7 kHz, which by their continuous nature, elicit negative responses at lower levels than intermittent sounds. Most research on the effects of industrial sound disturbance has been conducted on baleen whales - notably the bowhead whale. Strong behaviour changes in migrating bowhead whales have been noted at received levels of 124 dB from a drilling platform (Richardson *et al*., 1995: 286), and avoidance was recorded in bowheads exposed received sound levels of 122-131 dB from a suction dredge (Richardson *et al*., 1995: 279). They stopped feeding and moved from within 0.8 km of the sound projector to locations more than 2 km away.

Of the four most regularly occurring species in the region, harbour porpoises and bottlenose dolphins have predominantly nearshore distributions and so are unlikely to be affected by mid-Channel activities. Common dolphin and long-finned pilot whale do occur regularly offshore but only west of a line from Dorset to Normandy and so they are also likely to be liitle affected.

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