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A Conservation Literature Review for the Harbour Porpoise (*Phocoena phocoena*)

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Summary

UK waters encompass a wide range of seabed topography and physical and chemical conditions that create a huge diversity of marine ecosystems. These in turn influence the availability of biological resources that attract a significant diversity of marine mammals for European waters. In all, 28 cetacean species have been recorded in UK waters, of which eleven species occur regularly. Cetaceans in a given area are usually part of a larger and more widespread biological population. As a consequence of their wide ranges, all cetaceans are protected internationally through various conventions and agreements. Consequently, to be effective, their conservation needs must be considered on an international basis including the monitoring and surveillance essential to meet the requirements of the EU Habitats Directive and the Marine Strategy Framework Directive (MSFD).

The smallest and most abundant cetacean in UK (and neighbouring) shelf areas is the harbour porpoise (*Phocoena phocoena*). The species occurs throughout continental shelf waters and may, therefore, be affected by a range of human activities occurring in the same waters. The most important pressures identified include mortality as bycatch in fishing gear, acoustic disturbance, and bioaccumulation of persistent organic chemicals such as PCBs. Some pressures may lead to mortality, whilst others raise concern about potential long-term impacts on population health. The pressures identified that require further research include habitat degradation, prey depletion (e.g. competition with fisheries for food) and climate change. It should be noted that the cumulative effect of any combination of these pressures may result in more deleterious consequences than any single pressure in isolation.

Approaches to conservation need to be multifaceted, adaptable and tailored to particular local or regional conditions as appropriate. A key factor in determining whether our conservation efforts are effective is a better understanding of the abundance and distribution patterns of harbour porpoises, including seasonal variations, as well as better information on basic life history parameters such as reproductive rates and mortality. Such knowledge will help determine the magnitude of impacts experienced by the population and would help determine whether efforts aimed at reducing such pressures are effective. This paper outlines our current understanding of the anthropogenic pressures experienced by harbour porpoise and the mitigation options available to reduce these pressures. The UK currently has a conservation strategy for harbour porpoise, initially published in 2000, which is further supported by the UK Bycatch Response Strategy. Together these take a risk-based approach to harbour porpoise conservation. The strategies will be reviewed and updated where appropriate in light of the finding in this literature review.

Contents

1 Introduction

The harbour porpoise (*Phocoena phocoena*) (Figure 1.1) is a common and widely distributed species in cold temperate to sub-arctic waters of the Northern Hemisphere, found in both the Atlantic and Pacific Oceans (Figure 1.2; Hammond *et al* 2008; Wilson and Mittermeier, 2014). In the North Atlantic, it occurs from Cape Hatteras (North Carolina, USA) to Baffin Island (Canada) and West Greenland in the west, around the south tip of Greenland, around Iceland, Jan Mayen (Norway), and from the White Sea and Barents Sea (Russia and Norway) to Mauritania and Senegal in West Africa in the east. It is a native species in at least 24 European countries[1] (Hammond *et al* 2008). Harbour porpoises may travel in deep waters between landmasses, but typically occur over continental shelves, usually in waters less than 200m depth (Wilson and Mittermeier, 2014). Hammond *et al* (2008) suggested that the global abundance of the harbour porpoise was at least 700,000 individuals.

Figure 1.1. Harbour porpoise (courtesy of Geert Aarts)

1.1 Current conservation status

Globally, harbour porpoise is classified as being of 'Least Concern' on the IUCN Red List (Hammond *et al* 2008), meaning that the species is widespread and abundant, and that it is not considered to be threatened, near threatened or conservation dependent. However, the Baltic sub-population of *Phocoena p. phocoena* is classified as 'Critically Endangered' (Hammond *et al* 2008; Benke *et al* 2014). The 2013 assessment of the conservation status of harbour porpoises in UK waters is considered to be favourable (JNCC, 2013). Similar conclusions were reached for the European North Atlantic region (see http://bd.eionet.europa.eu/article17/reports2012/).

[1] Belgium; Bulgaria; Denmark; Estonia; Faroe Islands; Finland; France; Georgia; Germany; Iceland; Ireland; Latvia; Lithuania; Netherlands; Norway; Poland; Portugal; Romania; Russian Federation; Spain; Sweden; Turkey; Ukraine; United Kingdom

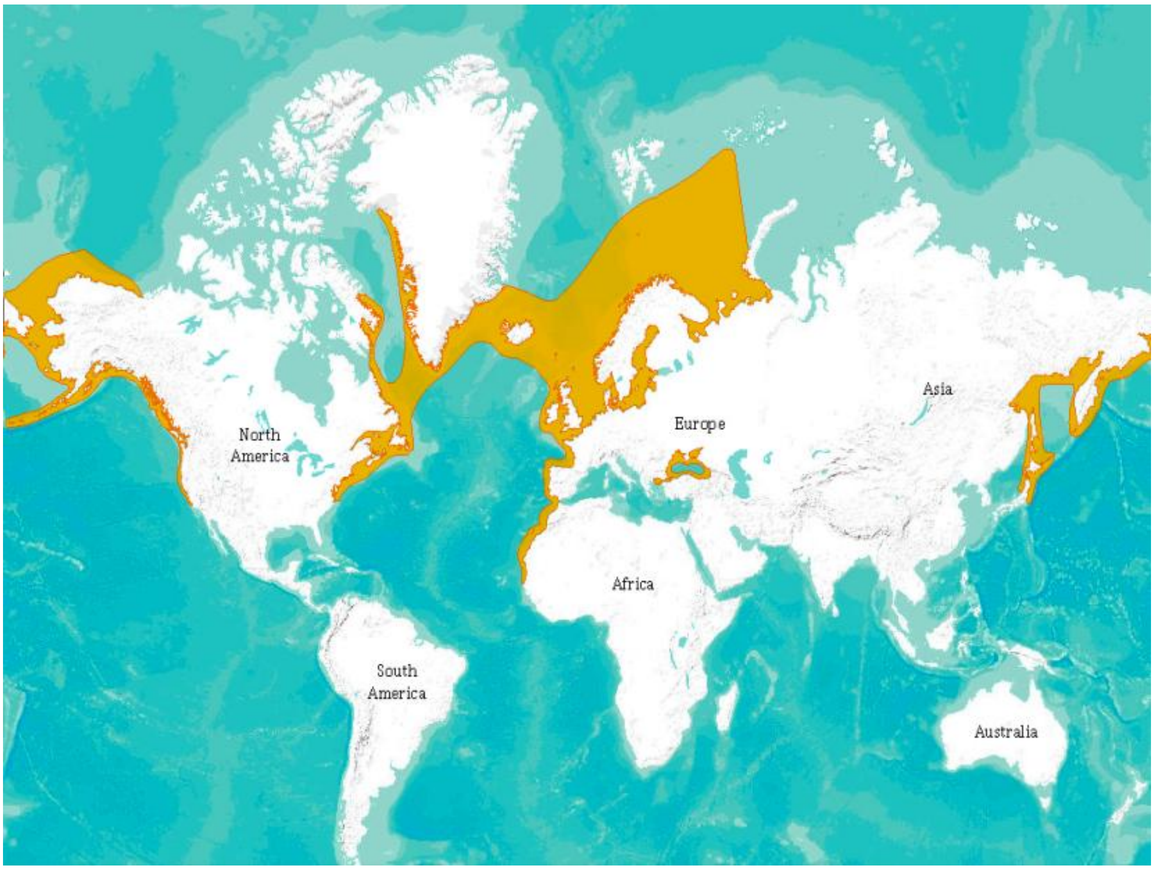
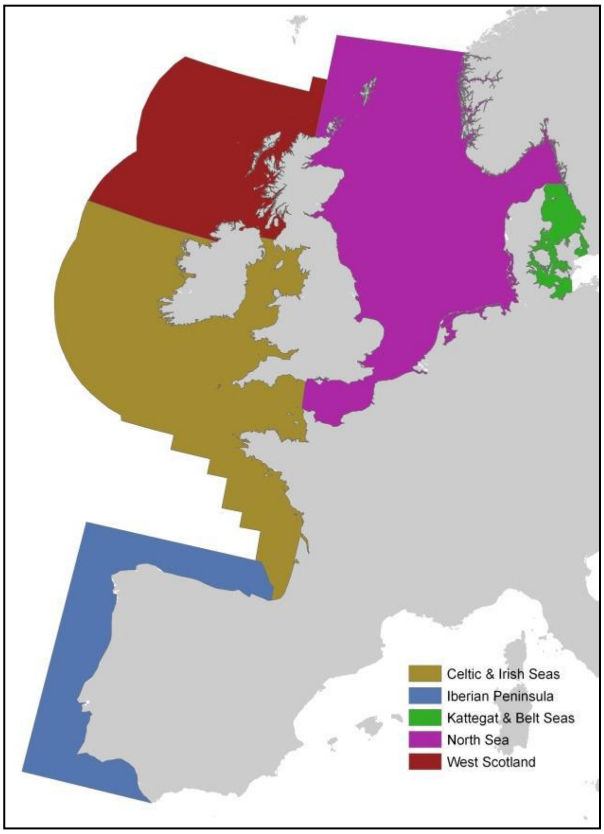


Figure 1.2. World distribution of the harbour porpoise *Phocoena phocoena* (from: Hammond *et al* 2008)

1.2 Harbour porpoise Management Units in the Eastern North Atlantic

Harbour porpoise within the eastern North Atlantic are generally considered to behave as a continuous biological population that extends from the French coasts of the Bay of Biscay northwards to the Arctic waters of Norway and Iceland (Tolley and Rosel, 2006; Fontaine *et al* 2007, 2014). Only the Iberian and Baltic populations are distinct (Fontaine *et al* 2007, 2010). For conservation and management purposes however, it is more practical to divide the population into smaller units. In 2014, ICES provided advice to OSPAR on the boundaries of five harbour porpoise assessment units in the European Atlantic, three of which are relevant to UK waters: the North Sea (NS), West Scotland (WS) and Celtic and Irish Seas (CIS) (Figure 1.3; ICES, 2014a; IAMMWG, 2015a). For the purposes of this document, hereafter, these assessment units are termed Management Units (MU).

These MUs reflect differences, to some extent, in the spatial preferences of individual harbour porpoise and also the spatial variation in human activities. As these MUs are defined at a smaller spatial scale than the population, it is important that management takes the potential interchange of individuals between MUs into account (MUs should thus not be treated as if they were demographically independent).



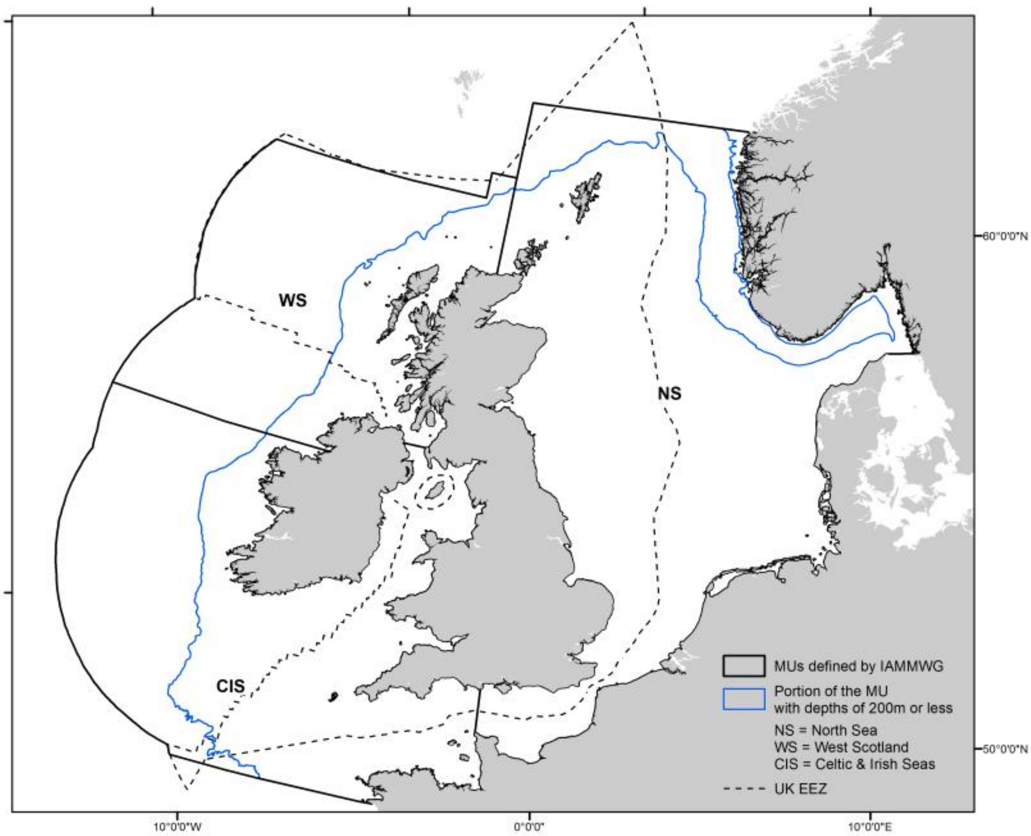


Figure 1.3. Management units (MUs) for the Harbour porpoise (*Phocoena phocoena*) in European Atltantic waters (top) and UK waters (bottom) (from ICES, 2014a and IAMMWG, 2015a, respectively).

Harbour porpoise distribution is not static, with marked seasonal and longer term shifts in distribution of the overall population. Around Europe, there are distinct geographical seasonal peaks in harbour porpoise sightings and strandings (Addink *et al* 1995; Berggren and Arrhenius, 1995; Blew *et al* 2006; Verfuß *et al* 2007; Gilles *et al* 2009; Camphuysen, 2011; Haelters *et al* 2011; Sveegaard *et al* 2012; Learmonth *et al* 2014; Vishnyakova and Gol'din, 2014). The temporal variability in distribution and abundance is extremely important and has significant implications for the way in which anthropogenic pressures are managed.

1.3 Harbour porpoises in UK waters

Harbour porpoise are predominantly found over the continental shelf in waters <200m depth (Figure 1.4, Pollock *et al* 2000; Weir *et al* 2001; CODA, 2009; Marubini *et al* 2009; Embling *et al* 2010; Booth *et al* 2013) throughout the year. Estimates of harbour porpoise abundance on the entire European Atlantic shelf are 375,358 [CV=0.197, 95% CI 256,304-549,713] (Hammond *et al* 2013). Of this, the current UK 'population' is approximately 177,000 animals, with the majority of these in the North Sea MU (Table 1.2). These population estimates for the continental shelf and for territorial waters are based on a single survey carried out in one month of one year (i.e. SCANS II, Hammond *et al* 2013).

Table 1.1. Estimates of abundance of harbour porpoise in the defined Management Units (from IAMMWG, 2015a) (CV = coefficient of variation and CI = confidence interval).

MU	Abundance of animals in MU (CV)	95% CI for MU	Abundance of animals in the UK portion of MU (CV)	95% CI for UK portion of MU	Source
WS	21,462 (0.42)	9,740 - 47,289	19,291 (0.49)	7,771 - 47,888	Hammond *et al* 2013; Macleod *et al* 2009
CIS	104,695 (0.32)	56,774 - 193,065	47,229 (0.32)	25,611 - 87,094	Hammond *et al* 2013; Macleod *et al* 2009
NS	227,298 (0.13)	176,360 - 292,948	110,433 (0.16)	80,866 - 150,811	Hammond *et al* 2013

It should be noted that because harbour porpoise are highly mobile, the numbers utilising UK waters will vary both seasonally and annually. For example, extensive tracking studies in Danish waters have demonstrated that some individual harbour porpoise tagged in the Kattegat and Skagerak range as far as the Shetland Islands in the west and Öland (Sweden) in the east, whilst others expressed some degree of site fidelity, particularly within the Inner Danish waters (Teilmann *et al* 2004, 2008; Sveegaard *et al* 2010).

In addition to individual mobility, large scale shifts in the population have also been recorded. For example, whilst the abundance of harbour porpoise in the North Sea and adjacent waters in July 2005 was similar to that recorded in July 1994, there was a distinct southerly shift (Figure 1.4, Hammond *et al* 2013). This change in distribution was also noted in sightings and strandings data from other European countries (Camphuysen, 1994; Kiszka *et al* 2004; Haelters and Camphuysen, 2009; Haelters *et al* 2010, 2011; Camphuysen, 2011; Camphuysen and Siemensma, 2011). Possibly, more remarkable was return of harbour porpoise to the eastern English Channel in 2005 after their noted absence in 1994 (Hammond *et al* 2002).

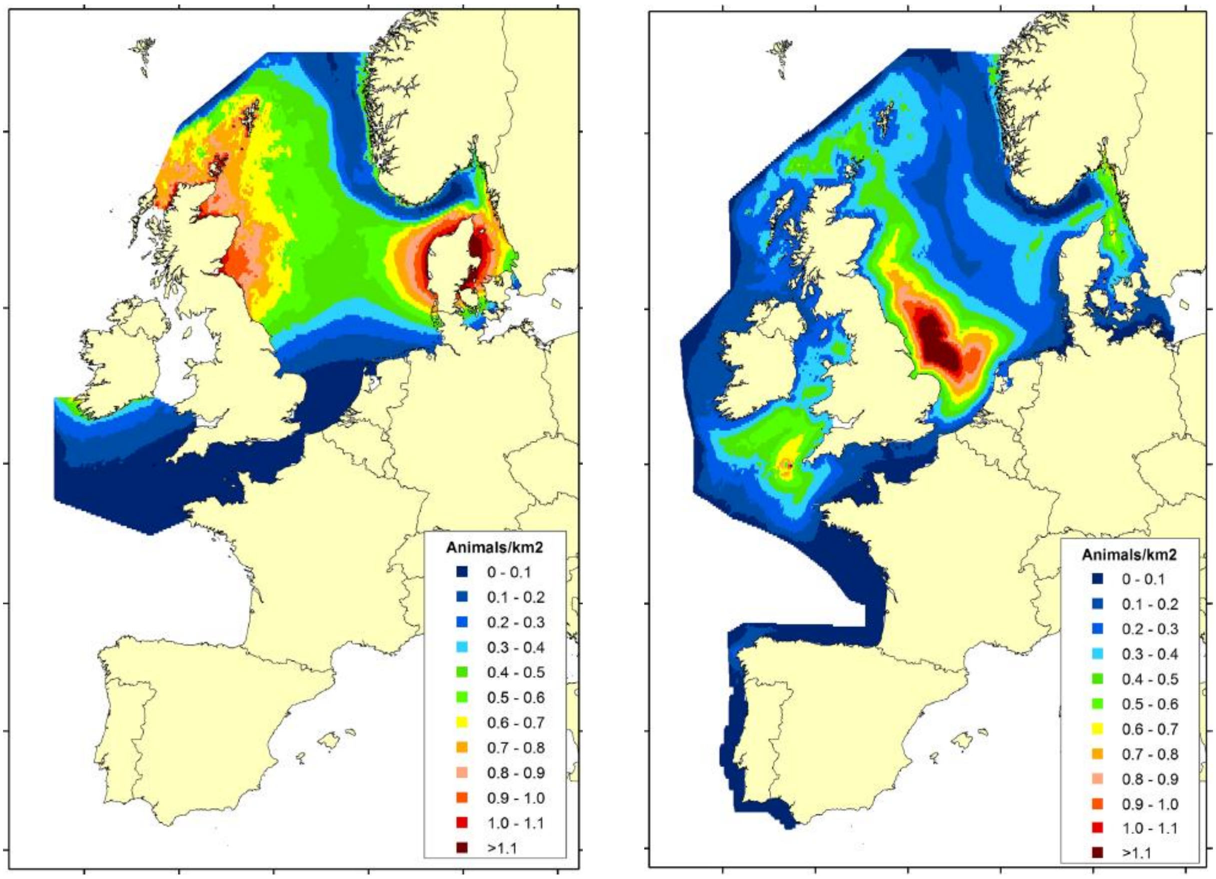


Figure 1.4. Predicted of estimated abundance of harbour porpoises in NW European waters from the SCANS survey in July 1994 (left) and from SCANS II in July 2005 (right). (From Hammond *et al* 2013).

1.4 Biological parameters

Factors affecting reproduction and mortality (vital rates) are important in determining population trends (Pianka, 1994; DeSante *et al* 2001). Cetacean strandings can be an essential source of data on demographic parameters, but these data are potentially biased due to the prevalence of individuals with a poor health status (Learmonth *et al* 2014).

Life history parameters determined for stranded and bycaught harbour porpoise from Scottish (UK) waters (1992-2005) revealed that females were slightly larger than males at the same age (Learmouth *et al* 2014). This is consistent with findings from other regions (Hall, 2011). In both sexes there seems to be a period of rapid growth that corresponds with attaining physical maturity. Growth continues thereafter, with maximum body size reached at about eight years of age (Learmonth *et al* 2014). It has been reported that harbour porpoise from the UK North Sea are generally smaller than animals in western UK waters (Murphy 2008), although no such differences were noted between eastern and western Scottish waters (Learmonth *et al* 2014).

Studies on stranded individuals have revealed a maximum life expectancy of approximately 24 years, with an average life expectancy of between 14 and 15 years (Lockyer, 1995). In the UK, the maximum estimated age was 20 years for both sexes, although average life expectancy is closer to 12 years (Learmonth *et al* 2014, ICES, 2014b).

The main period for mating and calving in harbour porpoise usually occurs between May and August, with a calving peak in June (Lockyer, 1995, 2003; Murphy *et al* 2010; Learmonth *et al* 2014). Gestation lasts approximately 10-11 months and lactation 8-11 months (Fisher & Harrison, 1970; Gaskin *et al* 1984; Lockyer, 2003).

Simultaneously pregnant and lactating females have been found in samples from several populations, indicating that some mature females may give birth every year (Gaskin *et al* 1984; Barlow and Boveng, 1991; Learmonth *et al* 2014). In most studies, however, the average calving interval is greater than one year (Fisher and Harrison, 1970; Gaskin *et al* 1984), and generally considered to be approximately two years in UK waters (Learmonth *et al* 2014).

High numbers of neonates found stranded in UK waters between June and September illustrate the relatively low survival (for both sexes) in the first year of life (Lockyer, 1995; Learmonth *et al* 2014). It has been reported that females have a higher survival rate than males during the first year of life (Murphy, 2008).

Rates of adult natural mortality are notoriously difficult to assess in harbour porpoise, and datasets based on stranded animals are probably too biased due to the prevalence of individuals with a poor health status.

1.5 Foraging ecology, trophic interactions

Harbour porpoise are largely piscivorous, feeding mainly on small fish from both demersal and pelagic habitats (Santos and Pierce, 2003; Camphuysen *et al* 2006). Prey is extremely variable both spatially and seasonally, although harbour porpoise are often thought to focus on 2-4 species at any one time (Pierce *et al* 2007). Prey species recorded include sandeels, whiting (*Merlandius merlangus*), gadoids, *Trisopterus* sp., clupeids (herring (*Clupea harengus*), sprat (*Sprattus sprattus*)) and horse mackerel (*Trachurus trachurus*) (Santos and Pierce, 2003; Santos *et al* 2004; Pierrepont *et al* 2005). They are also known to take cephalopods (*Loligo* spp.) and crustaceans (*Crangon crangon*).

When feeding pelagically, harbour porpoise are important drivers of multi-species foraging associations of seabirds and marine mammals when they herd prey, such as sandeels and clupeids, towards the sea surface (Camphuysen and Webb, 1999; Camphuysen *et al* 2006). Although the ability of porpoise to use echolocation to discriminate between objects on and buried in sand has been demonstrated experimentally (Kastelein *et al* 1997a), it is currently unclear how they hunt for prey on the seafloor.

Porpoise diet overlaps with diets of other piscivorous marine predators (e.g. other cetaceans, large predatory fish, seabirds and seals) and many of the main prey species are also taken by commercial fisheries. Santos and Pierce (2003) suggested that in the northeast Atlantic there had been a long-term shift from predation on clupeid fish (mainly herring; Rae 1965, 1973) to predation on sandeels and gadoid fish (Santos *et al* 2004), possibly related to the depression in herring stocks from the mid-1960s to the 2000s caused by fisheries (Corten, 1986, 1990).

1.5.1 Interspecies interactions

Lethal interactions between bottlenose dolphins (*Tursiops truncatus*) and harbour porpoises have been documented for decades in UK waters (Ross and Wilson 1996; Jepson and Baker, 1998; Deaville and Jepson, 2011). Casualties are frequent and a concern in some areas, but the harbour porpoise are killed rather than preyed upon by the dolphins (MacLeod *et al* 2007a; Baines and Evans, 2012).

More recently, there have been incidences of harbour porpoise being killed and partly consumed by grey seals *Halichoerus grypus* (Haelters *et al* 2012; Van Bleijswijk *et al* 2014; Bouveroux *et al* 2014; Leopold *et al* 2014, 2015; Stringell *et al* 2015). The scale of this predation on the population is not yet known.

1.6 Survey techniques and monitoring options

To monitor the conservation status of the population, managers have to rely on assessments of abundance in different areas and on trends in abundance over time. These trend data may be supplemented with information on reproductive success and aspects contributing to mortality. Depending on the underlying research questions, there are various, partly complementary, techniques for monitoring available. There is not a single method that can serve all needs and each method has specific advantages and disadvantages in relation to the following tasks:

- Assessment of distributional pattern
- Assessment of total numbers in an area (abundance)
- Changes in abundance (seasonal or otherwise)
- Reproductive success, social structure
- Causes of mortality
- Bycatch rates

Each of which may contribute to assessments of the importance of particular sea areas or of our understanding of anthropogenic pressures on harbour porpoises.

There is an urgent need to develop monitoring techniques to detect changes in distribution and abundance as they occur, for example, as a result of climate changes and major shifts in resource availability (Tasker, 2008). Such assessment, particularly looking at long term trends in overall abundance and detailed observations on seasonal patterns linked with habitat characteristics and key resources are problematic. The Joint Cetacean Protocol offers such a mechanism but further developmental work is required to make this operational at the appropriate international scale. A focus on area-based conservation is unlikely to be effective for this wide ranging mobile species, particularly when such an approach is not considered effective for resident coastal bottlenose dolphin (Cheney *et al* 2014; Hartel *et al* 2014).

With regard to the status of harbour porpoises in UK waters, there is a broad-scale lack of data on year-round seasonality in numbers and distribution and information on immigration and emigration to and from neighbouring MUs, with only limited data on demographical trends (fecundity and annual survival) and diet. Collecting these ecological data (which inform vital rates) is not easy, but they are necessary if population trends are to be explained or forecast, and conservation status assessed accurately.

2 Policy and legislative context for harbour porpoise conservation

2.1 Introduction

The harbour porpoise is legally protected in UK waters through international, European and national legislation. International treaties vary in scope, ranging from a multiple species level focus to regulation of specific habitats or species. As harbour porpoise are a mobile species, protection measures need to be coordinated at an international level to be effective. Nature conservation legislation of the European Union (EU), together with international treaties, impose a need for the strict protection of harbour porpoise, although usually focused at the national level.

2.2 Nature conservation legislation

The key nature conservation instruments for the protection of the harbour porpoise are:

- the Bern Convention which is delivered through the EU Habitats Directive (92/43/EEC) and additional national law;
- the Marine Strategy Framework Directive (MSFD; 2008/56/EC) with international coordination being achieved through the OSPAR Convention;
- Convention on the Conservation of Migratory Species of Wild Animals (also known as CMS or Bonn Convention) which is progressed through the auspices of the Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas (ASCOBANS);

Additional protection is provided through:

- The Convention on Biological Diversity (CBD).
- Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) which has been implemented through the Wildlife Trade Regulations at a European level and the Control of Trade in Endangered Species (Enforcement) Regulations 1997 (COTES) in UK.
- United Nations Law of the Seas (UNCLOS).

2.2.1 Bern Convention

The Bern Convention is intended to promote cooperation between Contracting Parties in order to conserve wild flora and fauna and their natural habitats and to protect endangered migratory species. Harbour porpoises are listed in Appendix II of the Convention, which prohibits intentional killing, taking, injuring or sale. The convention is largely implemented through the Habitats Directive.

2.2.2 EU Habitats Directive

Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora (otherwise known as the Habitats Directive) places upon Member States (MS) the obligation to achieve or maintain listed species, which includes the harbour porpoise, at a favourable conservation status (FCS) within the territory of the European Union. This is the primary objective of the Directive, which defines FCS as when population dynamics data indicate that the species is maintaining itself on a long-term basis as a viable component of its habitat and that the natural range of the species is neither being reduced, nor is likely to be reduced, in the foreseeable future. FCS is also evidenced by the presence, and likely continuing presence, of a sufficiently large habitat to maintain the population on a long-term basis.

Article 3 requires each Member State to identify and designate Special Areas of Conservation (SACs) for the species listed in Annex II, which includes the harbour porpoise. SACs are to be selected on the basis of criteria set out in Annex III; these include a global (overall) assessment of the value of the site for the conservation of the species. Article 4(1) specifically states that "*for aquatic species which range over wide areas, SACs will be proposed only where there are clearly identifiable areas representing the physical and biological factors essential to their life and reproduction*." The identification of such areas has proven difficult due to the mobile nature of the species and it is not until 2015 that the UK has found a robust and reliable method, despite several previous attempts (see section 2.2.2.1).

Through Article 12, Member States are required to establish a system of strict protection for harbour porpoise; prohibiting the deliberate killing, taking, disturbance or deterioration of breeding sites or resting places and the keeping, transport and sale of animals taken from the wild (this article implements most of the requirements of the Bern Convention and relevant parts of CITES). Under Article 12(4), the establishment of a system to monitor the incidental capture and killing of the harbour porpoise is required. In light of the information gathered, the Article obliges Member States to undertake further research or conservation measures to ensure that any incidental capture and / or killing does not have a significant negative impact on the conservation status of the species. Article 11 requires that Member States establish a system to monitor the conservation status of all listed habitats and species, whilst Article 17 requires MS to report on that status every six years.

The UK implementation of the Habitats Directive has required the introduction of new national legislation, but elements of Article 12 were already being implemented for harbour porpoises through the Wildlife and Countryside Act 1981 (WCA) in England, Scotland and Wales and through The Wildlife (Northern Ireland) Order 1985 in Northern Ireland. Both these pieces of legislation make it an offence (subject to exceptions) to intentionally kill, injure or take, possess, or trade in any wild animal listed in Schedule 5, which includes harbour porpoise, and prohibits interference with places used for shelter or protection, or intentionally disturbing animals occupying such places.

Since the passing of the WCA in 1981, there have been various amendments to the text of the Act, most significantly through the Countryside and Rights of Way (CRoW) Act 2000 (in England and Wales) and the Nature Conservation (Scotland) Act 2004 (in Scotland). Similarly, the Wildlife (Northern Ireland) Order 1985 was updated and amended through the introduction of the Wildlife and Natural Environment Act (Northern Ireland) 2011.

The main legislation introduced to transpose the requirements of the Habitats Directive into national law was the Conservation (Natural Habitats, &c.) Regulations 1994 for Great Britain and The Conservation (Natural Habitats, &c) Regulations (Northern Ireland) 1995 (as amended). The 1994 Regulations have subsequently been amended, updated and replaced by The Conservation of Habitats and Species Regulations 2010 (as amended in 2012), which consolidates all the various amendments made to the Conservation (Natural Habitats, &c.) Regulations 1994 in respect of England and Wales. In Scotland, the Habitats Directive is transposed through a combination of the Habitats Regulations 2010 (in relation to reserved matters) as well as the 1994 Regulations, and the Nature Conservation (Scotland) Act 2004.

The Offshore Marine Conservation (Natural Habitats, &c.) Regulations 2007 (as amended) transpose the EU Habitats Directive into national law for the UK's offshore marine area which covers waters beyond 12 nautical miles, to the 200 nm Exclusive Economic Zone (EEZ) limit. The Offshore Petroleum Activities (Conservation of Habitats) Regulations 2001, as amended in 2007, applies the requirements of the Habitats Directive in relation to oil and gas plans or projects within the EEZ. The Infrastructure Act 2015 covers marine renewables in the wider context.

Together these national regulations provide for the designation and protection of Special Areas of Conservation (SACs), the protection of 'European Protected Species' (EPS, from Article 12 requirements), and the adaptation of planning and other controls to ensure both the protection of the species and designated sites. An EPS license is required by anyone who wishes to carry out an activity prohibited under the Regulations, which can be requested at the relevant regulatory bodies for Wales and England, Scotland and Northern Ireland.

2.2.2.1 Special area conservation (SAC) and wider measures in UK waters

The UK currently has 34 SACs where the presence of harbour porpoise is noted, but the species is not a qualifying feature, i.e. there are no conservation objectives specific to the species. These sites are expected to contribute to the maintenance of the favourable conservation status of harbour porpoise through the conservation measures associated with the qualifying habitat features. Protection of the habitat features will benefit the prey resource and, therefore contribute to the conservation of harbour porpoises.

The UK currently has a single SAC (Skerries and Causeway) in Northern Ireland where the harbour porpoise is listed as a qualifying feature. On the basis of formal advice from JNCC and Statutory Nature Conservation Bodies (SNCBs), the Governments of Wales and of Northern Ireland, and Defra on behalf of England and offshore, have decided to proceed to consultation with five possible SACs for harbour porpoise (Figure 2.1). A public consultation for these five sites will precede recommendation to Europe.

The possible SACs are based on an analysis of high density areas that are persistent over the period between 1994 and 2011 (Heinänen and Skov, 2015; IAMMWG, 2015b). However, given recent patterns and trends associated with climate change, massive shifts in the distribution of potential prey items may occur, some of which may turn out to be irreversible, and areas of importance for a particular top-predator species today may become less so in the future (Víkingsson *et al* 2015).

Given the mobile nature of the species and the widespread nature of anthropogenic activities exerting pressures on the species, area protection will not, in isolation, be sufficient to maintain the harbour porpoise in favourable conservation status. Generic measures to prevent bycatch in certain fisheries metiers, to reduce pollution, and to mitigate the most problematic underwater sounds produced are required throughout the harbour porpoise range; albeit heightened management of pressures in ‘important areas’ may increase benefits beyond those from employing standard management approaches across the species range. An approach which primarily protects the species throughout its range, with area-based measures making a contribution, will likely be the most effective. To date, the UK has had very limited area protection for harbour porpoise and despite which the current assessments consider the species is at Favourable Conservation Status because the population is considered stable and there is no evidence that anthropogenic activitities are having a significant negative effect on the population.

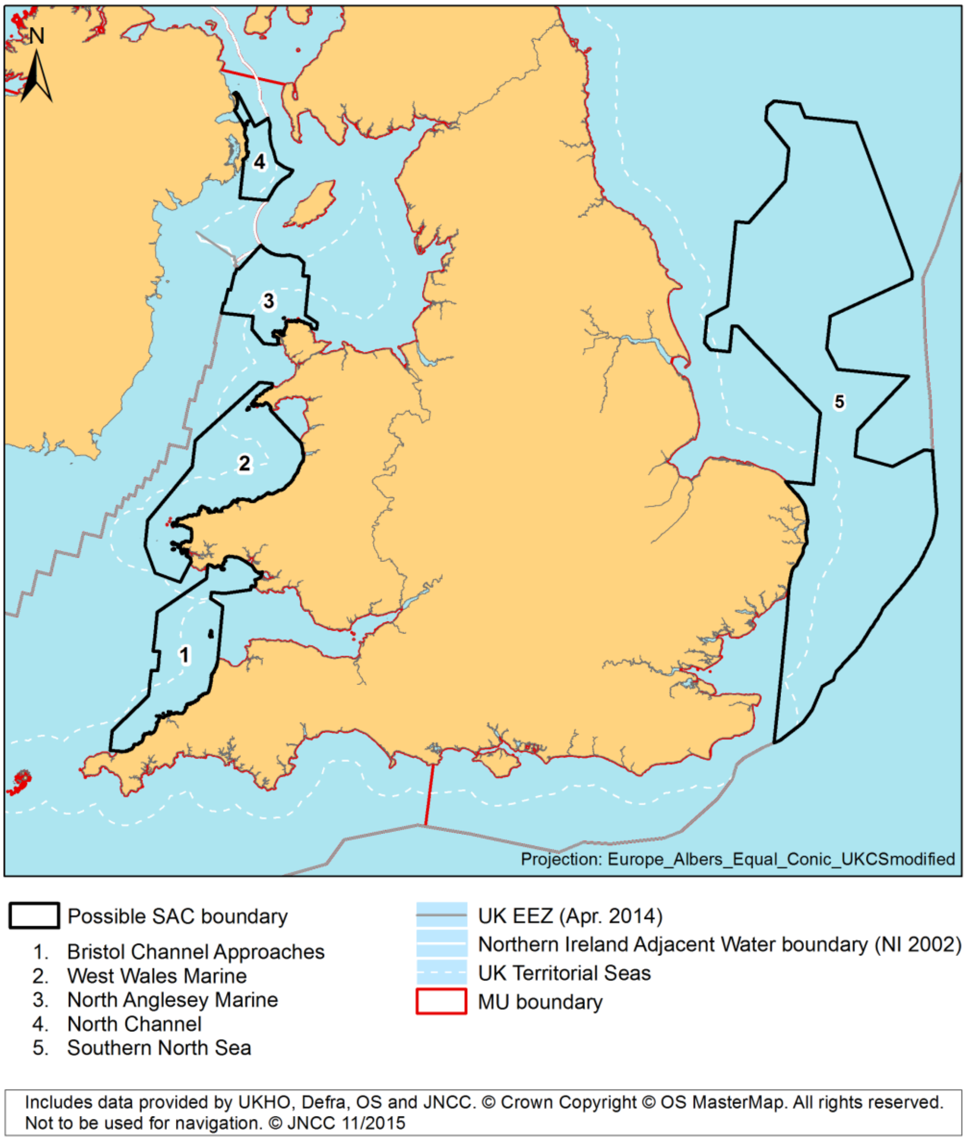


Figure 2.1. Final boundaries of the five possible SACs proceeding topublic consultation.

2.2.3 2008/56/EC Marine Strategy Framework Directive (MSFD)

The Marine Strategy Framework Directive (MSFD) formally adopted by the European Union in July 2008, requires EU Member States to develop marine strategies that apply '*an ecosystem-based approach to the management of human activities while enabling a sustainable use of marine goods and services, priority should be given to achieving or maintaining good environmental status in the Community's marine environment, to continuing its protection and preservation, and to preventing subsequent deterioration.... This approach should include protected areas and should address all human activities that have an impact on the marine environment*'.

The MSFD is complementary to, and provides the overarching framework for, a number of other key Directives and legislation at the European and UK level, including the EC Habitats Directive, the Common Fisheries Policy and the UK Marine and Coastal Access Act 2009. Article 11 states that '*Member States shall establish and implement coordinated monitoring programmes for the ongoing assessment of the environmental status of their marine waters...*

Monitoring programmes shall be compatible within marine regions or subregions and shall build upon, and be compatible with, relevant provisions for assessment and monitoring laid down by Community legislation, including the Habitats and Birds Directives, or under international agreements.... Member States sharing a marine region or subregion shall draw up monitoring programmes... and shall, in the interest of coherence and coordination, endeavour to ensure that:

> *(a) monitoring methods are consistent across the marine region or subregion so as to facilitate comparability of monitoring results;*
>
> *(b) relevant transboundary impacts and transboundary features are taken into account*.'

In order to determine Good Environmental Status (GES), eleven qualitative Descriptors have been developed. These include three which relate to harbour porpoise: Descriptor 1 Biological Diversity, Descriptor 8 Contaminants and Descriptor 11 Introduction of Energy, including underwater noise. The coordination of the Marine Strategy with other countries within the same marine region or subregion is being achieved through the Regional Seas Conventions, which for the UK is the OSPAR Convention (section 2.2.4).

OSPAR has also been leading the international development of indicators and targets for determining GES in the UK relevant subregion. In 2011, all Contracting Parties to OSPAR were requested to submit the biodiversity indicators being considered at a national level (Descriptor 1). Subsequently, a meeting was convened, the 'Amsterdam Workshop', to compare and contrast the different proposals and to develop a core set of common indicators of GES within each OSPAR region (Report of the meeting available at: http://www.ospar.org/documents/dbase/publications/p00575/p00575_ospar%20biodiversity%20workshop.pdf). Shortly afterwards, expert groups working under the Inter-sessional Correspondence Group for the Coordination of Biodiversity Assessment and Monitoring (COBAM) were formed to provide further scrutiny and elaboration of the common indicators proposed and to begin to describe their technical elements. The common indicators agreed for cetaceans were: 'Distributional range and pattern of cetacean species regularly present', 'Abundance at the relevant temporal scale of cetacean species regularly present' and 'Mortality rate of seals and cetaceans due to bycatch' (ICG-COBAM, 2012). These were formally endorsed by the Biodiversity Committee (BDC) in 2013 (summary record available at: http://www.ospar.org/v_meetings/browse.asp?menu=00050500000000_000000_000000). Subsequently work on the common marine mammal indicators is being further progressed through links between the COBAM expert group and ICES Working Group for Marine Mammal Ecology.

Post 2013, links between these groups and the ASCOBANS MSFD Working Group have also been established with the aim of making the most effective use of available international resource. At the national level, indicators and targets have been proposed that generally align with the needs of the Habitats Directive. The one possible exception is the explicit need to monitor contaminant levels in harbour porpoise. An additional 'Blubber PCB toxicity threshold' indicator for harbour porpoise has been proposed at OSPAR for MSFD Descriptor 8 Contaminants (ICES 2014b).

In addition, European Commission decided in September 2010 that two indicators for Descriptor 11: Introduction of energy, including underwater noise should be developed. These are: Indicator 11.1.1 on 'Low and mid frequency impulsive sounds' (e.g. seismic airguns, pile driving and explosives) and Indicator 11.2.1 on 'Continuous low frequency sound (ambient noise)'.

The UK option for monitoring impulsive sound (D11.1) is the development of a Marine Noise Registry (MNR) database. The UK has also been leading the discussions on the development of a common registry for the OSPAR regional seas. However, the realisation of a common registry will be dependent on contributions (data and funds) from OSPAR Contracting Parties (Adrian Judd, pers. comm.).

UK waters are situated in two MSFD subregions, the Greater North Sea and the Celtic Seas. Each Member State is required to develop a marine strategy for their waters, in coordination with other countries within the same marine region or subregion, through OSPAR.

In 2012, the UK produced Part One of the Marine Strategy, containing information on the first three elements of the MSFD (initial assessment of the current environmental status of UK waters; determination of Good Environmental Status and Targets and Indicators designed to show whether a Member State is achieving GES). In 2014, Part Two, which focuses on a coordinated monitoring programme for the ongoing assessment of GES was published. Part Three focuses on a programme of measures. A public consultation covering the programme of measures for each of the eleven MSFD Descriptors was undertaken between 30 January and 24 April 2015, the result of which have yet to be published.

A UK Marine Biodiversity Monitoring Programme is under development that will advise governments on biodiversity monitoring systems. This programme is presently (2015) concentrating on habitats, seabirds and cetaceans and being undertaken within the UK Marine Monitoring and Assessment Strategy (UKMMAS).

2.2.4 Convention for the Protection of the Marine Environment in the North-East Atlantic (OSPAR)

The Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) replaced both the Oslo and Paris Conventions, with the intention of providing a comprehensive and simplified approach to addressing issues associated with maritime pollution. Additionally, OSPAR also provides for the '*protection and conservation of the ecosystem and biological diversity of the maritime area*' through work undertaken under Annex V, which also includes criteria for identifying human activities and work on marine protected areas (MPAs). In 2004, OSPAR agreed a list of threatened and declining species that included harbour porpoise. The list is not legally binding and species and habitats can be added or removed in light of changes to their conservation status, to the threats they face and in light of the latest scientific assessments, according to the Texel-Faial Criteria (OSPAR 2003-13). For each listed species, a case document was prepared that outlined basic biology and ecology, trends in abundance and distribution, the IUCN status assessments, known threats to the species, existing management measures and actions to be undertaken by the relevant Contracting Parties. These documents were updated most recently in 2010.

As part of this revision, the harbour porpoise background document now includes a recommended list of monitoring requirements for the OSPAR area. Initially, baseline monitoring is required that includes visual surveys of abundance and distribution, and reporting strandings and bycatch. Additionally, acoustic surveys are required for areas known or suspected to host high densities of harbour porpoise or to be breeding, birthing, or rearing grounds. The monitoring should be enhanced when a population is considered to be endangered, or when a population has shown statistically significant declines.

This additional monitoring includes bycatch reporting on all vessels in fisheries known or suspected to have porpoise bycatch; aerial surveys of national areas at least every three years, preferably every year (or increased sighting surveys in areas of known or suspected problems, as well as the use of passive acoustic monitoring); collection of tissue samples of bycaught and stranded animals and necropsies (post-mortem examinations) of a sample of these animals; this should include the examination of all organs including brain, the inner ear, analysis of pollutants in tissues, and immune function tests. In 2013, OSPAR agreed Recommendation 2013/11 on furthering the protection and restoration of the harbour porpoise (*Phocoena phocoena*) in Regions II and III of the OSPAR maritime area, which encourages implementation of all relevant conservation measures focusing on the need to reduce anthropogenic impacts such as bycatch and disturbance.

In addition to the list of threatened and/or declining species and the associated monitoring requirements, OSPAR has also developed a number of Ecological Quality Objectives (EcoQOs) for the North Sea. A core aspiration of OSPAR is the sustainable use of ecosystem goods and services through the application of the ecosystem approach such that we can maintain a clean, healthy, and biologically diverse North-East Atlantic ecosystem (OSPAR, 2010). Consequently, the EcoQOs were developed to provide operational objectives and indicators for applying the ecosystem approach, which includes one for harbour porpoise bycatch. It was agreed at the fifth North Sea Conference in 2002 that an Ecological Quality Element relating to harbour porpoise bycatch in the North Sea would be given the objective: 'annual bycatch levels should be reduced to levels below 1.7% of the best population estimate'. The EcoQO aimed to reduce bycatch in the North Sea to a level that would allow the population to recover to at least 80% of the ecosystem's long-term carrying capacity. Higher bycatch rates were considered likely to affect population size in the longer term.

In 2008, the ICES Working Group on Marine Mammal Ecology tried to evaluate progress to date with this EcoQO on a North Sea wide basis (ICES, 2008). It was quickly apparent that many of the fisheries suspected to have the highest bycatch levels are conducted without bycatch observer programmes as these are not a requirement of EU Regulation 812/2004, although such monitoring was required through the Habitats Directive. With the introduction of the MSFD, however, almost all the EcoQOs, including that for harbour porpoise bycatch, have been further developed and form the basis of many of the indicators and targets to determine GES.

2.2.5 The Convention on the Conservation of Migratory Species of Wild Animals (CMS)

The Convention on the Conservation of Migratory Species of Wild Animals (also known as CMS or the Bonn Convention) is a global convention which aims to conserve migratory species throughout their range, with species that need, or would benefit from, international co-operation listed in Appendix II, including the harbour porpoise. For Appendix II species, CMS encourages states to conclude regional Agreements and in 1991, the Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas was concluded (ASCOBANS), entering into force in 1994. In February 2008, an extension of the agreement area came into force which changed the name to "Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas" (with the original acronym being retained). ASCOBANS aims to promote close cooperation amongst Parties with a view to achieving and maintaining a favourable conservation status for small cetaceans, including the harbour porpoise.

ASCOBANS includes a concise Conservation and Management Plan (CMP) that outlines the conservation and management measures to be implemented by the signatories. This states that research '*shall be conducted in order to (a) assess the status and seasonal movements of the populations and stocks concerned, (b) locate areas of special importance to their survival, and (c) identify present and potential threats to the different species*.' Besides these requirements to monitor abundance and distribution of small cetacean species, the CMP also states that '*each party shall endeavour to establish an efficient system for reporting and retrieving bycatches and stranding specimens and to carry out … full autopsies in order to collect tissues for further studies and reveal possible causes of death and to document food composition. The information shall be made available in an international database*'. In addition, the CMP also states that '*Information shall be provided to the general public in order to ensure support for the aims of the agreement in general and to facilitate the reporting of sightings and strandings in particular; and to fishermen in order to facilitate and* *promote the reporting of bycatches and the delivery of dead specimens to the extent required for research under the agreement*.'

The ASCOBANS Resolution on Incidental Take of Small Cetaceans has as its conservation objective to minimise (i.e. to ultimately reduce to zero) anthropogenic removals. The Resolution defines "unacceptable interactions" as being, in the short term, a total anthropogenic removal above 1.7 % of the best available estimate, and underlines the intermediate precautionary objective to reduce bycatch to less than 1% of the best available population estimate. In 2009, a Conservation Plan for the Harbour Porpoise in the North Sea was adopted by all Contracting Parties (see section 2.5.4).

2.2.6 Convention on Biological Diversity (CBD)

The Convention on Biological Diversity (CBD) aims at the conservation of biological diversity and the sustainable use of its components. In compliance with the requirements of the Convention on Biological Diversity (CBD), the UK prepared the UK Biodiversity Action Plan (UK BAP) which included a species action plan for harbour porpoise. These action plans have now been superseded by the UK post-2010 Biodiversity Framework (JNCC and DEFRA 2012) as the result of the CBD's Strategic plan for Biodiversity 2011-2020 project (https://www.cbd.int/sp/). The framework shows how the work of the four UK countries joins up with work at a UK level to achieve the 'Aichi Biodiversity Targets' and the aims of the EU biodiversity strategy.

Most work previously carried out under the UK BAP is now focussed at the country level (England, Northern Ireland, Scotland and Wales). Within England this is known as Biodiversity 2020 and was published in 2011; in Northern Ireland, as the 'Northern Ireland Biodiversity Strategy' published in 2002 with the second State of the Environment report for Northern Ireland ('From Evidence to Opportunity') published in 2014. The Welsh Government developed a new approach to manage the environment and natural resources known as 'The Living Wales Programme' (2013) and in 2015, published a Snapshot of the State of Wales' Natural Resources outlining the current evidence on the state of Welsh natural resources. In Scotland it is known as the '2020 Challenge for Scotland's Biodiversity - a strategy for the conservation and enhancement of biodiversity in Scotland' (published in 2013) as a supplement to 'Scotland's Biodiversity: It's in Your Hands' (2004), which set out a 25-year strategy for the conservation and enhancement of biodiversity in Scotland. The two documents together comprise the Scottish Biodiversity Strategy.

The priority actions identified at the UK level for cetaceans, but implemented nationally, reflect international obligations for the species. For harbour porpoise these are: undertake research on cetaceans using UK waters to identify areas of particular importance for breeding, feeding or migration; undertake any necessary research and fully implement mitigation measures to reduce bycatch as far as possible; develop and implement a UK Cetacean Surveillance Strategy; maintain the UK stranding scheme, which provides an indication of the extent of anthropogenic mortality, and implement appropriate remedial action when necessary (JNCC, 2010a).

2.2.7 CITES

The 1973 Convention on International Trade in Endangered Species of Wild Fauna and Flora, also known as CITES or the Convention of Washington, entered into force in 1975. It aims to ensure that international trade in specimens of wild animals and plants does not threaten their survival in the wild. In several appendices, CITES sets varying regulations for the international trade in endangered species, in live and dead animals, as well as in parts of them. The harbour porpoise is listed in Appendix II, which covers species that are not necessarily threatened with extinction, but may become so unless trade is closely controlled. Within the European Union, CITES has been implemented since 1 January 1984 through the EU Wildlife Trade Regulations.

The provisions in the EU Wildlife Trade Regulations are stricter than CITES. They include certain non-CITES species, and also contain provisions to prohibit or restrict imports of species which are considered to be a threat to native EC flora and fauna. All cetaceans are listed in Annex A of Council Regulation 338/97, which effectively treats them as if they were CITES Appendix I species. Commercial trade of these species within the European Community is therefore not allowed. The Control of Trade in Endangered Species (Enforcement) Regulations 1997 (COTES) makes provision for enforcement of the European Regulations in the UK.

2.2.8 United Nations Convention on the Law of the Sea

Originally introduced in 1956, the United Nations Convention on the Law of the Sea establishes rules governing all uses of the oceans and their resources. It sets out the global legal framework for human activities at sea and is based on the idea that the problems of the oceans are closely interrelated and therefore must be addressed as a whole (Camphuysen & Siemensma 2011). Included within the Convention are general provisions relating to marine conservation. Specifically, the Convention states that Contracting Parties "*shall cooperate with a view to the conservation of marine mammals and in the case of cetaceans shall in particular work through the appropriate international organizations for their conservation, management and study*" and that signatories must take measures "*necessary to protect and preserve rare or fragile ecosystems as well as the habitat of depleted, threatened or endangered species and other forms of marine life*". Organisations through which such actions could be taken are, for example, the International Whaling Commission (IWC) and ASCOBANS.

2.3 Fisheries legislation

Interacting with the nature conservation legislation and of key relevance to harbour porpoise is a variety of fisheries legislation. The European Commission has exclusive competence over fisheries management, which became enshrined in the 1992 Treaty on European Union (Article 3). Subject to powers delegated to the Member States, the European Council is therefore charged with establishing the conditions regulating fishing activities pursued by Community fleets, which is undertaken through the Common Fisheries Policy (EC 1380/2013. This applies to all commercial fishing vessels operating in EU waters and EU vessels operating elsewhere. Management under the CFP is delegated to Member States including the UK inside 12 nautical miles (nm), but vessels of other Member States with historical rights may fish in certain waters between 6 and12 nm from the coastline. Only the relevant Member State's vessels may fish between 0 and 6 nm from the coastline and in internal waters. In addition to the CFP, EU Regulation 812/2004 is also relevant to the conservation of harbour porpoise as it lays down measures concerning incidental catches of cetaceans in fisheries.

2.3.1 European Common Fisheries Policy (CFP)

The CFP has been reviewed and reformulated on an approximately decadal scale since it was first agreed in 1982, with the most recent reforms being agreed in 2013. The CFP brings together a range of measures designed to achieve a thriving and sustainable European fishing industry. Sustainability in this context includes environmental sustainability and while there is no explicit mention of marine mammal interactions in the CFP, it is widely recognised that fisheries have the potential to harm marine mammal populations. The responsibilities for conservation of harbour porpoises and management of activities influencing the species are therefore shared between Member States and the European Union.

As discussed in section 2.2.2, the harbour porpoise is protected under the EU Habitats Directive, which requires Member States to make sure that bycatch, one of the main pressures on porpoise, is not having a negative effect on the FCS. However, bycatch is occurring under activities administered through the CFP and, therefore, measures have to be introduced through the CFP in order to limit the effects of bycatch.

2.3.2 Council Regulation 812/2004 related to incidental catches of cetaceans in fisheries

EC Council Regulation No 812/2004 of 2004 lays down measures concerning incidental catches of cetaceans in fisheries. It amends Regulation EC No 88/98 and is part of the implementation of the CFP.

Regulation 812/2004 is in three parts. The first is the mandatory use, and the assessment of the effects, of acoustic deterrent devices in specified static and mobile gears to prevent bycatch. These acoustic deterrent devices, also called pingers, specifically aim at keeping porpoises (and other small cetaceans) away from fishing gear. The regulation gives technical criteria of the acoustic deterrent devices, on both signal and implementation characteristics. Vessels <12 metres in length are not required to use pingers under the Regulation.

The second part requires independent surveillance of fishing activities. Independent observations of fishing activities are essential to provide reliable estimates of the incidental catch of cetaceans. The development and implementation of independent on-board observer schemes or remote electronic monitoring (REM) in specified fisheries is required in to assess bycatch. However, this only applies as a mandatory requirement for vessels over 15 metres in length. The third part of Regulation 812/2004, is not applicable in UK waters as it relates to the prohibition of use of driftnets in the Baltic Sea.

None of the parts of Regulation 812/2004 remove the obligations of Member States under Article 12 of the Habitats Directive. Under Regulation 812/2004, the monitoring of cetacean bycatch is not required for a substantial part (i.e. hundreds of vessels <12m in length) of the European fleet and yet much of the fisheries that constitute the greatest risk to harbour porpoise are within this fleet segment. The European Commission has decided not to amend Regulation 812/2004 at present and to integrate monitoring of Protected and Endangered and Threatened Species (PETS) including marine mammals into the new Data Collection Framework (DCF) (ICES, 2014c). The implementation of the landing obligation (known as the discards ban)[2] under the reformed CFP may have profound consequences for how fishery monitoring is conducted in future. It could for example result in an increase in port- or market sampling schemes, and reductions in sea going observer schemes. Since marine mammals are not commercial species, there is no obligation to return them to port (and this would in any case infringe on much of the national legislation of many countries). Thus the only reliable way of recording bycatch will be through at-sea monitoring schemes that are likely to be reduced. ICES (2014c) advised that monitoring for protected species bycatch requires particular sampling stratification that may differ from that used by most DCF-based monitoring programmes. If DCF monitoring programmes are used, protocols should also

[2] http://ec.europa.eu/fisheries/cfp/fishing_rules/discards/index_en.htm

require specific monitoring of protected species and appropriate sampling methods (ICES, 2014c).

2.3.3 UK Fisheries legislation

The Secretary of State's function of granting licences under section 4 of the Sea Fish (Conservation) Act 1967 for fishing boats was transferred to the Marine Management Organisation and is covered under the Marine and Coastal Act 2009. UK commercial fisheries are regulated by the 1981 Fisheries Act, which also covers aquaculture and whaling. The section on whaling, extends the 1934 Whaling Act which prohibits the use of any ship for the whaling of any species of cetacean within United Kingdom Fishery Limits. The Sea Fisheries (Wildlife Conservation) Act 1992 requires that appropriate Ministers and relevant bodies have regard to the conservation of flora and fauna in the discharge of their functions under the Sea Fisheries Acts.

2.4 Marine spatial planning (MSP)

In July 2014, the European Parliament and the European Council adopted legislation to create a common framework for maritime spatial planning in Europe (Directive 2014/89/EU), '*aimed at promoting the sustainable growth of maritime economies, the sustainable development of marine areas and the sustainable use of marine resources*'. Article 5 states '*through their maritime spatial plans, Member States shall aim to contribute to the sustainable development of energy sectors at sea, of maritime transport, and of the fisheries and aquaculture sectors, and to the preservation, protection and improvement of the environment, including resilience to climate change impacts. In addition, Member States may pursue other objectives such as the promotion of sustainable tourism and the sustainable extraction of raw material*'.

There is considerable overlap in the requirements of the MSP and MSFD Directives and some debate about implementation (Brennan *et al* 2014). It is considered that any member state fully meeting the requirements of MSFD will not be required to do any additional work for the MSP Directive. The UK is fully committed to the further development of marine spatial planning.

2.4.1 SEA and EIA

The Strategic Environmental Assessment (SEA) (2001/42/EC) Directive has formal and explicit links with both the Habitats and EIA Directives with respect to activities in the marine environment. Article 1 states that the objective of SEA is to '*provide for a high level of protection of the environment and to contribute to the integration of environmental considerations into the preparation and adoption of plans and programmes with a view to promoting sustainable development, by ensuring that, in accordance with this Directive, an environmental assessment is carried out of certain plans and programmes which are likely to have significant effects on the environment'*.

This Directive contributes to the systematic and structured consideration of environmental concerns in planning processes and, by means of its requirements (environmental report, consultation and information of the authorities and public concerned etc.), it ensures better and harmonised planning procedures, and contributes to transparent and participatory decision making processes.

'The SEA Directive does not have a list of plans/programmes which require assessment, unlike the EIA Directive. However, '*SEA is mandatory for plans/programmes which:*

- *are prepared for agriculture, forestry, fisheries, energy, industry, transport, waste / water management, telecommunications, tourism, town & country planning or land use and which set the framework for future development consent of projects listed in the EIA Directive.*

  OR

- *have been determined to require an assessment under the Habitats Directive*.'

The Environmental Impact Assessment Directive (EIA) (2014/52/EU amending 2011/92/EU which in turn amended earlier versions) requires a process to predict environmental effects of certain activities, prior to development. An impact assessment can propose measures to adjust impacts to acceptable levels or investigate new technological solutions to reduce impact. An Environmental Impact Assessment (EIA) is used to examine the environmental and cumulative impacts associated with an individual project. The EIA Directive was revised and entered into force in May 2014. The amended EIA has simplified rules for assessing the potential effects of projects on the environment. Under the Directive, if projects do entail significant adverse effects on the environment, developers will be obliged to take the necessary steps to avoid, prevent or reduce such effects. These projects will now need to be monitored using procedures determined by the Member States.

'The SEA and EIA procedures are very similar, but there are some differences:

- *SEA requires environmental authorities to be consulted at the screening stage;*
- *scoping (i.e. the stage of the SEA process that determines the content and extent of the matters to be covered in the SEA report to be submitted to a competent authority) is obligatory under the SEA;*
- *SEA requires an assessment of reasonable alternatives (under the EIA the developer chooses the alternatives to be studied);*
- *under the SEA Directive, Member States must monitor the significant environmental effects of the implementation of plans/programmes in order to identify unforeseen adverse effects and undertake appropriate remedial action.*
- *the SEA Directive obliges Member States to ensure that environmental reports are of a sufficient quality*.'[3]

2.5 Cetacean conservation strategies

As a result of the wide variety of legal commitments and agreement obligations, various cetacean conservation strategies have been developed in both the UK and elsewhere in the world.

2.5.1 Existing UK strategies for harbour porpoise conservation

The key objective of all of the legal instruments and obligations outlined in sections 2.2 – 2.4, either directly or indirectly, is to maintain or contribute to an improvement of the conservation status of the harbour porpoise. In 2000, the UK published a conservation strategy for harbour porpoise (DETR 2000). Conservation efforts of the strategy concentrated on threat / impact

[3] From: http://ec.europa.eu/environment/eia/sea-legalcontext.htm

reduction coupled with wider surveillance as a mechanism to assess progress and effectiveness of mitigation and management measures. The plan required:

1) the identification and evaluation of the risk of key threats to the favourable conservation status of harbour porpoise;
2) monitoring of the key threats;
3) implementing measures to reduce identified threats and monitoring their effectiveness;
4) undertaking wider surveillance and assessment of the species to prioritise threats in a population context;
5) identifying SACs where they accord with the relevant terms of Article 4.1 of the Habitats Directive and carefully considering management measures within sites and the wider implications outside sites.

The UK has been concerned about the levels of cetacean bycatch in fisheries for a number of years. In addition to the UK's conservation strategy for harbour porpoise, a UK Small Cetacean Bycatch Response Strategy was developed in 2003 and updated in 2009 (Defra 2009). The bycatch strategy identified measures to reduce small cetacean bycatch to a level below 1.7% of the best population estimate set by ASCOBANS. Recommended mitigation measures focus on: legal requirements to use pingers; consideration of a mortality limit scheme; measures to restrict fisheries in designated SACs; secure funding for distribution and abundance data; establishment of a bycatch monitoring scheme; studying the effects of pinger use; investigation of net modifications; consideration of an accreditation system for fisheries adopting or cooperating towards cetacean-friendly methods; encouraging the Advisory Councils (ACs, former Regional Advisory Councils [RACs]) to consider which fishing sectors have an unacceptable level of bycatch and suggesting measures to reduce bycatch in those fisheries. A UK Bycatch Monitoring Programme was formally initiated in 2005 and currently focuses much of its independent observer monitoring on fisheries known or suspected to have high overall bycatch, covering the monitoring requirements of both EU Regulation 812/2004 and the Habitats Directive (Northridge & Kingston, 2010; Northridge *et al* 2011a, b, 2012a, 2013a, 2014).

In 2009, the UK's conservation strategy for harbour porpoise was reviewed as part of an assessment on maintaining favourable conservation status of the species (JNCC, 2010b). The overall UK approach to conserving harbour porpoise had not changed since the strategy was originally published in 2000 and the strategy was left unchanged in 2009.

2.5.2 Dutch harbour porpoise conservation plan

In 2011, at the request of the Dutch Ministry of Economics, Agriculture & Innovation, a species conservation plan for the harbour porpoise was developed (Camphuysen and Siemensma, 2011). The plan was based on current seasonal occurrence and abundance of porpoise within waters under Dutch jurisdiction with the aim of achieving favourable conservation status. Harbour porpoise have increased markedly in number in the southern North Sea in recent decades. The conservation status of the harbour porpoise in The Netherlands was evaluated as 'Inadequate', with the population evaluated as 'Vulnerable' due to unknown causes of a shift in the species in the North sea at large, the age structure and reproductive condition of harbour porpoise in Dutch waters and reported incidental bycatch (Camphuysen and Siemensma, 2011). It is expected that implementing research and mitigation measures, as advised in the Dutch plan, will serve to get harbour porpoise into the desired conservation status and to fulfil the obligations of the relevant international legal treaties.

The Dutch conservation plan includes a generic wider waters approach, rather than being area-specific. Bycatch and impulsive underwater noise were indicated as the biggest pressures. In relation to bycatch, the plan recommended the establishment of observer schemes on all passive gear fleets to assess harbour porpoise bycatch rates according to internationally accepted protocols. It also recommends the investigation of suitability of using alternative gear types or modifications to set-nets, the use of pingers (controlled) when porpoise bycatch is identified, the facilitation of bycatch landings, the control of illegal fisheries, the amendment of Regulation 812/2004 and the evaluation of the effectiveness of mitigation measures. For the adverse effects of impulsive underwater noise (detonation, seismic, pile driving), a system of standards and protocols to mitigate and investigate the impact was recommended.

2.5.3 Conservation plan for cetaceans in Irish waters

In 2007, the European Court of Justice ruled that Ireland could not demonstrate that it was meeting the requirements of Article 12 of the Habitats Directive (Case C-183/05). A Conservation Plan for cetacean species in Irish waters was published in 2009 (DoEHLG, 2009) as part of Ireland's response to this judgement. This plan covers the conservation of all cetaceans rather than providing species-specific objectives.

The Irish plan provides comprehensive information concerning the ecology of all cetacean species and identifies the primary threats / pressures as well as the measures required to address these. Bycatch is considered to be the most immediate threat to harbour porpoise and, although quantified for some fisheries, the cumulative impact is not known. The Irish plan emphasises the need for a multinational effort through the CFP as the best way forward to reduce the impact of fisheries on the harbour porpoise and other species.

Linked with the Irish plan, Ireland has prepared a National Cetacean Protection Strategy. This strategy focuses on (1) designating and monitoring SACs, (2) ensuring general regulatory and administrative functions are sufficiently rigorous and (3) pursuing an integrated strategy for general surveillance of cetaceans.

There are three SACs with harbour porpoise as a qualifying feature of interest (Blasket Islands, Roaringwater Bay and Islands, and Rockabill to Dalkey Island). There are generic Conservation Objectives for these sites. An appropriate assessment of commercial fishing activity in Roaringwater Bay and Islands SAC is currently being carried out (Marine Institute, 2013) and similar assessments are planned for the other SACs.

2.5.4 ASCOBANS conservation plan for harbour porpoise in the North Sea

The ASCOBANS conservation plan for the harbour porpoise in the North Sea (Reijnders *et al* 2009) aims at achieving and maintaining favourable conservation status through a series of priority actions (Table 2.1). The actions of the ASCOBANS conservation plan are largely focused on bycatch and categorised into management and monitoring actions, scientific actions essential for providing adequate management advice and actions aimed at improving our understanding of potential threats to harbour porpoise within the region.

A North Sea Steering Group has been established to coordinate the implementation and to evaluate the effectiveness of the plan. The 2014 interim report highlighted that the situation in the North Sea regarding bycatch remains unclear and suggested that further actions are needed by Member States in terms of reporting monitoring and fishing effort to clarify the conservation status of harbour porpoise in the North Sea. Efforts are also needed to ensure the successful completion of a further abundance survey (SCANS III) for a better understanding of the porpoise population and for the assessment of impact of direct mortality by anthropogenic activities.

Table 2.1. Priority actions from the ASCOBANS harbour porpoise conservation plan (Reijnders *et al* 2009).

ASCOBANS North Sea Conservation Plan for Harbour Porpoise
ACTION 1: Implementation of the Conservation Plan: coordinator and Steering Committee
ACTION 2: Implementation of existing regulations on bycatch of cetaceans
ACTION 3: Establishment of bycatch observation programmes on small vessel (<15m) and recreational fisheries
ACTION 4: Regular evaluation of all fisheries with respect to extent of harbour porpoise bycatch
ACTION 5: Review of current pingers, Development of alternative pingers and gear modifications
ACTION 6: Finalise a management procedure approach for determining maximum allowable bycatch limits in the region
ACTION 7: Monitoring trends in distribution and abundance of harbour porpoises in the region
ACTION 8: Review of the stock structure of harbour porpoises in the region
ACTION 9: Collection of incidental porpoise catch data through stranding networks
ACTION 10: Investigation of the health, nutritional status and diet of harbour porpoises in the region
ACTION 11: Investigation of the effects of anthropogenic sounds on harbour porpoises
ACTION 12: Collection and archiving of data on anthropogenic activities and development of a GIS

2.5.5 USA approach

In the USA, harbour porpoises, like all other marine mammals, are protected under the Marine Mammal Protection Act (MMPA) with conservation focused on the key anthropogenic activities that exert a pressure on the species. For harbour porpoise, approaches to address the issues of bycatch and underwater noise have been developed.

A Harbour Porpoise Take Reduction Plan (HPTRP) was established in 1998 to reduce the serious injury and mortality of the Gulf of Maine and Bay of Fundy stock of harbour porpoise in commercial gillnet fisheries. Mitigation measures were established for several fishery management areas comprising: seasonal closures during the months of the year when harbour porpoises are most concentrated in these areas; pinger requirements for sink gillnets or gillnets capable of catching multispecies, and gear modification requirements. Within this management plan, requirements for small and large mesh gear have been set (Federal Register, 2009). Due to low compliance with its measures and bycatch occurring outside the original management areas, the HPTRP was revised in 2010 (Orphanides and Palka, 2008; Orphanides, 2010). Based on the review, Orphanides and Palka (2013) suggested several actions were required for management actions to be effective:

(1) Steps must be taken to ensure compliance with management actions;

(2) Ensure regulatory measures are broad and flexible enough to allow for changes in the relevant fisheries and the effects of variability in the environment;

(3) Ensure pingers are all working and are present in the required numbers;

(4) Make relevant seasonal closures in space and time, and ensure compliance with the closures;

(5) Changes in fisheries management plans, target fish stocks, and fishing behaviours should be monitored, as these changes can have a substantial impact on marine mammal bycatch, particularly if bycatch reduction management plans are not flexible enough to adjust accordingly.

In relation to underwater noise, in 2010, NOAA committed to improving the tools used by the Agency to manage underwater noise impacts more comprehensively, including to better address cumulative impacts on whales, dolphins, and porpoises. This commitment led to the development CetMap and SoundMap (CetSound; http://cetsound.noaa.gov/), which aim to improve the ability to visualise cetacean density and distribution, and man-made underwater noise, respectively. Following the development of these tools, the Ocean Noise Strategy was developed, that identifies NOAA's long-term ocean noise management goals, as well as science and policy mechanisms required for NOAA to meet those goals.

2.5.6 IUCN conservation plan

The IUCN 2002-2010 Conservation Action Plan for the world's cetaceans (Reeves *et al* 2003) represents a consensus of the IUCN Cetacean Specialist Group concerning the status of the world's cetaceans, threats to their survival, and measures needed to better understand and address those threats. The plan recommends specific conservation actions, including some related directly to management. Although the focus is on conservation of cetaceans in developing countries, there are several important noteworthy key messages. The conservation plan emphasises the need for multifaceted, adaptable and tailored to particular local or regional conditions, approaches to conservation.

Bycatch in gill nets and trawls is the most readily identifiable threat to cetaceans in coastal Atlantic waters (Reeves *et al* 2003). Recommended ways forward to reduce bycatch are:

- the development of alternative fishing gear and practices and at the same time the implementation of immediate mitigation measures, ranging from fishery closures to the mandatory use of acoustic deterrents to prevent entanglement;
- the use of acoustic alarms is recommended, conditional upon the demonstration of effectiveness through controlled scientific experiments;
- the completion of field trials to address practical issues related to implementation; and the establishment of long-term scientific monitoring programs, preferably involving independent on-board observers.
- in relation to acoustic pollution the IUCN action plan stresses the importance of the awareness that cetaceans depend on the ability to sense their environment acoustically.

The plan notes that it is important that the management and conservation needs of cetaceans are recognised in legislation, and that such recognition is backed by the political will and funding needed to assure awareness and compliance. Laws simply protecting cetaceans from deliberate killing are insufficient because in many instances non-deliberate killing (e.g. bycatch in fisheries) is a more serious threat (Reeves *et al* 2003).

2.6 Policy and Legislation Summary

The harbour porpoise is legally protected in UK waters through international, European and national legislation. Nature conservation legislation of the European Union (EU), together with international treaties, imposes a strict protection of the species protecting them from incidental killing and capture and disturbance. Intentional killing, intentional disturbance, and trading and collection of the animals or parts of them is also illegal. There is also a variety of other legislative requirements that interact with the nature conservation legislation in order to achieve sustainable development and use of the marine environment.

3 Pressures and the scale of impact on the harbour porpoise

3.1 Introduction

In this section, the main pressures (actual and potential) on the harbour porpoise in UK waters are evaluated. Actual pressures are defined those that arise from activities known to impact porpoises directly or indirectly now or in the past. Potential pressures are defined as those that arise from activities that may have an impact in the future but for which there is currently little or no evidence. Pressures were evaluated from peer-reviewed papers and strandings and bycatch reports from the UK's monitoring schemes. In each case, the available evidence was screened for significant population level effects on the UK population and where relevant, within each of the management units.

3.2 Intentional takes (hunting)

In Europe, commercial catching of porpoise for food has been a significant issue in the past (Kinze, 1995; Camphuysen and Peet, 2006). However, there is no recent evidence of significant human consumption, except during World War II when the human continental population was starving (Camphuysen and Peet, 2006). There is no evidence of intentional killing of porpoises or any other cetaceans for consumption or otherwise in the UK.

Until recently, harbour porpoise were rarely kept in captivity (Reeves and Mead, 1999) although, coupled with more successful attempts to rehabilitate stranded animals, small numbers of porpoises are retained in aquarium collections today (e.g. in Denmark and The Netherlands) and even breed in these facilities (Kastelein *et al* 1997a, b; Lockyer *et al* 2003, Blanchet *et al* 2008). The UK, however, no longer has any captive cetaceans and nor are there any cetacean rehabilitation centres.

3.3 Fisheries Bycatch (Incidental killing and capture)

Incidental capture in fishing gear (bycatch) is generally seen as the most significant pressure to harbour porpoise populations (Lear and Christensen, 1975; Andersen and Clausen, 1983; Benke, 1994; Kinze, 1994; Baird and Guenther, 1995; Berggren, 1994; Kock and Benke, 1996; Carlström and Berggren, 1997; Tregenza *et al* 1997; Vinther, 1999; Clausen and Andersen, 1988; Mentjes, 2000; Skóra and Kuklik, 2003; Haelters *et al* 2004; Haelters and Kerckhof, 2004; Vinther and Larsen, 2004; Read *et al* 2006; Jauniaux *et al* 2008; Haelters and Camphuysen, 2009; Vishnyakova and Gol'din, 2014). The impact at the individual level is usually lethal.

Static nets such as gill and tangle nets are of greatest concern for harbour porpoise and several studies in European waters and around the UK have suggested that harbour porpoise bycatch levels in gillnet fisheries are high and in some areas may not be sustainable in the longer term. Bycatch levels can vary seasonally in relation to harbour porpoise distribution and overlap with the relevant fishery (Vinther, 1999; Vinther and Larsen, 2004; Herr *et al* 2009) and water depth (Bjørge *et al* 2013). The impact of intertidal recreational gillnet fisheries has also been noted in Belgium (Haelters and Kerckhof, 2004; Haelters *et al* 2004, 2006). Such recreational gill-netting is not gernally practiced in UK waters.

An assessment of overall harbour porpoise bycatch rates in the North Sea and in Baltic waters has also been carried out, using information gathered since 1995 (ICES, 2014c, d). This assessment indicated that bycatch rates in some fisheries may be above proposed reference limits, but the uncertainty is large. There may also be biases in the choice of fisheries to monitor towards fisheries with a higher bycatch (Northridge and Thomas, 2003). Better quality data on bycatch rates and fishing effort from more fisheries is required from EU Member States before conclusions can be drawn as to the overall bycatch of harbour porpoise in UK and adjacent waters. From the studies in the UK, an important message can be deduced, namely that despite any uncertainties for certain fleet segments, the bulk of the bycatch occurs from vessels "*not required to have* [mitigation measures in the form of] *pingers*" (i.e. <12m gillnetters; Northridge *et al* 2014; IAMMWG, 2015a).

3.3.1 UK fishery observations

EU Council Regulation 812/2004 requires Member States to monitor certain specified fleet segments in order to quantify cetacean bycatch. Harbour porpoise bycatch does not appear to be a major issue in any pelagic trawl fisheries in UK waters. Bycatch of porpoise is most common in demersal static gear (gillnet and tangle net) fisheries in the southwest (mainly fishing areas VIIdefgh, Figure 3.1), with some also occurring in the North Sea (IVc) (Northridge *et al* 2011a, 2012a, 2013a, 2014, 2015).

Harbour porpoise bycatch were recorded during scientific studies in gill and tangle nets for demersal fish species in the southern North Sea (IVc), the Celtic Sea (VIIg) and western Channel (VIIeh). Estimates have been made for gillnet metiers (ICES divisions VIIaefghj and VIII, *i.e.* Irish Sea, Western Channel and Celtic Shelf including northern Biscay) combined (SMRU, 2009; Northridge *et al* 2011a, 2012a, 2013a). Bycatch of porpoises within these fleet segments varied between an estimated 540 to 840 animals per annum. Harbour porpoise bycatch has been observed in other fishing metiers, such as in driftnets for pelagic and demersal fish species (Northridge *et al* 2012a), but the sparse data available do not suggest that bycatch occur on a large scale in other UK fisheries.

Bycatch estimates for the whole UK gillnet fleet in 2014 provided a conservative (high) estimate of porpoise bycatch between 1400 and 1700 porpoises per year (Northridge *et al* 2015). The range is a result of calculations made assuming fully effective pingers on the one hand or no pinger usage on the other. Because sampling has been focused in areas were the highest bycatch rates are thought to occur, the overall estimates are therefore likely to be biased high. These estimates require further refinement through a more detailed understanding of fishing effort metrics by vessels of different fleets, as well as a better understanding of spatial components of bycatch throughout the region being studied (Northridge *et al* 2014). The continuing monitoring focus in the southwest reflects our perception that this is the area where most marine mammal bycatch occurs in the UK. This is driven by the overlap of high levels of netting effort and relatively high densities of some mammal species. Sampling over a wider area will be needed to address uncertainties in bycatch rates elsewhere.

In summary, the precise population level effects of bycatch are unclear, as there are few reliable population estimates associated with reliable bycatch-rates (ICES, 2014d). Porpoise bycatch occurs mostly in static gears (gill nets, tangle and trammel nets) set to capture demersal fish species throughout European Atlantic waters.

3.3.2 UK strandings reports

Strandings data are an important source of information to identify cases of bycatch and were the source of evidence leading to the development of the UK's Bycatch Response Strategy.

Between 2000 and 2004, 563 harbour porpoises stranded in the UK were examined by post mortem and of these bycatch was the cause of death in 93 (approximately 17%) (Jepson, 2005). The majority of harbour porpoise bycatch typically stranded in south-west England (Cornwall and Devon) between December and April. Between 2005 and 2010, 478 harbour porpoises were examined at post mortem, of which 71 (approximately 15%) died as a result of bycatch. An analysis of post-mortem examinations conducted between 1991 and 2010 showed a slight decline in the proportion of bycatch in UK stranded harbour porpoises and a relative increase in the proportion of infectious disease and starvation in harbour porpoise (Deaville and Jepson, 2011).

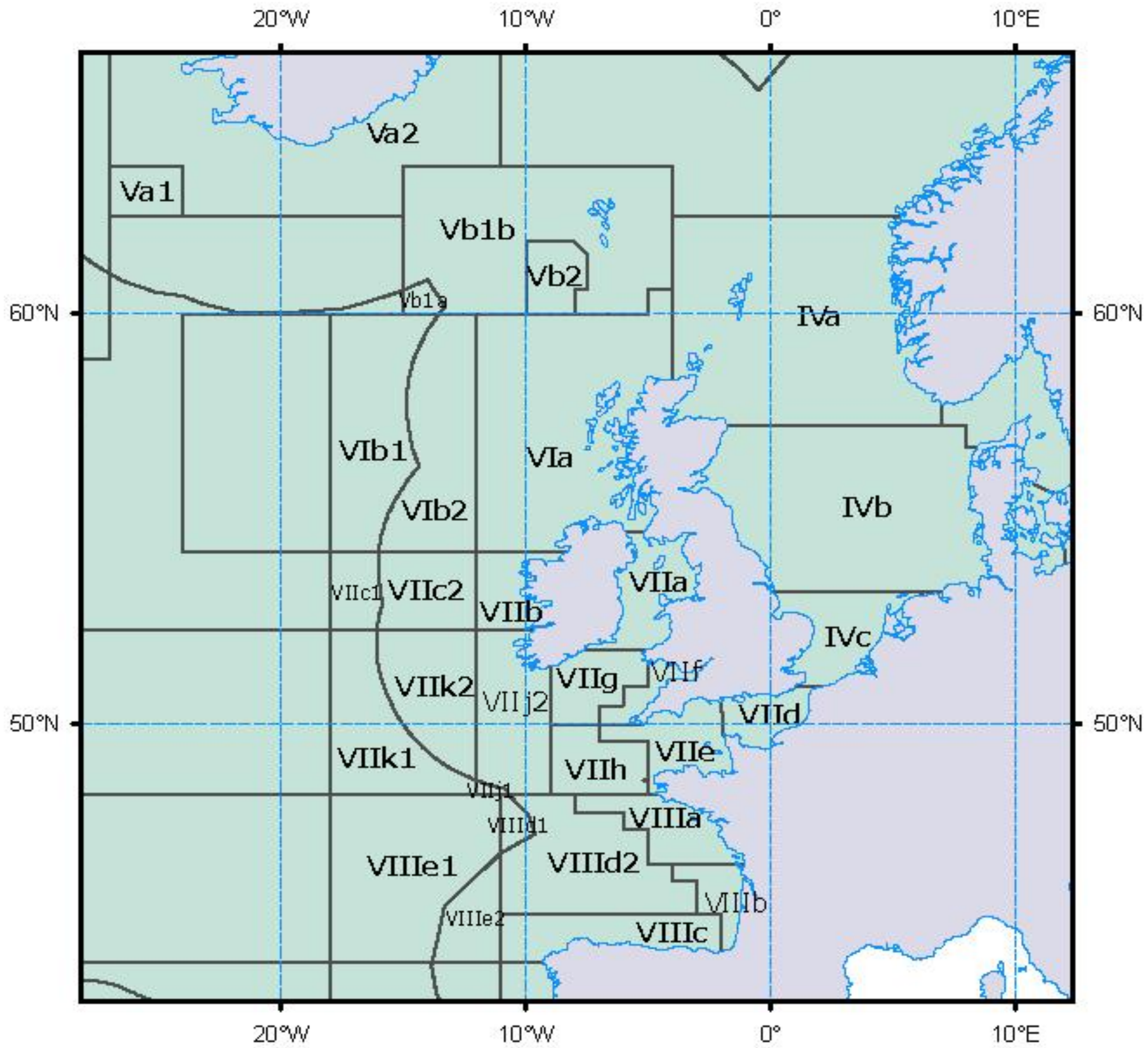


Figure 3.1. Detailed boundaries of the ICES subdivisions IV, V, VI, VII and VIII

3.4 Acoustic disturbance (underwater noise)

Marine mammals use sound for fundamental biological and ecological aspects of their lives including navigation, prey location and capture, predator avoidance, and communication (Richardson *et al* 1995; Wright *et al* 2007; Wilson and Mittermeier, 2014). Odontocete hearing has evolved to function in the presence of interfering noise from natural sources such as waves which can be sufficiently loud to result in auditory masking effects (when the perception of one sound is affected by the presence of another) (Richardson *et al* 1995). This section considers only man-made (anthropogenic) sounds that could have an effect on harbour porpoises.

Certain anthropogenic underwater noises are known to affect the behaviour, the overall range or localised use of available habitats, to be damaging (physical trauma) or even to be lethal for cetaceans (Richardson *et al* 1995; Jepson *et al* 2003; Mann *et al* 2010). Boyd (2008) listed 12 types of anthropogenic sound sources that could affect marine mammals (Table 3.1).

Table 3.1. Types of anthropogenic sound sources that could affect marine mammals and the possible effects if sounds are loud (From: Boyd 2008). Impulsive sounds are marked with an asterisk.

Source	**Possible effects**
Vessels	Masking, displacement from preferred habitat
Air guns *	Masking, Physical trauma, Hearing loss, Behavioural change, displacement from preferred habitat, Behaviourally-mediated effects
Intense low- or mid-frequency sonar *	Physical trauma, Hearing loss, Behavioural change, Behaviourally-mediated effects
Pile driving *	Physical trauma, Hearing loss, Behavioural change, Behaviourally-mediated effects
Other sonars *	(depth sounders, fish finders) Masking, Hearing loss, Behavioural change, Behaviourally-mediated effects
Dredges	Behavioural change, Behaviourally-mediated effects, displacement from preferred habitat
Drills	Hearing loss, Behavioural change, Behaviourally-mediated effects
Bottom towed fishing gear	Behavioural change, Behaviourally-mediated effects, displacement from preferred habitat
Explosions *	Physical trauma, Hearing loss, Behavioural change, Behaviourally-mediated effects
Recreational vessels	Masking, Behavioural change, Behaviourally-mediated effects
Acoustic deterrents (*)	Behaviourally-mediated effects
Over flying aircraft (including sonic booms*)	Behaviourally-mediated effects

Sources of particularly loud, explosive or sudden (impulsive) underwater sounds that could potentially cause physical trauma and/or hearing loss include seismic exploration by mainly the oil and gas industries (air gun arrays), pile driving activities during construction (e.g the installation of offshore wind farms), underwater explosions, and various seismic and sonar operations (Stone, 2015a; Theriault, 2005; Weilgart, 2007; Lucke *et al* 2009; Santos *et al* 2010; Thompson *et al* 2010; DeRuiter *et al* 2013; Goldbogen *et al* 2013; Kuningas *et al* 2013; Pirotta *et al* 2014; Tougaard *et al* 2014). Ear damage (resulting from exposure to loud impulsive sounds) is notoriously difficult to detect and study is both costly and time-consuming. Only very fresh carcasses can be used in these studies and it takes many years to begin to detect any patterns and trends (Jepson *et al* 2006).

More continuous underwater sounds (shipping, operational windfarms) are unlikely to cause physical trauma, but could make preferred habitats less attractive as a result of masking or disturbance (habitat displacement, area avoidance). The harbour porpoise is a relatively small, endothermic predator with limited energy storage capacity, dependent on foraging throughout the year without prolonged periods of fasting (Kastelein *et al* 1997a; Bjørge, 2003). The almost constant need to forage and feed makes harbour porpoise vulnerable to displacement from preferred feeding grounds as a result of underwater noise-related disturbance.

3.4.1 Seismic surveys, airguns

Seismic exploration is essential for the localisation of offshore oil and gas reservoirs. In UK waters, most seismic survey effort is in the central and northern North Sea, and takes place in summer between April and September (Stone*,* 2015a). Airgun arrays typically produce high amplitude sound with frequencies that overlap with the low frequency sound produced by baleen whales rather than harbour porpoise. However, airgun arrays may also produce significant high frequency sound energy, with airgun sound dominating frequencies up to 22 kHz within a few kilometres of the source.

Potential biological effects include physical/physiological effects, behavioural disruption, area avoidance, and possibly indirect effects associated with altered prey availability (Hassel *et al* 2002). Pirotta *et al* (2014) demonstrated that the probability of recording buzzes associated with attempted prey captures or social communication declined by 15% in the area where airguns were being used and was positively related to distance from the source vessel.

Sixteen years of information from observers on board vessels in UK and adjacent waters demonstrated responses of marine mammals to seismic surveys (Stone, 2015a). An examination of responses of cetaceans to the soft start procedure indicated that it is an effective mitigation measure, as all species had lower detection rates during the soft start (compared to not firing) and all species showed greater avoidance during the soft start than at any other time.

Harbour porpoise belong to a high frequency hearing group (functional hearing stretches from at least 250Hz to 160kHz (Kastelein *et al* 2002) and as most of the energy from seismic airguns is at lower frequencies, it has been assumed that small odontocetes such as porpoises are less vulnerable to disturbance from the sound of seismic airguns). Stone (2015a) found, however, that harbour porpoises displayed some degree of avoidance of ‘large arrays’ and the response was greater than previously thought. Highly reduced detection rates indicated that they were displaced to a greater extent beyond the visual and acoustic monitoring range. The results confirm previous studies showing that the response of cetacean species to noise from seismic airguns does not necessarily correlate with what might be expected based solely on their hearing abilities (see also Lucke *et al* [2009] for aversive behavioural reactions of harbour porpoise). The fact that the harbour porpoise was the only species with lower detection rates for both ‘large arrays’ and ‘small arrays’ suggests an increased sensitivity to airgun noise compared to other species (Stone, 2015a).

Physical/physiological effects could include hearing threshold shifts and auditory damage as well as non-auditory disruption, and can be directly caused by sound exposure or the result of behavioural changes in response to sounds (Gordon *et al* 2003). Evidence of physical trauma from seismic surveys has not been found, but may be difficult to detect. Additionally, stress responses may occur but have not yet been demonstrated. Loud underwater noises do cause disturbance and area avoidance, so that one effect of the seismic surveys (area avoidance) mitigates the risk of the other (physical trauma). The frequency of occurrence of seismic surveys is also relatively low, so that area avoidance is a relatively short-lived effect.

To address conservation concerns in relation to seismic surveys, in 1995 the UK government and the Joint Nature Conservation Committee (JNCC) issued guidelines for seismic operations taking place on the UK continental shelf (Stone, 2015a). The guidelines aim at reducing the risk of injury to negligible levels and to reduce the risk of disturbance from seismic surveys to marine mammals. The guidelines, which are reviewed periodically in the light of developing scientific understanding, include for example training requirements for marine mammal observers (MMOs), reporting requirements, guidance before and during seismic activities, a pre-shooting search, delays if marine mammals are detected within a 500m mitigation zone, and soft start requirements (JNCC, 2010c).

3.4.2 Underwater explosions

Underwater detonations have the potential for serious injury in marine vertebrates such as cetaceans (Koschinski, 2011). The high detonation velocity creates a shock wave and the main reason for physical injury is the extremely short signal rise time combined with a high overpressure. This can lead to impacts ranging from injury to area avoidance (Camphuysen and Siemensma, 2011). Although the effects of underwater explosions have been linked to other species (e.g. Brownlow *et al* 2014), to date there have been no strandings or deaths of harbour porpoise in UK waters as a result of explosive use.

3.4.3 Renewable energy

Since the beginning of the planning and installation of renewable energy developments, the possible impacts on marine mammals have been discussed within the scientific community (Nedwell and Howell, 2004; Thomsen *et al* 2006; ICES, 2010a, 2011, 2012) largely in relation to noise, but also collision risk. There are four phases to renewable energy developments (Table 3.2).

Table 3.2. The four phases of renewable energy developments (adapted from Nedwell & Howell, 2004)

Pre-construction	Include geophysical and geotechnical survey, meteorological mast installation and an increase in vessel traffic. Vessel traffic will increase in the vicinity of a wind farm before its construction and continue through to decommissioning.
Construction	One of most significant activities during construction is foundation installation. Dredging and rock laying may be undertaken, as well as cable laying, turbine and turbine-tower installation, and ancillary structure (e.g. offshore transformers) installation. In addition to this, divers will be used throughout construction to carry out underwater activities, and they may use a variety of tools.
Operation	This is the long phase and may result in low frequency sounds production.
Decommissioning	The industry has not reached this final stage yet. The majority of the work required may reflect the installation process. However, the process of foundation decommissioning is unclear, possibly including jet and explosive cutting below the seabed or the use of explosives and dredging.

The first offshore wind farm in the UK was a near-shore installation in Blyth Harbour, north east England, which started operating in 2000. Since then, the sector has developed with a series of licensing ‘Rounds’ co-ordinated by the Crown Estate. Round 1 was launched in 2001 and is now almost complete. It involved 18 sites in England and Wales, and added a potential capacity of 1.5GW. In 2003, Round 2 was issued, which had areas located further offshore and in deeper waters covering the Greater Wash, Greater Thames and Irish Sea. When complete, Round 2 will add another 7GW of capacity. Round 3, released in 2010 featured nine zones across the UK. The largest, Dogger Bank, has the potential to generate up to 13GW of power and is one of the largest energy projects anywhere in the world. Round 3 sites began the construction process during 2014 and will continue into the future, with a total of around 31GW already leased to developers (www.renewableuk.com).

In addition to developments regarding offshore wind energy, between 1000 MW (megawatts) and 2600 MW of marine renewable energy generating capacity could be achieved in Scotland using wave and tidal power devices (MEG, 2004).

Given that the number and size of renewable energy developments will increase, there is a need to also consider the cumulative impacts of these activities on marine species (Brabant *et al* 2015).

3.4.3.1 Pile driving (wind farms & tidal energy turbines in the construction phase)

Wind farm construction and the construction of wave and tidal power devices involves many types of activities that can generate high sound pressure levels, particularly pile-driving (Madsen *et al* 2006; Southall *et al* 2008). Noise created during pile-driving involve sound pressure levels that are considered high enough to impair or damage the hearing system of marine mammals near the source and disrupt their behaviour at considerable distances from the construction site (Nedwell and Howell, 2004; Thomsen *et al* 2006; Brandt *et al* 2011; Dähne *et al* 2013). At Horns Rev and Nysted offshore wind farms in Denmark the potential effects of wind farm construction and operation were investigated (Teilmann *et al* 2006; Tougaard *et al* 2006). At both wind farms, a substantial but short lived effect (area avoidance) of pile driving was observed, with larger responses at Nysted (silent periods after pile driving for several days) than at Horns Reef (hours of silence). David (2006) suggested that pile-driving has the potential to affect cetacean populations adversely up to 40km from the source. Bailey *et al* (2010) measured pile-driving noise at distances up to 80km from the source (before it was no longer distinguishable above background noise). However, the distances at which sounds are audible by marine mammals and elicit behavioural responses are influenced by the ambient noise and the propagation conditions (Kastelein *et al* 2010).

Brandt *et al* (2011) monitored the effect of pile-driving activities during the construction of the offshore wind farm Horns Rev II, which comprised 92 monopile foundations of 3.9m diameter. Using passive acoustic monitoring devices (T-PODs) to record porpoise echolocation clicks, harbour porpoise acoustic activity was found to be reduced by 100% for one hour after pile driving and stayed below normal levels for 24 to 72h at a distance of 2.6km from the construction site. A negative effect of pile driving on harbour porpoise acoustic activity was detectable out to a mean distance of 17.8km. At 22km the negative effect was no longer apparent, instead, porpoise activity temporarily increased. Out to a distance of 4.7km, the recovery time was longer than most pauses between pile driving events. Consequently, porpoise activity and possibly abundance were reduced over the entire five month construction period. Dähne *et al* (2013) found negative reaction distances to approximately 25km, with modelled results showing residual effects at c50 km (i.e. between 25 and 50km there were positive effects as the animals moved out of the region closer to the pile driving). Importantly, the associated aerial surveys supported the conjecture that porpoises leave the impact area rather than diminishing their vocal behaviour.
To address conservation concerns that have arisen in relation to piling activity, the JNCC issued guidelines for pile driving operations in 2010. The guidelines aim to reduce the risk of injury to negligible levels. The guidelines include training requirements for marine mammal observers (MMOs), equipment needed by MMOs, reporting requirements, passive acoustic monitoring, a mitigation zone, a pre-piling search, delays if marine mammals are detected within a minimum 500m mitigation zone (1km diameter), soft start requirements and delays

or a break in piling activities if marine mammals are detected, and the use of acoustic deterrent devices (JNCC, 2010d). The guidelines are designed to avoid porpoise injury or death, but do not address disturbance over the wider area.

The construction of renewable energy developments is considered to be a pressure that could lead to significant habitat loss for extended periods depending on the temporal and spatial scale of developments (Cartensen *et al* 2006; Tougaard *et al* 2009, 2014; ICES, 2010a; Brandt *et al* 2011; Dahne *et al* 2013; Tougaard *et al* 2014). Whilst the construction of a single development may in itself not lead to a population level affect, the cumulative impact of many developments could. This pressure should, therefore, be taken into account in areas of particular conservation value for harbour porpoises.

3.4.3.2 Operational wind farms

Koschinski *et al* (2003) recorded behavioural reactions of free-ranging porpoises to the simulated noise of a 2 MW wind power generator in operation and found a clear behavioural response, indicating that these animals were able to detect the low-frequency sound generated by operational turbines. Subsequent work undertaken indicates, however, that it is not possible to generalise the effect that an operational windfarm may have. For example, Tougarrd *et al* (2006) found a slight decrease in porpoise abundance at Horns Rev during construction and number returning to normal during the operation of the wind farm. By contrast, a significant decrease in the echolocation activity of porpoises was found at Nysted, both during construction and in the operational phase. The effect still persisted after two years of operation, with some indications of a slow recovery. It was suggested that the more turbulent and noisy environment at Horns Rev makes the turbines and the noise generated by these turbines less detectable to the porpoise. It is also not possible to determine if another, non wind-farm related factor, may have caused this change at Nysted. Polanen *et al* (2010) found no difference between the acoustic activity of harbour porpoises within a Dutch wind farm and a reference area during the second year of operation whilst Scheidat *et al* (2011) noted that acoustic activity was significantly higher inside an operational wind farm than in the reference areas, suggesting that harbour porpoise were in fact attracted to the area post construction.

The responses of harbour porpoise to operational windfarms varies, depending on the location of the site and perhaps the quality of the habitat. Enhanced food availability (the "*reef effect*", especially in heavily overfished areas with a sandy sea floor, such as in the Southern Bight; Scheidat *et al* 2011), the relative absence of vessels within the farm (sheltering effect), and the ban on some fisheries within some wind farms in some countries are aspects that would qualify as actually being beneficial for harbour porpoise.

3.4.3.3 Operational tidal and wave energy developments

There are limited data on the impacts of wet renewable devices on marine mammals but collision risk is considered a greater issue than acoustic disturbance. Tidal turbines are the most developed, with demonstration projects planned or constructed. Long-term monitoring of harbour porpoises was part of the monitoring programme associated with the installation of a tidal turbine at Strangford Lough, Northern Ireland, and there were no changes in abundance of porpoises which can be attributed to the presence or operation of the turbine (Royal Haskoning, 2011). However as the Strangford Lough device operated a shut down system for when marine mammals were detected, it is difficult to determine the risk of collision.

3.4.4 Coastal and harbour developments

Harbour constructions and other coastal developments (e.g. harbour or marina infrastructure and expansions), as well as new coastal developments, may affect harbour porpoise utilising the area. There is little literature exploring the impact of such developments on harbour porpoise populations. Monitoring of large harbour developments in Scotland has shown that there is local displacement for porpoise and bottlenose dolphins during construction activities. If pile driving or explosives are used, the same effects as discussed for the construction phase of renewable energy developments and detailed in the underwater explosives section can be expected.

3.4.5 Military Activity and Sonars

Worldwide, several cases of cetacean strandings have been connected to the use of powerful military sonar (Balcomb III and Claridge, 2001; Jepson *et al* 2003; but see Bradshaw *et al* 2005). However, most marine mammal strandings coincident with naval sonar exercises have involved Cuvier's beaked whales *Ziphius cavirostris*, some involved pilot whales *Globicephala melas* and possibly common dolphins *Delphinus delphis* (Tyack *et al* 2011; DeRuiter *et al* 2013; Jepson *et al* 2013).

Jepson *et al* (2003) reported evidence of acute and chronic tissue damage in stranded cetaceans that result from the formation in vivo of gas bubbles, challenging the view that these mammals do not suffer decompression sickness. When 85 harbour porpoises stranded on the Danish coastline between the 7 and 15 April 2005, a link with naval exercises in Danish waters on 7 April 2005 was proposed as a contributing factor (Wright *et al* 2013). Siebert *et al* (2013) subsequently found indications of gas embolism in the harbour porpoise, similar to that observed in beaked whales and other cetaceans in which a link with naval activities and death was established.

Naval exercises involving surface and submarine vessels are commonly conducted in the South Coast Exercise Area off the southern coastline of Cornwall, Devon and Dorset (Jepson *et al* 2013). In the Hebrides region, submarine exercises and torpedo testing occurs and the area hosts the bi-annual "Exercise Joint Warrior". In the absence of further evidence, the effect of military sonars used during naval activities is considered a potential pressure in UK waters.

3.4.6 Pingers and Acoustic Deterrent Devices (ADDs)

Although technically different devices, the terms pinger and acoustic deterrent devices (ADDs, also known as seal scarers) are often used interchangeably. This has lead to a great deal of confusion with, for example, EU Regulation 812/2004 using both. The main differences between the devices lie in the sound source levels and the purposes of use. Pingers are generally, but not all, low power devices (less than 150dB re: 1µPa at 1m) used on fishing nets to prevent bycatch by alerting the animals to the presence of the net. In contrast, ADDs produce high power sounds (more than 180dB re: 1µPa at 1m) and are usually used to permanently prevent seals from getting close to fish farm pens (Anonymous, 2010).

Acoustic devices specifically aimed at mitigating bycatch will collectively be referred to as pingers in this report. Acoustic devices aimed at preventing seals from getting close to fish farm pens or, more recently, used to help mitigate against physical injury due to underwater noise will collectively be referred to as ADDs.

3.4.6.1 Pingers

Many studies have been carried out to investigate the effectiveness of pingers to reduce harbour porpoise bycatch, showing significant positive results (Northridge and Kingston, 2010; Larsen and Eigaard, 2014). Pingers are the most effective measure to reduce harbour porpoise bycatch in static nets, particularly those using basic tonal 10 kHz signals and more complex multi-signals (ICES, 2010a). Preliminary bycatch estimates for the whole UK fleet provide conservative (high) estimates of porpoise bycatch of around 1600 to 1900 porpoises per year, depending on whether pingers are being used correctly or at all. The principal region where harbour porpoise bycatch is a concern is the south-western waters of the Western Channel and Celtic Sea; while the situation in the North Sea is less clear (SMRU 2009; Northridge *et al* 2011a, 2012a, 2013a, 2014). Currently, the bulk of the bycatch in UK fleets occurs from vessels "not required to have pingers" (i.e. <12m gillnetters; Northridge *et al* 2014). Since area avoidance is a much less serious impact on harbour porpoises than drowning and death, the use of pingers is important. Pingers should only be used in areas where bycatch is a significant issue and the effectiveness of use should be monitored.

3.4.6.2 Acoustic deterrent devices (ADDs)

ADDs can have a significant impact on cetacean distribution with reduced porpoise detections within several kilometres of active devices (e.g. Olesiuk *et al* 2002; Johnston, 2002; Northridge *et al* 2010). Tougaard *et al* (2014) critically evaluated ADDs and the harbour porpoise noise criteria and found that avoidance of mostly ‘mid-frequency’ devices were at ranges between 1 and 7.5km.

Most of these studies used the Airmar ADD, in striking contrast, a series of trials with the Terecos ADD found harbour porpoises showed weak or minimal responses to the sounds generated by this device (Northridge *et al* 2013b). Consequently, further tests using Terecos ADDs and those of other manufacturers would help to ascertain the extent to which these results can be generalised. Harbour porpoise and other cetaceans have been recorded feeding approximately 200m from the Terecos ADD (Northridge *et al* 2013b).

ADDs can be seen as a pressure leading to habitat loss, but they are also considered to be an effective mitigation tool to prevent injury from activities such as pile driving. Their use, therefore, needs to be balanced with the conservation needs of the species.

3.4.7 Shipping

Ships are a substantial source of continuous man-made noise in the marine environment, and harbour porpoise have been shown to be negatively affected (Skov *et al* 2014). The physical presence of vessels, and not just the noise created, can also disturb cetaceans (Pirotta *et al* 2015).

In UK waters, a negative influence of shipping density on the presence and abundance of harbour porpoise was found when shipping intensity surpassed thresholds of approximately 50 ships per day in the Celtic and Irish Sea MU and 80 ships per day in the North Sea MUs (Heinänen and Skov, 2015). Ship-avoidance behaviour in combination with masking effects by the ship-generated noises will make areas with high shipping densities thus less suitable for harbour porpoise.

3.4.8 Oil and gas platforms

Currently, there are 283 UKCS installations in production (numbers for 2014; see https://www.gov.uk/oil-and-gas-infrastructure#pipelines-and-platforms). Development of this industry in the UK began predominantly in the southern North Sea, followed by increased activity in the northern North Sea, the Moray Firth, and the Irish Sea. Most recently, activity has moved into the central North Sea and to the west of the Shetland Islands in an area often referred to as the Atlantic Frontier.

Acoustic disturbance during the exploration phase, i.e. seismic surveys, has been dealt with in section 3.4.1 and construction noise is usually associated with shipping (section 3.4.7) and pile driving (section 3.4.3). During operation, noise is largely associated with drilling, vessel traffic and helicopter movements. Drilling creates noise in the range 115-117 dB re 1 µPa with a band width of 10 Hz -~1 kHz with the main energy output at < 30-60 Hz (Thomsen *et al* 2011) and therefore overlaps the hearing range of harbour porpoise, and could result in injury and/or cause behaviourial changes that may lead to population consequences (Boyd, 2008).

Echolocation clicks of harbour porpoises detected with T-PODs deployed from an offshore-exploration-drilling-rig and gas-production-platform complex in the Dogger Bank region of the North Sea (2005-2006) revealed a pronounced diel pattern in echolocation activity. The number of porpoise encounters was greater by night than by day, suggesting that porpoise were feeding below or around the platform at night (Todd *et al* 2009). Other visual observations of harbour porpoise foraging around offshore platforms suggest that offshore installations may be attractive (Camphuysen and Krop, 2011).

Whilst the impact of drilling is potentially high (Boyd, 2008), there have been no studies that have demonstrated such an impact whilst others have indicated offshore installations may actually create foraging opportunities (Todd *et al* 2009; Camphuysen and Krop, 2011). At this time, therefore, this is considered a potential pressure.

3.4.9 Navigational dredging and aggregate extraction

Concerns about the impact that navigational and aggregate dredging has on marine life include entrainment, habitat degradation, noise, contaminant remobilisation, suspended sediments, and sedimentation, all of which may affect benthic, epibenthic, and infaunal communities and indirectly affect marine mammals through changes in prey (Tillin *et al* 2011; Todd *et al* 2014). Noise emitted during dredging operations is broadband, with most energy below 1 kHz and is unlikely to cause damage to marine mammal auditory systems, but masking and behavioural changes are possible (Tillin *et al* 2011). Dredging might be audible to most marine mammals up to several kilometres from the source, depending on conditions (Gardiner *et al* 2014). Given the evidence available and the scale of such operations, this activity is not generally considered to present a significant pressure.

3.4.10 Aircraft and helicopters

Disturbance reactions in cetaceans have been observed in response to low flying aircraft (and this includes aerial surveys to assess harbour porpoise abundance; Baptist, 1987; Richardson, 1995). There is, however, no evidence for a negative impact of low-flying aircraft on harbour porpoise populations in UK waters.

3.4.11 Whale watching

There are numerous publications evaluating the disturbance caused by whale-watching activities on cetaceans (Ritter, 2003; Christiansen *et al* 2013; Pirotta *et al* 2015). Harbour porpoises are, however, seldom the target species for whale watching but may be subject to indirect effects if they co-occur in areas of whale watching for other species. Recent work (Lusseau, 2003; Pirotta *et al* 2015) has suggested that commercial whale watching vessels in the Moray Firth could be having an impact on the bottlenose dolphin population.

Whilst there is no evidence that whale watching has an impact on harbour porpoise, additional care maybe required in areas of particular conservation value for the species.

3.4.12 Coastal recreation

Declines in relative abundance of cetaceans exposed to long-term disturbance have been documented and these include disturbance resulting from recreational near-shore activities such as yachting, surfing, jet-skis, speed boats, tourists in the water (Lusseau, 2005; Bejder *et al* 2006; Anonymous, 2010). Harbour porpoises are not listed in these studies, but given their avoidance response to shipping, coastal recreation may be expected to lead to area avoidance behaviour. Consequently, whilst not considered an important pressure, additional care maybe required in areas of particular conservation value for harbour porpoise.

3.5 Vessels strikes

Mortality and serious injury of cetaceans resulting from ship strikes is mainly reported in slow-swimming (e.g. sleeping) large baleen whales (Knowlton and Kraus, 2001; Nowacek *et al* 2004; Douglas *et al* 2008; Van der Hoop *et al* 2012). The literature does not contain many reports of ship strikes with smaller cetaceans such as harbour porpoise. Vessel strikes are perhaps not likely to occur frequently, due to the avoidance behaviour of porpoises (Polachek and Thorpe, 1990; Camphuysen and Siemensma, 2011).

The rapid expansion in high speed ferry traffic around the world is a matter of concern because fast ferries travelling at speeds of 13-14 knots or more have proven to be particularly lethal, with most collisions leading to severe injury or death of cetaceans (Carrillo and Ritter, 2010). Around the UK very fast ferry services are developing, including fast moving catamarans and hovercrafts operated at speeds >40 knots. At 40 knots, approaching a cetacean at 600 m leads to a maximum reaction time of 30 seconds (Bräger, 2009). Examples of very fast ferry services in British and Irish waters include connections between Dublin and Holyhead, Portsmouth and Cherbourg, Portsmouth and Isle of Wight, and Boulogne to Dover.

Jet skis and other fast-moving recreational vessels may pose a risk simply because they are fast and can change direction rapidly.

3.5.1 UK strandings reports

The CSIP identified only five harbour porpoise (in 1041 necropsies) with injuries consistent with a fatal impact from a boat strike between 2000 and 2010 (Jepson 2005, Deaville and Jepson 2011). In addition, a further 48 harbour porpoises died of acute physical trauma of unspecified origin which maybe the result of vessel strike, but could be undiagnosed bycatch or caused by bottlenose dolphin attacks.

In summary, the death of harbour porpoises as a result of vessel strikes in UK waters appears to be rare, suggesting that ship-strikes are a pressure with low impact rather than with population level effects.

3.6 Collision with tidal stream renewable energy devices

Marine renewable energy is seen as an important component of the UK's future energy strategy and contribution to reducing the greenhouse gas emissions responsible for climate change. Total theoretical UK resources are estimated to be:

- Wave: 69 TWh/year (27 GW);
- Tidal stream: 95 TWh/year (32 GW);
- Tidal range (barrage schemes): 96 TWh/year (45 GW); and
- Tidal range (lagoon schemes): 25 TWh/year (14 GW) (from TCE, 2012)

There are increases in vessel activities during exploration, maintenance and construction with associated risks of disturbance and collision, as well as potential collisions with the devices themselves. The consequences of encounters between cetaceans and wave and tidal power energy devices are as yet unknown (Dolman and Simmonds, 2010; ICES 2011, 2012), but these underwater devices may be positioned in arrays across habitats that cetaceans frequent. Pierpoint (2008) suggested that harbour porpoise forage in tide race habitats. Marubini *et al* (2009) reported increased harbour porpoise abundance in the Geater Minch Area in relation to maximum current speed whilst Embling *et al* (2010) found that harbour porpoise distribution was also best explained by maximum tidal current as well as the position in the spring-neap tidal cycle, with higher detection rates on spring tides. Such habitat preferences imply a likely risk of collisions in areas where tidal stream energy devices are deployed.

Wilson *et al* (2014) reviewed collision risks of harbour porpoises and marine renewable energy devices at sites of high tidal-stream energy in Scotland, following modelling work that suggested that interactions between tidal turbines and harbour porpoise could be common. Harbour porpoise were seen and acoustically detected in all of the areas surveyed, including the areas of strongest tidal flow in the Sound of Islay and the Kyle Rhea. However, rates of sightings and acoustic detections within these turbulent waters were an order of magnitude lower than surrounding waters. Wilson *et al* (2014) suggested that for these two sites, porpoise-turbine interactions were likely to be substantially rarer than if turbines had been deployed in other habitats, apparently more preferred by harbour porpoises. It was concluded that harbour porpoise did not appear to be particularly abundant within the tidal-streams of Kyle Rhea and the Sound of Islay, although some issues with the acoustic data collection methods may have had an affect on the result. These findings notably contrast results from Wales (Pierpoint, 2008), but whether these results are also true for larger tidal-energy sites such as the Pentland Firth has yet to be determined.

3.7 Marine pollution

Marine pollution has a clear anthropogenic background, but tends to be a generic problem rather than a regional one. Evidence for any effects of pollution tend to be derived from necropsies associated with studies of stranded animals (Jauniaux *et al* 1992; Jepson, 2005; Deaville and Jepson, 2011). This is a biased subset, but the only alternative approach would require the examination of (randomly selected) healthy individuals from the wild.

3.7.1 Oil pollution

Oil spills are one of the most conspicuous and visible forms of pollution of the marine environment. Oil enters the seas not only as a result of major oil incidents, but from diffuse sources, such as leaks, illegal tank-cleaning operations at sea, or discharges into rivers which are then carried into the sea. The North Sea is, or certainly was, one of the more severely oil polluted basins in the world (Clark, 2001; Camphuysen, 2007). The amount of oil released at sea by ships and offshore installations has declined gradually since the introduction of regulations in the early 1990s (Camphuysen, 2007, 2010). Major oil spills can still occur, either as a result of offshore oil exploration or exploitation activities, or from shipping incidents. Chronic oil pollution is of concern in areas with high traffic intensity. Around the British Isles, shipping is most intense in the Western Approaches and the English Channel and in the southern North Sea.

Cetaceans are not generally regarded as being particularly vulnerable to oil spills and there are no records of any spills in which a substantial number of harbour porpoise were affected, within Europe or anywhere in the world. No measurable effect of the "*Erika*" oil spill was found in cetaceans or seals (Ridoux *et al* 2004). The "*Braer*" spill on the Shetland Islands is not known to have affected porpoise, but small numbers of seals were contaminated with oil (Kingston, 1999).

3.7.2 Chemical pollution

One of the main human pressures affecting the marine environment results from the release and subsequent effects of organic pollutants and particles from industrial, agricultural and municipal waste in marine waters. Most research has focused on the persistent organic pollutants (POPs) due to their greater abundance and likely toxicity. 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]). These chemicals remain in the environment for decades, potentially even centuries, as they are resistant to environmental breakdown via biological, chemical and photolytic processes. Although the use of many of the more dangerous chemicals is now prohibited, new substances are emerging and toxic substances that were not initially recognised as a threat are later detected in the environment (Calewaert & McDonough, 2011). The main pollutants believed to be affecting cetaceans today are chlorinated hydrocarbons, brominated flame-retardants and polycyclic aromatic hydrocarbons (PAHs).

Cetaceans are particularly vulnerable as top predators of the marine environment (Reijnders *et al* 1999; Jepson *et al* 2005; ICES, 2010a; Yap *et al* 2012). Chemical pollution is considered to be a significant pressure, as pollutants may negatively affect health, nutrition, growth, reproduction, and susceptibility to infections and thereby increase annual mortality levels (Aguilar, 1985; Borrell and Aguilar, 1993; Aguilar and Borrell, 1995; Ridgway and Reddy, 1995; Lockyer and Kinze, 2003). The effects of chemical pollution on marine mammals are, however, typically delayed and difficult to detect (Kakuschke and Prange, 2007; Murphy *et al* 2010, 2015).

3.7.2.1 Butyltins

Butyltins were widely used as biocides, for example as anti-fouling treatments in paints applied to ship hulls, fish farm cages, and other marine structures. Butyltins have been reported to disrupt mammalian immune systems, including those of porpoise (Seinen and Willems, 1976; Seinen *et al* 1977a,b; de Swart, 1995; Nakata *et al* 2002). Strand *et al* (2005) found that concentrations of butyltin were higher in stranded rather than in by-caught harbour porpoises and also accumulated with age.

In 1986 the UK Government introduced legislation to control the sale of tributyltin (TBT)-based paints (Waite *et al* 1991), followed by a Europe-wide ban in 1987 for use on vessels under 25m in length (Parsons *et al* 2010). In October 2001, the International Maritime Organisation (IMO) adopted a new International Convention on the Control of Harmful Anti-fouling Systems on Ships, which prohibited the use of harmful organotins in antifouling paints used on ships and established a mechanism to prevent the potential future use of other harmful substances in anti-fouling systems worldwide. The Regulation was implemented between 2003 and 2008 (Law *et al* 2012).

Liver butyltin concentrations in harbour porpoise (410 necropsies) were assessed between 1992 and 2005, and again in 2009 to assess the effectiveness of the regulation (Law *et al* 2012). Summed butyltin concentrations had declined since the ban was put in place, and the percentage of animals in which TBT was detected had fallen sharply, indicating the cessation of fresh inputs. In 1992, 1993 and 1995, TBT was detected in 100% of samples analysed, between 2003 and 2005, this fell to 61-72%, and in 2009, following the completion of the ban, had reduced to 4%. Thus, the ban has proved effective in reducing TBT inputs to the seas from vessels which is confirmed elsewhere in the world (Choi *et al* 2013; Gubbins *et al* 2013).

3.7.2.2 Organohalogens

Organohalogen compounds are a class of organic compounds that contain at least one halogen (fluorine, chlorine, bromine, or iodine) bonded to carbon, with organochlorides being the most common. The effect of organochlorides on marine wildlife has been a major concern since the mass mortalities of several species of seabirds and the significant reductions in reproductive success of seals in the Wadden Sea in the 1960s (Koeman *et al* 1969; Koeman *et al* 1972; Koeman and Van Generen, 1972; Reijnders, 1980, 1984, 1986a,b). These studies highlighted the detrimental effects that indiscriminate use of pesticides can have. Subsequently, a large number of studies has been conducted, around the world, investigating levels and effects of contamination by organochlorines in marine biota, with an emphasis on DDT and PCBs in particular (e.g. Reijnders, 1980; Henry and Best, 1983; Schneider *et al* 1985; Duinker *et al* 1989; Law *et al* 1989; Muir *et al* 1992; Boon *et al* 1993; Borrell and Aguilar, 1993; Law *et al* 1996; Van Scheppingen *et al* 1996; Joiris *et al* 1997; Law *et al* 1997; Bruhn *et al* 1999; Covaci *et al* 2002; Chu *et al* 2003; Law *et al* 2003, 2005; Weijs *et al* 2009a,b,c, 2010; Gallo-Reynoso *et al* 2014; Law, 2014).

Other groups of organohalogens that pose health risks to marine mammals are brominated fire retardants (BFR) (Law *et al* 2006; Chen *et al* 2010) and perfluorinated organochemicals (Van de Vijver *et al* 2003, 2004). In the EU the use of certain BFRs is banned or restricted (EFSA 2014), but due to their persistence there are still concerns about the risks these chemicals pose to the marine environment. BFR-treated products, whether in use or waste, ‘leach’ BFRs into the environment and contaminate air, soil and water. These brominated compounds are bioaccumulative and of particular concern to species at high trophic levels. Studies have found perfluorinated organochemicals in the tissues of harbour porpoise in UK waters (Deaville and Jepson, 2011).

Bioaccumulation of immunosuppressive organochlorines may affect the health and viability of marine top-predators. Some organochlorines (such as DDT) can cause lethal poisoning in (small) mammals, but knowledge of lethal doses in cetaceans is lacking (Parsons *et al* 2010). In lower concentrations organochlorines are known to be immunosuppressive and to disrupt reproductive systems (reproductive abnormalities and failure; Ross, 1995; Kakuschke and Prange, 2007; Jepson *et al* 1999, 2005). In stranded harbour porpoise, animals diagnosed with 'infectious disease' had significantly greater chlorobiphenyl concentrations than the physical trauma group (e.g. bycatch; Jepson *et al* 1999). A reduced ability to withstand and fight off (bacterial, viral or other) infections in animals exposed to organochlorine contamination could significantly increase adult mortality levels (O'Shea and Brownell, 1994; Kleinvane *et al* 1995). Organochlorines are lipophilic (Boon *et al* 1996) and females can pass up to 80% of their PCB and DDT burden to a first calf. Consequently, cetacean calves and adult males often have the highest contaminant loads (Duinker and Hillebrand, 1979; Jepson *et al* 1999).

Data on organochlorine pesticides, polychlorinated biphenyls, and polybrominated diphenylether flame retardants derived from over 300 harbour porpoises stranded in the UK between 1989 and 2002 were analysed (Jepson, 2005). Regional differences in contaminant burdens were found with Scottish porpoises having significantly lower levels of PCBs and several organochlorine pesticides than porpoises from England and Wales. Levels of some organochlorine pesticides had gradually declined since 1990 in porpoises from all parts of the UK. In contrast, levels of polychlorinated biphenyls (PCBs) were generally higher, more stable over time and many porpoises (particularly in England and Wales) had blubber PCB levels considered toxic in other aquatic mammals. Concentrations of newer pollutants in the marine environment (specifically brominated flame retardants) were detected for the first time in UK-stranded cetacean tissues (Law *et al* 2013).

As with chlorobiphenyls, stranded cetaceans that die as a result of infectious disease had significantly higher organohalogen concentrations than the physical trauma group (e.g. bycatch; Jepson *et al* 1999; Deaville & Jepson, 2011). Adult females had significantly lower chlorobiphenyl levels than adult males, due again to maternal transfer to offspring. These findings are consistent with the hypothesis that chronic PCB exposure predisposes harbour porpoises in UK waters to infectious disease mortality, but do not prove a causal relationship. Bull *et al* (2006), using a data set of porpoises stranded in the UK between 1989 and 2002, found a significant, positive association between PCB levels and nematode burdens, but the nature of the relationship was confounded with porpoise sex, age and cause of death. It was concluded that while PCBs are important, they are not the sole determinants of nematode burdens in wild populations of the harbour porpoise around the UK (Yap *et al* 2012).

Most recently, PCBs have been linked to a reproductive failure in harbour porpoises either through endocrine disrupting effects or via immunosuppression and increased disease risk (Murphy *et al* 2015).

3.7.2.3 Polycyclic aromatic hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons (PAH) are found in fossil fuels (oil and coal) and in tar deposits, and are produced, generally, when insufficient oxygen or other factors result in incomplete combustion of organic matter in engines and incinerators. PAHs are accumulated by aquatic organisms, although they are not biomagnified and PAHs are readily metabolised by fish and some invertebrates. PAHs can affect DNA to cause cancers (Chen and Liao, 2006).

Samples of muscle tissue from 26 UK-stranded harbour porpoises have been analysed for total PAHs and levels were relatively low, with only one death considered to be the result of cancer (Law and Whinnett, 1992). The risk posed by PAH to porpoises in UK coastal waters is considered to be low.

3.7.2.4 Radionuclides

Anthropogenic sources of radionuclides include atmospheric fallout derived from nuclear tests, accidental release from nuclear installations, and discharges from nuclear plants. Radionuclides have been detected in marine ecosystems and in a number of cetacean species around the world (Rutgers van der Loeff and Lavaleye, 1986; Berrow *et al* 1998;

Watson *et al* 1999). Major sources of the radiocaesium isotope ^{137}Cs in UK waters include atmospheric fallout generated during nuclear weapons testing in the 1950s and 60s, and the Chernobyl accident. One of the most significant sources of direct discharges is the Sellafield nuclear fuel reprocessing plant (that incorporates the original nuclear reactor sites at Windscale and Calder Hall which currently are undergoing decommissioning and dismantling). The degree of contamination observed in marine mammals is related to their trophic level and contamination of the food source (Yoshitome *et al* 2003).

In comparison with other population studies, radioactive contaminant levels of ^{137}Cs in UK cetaceans and other marine mammals are the highest in the world (Berrow *et al* 1998; Born *et al* 2002; Yoshitome *et al* 2003). However, the mean concentrations of ^{137}Cs and naturally occurring Potassium-40 (^{40}K) indicate that the levels recorded are not of concern (Pinn, 2010). The levels of ^{137}Cs are approximately five times lower than those of naturally occurring ^{40}K in the same tissues. This is backed up by findings from the UK CSIP. Although some tumours have been observed, there have only been about 10 cases out of over 2000 harbour porpoise post mortems in 20 years (P. Jepson, pers. comm.). The high radioactive contaminant levels in UK waters are unlikely to be a significant pressure.

3.7.2.5 Trace elements and heavy metals

Some trace elements are essential nutrients required for healthy living, but these elements can be toxic at higher concentrations (Aguilar and Borrell, 1995). In contrast, heavy metals (i.e. metallic trace elements with a high atomic number, such as mercury [Hg] and cadmium [Cd]), are toxic to biological systems even in relatively small amounts (Reijnders, 1980; Nicholson *et al* 1983; Bouquegneau *et al* 1997).

There are considerable methodological difficulties in the study of bioaccumulation of trace elements in cetaceans (André, 1997). Metals and their effects on marine mammals have been reviewed by O'Shea (1999), Reijnders *et al* (1999) and Das *et al* (2003). Excess trace metal contamination is believed to adversely affect marine mammal health with a relationship between metal burden and lower resistance to disease has been shown in harbour porpoises from the North and Baltic Seas (Siebert *et al* 1999; Bennett *et al* 2001). Emaciated harbour porpoises from the southern North Sea have high levels of zinc (Zn) and mercury (Hg) in their tissues, which may be linked to their nutritional status (Das *et al* 2004; 2006). Harbour porpoises that died from infectious disease displayed significant higher hepatic concentrations of Cd, Hg, Se and Zn compared to healthy porpoises that died from physical trauma whilst adult porpoises displayed significant higher concentrations of Cd, Cr, Hg, Se and V in livers compared to juveniles (Mahfouz *et al* 2014).

UK-stranded porpoises (2000-2004) that died of infectious disease also had significantly elevated levels of some metals including Hg, Se and Zn in their livers (compared to those that died of physical trauma) but these associations may in part be linked to physiological redistribution caused by loss of nutritional condition in diseased animals (Bennett *et al* 2001; Jepson, 2005).

Data collected under the UK Cetaceans Strandings Investigation Programme for UK-stranded harbour porpoises show that trace metal contaminants have gradually declined over time since 1990 (Deaville and Jepson, 2011).

3.7.2.6 Summary for chemical pollutants

Monitoring chemical toxic pollutant levels in key species such as harbour porpoises enables measurable reduction targets for these compounds to be set (Jepson, 2005). Temporal or spatial changes in contaminant burdens may be found that could point at effective counter-measures to reduce pollution. For many contaminants which have been subject to regulation regarding their production and use (e.g. organochlorine pesticides, PBDE and HBCD flame retardants, butyltins) trends are currently downwards (Law, 2014). Polychlorinated biphenyl (PCB) levels, however, have been stable since 1997 and still occur at much higher concentrations than any other marine contaminants tested (Law *et al* 2010). There are regional differences in PCBs and OC pesticide levels within UK waters (lower levels in Scotland), possibly reflecting differences in diffuse inputs and transfer between regions.

In conclusion, butyltins are currently declining and the impact of PAHs, radionuclides and elevated trace elements are considered to be relatively low. In contrast, the evidence available for persistent organic pollutants such as the organohalogens indicate that they are a significant pressure on harbour porpoise. High concentrations may result in immunosuppression, impaired reproduction and/or vulnerability to infectious disease. Whilst the population scale of impact is difficult to assess, cumulative effects can be expected from the exposure to a mixture of contaminants throughout life. A continuation of the monitoring of chemical toxic pollutant levels in harbour porpoises during necropsies is therefore recommended.

3.7.3 Eutrophication and sewage pathogens

The primary biological response to nutrient enrichment in shelf seas, given suitable environmental conditions, is the growth of phytoplankton (Brockmann *et al* 1990; Valiela, 2006) which can lead to eutrophication when excess nutrients enter the sea. Known consequences of marine eutrophication include red tides, water discolouration and foaming (caused by the colonial flagellate *Phaeocystis*; Lancelot *et al* 1987), increased production, increased removal of oxygen, and in extreme cases resulting in local anoxia (Devlin *et al* 2007). Waste waters and sewage from domestic, industrial, agricultural sources and aquaculture contribute a mix of organic and inorganic compounds, as well as harmless and infectious micro-organisms.

As a result of the EU Water Framework Directive and other related legislation, the UK Governments made a commitment to upgrade sewage treatment for major urban populations where secondary sewage treatment plants would be installed (Defra, 2012). Such secondary treatment reduces the biological oxygen demand and removes the suspended solids that are not removed by less rigorous forms of treatment. There is no clear evidence for bacterial or viral infections of porpoises as a result of sewage in UK waters, but it should be noted that such evidence would be hard to obtain. The factor is listed as a potential pressure, particularly for areas near large river mouths, with potential health effects for harbour porpoise utilising these waters.

3.8 Marine litter

In the second half of the 20th century, the use of plastics and other synthetic materials has hugely increased (Laist, 1987) and the quantity of plastic debris entering the marine environment has undergone a similar increase (Jambeck *et al* 2015). Many of these products degrade slowly and the accumulating debris may pose an increasingly significant threat to marine megafauna (Laist *et al* 1999; Baulch and Perry, 2014). The main sources of marine litter include vessels, offshore installations, and land-based sources (Cozar *et al* 2014; Jambeck *et al* 2015).

Considering marine litter and cetaceans, the key issues are entanglements and plastic ingestion. Research on entanglement in lost or abandoned fishing gear (termed ‘ghost fishing’) has largely been confined largely to ‘passive gears’ such as gillnets, trammel nets, wreck nets, traps, and small seine nets. Brown *et al* (2005) concluded that in relation to the total number of nets being used in EU waters, the rates of permanent net loss appear to be rather low (<1% of nets deployed), largely because most nets are deployed in shallow waters. Often fishermen go to considerable lengths to recover their nets given the cost of replacement.

Plastic ingestion can have directly lethal effects (internal injury, suffocation, and blockage) or lead to starvation and delayed death. Around the world, there is evidence of lethal effects of plastic ingestion by cetaceans and several instances of plastic ingestion by harbour porpoises in the North Sea have been reported (Leopold and Camphuysen, 2006). A less well known and understood potential pressure is the absorption of polychlorinated biphenyls from ingested plastics, noting that there is increasing concern with respect to microplastics as a potential vector for POP burden (Arthur and Baker, 2012).

There is no evidence from post mortem examinations that marine litter in general has a significant impact on harbour porpoise (Deaville & Jepson, 2011). Similarly, there were no cases of harbour porpoise entanglement in lost gear, ropes etc between 2000-2010 (Jepson,2005; Deaville and Jepson, 2011). Entanglement in marine litter is currently not considered to be a pressure in UK waters.

There is evidence for marine litter ingestion in porpoise strandings examined at post-mortem in the UK during 2005-2010 in 10 out of 459 cases, but in none of these was there any significant pathological impact on the animal observed and the ingestion had no relationship to the cause of death (Deaville and Jepson, 2011). Plastic ingestion is therefore not a major concern for harbour porpoises in UK waters.

3.9 Ecological issues

Under ecological issues, impact factors are addressed which most likely have a natural origin. Disease is a cause of natural mortality in harbour porpoise. The species is also subject to predation and competition, and resources may fluctuate for natural reasons as well as under the influence of climate change. Animals have parasites, but the necropsies associated with harbour porpoise strandings networks sometimes have revealed parasite infections that require further attention and that may be signals of adverse effects in harbour porpoises with an anthropogenic origin (see also chemical pollution and disease).

3.9.1 Disease and parasites

Van Bressem *et al* (2009) reviewed infectious diseases in cetaceans, examined their potential to impact populations, re-assessed zoonotic risk and evaluated the role of environmental stressors. Cetacean morbilliviruses and papillomaviruses as well as *Brucella* spp. and *Toxoplasma gondii* were thought to induce high mortality rates, lower reproductive success and to increase the virulence of other diseases. Environmental factors seem to play a role in the emergence and pathogenicity of morbillivirus epidemics, lobomycosis/LLD, toxoplasmosis, poxvirus-associated tattoo skin disease and, in harbour porpoises, infectious diseases of multifactorial aetiology.

In two harbour porpoises, one found stranded in Kent (England), the other in the Moray Firth (Scotland), both necropsied in 1990, the presence of the morbillivirus antigen was at the time considered the first proof of morbillivirus infection in cetaceans from the British coast (Kennedy *et al* 1992). Continued monitoring in the UK has identified no further cases (Deaville and Jepson, 2011).

From the necropsies associated with strandings data, parasite levels are known to be generally quite high in harbour porpoises (Siebert *et al* 2001; Jauniaux *et al* 2002; García Hartmann *et al* 2004; Leopold and Camphuysen, 2006; Osinga *et al* 2008). Studies to investigate this relationship should continue through established stranding and post-mortem work.

Infectious disease and parasites can potentially have a moderate impact on porpoise populations. Additional research (including a meta-analysis of necropsy data that have accumulated over time) would help to understand further the cause(s), the seasonality, long-term trends, the frequency in different sex and age categories, and the environmental conditions that may enhance the occurrence of infectious disease and parasite burden as a cause of death harbour porpoises.

3.9.2 Predation of harbour porpoises

Harbour porpoise are positioned near the top of the marine food web, but are not quite apex predators in all ecosystems (Bjørge, 2003). Reports of bottlenose dolphins *Tursiops truncatus* in UK (Ross and Wilson, 1996; Patterson *et al* 1998; MacLeod *et al* 2007a), and grey seals *Halichoerus grypus* in Europe (Haelters *et al* 2012; Van Bleijswijk *et al* 2014; Bouveroux *et al* 2014; Leopold *et al* 2014, 2015) and UK (Stringell *et al* 2015) suggest they attack and kill harbour porpoises in part of their range. Harbour porpoise are killed rather than preyed upon by the dolphins (MacLeod *et al* 2007a; Baines & Evans, 2012). Bottlenose dolphin – harbour porpoise interactions are most common in Scottish (e.g. Moray Firth; Ross & Wilson, 1996; MacLeod *et al* 2007a), Welsh (Deaville and Jepson, 2011; Baines and Evans, 2012), and in Cornish waters where harbour porpoise distribution overlaps with that of inshore bottlenose dolphins (Deaville and Jepson, 2011). There is circumstantial evidence for violent interactions between white-beaked dolphins *Lagenorhynchus albirostris* and harbour porpoises within the North Sea (Camphuysen and Peet, 2006; Haelters and Everaarts, 2011). Killer whales have also been known to take harbour porpoise (Weir, 2002).

The recent publications reviewing grey seal – harbour porpoise interactions point to a newly identified pressure (Haelters *et al* 2012; Van Bleijswijk *et al* 2014; Bouveroux *et al* 2014; Leopold *et al* 2014, 2015; Stringell *et al* 2015). In a recent Dutch study, 271 animals were sufficiently fresh to allow macroscopic assessment of grey seal-associated wounds with certainty (Leopold *et al* 2014). In 25% of these, bite and claw marks were identified that were consistent with the marks found on animals that had tested positive for grey seal DNA (van Bleijswijk *et al* 2014). Affected animals were mostly healthy and fat juveniles that had recently fed. It is concluded that the majority of the harbour porpoises were victims of grey seal attacks and inferred as predation rather than scavenging (Leopold *et al* 2014). More recently, Stringell *et al* (2015) report on direct observations of predation events in Wales, where porpoises were pursued, captured, killed and consumed by adult male grey seal, providing the first definitive evidence of this predation phenomenon in UK waters.

3.9.3 Variability in harbour porpoise prey

Reduced prey availability due to sea temperature rise, changing ocean currents and other climatic aspects, fisheries or a combination of factors may affect porpoise distribution and abundance. Harbour porpoises are opportunistic feeders and may change their diet, or simply move further away to more favourable feeding grounds within their geographical range. In the absence of solid information on prey preferences, prey quality, and prey availability (levels and thresholds of profitable feeding in particular habitats), it is unclear whether harbour porpoise can switch easily from one prey to another without any adverse effects. Santos and Pierce (2003) concluded that porpoises in any one area feed primarily on few (2-4) "main species", although whether this was a reflection of preference or the result of area specific differences in prey availability was unclear.

A shift from (fatty) clupeid to (lean) gadoid prey could have adverse health consequences or could, for example, compromise fecundity or longevity (the "junk-food hypothesis"; Rosen & Trites, 2000). The major distributional shift in harbour porpoise within the North Sea in recent decades is assumed to have a resource background, and a commonly heard hypothesis is that feeding conditions (notably on sandeels) have deteriorated in the northern North Sea for piscivorous seabirds and marine mammals alike (Camphuysen, 1994, 2004; Heubeck and Shaw, 2004; Frederiksen *et al* 2004; MacLeod *et al* 2007b).

Currently we cannot relate prey type or quality with prey availability, and there are no data indicating how behaviour, distribution, reproduction or survival depends on fluxes in prey availability. Nor are all prey species commercially important and, therefore, understanding the potential impacts of human activities, such as fishing, is difficult. The issue of prey resource availability, however, is considered to be important.

3.9.4 Climate change

Understanding and combating the effects of climate change on ecosystems is a recognised global need (Philippart *et al* 2011; Hobday *et al* 2015; Elliott *et al* 2015). The impact of climate change on marine mammals still remains poorly understood. For cetaceans, direct impacts are likely to be observed in species tracking a specific range of water temperatures in which they can survive (MacLeod *et al* 2005), while indirect impacts include prey availability affecting distribution and abundance as well as susceptibility to disease and contaminants (Learmonth *et al* 2006). However, there are many confounding effects (e.g., natural climate variability, human exploitation of the prey resource) and any changes observed may simply be the result of the cetacean species responding to short-term regional variability in the prey resource rather than long-term anthropogenically driven climate change (Pinn, 2010).

Understanding ecosystem regulation is important for predicting how the distribution of cetaceans and their prey may change. As a result of changes in distribution pattern over time, areas identified as being of significance for harbour porpoise (where overall densities are now high) may become less significant in future or vice versa (Víkingsson *et al* 2015).

3.10 Summary of pressures and the risk to harbour porpoise

The impact and risk of activities on harbour porpoise in UK waters is summarised in Table 3.3. This presents the relative risk of each pressure. In order to determine the relative risk, the likely population consequence (ranging from mortality, injury, affects on reproduction and health, prey availability, and behavioural affects leading to habitat displacement) was considered. The impact was assessed ranging from widespread or common, to rare, insignificant, or not applicable for UK waters. This assessment of risk does not take mitigation into account.

The anthropogenic pressures considered to be greatest risk are:

- bycatch in static net fisheries
- acoustic disturbance through impulsive sound (e.g. pile driving, seismic surveys)
- chemical pollution, notably persistent organic pollutants

Other anthropogenic pressures occur but were of lesser importance, because there was relatively little evidence of occurrence, the activity is relatively new or because the impact on the population was perceived to be low. These were:

- Acoustic disturbance through continuous rather than impulsive sounds (e.g. ADDs, shipping)
- Collisions with renewable energy installations
- Collisions with vessels

Variability of food resources leads to increased competition and changes in distribution. Such changes may be considered an ecological (natural) issue, but overfishing and climate effects (which have anthropogenic causes) cannot be excluded. Another pressure potentially impacting at the population level is that mortality and physical trauma inflicted by bottlenose dolphins, killer whales and grey seals.

Table 3.3. Summary of pressures to harbour porpoises in UK waters (prior to consideration of mitigation activities) and the current level of risk relative to each other in UK waters.

Pressure	Resulting impact	Current level of risk relative to other pressures
Intentional takes Hunting	Mortality	Does not occur
Incidental killing and capture Bycatch in fisheries (static net fisheries)	Increased mortality. Actual pressure with population level impact.	High
Acoustic disturbance (impulsive sound) Seismic surveys	Disturbance: short term habitat reduction	Moderate
Underwater explosions	Injury leading to increased mortality and disturbance: short term habitat reduction	Low to Moderate
Pile driving	Disturbance: habitat reduction. The scale of impact depends on spatial and temporal scale of piling. Potential for population level consequences.	Moderate (increasing)
Military activity and sonar	Disturbance, Habitat reduction. Potential pressure but with relatively little evidence of effect.	Low
Acoustic disturbance (ambient sound) Operational wind farms	Disturbance, Habitat reduction. Evidence is variable with some indicating a positive impact.	Low to None
Acoustic deterrent devices (ADDs)	Disturbance, Habitat reduction	Moderate (regionally)
Fish finders and depth sounders	Disturbance, Habitat reduction. Potential pressure but little evidence.	Low, more research required
Pingers	Disturbance, Habitat reduction	Actual pressure, limited effect used to prevent more significant impact
Mining/dredging activities, shipping, aircraft, whale-watching, recreation	Disturbance and habitat reduction. Potential pressure but little evidence.	Low, but maybe moderate locally
Collisions Vessel strikes	Increased mortality. Potential pressure but limited evidence.	Low

Pressure	**Resulting impact**	**Current level of risk relative to other pressures**
Collision with tidal stream renewable energy devices	Increased mortality. No evidence to date due to shut down procedures currently employed.	Low (but potentially regionally important)
Marine pollution Oil pollution	Health issues, impact thought to be declining as regulation has improved.	Low
Chemical pollution (e.g. POPs, butyltins, organohaologens, PAHs, radionuclides, trace elements)	Health issues and reduced fecundity. Bioaccumulation leading to population level effects.	High for POPs including PCBs
Plastic pollution (ingestion)	Potential pressure leading to health issues but no evidence of an impact.	Low
Entanglements in marine litter & ghost nets	Increased mortality. Potential pressure but no evidence of impact.	Low
Eutrophication, sewage pathogens	Potential pressure leading to health issues but no evidence of an impact.	Low
Ecological issues Disease and parasites	Health issues potentially leading to increased mortality	Low
Variability in resources	Starvation leading to increased mortality, reduced fecundity and/or longevity. However, the links between prey type/quality, availability and population level effects are poorly understood.	Moderate
Predators and competitors	Increased mortality. Pressure may increase in future.	Low but regionally important
Climate	Health and survival but effects currently unclear and unpredictable.	Unclear

4 Effective mitigation and management measures

4.1 Introduction

In order to maintain the favourable conservation status of harbour porpoise in UK waters, the use of effective mitigation and management measures will be required to reduce the pressures of those anthropogenic activities identified as exerting the greatest impacts. Whilst work is ongoing at the national level, such measures need to be applied at the appropriate ecological scale to be effective (i.e. that of the population and not just UK waters). Mitigation and the management of certain pressures therefore calls for a national and international, coordinated approach, i.e. beyond the scope of UK boundaries.

Further work is also required to improve and develop potential measures for mitigation and management and the pros and cons of available approaches being considered. This chapter will largely consider those activities and pressures considered to be of greatest relative risk; i.e. bycatch, acoustic disturbance (pile driving, seismic surveys and ADDs), chemical pollution (persistent organic pollutants) and variability of food resources.

4.2 Bycatch mitigation and management

Bycatch in demersal gill-, tangle- and trammel net fisheries is considered the most significant pressure to the harbour porpoise population and an important cause of death in the European North Atlantic, including UK waters. There are a variety of measures available to mitigate the incidental killing and capture of harbour porpoise, but an understanding of where, when, in which numbers and how bycatch occurs is important in the development and application of effective mitigation strategies.

The UK has been concerned about the levels of cetacean bycatch in fisheries for many years and has been funding research in this area since the 1990s to identify which fisheries pose the greatest risk and to identify suitable mitigation measures (Northridge, 1996; Northridge and Hammond, 1999). In UK waters, bycatch in demersal gill- and tangle nets is of particular concern in MU CIS (where monitoring has been ongoing for many years). Concern has also been raised with respect to the MU NS.

Northridge *et al* (2012b) compared observed bycatch rates with a crude index of overall fishing effort for static nets, and with that indicated which species are most likely and least likely to be subject to unsustainable levels of annual removal. Northridge *et al* (2012b) developed a method of calculating and displaying risk of bycatch and presented maps and guides to where further monitoring and / or mitigation measures might best be focused. The areas with the predicted highest co-occurrence between porpoises and set nets are off the Yorkshire and Tyneside coasts of England, in the central/eastern North Sea, west of Jutland, north of west of Shetland and off the coast of East Anglia

It is also important to note, that many of the fisheries that pose the greatest risk in UK waters are also targeted by other Member States of the European Union. Consequently, the European Commission needs to introduce measures that ensure a coordinated action as they hold management responsibility for fisheries management outwith 12nm for all vessels and between 6-12nm for the non-UK vessels, such that the favourable conservation status of harbour porpoises in European waters can be maintained into the future.

Following a period of research and due to ongoing concern, a UK Small Cetacean Bycatch Response Strategy was developed in 2003 and updated in 2009 (Defra, 2009), which aims to reduce small cetacean bycatch to a level below 1.7% of the best population estimate. Recommended mitigation measures focused on legal requirements to use pingers; consideration of a mortality limit scheme and measures to restrict fisheries in designated

SACs; establishing an independent observer monitoring scheme; study effects of pinger use; investigate net modifications; securing funding for distribution and abundance data.

4.2.1 Monitoring and assessing bycatch

Regulation 812/2004 requires Member States to monitor certain specified fleet segments over 15m in order to quantify cetacean bycatch whilst the Habitats Directive has a broader requirement to monitor bycatch and ensure it does not have a negative impact on conservation status. Member states have to report annually to the European Commission on the implementation of Regulation 812/2004, whilst reports are required every six years under the Habitats Directive. The UK has always included a summary of observations and estimates of cetacean bycatch made in other fleet segments (i.e. those <15m as required by the Habitats Directive) within the annual 812/2004 reports submitted to the European Commission (SMRU, 2009; Northridge *et al* 2011a, 2012a, 2013a, 2014). The European Commission has noted that the UK's approach to monitoring bycatch provides an example of best practice (EC, 2009)

The UK monitoring programme is managed and coordinated by SMRU, in collaboration with the Centre for Environment, Fisheries and Aquaculture Science at Lowestoft (Cefas) and the Agri-Food and Biosciences Institute of Northern Ireland (AFBINI). Data provided by Cefas and AFBINI include discard sampling conducted under the Data Collection Framework (DCF), other specific research efforts and a limited number of dedicated sea days where protected species bycatch monitoring is the main focus for their observers. Data collected under the programme are also increasingly being used to assess bycatch of other non-cetacean but protected or potentially vulnerable taxonomic groups or species, including seals and seabirds.

The UK monitoring covered a wide variety of gear types and major fishing areas. Roughly 82% of static gear sampling was monitored in the south and west of the UK (ICES Subarea VII) where the bycatch risk is considered to be greatest, and around 18% in the North Sea (ICES Subarea IV) (Northridge *et al* 2014). Most of the UK sampled static gears in 2013 were categorised as fixed nets (321 days compared to 25 days with drift nets) (Northridge *et al* 2014**).** Bycatch estimates are highly dependent on assumptions made about gillnet fishing effort per day at sea. However, logbook records are insufficiently detailed (e.g. individual net lengths are not recorded) and therefore on-board observers or Remote Electronic Monitoring (REM) programmes are currently the only reliable way to estimate functional fishing effort (Northridge *et al* 2014). There is therefore, a need to develop mechanisms to better assess effort, particularly within the bottom set net fleet.

4.2.1.1 International collaboration and the determination of bycatch

ICES annually collates and assesses the reports of EU Member States on bycatch, mostly based on Regulation 812/2004 requirements for reporting, though other data on bycatch provided by Member States is also assessed. This work is progressed through the ICES Working Group on Protected Species Bycatch (WGBYC) in which the UK actively participates.

A preliminary assessment of overall harbour porpoise bycatch rates in the North Sea was carried out using information gathered since 1995 (ICES, 2014d). This assessment indicated that bycatch rates in some fisheries may be above any proposed reference limits (although the uncertainty is large) and may therefore pose a future conservation risk. Better quality data on bycatch rates and fishing effort from more fisheries is required from EU Member States before this assessment can be refined and conclusions drawn as to the overall bycatch of harbour porpoise in the North Sea (ICES, 2014c). ICES also recommended the use of 'net metre per immersion day' as a more precise unit for reporting static gear effort than 'days at sea' (ICES, 2014c).

ICES (2015) provided estimates of potential bycatch mortality of harbour porpoises in the European Atlantic, with data from 2005 for MU CIS, that suggested that 1.39% of the harbour porpoise population is being taken and for MU NS 0.88% (upper 95% confidence interval bycatch rate is applied), which are both below the ASCOBANS 1.7% limit . However, ICES (2015) emphasised that fishing effort data are likely to be underestimated as effort from smaller vessels is not fully represented in all areas. In this respect the estimated bycatch range may be biased low, but the range may also be biased high as much of the sampling has been done on larger vessels that use more gear and are likely to have a higher bycatch rate per day than smaller vessels.

ICES (2015) emphasised that the lack of statutory reports from some major fishing nations compromises its ability to assess the overall impact of fisheries on small cetaceans and other marine animals. In this respect, the UK has a very good record of reporting with its monitoring scheme.

It is important to note, that assessing bycatch numbers and calculating impact of bycatch on a population not only requires information from the fisheries but also requires information on distribution and abundance of harbour porpoise.

4.2.1.2 Improving bycatch monitoring in the <12m fleet

There is no specific requirement to monitoring bycatch on vessels <12m in length due to the general lack of space on board such vessels (although there is an onus on MS to ensure that such bycatch is not having a significant negative impact on FCS). ICES (2013) indicated that the use of remote electronic monitoring (REM) as a tool for monitoring would be a cost-effective way of assessing bycatch in the future.

REM is based on a camera monitoring system to document fisheries discards and bycatch of marine mammals and birds. An REM system can be installed to document only the hauling process of set gillnets. The system automatically becomes activated when the hydraulic hauling system is activated and the nets are hauled, although the use of cameras onboard can reduce privacy. Such systems have been, or are being trialled, in a number of countries, including Denmark, the Netherlands, and Sweden.

To investigate the potential of REM to record bycatch of marine mammals, Danish commercial gillnetters (10 to 15m in length) were equipped with these systems, which provided video footage, time and position of all net hauls and bycatch of marine mammals. The cameras were installed such that different angles of the hauling of the gear and the catch handling were monitored. In relation to bycatch detection rates, Kindt-Larsen *et al* (2012) noted the importance that a camera covers the position where the nets break the surface, since the results showed that from the 14 bycatch observations missing in the logbooks, seven porpoises dropped out of the nets before the fishermen could record them. Consequently, cameras focused only on the net as it comes on board will not detect all occurrences of bycatch. In earlier work, Bravington & Bisack (1996) reported that 58% of harbour porpoises fell out of the net before it reached the deck. Kindt-Larsen *et al* (2012) provides a review the advantages and challenges of using an REM system. REM has proven to be an effective method that can be incorporated alongside an independent observer scheme, where international accepted protocols to assess the impact of bycatch in gillnet fisheries are adopted.

4.2.1.3 Future bycatch monitoring at EU level

Under Regulation 812/2004, the monitoring of cetacean bycatch is not required for <12m fleet and yet the fisheries that constitute the greatest risk to harbour porpoise are almost exclusively contained within this fleet segment. The European Commission has decided not to amend Regulation 812/2004 and to integrate monitoring of protected and endangered species (PETS) into the new data collection framework (DCF, DCMAP in the future). ICES (2014c, 2015) has advised that any moves to integrate monitoring of the bycatch of protected species in all EU waters within the DCF needs very careful consideration of sampling regimes as such monitoring will require significant adjustments from those used to monitor commercial fish bycatch.

4.2.2 Management measures - Bycatch reference points

Whilst the main is to reduce bycatch to zero, it is valuable for conservation purposes to define a trigger or limit that indicates where additional action is needed because the bycatch may have a population level effect. Several methods have been used to define such limits or threshold reference points. The robustness of the various models to uncertain information varies (ICES, 2014d). Possible reference points for harbour porpoise bycatch are:

- ASCOBANS limit of 1.7% of best population estimate,
- Potential Biological Removal (PBR as utilised by the USA) and
- Catch Limit Algorithm (CLA initially developed during SCANS II project) methods (ICES 2014d).

The latter approaches have the advantage of being able to build in uncertainty with respect to both the population size and the degree of bycatch occurring. However, the definition of the overall conservation objective in terms that can be used in mathematical models is reliant on societal decisions before these, potentially more conservative, approaches can be adopted.

ICES (2014d) have repeated its recommendation that the European Commission initiate a process involving both managers and scientists to review management frameworks and approaches for determining unacceptable levels of bycatch. ICES has also repeated that a bycatch risk-based approach be used to identify areas and fisheries that pose the greatest risk to protected species (ICES 2013, 2014cd). This bycatch risk-based approach splits the population numbers of each protected species into different management units (MUs) and calculates bycatch limits of species by area for any reference point used. By using an expected bycatch rate multiplied by the total fishing effort, an approximate total number of bycaught animals can be estimated for each fishery and compared with any proposed threshold or limit.

Further development of an indicator under the MSFD for bycatch is also pending a decision from the European Commission on a bycatch threshold, to be adopted under the CFP. It is not appropriate to have different thresholds for the same impact under different pieces of European legislation. As the European Commission has management responsibility for fisheries, their approach will take precedence. Scheidat *et al* (2013) used the Netherlands as a case study to demonstrate the situation faced by a number of European countries for setting limits to anthropogenic mortality and the difficulties associated with current mortality thresholds. Scheidat *et al* (2013) recommended the use of management procedures for setting mortality limits that take into account available data including associated uncertainties and biases in abundance and mortality estimates, and whose performance has been extensively tested through simulation.

4.2.3 Management measures – Pingers

In 2013, between 26 and 31 UK registered vessels were fishing in such a way as that pingers were required under Regulation 812/2004 (Northridge *et al* 2014). Although it should be noted that logbook records are insufficiently detailed to identify exactly which vessels are required to use pingers (Northridge *et al* 2014). A large part of the UK gillnet fleet however, operates from vessels < 12 metres in length and, therefore, no pingers are required under the Regulation. This part of the fleet is where the greatest risk of bycatch occurs and, as such, Article 12 of the Habitats Directive applies.

4.2.3.1 Use of pingers by the UK fleet

Pingers are currently the most effective way to reduce harbour porpoise bycatch in gillnet fisheries, other than significant effort controls in fisheries with a high risk of bycatch (ICES, 2010b).

Given the issues encountered in the UK fleet with the robustness and suitability of the pingers listed for use in the Regulation, the UK has a derogation to use the Dolphin Dissuasive Device (DDD). The DDD pinger has a louder output than the other pingers listed for use and, therefore, fewer units are required on a single string of nets significantly reducing some of the handling and safety issues initially encountered.

In the Western Channel and Celtic Sea, the DDDs have proven a viable means of minimising cetacean bycatch (Northridge and Kingston, 2010). The spacing of pingers and whether they are active, influences their effectiveness (Palka *et al* 2008; Orphanides, 2012; Dawson *et al* 2013; Larsen *et al* 2013; Northridge *et al* 2014). UK monitoring showed that DDD-03 pingers are effective (circa 90% reduction) as long as they are spaced on nets no more than four kilometres (km) apart. Larsen *et al* (2013) demonstrated that the Aquatec AQUAmark100 pinger was effective to a spacing of 455m (when the regulation required 200m). Increasing the distance between two pingers will reduce some of the disadvantages of widespread pinger deployment (e.g. costs, practicality and noise introduction).The results of the work by Larsen *et al* (2013) and Northridge *et al* (2014) also stress the importance of basing development and implementation of a regulation on solid evidence.

4.2.3.2 UK pinger monitoring, enforcement and compliance

It has generally proved difficult to monitor and enforce the use of pingers required under Regulation 812/2004 given the difficulties in testing whether devices are operational and/or whether fishermen have properly deployed them on gear. As such, observation schemes are essential in both determining whether mitigation measures are needed and whether mitigation measures that are deployed are working (ICES, 2010a; Dawson *et al* 2013).

In the UK the masters of all relevant vessels are aware of their obligations to use pingers and all such vessels are subject to routine inspection at sea, with all south west[4] based over 12m vessels using them (Northridge *et al* 2014). Operating procedures for the use of the DDD-03L pingers in the Celtic Sea and English Channel were developed in 2012 in collaboration with the Cornish Fish Producers Organisation (CFPO) which represents most of the >12m vessels using static nets in this area. Whilst any pinger listed in the legislation is suitable for use, due to practical handling benefits, most favour the DDD-03 device (Northridge *et al* 2014). More recent developments include a newly designed robust multi-charger which can charge 10 DDD-pingers simultaneously from a single power source aboard a vessel. The unit

[4] ICES area VIIe,f,g,h

also allows battery voltages (a proxy for pinger functioning) to be tested quickly (Northridge *et al* 2014).

Fisheries Inspectors from the Marine Management Organisation and Marine Scotland are responsible for compliance and enforcement of fishery regulations in UK waters, and have developed protocols for assessing vessel compliance through shore side and at sea inspections. In addition, naval officers have received training in the interpretation of Regulation 812/2004. Pinger detection units are being used to determine compliance at sea, including when nets are deployed (Northridge *et al* 2014). The UK industry has only recently adopted the routine use of pingers and it is too early to make a proper judgment about the effectiveness of the scheme.

4.2.3.3 Habitat exclusion and pingers

Concerns have been raised about the potential for widespread use of pingers to result in habitat exclusion (Culik *et al* 2001; Carlstrom *et al* 2009; Kingston and Northridge, 2011; Larsen and Eigaard, 2014). Such exclusion equates to the distances at which such devices are effective at reducing bycatch. Kingston and Northridge (2011) calculated potential exclusion rates which ranged from 0.04% to 11% of the total area of the Celtic Sea and Western Channel, depending on the model, spacing and fleet sectors were chosen. Dawson *et al* (2013) considered such displacement was unlikely to be problematic at larger scales. The impact of such exclusion at the population level will depend on how important these habitats are and whether there are alternative foraging locations available (Larsen and Eigaard, 2014).

Given the aspect of habitat exclusion, which depends on a number of factors, pingers should only be used in areas where bycatch is a significant issue and the effects of use on porpoises should be monitored throughout. Further development work is needed to be continued to improve the reliability, durability and cost of pingers.

4.2.3.4 Further development of pinger technology

The characteristics of existing pingers that effectively deter harbour porpoises from fishing gear are now reasonably well understood and work on the further development of new pingers is being undertaken.

In initial tests by Crosby *et al* (2013), use of the Fishtek Banana Pinger resulted in a reduction in acoustic detections of harbour porpoise. Whether this translates into a reduction in bycatch in commercial fisheries has yet to be demonstrated. ICES stress that the effectiveness of new devices must be tested in a commercial setting with a demonstratable reduction in bycatch prior to its use being promoted. Larsen and Eigaard (2014) have shown a highly significant difference in bycatch between nets with active pingers of the LU-1-pinger (developed by Loughborough University with a source level of 145dB and 8 different signals between 40 and 120 kHz) and nets with inactive or no pingers for wreck net fisheries and the flat bottom/stony ground fishery. Porpoise Alarm (PAL) pingers emit synthetic communication sounds that simulate natural porpoise echolocation, aiming to minimise or avoid potential negative effects of conventional pingers such as habitat exclusion (ICES, 2014c). During field tests a signal could be identified that increases the echolocation intensity (click rate), but also increased minimum distance of harbour porpoise to the PAL device. ICES (2014c) recommended that trials should be continued to achieve statistically sound results about the effectiveness of PAL devices. ICES (2014c) also stressed the importance of testing the principle “are porpoises that have higher click rates less likely to get caught than those with lower click rates” preventing an endless search for a new ‘alerting sound’.

Further studies are needed to define pinger standards for harbour porpoises and ICES have recommended that a performance standard be set. For a pinger to become acceptable, it should have a proven ability to reduce bycatch in the setting of a commercial fishery (ICES, 2013, 2014c).

4.2.4 Management measures - Time-area closures for specified fisheries

Spatial and/or temporal closures may be effective in areas or at times where harbour porpoise occurrence is particularly predictable and seasonal. For example, based on results of bycatch monitoring of the Norwegian coastal gill net fleet (<15m), which showed that bycatch rates decreased linearly with increasing depth, Bjørge *et al* (2013) recommended that the monkfish fishery be prohibited at depths less than 50m leading to the closure of a specified area aiming to reduce bycatch.

Any closure requires careful planning in order to avoid unwanted consequences such as displacement into other areas or to gears that may have other unwanted environmental effects, such as an increased bycatch due to a change in fishing behaviour (ICES, 2010b). At this time, there is insufficient understanding of the seasonal use of UK waters by harbour porpoises at the appropriate scale (temporal and spatial) such that time-area closures could be considered an appropriate management tool.

4.2.5 Management measures - Adaptation of or changing fishing gear

Investigations of gear adaptations or changes in the type of gear used to mitigate bycatch of small cetaceans is one of the adopted terms of reference[5] of the ASCOBANS working group on bycatch. Whilst a variety of studies have been conducted over the years using chemical adaptations of nets (e.g. the inclusion of iron oxide or barium sulphate) to increase stiffness or reflectivity, results have been mixed (e.g. Larsen *et al* 2002; Larsen *et al* 2007; Mooney *et al* 2007). Net soak time, porpoise or prey density and behaviour, and low echolocation activity have all been proposed as reasons for the variation results.

An alternative is to consider changing gear altogether. For example, trials with fish pots (traps) aimed at reducing seal depredation in a Swedish cod fishery also resulted in an absence of harbour porpoise bycatch (Königson *et al* 2010). However, the catch rate of fish pots (or traps) is generally lower than that of gillnets in the same fishery (ICES, 2010c) and initial trails in UK waters were not particularly promising (Al Kingston pers. comm.). The applicability of such measures will also be influenced by factors such as water depth and current speeds (Königson *et al* 2015) and may also require vessel modifications to accommodate the new gear.

There is a wide variety of static net fisheries operating in the UK targeting various species (Vanstaen and Silva, 2010; CCW, 2010; Kingston and Northridge, 2011; Northridge *et al* 2014) so the use of modified or alternative gear might provide a suitable alternative to static nets.

4.3 Acoustic disturbance & ambient noise

Various legal instruments, including the Habitats Directive and its associated national legislation, require levels of underwater noise to be managed in such a way that they do not

[5] Annex 7 of the Report of the 18th meeting of the ASCOBANS Advisory Committee, Germany, Bonn 2011. http://www.ascobans.org/en/document/report-18th-meeting-ascobans-advisory-committee

adversely affect the conservation status of harbour porpoise. This is also supported by requirements of the MSFD and indicator development for Descriptor 11 noise which has indicators for the introduction of loud impulsive sounds (e.g. pile driving, seismic surveys) and for continuous ambient sound (e.g. shipping noise). For harbour porpoise, it is impulsive noise that is of the greater concern at this time.

4.3.1 General mitigation and management measures

In response to concerns over impulsive noise sources, JNCC together with regulators and industry, have developed guidelines for minimising the risk of injury to marine mammals from explosives and from piling noise (JNCC, 2010d,e) and for minimising the risk of injury and disturbance from seismic surveys (JNCC, 2010c). Guidance for the industry has also been developed on the protection of marine European Protected Species (EPS, which includes all cetacean species) from injury and disturbance (Anonymous, 2010; Marine Scotland, 2014). This guidance is intended to provide a resource for marine users, regulators, advisors and the enforcement authorities when considering whether an offence of deliberately (or recklessly in Scotland) disturbing or injuring/killing an EPS is likely to occur or to have occurred as a result of an activity. For military activities a range of mitigation measures are used that adhere to these guidelines.

The guidelines for minimising the risk of injury require the use of qualified Marine Mammal Observers (MMOs) undertaking visual detections. To ensure detection is maximised during low visibility (e.g. high sea state, fog, dark) the use of addition acoustic monitoring is required. Marine mammal observers have to be qualified to a particular standard (JNCC, 2010c, d, e). The MMO reports have to be submitted to JNCC and are collated periodically (e.g. Stone, 2015a). Stone (2015b) concluded that MMO data requirement provides a valuable resource for evaluating the mitigation measures within the guidelines and recommended that such studies should aim to improve mutual understanding between regulators/ advisors and industry in order that mitigation is applied correctly, is logistically feasible, is well justified and is proportional to the risk to species.

Planning is essential for all activities bringing noise into the marine environment. Whilst the impact of an individual operation or activity may in itself not be significant, the cumulative impact of many operations occurring in close proximity either in time or space could be detrimental at the population scale. Accurate abundance and distribution data (such as seasonal movements) at an appropriate temporal and spatial scale are therefore also essential.

4.3.1.1 Marine Noise Registry

Under the Marine Strategy Regulations (2010), there is now a requirement to monitor loud, low to mid frequency (10Hz to 10kHz) impulsive noise. Activities where this type of noise is produced include use of seismic airguns, other geophysical surveys (<10kHz), pile driving, explosives and certain acoustic deterrent devices. In order to do this the Marine Noise Registry (MNR) has been created and populated with data from Regulators, industry representatives and individual licence holders. The data held includes activity type (geophysical surveys, piling, explosives, acoustic deterrent devices and multi-beam echo sounders), source properties (SEL/SPL and source proxies; TNT Equivalent, maximum hammer energy etc), locations and dates the activity occurs in/on.

The UK MNR is now operational. As one of the first, its approach could be adopted by other Member States. The UK have been leading the discussions on the development of a common registry for OSPAR, which has aspirations to implement an impulsive noise registry for the North East Atlantic thereby aiding regional seas reporting requirements of MSFD.

4.3.2 Seismic activities

Sounds generated during seismic surveys are a recognised pressure on harbour porpoises in UK waters. Most seismic survey effort is in the central and northern North Sea between April and September (DECC, 2009, 2010; Stone, 2015a). The guidelines developed to minimise the risk of injury and acoustic disturbance of marine mammals by oil and gas industry seismic surveys (JNCC, 2010c) and the EPS Guidance (Anonymous, 2010; Marine Scotland, 2014) have already been outlined. In addition to the use of MMOs and PAM, a soft start procedure (or ramp up) is required.

The soft start means that the power source is started in a low-power mode and then gradually increased to the required level over a specified period (minimum 30 minutes). This time period should be long enough for the animals to relocate to a 'safe' distance. The assumption is that the animals actually respond in this manner to the sound, either instinctively or because they have learned to do so. Whilst the effectiveness of ramp up procedures have been questioned (Weir and Dolman, 2007; Parsons *et al* 2009), recent studies have indicated that ramp up is an effective mitigation measure (Ainslie and Von Benda-Beckmann, 2012; Von Benda-Beckmann *et al* 2013; Stone 2015a).

An examination of sixteen years of UK information from observers on board vessels during seismic surveys in UK noted lower detection rates of all cetaceans during the soft start (compared to not firing) and all showed greater avoidance during the soft start than at any other time, including harbour porpoises (Stone, 2015a). It is recognised that a side effect of a ramp up scheme is that it will increase the total duration of an operation, thus also possibly increasing the total acoustic energy transmitted into the environment (Ainslie *et al* 2009).

Power down (i.e. a shut down of the operation) has been proposed as a requirement should a cetacean enter a predefined area whilst surveys are being conducted (Parsons *et al* 2009). This will however extend the exposure time to the noise source considerably and is not currently considered an effective mitigation measure. For large surveys, however, the JNCC guidelines (JNCC, 2010c) require the airgun firing to be terminated when ships are turning to a new heading.

4.3.2.1 Adapted or alternative power sources for seismic surveys

The frequency range that is used for seismic exploration depends on the required image resolution and on the depth of penetration of the substratum required. The usable bandwidth ranges from 10 Hz to 1000 Hz, where the depth of penetration required is more than 2km, then the usable bandwidth typically ranges from 10 Hz to 200 Hz (Ainslie *et al* 2009).

An airgun not only generates the 'usable' frequencies, but also produces much higher 'waste' frequencies up to 10 kHz (Ainslie *et al* 2009). Eliminating these waste frequencies would reduce the amount of noise introduced to the environment and benefit harbour porpoise where those waste frequencies overlap with their hearing range.

The Quieting Technologies for Reducing Noise During Seismic Surveying and Pile Driving Workshop held in 2013 concluded that marine vibroseis had potential as an alternative to using airguns, but it still an emerging technology in need of commercial development. Notable applications were suggested in shallow water, sensitive habitats, and near vulnerable biological resources (CSA Ocean Sciences Inc., 2014).

4.3.3 Pile-driving for offshore wind farm construction

Of all the anthropogenic pressures to which harbour porpoise is exposed, the ongoing development of renewable energy in UK waters means that acoustic disturbance as a result of pile driving will continue to increase as a pressure into the future. The number and arrangement of turbines and the physical characteristic of the site (e.g. sediment type, water depth) varies considerably between projects and has implications for determining the most effective monitoring and mitigation (ICES, 2010a; CSA Ocean Sciences Inc., 2014).

Koschinski & Ludemann (2013) provided a comprehensive overview describing the potential for noise mitigation and the state of development for various noise mitigation measures for impact pile driving (e.g. bubble curtains, isolation casings, cofferdams, hydro sound dampers and acoustic improvements of the piling process), and summarised noise mitigation measures for impact pile driving, their reduction potential, development status and next steps to be done. They also described alternative low-noise foundation methods (e.g. vibratory pile-driving, drilled foundations, gravity base foundations, floating wind turbines and bucket foundations), concluding that all methods still have the potential for improvement with respect to their effectiveness, handling and economic efficiency. Similar reviews are also provided by Spence *et al* (2007), Nehls *et al* (2007), ICES (2010a), Saleem (2011), Koschinski and Ludemann (2013), CSA Ocean Sciences Inc. (2014) and Wright (2014).

Besides the use of MMOs and PAM, the UK's Guidance (JNCC, 2010d), requires the use of soft start, i.e. gradual ramping up of piling power, incrementally over a set time period (not less than 20 minutes), until full operational power is achieved. In addition, the use of ADDs has the potential to exclude animals from the piling area, but should only be used in conjunction with visual and/or acoustic monitoring. It should be noted that the use of acoustic deterrents adds further to the total amount of underwater noise being generated. This approach follows that recommended by ICES (ICES, 2010a) and is considered fit for purpose at this time (Herschel *et al* 2013). However, as the scale of the industry increases, it is likely that there will be a need to review and update the guidance, particularly for the planned large offshore wind farms.

ICES (2010a) recommended that a set of common accepted tolerance limits for acute noise exposure and the development of common guidelines for mitigation in relation to pile driving was required internationally. If a temporary exclusion from the construction site and adjacent areas impacted can be shown not to have a population level consequence in the relevant management area, then it may be appropriate to mitigate at the level of physical injury (TTS, PTS and non-auditory effects). If, however, there would be insufficient information available or direct concern that temporary habitat loss will have population level consequences, then ICES (2010a) recommended that mitigation must take place that also takes the effects of disturbance into account.

4.3.3.1 Cumulative risk assessments

ICES (2014a) recognised that a significant problem in assessing impacts of marine renewable energy on marine mammals lies in linking impacts on individual animals to population-level consequences. Assessing such broad-scale impacts requires assessment of long-term effects on animal energetics, health, reproductive rates and survival. Collecting such data on populations of long-lived, wide-ranging marine mammals is likely to require detailed long-term monitoring programs (ICES, 2014a). Until such data become available, risk modelling is a potential tool to assess the impact of pressures and threats. Examples of such risk modelling tools are the Interim Population Consequences of Disturbance (PCoD) framework and the Disturbance Effects on the Harbour Porpoise Population in the North Sea (DEPONS) project. These methods provide an example of a theoretical approach where a wide range of data are used to assess potential population consequences (Lusseau *et al* 2012).

PCoD - Information from realistic construction schedules provided by offshore wind farm developers is being used within the Interim PCoD framework to provide an estimate of the cumulative impact of UK North Sea offshore wind developments on the harbour porpoise population. Sites considered for this assessment will be: Dogger Teeside A and B, Dogger Creyke Beck, Hornsea 1 and 2, East Anglia 1, 3 and 4, Triton Knoll, Race Bank and Dudgeon. Expected output of this project would be a report delivering a cumulative impact assessment and provide a range of output measures that will describe the potential impacts along with recommendations for further work to encompass impulsive noise activities covering a wider area of the North Sea MU.

In 2014, the PCoD framework was used by the Netherlands Ministry of Infrastructure and the Environment to assess the potential cumulative effects on the North Sea harbour porpoise management unit of planned offshore wind farm developments and seismic surveys in the North Sea between 2016 and 2022. Results are expected to be available later in 2015.

DEPONS - As part of the Disturbance Effects on the Harbour Porpoise Population in the North Sea (DEPONS) project, an individual-based model (IBM) was developed to simulate the cumulative impacts of different kinds of disturbances on the porpoise population in the Inner Danish waters. This project has been extended to evaluate the impact of pile-driving noise from offshore wind farm construction on the porpoise population in the North Sea. Although the results should be considered preliminary, the patterns generated by the current version of the DEPONS model did not suggest any clear, long-lasting effects of pile-driving noise on the average porpoise population size and dynamics in the North Sea. (Van Beest *et al* 2015). Empirical data on harbour porpoise movements in the North Sea are required to better parameterise the model. The DEPONS model could, in the future, be extended to include other species, disturbances, and environmental processes which currently have not been considered (VanBeest *et al* 2015).

4.3.3.2 Setting European standards for the introduction of impulsive sound

As part of the developments of indicators for MSFD, a system of international standards applying thresholds for the introduction of all impulsive underwater sounds is being progressed. Such thresholds are already in operation in some countries with, for example, Germany requiring pile driving noise to be limited to a sound exposure level (SEL) of 160 dB re 1µPa within 750m of the source and a sound pressure level (SPL) of 190 dB re 1µPa should not be exceeded (Werner, 2012). This requirement has catalysed the development of alternative methods for pile driving including tripod, jacket, gravity and suction caisson foundations and the development of mitigation devices such as bubble screens.

Initial work has included an assessment of how different countries regulate and licence activities that generate underwater noise as well as looking at approaches enabling international harmonisation and definition of noise exposure criteria (Lucke *et al* 2013). Significant gaps in our knowledge exist in understanding of the impacts of noise and that agreement needs to be reached on sound exposure criteria. This will require a matrix of different effects (injury, hearing deficiencies, behavioural changes, masking) against a range of animal groups and different sound sources.

4.3.4 Acoustic deterrent devices (ADD)

ADDs are used in aquaculture and salmon fisheries to prevent seal depredation and, more recently, have been used to encourage cetaceans to move away from areas where noisy activities will shortly commence. The Global Standards for Salmon Aquaculture, developed in 2012, require the companies that sign up to phase out the use of ADDs in favour of more appropriate methods to prevent seal depredation (Northridge *et al* 2013b). In the UK, following the EPS licensing guidance (Anonymous, 2010; Marine Scotland, 2014), in areas of high and regular cetacean occurrence (e.g. SACs), the use of ADDs acoustic devices in aquaculture should be avoided or, where use is required, it should be for as short a period as possible. An assessment of the likelihood to commit an offence under the Habitats Regulations or the Offshore Marine Regulations (OMR) should be undertaken prior to the use of these devices. This should be carried out in consultation with the relevant Regulatory Authorities and the SNCBs.

4.3.5 Military Activities and Sonar

There are well established mechanisms that are used during military activities to avoid harm and disturbance of cetaceans. The Marine Environment and Sustainability Assessment Tool (MESAT) is an interactive tool incorporated into electronic charts to provide advice on the suitability of military activities in particular locations. It also includes identification of the ranges of PTS and TTS for cetacean species most likely to be in the area (but always including beaked whales). From transmission source profiles, the size of a mitigation action zone is identified within which avoiding action will be taken.

Geographical areas of known high risk for cetaceans are avoided where possible to reduce risks of embayment or driving animals towards a shallow coast. JNCC provides (via the UK Hydrographic Office) some of the underlying data on the distribution of marine mammals and participates in regular technical reviews of the tool (now held every two years) providing views on the degree to which the tool meets legislative requirements. The science which goes into the risk assessment tool and that which UK regulators are utilising to underpin their guidance and advice is independently reviewed to ensure that the risk assessment process remains valid and capable of meeting regulatory requirements.

During activities, a looking and listening approach is used which involves dedicated visual and PAM monitoring of an area around the source immediately prior to transmission for evidence of cetaceans. This monitoring occurs at least 30 minutes before transmission in waters shallower than 200m and for at least 60 minutes in deeper waters. Monitoring continues throughout transmission and for 30 minutes afterwards.

Additionally, the naval mitigation of potential impacts of helicopters and fixed-wing aircraft includes maintaining a 500m minimum flight altitude, wherever practicable, if any cetaceans are seen on the surface (Jepson *et al* 2013). Following the mass stranding of common dolphins in 2008, an alert system was established to facilitate rapid exchange of information between cetacean strandings/sightings organisations and Royal Navy Naval Command Headquarters. This alter system was used to report a near-MSE of over 20 common dolphins in the Fal estuary in April 2009 that was seen 15 minutes after Royal Navy sonar trials were initiated. The Royal Navy immediately modified the naval exercise (including use of active sonars) until the group of dolphins had returned to open sea several hours later. The need to alter training exercises due to the presence of dolphins has not subsequently occurred in this region. Such continual improvement of mitigation strategies by the military themselves is probably the best way to limit future environmental impacts of naval activities, including cetacean mass stranding events. A similar alert system has been used in Scotland for routine ordinance clearing activity in training areas.

4.4 Chemical Pollution

Chemical pollution is a generic problem, but a regional approach can be useful to assess sources and likely solutions. Evidence for any effects of pollution tends to be derived from necropsies associated with studies of stranded animals. Monitoring temporal or spatial changes in contaminant burdens can point at effective counter-measures to reduce overall pollution. The UK Cetacean Strandings Investigation Programme (CSIP) has been running since 1990 and aims to:

- Collate, analyse and report data for all cetacean strandings around the coast of the UK;
- Determine the causes of death in stranded cetaceans, including bycatch and physical trauma;
- Undertake surveillance on the incidence of disease in stranded cetaceans in order to identify any substantial new threats to their conservation status;
- Maintain a national cetacean tissue archive;

To establish the cause of death a proportion of the stranded animals is retrieved for post-mortem investigation. Information on causes of death, disease, contaminants, reproductive patterns, diet and also useful pointers to the general health of the population is collected through the scheme. Data collected through CSIP from stranded harbour porpoise has shown that various contaminant levels have gradually declined since 1990 with the introduction of legislative requirements (Jepson, 2005; Deaville and Jepson, 2011). However, despite legislation now being in place for many decades, the contaminant burden of many persistent organic pollutants present in harbour porpoise have levelled in recent years (Law *et al* 2013). This indicates the presence of legacy sources, which need to be identified if further reductions in contaminant burdens are to be seen.

The UK has the best record of historical and current pollutants levels in harbour porpoise in Europe, despite this work being undertaken on an ad hoc basis. The continued monitoring of chemical pollutants such as POPs has been included in the Coordinated Environmental Monitoring Programme (CEMP) of OSPAR. A ‘Blubber PCB toxicity threshold’ indicator has also been put forward under MSFD Descriptor 8 Contaminants at OSPAR (ICES, 2014a).

4.5 Collision risk and renewable energy developments

There are limited data on the impacts of wet renewable devices on marine mammals. Of these, tidal turbines are the most developed with demonstration projects planned or constructed. Long-term monitoring of harbour porpoises was part of the monitoring programme associated with the installation of a tidal turbine at Strangford Lough, Northern Ireland, and there were no long-term changes in abundance of porpoises which can be attributed to the presence or operation of the turbine (Royal Haskoning, 2011). However as the Strangford Lough device operated a shut down system for when marine mammals were detected, it is difficult to determine the risk of collision. Work is currently underway to develop animal detection systems, e.g. sonar that could be used to automate a shutdown procedure and prevent collisions with moving blades. In addition, the use of ADDs has been suggested as a mitigation tool to scare animals away from the vicinity of turbines. There is the potential for such interactions to increase in the future as more of this technology is deployed.

Drifters equipped with passive acoustic detectors offer a new, rapid and inexpensive tool for investigating porpoise occurrence and behaviour in tidal-stream habitats. This new tool should be considered as part of a comprehensive marine mammal monitoring approach of these energetic environments in the context of marine renewable energy development and other industries.

4.6 Ecological issues

Studies of the ecology of harbour porpoise are required to shed more light on prey availability and potential depletion. The health status and also stomach contents are assessed at post-mortem as part of both the cetacean stranding and bycatch schemes. At the EU level, the ecosystem approach being further developed for fisheries management through the

Common Fisheries Policy (CFP) needs to continue to build in and account for the needs of predators dependant on the same fish stocks being harvested.

4.7 Discussion and conclusions

In order to maintain the favourable conservation status of harbour porpoise, the mitigation and management of human activities is required. The most important anthropogenic pressures experienced by harbour porpoise are bycatch, acoustic disturbance and chemical pollution. There are a number of mitigation and management measures, some proven to be effective, whilst others still need further evidence and / or further research to proof their efficacy. However, although measures might have proven to effectively reduce the impact of a certain pressure, implementation does not per se guarantee the desired effect. Difficulties related to enforcement, lack of compliance, practical issues with the robustness of mitigation devices, changes in industry practices or other factors such as area specific features (e.g. current, depth, bottom substrate) may reduce the efficiency and efficacy of a measure. Therefore, approaches to conservation need to be multifaceted, adaptable, and tailored to particular local or regional conditions, which might result in different approaches for different areas.

Furthermore, a better understanding of the abundance and distribution patterns of harbour porpoises is essential to help determine the magnitude of impacts on populations and assess the effectiveness of mitigation and management at the population scale (UKMMAS, 2010).

5 Looking to the Future

The harbour porpoise is legally protected in UK waters through international, European and national legislation, with conservation status being of paramount importance (Table 5.1). In order to assess the conservation status, not only is a good knowledge of the scale of important anthropogenic pressures required, but also the population context against which the effectiveness of management of those pressures can be judged.

Table 5.1. Summary of current commitments to conservation and monitoring requirements (see glossary for abbreviations).

Population characteristic	**Ecological parameter**	**Links to Legislation/Obligation**
Species distribution	Distribution range and pattern	Habitats Directive and national implementing legislation, CMS and ASCOBANS, WCA, MSFD and national implementing legislation, OSPAR
Population size	Population abundance	Habitats Directive and national implementing legislation, CMS and ASCOBANS, MSFD and national implementing legislation, OSPAR, EU Reg 812/2004
Population condition	Population demographic characteristics (e.g. body size, sex ratio, reproductive rate, age class structure, genetic structure, mortality [natural and anthropogenic])	Habitats Directive and national implementing legislation, WCA, ASCOBANS, OSPAR
	Population health (disease prevalence, pollutant contamination)	ASCOBANS, OSPAR, UK indicator proposed for MSFD
Habitat for the species	Size and quality (local scale protected areas as well as the wider environment)	Habitats Directive and national implementing legislation, WCA, MSFD and national implementing legislation, SEA, EIA

UK already has a conservation plan for porpoises which is further supported by a UK cetacean bycatch strategy. In light of this literature review, consideration will be given to reviewing and updating that plan in the future.

The overarching objective of the UK's current conservation plan is the maintenance of the favourable conservation status (FCS) of harbour porpoise, which is required under the Habitats Directive. This is also an obligation associated with the UK's participation in ASCOBANS and, particularly, the North Sea Harbour Porpoise Conservation Plan.

Assessment of FCS requires consideration of range and population (including trends) and habitat preferences and availability. Although not explicitly noted in the description of FCS, it also requires knowledge of the main pressures and threats to the species that may affect its future prospects. As a predominantly continental shelf species, harbour porpoise are exposed to a wide range of pressures, which can be either ubiquitous or patchy in nature (Table 5.2). The anthropogenic pressures considered to be greatest risk are:

- bycatch in static net fisheries
- acoustic disturbance through impulsive sound (e.g. pile driving, seismic surveys)
- chemical pollution, notably persistent organic pollutants

Other anthropogenic pressures occur but were of lesser importance, because there was relatively little evidence of occurrence, the activity is relatively new or because the impact on the population was perceived to be low. These were:

- Acoustic disturbance through continuous rather than impulsive sounds (e.g. ADDs, shipping)
- Collisions with renewable energy installations
- Collisions with vessels

Variability of food resources leads to increased competition and changes in distribution. Such changes may be the result of an ecological (natural) change, changes of the prey resource through fishing and/or climate effects. Also of relevance but not currently considered to be related to anthropogenic activities are the lethal species interactions with bottlenose dolphins, killer whales and grey seals. In addition, the effects of anthropogenically mediated climate change will need to be taken into account, although it is currently extremely difficult to the disentangle changes that result from short-term regional variability in the prey resource from those associated with long-term anthropogenically driven climate change.

Table 5.2. Key human activities affecting harbour porpoise in UK waters and the relative level of effect. These potential effects are prior to any current mitigation.

Activities*	Possible effects	Current relative level of effect**
Commercial fisheries with bycatch of harbour porpoise (predominantly bottom set nets)	• Mortality through entanglement/bycatch	High
Contaminant discharges, mostly historical, of Persistent Organic Pollutants (POPs), including Polychlorinated Biphenyls (PCBs).	• Health issues (e.g. on reproduction). These chemicals are accumulating through contaminated prey	High
Impulsive anthropogenic sounds: pile driving, acoustic surveys, underwater explosion, military activity, acoustic deterrent devices	• Mortality • Internal injury • Disturbance leading to physical and acoustic behavioural changes (potentially impacting foraging, navigation, breeding, socialising)	Medium to high (particularly in areas of importance)
Continuous anthropogenic sounds: Shipping, drilling, operational wind farms, dredging and disposal, aggregate extraction, echosounders and recreational boating activity	• Disturbance leading to physical and acoustic behavioural changes (potentially impacting foraging, navigation, breeding, socialising)	Low
Commercial fisheries (reduction in prey resources)	• Reduction in food availability • Increased competition from other species	Medium
Collision risk: tidal energy installations	• Mortality • Injury	Unknown

*Some of the activities listed will have a greater effect on the species than others, depending on the degree of overlap and frequency of occurrence of the activity.

**relative to other impacts or potential impacts on harbour porpoise in the UK

6 Glossary

AC	Advisory Council, former Regional Advisory Council (RAC) http://ec.europa.eu/fisheries/partners/advisory-councils/index_en.htm
ADD	Acoustic deterrent device, utilised to prevent seal predation at fish farms and also as a mitigation tool to move animals away from noisy activities that may cause physical damage
AFBINI	Agri-Food and Biosciences Institute of Northern Ireland, http://www.afbini.gov.uk
As	Arsenic
ASCOBANS	Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas http://www.ascobans.org
BDC	OSPAR's Biodiversity Committee http://ospar.org/html_documents/ospar/html/11-04e_tor_committees.pdf#page=4
BFR	Brominated fire retardants (organohalogen compound)
BOEM	Bureau of Ocean Energy Management http://www.boem.gov/
BSH	Bundesamt für Seeschiffart und Hydrographie, German Federal Maritime and Hydrographic Agency, http://www.bsh.de/en/
CBD	Convention on Biological Diversity https://www.cbd.int/
Cd	Cadmium
CEFAS	Centre for Environment, Fisheries and Aquaculture Science, http://www.cefas.defra.gov.uk
CEMP	Coordinated Environmental Monitoring Programme (CEMP) of OSPAR http://www.ospar.org/content/content.asp?menu=00900301400000_000000_000000
CFP	The Common Fisheries Policy http://ec.europa.eu/fisheries/cfp/index_en.htm
CFPO	Cornish Fish Producers Organisation http://www.cfpo.org.uk
CI	Confidence interval (usually 95% CI), i.e. the probability that the confidence range captures this true population parameter given a distribution of samples
CIS	Celtic and Irish Seas Management Unit
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora http://www.cites.org/
CLA	catch limit algorithm
CMP	Conservation and Management Plan
COBAM	OSPAR's Coordination of Biodiversity Assessment and Monitoring expert group http://www.ospar.org/content/content.asp?menu=01500537000000_000000_000000
CODA	Cetacean Offshore Distribution and Abundance in the European Atlantic

	http://biology.st-andrews.ac.uk/coda/
COTES	Control of Trade in Endangered Species (Enforcement) Regulations 1997 http://www.legislation.gov.uk/uksi/2005/1674/contents/made
C-POD	Autonomous, passive, acoustic-monitoring device to detect echolocation clicks of harbour porpoise. Digital successor of the T-POD (see below), capable of detecting broader-band clicks and to collect a wider range of data which allows for species identification. http://www.chelonia.co.uk/cpod_specification.htm
Cr	Chromium
CRoW	Countryside and Rights of Way Act 2000 http://www.legislation.gov.uk/ukpga/2000/37/contents
^{137}Cs	Radioactive isotope of Caesium
Cu	Copper
CSIP	UK Cetacean Strandings Investigation Programme http://ukstrandings.org/
CV	Coefficient of variation; a standardised measure of dispersion of a probability distribution or frequency distribution. It is defined as the ratio of the standard deviation σ to the mean μ.
DCF	Data Collection Framework https://datacollection.jrc.ec.europa.eu
DDD	Dolphin Dissuasive Device, http://www.stm-products.com/en/sub-cat/14/Marine-technology/24/DDD.html
DDT	Dichlorodiphenyltrichloroethane, a pesticide
DECC	Department of Energy & Climate Change https://www.gov.uk/government/organisations/department-of-energy-climate-change
DEPONS	Disturbance Effects on the Harbour Porpoise Population in the North Sea, http://depons.au.dk
EcoQO	Ecological Quality Objective http://www.ospar.org/content/content.asp?menu=00690302200000_000000_000000
EEZ	Exclusive Economic Zone https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/346014/UK_Exclusive_Economic_Zone.pdf
EIA	The Environmental Impact Assessment Directive (EIA) (2014/52/EU amended 2011/92/EU) http://ec.europa.eu/environment/eia/eia-legalcontext.htm
EPS	European Protected Species (listed on Annex IV of the of the Habitats Directive)
EU	European Union
FCS	Favourable Conservation Status
GES	Good Environmental Status http://ec.europa.eu/environment/marine/good-environmental-status/index_en.htm
HBCD	Hexabromocyclododecane (HBCD or HBCDD), a brominated flame retardant.

HD	Habitats Directive - http://ec.europa.eu/environment/nature/legislation/habitatsdirective/index_en.htm
Hg	Mercury
HPTRP	Harbour Porpoise Take Reduction Plan http://www.greateratlantic.fisheries.noaa.gov/protected/porptrp/
HPTRT	Harbour Porpoise Take Reduction Team
HR	Habitat Regulations. These implement the habitats Directive into national law.
ICES	International Council for the Exploration of the Sea http://www.ices.dk/Pages/default.aspx
IFCA	Association of Inshore Fisheries and Conservation Authorities, http://www.association-ifca.org.uk
IFG	Inshore Fisheries Groups www.ifgs.org.uk
IMO	International Maritime Organization, London http://www.imo.org/en/Pages/Default.aspx
Impact	A demonstrated effect on the population or on individual animals
IUCN	International Union for Conservation of Nature http://www.iucn.org/
Jastarnia Plan	Recovery plan for the harbour porpoise in the Baltic http://www.ascobans.org/es/document/recovery-plan-baltic-harbour-porpoises-jastarnia-plan-revision
JNCC	Joint Nature Conservation Committee http://jncc.defra.gov.uk/
^{40}K	Potassium-40 isotope
MESAT	Marine Environment and Sustainability Assessment Tool
MMO	Marine Mammal Observer (for example onboard ships engaged in seismic surveys)
MMPA	Marine Mammal Protection Act, http://www.nmfs.noaa.gov/pr/laws/mmpa/
Mn	Manganese
MNR	Marine Noise Registry
MOD	UK Government Ministry of Defence https://www.gov.uk/government/organisations/ministry-of-defence
MPA	Marine Protected Areas, http://jncc.defra.gov.uk/marineprotectedareas
MSCC	UK Government's Marine Science Co-ordination Committee, https://www.gov.uk/government/groups/marine-science-co-ordination-committee
MSFD	Marine Strategy Framework Directive - http://ec.europa.eu/environment/marine/eu-coast-and-marine-policy/marine-strategy-framework-directive/index_en.htm
MU	Management Unit
NE	Natural England https://www.gov.uk/government/organisations/natural-england

NGO	Non-Governmental Organisation
NRW	Natural Resources Wales https://naturalresources.wales/splash?orig=/
NS	North Sea Management Unit
OC	Organochlorine pesticides are hydrocarbon compounds containing multiple chlorine substitutions
OMR	Offshore Marine Conservation Regulations http://jncc.defra.gov.uk/page-4550
ORJIP	Offshore Renewables Joint Industry Programme http://www.carbontrust.com/orjip
OSPAR	Convention for the protection of the marine environment in the North-East Atlantic (http://www.ospar.org)
PAHs	Polycyclic Aromatic Hydrocarbons
PAL pinger	Porpoise Alarm Pinger, simulating natural porpoise communication sounds
PAM	Passive Acoustic Monitoring
PBR	Potential Biological Removal
PCBs	Polychlorinated Biphenyls
PCoD	Interim Population Consequences of Disturbance framework, http://www.smru.co.uk/pcod/
PETS	Protected, Endangered and Threatened Species (as defined in the Common Fisheries Policy)
Pinger	Acoustic devices specifically aiming at mitigating bycatch
POPs	Persistent Organic Pollutants
Pressures	Activities or issues known to affect harbour porpoise or porpoise habitats currently and/or in the past
PTS	Permanent Threshold Shift
REM	Remote Electronic Monitoring
SAC	Special Areas of Conservation http://jncc.defra.gov.uk/page-23
SCANS	Distribution and Abundance of the harbour porpoise and other small cetaceans in the North Sea and Adjacent waters http://biology.st-andrews.ac.uk/scans2/inner-background.html
SCANS II	Small Cetaceans in the European Atlantic and North Sea http://biology.st-andrews.ac.uk/scans2/
Se	Selenium
Seafish	Seafish Industry Authority http://www.seafish.org
SEA	Strategic Environmental Assessment (2001/42/EC) Directive http://ec.europa.eu/environment/eia/sea-legalcontext.htm
SEL	sound exposure level
SMASS	Scottish Marine Animal Stranding Scheme http://www.strandings.org/
SMRU	Sea Mammal Research Unit http://www.smru.st-and.ac.uk

SNCBs	Statutory Nature Conservation Bodies
SNH	Scottish Natural Heritage http://www.snh.gov.uk
SPL	sound pressure level
TBT	Tributyltin, organotin compound based on tin with hydrocarbon substituents
T-POD	Autonomous, passive acoustic-monitoring device to detect echolocation clicks of harbour porpoises
TTS	temporary threshold shift
UK	Scotland, England, Wales and Northern Ireland
UK BAP	UK Biodiversity Action Plan
UKCS	UK Continental Shelf
UKMMAS	UK Marine Monitoring and Assessment Strategy https://www.gov.uk/government/groups/marine-science-co-ordination-committee
UNCLOS	United Nations Convention on the Law of the Sea http://www.un.org/depts/los/convention_agreements/texts/unclos/closindx.htm
UNEP	United Nations Environment Programme http://www.unep.org/
USA	United States of America
V	Vanadium
WCA	Wildlife and Countryside Act 1981 http://www.legislation.gov.uk/ukpga/1981/69/contents
WGBYC	ICES Working Group on Protected Species Bycatch http://www.ices.dk/community/groups/Pages/WGBYC.aspx
WGMME	ICES Working Group on Marine Mammal Ecology http://www.ices.dk/community/groups/Pages/WGMME.aspx
WS	West Scotland Management Unit
Zn	Zinc

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