Background information on marine mammals for Strategic Environmental Assessment 6

P.S. Hammond, S.P. Northridge, D. Thompson, J.C.D. Gordon,
A.J. Hall, G. Aarts & J. Matthiopoulos

Sea Mammal Research Unit
Gatty Marine Laboratory
University of St Andrews
St Andrews, Fife KY16 8LB

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Sea Mammal Research Unit

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Non-technical summary

Distribution and abundance

Seven marine mammal species are known to occur regularly in this area: grey seal, harbour seal, harbour porpoise, short-beaked common dolphin, bottlenose dolphin, Risso's dolphin and minke whale.

There is extensive information on the distribution and abundance of grey and harbour seals around Britain from annual aerial surveys of breeding colonies and haul-out sites and an increasing body of data from satellite telemetry studies. Information on cetacean distribution comes from both dedicated and opportunistic sightings surveys made by a wide spectrum of organisations, some voluntary and some funded by industry and by governmental agencies. There are estimates of abundance only for bottlenose dolphins associated with the Cardigan Bay SAC (213; 95% CI 183-279), and for harbour porpoises in the same area (122; 95% CI 90-165).

Harbour seals in the SEA6 area are concentrated along the coast of Northern Ireland and in the Firth of Clyde. The number of animals in the area is likely to be around 3,500-4,000, concentrated in the far north, out of a total UK population of 50-60,000. Harbour seals spend more time ashore during summer when they are pupping and moulting.

The British grey seal population has been increasing by around 6% annually since the 1960s. Its current size is estimated at 113,000 individuals. In the SEA6 area, the size of the population breeding in Wales and Ireland has been estimated at 5-7,000 animals. During the pupping season in late summer - early autumn and the moulting season in spring they spend more time ashore than at other times of the year. Their at-sea distribution in the SEA6 area is limited to Liverpool Bay, the southern Irish Sea and northern St George's Channel.

Minke whales occur mainly in the south and west of the SEA6 area, and are most frequently recorded in summer. The harbour porpoise is the commonest cetacean in the region, with sightings throughout much of the area throughout the year. Risso's dolphins are recorded regularly though infrequently, mainly in the south of the SEA6 area and in summer. Common dolphins are recorded in large groups especially in summer in the southern part of the SEA6 area from the Bristol Channel to Southeast Ireland. Bottlenose dolphin sightings are most frequent in and around the Cardigan Bay SAC, though there are also sightings in other areas of the SEA6 area; sighting rates are again highest in summer.

Ecological importance

Little is known about grey seal diet in the SEA6 area. Grey seal foraging in the area has recently been studied by deploying Satellite Relay Data Loggers on animals at three sites in Wales. A modelling framework that uses these and other data to generate predicted distributions of where animals spend their time at sea shows that grey seal foraging activity in the SEA6 area is limited to the southern Irish Sea, northern St George's Channel and Liverpool Bay. There are areas of high use in southern Liverpool Bay, west of the Lleyn peninsula, off West Wales and off southeast Ireland and parts of the SEA6 area are clearly important as foraging habitat for grey seals hauling out in Wales and Ireland. There is evidence that the grey seals that haul out in the SEA6 area may form a fairly discrete population from the seals to the north off western Scotland and to the south off Cornwall and France.

There is very limited information on the ecological importance of harbour seals in the SEA6 area. In Northern Ireland, they have been found to consume small flatfish and gadoids, but there is no information on where these animals forage. Some harbour seals tracked from southwest Scotland have spent time in the Firth of Clyde.

There is relatively little information on the ecology of cetaceans throughout British waters. There are a few stomach contents data for harbour porpoises in the SEA6 area, which suggest that, as elsewhere, whiting and other small gadoids are important. Some animals, especially younger ones, recovered from Welsh beaches have been found to consume large quantities of gobies. The harbour porpoise is the most numerous marine mammal in the region, and total annual fish consumption seems likely to run into tens of thousands of tonnes for the region as a whole (Irish Sea). Bottlenose dolphins are known to eat gadoid fish such as cod, haddock and whiting elsewhere, and also salmon which is present in several Welsh rivers and their estuaries. Minke whales might be expected to feed on herring, sprats and sandeels as they do elsewhere in UK coastal waters, while Risso's dolphins feed mainly on squid. Common dolphins are presumed to consume small pelagic fish and/or squid in this region. The significance of these species' predation from an ecological perspective has not been assessed.

The abundance and availability of fish, especially those species mentioned above, is clearly of prime importance in determining the reproductive success or failure of marine mammals in this area, as elsewhere. Changes in the availability of principal forage fish may therefore be expected to result in population level changes of marine mammals. It is currently not possible to predict how any particular change in fish abundance would be likely to affect any of these marine mammal populations.

Sensitivity to disturbance, contamination and disease

Noise

Offshore oil and gas production is noisy. Each stage of the oil extraction process produces loud and potentially disturbing or even damaging sounds. Exploration entails seismic surveys that produce intense low frequency impulse noise, extraction includes drilling, increased vessel traffic, pipeline laying and seismic site surveys, and decommissioning can involve explosive removals.

There is an increasing awareness of the importance of sound to marine mammals. Any man-made noise could potentially have an effect on a marine mammal. The effects could range from mild irritation through impairment of foraging or disruption of social interactions to hearing loss and in extreme cases may lead to injury or even death. Most of the noise generated by offshore oil operations is low frequency, mostly <1kHz, although higher frequency sounds are also generated. Seals are known to be sensitive to those frequencies whereas small (toothed) cetaceans are relatively insensitive to low frequencies. There are no direct measurements of either the frequency range or sensitivities of hearing in large whales, but circumstantial evidence suggests that they may have good low frequency hearing.

Seismic surveys have been shown to cause avoidance behaviour in grey and harbour seals, and in a range of large cetacean species. Seismic survey work may affect foraging behaviour of seals and any large whales in the SEA6 area. Current mitigation methods are probably generally effective in preventing physical damage. The development of 4D or time lapse seismic surveys means that areas with intense oil extraction activity may be subjected to repeated disturbance. The effects of such repeated surveys are not known, but minor or even insignificant transient effects may become important if disturbance is repeated and/or intensified.

There are no reliable data to suggest that vessel noise or drilling noise adversely affect seals or small cetaceans but there are indications that large whales may avoid areas of intense activity.

Decommissioning work that involves the use of explosives is likely to impact animals in the vicinity. Explosives can cause injury and death and may cause hearing damage at substantial ranges. Difficulties in observing and monitoring behaviour and the apparent attractiveness of submerged structures means that some marine mammals, especially seals, are likely to be damaged in blasts. Current mitigation methods are unlikely to be totally effective.

A relatively new source of noise in UK coastal waters is that associated with the construction and running of offshore wind farms. To date there is limited information on the noise generated during each of the survey, construction and operation phases. Harbour porpoises have shown equivocal responses to construction activity at two sites in the Danish North Sea. Harbour seals and harbour porpoises have shown relative mild aversive behavioural responses to the playback of underwater noise from a simulated 2MW wind turbine.

Contaminants

A substantial amount of information is available on the uptake of lipophillic contaminants by marine mammals, such as polychlorinated biphenyls, DDTs and chlorinated pesticides. Other studies on captive and wild populations have shown that these compounds probably have toxic effects on the reproductive and immune systems. Certain heavy metals such as mercury, lead, cadmium, copper and zinc are taken up by marine mammals although there is little evidence that these cause substantial toxic responses, except at high concentrations. Cetacean species which feed lower down the food chain may be at risk from exposure to polyaromatic hydrocarbons, although very little is known about current exposure levels or the effects of chronic exposure in marine mammals.

Oil spills

Direct mortality as a result of contaminant exposure associated with major oil spills has been reported, e.g. following the Exxon Valdez oil spill in Alaska in 1989. Many animals exposed to oil developed pathological conditions including brain lesions. Additional pup mortality was reported in areas of heavy oil contamination compared to unoiled areas.

More generally, marine mammals are less vulnerable than seabirds to fouling by oil, but they are at risk from hydrocarbons and other chemicals that may evaporate from the surface of an oil slick at sea within the first few days. Symptoms from acute exposure to volatile hydrocarbons include irritation to the eyes and lungs, lethargy, poor coordination and difficulty with breathing. Individuals may then drown as a result of these symptoms.

Grey and harbour seals come ashore regularly throughout the year between foraging trips and additionally spend significantly more time ashore during the moulting period (February-April in grey seals; August in harbour seals) and particularly the pupping season (September-December in grey seals; June-July in harbour seals). Animals most at risk from oil coming ashore on seal haul-out sites and breeding colonies are neonatal pups, which are therefore more susceptible than adults to external oil contamination.

Oil dispersants

There have been no specific studies on the direct acute or chronic toxicity of oil dispersants to seals and cetaceans.

Disease

A small-scale survey of anthropogenic bacteria, including Salmonella and Campylobacter, has been conducted in seals but there is no information on the occurrence of anthropogenic viruses, such as enteroviruses.

Bycatch and other non-oil related management issues

Bycatch

The accidental capture (bycatch) of marine mammals in fishing gear is an issue of current concern throughout EU waters and beyond. Bycatch in gill and tangle nets represents a significant source of mortality for harbour porpoises in many areas, but it has not been assessed in this region. The relatively low levels of fishing effort by gill and tangle net fisheries in the SEA6 area make it unlikely that more than a few tens of porpoises are taken per year in this area. Bycatches of other cetacean species in the area has only rarely been recorded and is not believed to be an issue of major concern.

Ship collisions

A potential source of mortality to cetaceans in this and other areas is through collisions with shipping. In other areas, where ships are numerous and cetacean numbers are depleted, this is a serious cause for concern. The frequency of such events in the Irish Sea is unknown and consequently this has not been identified as a significant source of additional mortality in this region.

Conservation frameworks

Marine mammals are included in a wide range of conservation legislation. All species are listed on Annex IV (Animal and Plant Species of Community Interest in Need of Strict Protection) of the European Commission's Habitats Directive. Under Annex IV, the keeping, sale or exchange of such species is banned as well as deliberate capture, killing or disturbance. The harbour porpoise, bottlenose dolphin, grey seal and harbour seal are also listed in Annex II of the Habitats Directive. Member countries of the EU are required to consider the establishment of Special Areas of Conservation (SACs) for Annex II species. SACs have been established for the bottlenose dolphin in the Moray Firth (one) and in Cardigan Bay (two). No SACs have yet been established for the harbour porpoise. A number of terrestrial SACs have been established for grey and harbour seals around the coast of the UK, including three for grey seals in Wales. There are currently no marine SACs for seals.

Under the Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS) provision is made for protection of specific areas, monitoring, research, information exchange, pollution control and heightening public awareness. Measures cover the monitoring of fisheries interactions and disturbance, resolutions for the reduction of by-catches in fishing operations, and recommendations for the establishment of specific protected areas for cetaceans.

In British waters, all species of cetacean are protected under the Wildlife and Countryside Act 1981 and the Wildlife (Northern Ireland) Order 1985. Whaling is illegal under the Fisheries Act 1981. Guidelines to minimise the effects of acoustic disturbance from seismic surveys, agreed with the oil and gas industry, were published by the Department of the Environment in 1995 and are revised from time to time. In 1999, the Department of the Environment, Transport and the Regions produced two sets of guidelines aimed at minimising disturbance to cetaceans. Grey and harbour seals in the vicinity of fishing nets can be killed to prevent damage to the nets or to fish in the nets under the Conservation of Seals Act 1970. Both species are protected during the breeding season; however, licences to kill seals may be granted for any time of the year for specific listed purposes.

Conclusions

- The SEA6 area is an important area for marine mammals. A relatively small but fairly discrete population of grey seals utilises all but the northwest Irish Sea. Harbour seals are found primarily in the far north of the area. Harbour porpoises are seen year round throughout the area and bottlenose dolphins are present year round off Wales. Minke whales, Risso's dolphins and common dolphins are regularly seen in summer mainly in the far south.
- Marine mammals are important predators in this region. Because of the link between the abundance and availability of fish prey and the reproductive success of marine mammals, changes in the availability of principal forage fish may be expected to result in population level changes of marine mammals. It is currently not possible to predict the extent of this.
- Seals are sensitive to the low frequency sounds generated by oil exploration and production. Small cetaceans are relatively insensitive to low frequencies. Circumstantial evidence suggests that large whales may have good low frequency hearing.
- It is likely that seismic survey work will affect foraging behaviour of seals and large whales in the SEA6 area. Current mitigation methods are probably effective in preventing physical damage.
- There are no reliable data to suggest that vessel noise or drilling noise adversely affect seals or small cetaceans. Large whales may avoid areas of concentrated activity but there are no deep-water areas in the SEA6 area where this is of particular importance.
- Decommissioning work that involves the use of explosives is likely to impact animals in the vicinity, potentially causing injury and death at close range, and causing hearing damage at substantial ranges. Difficulties in observing and monitoring behaviour and the apparent attractiveness of submerged structures means that some marine mammals, especially seals, are likely to be damaged in blasts. Current mitigation methods are unlikely to be totally effective.

- Contaminants, such as polychlorinated biphenyls, DDTs and chlorinated pesticides probably have toxic effects on the reproductive and immune systems of marine mammals. There is little evidence that heavy metals cause substantial toxic responses, except at high concentrations. Cetacean species which feed lower down the food chain may be at risk from exposure to polyaromatic hydrocarbons, although very little is known about current exposure levels or the effects of chronic exposure in marine mammals.
- Major oil spills are likely to result in direct mortality. More generally, marine mammals are less vulnerable than seabirds to fouling by oil, but they are at risk from chemicals evaporating from the surface of an oil slick at sea within the first few days. Individuals may drown as a result of associated symptoms. Neonatal seal pups are at risk from oil coming ashore.
- It is not possible to say how many marine mammals are subject to fisheries bycatch in the SEA6 area, but the fact that gillnet fisheries play a relatively small role in overall fishing activity in this area means that bycatches are likely lower than in many other areas around Britain.

1. DISTRIBUTION AND ABUNDANCE

1.1 Introduction

This section summarises information on the distribution and abundance of marine mammals occurring in the Irish Sea, with particular reference to the SEA6 area.

Eighteen cetacean species have been recorded in the region. Of these, five species are known to occur regularly: harbour porpoise, bottlenose dolphin, short-beaked common dolphin, Risso's dolphin, and minke whale. There are occasional at-sea records of a further 10 species: fin whale, sei whale, humpback whale, sperm whale (one sighting only), northern bottlenose whale, killer whale, long-finned pilot whale, striped dolphin (one sighting only), Atlantic white-sided dolphin and white-beaked dolphin, whilst there have been strandings only of the following three species: pygmy sperm whale, Cuvier's beaked whale, and Blainville's beaked whale (one sighting only).

No quantitative information on absolute abundance is available for the region as a whole. The Cardigan Bay Special Area of Conservation in West Wales was surveyed for an abundance estimate between May and October 2001 (see Figure 1 for survey tracks, from Baines *et al.*, 2002). The SCANS (Small Cetacean Abundance in the North Sea) survey that took place in July 1994 (Hammond *et al.*, 2002) only marginally entered the southern boundary of the Irish Sea. The SCANS-II survey taking place in July 2005 will cover the whole of the Irish Sea. Other effort-related sightings surveys have been conducted by various organizations (Sea Watch Foundation, Joint Nature Conservation Committee's Seabirds at Sea Team, EarthKind, Whale & Dolphin Conservation Society, Friends of Cardigan Bay and Marine Awareness North Wales), mainly off the Welsh coast, and between the months of May and October. Their survey effort is largely included in the enclosed maps of sightings rates per standardized unit of effort for particular species, which update those in the Atlas of Cetacean Distribution in North-west European Seas (Reid *et al.*, 2003). Spatial variation in effort is shown in Figure 2. Opportunistically obtained sightings are also mapped for several species.

Coastal acoustic monitoring (using self-contained click detectors called PODs) has occurred at a number of coastal sites around Wales (notably Newport Bay, north Pembrokeshire, Cardigan Bay, and north cast of Anglesey), mainly for harbour porpoise.

In the following sections, each of the more abundant species is briefly described with particular reference to its distribution and abundance in the SEA6 area.

Extensive information on the distribution and abundance of grey seals around Britain is available from studies carried out by the Sea Mammal Research Unit (SMRU). These include annual aerial surveys of breeding colonies to estimate pup production and population size (SCOS 2004), aerial thermal image surveys of haul-out sites during August (SCOS 2004), and data from around 150 animals fitted with satellite-relayed data loggers (e.g. McConnell *et al.* 1999; Matthiopoulos *et al.* 2004). In the SEA6 area, most work on grey seals has been conducted by CCW (e.g. Baines *et al.* 1995; Wescott & Stringell 2004) but new data are now available from a SMRU study supported by DTI (Hammond *et al.* 2005). Information from Ireland is available from Keily *et al.* (2000).

There is less information on harbour seals; the most detailed data are from aerial thermal image surveys conducted during the moult by SMRU (SCOS 2004; Cronin *et al.* 2004; SMRU unpublished data).

1.2 Baleen Whales

1.2.1 Minke whale *Balaenoptera acutorostrata*

The minke whale is widely distributed in all the major oceans of the world from tropical to polar seas, though most abundant in relatively cool waters and on the continental shelf (in depths of 200 m or less).

It occurs in small numbers along the Atlantic seaboard of Europe mainly from Norway south to France, and in the northern North Sea., occurring less commonly in the central and southern North Sea; it is rare in the southernmost North Sea and eastern half of the English Channel. In the western English Channel, it is evenly distributed in low numbers to the continental shelf edge, being largely absent from the deeper parts of the Bay of Biscay. The species has been recorded in every month of the year in UK waters, but is mainly seen near the coast between May and September (Evans, 1990; Northridge *et al.*, 1995; Evans *et al.*, 2003).

Minke whales in the SEA6 area are considered by the International Whaling Commission as part of a single northeastern Atlantic stock. They occur mainly on the western side, south of the Isle of Man (Figures 3 and 4). Minke whales are not common in the Irish Sea, occurring mainly in summer in and around the Celtic Deep, and are rarely recorded north of the Isle of Man.

1.3 Toothed whales

1.3.1 Harbour porpoise *Phocoena phocoena*

The distribution of the harbour porpoise is restricted to temperate and sub-arctic (mainly 5-14º C) seas of the Northern Hemisphere. In the eastern North Atlantic, it is common and widely distributed on the continental shelf (mainly at depths of 20-200 m) from the Barents Sea and Iceland south to the coasts 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 remains the most frequently observed (and stranded) cetacean in British and Irish waters where it is most abundant around North-west and North-east Scotland, in western and southern Ireland, most of Wales and off South-west England (Figures 5 and 6). The harbour porpoise is comparatively rare in waters exceeding 200 metres, and therefore is primarily a species of the continental shelf.

Metrical studies using skeletal material, along with studies of tooth ultra-structure and genetics together suggest that subpopulations of harbour porpoises may exist in the North Sea and adjacent waters, with possible separate populations occurring in the Irish Sea (Wales), northern North Sea, and southern North Sea (Netherlands) (Andersen, 2003; Lockyer, 2003). Genetic evidence from the UK and elsewhere also indicates that males disperse more widely than females (Walton 1997; Andersen *et al.*, 1997; Tolley *et al.*, 1999).

In the Cardigan Bay SAC, an abundance estimate of 122 animals (95% CI 90-165) was made between May and October 2001, but with three times as many sightings in August-September compared with May-July (Baines *et al.*, 2002). However, acoustic monitoring in West Wales suggests peak activity in December (Pierpoint *et al.*, 1999). There are no other abundance estimates.

The harbour porpoise is widely distributed in the SEA6 area, with particular concentrations in the southern sector where it occurs year-round.

1.3.2 Risso's dolphin *Grampus griseus*

The Risso's dolphin is widely distributed in tropical and temperate seas of both hemispheres, occurring in small numbers along the Atlantic European seaboard from the Northern Isles south to northwest France, the southern Bay of Biscay, around the Iberian Peninsula and east into the Mediterranean Sea. A major concentration in northern European waters occurs in the Hebrides but the species is regularly seen also in the Northern Isles, in the Irish Sea and off southwest Ireland, while it is rare in the North Sea and all but the western end of the English Channel.

In the Irish Sea it is seen particularly off north Wales (around Bardsey Island) and in the St George's Channel (mainly off the Wexford coast of Ireland near the Saltee islands and west of Pembrokeshire islands, southwest Wales). There are also incidental sightings around the Isle of Man (Figures 7 and 8).

Risso's dolphins occur mainly in the southern Irish Sea but are nowhere common in the SEA6 area. They have mainly been observed in the region in summer and not at all between December and March.

1.3.3 Short-beaked common dolphin *Delphinus delphis*

The short-beaked common dolphin has a worldwide distribution in oceanic and shelf-edge waters of tropical, subtropical and temperate seas of the Atlantic and Pacific Oceans, occurring in both hemispheres. It is abundant and widely distributed in the eastern North Atlantic, mainly occurring in deeper waters from the Iberian Peninsula north to the Faroe Islands. Its distribution appears to be associated with the Gulf Stream in temperatures of 8-28º C, although it generally occurs in shallower waters closer to the continental shelf edge than the striped dolphin.

The species is common in the western half of the English Channel and Celtic Sea, especially in the winter, and in the Sea of Hebrides and southern part of the Minch (Figures 9 and 10). It is also common south and west of Ireland, whilst off the edge of the continental shelf it can be found north to latitude about 65º N (though rare north of 62º N) during the summer. In some years, the species occurs further north and east in shelf seas - in the northern Hebrides, around Shetland and Orkney, and in the northern North Sea. It is generally rare in the central and southern North Sea and eastern portion of the English Channel.

Common dolphins are regularly seen in the far south of the SEA6 area, particularly in summer.

In near-shore waters of Ireland, the greatest number of sightings reported to the Irish Whale and Dolphin Group has been from Galway Bay, around the Aran Islands, and along the south Cork coast (Berrow *et al.*, 2001).

Although no population estimates exist for the region, common dolphins are probably second only to the harbour porpoise in abundance in summer, because groups may number in the low hundreds. The estimate from the SCANS survey in July 1994 for the Celtic Sea was 75,449 (95% CI 22,900-248,900 uncorrected for animals missed on the transect line or for responsive movement; Hammond *et al.*, 2002).

1.3.4 Bottlenose dolphin *Tursiops truncatus*

The bottlenose dolphin has a worldwide distribution in tropical and temperate seas of both hemispheres. Along the Atlantic seaboard of Europe, the species is locally fairly common near-shore off the coasts of Spain, Portugal, north-west France, southern and western Ireland, North-east and South-west Scotland, in the Irish Sea, and in the English Channel (Evans *et al.*, 2003). Smaller groups of bottlenose dolphins have also taken up short-term residence at other localities – for example, around various Hebridean islands. The species also occurs offshore along the shelf edge in the eastern North Atlantic. In coastal waters, bottlenose dolphins often favour river estuaries, headlands or sandbanks where there is uneven bottom relief and/or strong tidal currents (Lewis and Evans, 1993; Liret *et al.*, 1994; Wilson *et al.*, 1997; Rogan *et al.*, 2000; Ingram and Rogan, 2002).

In the Irish Sea, there are concentrations in Cardigan Bay (particularly the southern portion) and off the coast of Co. Wexford in south-east Ireland (Figure 11). Although effort-related observations are few in the northern Irish Sea, the species is sighted regularly in summer off the Galloway coast of south-west Scotland, around the Isle of Man and north Anglesey (Figure 12).

The bottlenose dolphin population of the Cardigan Bay SAC and coastal waters down to Fishguard has been estimated using photo-identification methods (mark-recapture models) at 213 individuals (95% CI = 183-279), concentrated mainly in coastal waters (Baines *et al.*, 2002). However, the overall population is likely to be larger since the species occurs some distance north of the SAC (see Figures 11 and 12).

Numbers at most UK coastal sites are greatest between May and September, although some animals are present near-shore in every month of the year. In Wales, sightings rates and individual rates increase through the summer, peaking in July-August, with a low between October and April. A long-term land-based study (1989-96) at New Quay in Cardigan Bay, West Wales found that 92% of all sightings occurred between April and November, with 48% between June and August; sightings rates were lowest in March and highest in July (Bristow & Rees, 2001). These findings were similar to those reported from a shorter study (1987-90) from the same locality, where numbers were highest between June and August, although in that study there was a secondary peak in November and December (Lewis & Evans, 1993).

In summary, the bottlenose dolphin is found over much of the SEA6 area, but mostly in Cardigan Bay and particularly south of Aberystwyth. The species occurs year-round but with largest group sizes in late summer. Photo-identification studies indicate that individuals may range over tens of kilometres up and down the coast (Lott *et al.*, 2005), and there is some evidence for an offshore population comprising larger groups, which seasonally enter coastal waters and mix with coastal animals.

1.4 Other species

Three other species of cetaceans have been recorded more than casually. These are the fin whale, long-finned pilot whale and killer whale.

1.4.1 Fin whale *Balaenoptera physalus*

The fin whale occurs worldwide in mainly temperate and polar seas of both hemispheres. In the eastern North Atlantic, it is uncommon, presently occurring mainly in deep waters (200-4,000 m depth, particularly around 1,000 m isobath) from Iceland and Norway south to the Iberian Peninsula, and east into the Mediterranean. In the SEA6 and adjacent areas fin whales are occasionally sighted off southern Ireland and into the St George's Channel (Figure 13).

1.4.2 Long-finned pilot whale *Globicephala melas*

The long-finned pilot whale has a worldwide distribution in temperate and sub-polar seas of both hemispheres. It is common and widely distributed in deep North Atlantic waters. In British and Irish waters, long-finned pilot whales occur mainly along the continental shelf slope, particularly around the 1,000 metre isobath. It is rare in the Irish Sea, mainly recorded in the eastern sector, sometimes very close to the coast (Figure 14).

1.4.3 Killer whale *Orcinus orca*

The killer whale has a worldwide distribution in tropical, temperate and polar seas in both hemispheres (with greatest abundance at higher latitudes). It is widely distributed on the Atlantic seaboard of northern Europe, mainly around Iceland, western Norway, and northern Scotland, but it is occasionally seen south to the Iberian Peninsula and east into the Mediterranean Sea.

In the SEA 6 area killer whales are occasionally seen around the Isle of Man (northern Irish Sea), and St George's Channel (Figure 15).

1.5 Pinnipeds

1.5.1 Grey seal *Halichoerus grypus*

Grey seals are restricted to the North Atlantic and adjacent seas. There are three recognised populations: the northwest Atlantic (breeding primarily on Sable Island, Canada and in the Gulf of St Lawrence); the Baltic Sea; and the northeast Atlantic (breeding primarily on offshore islands around the British Isles but also in Iceland, the Faroe Islands, France, the Netherlands, central and northern Norway, and around the Kola peninsula in Russia). Grey seals haul out on land between foraging trips and for pupping and moulting, when they can form large colonies or aggregations. Timing of pupping differs throughout the range of the species. In Northern Britain pupping occurs from October to late November. In Wales, pups have been born in all months of the year but there is a peak in September. Moulting occurs February - April.

The British grey seal population has been increasing by around 6% annually since the 1960s. Its current size is estimated at 113,000 individuals (SCOS 2004). In the SEA6 area, the size of the population breeding in Wales and Ireland has been estimated at 5-7,000 animals (Keily *et al.* 2000). The distribution of grey seals around the Irish Sea in summer is shown in Figure 16.

Note that in the SEA6 area most grey seals spend the majority of their time on land for several weeks in autumn whilst pupping and mating, and in spring during the moult. Densities at sea are therefore lower during these periods than at other times of the year.

The distribution of grey seals at sea in the SEA6 area has recently become elucidated through a study that tracked animals fitted with satellite relay data loggers (Hammond *et al.* 2005). Figure 17 shows the tracks of 19 grey seals recorded from July to December 2004. Figure 18 shows the predicted distribution of grey seals in the Irish Sea based on these data and counts of animals at haul-out sites during the summer. A more detailed description of these data is given in section 2.2.3.

1.5.2 Harbour (or common) seal *Phoca vitulina*

Harbour seals are one of the most widespread pinniped species and have a practically circumpolar distribution in the Northern Hemisphere. Around Britain and Ireland, harbour seals haul out on tidally exposed areas of rock, sandbanks or mud. Pupping occurs on land from June to July during which time females and pups spend a high proportion of their time ashore. The moult is centred around August and extends into September. Moulting seals also spend a high proportion of their time ashore so from June to September harbour seals are ashore more often than at other times of the year.

There are four sub-species. Only the eastern Atlantic harbour seal, *Phoca vitulina vitulina*, occurs around Britain. The number of harbour seals around Britain is estimated to be at least 50,000, based on minimum population counts of 34,000 during the moult (SCOS 2004). There are few harbour seals around the Irish Sea except along the coast of Northern Ireland and in the Firth of Clyde (Figure 19). Based on the counts shown in Figure 19, the number of seals in the area is likely to be around 3,500-4,000.

2. ECOLOGICAL IMPORTANCE

The abundance and availability of fish, especially those species mentioned above, is clearly of prime importance in determining the reproductive success of marine mammals in this area, as elsewhere. Changes in the availability of principal forage fish may therefore be expected to result in population level changes of marine mammals. It is currently not possible to predict how any particular change in fish abundance would be likely to affect any of these marine mammal populations.

2.1 Cetaceans

The five most frequently seen species of cetacean in the SEA6 area are the harbour porpoise, minke whale, short-beaked common dolphin, bottlenose dolphin and Risso’s dolphin.

2.1.1 Minke whale

Minke whales are known to feed on a variety of fish species, including herring, cod and haddock in Norwegian waters. In past decades, minke whales were associated with herring in the North Sea and were presumed to feed on them (Northridge 1988). Stephenson (1951) reported that most minke whales taken by commercial whaling in the UK waters of the North Sea during 1948 had been feeding on herring, with some mackerel and sand eels also reported. At least one animal in recent years has also been recorded feeding on sandeels (Santos *et al.* 1994). There is no specific information on feeding in the SEA6 area.

2.1.2 Harbour porpoise

Although well studied in the North Sea, and to a lesser extent in the southwest of England, the diet of the harbour porpoise is less well studied in the Irish Sea. Stomach contents examined by the IoZ/SMRU from the Irish Sea suggest that, for smaller animals at least, gobies are an important source of food, while poor-cod and whiting make a significant contribution to the diet of adults too (IoZ/SMRU unpublished data). Elsewhere in the UK whiting are also important, prey species, as are sprats, herring, small gadoids and sandeels. (Rae 1965, 1973, Martin 1995, Santos & Pierce 2003; Santos *et al.* 2004).

The harbour porpoise is probably the most numerous marine mammal species in the SEA6 area and adjacent waters. It is not possible to calculate total fish consumption per annum in the SEA6 area but this is likely to run into tens of thousands of tonnes for the Irish Sea as a whole. The significance of this species’ predation from an ecological perspective has not been assessed.

2.1.3 Risso’s dolphin

There are no data on Risso’s dolphin feeding habits in the SEA6 area, but they are generally assumed to restrict their feeding to squids. It is not possible to assess the ecological significance of this.

2.1.4 Short-beaked common dolphin

There is little if any information on the feeding habits of this species in the SEA6 area, but in the Channel and Biscay area, where common dolphins are more numerous, the main food items are mesopelagic fishes, squids and pelagic crustaceans in the offshore region (Hassani *et al.* 1997), and sardines, horse mackerel and mackerel over continental shelf waters (SMRU/IoZ unpublished data). In the SEA6 area, small pelagic schooling fishes and squids are therefore the likely main food items. Although there are no abundance estimates for the SEA6 Area, common dolphins are seasonally very numerous in the southern part of the SEA6 area at least. Their ecological importance is unknown, but could be significant locally.

2.1.5 Bottlenose dolphin

Despite the large amount of information on bottlenose dolphins in the SEA6 area, little is known about their diet. The best information for bottlenose dolphins in the UK comes from an analysis of the prey remains in ten stomachs from animals that were stranded and by-caught around Scotland between 1990 and 1999 (Santos *et al.* 2001). Cod, saithe, and whiting, were found to be the main prey eaten although several other fish species were also found, including salmon and haddock, as well as some cephalopods.

2.1.6 Other species

The feeding habits of fin whales in this area are unknown, but elsewhere these species consume planktonic crustaceans and small schooling fish (herring, capelin, sandeels, etc). Long-finned pilot whales, are predominantly squid feeders. Killer whales have a catholic diet including marine mammals and schooling fish like herring and mackerel, but nothing is known of their diet in this area.

2.2 Grey seal

Grey seals are large marine predators. Adult males may weigh up to 350 kg and grow to over 2.3 m in length. Females are smaller at a maximum of 250 kg in weight and 2 m in length. The species is relatively abundant in the SEA6 area (see Section 1) and is thus an important marine predator in this region. Grey seals have no significant natural predators in this area.

2.2.1 Diet composition

The diet of grey seals has been studied extensively around Scotland and the east coast of England, although much of the information is nearly 20 years old. The diet comprises primarily sandeels, gadoids and flatfish, in that order of importance, but varying seasonally and from region to region (Prime & Hammond 1990; Hammond & Prime 1990; Hammond *et al.* 1994a, b). Updated information on grey seal diet in Scotland and England in 2002 will be available later this year from a study supported by Defra, SEERAD and SNH. There is very limited information on grey seal diet in the SEA6 area.

2.2.2 Prey consumption

The average daily energy requirement of a grey seal has been estimated as 5,500 Kcals (Hammond & Fedak 1994). The equivalent weight of prey depends on the fat content of the prey but equates approximately to 7 kg of cod or 4 kg of sandeels per day. The grey seal population associated with breeding colonies within the Irish Sea and St George's Channel would thus be expected to consume approximately 10-15,000 tonnes of prey per year.

2.2.3 Foraging movements and distribution

As mentioned in Section 1, there has been a recent study of grey seal distribution and movements in the SEA6 area using satellite-linked telemetry. The tracks for all seals are shown in Figure 17. Each individual seal is represented by a different colour. All seals remained in the Irish Sea, the northern part of St George's Channel and the north-western part of the Bristol Channel. There was very limited activity in the northwest Irish Sea north of Dublin and west of the Isle of Man including waters adjacent to Northern Ireland. No animals travelled north of the Mull of Galloway through the North Channel.

The data show much individual variability in the movement patterns, as has been found in other telemetry studies of grey seals around Britain (McConnell 1999; Matthiopoulos *et al.* 2004). Some animals ranged widely and spent time in a variety of locations; others remained in one limited area for most of the time.

Figure 18 shows the modelled at-sea usage for grey seals in the Irish Sea. Several areas of relatively high usage are clear. One is along the north coast of Wales out to up to about 40 km from the coast. Another is west of the Lleyn peninsula covering an area from about 30km west of Bardsey Island to about 30km from the Irish coast. A third, almost adjacent, area is southwest of the Lleyn peninsula extending about

60km offshore. Further south, there is an area in the southern part of Cardigan Bay extending 40-50 km offshore, and another group of areas west and south of Dyfed, including one off Lundy. Finally, there is a high use area off the southeast coast of Ireland extending out to about 40km offshore.

The data therefore show that the southern Irish Sea and northern St George's Channel is extensively used by grey seals, and that the southern part of Liverpool Bay is also heavily used. Predicted at-sea usage is based on return trips to the same haul-out site so these high use areas are not simply the result of travelling between haul-out sites and can be assumed to be foraging area.

Grey seals from other SRDL deployments off western Scotland and off northern France have not entered the Irish Sea (Matthiopoulos *et al.* 2004). There is thus some indication from these data that the grey seals that haul out at sites in Liverpool Bay, Wales and southeast Ireland form a separate population from the seals to the north off western Scotland and to the south off Cornwall and France.

Although the data from these 19 seals represent an important step in our understanding of the at-sea distribution and movements of grey seals in the Irish Sea and St George's Channel, the sample of animals is a very small proportion of the estimated population of approximately 5,000 grey seals breeding along the coast of Wales. Some of the high-use areas are the result of data from only one or two seals, for example in the Bristol Channel and southern Cardigan Bay. However, the other high use areas were visited by several animals and we can infer that these are likely to be important foraging areas for grey seals that haul out in Wales and southeast Ireland.

In summary, a significant portion of the SEA6 area is clearly important as foraging habitat for grey seals hauling out in Wales and Ireland.

2.3 Harbour seal

The harbour seal is the smaller of the two species of pinniped that breed in Britain. Adults typically weigh about 80-100 kg. Males are slightly bigger than females. As described in Section 1, harbour seals are not as abundant as grey seals around Britain and are found in low numbers around Irish Sea coasts except in Northern Island. They have no significant natural predators in this area.

2.3.1 Diet composition

Harbour seal diet has been studied in Shetland (Brown & Pierce 1998), the Moray Firth (Tollit & Thompson 1996; Tollit *et al.* 1997), and The Wash (Hall *et al.* 1998). There are also unpublished results from the Firth of Tay (Sharples 2005). From these studies, harbour seal diet can be summarised as a wide variety of prey including sandeels, whitefish, flatfish, herring and sprat, octopus and squid. Diet varies seasonally and from region to region.

In the Irish Sea, the only study of harbour seal diet is by Wilson *et al.* (2002), who found that the main species consumed between 1995 and 2000 were small flatfish and gadoids, with the emphasis shifting from flatfish at the beginning to gadoids (mainly whiting, haddock, pollock and saithe) at the end.

2.3.2 Prey consumption

There are no published estimates of prey consumption by harbour seals around Britain. Harbour seals probably require around 3-4 kg per day depending on the prey species. A very rough estimate of prey consumption by harbour seals in the SEA6 area is about 4-5,000 tonnes per year.

2.3.3 Foraging movements and distribution

There are few data on foraging movements and distribution of harbour seals in the SEA6 area. Of 10 seals tracked by SMRU via SRDL in 2003-04, three animals spent time in the Firth of Clyde and a further two travelled through the North Channel to the Rinns of Galloway (SMRU unpublished data). None went into the Irish Sea proper. To what extent the seals that haul out along the coast of Northern Ireland forage in the SEA6 area is unknown. Overall, it seems unlikely that there would be much harbour seal foraging activity in the southern parts of the Irish Sea and St George's Channel.

3. SENSITIVITY TO DISTURBANCE, CONTAMINATION AND DISEASE

3.1 Noise

Marine mammals spend most or all of their lives at sea, and spend the majority of that time submerged. Light is absorbed quickly in salt water and in many marine habitats visibility will be restricted to a few metres: thus vision may be of limited use. Sound, however, propagates efficiently through water and marine mammals use sound for a variety of purposes e.g. finding prey, detecting predators, communication -often over great ranges- and probably navigation.

Many human activities generate sound in the water, e.g. shipping, ice breaking, oil and gas exploration, sonars and explosions, and some of these sounds are extremely intense. Often anthropogenic noise is in the low to mid frequency bands that propagate well and as a consequence anthropogenic noise can be detectable at substantial ranges. Recent technological developments have introduced many new sources of noise in offshore waters. For example, shipping is the dominant noise source at low frequencies in most locations yet this sound source was completely absent before the introduction of mechanised shipping. Ross (1976) estimated that shipping had caused levels of ambient noise to rise by 10dB between 1950 and 1975 and he predicted a rise of another 5dB by the end of the 20th Century. This perturbation of the acoustic environment may have profound implications for marine mammals that evolved to function efficiently in a very different, rather quieter acoustic environment.

A relatively new source of noise in many UK coastal waters is that associated with the construction and running of offshore wind farms, which will be mainly restricted to shallow waters. There are proposals to develop additional wind farms in the SEA6 area. To date there is limited information on the noise generated during each of survey, construction and operation phases.

3.1.1 Effects of man-made sounds on marine mammals

Any man made noise could potentially have an effect on a marine mammal that is sensitive to it. Effects could range from mild irritation through impairment of foraging or disruption of social interactions to hearing loss and in extreme cases physical injury or even death.

Richardson *et al* (1995) defined a series of zones of noise influence as the ranges within which certain acoustic effects can be expected. They recognised four zones, three of which are generally thought of as occur at increasing sound level: the zone of audibility; zone of responsiveness; and the zone of hearing loss, discomfort or injury. The extent of a fourth zone, the zone of masking, depends on the characteristics of sounds that might be masked. When one is considering the detection of very faint sounds the zone of masking could be almost as great as the zone of audibility. Recent research that hints at the possibility that disruption of normal diving behaviour, which may be noise induced, could lead cetaceans to develop decompression sickness (Jepson et al, 2003) suggests that in some cases severe physical effects could be caused within the zone of responsiveness by sound at levels lower than those required for direct physical effects.

3.1.1.1 Zone of audibility

This zone is defined by the range at which an animal can just detect the sound. For a sound to be detected it must be both above the absolute hearing threshold for that frequency and be detectable against the background noise level in that frequency band.

Both conditioned behavioural responses to sound playback and electrophysiological measurements have been used to measure hearing sensitivities for a number of marine mammal species (see Richardson *et al* 1995). Such research has been confined to pinnipeds and small odontocetes that can be maintained in captivity. The resulting audiograms are typically U shaped with sensitivities declining rapidly at high and low frequencies. Absolute sensitivity and hearing range varies markedly between marine mammal groups and also between individuals.

Information on the hearing sensitivity of those species likely to be encountered in the SEA6 area is summarised below and an extensive review of available information on marine mammal audiograms has recently been collated by Nedwell, Edwards, Turnpenny and Gordon (2004)..

3.1.1.1.1 Hearing sensitivity of pinnipeds

Underwater audiograms have been measured for a range of phocid species and all show a similar pattern over the range of frequencies tested (Richardson *et al*. 1995). The audiograms for harbour seals are typical, indicating a fairly flat frequency response between 0.1 and about 40kHz, with hearing thresholds between 60 and 85 dB re 1 µPa. Sensitivity decreases rapidly at higher frequencies, but in the one animal tested at low frequency, the threshold at 0.1 kHz was 96 dB re 1 µPa. indicating good low frequency hearing (Table 1). No behavioural audiograms are available for grey seals, but electro-physiological audiograms (based on auditory evoked potentials) showed a typical pinniped pattern over the range of frequencies tested (Ridgeway and Joyce 1975). The fact that grey seals make low frequency calls suggests that they also have good low frequency hearing (Table 2). There are no audiograms for hooded seals. While it might be considered likely that their pattern of hearing sensitivity will be similar to that of grey and harbour seals, there is evidence that the hearing of another deep diving species, the Northern Elephant seal, is better-adapted for low frequency hearing than are grey and harbour seals (Kastak & Schusterman 1999). It is possible, therefore, that the hooded seal's hearing may be similarly adapted.

In-air sensitivities have been determined behaviourally for the harbour seal (Table 3). Pinnipeds appear to be considerably less sensitive than humans to airborne sounds below 10 kHz.

Table 1. Hearing sensitivity of the harbour seal from underwater audiograms (Richardson *et al*., 1995).

Species	Low Freq. (kHz)	Threshold (dB re1µPa)	Best Freq. (kHz)	Threshold (dB re1µPa)	Upper Freq. (kHz)	Threshold (dB re1µPa)
Harbour seal	0.1	96	10-30	60-85	180	130

Table 2. Characteristic frequencies of vocalisations produced by grey seals.

Species	Frequency range of vocalisations (kHz)
Grey seal	0.1 – 3

Table 3. Hearing sensitivity of pinnipeds from in-air audiograms (Richardson *et al*., 1995).

Species	Lower Frequency (kHz)	Threshold (dB re 1 µPa)	Upper Frequency (kHz)	Threshold (dB re 1 µPa)
Harbour seal	0.1	95	20	85

3.1.1.1.2 Hearing sensitivity of baleen whales

There are no published audiograms for baleen whales. It is assumed that they are sensitive to sound of low and medium frequencies because they predominantly emit low frequency sounds, primarily at frequencies below 1 kHz with vocalisations of some species being largely infrasonic (<20Hz) sounds.

Baleen whales react behaviourally to low frequency calls from conspecifics. However, these observations do not provide accurate indications of hearing thresholds.

Estimates of the frequency range of vocalisations of those species present in the SEA 6 area are shown in Table 4. The high upper frequencies quoted here often represent unusual outliers. Most baleen whale sounds are concentrated at frequencies less than 1 kHz, but sounds up to 8 kHz are not uncommon. The dominant call from fin whales is an infrasonic 20Hz pulse and in many oceans their calls are a prominent feature of ambient noise at these frequencies in certain times of the year.

The anatomy of baleen whale ears also indicates that they are most sensitive to low frequencies (Ketten, 1997).

Table 4. Characteristic frequencies of vocalisations produced by baleen whales (Richardson *et al*., 1995).

Species	Frequency range of vocalisations (kHz)
Minke whale	0.06 – 20
Humpback whale	0.02 – 8.2
Fin whale	0.01 – 28
Sei whale	0.012 – 3.5

3.1.1.1.3 Hearing sensitivity of toothed whales

Behavioural audiograms have been reported for some odontocete species (Table 5). The hearing thresholds have been measured in the smaller toothed whales (dolphins and porpoises). These are most sensitive to sounds above about 10 kHz and below this sensitivity deteriorates. High frequency hearing is good; upper limits of sensitive hearing range from about 65 kHz to well above 100 kHz. This reflects the use by these species of high frequency sound pulses for echolocation and moderately high frequency calls for communication.

Within the range of middle frequencies, where odontocetes have their best sensitivity, their hearing is acute. Frequencies at which the species in Table 5 had best sensitivity ranged from about 8 to 90 kHz. Below the frequency range of optimum sensitivity, thresholds increase gradually with decreasing frequency.

Hearing sensitivity has not been measured in the majority of the larger odontocetes including sperm whales, pilot whales and all of the beaked whales.

Table 5. Hearing sensitivity of toothed whales from underwater audiograms (Richardson *et al*., 1995).

Species	Lowest Frequency tested (kHz)	Threshold (dB re 1 µPa)	Most sensitive Frequency 9kHz)	Threshold (dB re 1 µPa)	Upper Frequency (kHz)	Threshold (dB re 1 µPa)
Killer whale	0.5	100	16	30	120	85
Bottlenose dolphin	0.075	130	60	47	150	135
Risso's dolphin	2	120	80	74	100	120
Harbour porpoise	0.25	115	100	32	180	106

For those species occurring in the SEA 6 area for which data on hearing sensitivity are not available, the frequency range of assumed reasonably acute hearing (for species with data on characteristic frequencies of vocalisations) is shown in Table 6.

Table 6. Characteristic frequencies of vocalisations produced by other toothed whales found in the SEA 6 area.

Species	Frequency range of vocalisations (kHz)
Long-finned pilot whale	1 - 18
Sperm whale	0.1 - 30
Northern bottlenose whale	3 - 16
Sowerby's and Cuvier's beaked whale	0.3 - 11
White-beaked dolphin	2 - 20
Common dolphin	2 - 18
Harbour Porpoise	100-150kHz

Small odontocetes are more sensitive at high frequencies than are phocid seals. At their best frequencies, odontocetes are around 20-30 dB re 1µPa more sensitive than phocids. However, below about 2 kHz phocids become relatively more sensitive than small odontocetes, eg. At 2kHz harbour porpoises and juvenile bottlenose dolphins had estimated hearing thresholds of 50-70 dB re 1µPa, similar to estimates for a range of phocid seal species. At 100Hz, dolphin hearing thresholds had risen to 130 dB re 1µPa. At 100Hz, harbour seal threshold was estimated to be 95dB re 1µPa, approximately 35dB better than the dolphin. Many of the man-made sounds in the sea are in this low frequency range.

3.1.1.2 Zone of responsiveness

This is defined as the region around a source within which a marine mammal shows an observable response (Richardson *et al*. 1995). Behavioural responses are always inherently variable. While the physical process of detecting or being damaged by a sound can be predicted reasonably reliably from combinations of empirical studies and acoustic models, this is not the case for behavioural reactions to sound. The reactions of an intelligent marine mammal to a particular stimulus may be affected by several factors, e.g. nutritional state (hungry or satiated), behavioural state (foraging, resting, migrating etc.), reproductive state (pregnant, lactating, juvenile, mature), location and previous exposure history.

To date there have been a number of observational studies of changes in patterns of distribution and movement of marine mammals in the presence of acoustic stimuli. For practical and political reasons, these have usually involved studies of large cetacean species. Thus, in their comprehensive review of marine mammals and sound, Richardson *et al* (1995) devoted 15 pages to the responses of cetaceans to ships and boats and only two pages to the reactions of pinnipeds.

One of the best known examples of noise inducing an acute and serious effect on marine mammals is the mortalities resulting when beaked whale strand in response to military sonar (see below). While the causal association between the use of mid-frequency sonar and these dramatic incidents is now accepted, the mechanisms that lead to these mortalities have yet to be established. Recent observations suggest that these animals may have developed decompression sickness (Jepson *et al.* 2003) and that this may be induced when the diving behaviour of animals is altered when they respond to sonar signals. For example, animals disturbed by sonar may surface too quickly and/or remain too long at the surface. While this mechanism remains hypothetical, it does serve to emphasise that behavioural changes in response to acoustic signals can have acute and serious consequences.

Available information on behavioural and physiological responses of seals and cetaceans, to each of the potential noise sources in the SEA 6 area are described below.

3.1.1.3 Zone of masking

To be audible, a sound must be detectable against the background noise. Thus, the level of background noise will often determine whether a sound is detectable or not, especially at frequencies where the animal's hearing is highly sensitive. As a rule of thumb, Richardson *et al* (1995) suggest that a mammal can barely detect a sound signal if its received spectrum level[1] is equal to the level of noise in the 1/3 octave band in which it lies.

Critical ratios, i.e. the ratio of sound level to background level at which detection is masked, have been estimated for a range of species. These have so far involved high frequency or continuous tone sound sources (Southall *et al* 2000, Richardson *et al* 1995). For harbour seals, Turnbull and Terhune (1993) showed that increasing repetition rate decreased hearing threshold for pulsed sounds above 2kHz irrespective of the level of masking, i.e. faster repetition decreased the critical ratio. This implies that critical ratios for irregular short pulses will be higher than for continuous tones. To date there are no useful data on the masking effects of background noise on ability to detect low frequency pulsed sounds.

The efficient detection of a wide range of sounds is biologically important for marine mammals. These will include sounds made by conspecifics, prey and predators, ambient noise useful for orientation and navigation, and for echo-locators the echoes returning from ensonified objects. Masking by noise will decrease the maximum range at which these activities can take place. A useful way to think about the significance of masking for an animal is in terms of the reduction it causes in the efficiency with which these activities can be performed. Where a directional sound beam is produced, in the case of echolocation for example, the proportional decrease in effective range will be the most appropriate metric. For other acoustic tasks the decrease in effective area or volume should be considered. Mohl (1981) modelled masking effects in these terms. He found that proportional decrease in detection range was independent of the signal to noise ratio necessary for a particular task and that it was inversely related to the amount of background noise already in the environment. Even low levels of anthropogenic noise can significantly decrease the efficiency with which acoustic tasks can be performed, especially in regions that have low levels of "natural" background noise.

Masking effects have not been studied in large cetaceans. However, as they tend to produce lower frequency vocalisations we can assume that they will be most affected by low frequency noise.

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[1]Spectrum level is the level in dB re 1μPa^2/Hz.

3.1.1.4 Zones of hearing loss and injury

In terrestrial mammals, exposure to loud sounds can lead to temporary threshold shifts (TTS), permanent threshold shifts (PTS) and even non-auditory tissue damage, which may be fatal. For continuous sound sources, the intensity of the signal relative to the hearing threshold at that frequency, and the duration of the exposure can both affect the timing of the onset of TTS and PTS. As a general rule, if a sound can cause a TTS, a prolonged exposure to it will lead to a PTS. For impulsive sounds, the intensity, rise time, pulse duration, pulse repetition rate and duration of exposure can all affect the timing and extent of TTS and PTS (Richardson *et al*. 1995). In the case of extremely loud sounds there may be an instant PTS and even damage to non-auditory organs.

3.1.1.4.1 Hearing loss

Only recently have experiments to induce threshold shifts been conducted on captive marine mammals. Schlundt *et al.* (2000) measured the levels of intense tones required to cause a 6dB reduction in masked hearing threshold in two beluga and five bottlenose dolphins. To provide a more or less constant noise floor in the uncontrolled study location, San Diego Bay, an environment with significant and variable ambient noise levels, masking noise was broadcast as a background during experiments. Hence "masked thresholds", not absolute thresholds were measured and it should be noted that shifts in masked thresholds are generally smaller than the non-masked TTS that would be induced by the same level of fatiguing noise. 1 second tones centred at 0.4, 3, 10, 20, and 75 kHz were used as fatiguing noises used in this experiment. At 10 and 20kHz received levels of 192dB were required to cause a 6dB mTTS.

Au *et al.* (1999) subjected individuals to a 5-10kHz, octave band, fatiguing source for at least 30 minutes over a one hour period to explore the effects on bottlenose dolphins of longer exposures to broader band noise. They found no TTS at a received level of 171dB but a threshold shift of 12-18dB occurred at 179dB re 1µPa.

TTS has been induced, experimentally, in three pinniped species, harbour seal, northern elephant seal and Californian sea lions (Kastak & Schusterman, 1996, Kastak *et al* 1999). All three species showed a similar TTS of 4.6-4.9 dB, after 20-22 minutes of exposure at 65-70 dB above threshold level in the frequency range 0.1-2 kHz.

With the absence of reliable information on the levels of sound likely to cause hearing damage in most marine mammal species, it has been common practice to apply human Damage Risk Criteria (DRC) to other mammals (Richardson *et al*., 1995). Empirical studies have shown that humans exposed, in air, to continuous sound levels 80dB above their absolute hearing thresholds are likely to suffer TTS and eventual PTS. If this DRC is applied to marine mammals we would predict that at low frequencies (<500 Hz) TTS would occur at around 165-180 dB re 1µPa in phocids and at around 180-210 dB re 1µPa in small odontocetes.

These represent the DRC for exposure to continuous noise. For intermittent sounds, e.g. airgun blasts, the sound levels may be significantly higher, and will depend on the length and number of pulses received. Richardson *et al* (1995) estimated the DRC for 100 pulses to be 138 dB above absolute hearing threshold. This would be approximately 208 dB for a harbour seal and would be higher for small odontocetes. Such levels could be encountered within 100m horizontally from a large commercial airgun array.

It must be stressed that the validity of applying DRC derived from human studies to seals and odontocetes is unproven, though the recent TTS studies mentioned above suggest that this is not an unduly conservative assumption. Given the lack of information on threshold levels for large cetaceans it is not possible to suggest reliable DRCs for this group.

One example of noise induced damage highlights the problem of our lack of knowledge. Mass strandings of Cuviers's beaked whales linked to the use of powerful sonars had suggested that this species, and perhaps beaked whales generally are particularly vulnerable to being damaged by such sound sources (Frantzis *et al.* 1997). Whales killed in two recent well documented, but so far incompletely reported, standing in the Bahamas and the Canaries exhibited physical damage to a variety of structures associated with hearing and/or adjacent to air spaces and symptoms consistent with decompression sickness (Balcomb, 2001, Evans and England, 2001; Jepson *et al.* 2003)). It now seems likely that military sonar has been causing beaked whales to strand regularly since the sixties. This phenomenon is a cause for more general concern for several reasons:

1. Our knowledge of the anatomy and vocal behaviour of beaked whales provide no indications to their apparent vulnerability to noise;
2. Other species may be equally vulnerable, and this group may be vulnerable to other intense noise sources;
3. The mechanism that led to the injury and damage in these animals remains unknown.
4. Although with hindsight mass strandings appear to be linked in time and space with sonar deployments, it has taken 40 years for the association to be accepted.

3.1.1.4.2 Non-auditory effects

Blast injury

Very intense pressure waves, e.g. blast waves from explosions, have the potential to cause damage to body tissues. Damage is most likely to occur where substantial impedance differences occur, e.g. across air/tissue interfaces in the middle ear, sinuses, lungs and intestines.

Blast damage in marine mammals has been investigated using both submerged terrestrial mammals (Goertner,1982; Richmond, Yelverton *et al*., 1973; Yelverton, Richmond *et al*., 1973) and dolphin cadavers (Myrick, Cassano *et al*. 1990). Goetner (1982) estimated distance at which slight lung and intestinal injuries would occur in various marine mammals. Marine mammals are at greatest risk of injury when they are at the same depth as, or slightly above, the explosion. Risks drop off quite sharply above and below this depth. E.g. a harbour porpoise within 750m of an explosion of a 545kg charge at 38m is likely to suffer injury if it is at the same depth. But 30m above, or 43m below it, range for injury is predicted to have reduced to 500m "Safe" distances for larger animals are expected to be shorter than for smaller ones (Richardson *et al*. 1995). Young (1991) estimated safe ranges for marine mammals of three different sizes and for human divers. However, the "safe" distances for humans are substantially greater than those for an equivalent sized marine mammal. Richardson *et al.* (1995) have suggested that a precautionary approach would involve applyng the human value for all marine mammals. This would give a safe distance of 600m for a 1kg explosion, 900m for a 10kg explosion and 2km for a 100kg explosion.

Small explosive charges have been used to try to keep seals and small whales away from fishing gear, but with limited success. Humpback whales did not apparently move away from a construction site off the coast of Newfoundland where very large charges (200-2,000 kg) were used in construction work (Lien *et al*., 1993). However, two whales with severely damaged ears became entangled in fishing gear during this time, and it seems very likely that the explosions were at least partly responsible for their deaths (Ketten *et al*., 1993). Five of eleven Weddell seals sampled in the vicinity of blasting sites showed signs of inner ear damage (Bohne *et al* 1985,1986) and various otariid seals have been observed to be killed directly by explosives (Fitch & Young 1948, Trasky 1976). It would seem that although the behaviour of marine mammals is not much affected by explosions, and they don’t seems to move out of areas where blasting is taking place, they are nonetheless damaged by them.

It isn’t clear whether intense sound sources, such as seismic airguns or military sonar, could cause tissue damage. If so, this would be at very short range and small numbers of animals would be affected so severely.

Other effects

Air filled cavities within the body may be made to vibrate by intense, continuous wave underwater sound. Effects will be most marked at frequencies close to their resonant frequencies, which may vary with dive depth.

Human divers exposed to intense low frequency sound report feelings of vibration, discomfort and disorientation which may be linked with over stimulation of the vestibular system. It is likely that some of the effects reported by divers also occur in marine mammals. If so, they are likely to be evinced as behavioural disruption and disorientation.

Intense sound fields may also cause gas bubbles to develop around micronuclei within tissues. This could be a major concern for human divers whose body tissues become super-saturated from breathing compressed gasses during dives. Marine mammals do not breath compressed air, but the repetitive nature of their diving may lead to super-saturation (Ridgway and Howard, 1982; Houser, Howard and Ridgway, 2001)

Crum and Mao (1996) modelled the process of bubble growth in sound fields and concluded that a few minutes of exposure to 190 dB re 1µPa in the frequency range of 250-1000 Hz, could induce bubble formation which might lead to occlusion of capillaries. Thus, exposure to intense sound could be the critical factor triggering the bends in human divers or marine mammals with super-saturated tissues.

The observation of symptoms consistent with decompression sickness in beaked whales that stranded during a sonar related incident in the Canaries has led to speculation that sound exposre may lead to decompression sickness in cetaceans at lower received levels, perhaps by disrupting patterns of diving behaviour (Jepson *et al.*, 2003).

3.1.2 Responses of marine mammals to different types of noise

Many offshore activities are noisy. Two that are of particular concern in the SEA6 area are offshore oil and gas exploration and production and the construction and operation of wind farms. These activities involve a number of distinct phases and different loud and potentially disturbing and or even damaging sounds are produced in each. Wind farm development is a relatively new activity and knowledge of noise production and marine mammal responses associated with offshore oil and gas are much better known.

3.1.2.1 Oil and Gas

Three phases in the life of an oil and gas field can be identified

- **Exploration** (Seismic Survey, sidescan sonar),
- **Extraction** (Drilling, FPSO vessels, dynamically positioned vessels, sonar surveys, seismic site surveys, increased boat traffic, pipeline laying)
- **Decommissioning** (Explosive removals)

We very briefly describe some of the known and potential effects of noise and how these relate to various stages in the life of offshore oil and gas fields. We then try to identify the key knowledge gaps and prioritise the research needed to close them.

3.1.2.1.1 Seismic surveys

Exploration for oil and gas reserves usually requires a series of seismic surveys to characterise the sub-surface rock formations. This involves generating a series of high energy acoustic pulses in the water column. Sound pressure waves penetrate the seabed to produce seismic waves. By measuring the strength and time of arrival of reflected signals geophysicists can map the patterns of the reflective boundaries between different rock strata.

Airgun arrays are currently the commonest high energy source used for seismic survey; by 1985 more than 97% of marine seismic surveys used airguns (Turnpenny & Nedwell, 1994). Airguns produce sound pulses by rapidly venting high pressure gas from a chamber. The resulting oscillating bubble produces a series of pressure waves with a waveform that can be described as a damped cosine, with a reduced amplitude and slight delay in the initial peak (Malme *et al* 1986, Turnpenny & Nedwell, 1994; Barger & Hamblen, 1980). Airgun arrays are towed behind purpose built survey vessels. Guns are suspended at depths of 1 to 10 m and fired at intervals of several seconds, depending upon the speed of the survey vessel and the depth of the water. In general the boats travel at 4-5 knots (2-2.5 $m.s^{-1}$) and guns are fired at roughly 10 s intervals. The length of any firing sequence is dictated by the individual survey requirements, but it is not unusual for firing sequences to continue for many hours.

With the exception of explosives, airgun arrays are the most intense man made sound sources in the sea. The peak levels of sound pulses are much greater than the RMS levels from continuous sources such as ship noise or other industrial sources (Richardson *et al.*1995). However, because the sound pulses are short relative to the inter-pulse intervals, the total energy transmitted to the water may be lower than from some continuous sources. Direct comparisons between different types of sources are therefore difficult to interpret. Their ability to cause hearing damage will of course also depend on the characteristics of the receiver (marine mammal ears) which in many cases are poorly known. Broadband source levels of 248-259 dB re 1µPa @1m are typical of large arrays (Richardson *et al*. 1995).

Airgun arrays are designed so that signals from individual guns interact to maximise the downward transmission of the acoustic energy. Pressure fronts from different points in the array, which constructively interfere in the vertical plane, are unlikely to do so in the horizontal plane. So, effective source levels for horizontal transmission will generally be lower than for vertical transmission and will depend critically on the geometry of the array and the position of the receiver relative to it. A linear array of guns will generally have a much lower effective source level along its axis than to the side.

While these horizontal transmissions are lower than the levels directed vertical, they are very loud in absolute terms and relative to background levels. Estimated source levels for a 28.7 litre array at 'end-fire' aspect were 217dB re 1µPa@1m, and would be expected to be greater at the sides (Malme *et al.* 1983). Thus, significant amounts of acoustic energy may be transmitted horizontally through the water column (Richardson *et al*. 1995). Goold and Fish (1998) detected sound levels above background, at ranges up to 8km from a 37 litre array and detection ranges of 100s of miles are not uncommon.

Most of the energy in airgun blasts is below 200 Hz. Barger & Hamblen (1980) reported a bandwidth of 40Hz centred about 120 Hz. The peak spectral level (the SPL in 1Hz steps) occurred between 35 and 50 Hz, and decreased monotonically with increasing frequency; spectral level at 200Hz was 48dB down on the peak at 40Hz.

Source levels at higher frequencies are low relative to that at the peak frequency but are still loud in absolute terms and relative to background levels. Goold and Fish (1998) recorded 8 kHz sounds above background levels at a range of 8km from the source, even in a high noise environment.

The now extensive literature on the effects of seismic surveys on marine mammals have recently been reviewed by Gordon *et al.* (2004).

The reactions of some baleen whales (bowhead, grey, blue, fin, minke and humpback) to airgun noise have been studied in the field (summarised in Gordon *et al.* (2004) table 2). Clear behavioural responses, in terms of changes in surfacing patterns and movement away from the source when it was within 5 km of the whales, have been observed on a number of occasions (Malme *et al* 1983, 1984,1988, Richardson *et al* 1995). Reactions have been most pronounced when the whales were to the side of the arrays long axis. McCauley *et al*. (1998) showed consistent avoidance of airguns by humpback whales during a series of careful observations made in Australia. They found that mothers and calves were more vulnerable to disturbance than single animals. Fin and blue whales continued to call in presence of airgun noise (McDonald *et al* 1993). But McDonald also showed apparent avoidance by fin or blue whale. In UK waters, minke whales were sighted significantly further away from seismic vessels during periods of seismic array activity, suggesting active avoidance (Stone 1997,1998).
The hearing ability of toothed whales is relatively poor at low frequencies; nevertheless there is sufficient high frequency energy in the output of airgun to make them audible at distances of >10km. In addition seismic arrays carry a network of high frequency transponders for positioning. Goold (1996) presented evidence which he interpreted as showing large scale, long term changes in abundance and distribution of common dolphins during a survey and shorter term changes in behaviour between periods when guns were on and off within a survey block. In a later paper (Goold, 1998), seasonal changes in the distribution of dolphins in the same area at the same time were revealed that may explain some, or all, of the larger scale changes previously attributed to seismic surveys. If nothing else, this shows the difficulty of interpreting correlational studies made from platforms of opportunity.

Stone (1997, 1998, 2000, 2001) summarised reports from seismic vessels operating around the British Isles in which white-beaked and white-sided dolphins were seen less often during periods of seismic array activity. Conversely, more pilot whales were seen during periods of activity. This may indicate different avoidance strategies for deep diving animals like pilot whales. Sperm whales have been reported to stop calling and/or move away from distant airgun noise (Mate *et al* 1994, Bowles *et al* 1994). However, other observations suggest that sperm whales indicate rather little response to airguns (Swift *et al.*, 1999; Madsen *et al.* 2002).

Both harbour and grey seals showed short-term avoidance behaviour during controlled exposure experiments with small airguns (Thompson *et al* 1998). In both cases seals abandoned foraging sites and swam away from airguns but returned to forage in the same areas on subsequent days. By contrast, Harris *et al.* (2001) making observations from a seismic vessel operating in a shallow lagoon system in the Canadian Arctic, found no significant change in sightings rate between firing and non firing periods. Mean radial distance to sightings did increase, suggesting some local avoidance behaviour.

4D or time lapse seismic is rapidly becoming an accepted tool for reservoir management (Bouska *et al.* 2000, Koster *et al.* 2000). Data from sequential seismic surveys are compared, and differences between these “time lapse” datasets can be interpreted in terms of changes in the reservoir due to extraction activity. In addition, smaller scale “site surveys” may be made throughout the life of some oil fields. The effects of such repeated surveys are not known, but minor or even insignificant transient effects may become important if disturbance is repeated and/or intensified.

3.1.2.1.2 Vessel noise

There is substantial medium sized commercial and military shipping activity in the northern and southern parts of the SEA6 area and heavy traffic on ferry routes between Great Britain, Ireland and the Isle of Man. Noise from shipping is roughly related to vessel size; larger ships have larger, slower rotating propellers, which produce louder, lower frequency sounds. Various models for predicting shipping noise on the basis of speed and hull length have been developed and are summarised and compared in a review by Heitmeyer *et al.* (2004). Broadband source levels of ships between 55 and 85m are around 170-180 dB re 1 μPa@1m (Richardson *et al.*, 1995), with most energy below 1 kHz. Use of bow thrusters increases broadband sound levels, in one case by 11 dB and includes higher frequency tonal components up to 1 kHz (Richardson *et al*. 1995).

Richardson *et al*. (1995) reviewed the published literature on the response of marine mammals to vessel noise. Many toothed whales appear to be tolerant of vessel noise and are regularly observed in areas where there is heavy traffic. Sperm whales have been reported to react to vessels with powerful outboard engines at distances of up to 2 km. Humpback whales and right whales are also reported to avoid large vessels in some areas. Fin whales are reputed to ignore large vessels, but they respond to close (< 100 m) approaches by whale-watching vessels by spending less time at the surface and by making shorter dives. In general, whales show very little response to slow approaches by vessels, but they may swim rapidly away from vessels producing sound which changes in intensity or head directly towards them. There is little or no data on the response of seals to vessel noise out at sea. The fact that so many large whales are struck and killed by shipping, indeed this may be a major factor preventing the recovery of North Atlantic right whale populations, is testament to the fact that these animals don’t always detect and respond appropriately to shipping (Laist et al 2001, Nowachek *et al.* 2004). Increased shipping associated with offshore activities will increase the risk of ship-strike mortality for larger cetaceans.

3.1.2.1.3 Drilling noise

Drilling noise is generally low frequency, with highest levels being recorded from drill ships. Conventional drill platforms produce very low frequency noise, with strongest signals at around 5 Hz whereas drill ships produce noise with tonal elements up to 600 Hz (Richardson *et al* 1995, Greene, 1987).

There is little data on the reactions of marine mammals to drilling noise. Studies of grey and bowhead whales during migration suggest that they are generally tolerant of low level drilling noise from drill ships, but show some avoidance behaviour when sounds are loud (>20 dB above background) (Richardson *et al* 1985, 1990, Wartzok *et al*. 1989). Bowhead whales apparently reacted more to play backs than to real operational sounds. Migrating Grey whales have been shown to change course to avoid drilling noise (Malme *et al* 1983,1984).

There is no clear evidence of avoidance behaviour by small odontocetes to drilling noise. Bottlenose, Risso’s and common dolphins were seen close to oil platforms in the North West Atlantic, and sightings rates were similar in areas with and without rigs (Sorensen *et al* 1984).

There is no evidence that phocid seals avoid drilling platforms. Both bearded and ringed seals approached a simulated drilling sound source, coming within 50m of the source (Richardson *et al*. 1995).

Construction activities associated with establishing new platforms and pipelines will also generate noise. The loudest sounds are likely to be impulsive hammering sounds, associated with pile driving and pipe installation. Source levels can be high, levels of 131-135 dB re 1 μPa. were measured 1km from a hammer used for pipe installation on an artificial island (Richardson *et al* 1995). Such impulsive sounds have similar frequency components to those generated by airguns. There are no available data on effects of pile driving noise on marine mammals.

3.1.2.1.4 Decommissioning

In the latter stages of an oilfield's life, decommissioning of fixed structures, eg. large numbers of redundant well heads, becomes a frequent requirement. Decommissioning may involve some increase in shipping noise, in particular when noisy, dynamically positioned diving support vessels are used. Although there are alternative methods of installation removal, the use of explosives for underwater cutting and demolition is still common practice and poses a serious risk of inducing PTS, tissue damage, or death and is probably the greatest potential cause of acute mortality for marine mammals related to oil and gas exploration and production activities.

Ranges at which animals may suffer damage can be estimated using the models described above.

For cetaceans, risk of damage can be reduced by blasting only when observations indicate that there are no cetaceans within the danger area. However, probabilities of seeing cetaceans, especially small ones such as porpoises, may be low even in good weather. Decommissioning often takes place when sightings conditions are poor, and blasting may occur at short notice during the night or day. In sub-optimal sightings conditions such precautions will be ineffective. Passive acoustic monitoring used in addition to visual observation can very significantly increase detection probabilities for most cetaceans during some activities, such as seismic surveys(Gordon *et al*., 2000). Acoustic monitoring is compromised by the high noise levels produced by DP vessels, however (J. Gordon, unpublished data).

Mitigation procedures dependent on real time detection are even less appropriate for seals. Even in good sightings conditions seals are rarely seen at the surface and seals are rarely vocal. This problem is exacerbated by the fact that seals and possibly small cetaceans may be attracted to offshore structures, probably because they cause fish to aggregate and are good foraging locations.

Current demolition practices probably injure and may even kill seals regularly. No effective mitigation practices have been developed.

3.1.2.2 Wind farms

Somewhat similar phases can be identified in the operational life of a wind farm.

- **Site Survey** (Seismic Survey, sidescan sonar),
- **Construction** (vessel traffic, pile driving in many cases, dredging)
- **Operations** (Turbine noise)
- **Decommissioning** (Possible Explosive removals)

Nedwell and Howell (2004) review likely noise sources at windfarms during these different phases. Geophysical site survey work would probably involve boomers and sparkers. These are less powerful than the seismic arrays used during oil and gas exploration but there is little information on their source levels or other acoustic characteristics.

The construction phase will often involve pile driving of monopiles and dredging activity. Source levels of 215 dB re 1 μPa have been recorded during pile driving and measurements of suction and hopper dredgers have shown levels of up to 177 dB re 1 μPa in the range 80-200Hz. Harbour porpoises showed equivocal responses to construction activity at two sites in the Danish North Sea. At Horn's Reef, encounter rates increased whereas at Nysted they decreased by a factor of 8 indicating almost complete avoidance of the area during construction (Henriksen *et al.* 2004; Tougaard *et al.* 2004). Porpoise density from sightings was not significantly different between the year before and after construction work at Horn's Reef. There is little information on the responses of seals to such construction activity although a small sample of satellite tracked harbour seals continued to transit across Horn's Reef during construction work (Tougaard et al 2003).

Both harbour seals and harbour porpoises showed behavioural responses to playback of underwater noise from a simulated 2MW wind turbine (Koschinski *et al.* 2003). Porpoises did not approach as close and vocalised more when the source was on, although the behavioural responses were less dramatic than those seen in response to net pingers. Harbour seals also appeared to move away from the source, although the increase in median distance was small, 120m to 180m.

3.1.3 Research Requirements

It is clear from earlier sections that current understanding of the effects of noise on marine mammals and the risks that this may cause is in most cases rudimentary. In most scenarios the main uncertainty is in the form of the relationship between observable responses and population consequences. However, there are legitimate grounds for concern and appropriate application of the precautionary principle will be required. From an industry perspective, applying the precautionary principle in a situation with great uncertainty results in a restrictive management regime. Reducing uncertainty with focused research should allow the development of management schemes, which achieve conservation objectives while producing controls within which industry can operate. An appropriate risk assessment framework developed by Harwood (1999) for cetacean by-catch reduction can be applied to the marine mammal noise issue (Tyack *et al.* 2004). Without pre-judging the outcome of individual risk analyses we can identify broad areas of research, which are feasible and likely to be valuable.

- **Dose Response**. Research, often in the form of controlled exposure experiments, is neeeded to address key uncertainties about marine mammal acoustics, sensitivities to and effects of sound. The practical and ethical issues involved in designing and conducting controlled exposure experiments have been widely discussed within the marine mammal scientific community. An in-depth analysis of these issues has recently been presented by Tyack *et al.* (2004).

- **Exposure Risk.** Targeted surveys together with telemetry based studies of movements and behaviour of selected species should be linked with oceanography and monitoring of other components of the ecosystem to identify important habitats and explore why they are important and improve our ability to predict marine mammal distributions at sea, year round.

- Assessing **medium** or **long term consequences** of particular activities will require long term monitoring of status and distribution of populations of interest. To be useful this must be in place before new activities develop, i.e. managers must be pro-active in establishing monitoring. There are currently no monitoring schemes for any offshore cetacean populations in UK waters that would be capable of detecting even large changes in population levels. Achieving this cost effectively will require the development of new methods; passive acoustic techniques are one promising possibility for some species. Even with such programs, establishing direct cause and effect will be difficult and necessarily retrospective.

- **Development of effective mitigation**. Current mitigation practices are largely based on "common sense" measures and little work has been done to establish whether they work and/or could be made more effective. It will always be prudent to utilise effective mitigation measures, if they are easy to apply, even when harmful effects of noise have not been proven.

Addressing these knowledge gaps will require a substantial research program. Partnerships amongst noise producers (e.g. industry, renewables, shipping, military) should be established. While this may seem a daunting scientific task, it is in reality trivial compared to the engineering challenges that offshore engineers face and overcome every day.

3.2 Contaminants

3.2.1 Background

Marine mammals are exposed to a variety of anthropogenic contaminants. The main route for exposure is through the food chain and as these mammals are top predators they are at particular risk from contaminants which biomagnify through the food chain (i.e. are found at increasing concentrations at higher trophic levels). Most research has focussed on two main groups of contaminants: the persistent organic pollutants (POPs) and the heavy metals. However, there is some information on other contaminants including the polyaromatic hydrocarbons (PAHs) and the butyl tins.

3.2.1.1 Persistent organic pollutants

This group of chemicals includes the organohalogenated compounds (such as the polychlorinated biphenyls - PCBs), the dichlorodiphenyltrichloroethanes (DDTs), polybrominated biphenyls (PBBs), polybrominated diphenyl ethers (PBDEs), chlordane, toxaphene, the cyclodienes (such as aldrin and dieldrin), and polychlorinated terphenyls (PCTs). Of these the occurrence and potential effects of the organochlorine compounds (OCs) are by far the best investigated. Many chlorinated pesticides are also included in this group. The significance of these compounds for marine mammals is that:

- they are highly lipophilic and hydrophobic.
- they are differentially accumulated in the lipids of animals and are therefore sometimes found at high concentrations in marine mammal blubber.
- they are chemically very stable and persistent, many compounds being resistant to metabolic degradation.
- they are present as many different isomers and congeners, and comprise hundreds of different chemical formulations which may have different behaviours and toxicities.
- they have reproductive and immunosuppressive effects, and many are ‘endocrine disrupters’ - acting as hormone agonists or antagonists.

In marine mammals most of these compounds are sequestered into the blubber so much of the determination of POP residues has concentrated on this tissue. Between 90 and 95% of the total burden of many POPs, particularly PCBs and DDTs, are found in the blubber because of its high lipid content (Aguilar 1985). The compounds are essentially bound away in this tissue until the tissue is mobilised for energy requirements or for the production of milk. This aspect of the life cycle of marine mammals means they may be re-exposed to the contaminants when they call upon their blubber reserves during periods of natural fasting. This is particularly the case for animals that do not feed during the breeding season, and means that females can offload a large proportion of their contaminant burdens to their offspring (Debier *et al.,* 2003). Other POPs may behave slightly differently and recent studies have shown PBDEs to be at high concentrations in the adrenal glands as well as the fat stores (Klasson Wehler *et al.* 2001). These compounds, particularly the tetra and penta group, are now found in the blubber of seals and cetaceans from UK waters (Allchin *et al.,* 1999) and in studies on juvenile grey seals, larga and ribbon seals are associated with thyroid hormone disruption (Hall *et al.*, 2003, Chiba *et al.,* 2001).

Many factors can affect the occurrence and distribution of POPs in marine mammals. These include diet, foraging strategy, age, species, sex, and nutritional condition. These confounding variables need to be considered when interpreting the significance of reported tissue concentrations (Aguilar *et al.* 1999). The large majority of persistent organic pollutants do not arise from oil exploration and production.

3.2.1.2 Heavy metals

The heavy metals are a heterogeneous group of compounds. Some are bioaccumulative (such as mercury) whereas others appear not to be (such as cadmium, chromium, nickel and copper). Data on zinc and lead in various species in the marine food web are equivocal (Muir *et al.* 1992). The liver, kidney and bone are the main target organs for heavy metals and levels can vary widely depending on the geographical location of the species. Marine mammals appear be protected against the effect of many heavy metals because of the presence of metallothioneins (Bowles, 1999). These are proteins whose production is induced by the occurrence of divalent cations such as Hg++, Cd++, Cu++ and Zn++. These proteins have a high affinity for binding such cations, which sequester the metals to form biochemical complexities with reduced toxicities. High levels of liver cadmium have been reported in a number of cetacean species and this probably reflects dietary preferences. High concentrations of cadmium are accumulated in the liver and gonads of cephalopods (Hamanaka *et al.,* 1982) and Antarctic krill (Honda *et al.,* 1987), the prey species of many cetaceans.

3.2.1.3 Polyaromatic hydrocarbons (PAHs)

The potential for biomagnification of PAHs is low, because fish (the main food of marine mammals) are good metabolisers of PAHs compared with molluscs. Bioaccumulation of these compounds will be lower in fish-eating marine mammals than those that feed on cephalopods or small crustaceans and plankton. Seals and cetaceans also have a detoxification enzyme system in the liver, which is induced in response to various xenobiotic compounds, including PAHs. This system (known as the mixed function oxidase, MFO or cytochrome P450 system) can convert parent compounds to excretable metabolites largely by the addition of a hydroxyl group (Sipes and Gandolfi, 1991). This biotransformation of compounds may, however, be toxic if the metabolites produced are bioactive. In addition the rate at which transformation occurs is critical. If the non-toxic pathway is saturated, minor pathways, which produce further toxic intermediates, become involved. One isoform of the cytochrome P450 enzyme system is also called aryl hydrocarbon hydroxylase because it plays a role in the metabolism of PAHs. The regulation of certain cytochrome P450 enzymes involves a ligand-activated transcription factor known as the Ah (aromatic hydrocarbon) receptor (Timbrell, 1991). This has been investigated in a very limited number of marine mammals but induction and activity of the cytochrome enzymes is widely used as a marker of exposure to inducers such as PAHs and PCBs (Troisi and Mason 1997, Mattson *et al.* 1998, Wolkers *et al.* 1999).

In 1995 the North Atlantic Marine Mammal Commission held a conference on Marine Mammals and the Marine Environment in Lerwick, Shetland. The papers from this meeting were published in a Special Issue of Science of the Total Environment (Vol 186, Nos 1 and 2, 1996). This included studies resulting from the impact of the 1993 *Braer* oilspill. Hall *et al* (Hall *et al.,* 1996) found an increase in respiratory symptoms among the grey seals hauled out in the area of the spill compared to a control site. However, this finding was correlative and causal relationship with exposure to oil on the surface of the sea was not established. An ecological steering group was also established to monitor the environmental impact of the *Braer* spill (Ritchie & O'Sullian, 1994). Their conclusions were that the impact on the environment and ecology of South Shetland had been minimal and adverse impacts that did occure were both localised and limited. A recent study on PAHs in blue mussels from the coastal waters of Shetland and Orkney (Webster *et al.,* 2003) reported that the bioavailability of these compounds from the sediment was low.

3.2.1.4 Butyl Tins (Tributyl tin (TBT), Dibutyl tin (DBT) and Monobutyl tin (MBT))

These groups of compounds have only quite recently been identified in marine mammals, despite knowledge about their toxicity and endocrine disrupting effect in invertebrates and fish having been available for a number of years (Iwata *et al.* 1994). Results of analysis in liver samples from stranded animals have indicated a widespread contamination around the coasts of England and Wales; indeed TBT and DBT have been found in open ocean cetacean species, which indicates a wider contamination of the sea by these compounds (Law *et al.* 1999). However, recent data on temporal trends of DBT, TBT and MBT in harbour porpoises from Norwegian waters (Berge *et al.,* 2004) have found a decrease in tissue concentrations following the restrictions on the use of TBT on small boats in the late 1980s.

3.2.2 Sources of Data

There is a huge body of literature on contaminants in marine mammals worldwide. For example, the US Marine Mammal Commission (Long, 2000) recently issued a bibliography containing over 1,200 references. In addition, there are many good reviews on the levels of contaminants found, the patterns of different compound groups in various species and the temporal changes in concentrations. The most comprehensive are: Aguilar and Borrell (1997), Geraci and St. Aubin (1990), Hall (2001), Law (1996), O'Shea (1999), Reijnders, Aguilar and Donovan (1999).

3.2.3 Knowledge

Our knowledge of the effects of contaminants on marine mammals remains limited. This is largely due to the difficulties involved in investigating the responses in wild animals. Whilst it is relatively easy to determine the tissue concentrations of various compounds in dead and live-captured animals, the significance of these concentrations for the health and ultimate survival of the individuals remains difficult to assess. A few studies have investigated the responses to exposure on animals in captivity, comparing responses in exposed and control groups and some associations between dysfunction and contaminant exposure have been reported in free-living individuals and populations.

3.2.3.1 Persistent organic pollutants

Two observations on wild populations suggested that the uptake of POPs by marine mammals could have toxic effects similar to those reported in laboratory species. The first was the report that a serious decline in the population of harbour seals in the Wadden Sea might be due to the reproductive effects of contaminant exposure (Reijnders 1980; Reijnders 1984). Reijnders (1986) addressed this more directly in an experiment using captive harbour seals. Two groups of female harbour seals were fed fish from different areas one contaminated with OCs the other much cleaner. Reproductive success was significantly lower in the group fed contaminated fish and failure was thought to occur at the implantation stage of pregnancy. The second effect was investigated following the outbreak of phocine distemper among harbour and some grey seals in European waters, in which differential mortality rates were reported among harbour seal populations around the UK coast (Hall *et al.* 1992a). This observation led to a study of the OC contaminant burdens among animals that were victims and survivors of the epidemic. The results suggested that animals that died of the disease had higher blubber levels of OCs than survivors, although it was not possible to control for all potential confounders (Hall *et al.* 1992b). Interestingly this finding was also repeated in a study of contaminant burdens in striped dolphins following a similar outbreak of dolphin morbillivirus in the Mediterranean Sea in 1990 (Aguilar and Borrell 1994). Later studies by Ross *et al.* (1995) and DeSwart *et al.* (1994) found evidence for immunosuppression in a group of captive harbour seals fed contaminated fish compared with animals fed clean fish. Natural killer cell activity (white blood cells that are particularly required in the defence against viral infection) in particular was depressed and lymphocyte function measured *in vitro* was lower in the exposed group.

Bergman and Olsson (1985) also reported the occurrence of adrenocortical hyperplasia, hyperkeratosis and other lesions in grey (*Halichoerus grypus*) and ringed (*Phoca hispida*) seals from the Baltic. The pathologies seen were indicative of a disease complex involving OCs and hormone disruption, a finding also demonstrated in laboratory animals (Fuller and Hobson, 1986). Other abnormalities associated with high exposure to PCBs include skull and bone lesions in grey seals (Bergman *et al.* 1992); (Zakharov and Yablokov 1990) and harbour seals from the Baltic (Mortensen *et al.* 1992).

More recently a study by Jepson *et al.* (1999) indicated that harbour porpoises (*Phocoena phocoena*) stranded along the coast of England and Wales which had died of infectious diseases had significantly higher concentrations of PCBs in their blubber than those which died from trauma, such as by-catch in fisheries or ship strikes.

3.2.3.2 Heavy metals

Of the toxic elements studied those of most importance are cadmium, lead and mercury.

Cadmium can sometimes be found at high concentrations in the livers of marine mammals (Law *et al.*, 1991), but there does not appear to be any published information on cadmium-induced pathology in marine mammals. These high levels are probably due to naturally high cadmium concentrations in prey species such as squid (Bustamante *et al.* 1998). Metallothionen sequestration appears to protect marine mammals from cadmium toxicity.

Lead is also found in many marine mammal tissues, particularly liver and kidney, but not at concentrations that are cause for concern (Law *et al.* 1991). Bone is a long-term storage target organ for lead, although again no associated histopathological lesions have been reported. Smith *et al.* (1990) used isotopic ratios to show that the source of lead in some marine mammal species has shifted from naturally derived lead to anthropogenic aerosol-dominated forms.

Mercury can bioaccumulate through the food chain and is a well-recognised neurotoxin. Its interaction with selenium appears to be protective and various laboratory studies have shown that toxic effects of mercury were prevented or reduced by simultaneous exposure to selenium (Cuvin-Aralar and Furness, 1991). Some of the concentrations of mercury in the liver of marine mammals have exceeded those known to be toxic to other mammals but lethal effects have not been observed (Britt and Howard, 1983). Marine mammals seem able to metabolise mercury from its toxic methyl form found in fish. Although marine mammals can tolerate high concentrations of mercury immobilised as the selenide, methylmercury poisoning has been reported in a ringed seal an area of heavy industrialisation (Helminen *et al.* 1968).

Copper is an essential dietary element for mammals and a wide range of concentrations has been reported in marine mammals. In the UK levels of between 3 and 30 mg/kg have been measured in the liver of stranded animals and it has been suggested that this may represent the normal range of homeostatic control in marine mammals (Law, 1996).

3.2.3.3 Polyaromatic hydrocarbons (PAHs)

Polyaromatic hydrocarbons have rarely been studied in the tissues of marine mammals but where measurements in muscle tissue, liver and blubber have all generally been below 1µg/g. Law and Whinnett (1992) investigated PAHs in the muscle tissue of harbour porpoises stranded around the UK coast and found total PAH concentrations ranging from 0.11-0.56 ug/g wet weight and 0.47-2.4 µg/g wet weight Ekofisk crude oil equivalents. Specific PAHs were 2-4 ring compounds (naphthalenes, phenanthrenes, anthracene, fluoranthene and pyrene). Bond (1993) found similar compounds in the blubber of seals from the Moray Firth. The PAH levels in this species displayed large variations, with grey seals having higher levels than harbour seals (mean 15.78 (SD 25.54) µg/g dry weight in grey seals 2.67 (SD 5.77) in harbour seals).

The effects of PAHs on marine mammals are reviewed in Geraci and St Aubin (1990) and various responses from effects on the central nervous system, eyes and mucous membranes, thermal regulatory effects from fouling of fur, to induction of metabolic enzyme systems and effects on hormone levels were reported. These effects are largely observed following short-term acute exposure. Less is known about the effects of long-term chronic exposure. Although studies have shown that fish readily convert aromatic hydrocarbons to metabolites such as dihydrodiols and phenols (Krahn *et al.* 1984) and therefore fish-eating mammals may receive lower doses of parent PAHs, cetaceans which feed lower down the food chain are likely to be most at risk. The carcinogenic nature of certain PAHs, such as benzo(a)pyrene has been a concern for example (Beland *et al.* 1993) reported the detection of benzo(a)pyrene adducts in DNA from Beluga whales in the Gulf of St Lawrence, but there is little evidence for the substantial exposure of marine mammals in UK waters to this compound. One of 27 UK harbour porpoises examined by (Law and Whinnett 1992) between 1988 and 1991 was considered to have died as a result of a tumour.

Butyl tin compounds, largely tri- and di-butyl tin have now been reported in the liver and blubber of pelagic cetaceans and marine mammals in UK waters (Law *et al.* 1999), but no reports on their effects have been published.

3.2.3.4 Oil spills

Direct mortality from contaminant exposure has rarely been reported, and has usually been associated with major oil spills such as the *Exxon Valdez* in Alaska in 1989. High concentrations of phenanthrene (PHN) and naphthalene (NPH) were reported in the bile of oiled harbour seals (*Phoca vitulina*) collected following the spill (up to 23 times higher than in control seals) and high concentrations of PAHs in the blubber (up to 400 ppb) (Frost and Lowry 1993). Due to the condition of many of the carcasses examined it was difficult to attribute cause of death to oil toxicity, but many animals exposed to oil did develop pathological conditions including brain lesions. Additional pup mortality was also reported in areas of heavy oil contamination compared to unoiled areas.

More generally, marine mammals rely on their blubber for insulation and are thus less vulnerable than seabirds to fouling by oil (Geraci and St Aubin, 1990). However, they are at risk from hydrocarbons and other chemicals that may evaporate from the surface of an oil slick at sea within the first few days. Seals often barely raise their nostrils above the surface of the water when they breathe, so any seal surfacing in a fresh slick is likely to inhale vapours. Cetaceans also typically inhale close to the surface. Symptoms from acute exposure to volatile hydrocarbons include irritation to the eyes and lungs, lethargy, poor coordination and difficulty with breathing. Individuals may then drown as a result of these symptoms.

Grey and harbour seals come ashore regularly throughout the year between foraging trips and additionally spend significantly more time ashore during the moulting period (February-April in grey seals; August in harbour seals) and particularly the pupping season (October-December in grey seals; June-July in harbour seals). Animals most at risk from oil coming ashore on seal haul-out sites and breeding colonies are neonatal pups. These animals are born without any blubber and rely on their prenatal fur (the white lanugo in grey seals) and metabolic activity for thermal balance. They are therefore more susceptible than adults to external oil contamination (Ekker, Lorentsen and Rov, 1992). Grey seals pups remain on the breeding colonies until they are weaned and unlike adults or juveniles, would be unable to leave the contaminated area. Females may also abandon contaminated pups during an oil spill, leading to starvation and premature death.

3.2.3.5 Oil dispersants

There have been no specific studies on the direct acute or chronic toxicity of oil dispersants to seals and cetaceans. The toxicity of oil spill dispersants to aquatic organisms under laboratory conditions appears to relate primarily to the chemical composition of the individual dispersant. For example, the type of solvent, aromatic content (is oil based dispersants), functional group(s) and molecular structure of the surfactants, chemical stability, and the concentration. Other factors that are important in oil spill dispersant aquatic toxicity are the duration of exposure of the organism, water temperature of the sea, oxygen content of the seawater, organism species/type, organism age, organism stage of growth/development, organism health. Indirect effects may occur if the prey items of marine mammals further down the food chain are affected.

3.2.4 Gaps in knowledge

With respect to the impact of oil exploration activities on contaminant exposure in marine mammals, no recent studies on the uptake of PAHs by marine mammals around the UK or pelagic cetaceans exist, and there is no information on the potential effects of longterm chronic exposure. Further studies are needed to determine current and background exposure levels in a variety of species and their prey, particularly prior to oil exploration and production activities within marine mammal foraging areas. In addition we have no information on alkylated phenols in marine mammals. PAH sources from exploration and production are not now very significant (100 t/yr, OSPAR 2000) and most North Sea PAHs come from terrestrial combustion sources (> 7000 t/yr).

Further work on the uptake and effect of polybrominated diphenyl ethers (the brominated flame retardants) on marine mammals is clearly needed, particularly as higher levels of these compounds, in a variety of invertebrates and fish as well as marine mammals, have been reported in the UK than elsewhere in Europe (Zegers *et al.* 2001). However, these compounds are not linked to oil exploration and production.

Few investigations on contaminants in marine mammals have been able to address the effects at the population level. This is particularly important where, from dose-response studies, contaminants or mixtures of contaminants are likely to have effects on survival or fecundity. In particular we need to develop a framework in which the *population* risks can be evaluated. This is been investigated to some extent (Harwood *et al.* 1999) but more detailed empirical information is required. Early simulations suggest that mathematical and statistical models would be of great benefit to any risk assessment procedure.

3.3 Disease

3.3.1 Background

It has long been known that marine mammals harbour large numbers of macroparasites, such as nematodes and cestodes as well as various ectoparasites (Margolis 1954, Reijnders *et al.* 1982, Baker and

Martin 1992). However, these parasites usually do not cause severe harm unless the animals have an underlying primary disease or are stressed for other reasons.

There have been outbreaks of viral disease epidemics among seals and cetaceans worldwide and these seem to have increased in frequency, particularly in the US, in recent years (Harvell *et al.* 1999). In UK and European waters major epidemics from phocine distemper in harbour and grey seals (PDV) and morbillivirus (DMV) in Mediterranean striped dolphins were widely documented in 1988 and 1990 respectively (Dietz *et al.* 1989, Aguilar and Raga 1993). These were followed by other mass mortalities in the late 1990s, such as among Mediterranean monk seals, whose cause was disputed although some evidence pointed to PDV as the primary cause (Osterhaus *et al.* 1997, Harwood 1998, Hernandez *et al.* 1998). More recently a second major PDV outbreak occurred in Europe and the UK in 2002. This has led to a number of studies in which the grey seal, less susceptible to the disease than harbour seals, are being investigated as potential vectors for PDV.

Apart from such high profile, large-scale epidemic diseases, seals are known to suffer from a range of viral and bacterial infectious diseases.

3.3.2 Sources of data

A number of reviews of infectious diseases in marine mammals have been published and the major sources are given below: Dierauf and Gulland (2001), Van Bressem, Van Waerebeek and Raga. (1999), Harwood and Hall (1990), Visser, Teppema and Osterhaus (1991) (Gulland & Hall, In Press).

3.3.3 Knowledge

3.3.3.1 Viruses

Table 7 indicates the viral infections that have been reported among marine mammals. The morbilliviruses and influenza viruses have accounted for large scale mortalities around the world.

3.3.3.2 Bacteria

A range of organisms has been cultured from healthy and sick marine mammals and many are secondary infections in malnourished and starveling animals, particularly juveniles. (Baker 1984) found that 40% of the grey seal pups died of infections such as peritonitis and septicaemia. *Corynebacterium* and *Streptococcus* accounted for the majority of infections and during the 1988 PDV epidemic *Bordetella* organisms were isolated from a large proportion of the sick animals but was not found in healthy individuals (Munro *et al.* 1992). *Mycoplasmas* were also isolated in sick animals from the Wadden Sea and are thought to be the causative organism of seal finger (Baker *et al.* 1998).

More recently *Brucella maris* has been isolated in seals and cetaceans from the North sea (Patterson *et al.* 1998). Bacteriological investigations have shown these organisms to be significantly different from other Brucella species. Serological studies of seals in particular have shown evidence of widespread infection in ten species of cetaceans and four species of seal. However, pathological changes associated with B. maris solations have only been found in a total of nine cetacean and two seals, largely sub-blubber abcessation and pneumonia. A laboratory worker was infected with one isolate indicating that this is a potential zoonotic agent (Patterson *et al.* 1998). However, in 1999 a report of Brucella inducing abortions in Bottlenose dolphins was reported. The causative organism was specific to this species and was name *Brucella delphini* (Miller *et al.* 1999). It is not known how these two isolates are related or if they are indeed the same organism.

Leptospira pomona has also been found in some marine mammals but has not been reported in those from UK waters. This organism can be highly pathogenic and has been associated with episodic outbreaks among California sea lions in which it causes abortion (Buck and Spotte 1986).

Tuberculosis (*Mycobacterium tuberculosis*) has been diagnosed in various fur seal and sea lion species, largely in Australia, New Zealand and on the Argentine coast (Cousins *et al.* 1990, Forshaw and Phelps, 1991, Bastida, 1999). To our knowledge it has not yet been reported among European marine mammal species.

Anthropogenic pathogens are largely found in marine mammals from the discharge of untreated sewage or effluent from facilities, which contain domestic animals. Salmonella species associated with man or his domestic animals have been cultured from marine mammals directly or their faeces, particularly *Salmonella bovis-morbificans* and *S. enteriditis* (Baker *et al.* 1995). In some cases these have been associated with pathologies and septicaemia. It was found that between 1.4 and 11.8% of grey and harbour seals in the East coast of England taken into rehabilitation centres were positive for Salmonella. Although the origin of some of these organisms is not known, *S. bovis-morbificans* is generally specific to cattle and may indicate contamination of marine mammals by anthropogenic organisms.

3.3.3.3 Toxic Algae (Harmful Algal Blooms)

There have been a number of incidents in the US, and more recently on the west coast of Africa, where toxins produced by algae have been associated with mortalities of marine mammals. Incidents include dinoflagellate toxins in Florida manatees and Humpback whales (Geraci *et al.* 1989, O'Shea *et al.* 1991), brevetoxins in Bottlenose dolphins (Geraci 1989), saxitoxin in sea otters (DeGange and Vacca 1989), and ciguatoxin in Hawaiian monk seals (Gilmartin *et al.* 1987). More recently a mass mortality among California sea lions was linked to *Pseudo-nitzschia australis* that produces domoic acid, a neurotxin, which was found in fish and in the body fluids of the sea lions that died (Scholin *et al.* 2000).

3.3.4 Gaps in Knowledge

Whilst there has been a considerable amount of recent research on infectious and pathogenic diseases in marine mammals, particularly in the 10 years following the morbillivirus outbreaks of the 1980s, we know surprising little about the incidence of infection in European seal populations. Strandings schemes designed to determine mortality rates and causes of death of marine mammals around the UK have been forced by limited funding to concentrate their efforts on cetaceans rather than seals. Serological surveys could provide invaluable data on the exposure and immunity of populations to various diseases and this approach was proved useful in estimating the size of the susceptible harbour seal population in the UK before the recent outbreak of PDV in Europe (Thompson *et al.,* 2002).

A small-scale survey of anthropogenic bacteria such as *Salmonella* has been conducted in seals but we have no information on the occurrence of anthropogenic viruses such as enteroviruses. Indeed some pilot work suggested that other sewage related organisms such as *Campylobacter* may be a risk for marine mammal health but this study has not been followed up.

Table 7. Viruses in marine mammals – From Visser *et al.* (1991).

Virus Family	Virus	Species
Adenoviridae	Sea Lion Hepatitis Virus	California sea lion Sei whale
Herpesviridae	Alphaherpesvirinae Phocine herpesvirus-1 Uncharacterised herpesvirus	Harbour seal California sea lion Beluga whale Harbour porpoise
Poxviridae	Seal poxvirus Parappoxvirus Orthopoxvirus	Harbour seal Grey seal California sea lion Northern fur seal S. American sea lion Bottlenose dolphin White sided dolphin Harbour porpoise Grey seal
Picornaviridae	Picornavirus	Harbour seal Grey whale
Caliciviridae	San Miguel sea lion virus Calicivirus	California sea lion Northern fur seal Northern elephant seal Pacific walrus Stellar sea lion Grey seal Bottlenose dolphin Fin whale Grey whale Bowhead whale Sperm whale
Orthomyxoviridae	Influenzavirinae H7N7 Influenza A virus H4N5 H13N9 H13N2	Harbour seal Pilot whale Striped dolphin
Paramyxoviridae	Canine Distemper Virus (CDV) Phocine Distemper Virus (PDV) Porpoise Morbillivirus Dolphin Morbillivirus	Crabeater seal Baikal seal Harbour seal Grey seal Ringed seal Harp seal Harbour porpoise Striped dolphin
Coronaviridae	Coronavirus	Harbour seal
Rhabdoviridae	Rabies virus	Ringed seal
Retroviridae	Spumavirus	California sea lion
Papovaviridae	Papillomavirus	Burmeister's porpoise Cetacean spp.

4. BYCATCH AND OTHER NON-OIL MANAGEMENT ISSUES

4.1 Bycatch

The accidental capture of marine mammals in fishing gear is an issue of some current concern throughout EU waters, and beyond. Work by the SMRU since 1993 has been targeted at determining accidental catch ('bycatch') rates of marine mammals in several fisheries in UK waters. Similar work has been conducted by DIFRES for Danish vessels fishing in the North Sea (Vinther 1999, Vinther and Larsen 2002).

The SEA 6 area is exploited by fishing vessels from several EU and other states, and there is a lack of detailed information on the activities of these vessels that hinders any assessment of the overall scale of bycatches in this area. However, compared with some other areas around the UK, the levels of fishing effort by gear types that are generally considered dangerous to marine mammals (pelagic trawls and gillnets) are low. There has been very little monitoring of bycatch in this area.

It is likely that the greatest numbers of marine mammals caught in fishing gear in this region (as in most other areas) are taken in static nets, mainly gillnets and tangle nets. These nets ensnare bottom feeding seals and cetaceans almost wherever they are used. Thomas (2003) has reviewed the known extent of interactions between marine mammals and net fisheries in Wales, and reported that between 1990 and 2002 there had been 35 records of porpoises stranded on Welsh coasts that were diagnosed as having died in fishing gear, in addition to two common dolphins and a single bottlenose dolphin. Northridge and Thomas (2004) noted that because gill and tangle net fishing effort is so low in the Irish Sea, even assuming relatively high bycatch rates for porpoises, it is very unlikely that more than 88 porpoises would be taken per year.

4.2 Other issues

Another potential source of mortality to cetaceans may be through collisions with shipping. Whales are occasionally reported to be struck and killed, especially by fast-moving ferries, in other parts of the world, and smaller cetaceans can also be impacted by propeller strikes from small vessels. In some areas, where ships are numerous and cetacean numbers are depleted, this can be a serious cause for concern. There are very few data with which to estimate the frequency of such events, and consequently this has not been identified as a significant source of additional mortality in this region.

5. CONSERVATION FRAMEWORKS

5.1 Cetaceans

5.1.1 Europe

All cetacean species are listed in Annex IV (Animal and Plant Species of Community Interest in Need of Strict Protection) of the European Commission's Habitats Directive. Under Annex IV, the keeping, sale or exchange of such species is banned as well as deliberate capture, killing or disturbance.

The harbour porpoise and the bottlenose dolphin are also listed in Annex II of the Habitats Directive. Member countries of the EU are required to consider the establishment of Special Areas of Conservation (SACs) for Annex II species. Candidate SACs have been established for the bottlenose dolphin, one in the Moray Firth, Scotland and two in Cardigan Bay, Wales (see Figure 20). No candidate SACs have yet been established for the harbour porpoise.

The Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS) was formulated in 1992 and nine European countries including the UK are now Parties to the Agreement. Under the Agreement, provision is made for protection of specific areas, monitoring, research, information exchange, pollution control and heightening public awareness. Measures cover the monitoring of fisheries interactions and disturbance, resolutions for the reduction of by-catches in fishing operations, and recommendations for the establishment of specific protected areas for cetaceans. The UK applies the provisions of ASCOBANS to waters under its jurisdiction.

All cetacean species are listed on Annex A of EU Council Regulation 338/97 and are therefore treated by the EU as if they were on CITES Appendix I, thus prohibiting commercial trade.

5.1.2 UK

In British waters, all species of cetacean are protected under the Wildlife and Countryside Act 1981 and the Wildlife (Northern Ireland) Order 1985. Whaling is illegal under the Fisheries Act 1981.

Guidelines to minimise the effects of acoustic disturbance from seismic surveys, agreed with the oil and gas industry, were published by the then Department of the Environment in 1995 and are revised regularly. Member companies of the UK Offshore Operators Association (UKOOA) have indicated that they will comply with these Guidelines in all areas of the UK Continental Shelf. Under the Guidelines there is a requirement for visual and acoustic surveys of the area prior to seismic testing to determine if cetaceans are in the vicinity, and a slow and progressive build-up of sound to enable animals to move away from the source.

In 1999, the then Department of the Environment, Transport and the Regions produced two sets of guidelines aimed at minimising disturbance to cetaceans. The first, Minimising Disturbance to Cetaceans from Whale Watching Operations, is aimed at tour operators and members of the public involved in whale, dolphin and porpoise watching activities. The second, Minimising Disturbance to Cetaceans from Recreation at Sea, is aimed at anyone involved in any recreational activity in UK coastal waters who may incidentally encounter cetaceans.

5.2 Seals

5.2.1 Europe

The grey and harbour seal are listed in Annex II of the Habitats Directive under which member countries of the EU are required to consider the establishment of Special Areas of Conservation (SACs). A number of terrestrial candidate SACs have been established for grey and harbour seals around the coast of the UK, three of them for grey seals are in Wales (see Figure 20). There are currently no marine candidate SACs.

All seal species are listed on Annex A of EU Council Regulation 338/97 and are therefore treated by the EU as if they were on CITES Appendix I, thus prohibiting commercial trade.

5.2.2 UK

Under the Conservation of Seals Act, 1970, grey and harbour seals in the vicinity of fishing nets can be killed to prevent damage to the nets or to fish in the nets. Both species are protected during the breeding season: September-December in the case of grey seals; June-August in the case of harbour seals. However, licences to kill seals may be granted for any time of the year for specific listed purposes.

Under the Act, the Natural Environment Research Council (NERC) has a duty to provide scientific advice to government on matters related to the management of seal populations. NERC has appointed a Special Committee on Seals (SCOS) to formulate this advice so that it may discharge this statutory duty. Formal advice is given annually based on the latest scientific information provided to SCOS by SMRU. SMRU also provides to government scientific review of applications for licences to shoot seals, and information and advice in response to parliamentary questions and correspondence.

6. CONCLUSIONS

- The SEA6 area is an important area for marine mammals. A relatively small but fairly discrete population of grey seals utilises all but the northwest Irish Sea. Harbour seals are found primarily in the far north of the area. Harbour porpoises are seen year round throughout the area and bottlenose dolphins are present year round off Wales. Minke whales, Risso's dolphins and common dolphins are regularly seen in summer mainly in the far south.
- Marine mammals are important predators in this region. Because of the link between the abundance and availability of fish prey and the reproductive success of marine mammals, changes in the availability of principal forage fish may be expected to result in population level changes of marine mammals. It is currently not possible to predict the extent of this.
- Seals are sensitive to the low frequency sounds generated by oil exploration and production. Small cetaceans are relatively insensitive to low frequencies. Circumstantial evidence suggests that large whales may have good low frequency hearing.
- It is likely that seismic survey work will affect foraging behaviour of seals and large whales in the SEA6 area. Current mitigation methods are probably effective in preventing physical damage.
- There are no reliable data to suggest that vessel noise or drilling noise adversely affect seals or small cetaceans. Large whales may avoid areas of concentrated activity but there are no deep-water areas in the SEA6 area where this is of particular importance.
- Decommissioning work that involves the use of explosives is likely to impact animals in the vicinity, potentially causing injury and death at close range, and causing hearing damage at substantial ranges. Difficulties in observing and monitoring behaviour and the apparent attractiveness of submerged structures means that some marine mammals, especially seals, are likely to be damaged in blasts. Current mitigation methods are unlikely to be totally effective.
- Contaminants, such as polychlorinated biphenyls, DDTs and chlorinated pesticides probably have toxic effects on the reproductive and immune systems of marine mammals. There is little evidence that heavy metals cause substantial toxic responses, except at high concentrations. Cetacean species which feed lower down the food chain may be at risk from exposure to polyaromatic hydrocarbons, although very little is known about current exposure levels or the effects of chronic exposure in marine mammals.
- Major oil spills are likely to result in direct mortality. More generally, marine mammals are less vulnerable than seabirds to fouling by oil, but they are at risk from chemicals evaporating from the surface of an oil slick at sea within the first few days. Individuals may drown as a result of associated symptoms. Neonatal seal pups are at risk from oil coming ashore.
- It is not possible to say how many marine mammals are subject to fisheries bycatch in the SEA6 area, but the fact that gillnet fisheries play a relatively small role in overall fishing activity in this area means that bycatches are likely lower than in many other areas around Britain.

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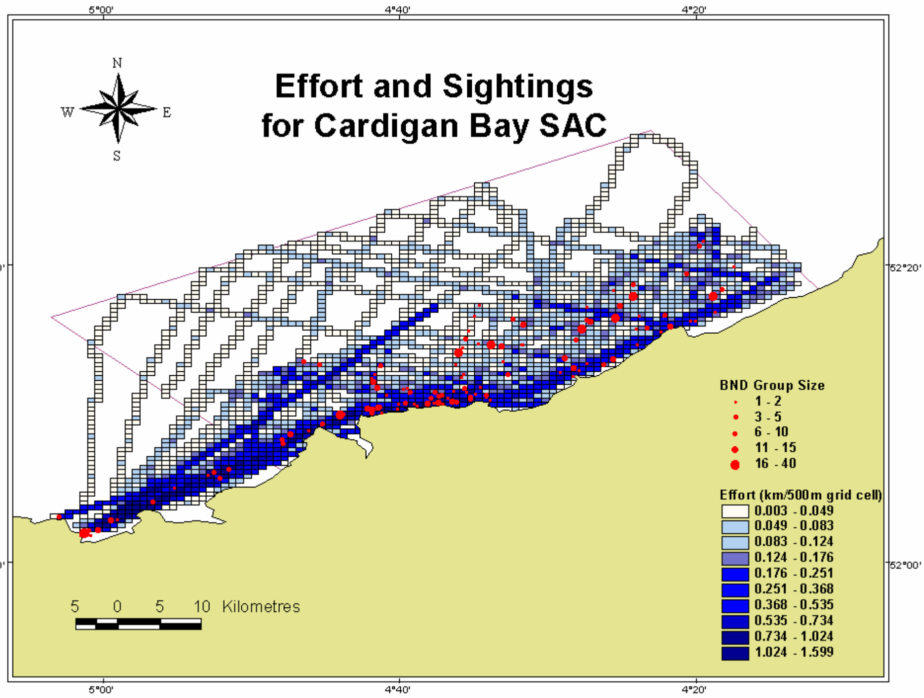


Figure 1: Distribution of sightings effort and bottlenose dolphin sightings in the Cardigan Bay SAC.

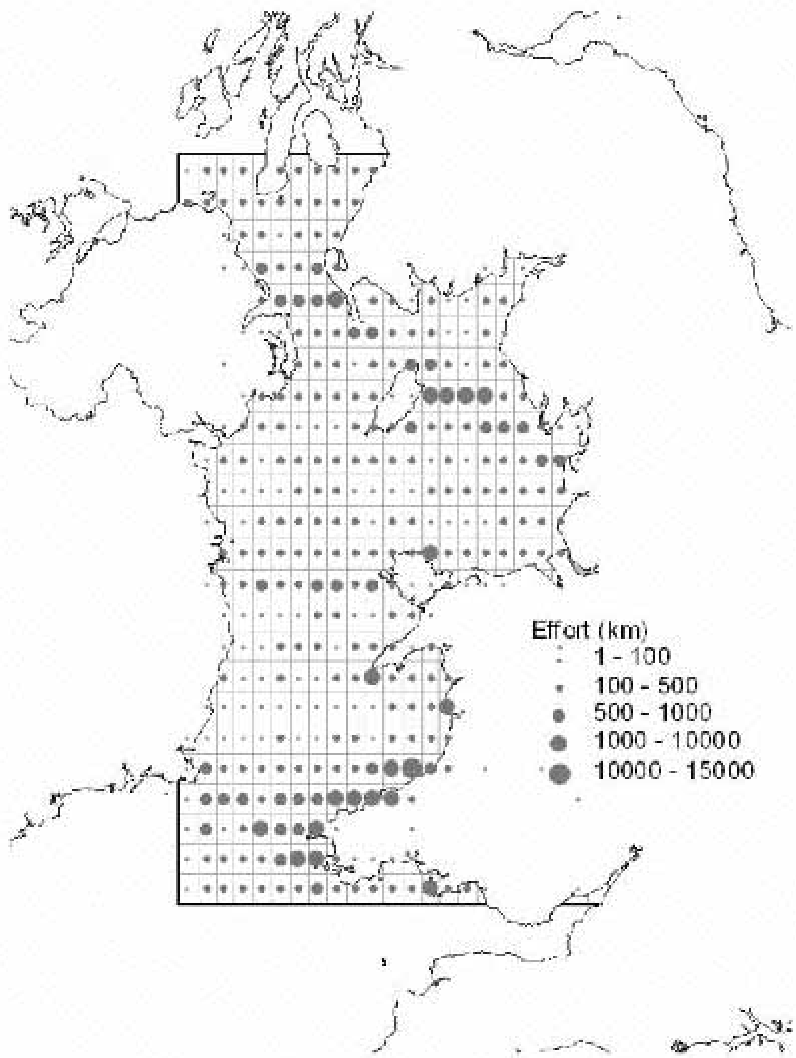


Figure 2: Distribution of sightings effort in the SEA5 area from a variety of sources (see text)

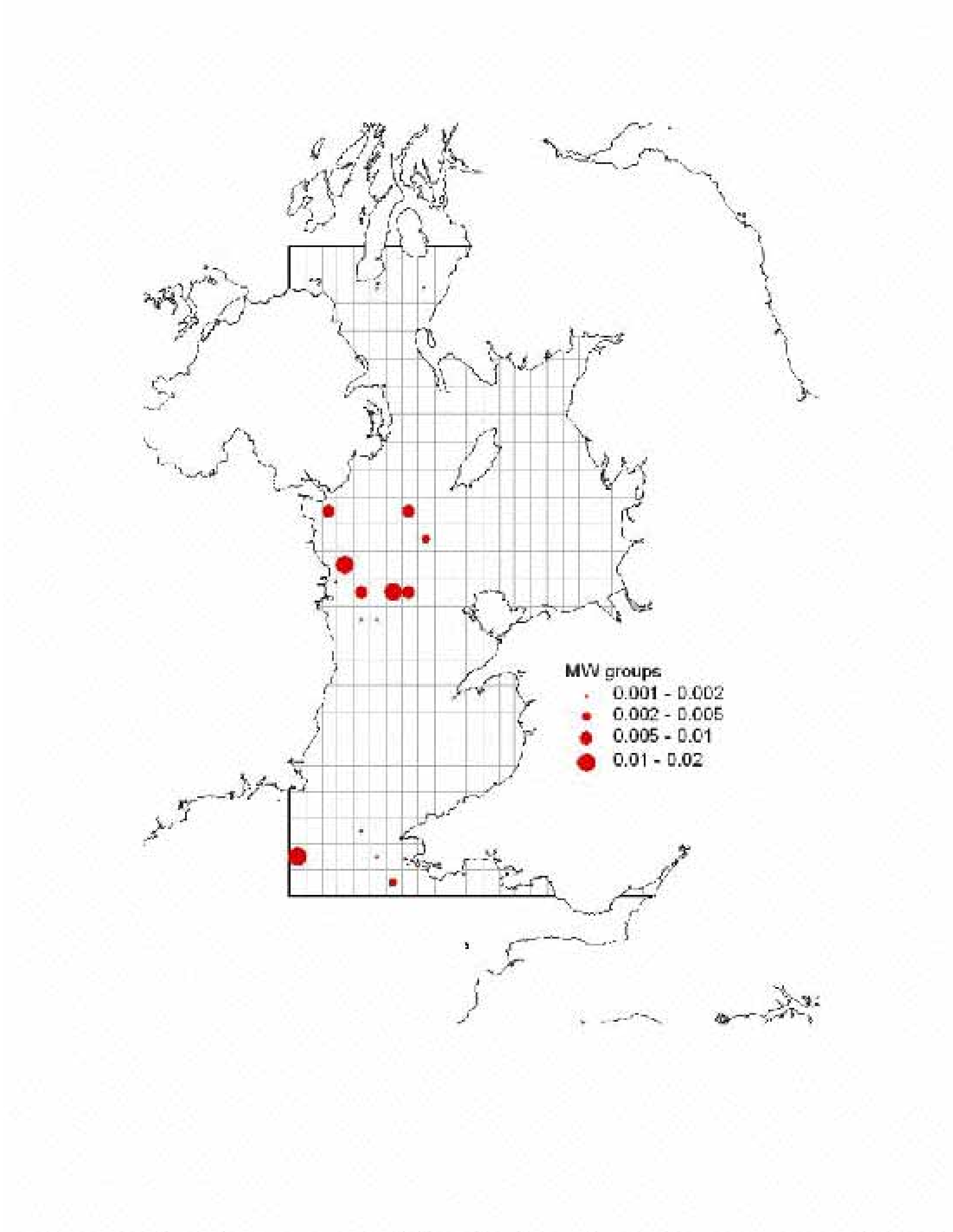


Figure 3: Minke whale sightings rates for the SEA6 area

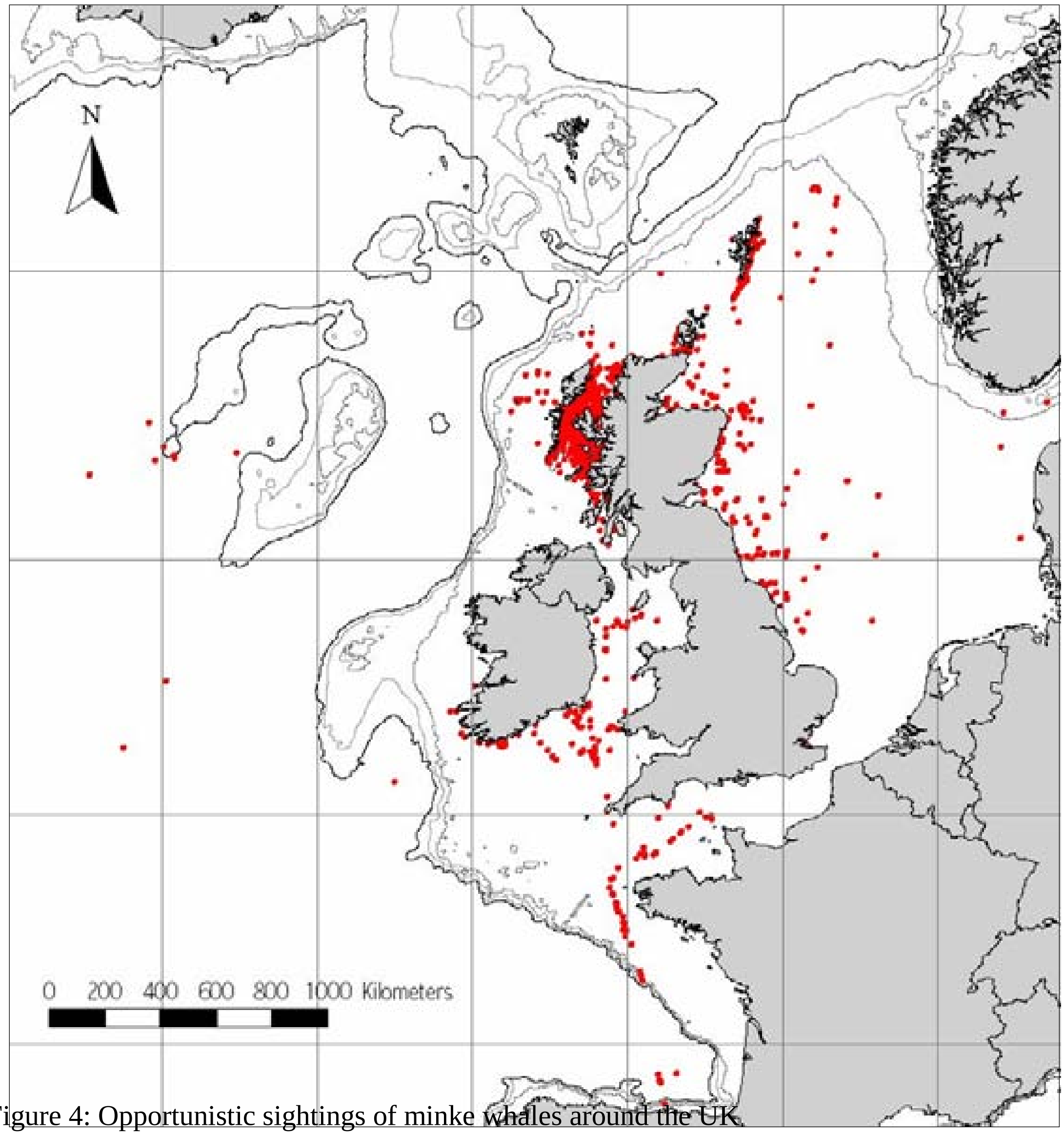


Figure 4: Opportunistic sightings of minke whales around the UK

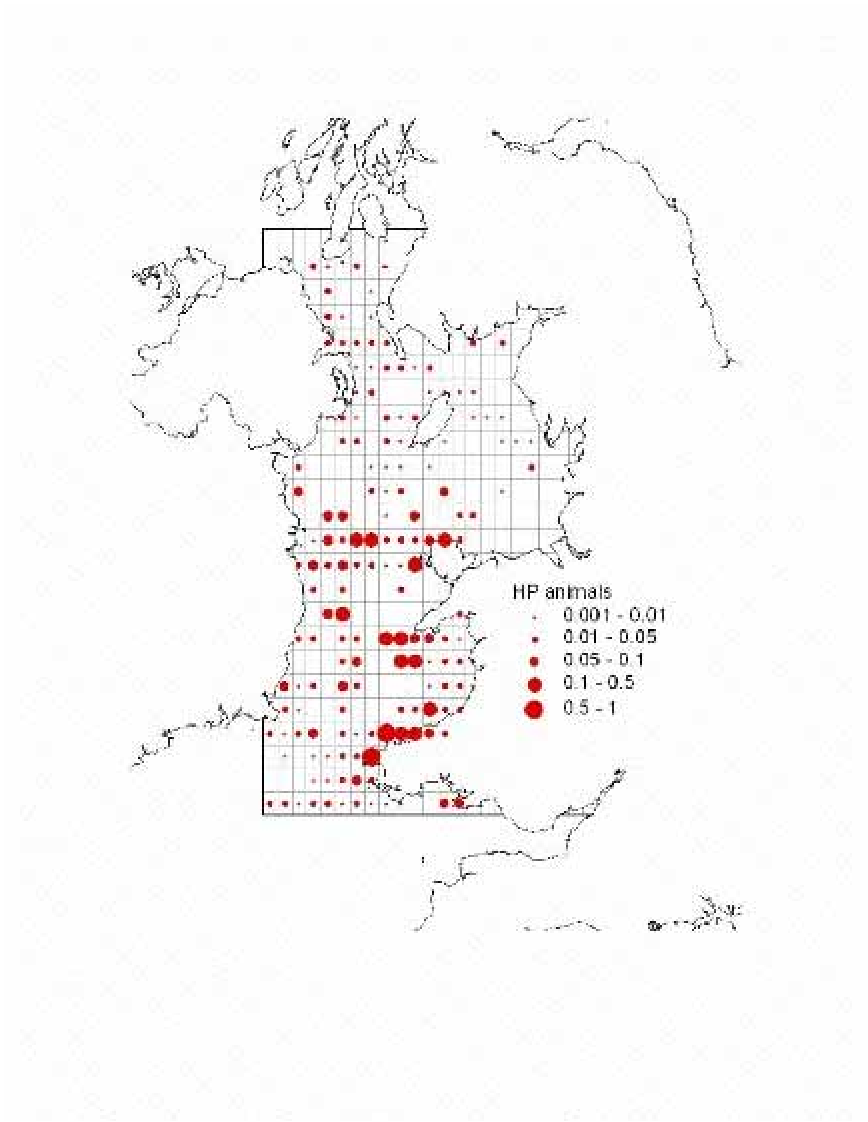


Figure 5: Harbour porpoise sighting rates in the SEA6 area.

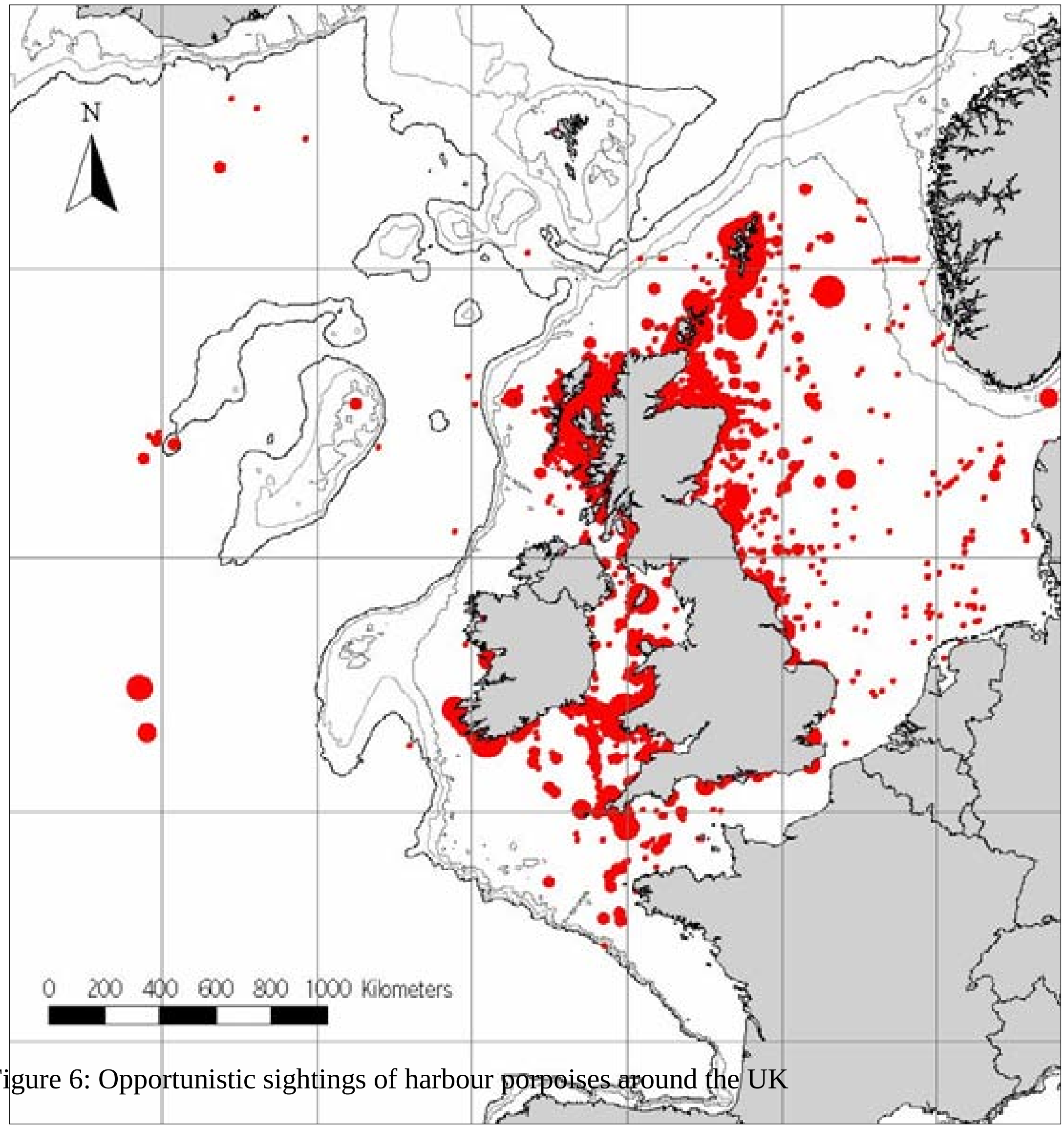


Figure 6: Opportunistic sightings of harbour porpoises around the UK

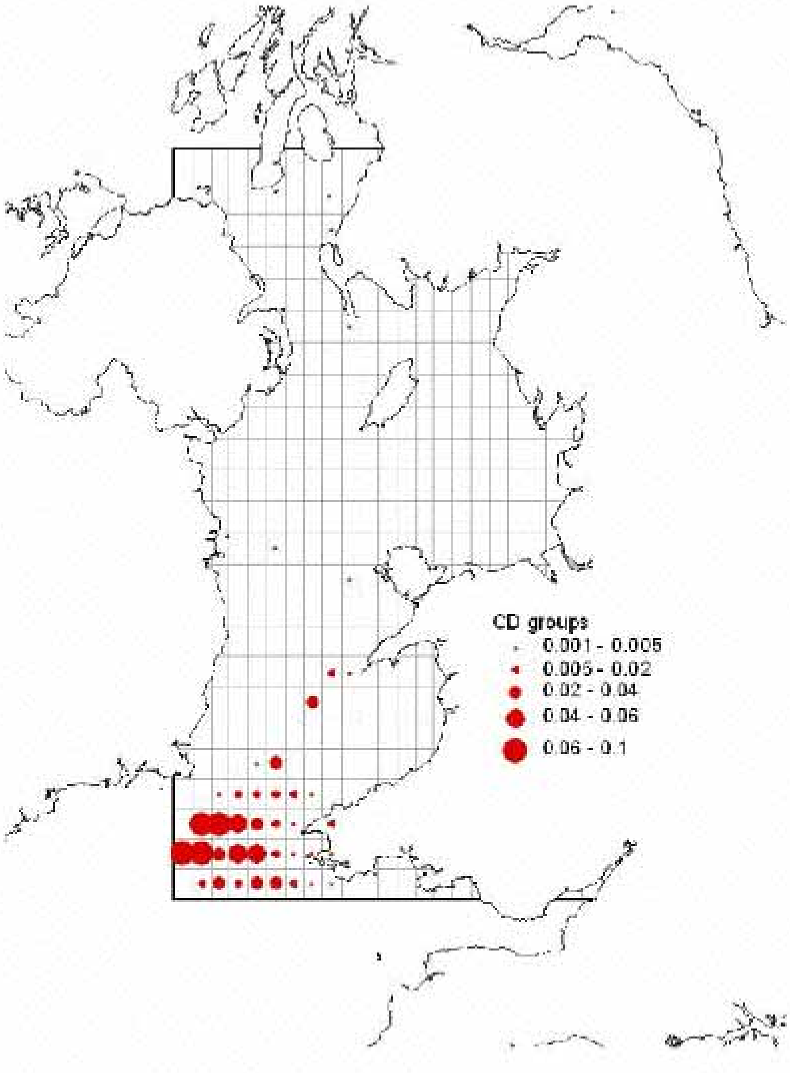


Figure 7: Risso's dolphin sighting rates in the SEA6 area.

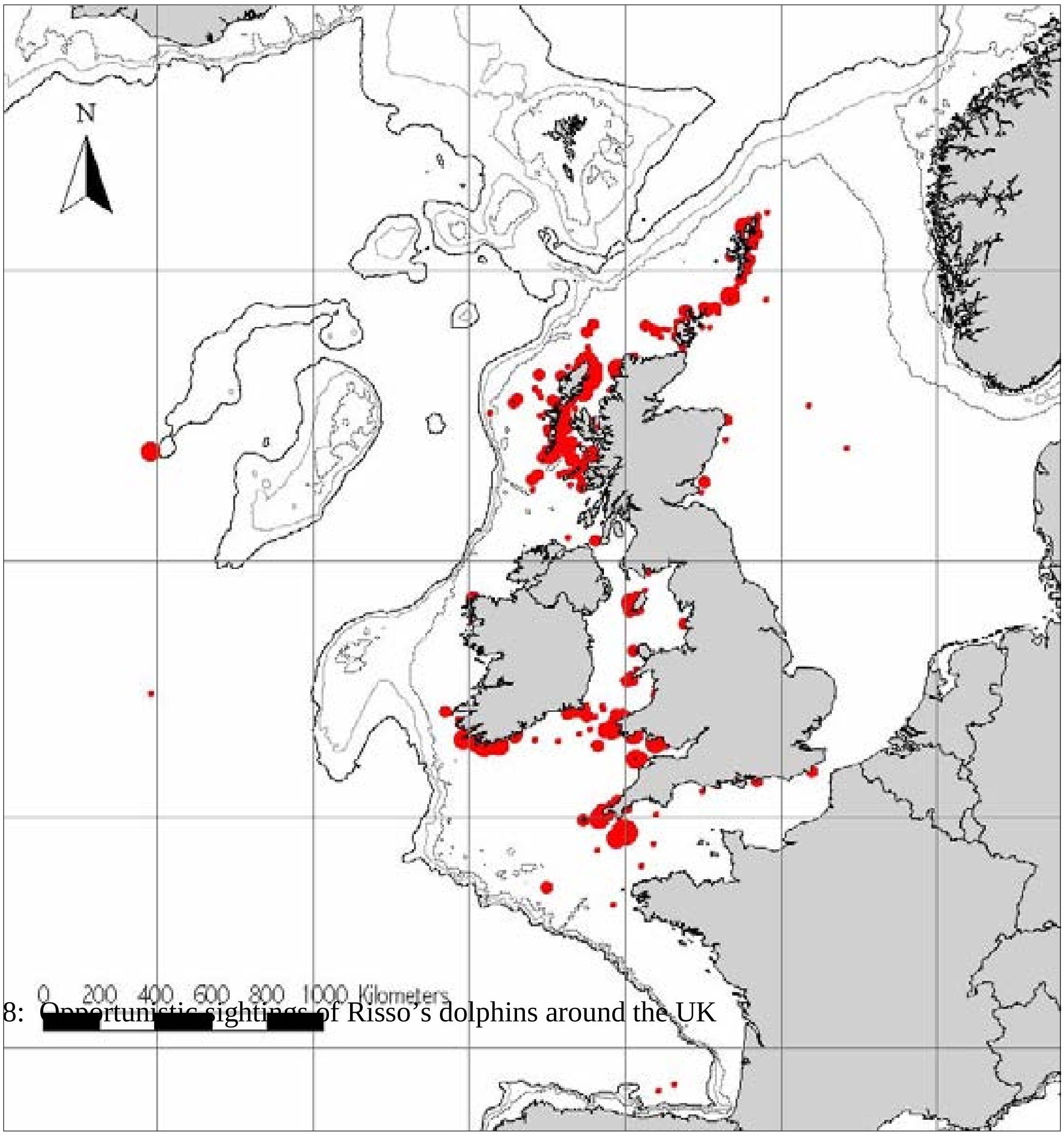


Figure 8: Opportunistic sightings of Risso's dolphins around the UK

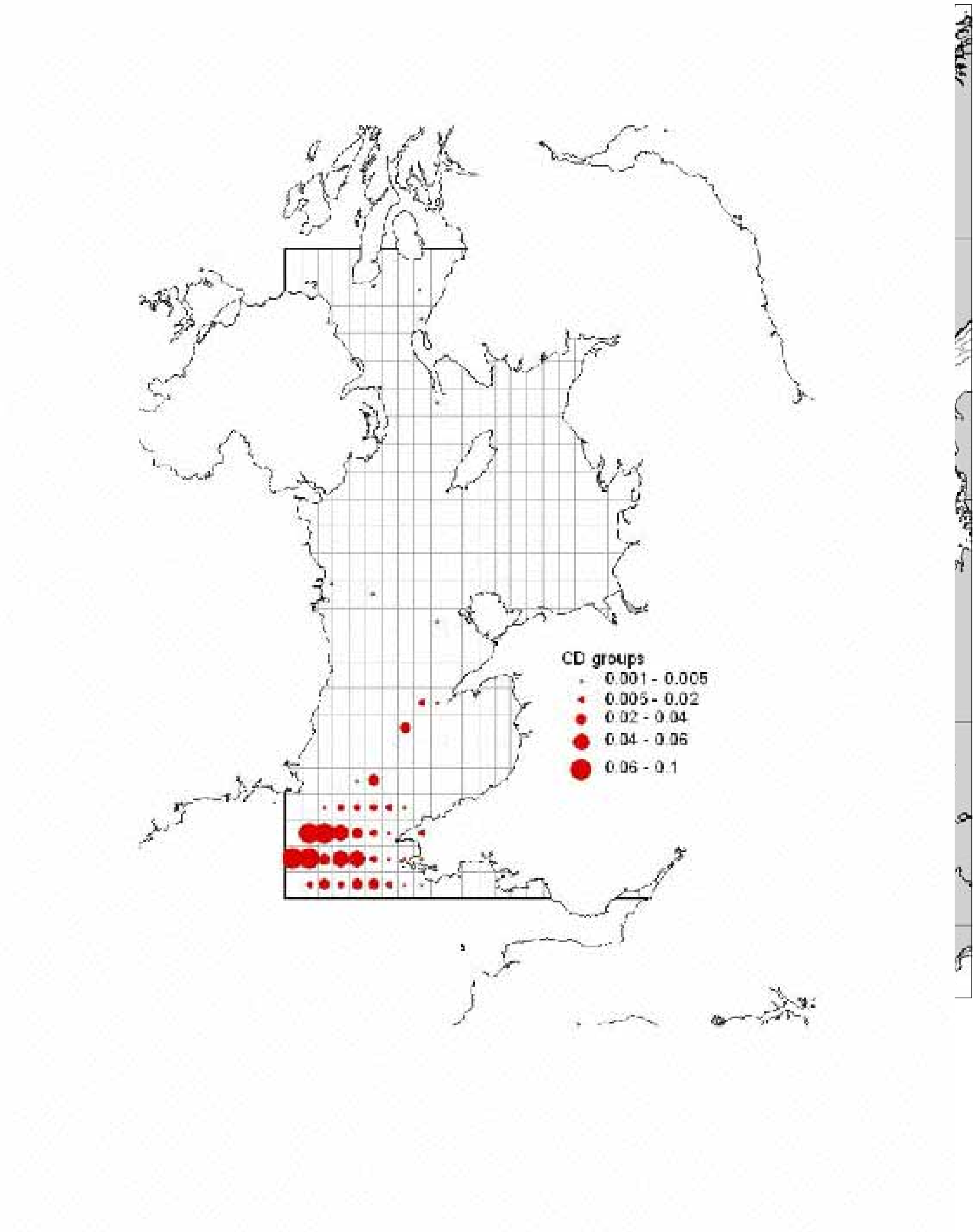


Figure 9: Short-beaked common dolphin sighting rates in the SEA6 area.

Figure 10: Opportunistic sightings of short-beaked common dolphins around the UK

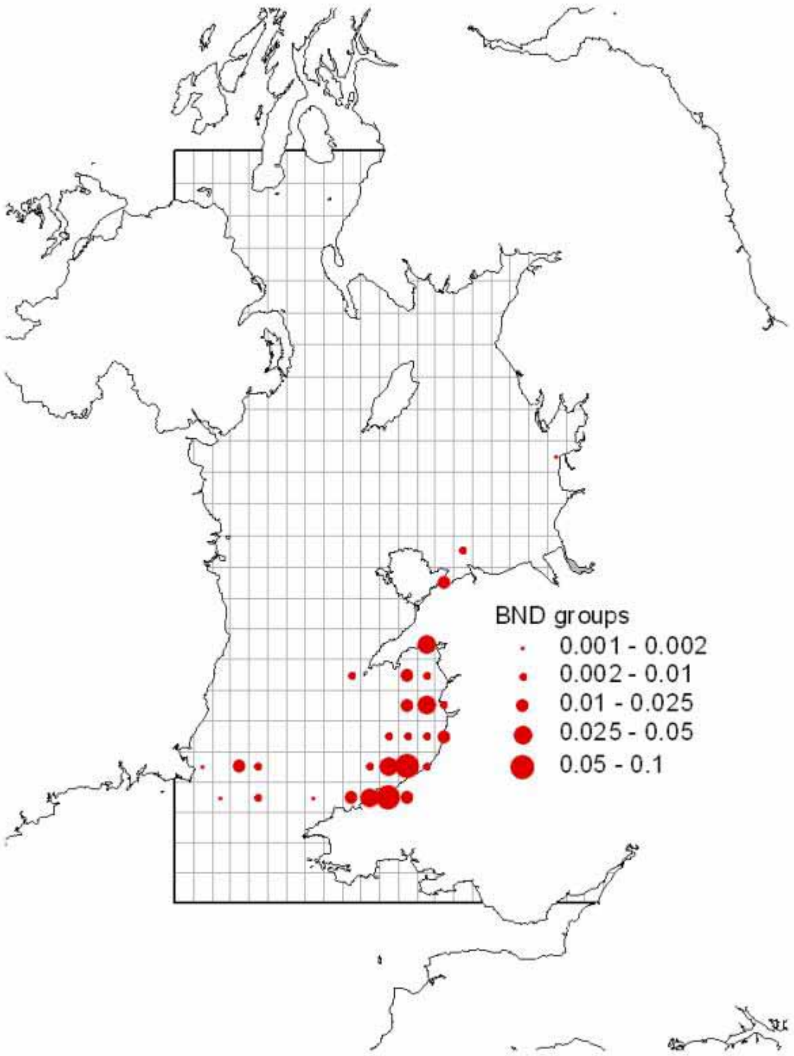


Figure 11 Bottlenose dolphin sighting rates in the SEA6 area.

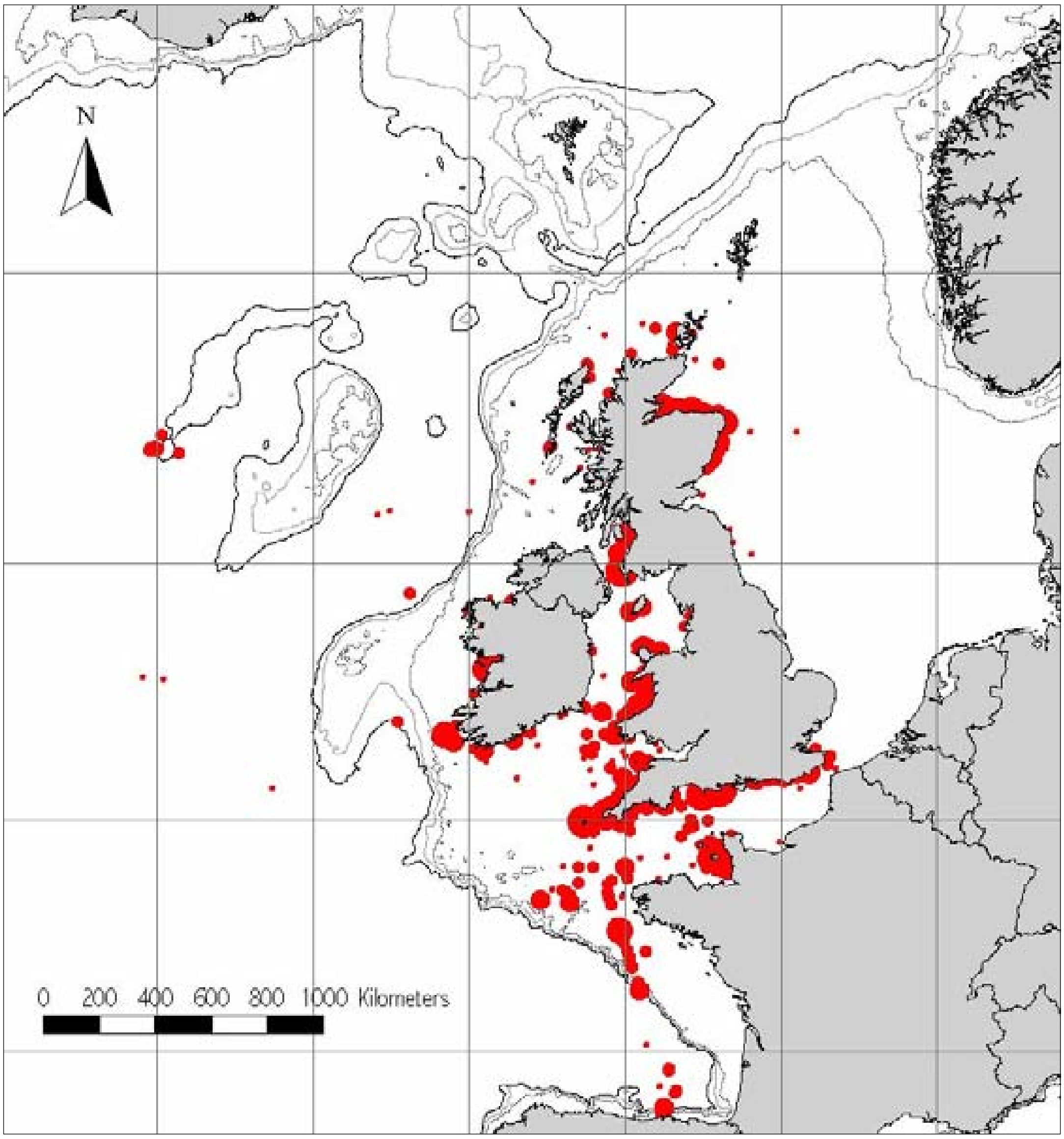


Figure 12: Opportunistic sightings of bottlenose dolphins around the UK

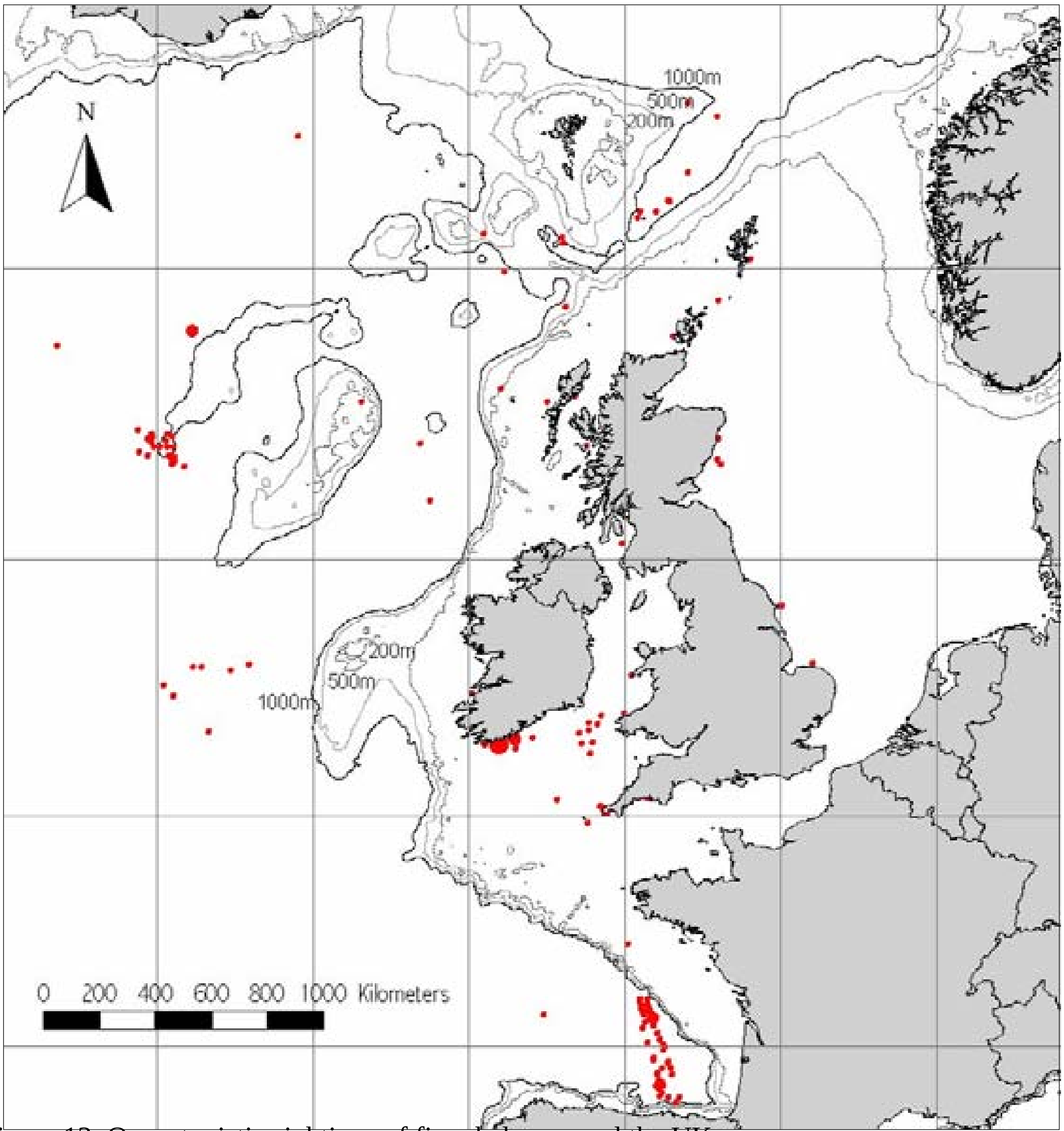


Figure 13: Opportunistic sightings of fin whales around the UK

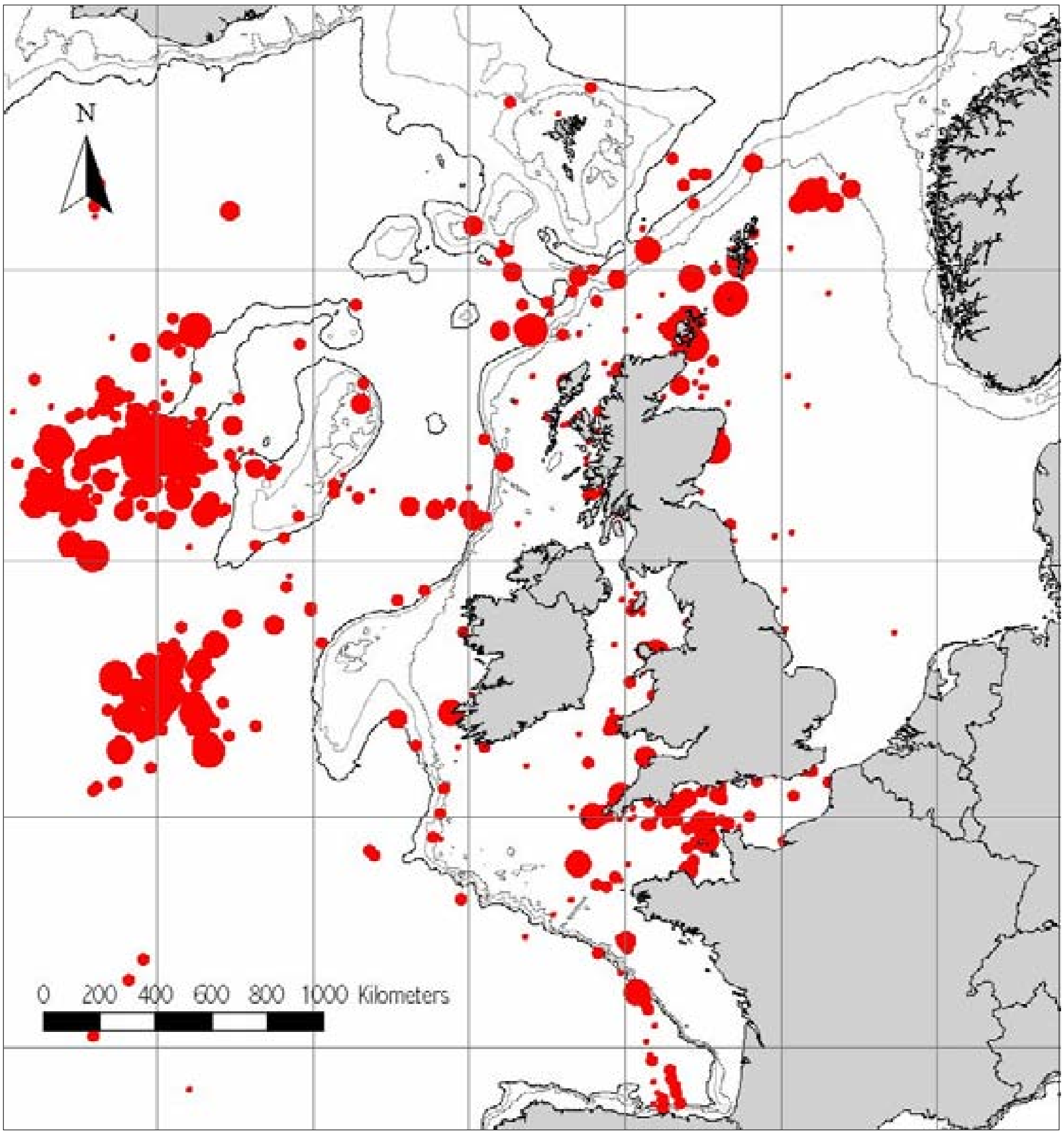


Figure 14: Opportunistic sightings of pilot whales around the UK

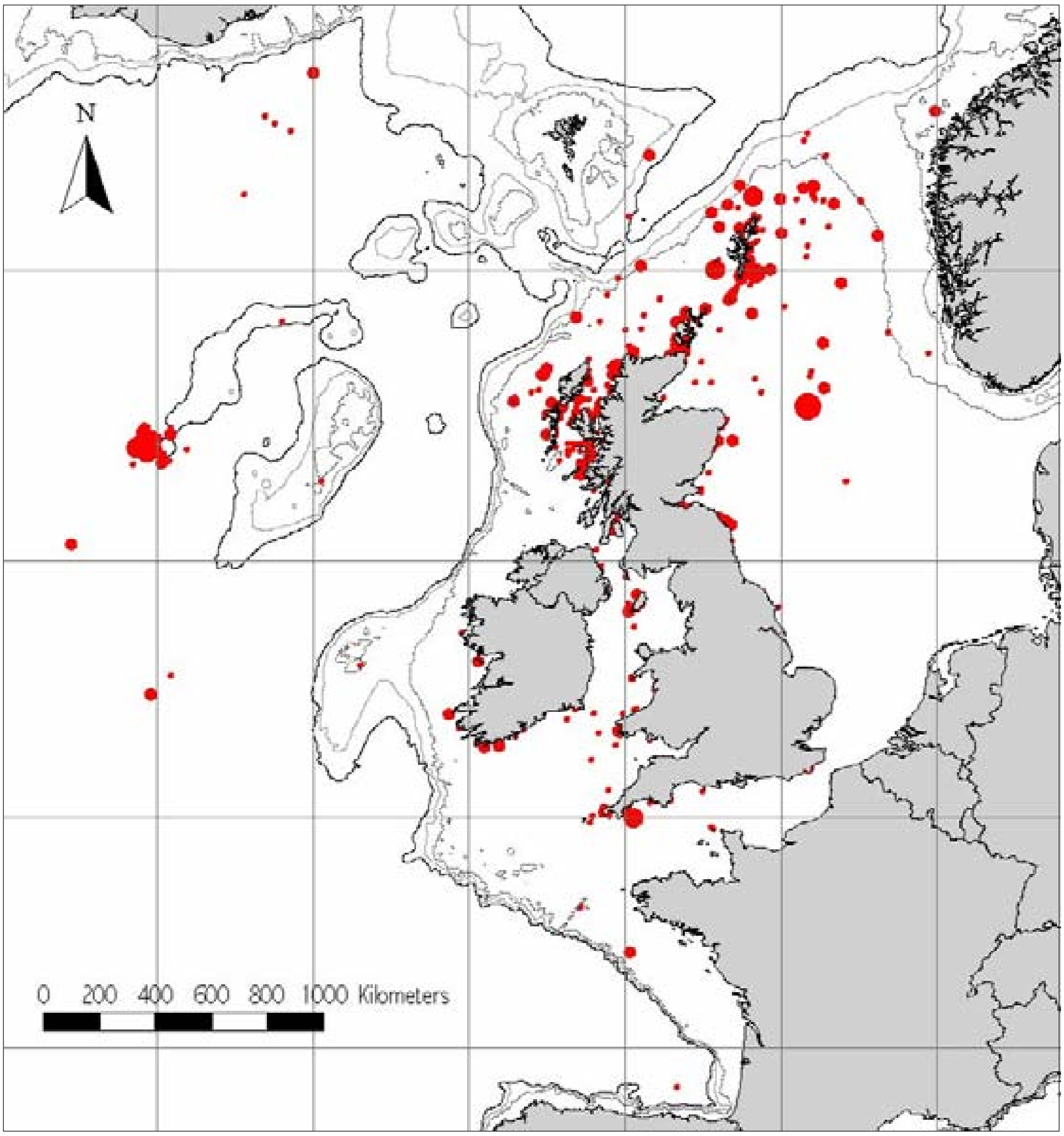


Figure 15: Opportunistic sightings of killer whales around the UK

Figure 16. The distribution of grey seal haul-out sites around the Irish Sea.

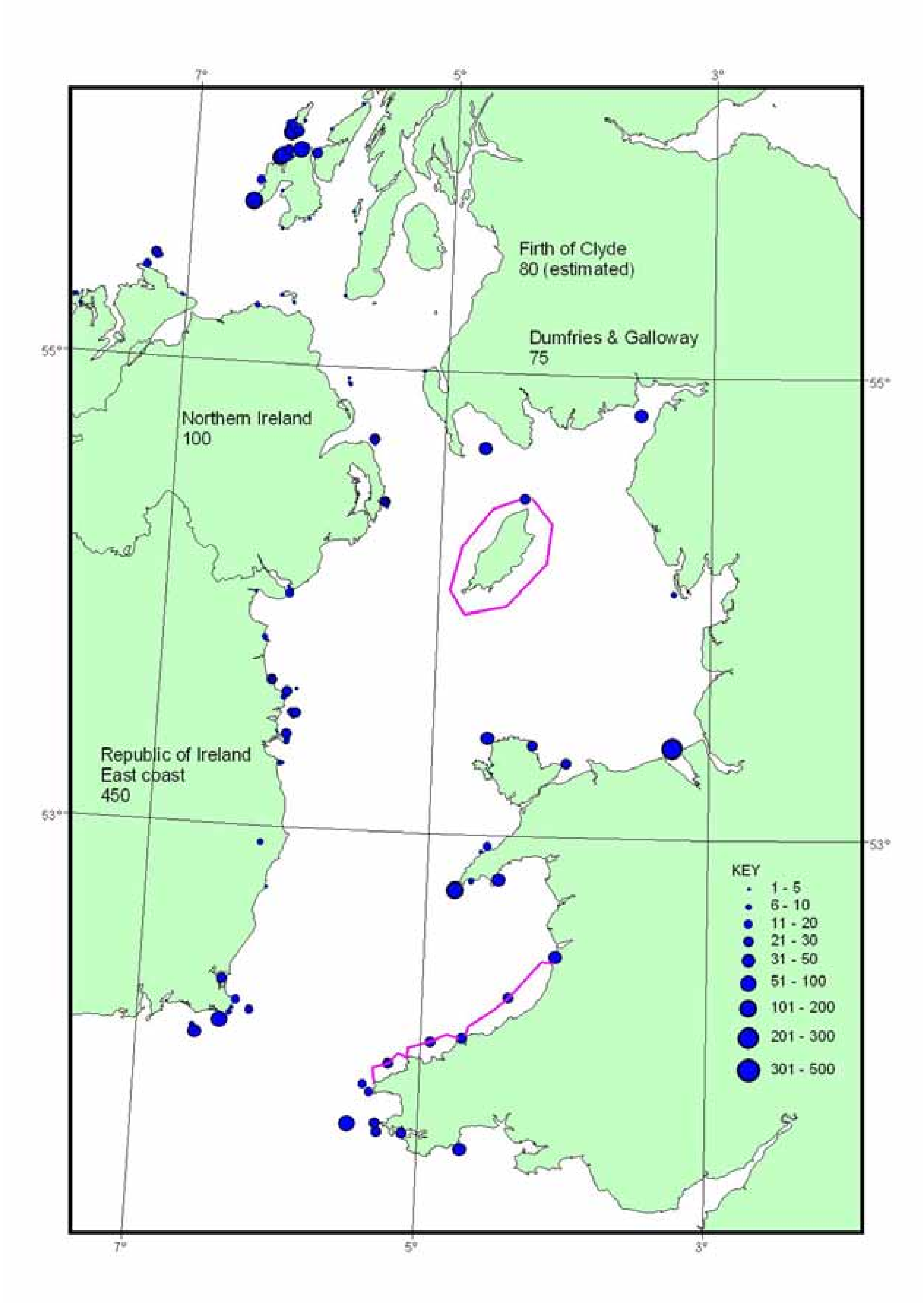


Figure 17. Tracks of all grey seals. Each individual is in a different colour.

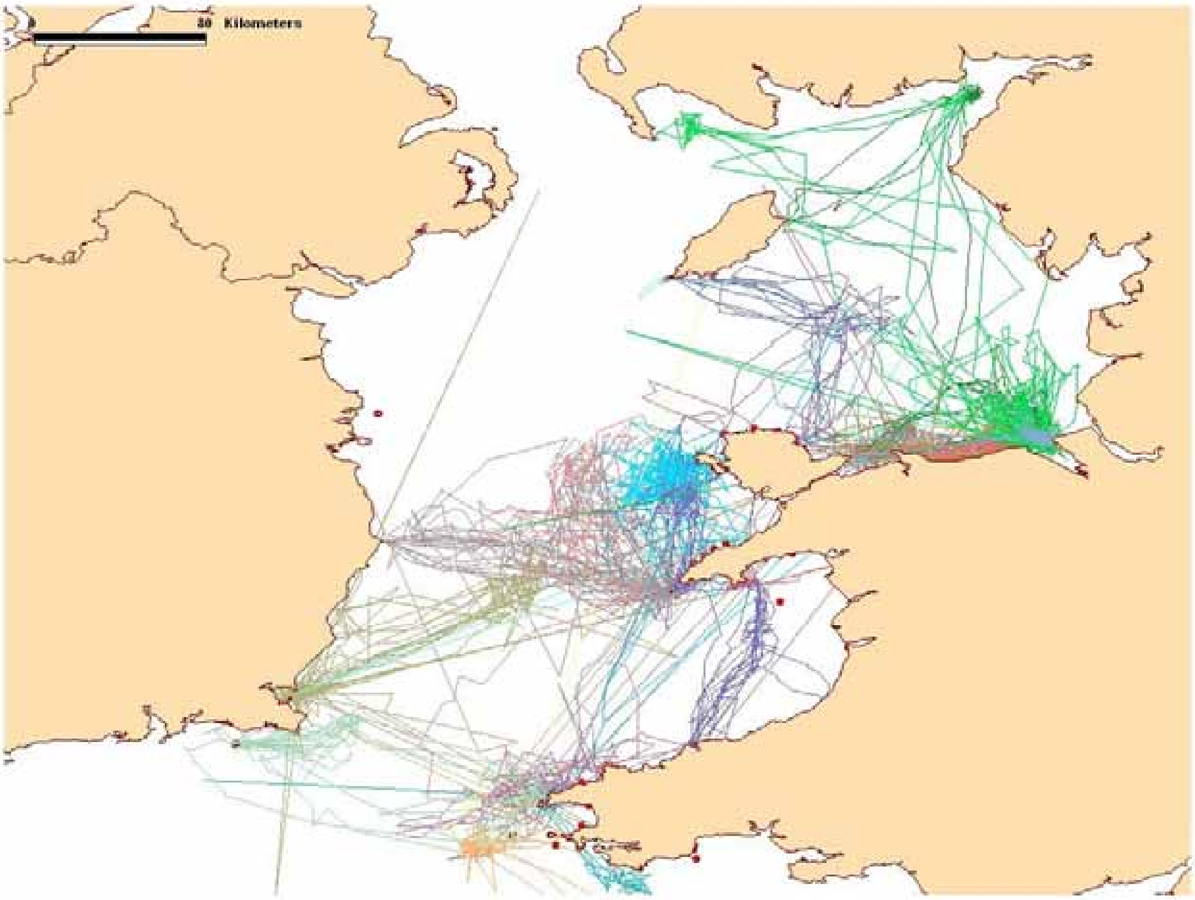


Figure 18. Estimated at-sea usage of the Irish Sea by grey seals tagged in Wales. Warm colours indicate higher usage.

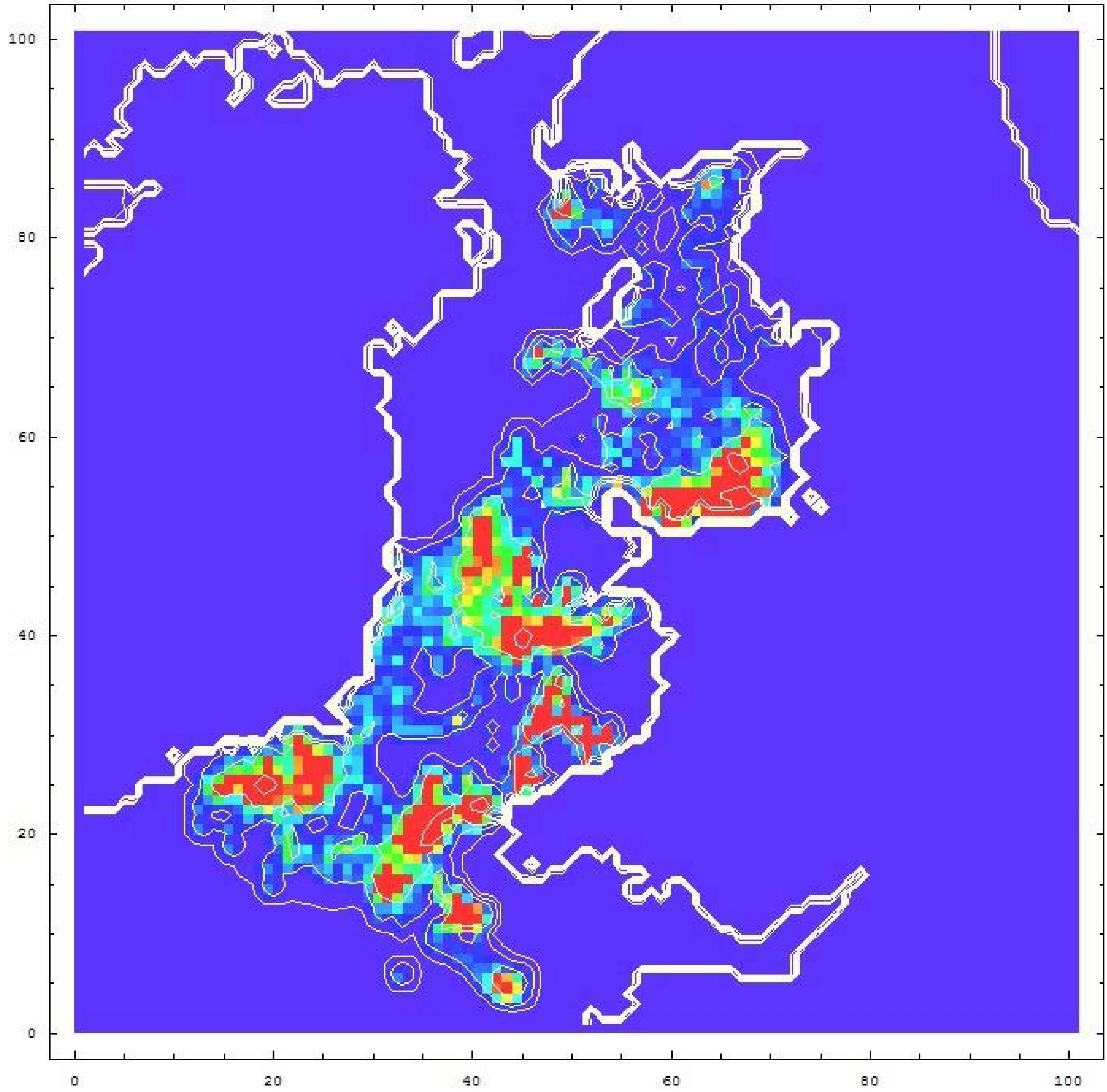


Figure 19. The distribution of harbour seal haul-out sites around the Irish Sea.

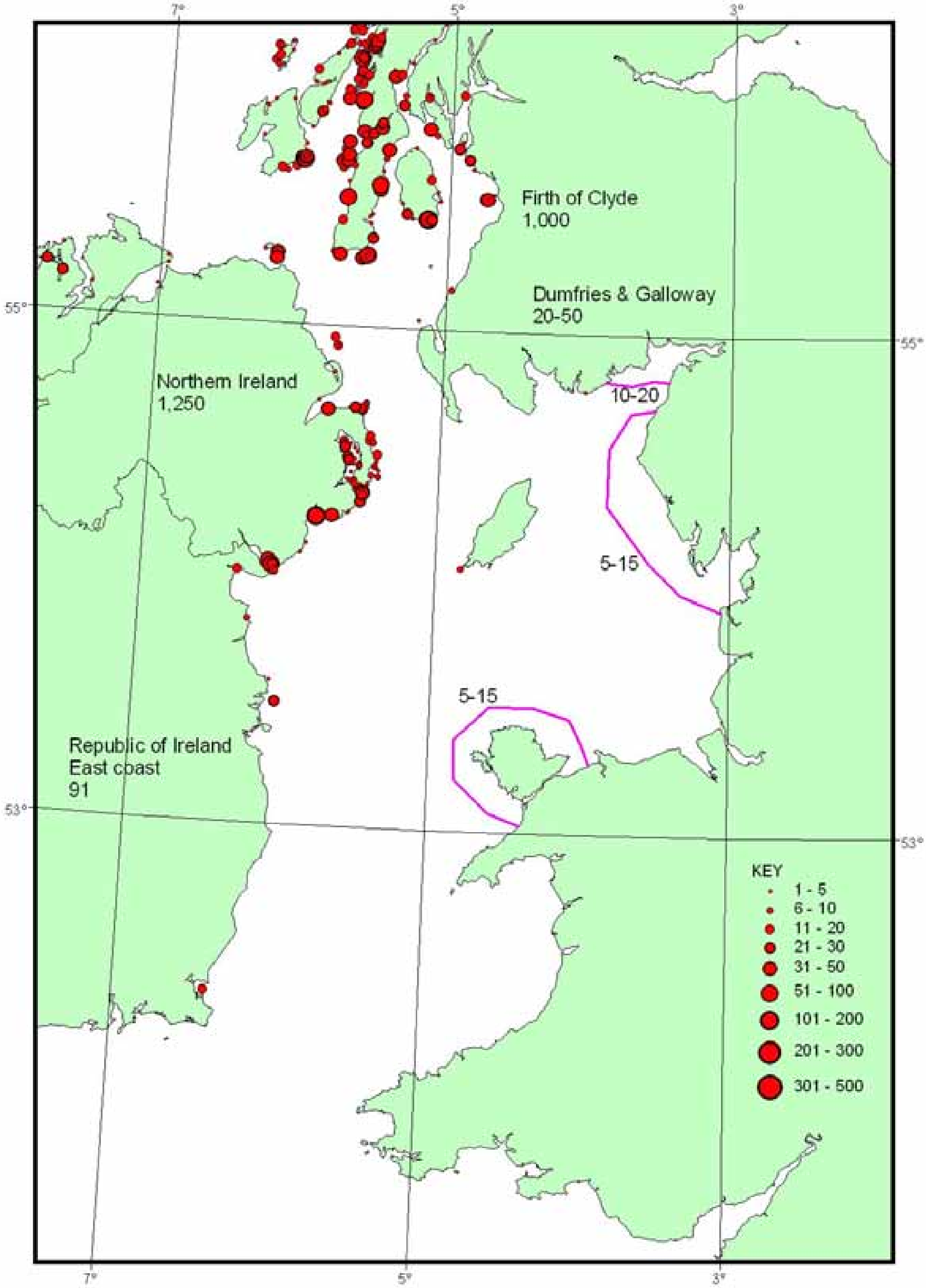
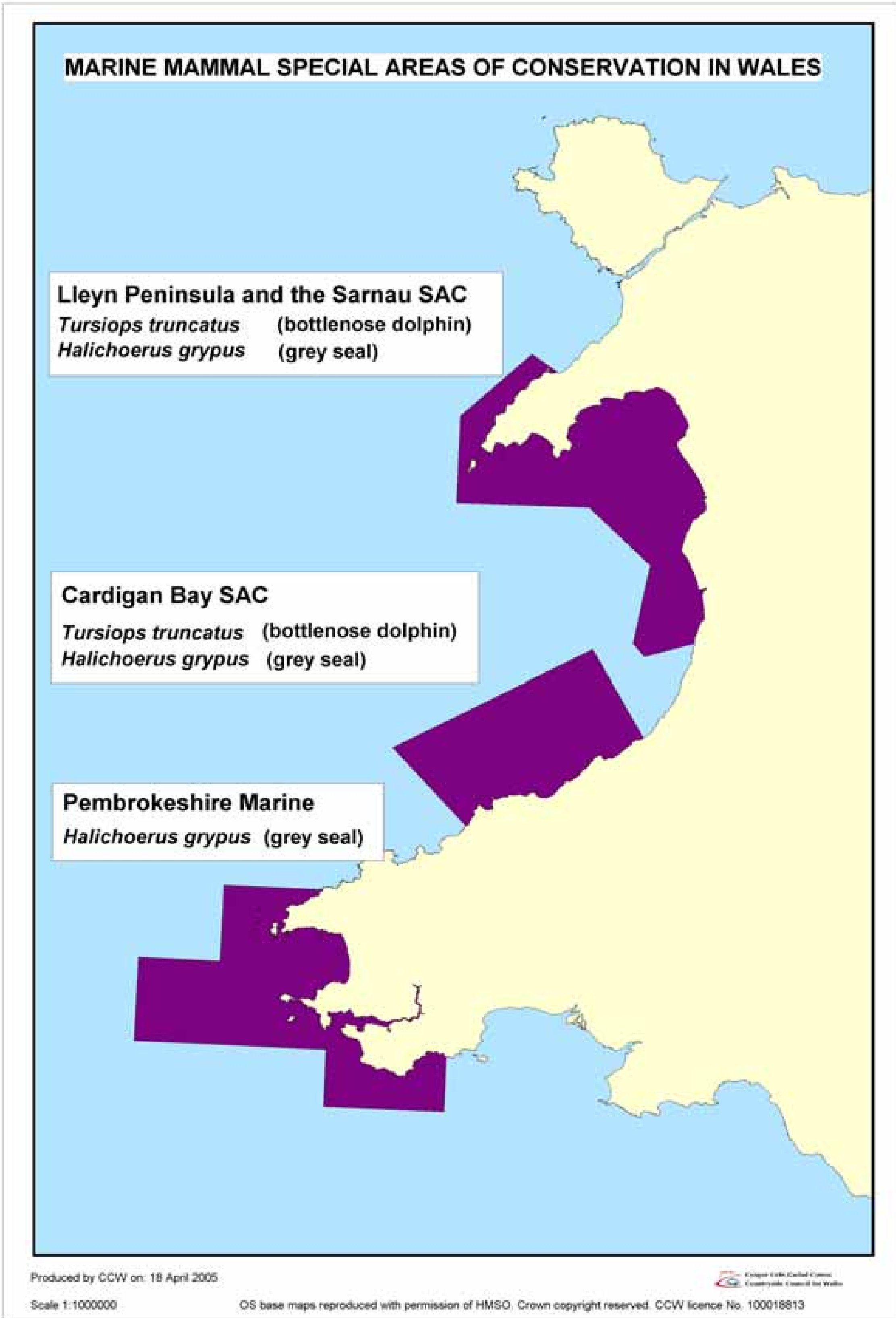


Figure 20. SACs for grey seals and bottlenose dolphins in Wales


MARINE MAMMAL SPECIAL AREAS OF CONSERVATION IN WALES
Lleyn Peninsula and the Sarnau SAC
Tursiops truncatus (bottlenose dolphin)
Halichoerus grypus (grey seal)
Cardigan Bay SAC
Tursiops truncatus (bottlenose dolphin)
Halichoerus grypus (grey seal)
Pembrokeshire Marine
Halichoerus grypus (grey seal)
Produced by CCW on: 18 April 2005
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