Healthy and Biologically Diverse Seas Evidence Group Technical Report Series:

Evaluation and gap analysis of current and potential indicators for Cetaceans

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Preface

The UK Marine Monitoring and Assessment Strategy (UKMMAS) aims to provide coordinated and integrated marine monitoring programmes which support periodic assessments of the state of the UK marine environment. The strategy aims to provide vital data and information necessary to help assess progress towards achieving the UK's vision of clean, healthy, safe, productive and biologically diverse seas. The overarching strategy is supported and delivered by four evidence groups; Clean and Safe Seas Evidence Group (CSSEG); Productive Seas Evidence Group (PSEG); Healthy and Biologically Diverse Seas Evidence Group (HBDSEG) and Ocean Processes Evidence Group (OPEG). These groups are responsible for implementing monitoring and observations programmes to contribute to ecosystem-based assessments of marine environmental status.

As part of the HBDSEG programme of work, a series of reviews of environmental indicators was undertaken for the following marine ecosystem components:

1. Rock and biogenic reef habitats
2. Sediment habitats
3. Deep sea habitats
4. Seabirds and waterbirds
5. Cetaceans
6. Seals
7. Plankton
8. Microbes

The aim of the reviews was to evaluate a wide range of currently available and potential indicators for marine biodiversity monitoring and assessment. This task was undertaken particularly to inform future needs of the EU Marine Strategy Framework Directive (MSFD). The work was carried out by a group of consultants and contributors and was managed by JNCC.

Each review included a process to evaluate indicator effectiveness against a set of specified scientific and economic criteria. This process identified those indicators of activity, pressure, state change/impact and ecosystem structure and function that were considered to be scientifically robust and cost effective. The indicators which met these criteria were then assessed for inclusion within an overall indicator suite that the reviewers considered would collectively provide the best assessment of their ecosystem component's status. Within the review, authors also identified important gaps in indicator availability and suggested areas for future development in order to fill these gaps.

This report covers one of the ecosystem components listed above. It will be considered by HBDSEG, together with the other indicator reviews, in the further development of monitoring and assessment requirements under the MSFD and to meet other UK policy needs. Further steps in the process of identifying suitable indicators will be required to refine currently available indicators. Additional indicators may also need to be developed where significant gaps occur. Furthermore, as the framework within which these indicators will be used develops, there will be increasing focus and effort directed towards identifying those indicators which are able to address specific management objectives. There is no obligation for HBDSEG or UKMMAS to adopt any particular indicators at this stage, based on the content of this or any of the reports in this series.

This report has been through a scientific peer review and sign-off process by JNCC and HBDSEG. At this time it is considered to constitute a comprehensive review of a wide range of currently available and potential indicators for this marine ecosystem component.

Summary

This report provides an evaluation of cetacean indicators (current and potential) with respect to a predefined list of activities and pressures, and also ecosystem structure and function. A summary of national and international policy and legal commitments for monitoring and surveillance is also provided.

There is only a single indicator currently in operation associated with a particular pressure: bycatch. Bycatch is the single most important anthropogenic impact on cetaceans in general and, in particular, small cetaceans. Additionally, a single ecosystem structure and function indicator is also in current operation: bottlenose dolphin abundance and area usage in relation to Special Areas of Conservation.

Because so few pressure related indicators exist for cetaceans, this review also includes consideration of potential indicators for which a body of work already exists. These are predominantly focused on synthetic and non-synthetic pollutants (e.g. metals, organotins, PCBs, brominated flame retardants and radioactivity), but also cover elements of underwater noise, climate change and additional ecosystem structure and function indicators. It should be noted that these potential indicators are speculative and would require validation prior to their implementation.

The sample requirements for this variety of indicators can readily be met by current monitoring and surveillance (e.g through the UK Cetacean Strandings Investigation Programme and the UK Bycatch Monitoring Scheme), although, a commitment to undertake additional analytical work will be required. The most significant gap the UK has in implementing its policy obligations is a systematic surveillance and monitoring scheme. Such a strategy is currently under development by JNCC in line with the UK Marine Monitoring and Assessment Strategy (UKMMAS).

With cetaceans it is often difficult to link cause and effect, and to distinguish natural from human impacts on the species. The implementation and refinement of a strategic monitoring and surveillance programme will be essential to meet the requirements of the EC Habitats Directive and the MSFD. This will need to advocate a coordinated transboundary approach due to the wide ranging and highly mobile nature of cetaceans. A better understanding of the abundance and distribution patterns of cetaceans, including any existing persistent seasonal variations, as well as basic life history parameters for most species (growth rates, age at sexual maturity, reproductive rates and mortality) would help determine the magnitude of any impacts to populations and also potentially aid industry in reducing the risk of impacts.

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1 Introduction

1.1 Aims & objectives of report

Given the multiple policy needs for effective monitoring and assessment of the marine environment, the significant gaps in our current biodiversity monitoring effort and overall high costs of marine monitoring programmes, it is desirable to work towards a single monitoring framework that will meet all national and international policy and legal commitments, while ensuring adequate scientific evidence is available to fully assess the state of the marine environment and any changes over time. The aim of this report is to assess the applicability of existing and proposed cetacean indicators and monitoring programmes, to identify where modifications might be appropriate and to identify significant gaps.

1.2 Work undertaken in report

The following work was undertaken in the development of this report:

- *Document past and current monitoring and associated indicators*
  A description of past and current monitoring is provided and, where appropriate, associated indicators are described.

- *Review of Indicators against pressures*
  There is only a single indicator currently in operation associated with a particular pressure. In addition, a single ecosystem structure and function indicator is also assessed on a regular basis. Both of these are evaluated against predefined scientific and economic criteria.

- *Assessment of which pressures are not adequately addressed by existing indicators*
  Because so few pressure related indicators exist for cetaceans, this review also includes consideration of potential indicators for which a body of work already exists. Each indicator is critically reviewed against the relevant pressure(s) and the impact(s) of the pressure(s) they could be considered for. In addition, several more ecosystem structure and function indicators are also evaluated. It should be noted, however, that these potential indicators are speculative and would require validation prior to their implementation.

1.3 Introduction to the ecosystem component of interest: Cetaceans

Whales, dolphins and porpoises, collectively known as cetaceans, comprise at least eighty six species on a global basis. As more genetic and morphological information emerges it is likely that new species will be identified, including some taxa that are currently categorised as subspecies.

These iconic marine mammals are a diverse group. Baleen whales (collectively known as Mysticeti) filter feed on large volumes of small prey such as krill, plankton or small fish. In contrast, the toothed cetaceans (collectively known as Odontoceti) capture larger prey including fish, squid and, in a few cases, other marine mammals. The terms whale and dolphin are English language terms that broadly reflect body size rather than taxonomy. For example, the killer whale or orca (*Orcinus orca*) and the two pilot whales (*Globicephala* spp.) are actually members of the dolphin family (Delphinidae).

Policy Twenty eight species of cetacean have been recorded in UK waters, although only 11 are commonly observed. This represents a high level of cetacean diversity within the UK's comparatively small section of the North Atlantic, and is due to the considerable diversity in topography, habitats and food resources available in these waters. The greatest diversity of cetacean species is found off the continental shelf, particularly in waters to the north and west of Scotland and in the southwest towards the Bay of Biscay. Many cetaceans in UK waters have a world-wide distribution, e.g. fin (*Balaenoptera physalus*) and killer (*Orcinus orca*) whales. Even those with more restricted global distributions, for example white-beaked (*Lagenorhynchus albirostris*) and white-sided (*L. acutus*) dolphins, are widespread within parts of the North Atlantic.

Cetaceans are very mobile and, as marine animals facing little in the way of geographical barriers, individuals can range over large distances. Some species, such as the humpback whale, are highly migratory, moving between feeding areas in high latitudes and breeding grounds in warmer waters. Other species, e.g. short-beaked common dolphins (*Delphinus delphis*), show more localised seasonal movements, often between inshore and offshore areas. Consequently, for almost all cetacean species, the animals found in UK waters are part of a much larger biological population or populations whose range extends beyond UK waters into the waters of other States and/or the High Seas. Equally, the number of individuals present at any one time may be only a small proportion of those that make use of UK waters at some point.

1.4 Background

Cetaceans are protected by a number of international conventions, including the Convention on the Conservation of European Wildlife and Natural Habitats (commonly known as the Bern Convention), the Convention on Migratory Species (usually referred to as CMS or Bonn Convention), the Convention on Biological Diversity (CBD or Biodiversity Convention), and the Convention for the Protection of the Marine Environment of the Northeast Atlantic (OSPAR). These conventions have been translated into legal requirements through a number of different instruments at both the European and national level.

1.4.1 Bern Convention and the Habitats Directive

On a global basis, the Convention on the Conservation of European Wildlife and Natural Habitats (or the Bern Convention) provides certain marine mammals with a strict protection while, for others, exploitation is allowed so long as their population numbers are not put in danger. For Member States of the European Community, the provisions of the Bern Convention are largely taken up in the 1992 Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (92/43/EEC), otherwise known as the 'Habitats Directive'.

The Habitats Directive requires that *'Member States shall undertake surveillance of the conservation status of the natural habitats and species referred to in Article 2 with particular regard to priority natural habitat types and priority species*.' All species of cetacean are included in Article 2, although none are identified as 'priority species'. All cetacean species are listed in Annex IV, 'animal and plant species of community interest in need of strict protection'. Two species, harbour porpoise *Phocoena phocoena* and [common] bottlenose dolphin *Tursiops truncatus*, are also listed in Annex II, 'animal and plant species of Community interest whose conservation require the designation of Special Areas of Conservation' (SAC) if certain conditions are met.

The UK also has obligations under articles 2 and 12 of the Habitats Directive '*to maintain or restore, at favourable conservation status, natural habitats and species of wild fauna and flora of Community interest* [which includes all cetaceans] and …*Member States shall establish a system to monitor the incidental capture and killing of the animal species listed in Annex IV (a)* [which includes all cetaceans]. *In the light of the information gathered, Member States shall take further research or conservation measures as required to ensure that incidental capture and killing does not have a significant negative impact on the species concerned.*'

Prior to the introduction of the Habitats Directive, the main piece of legislation relating to nature conservation in Great Britain was the Wildlife and Countryside Act 1981, with all Cetacea listed under Schedule 5 (protected wild animals). However, the introduction of the Habitats Directive required supplementary legislation: the Conservation (Natural Habitats, &c.) Regulations 1994 (as amended) and the Countryside and Rights of Way (CRoW) Act 2000 for England and Wales, and the Nature Conservation (Scotland) Act 2004 and The Conservation (Natural Habitats, &c.) Amendment (Scotland) Regulations 2007 in Scotland. In Northern Ireland, the main legislation was initially contained in the Wildlife (Northern Ireland) Order 1985 and then supplemented with the Conservation (Natural Habitats, etc) Regulations 1995 (as amended). More recently, The Environment (Northern Ireland) Order 2002 and the Conservation of Natural Habitats Regulations (Northern Ireland) 2009 were introduced. All these acts only relate to inshore waters (i.e. inside 12 nautical miles). To cover offshore waters, the Offshore Marine Regulations 2007 were developed. Both the inshore and offshore legislation was amended in 2010.

1.4.2 Bonn Convention and ASCOBANS

The Convention on Migratory Species (Bonn convention or CMS) sets out general provisions for the protection and conservation of certain migratory marine mammals, and also operates as a framework for a range of more specific multilateral agreements dealing with cetaceans, e.g. the Agreement on the Conservation of Small Cetaceans in the Baltic and North Seas[1] (ASCOBANS), to which the UK is a Contracting Party.

ASCOBANS includes a concise Conservation and Management Plan (CMP) that outlines the conservation and management measures to be implemented by 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 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*

[1] At the ASCOBANS meeting of the Parties in 2006 it was agreed to change the name to the Agreement on the Conservation of Small Cetaceans in the Baltic, North East Atlantic, Irish and North Seas. The UK is in the process of ratifying this change.

document food composition.' In addition, the conservation and management plan 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.*'

At the national level, these obligations are implemented through the same legislation as the Habitats Directive.

1.4.3 Biodiversity Convention and the UK Biodiversity Action Plan

The Convention on Biological Diversity (CBD or Biodiversity Convention) came into force in 1993, with the UK ratifying it in 1994. In the same year, the government launched the UK Biodiversity Action Plan (UK BAP). At that time, four plans covering cetaceans were implemented; grouped plans for baleen whales, toothed whales and small dolphins and a species plan for harbour porpoise. A review of BAP targets was undertaken in 2004 with the Cetacean BAP Steering Group suggesting that the UK should move towards a single Cetacean BAP, as many of the targets were generic across all cetacean species and very few are pertinent to a single species or group of species. This was, however, not implemented.

In 2007 a BAP species and habitat review was undertaken. Under the review criteria, 20 cetacean species were identified for inclusion. During 2008, priority actions were developed for these species which reflected our international obligations for surveillance and monitoring under the Habitats Directive and other European legislation.

1.4.4 Marine Strategy Framework Directive and Good Environmental Status

The MSFD requires 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*'.

Each Member State is required to develop a marine strategy by 2012 that ensures '*integration of conservation objectives, management measures and monitoring and assessment activities*' with the conservation element focused on protected areas. These marine strategies must include '*an assessment of the current environmental status and the environmental impact of human activities thereon'* and the establishment '*of a series of environmental targets and associated indicators'*. By 2014, establishment and implementation of a monitoring programme for ongoing assessment and regular updating of targets is required.

The MSFD is being transposed into national legislation through the Marine Bill and other equivalent pieces of legislation for the Devolved Administrations. Concurrent with this, consideration is being given to the definition of GES and possible indicators that could be used to measure it. Although cetaceans have not been identified specifically, Annex III of the MSFD identifies pressures such as physical disturbance through underwater noise, contamination by hazardous substances and biological disturbance such as bycatch that need to be included within the national marine strategy.

1.4.5 The Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR)

The Convention for the Protection of the Marine Environment of the Northeast Atlantic 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*' in Annex IV and lays down 'criteria for identifying human activities for the purpose of Annex V' in Appendix 3. In 2004 OSPAR produced a list of threatened and declining species that included the blue and northern right whales and the harbour porpoise. More recently, OSPAR has confirmed that '*the Quality Status Report 2010, a comprehensive evaluation of the state of the environment of the North-East Atlantic, will provide an excellent basis to assist Member States with producing their initial assessment for national marine strategies required by the European Commission for 2012*' under the MSFD.

1.4.6 European Council Regulation 812/2004

Bycatch, the incidental capture of cetaceans during fishing activities is the main form of direct human-caused mortality in UK waters. The monitoring of cetacean bycatch is specifically required for certain fisheries under fishery regulation EC 812/2004 of 24 April 2004, which also amends regulation (EC) No. 88/98. Prior to this, however, the UK Small Cetacean Bycatch Response Strategy was launched in March 2003 and set out the Government's thinking on how to tackle the problem of bycatch in certain fisheries in UK waters.

The measures in Regulation 812/2004 pertinent to the UK include:

- the coordinated monitoring of cetacean bycatch through compulsory onboard observers for given fisheries; and
- the mandatory use of acoustic deterrent devices ('pingers') in certain fisheries

The two main species affected by fishing in UK waters are the harbour porpoise (*Phocoena phocoena*) and the short-beaked common dolphin (*Delphius delphis*).

1.4.7 Environmental Liability Directive 2004/35/EC

This Directive seeks '*to establish a framework of environmental liability based on the 'polluter-pays' principle, to prevent and remedy environmental damage*', including the loss of biodiversity. Embedded within this is reference to the maintenance of favorable conservation status for species of European importance, which includes all species of cetacean.

This Directive was translated into national law through the Environmental Damage (Prevention and Remediation) Regulations 2009 and came into force on 1 March 2009. There are separate Regulations for Northern Ireland, Scotland and Wales which will also come into force during 2009. With these Regulations the emphasis is on proactively putting in place appropriate pollution prevention measures so that imminent threats and damage to habitats and species do not arise.

1.4.8 OSPAR/UKMMAS assessment framework background

The assessment framework developed by JNCC was first presented to the OSPAR Convention's Biodiversity Committee in February 2007 and has since gained wide support across OSPAR as a tool to guide the development of a strategic approach to biodiversity monitoring. It has been particularly welcomed for its potential benefit in meeting the needs of the Marine Strategy Framework Directive (MSFD).

The framework takes the form of a matrix which relates ecosystem components (e.g. deep-seabed habitats) to the main pressures acting upon them (e.g. physical disturbance to the seabed). The ecosystem components have been correlated with components used by OSPAR and the MSFD. The columns of the matrix are a generic set of pressures on the marine environment, which are based on those used by OSPAR, MSFD and the Water Framework Directive (WFD). A 3-point scale of impact (low, moderate, high) reflects the degree of impact each pressure has on an ecosystem component. Each cell of the matrix has additionally been populated with a set of known indicators[2], derived from statutory and non-statutory sources, which are used to monitor and assess the state of that ecosystem component. The assessment matrix helps to highlight priorities for indicator development and monitoring programmes, based on the likely degree of each impact on the ecosystem component in question.

Since 2007 this approach has also been introduced to the UK's Marine Monitoring and Assessment Strategy (UKMMAS) and is being further developed by the Healthy and Biologically Diverse Seas Evidence Group (HBDSEG). The intention has been to have parallel development at UK and OSPAR levels which will help ensure similar biodiversity strategies are developed at national and international levels. It is also envisaged that the development process will benefit from wide input across OSPAR Contracting Parties.

The overall goal of the UKMMAS is to implement a single monitoring framework that meets all national and international multiple policy commitments (UKMMAS, 2007). This will identify if there are any significant gaps in the current monitoring effort and aim to minimise costs by consolidating monitoring programmes. To help meet this goal, the assessment matrix has been developed with HBDSEG to provide a useful framework that analyses components of an ecosystem and their relationships to anthropogenic pressures. The framework aims to encompass three key issues: an assessment of the state of the ecosystem and how it is changing over space and time, an assessment of the anthropogenic pressures on the ecosystem and how they are changing over space and time, and an assessment of the management and regulatory mechanisms established to deal with the impacts.

The further development of the assessment framework has been divided into five shorter work packages: 1) assessment of pressures, 2) mapping existing indicators to the framework, 3) review of indicators and identification of gaps, 4) modifying or developing indicators and 5) review of current monitoring programmes. The following work will contribute to work package 3 and will critically review indicators, identify gaps and recommend an overall suite of the most effective indicators for the ecosystem component in question.

[2] Note: cells of the matrix where impacts have been identified currently contain a number of species and habitats on protected lists (OSPAR, Habitats Directive), which could potentially be used as indicators of the wider status of the ecosystem component which they are listed against. Should this be appropriate, certain aspect of the species or habitat (e its range, extent or condition) would need to be identified to monitor/assess.

1.5 Definitions used within the report and analysis

Definitions of activity, pressure, state change/ecological impact and ecosystem structure and function are used within this report as follows (adapted from the 2008 CP2 methodology[3]):

***Activity* -** Human social or economic actions or endeavours that may have an effect on the marine environment e.g. fishing, energy production.

***Pressure* -** the mechanism (physical, chemical or biological) through which an activity has an effect on any part of the ecosystem, e.g. physical disturbance to the seabed.

***State change/ecological impact* -** physical, chemical or biological condition change at any level of organisation within the system. This change may be due to natural variability or occurs as a consequence of a human pressure, e.g. benthic invertebrate mortality.

***Ecosystem structure and function* -** ecosystem level aspects of the marine environment (i.e. structural properties, functional processes or functional surrogate aspects) which are measured to detect change at higher levels of organisation within the system (i.e. changes at ecosystem scales), that is not attributable to any pressure or impact from human activity, e.g. natural changes in species' population sizes. Please see Annex 4.

***Defined pressures list* -** The standard list of pressures against which indicators for this ecosystem component are reviewed is taken from the generic pressures list in the latest version (v11) of the UKMMAS / OSPAR assessment framework. Those pressures which are relevant to the ecosystem component (i.e. those that cause any impact on it) are used within the critical indicators review, gap analysis and this report.

[3] Robinson, L.A., Rogers, S., & Frid, C.L.J. 2008. *A marine assessment and monitoring framework for application by UKMMAS and OSPAR – Assessment of Pressures and impacts* (Contract No: C-08-0007-0027 for the Joint Nature Conservation Committee). University of Liverpool, Liverpool and Centre for the Environment, Fisheries and Aquaculture Science, Lowestoft.

2 Methods & data sources

In order to complete this evaluation report, the following was undertaken:

- **Document past and current monitoring and associated indicators**

  A description of past and present monitoring is provided and associated indicators (both current and potential) included. This was undertaken using a combination of literature reviews and interviews.

- **Review of Indicators against pressures**

  There is currently only one programme in place that monitors a cetacean specific indicator that relates to a particular pressure: the UK Bycatch Monitoring Scheme. This scheme was evaluated in collaboration with Simon Northridge (SMRU), the project manager.

  The majority of monitoring work ongoing in the UK tends to focus on distribution and abundance estimates and is, thus, mainly related to ecosystem quality or state. As part of this the current monitoring of [common] bottlenose dolphin (*Tursiops truncatus*) feature of SACs is reviewed in collaboration with Paul Thompson (Aberdeen University) in section 6.3.

- **Assessment of which pressures are not adequately addressed by existing indicators**

  Because very few pressure related indicators exist for cetaceans, this report also includes consideration of potential indicators for which there is an existing body or time series of data (either continuous or interrupted) that can be used to evaluate the indicator. It should be noted that these potential indicators are speculative and would require validation prior to their implementation.

  The UK Cetacean Stranding Investigation Programme (CSIP) monitors strandings and performs post mortems to ascertain cause of death where appropriate which can be linked to particular anthropogenic pressures. The CSIP yields much valuable data that is used as the basis for a number of other potential indicators including pollutants and biological attributes in particular cetacean species, which are reviewed in section 6: Gap Analysis. These were reviewed in collaboration with the relevant researchers or project manager (Sinead Murphy [SMRU], Rob Deaville and Paul Jepson [IoZ, London], Robin Law [CEFAS] and Colin McLeod [Aberdeen University]).

3 Review of the existing indicators and critical evaluation

3.1 Current indicators summary

3.1.1 UK Cetacean Bycatch Monitoring Scheme

As a result of continued concern regarding cetacean bycatch, in 2003, the UK published its Cetacean Bycatch Response Strategy. Additionally, the UK, along with other Member States of the EU, is obliged under Council Regulation 812/2004 to undertake monitoring of specified fisheries to monitor cetacean bycatch levels. The Habitats Directive also requires Member States to undertake monitoring to determine the levels of incidental mortality. Since 2005, the Sea Mammal Research Unit (SMRU) has been contracted by the Defra and the Scottish Government to meet these monitoring obligations and to make estimates of the numbers of cetaceans that are killed directly as a result of fishing activity.

Since EC Regulation 812/2004 came into force, for four years running (2005-2008 inclusive) there have been no observations of cetacean bycatch in any of the fleet segments listed for compulsory monitoring (Northridge *et al* 2007; SMRU, 2008a, 2009). This is not to suggest that UK fisheries do not have a bycatch of any cetaceans, but rather that the segments being statutorily observed under the regulation have very low bycatch rates and are thus unlikely to be at a level that are a conservation threat (SMRU, 2008a, 2009).

Additional monitoring of pelagic trawl and static net fisheries is also undertaken for the purposes of Article 12 under the Habitats Directive and ‘Scientific Studies’ under Regulation 812/2004. Between 2005 and 2006, approximately 460-730 harbour porpoises and 410-610 short-beaked common dolphins were bycaught in the Celtic and Irish Sea areas (ICES sub area VII) (Northridge *et al* 2007) whilst in 2007 the estimate was 206-1699 harbour porpoises and 29-440 short-beaked common dolphins (SMRU, 2008a). For 2008, the bycatch estimates of harbour porpoise in gillnet and tanglenet fisheries in the Irish and Celtic Sea areas was 498-1409 and for common dolphins 279-1019 (SMRU, 2009). The bycatch levels recorded are below 1.7% of the best population estimate and unlikely to represent a major conservation threat to either species. However, there are bycatches in many other European fisheries affecting the same biological populations, and it is not yet possible to determine the cumulative significance of the various estimates available at this time.

This scheme also provides the data to meet the UK’s obligations under OSPAR for the EcoQO for harbour porpoise bycatch in the North Sea. The scheme therefore provides the basis for the most important cetacean indicator related to a specific pressure: the removal of non-target species.

3.1.2 OSPAR EcoQO for harbour porpoise (*Phocoena phocoena*) bycatch in the North Sea

At the fifth North Sea Conference in 2002 it was agreed 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*”. OSPAR 2006 adopted the agreement on the application of the EcoQO system in the North Sea which required in 2008, the first assessment of the application of the EcoQO system and in 2009 an improved elevation of the results of the EcoQO system as a contribution to the Quality Status Report (QSR) 2010.

In 2008, the ICES Working Group on Marine Mammal Ecology tried to evaluate progress to date with this EcoQO (ICES, 2008b). 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 EC Regulation 812/2004. Consequently it is not currently possible to evaluate whether or not the EcoQO has been met. Until such observer programmes are implemented it will not be possible to assess overall progress with this EcoQO within the UK or the North Sea as a whole. Consequently, the EcoQO is not considered further in this report, although an indicator for bycatch is.

3.1.3 UK Cetacean Stranding Investigation Programme (CSIP)

As a signatory to ASCOBANS, the UK has an obligation to investigate the strandings of cetaceans. Additionally, this work contributes in part to the monitoring required under Article 12 of the Habitats Directive. Strandings are recorded and reported through the UK CSIP, which is coordinated by the Institute of Zoology (London) with the Joint Nature Conservation Committee (JNCC) providing day-to-day management on behalf of Defra and the Devolved Administrations who fund the project.

There are approximately 750 strandings reported annually, with the two most common species, harbour porpoise and short-beaked common dolphin, accounting for approximately 80% of all strandings; although the proportions vary regionally with a much greater range of species stranding in Scotland and Northern Ireland than elsewhere in the UK (Berrow, 2008; Deaville & Jepson, 2008; Pinn, 2008). From the strandings occurring, approximately 100 post mortem investigations are undertaken annually to enable determination of cause of death.

The scheme yields much valuable information on basic biology and pathology of UK cetacean species and has contributed significantly to our understanding of pollutant levels and their impact on cetaceans. The scheme therefore provides the basis of a number of separate indicators relating to the health status of cetaceans, levels of various contaminants (synthetic, non-synthetic and radioactivity) and also reproductive biology that are reviewed in Section 6: Gap Analysis.

3.1.4 Inshore monitoring

At the individual country level, surveying and monitoring has been undertaken through funding from the Devolved Administrations or Countryside Agencies. In Welsh waters for various species including bottlenose dolphin (particularly with respect to the SAC), harbour porpoise, Risso’s dolphin and baleen whales. Through collaboration with Irish colleagues, a data collection exercise has resulted in a Welsh Marine Mammal Atlas which, despite its name, covers the entire Irish Sea. This provides an assessment of the distribution data from effort-related sightings available between 1990 and 2007, and assesses trends for harbour porpoise, [common] bottlenose dolphin, short-beaked common dolphin, Risso’s dolphin and minke whale.

In Scotland, a variety of projects are ongoing focusing on abundance, stock structure and diet of killer whales, distribution and habitat preferences of white beaked dolphins, and the distribution, abundance and population structure of bottlenose dolphins (particularly with respect to the SAC). In England, much of the work is focused on the distribution and abundance of bottlenose dolphins and, to a small extent, common dolphins and harbour porpoises in the south west.

In November 2008, the Northern Ireland Environment Agency (NIEA) began implementation of a systematic cetacean monitoring programme. Monthly shore-based effort watches are now conducted from 12 key sites using a standard monitoring methodology. This will provide data from inshore waters to address local management issues and the potential identification of SACs in future years. As this monitoring programme develops, boat-based visual surveys and acoustic monitoring of key sites will also be included.

This country-level monitoring provides the basis for a variety of ecosystem quality indicators. In several reviews in recent years, the abundance of harbour porpoises (Langenberg & Troost, 2008) and bottlenose dolphins (Feral *et al* 2003) have been proposed as a potential indicators. Currently no regular annual monitoring scheme is in place for harbour porpoises. Consequently, development of this indicator is considered in section 6: Gap Analysis. In contrast, the inshore bottlenose dolphins' populations of the SACs in Wales and Scotland are studied on an annual basis. They are therefore used as an example of an ecosystem structure and function indicator in this report.

3.1.5 Fixed-route visual surveys

The Atlantic Research Coalition (ARC) was established in 2001 and comprises eight organisations which regularly conduct fixed-route transect surveys on 15-20 commercial ferry routes throughout north-west European waters using effort-related and standardised scientific recording methods. The majority of these organisations are non-governmental and rely on trained volunteers to collect the data, the exception being Aberdeen University.

Although only established in 2001, data has actually been collated on many of the routes since the mid 1990s by the individual organisations involved. For example, Organisation Cetacea (ORCA) has been conducting visual surveys from the ferries from Portsmouth and Plymouth to northern Spain since 1996. As part of ARC, Aberdeen University have been conducting surveys using line-transect methods on six ferry routes in western Scotland usually during the summer (May - September). This work aims to study fine scale spatial and temporal distribution of cetacean species.

This body of work provides the basis for a climate change related indicator: the ratio of white beaked dolphins (a cold water species) to common dolphins (a warmer water species).

3.1.6 Opportunistic sightings data

A national sightings database has been run by the UK Mammal Society Cetacean Group and later the Sea Watch Foundation since 1973 (also including some earlier records). This includes opportunistic sightings at sea by a large number of mainly volunteer observers, together with some effort-related data. Currently around 5000 records are received each year.

Although not wholly quantitative, this large data set is useful for showing distribution and range, particularly in coastal areas. Coverage varies considerably between areas and times of year, so the data is limited for showing relative abundance within the range. It does give a general indication of relative abundance of different species and, for uncommon and rarer species, opportunistic sightings are always likely to comprise a significant part of the information available. As a long running scheme, it does provide some indication of long term trends, although there are biases. In more recent years, Sea Watch Foundation have also been carrying out dedicated ship-based surveys in certain regions of the UK.

3.2 Evaluation of the effectiveness of indicators against standard scientific and economic criteria

3.2.1 Criteria used to evaluate indicators.

In order to achieve a consistent critical appraisal of all indicators, the indicators for this ecosystem component have been reviewed and scored against the following set of criteria. These criteria have been built into the online indicators database application and the data has been stored electronically.

A. Scientific criteria:

The criteria to assess the scientific 'effectiveness' of indicators are based on the ICES EcoQO criteria for 'good' indicators. The scoring system is based on that employed within the Netherlands assessment of indicators for GES (2008)[4]. A confidence score of 3 – High, 2 – Medium, 1 – Low is assigned for each question. A comment is given on the reasons for any low confidence ratings in the comment box provided within the database. All efforts have been made to seek the necessary information to answer criteria questions to a confidence level of medium or high.

INDICATOR EVALUATION:

1. Sensitivity: Does the indicator allow detection of any type of change against background variation or noise:

Score	3	2	1	Confidence
Options	Usually	Occasionally	Rarely	

2. Accuracy: Is the indicator measured with a low error rate:

Score	3	2	1	Confidence
Options	Usually	Occasionally	Rarely	

If the indicator scores 1 or 2 for question 1 or 2, conclude that it is ineffective and do not continue with the evaluation –the indicator will still be stored within the database as considered but will be flagged as 'insensitive, no further evaluation required'

3. Specificity: Does the indicator respond primarily to a particular human pressure, with low responsiveness to other causes of change:

Score	3	2	1	Confidence
Options	Usually	Occasionally	Rarely	

[4] Langenberg. V.T. & Troost T.A. (2008). Overview of indicators for Good Environmental Status, National evaluation of the Netherlands.

4. Performance:

For questions 4a-f, if a score of 1 is given, please consider if the indicator is of real use. Please justify (within the report) continuing if a score of 1 is given.

The following criteria are arranged with descending importance:

i. Simplicity: Is the indicator easily measured?

Score	3	2	1	Confidence
Options	Usually	Occasionally	Rarely	

ii. Responsiveness: Is the indicator able to act as an early warning signal?

Score	3	2	1	Confidence
Options	Usually	Occasionally	Rarely	

iii. Spatial applicability: Is the indicator measurable over a large proportion of the geographical to which the indicator metric it to apply to, e.g. if the indicator is used at a UK level, is it possible to measure the required parameter(s) across this entire range or is it localised to one small scale area?

Score	3	2	1	Confidence
Options	Usually	Occasionally	Rarely	

iv. Management link: Is the indicator tightly linked to an activity which can be managed to reduce its negative effects on the indicator, i.e. are the quantitative trends in cause and effect of change well known?

Score	3	2	1	Confidence
Options	Usually	Occasionally	Rarely	

v. Validity: Is the indicator based on an existing body or time series of data (either continuous or interrupted) to allow a realistic setting of objectives?

Score	3	2	1	Confidence
Options	Usually	Occasionally	Rarely	

v. Relatively easy to understand by non-scientists and those who will decide on their use:

Score	3	2	1	Confidence
Options	Usually	Occasionally	Rarely	

***Thresholds for scientifically poor, moderate and good indicators*:**

Combine indicator evaluation scores for:

1. Sensitivity
2. Accuracy
3. Specificity
4. Performance

Evaluation Score	Indicator 'Effectiveness' Category
22-27	Good
16-21	Moderate
9-15 OR not all questions completed due to expert judgement not to continue	Poor

Further economic evaluation required – see section B below (applies to Good and Moderate)

B. Economic criteria:

Having identified the most scientifically robust indicators using the above stated criteria, a further economic evaluation of those most effective indicators (i.e. those falling in the good or moderate categories) is carried out using the criteria stated below.

i. Platform requirements

Score	4	3	2	1
Options	None, e.g. intertidal sampling	Limited, e.g. coastal vessel	Moderate, e.g. Ocean going vessel or light aircraft	Large, e.g. satellite or several ocean going vessels

ii. Equipment requirements for sample collection

Score	4	3	2	1
Options	Simple equipment requirements, e.g. counting number of organisms	Limited equipment requirements, e.g. using quadrats on the shoreline	Moderate equipment requirements, e.g. measuring physiological parameters	Highly complex method, e.g. technical equipment operation

iii. Amount of staff time required to plan collection of a single sample

Score	4	3	2	1
Options	Hours	Days	Weeks	Months

iv. Amount of staff time required to collect a single sample

Score	4	3	2	1
Options	Hours	Days	Weeks	Months

v. Amount of staff time required to process a single sample

Score	**4**	**3**	**2**	**1**
Options	Hours	Days	Weeks	Months

vi. Amount of staff time required to analyse & interpret a single sample

Score	**4**	**3**	**2**	**1**
Options	Hours	Days	Weeks	Months

vii. Amount of staff time required to QA / QC data from a single sample

Score	**4**	**3**	**2**	**1**
Options	Hours	Days	Weeks	Months

***Thresholds for economically poor, moderate and good indicators*:**

Evaluation Score	**Indicator 'Effectiveness' Category**
21-28	Good
14-20	Moderate
7-13	Poor

Those indicators which fall within the 'Good' or 'Moderate' economic category will then be tagged within the summary database as 'Recommended' indicators. Indicators can also be 'recommended' via expert judgement even if the evaluation of the indicator does not score well enough to be automatically recommended. This judgement will be justified within the report text.

3.2.2 Pressures list relevant to the ecosystem component

The key anthropogenic pressure relevant to cetaceans is the removal of non-target species, otherwise referred to as bycatch. This is a global problem and not just related to UK waters. This the only pressure for which a cetacean indicator is currently in operation.

Other relevant pressures include:

- pollution by hazardous substances (heavy metals, synthetic pollutants such as organochlorines including PCBs, organotins and radionuclides),
- potential environmental changes associated with climate change (predominantly through water temperature changes but also indirectly through prey distribution and abundance, and susceptibility to disease),
- underwater noise
- habitat damage or loss (predominantly through prey species)

Additional pressures, although much less significant are:

- death by injury or collision, and
- litter.

Development of speculative indicators for these pressures, where sufficient data exists, is considered in section 6: Gap Analysis. However, validation of their efficacy will be required prior to their implementation.

3.2.3 Additional information on the critical analysis of indicators

i. Indicator for the removal of non-target species

Bycatch, the incidental capture of cetaceans during fishing activities is the main form of direct human-caused mortality in UK waters. The monitoring of cetacean bycatch is specifically required by a variety of legislation and conservation obligations, but is driven by the needs of EC Regulation 812/2004 and the Habitats Directive. Bycatch predominantly effects two species in the UK: harbour porpoise (*Phocoena phocoena*) and short-beaked common dolphin (*Delphinus delphis*). [Common] bottlenose dolphins (*Tursiops truncatus*) have also been recorded but at insufficient levels to enable accurate assessments of bycatch to be made.

Scientific evaluation of bycatch indicator.

Sensitivity: **Does the indicator allow detection of any type of change against background variation or noise?**

As fishing effort changes so there is a direct link with the level of bycatch. Estimates of bycatch levels can be made for the majority of UK fishing fleet segments.

Accuracy: **Is the indicator measured with a low error rate?**

EC Regulation 812/2004 requires that sampling should be geared to achieve a bycatch estimate with a coefficient of variation (CV) of less than 0.3. This can only be achieved if there is one or more observed bycatch event (see Northridge and Thomas 2003 for an alternative approach to setting targets for sampling levels). In the absence of any observed bycatch, and assuming continued monitoring is needed, the UK uses the ‘pilot study’ levels of 10% and 5% for the various fishery segments as the most appropriate approach to setting monitoring requirement levels.

Specificity: **Does the indicator respond primarily to a particular human pressure, with low responsiveness to other causes of change?**

Fishing is the only activity through which this pressure is caused.

Performance:

i. Simplicity: Is the indicator easily measured?

It requires the presence of an independent observer on fisheries vessels. They examine hauls as they are brought aboard.

ii. Responsiveness: Is the indicator able to act as an early warning signal?

Assessments are made on an annual basis. Combined with data obtained through the UK CSIP, this is a sufficient timescale to act as an early warning system.

iii. Spatial applicability: Is the indicator measurable over a large proportion of the geographical to which the indicator metric it to apply to, e.g. if the indicator is used at a UK level, is it possible to measure the required parameter(s) across this entire range or is it localised to one small scale area?

Monitoring is undertaken at the UK fleet level, with assessment of bycatch made by fleet sector, ICES area and/or species bycaught.

iv. Management link: Is the indicator tightly linked to an activity which can be managed to reduce its negative effects on the indicator i.e. are the quantitative trends in cause and effect of change well known?

Levels of bycatch are tightly linked to levels of fishing effort. As such there is a tight management link. Except for fishing in the 0-6 nautical mile limit and for UK vessels operating in 6-12nm, competency for fisheries management lies with Europe and the Common Fisheries Policy rather than the UK government or Devolved Administrations.

v. Validity: Is the indicator based on an existing body or time series of data (either continuous or interrupted) to allow a realistic setting of objectives?

Ad-hoc bycatch monitoring has been ongoing for some considerable time. The monitoring of bycatch in UK waters was initiated in 1995 as a research project and transformed into a formal monitoring scheme in 2005. This bycatch data is, however, relatively meaningless without accurate abundance data (e.g. SCANS in1994 and SCANS II in 2005).

vi. Relatively easy to understand by non-scientists and those who will decide on their use?

There is a general public concern, including substantial NGO work and media attention regarding the impact of fishing on these charismatic species.

Economic Evaluation of bycatch indicator:

Platform requirements:

There is no requirement to charter vessels for this work. It is access to commercial fishing vessels that is required, i.e. there is a need to pay of observer time whilst onboard, but not the vessel.

Equipment requirements for sample collection:

Counts of cetacean bycatch, including species identification.

Amount of staff time required to plan collection of a single sample:

The bycatch monitoring scheme plans on an annual basis to enable coverage of the required fleet segments and areas. A single sample is considered to equate to a single haul. The annual planning takes approximately 10 days, which covers approximately 1,500 hauls per year.

Amount of staff time required to collect a single sample:

A single sample is considered to equate to a single haul.

Amount of staff time required to process a single sample:

It is usually immediately obvious when a cetacean has been bycaught.

Amount of staff time required to analyse & interpret a single sample:

Analysis and interpretation of a single sample can be done in seconds. However, analysis and interpretation is usually undertaken by species bycaught, fleet segment and/or sea area rather than by haul.

Amount of staff time required to QA / QC data from a single sample:

This is done during data entry, which is part of processing.

4 Gap analysis - Review of indicators against relevant pressures and important aspects of ecosystem structure and function

4.1 Review of indicators against pressures and identification of gaps

Please refer to the associated spreadsheet 'Annex 1 CETACEANS pressures.xls'. This gap matrix was produced as a tool to aid authors in identifying significant gaps in current or potential indicators, i.e. where relevant and important pressures on the ecosystem component do not have any suitable indicators associated with them. All recommended indicators have been prefixed with [R] and the cells containing them are coloured green. However, it should be noted that many of the indicators identified are speculative and would require validation prior to their implementation.

It should also be noted that if a single indicator is associated with more than one pressure within the pressures gap matrix, it may mean that this indicator responds to a range of pressures or the synergistic effects of a combination of pressures. Such an indicator would not necessarily be able to detect change which can be attributed to each individual pressure.

Pressures not currently addressed by indicators include:

- pollution by hazardous substances (heavy metals, organotins, organochlorines including PCBs, brominated flame-retardants, and radionuclides);
- potential environmental changes associated with climate change (predominantly through water temperature changes but also indirectly through prey distribution and abundance, and susceptibility to disease);
- litter;
- underwater noise;
- death by injury or collision;
- and habitat damage or loss (predominantly through prey species).

Some of these pressures, although effecting cetaceans, do not occur with sufficient frequency to enable the development of an indicator. For example, despite UK waters containing some of the busiest shipping routes in the world, e.g. the English Channel and the North Sea, relatively few deaths are recorded as a result of ship, small vessel or propeller strikes. Such causes of death have only been recorded in harbour porpoises, short-beaked common dolphins and fin whales.

Since 2000, over 1100 post mortems have been conducted on these three species and of these only 11 have been attributed to ship, small vessel or propeller strikes (Jepson, 2006; Deaville & Jepson, 2007, 2008, 2009). With the increasing recreational use of our waters including activities such as dolphin watching, and the continuing development of offshore industries, impact from this pressure has the potential to increase. At this time, however, it is felt best to continue to monitor such interactions through the CSIP, as is currently undertaken. Reinforcing this approach, in September 2009 at the Meeting of the Parties, ASCOBANS agreed to a new reporting format that specifically records vessel collisions. As part of our annual report to ASCOBANS we will need to detail such occurrences, beginning in 2010. This provides with an annual assessment of such interactions and should they increase significantly then an indicator could potentially be developed.

Plastic litter has been identified as an increasing anthropogenic pressure in the marine environment (Moore, 2008). Although discarded fishing gear can be an issue, the ingestion of plastics is not considered to be a significant pressure on cetaceans at this time in UK waters. Where plastics have been identified in the stomachs of stranded cetaceans, there is little to no evidence of any pathological effect (R. Deaville pers. comm.). Therefore the development of such an indicator is inappropriate at this time although ad hoc investigation will continue through post mortems.

Habitat damage and/or loss, particularly through availability of prey, is another pressure for which insufficient data exists to enable the development of an indicator. Cetacean habitats (e.g. feeding and breeding areas) vary temporally and spatially and are influenced by natural and anthropogenic factors (e.g. Ingram *et al* 2007; MacLeod *et al* 2007; Weir *et al* 2007; Maribini *et al* 2009). It is often difficult to determine what features characterise cetacean habitats and in quantifying their extent. Consequently, habitat use is highly correlated with prey density rather than any particular habitat type.

For example, examination of porpoise diets in the north-east Atlantic suggests that there has been a long term shift from feeding on clupeid fish (mainly herring *Clupea harengus*) to feeding on sandeels and gadoid fish, possibly related to the decline in herring stocks since the mid-1960s (Santos and Pierce 2003; Pierce *et al* 2007). Although based on a relatively small sample size, MacLeod *et al* (2007a) suggested that in recent years, for north-east Scotland, a concurrent increase in the proportion of stranded porpoises for which the cause of death was due to starvation and the decline in proportion of sandeels in the diet were linked. However, there has been some debate about the biological significance of this work (Thompson *et al* 2007) and the original authors acknowledge that the phenomenon is limited to spring and that considerably more research covering a larger area is needed before such links can be ascertained and generalised (McLeod *et al* 2007b).

5 Indicators that could potentially address these gaps

5.1 Non-synthetic compound contamination

Metals of biological concern can be divided into those normally transported as mobile cations in aqueous solutions (e.g. sodium, potassium and calcium), transitional metals essential at low concentrations but toxic at high levels (e.g. iron and copper) and metalloids which are generally not required for metabolic activity (e.g. cadmium, mercury, lead, tin, selenium and arsenic) (Clark *et al* 1999). Marine mammals generally have high levels of mercury and cadmium in their tissues compared to other marine groups, predominantly as a result of their trophic status (Das *et al* 2003). For some metals, however, other factors may also be important, e.g. assimilation and excretion rates, body size and age (Das *et al* 2003).

5.1.1 Indicator for non-synthetic compound contamination: heavy metals and organotins

Research predominantly on UK-stranded harbour porpoises between 1999 and 2005 has shown that liver concentrations of trace metals tested (Hg, Cd, Pb, Se, Ni, As, Cu, Ag) are stable or declining (see Jepson, 2005). Levels of organotins (MBT, DBT, TBT) are also very low since these compounds have been effectively phased-out from use as antifouling agents in ships. Cetaceans have also evolved metal detoxification mechanisms to tolerate the bioaccumulation of metals in the marine environment from natural sources (unlike PCBs). One study did show elevated liver Hg concentrations and elevated He:Se ratios in UK-stranded harbour porpoises that died of infectious disease (compared to porpoises that died of physical trauma) (Bennett *et al* 2001), but this may be redistribution of organic Hg from muscle to liver caused by muscle breakdown associated with loss of nutritional status (Jepson, 2005). Samples have been collected as part of the UK CSIP since 1990, although not all have been analysed. Recently, as part of the 2008 short-beaked common dolphin mass stranding investigation, the mean hepatic concentrations of all butyltins and Cr, Ni, Cu, Zn, As, Se, Ag, Cd, Hg and Pb for all adults were compared to samples taken from UK stranded from 1990-1992 and found to be lower (Jepson & Deaville, 2009).

Unlike PCBs (Jepson, 2005; Jepson *et al* 2005; Hall *et al* 2006), there is no compelling evidence for toxic effects from exposure to metals or organotins in UK-stranded cetaceans. Most trace metals and organotins are stable or declining in the marine environment, if new sources were to enter the marine environment, exposure would readily be detected through this proposed indicator.

Scientific Evaluation of heavy metals and organotins indicator:

Sensitivity: Does the indicator allow detection of any type of change against background variation or noise?

Standard analytical methods for metals and organotins concentrations in tissues are both highly sensitive and internationally standardised for comparison with tissue levels in other regions (Waldock *et al* 1989; Jones & Laslett, 1994).

***Accuracy:* Is the indicator measured with a low error rate?**

Analytical methods for metals and organotins concentrations in tissues are both highly sensitive and internationally standardised for comparison with tissue levels in other regions.

***Specificity:* Does the indicator respond primarily to a particular human pressure, with low responsiveness to other causes of change?**

Analytical methods for metals and organotins concentrations in tissues are highly specific. Metals are present in the environment as a result of both natural sources and man's activities. Butyltins arose primarily as a result of the use of tributyltin in antifouling paints applied to vessels, although there are also industrial applications using dibutyltin.

Performance:

i. Simplicity: Is the indicator easily measured?

Trace metals and organotin concentrations in tissues are easily and accurately measured from blubber samples from dead stranded animals. Biopsies can also be from live animals if appropriate sampling and analytical methodologies are in place.

ii. Responsiveness: Is the indicator able to act as an early warning signal?

Most trace metals and organotins are stable or declining in the marine environment, so significant newer inputs into the marine environment are unlikely to occur in European waters. But, if new sources were to enter the marine environment, exposure would readily be detected using existing analytical methodologies.

iii. Spatial applicability: Is the indicator measurable over a large proportion of the geographical to which the indicator metric it to apply to, e.g. if the indicator is used at a UK level, is it possible to measure the required parameter(s) across this entire range or is it localised to one small scale area?

Trace metal and organotin exposure data derived from by-caught, biopsied or stranded animals can show geographical variation in exposure (Jepson, 2005).

iv. Management link: Is the indicator tightly linked to an activity which can be managed to reduce its negative effects on the indicator, i.e. are the quantitative trends in cause and effect of change well known?

Management interventions to reduce exposure to organotins at both the national and international level have already been relatively effective: the levels recorded in cetaceans are declining. Reductions in anthropogenic inputs into the marine environment have also been effective for many trace metals, but more can undoubtedly be done in areas of highest exposure (e.g. Liverpool Bay region).

v. Validity: Is the indicator based on an existing body or time series of data (either continuous or interrupted) to allow a realistic setting of objectives?

Data on organotin and trace metal exposure in UK-stranded harbour porpoises are derived from time-series data collected from 1989-2001 (see Jepson, 2005). The analytical methods used for organotin and trace metal determination were conducted by a single laboratory using internationally standardised methodologies.

vi. Relatively easy to understand by non-scientists and those who will decide on their use?

There is considerable public and NGO understanding/awareness of the risk of toxic pollutant accumulation in marine top predators such as marine mammals.

Economic criteria of heavy metals and organotins indicator:

Platform requirements

Liver samples for assessing organotin and trace metal exposure can be collected from stranded/by-caught animals.

Equipment requirements for sample collection

Liver samples for assessing organotin and trace metal exposure can be collected from stranded/by-caught animals using simple/basic equipment.

Amount of staff time required to plan collection of a single sample

Collection of liver samples for assessing organotin and trace metal exposure can be opportunistically collected from stranded/by-caught animals with minimal preparation.

Amount of staff time required to collect a single sample

A liver sample for assessing organotin and trace metal exposure can be collected from stranded/by-caught animals within hours.

Amount of staff time required to process a single sample

Time necessary to process a single liver sample for organotin and trace metal concentrations using current UK (CEFAS) methodology is 1 day.

Amount of staff time required to analyse & interpret a single sample

Time necessary to analyse and interpret a single liver sample for organotin and trace metal concentrations using current UK (CEFAS) methodology is 1-2 days.

Amount of staff time required to QA / QC data from a single sample

Time necessary to QA/QC a single liver sample for organotin and trace metal concentrations using current UK (CEFAS) methodology is 4 hours.

5.1.2 Synthetic compound contamination

The presence of high concentrations of contaminants in the body tissues might reduce the viability of some cetacean species. Many contaminants have the potential to disrupt the endocrine system of cetaceans, affecting reproduction, growth and development (Reijnders, 2003). For example, as part of the assessments to determine the cause of the 2008 short-beaked common dolphin mass stranding event in Cornwall, organochlorine contaminant levels were measured. Although not contributory to the stranding, it was determined that mean levels of all organochlorine contaminants in the adult females, when compared to a similar group of UK stranded individuals from 1990-1992, was found to have significantly reduced (Jepson & Deaville, 2009). An organochlorine indicator is further developed in section 6.3.1.

Of the organochlorines, it is the PCBs that are of greatest concern. Harbour porpoises that died as a result of infectious disease had significantly higher levels of PCBs than healthy porpoises that died as a result of traumatic deaths such as bycatch or bottlenose dolphin attacks (Jepson *et al* 2005; Hall *et al* 2006). PCB contamination has also been linked to higher parasite burdens and reduced pregnancy rates in harbour porpoises (Bull *et al* 2006; Pierce *et al* 2008). More recently, 17mg/kg lipid has been identified as the critical level at which the concentration of PCBs begins to affect harbour porpoise health (Jepson *et al* 2008). This level has recently been proposed as one of the criteria used to assess the health status of harbour porpoises under monitoring plans being developed for the species by OSPAR and is further developed in section 6.3.2 as an indicator.

Work from UK CSIP (e.g. Law *et al* 2002) contributed to the EU risk assessment of flame retardants and the subsequent ban in 2004 on production and use of penta-mix and octa-mix polybrominated diphenyl ether retardants (PBDEs or BFRs). These and other brominated flame retardants, including hexabromocyclododecane (HBCD), have been found in higher concentrations in harbour porpoises in poorer body condition, with evidence of maternal transfer (Law *et al* 2006). Levels of HBCD have been found in harbour porpoises has decreased since 2003, possibly linked with the closure of a manufacturing plant at that time (Law *et al* 2008a). More recently, attention has focused on perfluoroctane sulphonate (PFOS), a synthetic chemical with a wide range of uses including provision of resistance to water and oil, use as a flame retardant and as an active ingredient in pesticides and cleaning products. This has been found in significant concentrations in harbour porpoises stranded or bycaught in UK waters (Law *et al* 2008b). This data is contributing to the OSPAR assessment of efficacy of regulatory controls and voluntary limitations on PFOS use. Currently the European Commission are considering measures to restrict the production, marketing and use of PFOS. An indicator for brominated flame retardants is evaluated in section 6.3.3.

5.1.3 Indicator for synthetic compound contamination: Organochlorine pesticides

Research on UK-stranded harbour porpoises has shown that blubber concentrations of all organochlorines pesticides tested (DDT and metabolites, dieldrin, lindane etc) are at significantly lower levels than polychlorinated biphenyls (PCBs) and are declining more rapidly than PCBs in UK-stranded harbour porpoises (see Jepson, 2005). Based on research on UK-stranded cetaceans by the UK Cetacean Strandings Investigation Programme (www.ukstrandings.org), PCBs should be prioritised for monitoring over organochlorine pesticides. For the purposes of this report, however, OCs and PCBs have been evaluated separately.

Scientific evaluation of organochlorine exposure and toxicity indicator:

***Sensitivity:* Does the indicator allow detection of any type of change against background variation or noise?**

Standard analytical methods for organochlorine pesticide concentrations in tissues are both highly sensitive and internationally standardised for comparison with tissue levels in other regions.

***Accuracy:* Is the indicator measured with a low error rate?**

Analytical methods for organochlorine pesticide concentrations in tissues are both highly sensitive and internationally standardised for comparison with tissue levels in other regions.

***Specificity:* Does the indicator respond primarily to a particular human pressure, with low responsiveness to other causes of change?**

Analytical methods for organochlorine pesticide concentrations in tissues are highly specific.

Performance:

a Simplicity: Is the indicator easily measured?

Organochlorine pesticide concentrations in tissues are easily and accurately measured provided blubber samples from dead stranded animals or biopsies from live animals are available and appropriate sampling and analytical methodologies are in place.

b Responsiveness: Is the indicator able to act as an early warning signal?

Organochlorines are declining in the marine environment having been banned in developed countries in the late 1960s/early 1970s. However, if new sources of organochlorine pesticides were to enter the marine environment, exposure would readily be detected using existing analytical methodologies.

c Spatial applicability: Is the indicator measurable over a large proportion of the geographical range to which the indicator metric it to apply to, e.g. if the indicator is used at a UK level, is it possible to measure the required parameter(s) across this entire range or is it localised to one small scale area?

This is a UK wide indicator. However, organochlorine pesticide exposure data derived from by-caught, biopsied or stranded animals can show geographical variation in exposure. For example, blubber organochlorine pesticide levels in harbour porpoises stranded in Scotland are significantly lower than those stranded in England and Wales (Jepson, 2005).

d Management link: Is the indicator tightly linked to an activity which can be managed to reduce its negative effects on the indicator, i.e. are the quantitative trends in cause and effect of change well known?

Management interventions to reduce exposure to organochlorines at both the national and international level have already been relatively effective: the levels recorded in cetaceans are declining. Although management interventions to directly reduce PCB and organochlorine pesticide exposure are rather limited for cetaceans, targeted/prioritised conservation measures to limit all other anthropogenic pressures (e.g. by-catch) may be required in those species with highest organochlorine exposure (e.g. *Tursiops truncates* and *Orcinus orca*).

e Validity: Is the indicator based on an existing body or time series of data (either continuous or interrupted) to allow a realistic setting of objectives?

Data on organochlorine pesticide exposure in UK-stranded harbour porpoises are derived from time-series data collected from 1989-2005 (see Jepson, 2005). The analytical methods used for organochlorine pesticide determination were conducted by a single laboratory using internationally standardised methodologies.

f Relatively easy to understand by non-scientists and those who will decide on their use?

There is considerable public and NGO understanding/awareness of the risk of toxic pollutant accumulation in marine top predators such as marine mammals.

Economic evaluation of organochlorine exposure and toxicity indicator

Platform requirements

Samples for assessing organochlorine pesticide exposure can be collected from stranded/by-caught animals which have no platform requirements. In addition, blubber samples could also be collected from biopsies of free-living cetaceans requiring coastal or ocean going vessels. To date, the data used for this indicator has been collected from stranded and bycaught animals.

Equipment requirements for sample collection

Blubber samples for assessing organochlorine pesticide exposure can be collected from stranded/by-caught animals using simple/basic equipment. Should samples be collected by biopsy from live animals, more technical, expensive equipment and techniques will be required.

Amount of staff time required to plan collection of a single sample

Collection of blubber samples for assessing organochlorine pesticide exposure can be opportunistically collected from stranded and bycaught animals with minimal preparation. Should samples be collected from free-living animals using biopsy, much greater preparation is required (e.g. Home Office licensing, practicing biopsy techniques and dedicated time at sea to collect samples).

Amount of staff time required to collect a single sample

A blubber sample for assessing organochlorine pesticide exposure can be collected from stranded/by-caught animals within hours. Similarly for blubber samples collected via biopsies of free-living cetaceans.

Amount of staff time required to process a single sample

Time necessary to process a single blubber sample for organochlorine pesticide concentrations using current UK (CEFAS) methodology is 1 day.

Amount of staff time required to analyse & interpret a single sample

Time necessary to analyse and interpret a single blubber sample for organochlorine pesticide concentrations using current UK (CEFAS) methodology is 1-2 days.

Amount of staff time required to QA / QC data from a single sample

Time necessary to QA/QC a single blubber sample for organochlorine pesticide concentrations using current UK (CEFAS) methodology is 4 hours.

5.1.4 Indicator for synthetic compound contamination: PCBs

Marine mammals are exposed to a range of potentially toxic chemicals in their environment. Some lipophilic and persistent organic compounds bioaccumulate to very high levels, particularly in marine top predators such as harbour porpoises, bottlenose dolphins and killer whales. Detailed research on UK-stranded harbour porpoises conducted under the UK Cetacean Strandings Investigation Programme (www.ukstrandings.org) has shown strong links between elevated blubber PCB levels and infectious disease mortality (Jepson *et al* 1999; Jepson *et al* 2005; Hall *et al* 2006) consistent with fatal PCB-induced immunosuppression. These studies allow for an estimated threshold of toxicity for blubber PCB concentrations that exceed 20 mg/kg lipid wt (for summed 25CB congeners) in harbour porpoises (see Jepson *et al* 2005). This equates to a blubber PCB toxicity threshold concentration of 13mg/kg lipid wt (for summed ICES7 CB congeners) that could readily be applied to all marine mammals (not just harbour porpoises).

Scientific evaluation of PCB toxicity threshold indicator:

Sensitivity: Does the indicator allow detection of any type of change against background variation or noise?

Standard analytical methods for PCB concentrations in tissues are both highly sensitive and internationally standardised for comparison with tissue PCB levels in other regions.

***Accuracy: Is* the indicator measured with a low error rate?**

Analytical methods for PCB concentrations in tissues are both highly sensitive and internationally standardised for comparison with tissue PCB levels in other regions.

Specificity: Does the indicator respond primarily to a particular human pressure, with low responsiveness to other causes of change?

Analytical methods for PCB concentrations in tissues are highly specific for PCB levels in tissues. Environmental levels of PCBs arise primarily from their use as dielectric fluids in transformers, mainly on land.

Performance:

a Simplicity: Is the indicator easily measured?

The levels of PCBs in tissues are easily and accurately measured provided blubber samples from dead stranded animals or biopsies from live animals are available and appropriate sampling and analytical methodologies are in place.

b Responsiveness: Is the indicator able to act as an early warning signal?

The use of an established threshold concentration for PCB-induced toxicity using empirical cetacean data enables the early detection and assessment of cetacean individuals and populations exposed to levels of PCBs that are likely to induce potentially lethal toxic effects including immunosuppression and reproductive impairment.

c Spatial applicability: Is the indicator measurable over a large proportion of the geographical range to which the indicator metric is to apply to, e.g. if the indicator is used at a UK level, is it possible to measure the required parameter(s) across this entire range or is it localised to one small scale area?

This is a UK wide indicator. At the regional level, however, PCB exposure data derived from by-caught, biopsied or stranded animals can show geographical variation in PCB exposure and health risk. For example, blubber PCB levels of PCBs in harbour porpoises stranded in Scotland are significantly lower than those stranded in England and Wales (Jepson *et al* 2005).

d Management link: Is the indicator tightly linked to an activity which can be managed to reduce its negative effects on the indicator, i.e. are the quantitative trends in cause and effect of change well known?

Management interventions to reduce exposure to PCBs at both the national and international level have already been relatively effective: the levels recorded in cetaceans are declining albeit slowly (Figure 1).

PCBs have the potential to cause death and impair reproduction in populations with highest exposure. PCB levels in UK-stranded bottlenose dolphins and killer whales currently greatly exceed levels associated with infectious disease mortality in harbour porpoises (data: Jepson *et al* 2005; UKCSIP/CEFAS datasets). High PCB exposure also has the potential to inhibit the recovery of depleted populations historically exposed to other forms of anthropogenic pressures (e.g. hunting/by-catch). Although management interventions to directly reduce PCB exposure are rather limited for cetaceans, targeted/prioritised conservation measures to limit all other anthropogenic pressures (e.g. by-catch) may be required in those species with highest PCB exposure (e.g. *Tursiops truncatus* and *Orcinus orca*).

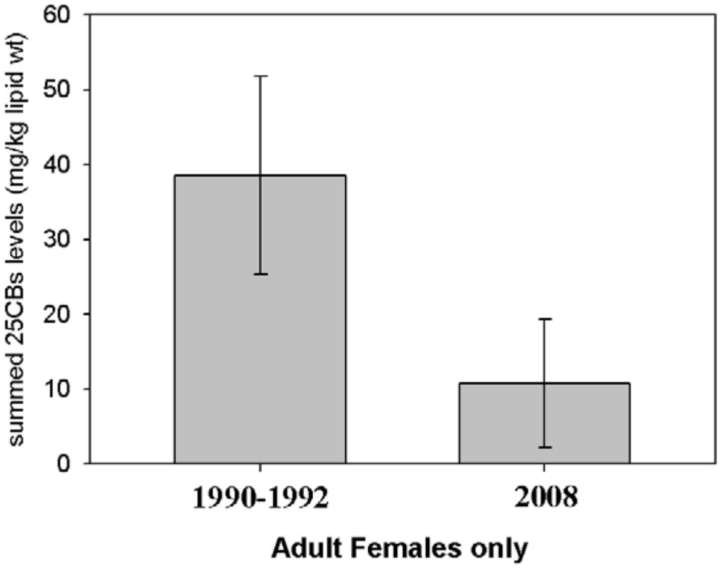

Figure 1. Comparison of PCB levels between 1990-92 and 2008 in adult female common dolphins (from Jepson *et al* 2009).

e Validity: Is the indicator based on an existing body or time series of data (either continuous or interrupted) to allow a realistic setting of objectives?

Data on associations between health effects and PCB exposure in UK-stranded harbour porpoises were initially derived from data collected from 1989-2001 in 255 individuals enabling statistical analyses to control for potentially confounding factors such as age, sex, and nutritional status (Jepson *et al* 2005; Hall *et al* 2006). Current unpublished data on associations between health effects and PCB exposure in UK-stranded harbour porpoises are derived from data collected from 1989-2005 and consists of nearly 500 animals in total making the UK data one of the largest datasets of PCBs and their effects in any marine mammal species. The analytical methods used for PCB determination were conducted by a single laboratory using internationally standardised methodologies.

f Relatively easy to understand by non-scientists and those who will decide on their use?

There is considerable public and NGO understanding/awareness of the risk of toxic pollutant accumulation in marine top predators such as marine mammals.

Economic evaluation of PCB toxicity threshold indicator

Platform requirements

Samples for assessing PCB exposure are currently collected from stranded and bycaught animals. Although not undertaken at present, blubber samples can also be collected from biopsies of free-living cetaceans requiring coastal or ocean going vessels

Equipment requirements for sample collection

Blubber samples for assessing PCB exposure can be collected from stranded and by caught animals using limited equipment. Should the monitoring of PCB level in free-living cetaceans be required, more technical, expensive equipment and techniques will be required.

Amount of staff time required to plan collection of a single sample

Collection of blubber samples for assessing PCB exposure can be opportunistically collected from stranded and bycaught animals with minimal preparation. Should samples be collected from free-living animals using biopsy, much greater preparation is required (e.g. Home Office licensing, practicing biopsy techniques and dedicated time at sea to collect samples).

Amount of staff time required to collect a single sample

A blubber sample for assessing PCB exposure can be collected from stranded and bycaught animals within hours. Similarly for biopsy samples.

Amount of staff time required to process a single sample

Time necessary to process a single blubber sample for PCB concentrations using current UK (CEFAS) methodology is 1 day.

Amount of staff time required to analyse & interpret a single sample

Time necessary to analyse and interpret a single blubber sample for PCB concentrations using current UK (CEFAS) methodology is 1-2 days.

Amount of staff time required to QA / QC data from a single sample

Time necessary to QA/QC a single blubber sample for PCB concentrations using current UK (CEFAS) methodology is 4 hours.

5.1.5 Indicator for synthetic compound contamination: Brominated flame retardants

Research on UK-stranded harbour porpoises has demonstrated emerging concentrations in blubber of a range of newer brominated flame retardants and perfluorinated organic acids (PBDEs, HBCD, PFOS) (Jepson 2005; Law *et al* 2002, 2005, 2006, 2008a,b&c). Levels of these compounds should continue to be monitored in UK-stranded cetaceans.

Scientific evaluation of exposure to flame retardants indicator:

Sensitivity: Does the indicator allow detection of any type of change against background variation or noise?

Standard analytical methods for brominated flame retardant and perfluorinated organic acid concentrations in tissues are both highly sensitive and internationally standardised for comparison with levels in other regions.

Accuracy: **Is the indicator measured with a low error rate?**

Analytical methods for brominated flame retardant and perfluorinated organic acid concentrations in tissues are both highly sensitive and internationally standardised for comparison with levels in other regions.

Specificity: **Does the indicator respond primarily to a particular human pressure, with low responsiveness to other causes of change?**

Analytical methods for brominated flame retardant and perfluorinated organic acid concentrations in tissues are highly specific. Their environmental presence results from their use in industrial applications on land.

Performance:

a Simplicity: Is the indicator easily measured?

Brominated flame retardant and perfluorinated organic acid concentrations in tissues are easily and accurately measured provided blubber samples from dead stranded animals (from which all data has been collected to date). In addition, biopsies from live animals could also be utilised should appropriate sampling and analytical methodologies be put in place.

b Responsiveness: Is the indicator able to act as an early warning signal?

Brominated flame retardants and perfluorinated organic acids have already been detected in cetaceans in European waters (including UK).

c Spatial applicability: Is the indicator measurable over a large proportion of the geographical to which the indicator metric it to apply to, e.g. if the indicator is used at a UK level, is it possible to measure the required parameter(s) across this entire range or is it localised to one small scale area?

Brominated flame retardant and perfluorinated organic acid exposure data derived from by-caught, biopsied or stranded animals can show geographical variation in exposure. For example, blubber brominated flame retardant (PBDEs) levels have already shown higher levels in harbour porpoises stranded in the North Sea compared to other parts of the UK (Jepson, 2005; Law *et al* 2002).

d Management link: Is the indicator tightly linked to an activity which can be managed to reduce its negative effects on the indicator, i.e. are the quantitative trends in cause and effect of change well known?

Data from UK-stranded harbour porpoises has already resulted in an EU ban on some types of polybrominated diphenyl ether flame retardants. Work from UK CSIP (e.g. Law *et al* 2002) contributed to the EU risk assessment of flame retardants and the subsequent ban in 2004 on production and use of penta-mix and octa-mix polybrominated diphenyl ether retardants (PBDEs or BFRs).

e Validity: Is the indicator based on an existing body or time series of data (either continuous or interrupted) to allow a realistic setting of objectives?

Data on brominated flame retardant and perfluorinated organic acid exposure in UK-stranded harbour porpoises are derived from time-series data collected from 1995-2001 (see Jepson, 2005) and tissue samples within the UKCSIP archive would enable time series studies on any contaminant from 1990-present. The analytical methods used for brominated flame retardant and perfluorinated organic acid determination were conducted by a single laboratory using internationally standardised methodologies.

f Relatively easy to understand by non-scientists and those who will decide on their use?

There is considerable public and NGO understanding/awareness of the risk of newer chemicals like brominated flame retardants and perfluorinated organic acids that can accumulate in marine top predators such as marine mammals.

Economic evaluation of exposure to flame retardants indicator

Platform requirements

Samples for assessing brominated flame retardant and perfluorinated organic acid exposure have been collected from stranded and bycaught animals to date. Should an appropriate sampling programme be put in place, it would also be possible to collect biopsy samples from free-living cetaceans for this indicator, which would require coastal or ocean going vessels.

Equipment requirements for sample collection

Blubber samples for assessing brominated flame retardant and perfluorinated organic acid exposure can be collected from stranded and bycaught animals using simple/basic equipment. The collection of samples from free-living cetaceans would require more technical and expensive equipment and techniques.

Amount of staff time required to plan collection of a single sample

Collection of blubber samples for assessing brominated flame retardant and perfluorinated organic acid exposure can be opportunistically collected from stranded and bycaught animals with minimal preparation. Should samples be collected from free-living animals using biopsy, much greater preparation is required (e.g. Home Office licensing, practicing biopsy techniques and dedicated time at sea to collect samples).

Amount of staff time required to collect a single sample

A blubber sample for assessing brominated flame retardant and perfluorinated organic acid exposure can be collected from stranded/by-caught animals within hours. Similarly for biopsy samples.

Amount of staff time required to process a single sample

Time necessary to process a single blubber sample for brominated flame retardant and perfluorinated organic acid concentrations using current UK (CEFAS) methodology is 1 day.

Amount of staff time required to analyse & interpret a single sample

Time necessary to analyse and interpret a single blubber sample for brominated flame retardant and perfluorinated organic acid concentrations using current UK (CEFAS) methodology is 1-2 days.

Amount of staff time required to QA / QC data from a single sample

Time necessary to QA/QC a single blubber sample for a range of brominated flame retardant and perfluorinated organic acid concentrations using current UK (CEFAS) methodology is four hours.

5.1.6 Radionuclide contamination

Levels of the radionuclide Cs^{137} and the naturally occurring K^{40} were determined in liver/muscle samples from UK-stranded common and grey seals and harbour porpoises collected in part by the UK Cetacean Strandings Investigation Programme (CSIP, www.ukstrandings.org) in the mid-1990s (Watson *et al* 1999). Low levels of Cs^{137} were also found in a similar study of harbour porpoises from British and Irish waters from 1989-1993 (Berrow *et al* 1998). Levels of radioactivity from Cs^{137} were higher in animals that stranded in the Irish Sea (compared to the North Sea and other regions) but were generally much lower than levels from the naturally occurring radioisotope K^{40} (Berrow *et al* 1998; Watson *et al* 1999).

A third study looked at Cs^{137} in minke whales caught in 1998 in West Greenland, NE Atlantic and North Sea with the highest levels in the North Sea. Since radionuclide exposure is primarily associated with development of neoplasia (cancer), the monitoring of cetaceans for the prevalence of tumours is a key indicator of potential biological effect (Jepson, 2005). Recorded levels of Cs^{137} in UK marine mammals in early 1990s were low and only 11 cases of fatal neoplasia (tumours) have been diagnosed in UK-stranded cetaceans (all harbour porpoises) from 1990-2008 (UK CSIP database). Nonetheless, the continued monitoring for tumours and, periodically, for radionuclide levels is still warranted considering that a) the last studies of radionuclide exposure in marine mammals in UK/European waters were over 10 years ago and; b) that there is a renewed (inter)national commitment to nuclear power generation to meet international targets on climate change.

Scientific evaluation of radionuclide contamination indicator:

Sensitivity: Does the indicator allow detection of any type of change against background variation or noise?

Standard analytical methods for radionuclide concentrations in tissues are both highly sensitive and internationally standardised for comparison with tissue levels in other regions

Accuracy: I**s the indicator measured with a low error rate?**

Analytical methods for radionuclide levels in tissues are both highly sensitive and internationally standardised for comparison with tissue levels in other regions.

Specificity: **Does the indicator respond primarily to a particular human pressure, with low responsiveness to other causes of change?**

Analytical methods for radionuclide levels in tissues are highly specific.

Performance:

a Simplicity: Is the indicator easily measured?

Radionuclide levels in tissues are easily and accurately measured provided tissue samples from dead stranded cetaceans are available.

b Responsiveness: Is the indicator able to act as an early warning signal?

If new radionuclide sources were to enter the marine environment, exposure would readily be detected using existing analytical methodologies.

c Spatial applicability: Is the indicator measurable over a large proportion of the geographical to which the indicator metric it to apply to, e.g. if the indicator is used at a UK level, is it possible to measure the required parameter(s) across this entire range or is it localised to one small scale area?

Radionuclide exposure data derived from by-caught, biopsied or stranded animals can reliably show geographical variation in exposure (Watson *et al* 1999).

d Management link: Is the indicator tightly linked to an activity which can be managed to reduce its negative effects on the indicator, i.e. are the quantitative trends in cause and effect of change well known?

Environmental legislation to limit marine input of radionuclides is rigorously implemented on an international scale. Continued monitoring for radionuclides in marine mammal tissues in UK waters would help ensure public confidence in good environmental/public health status.

e Validity: Is the indicator based on an existing body or time series of data (either continuous or interrupted) to allow a realistic setting of objectives?

Published data on radionuclide levels in UK-stranded harbour porpoises and pinnipeds were derived from tissue samples collected in early-mid 1990s (Watson *et al* 1999). Tissues archived in the UK CSIP tissue bank (collected from approximately 3500 individual marine mammals over a twenty year period) would enable a time series analysis to be conducted from 1990-present. The analytical methods are conducted using internationally standardised methodologies.

f Relatively easy to understand by non-scientists and those who will decide on their use?

There is considerable public and NGO awareness/concern of the risk of radionuclide contamination in marine top predators such as marine mammals

Economic evaluation of radionuclide contamination indicator:

Platform requirements

Liver or muscle samples have been used to assess radionuclide radiation levels in stranded/by-caught marine mammals.

Equipment requirements for sample collection

Liver/muscle samples for assessing radionuclide radiation levels can be collected from stranded/by-caught animals using limited equipment requirements.

Amount of staff time required to plan collection of a single sample

Liver/muscle samples for assessing radionuclide radiation levels can be opportunistically collected from stranded/by-caught animals with minimal preparation

Amount of staff time required to collect a single sample

A liver/muscle sample for assessing radionuclide radiation levels can be collected from stranded/by-caught animals within hours.

Amount of staff time required to process a single sample

Time necessary to process a single liver/muscle sample for radionuclide radiation levels using current UK (CEFAS) methodology is hours.

Amount of staff time required to analyse & interpret a single sample

Time necessary to analyse and interpret a single tissue sample for radionuclide radiation levels is hours/days.

Amount of staff time required to QA / QC data from a single sample

Time necessary to QA/QC a single tissue sample for radionuclide radiation levels is hours.

5.1.7 Underwater Noise

Cetaceans are susceptible to acoustic disturbance, which can lead to displacement, behavioural changes, physical injury and even death (Weilgart, 2007). One of the few known potential biological effects of high intensity acoustic exposure are mass stranding events (MSEs), predominantly involving beaked whales, and causally linked to anti-submarine mid-frequency active sonars (Simmonds and Lopez-Jurado, 1991; Frantzis, 1998; Jepson *et al* 2003; Cox *et al* 2006). Gas and fat embolic pathologies similar to decompression sickness

(DCS) in humans have been found in sonar-induced beaked whale MSEs suggesting that a DCS-like mechanism may underpin these acoustically-induced MSEs (Jepson *et al* 2003: Fernandez *et al* 2005; Jepson *et al* 2005; Cox *et al* 2006; Zimmer and Tyack, 2008). Gas embolic lesions have also been identified (Jepson *et al* 2005b; Jepson, 2006).

Research on UK-stranded cetaceans by the UK Cetacean Strandings Investigation Programme (www.ukstrandings.org) has also demonstrated acute and chronic gas/fat embolic pathologies in several short-beaked common dolphins, Risso's dolphins, and harbour porpoises; although the acoustic exposure histories of these isolated UK-stranded cetacean cases were unknown (Jepson, 2005, 2006; Jepson *et al* 2005). MSEs of cetaceans other than beaked whales which were coincident in time/space with naval activities have also occurred, but in the absence of DCS-like pathologies (e.g. Jepson and Deaville, 2009). Since gas/fat embolic pathology provides one of the few established and detectable biomarkers of high-intensity acoustic exposure in cetaceans, the post-mortem screening of stranded cetaceans for DCS-like pathology (along with detailed investigations of any future MSEs) are essential indicators to monitor the potential impacts of high-intensity anthropogenic noise sources.

Scientific evaluation of DCS/MSEs indicator:

Sensitivity: Does the indicator allow detection of any type of change against background variation or noise?

Data on cetacean strandings have been held in the UK and other countries for many years. The criteria for detection of MSEs and DCS-like pathology are well established and can be readily detected against background noise. Since 1990, dedicated strandings surveillance has included post-mortem examinations in the UK using internationally standardised methods (funded by UK Government). The pathology of gas/fat embolism (DCS) is now well established (Jepson *et al* 2003; Jepson *et al* 2005; Fernandez *et al* 2005).

Accuracy: Is the indicator measured with a low error rate?

MSEs are rare events that are easily detected by non-trained personnel. The pathology of gas/fat embolism (DCS) is now well established (Jepson *et al* 2003; Jepson *et al* 2005; Fernandez *et al* 2005) but may require experienced pathologists for their confident detection in some cases.

Specificity: Does the indicator respond primarily to a particular human pressure, with low responsiveness to other causes of change?

Cetacean MSEs are readily detected but the potential causes of MSEs are many. That is why any MSEs require detailed pathological and other studies to investigate all possible causes of all MSEs (acoustic and non-acoustic) (e.g. Jepson and Deaville, 2009). The pathology of gas/fat embolism (DCS) is now well established for beaked whale MSEs linked to active naval sonars (Jepson *et al* 2003; Fernandez *et al* 2005; Cox *et al* 2006). Isolated UK cetacean cases have been detected and may have been induced by acoustic exposure (their acoustic exposure history was unknown) (Jepson, 2005; Jepson *et al* 2005). Since cetacean DCS has only been detected in sonar-induced beaked whale MSEs or in areas/countries where naval exercises occur, and given that cetacean biomarkers of acoustic exposure and effect are extremely rare, DCS remains an important global indicator for the potential effects of high-intensity acoustic exposure in cetaceans.

Performance:

a Simplicity: Is the indicator easily measured?

Cetacean MSEs are readily detectable, even in areas with low human population densities. The pathology of gas/fat embolism (DCS) is now well established for beaked whale MSEs linked to active naval sonars (Jepson *et al* 2003; Fernandez *et al* 2005; Cox *et al* 2006) but often require experienced pathologists for their detection. Isolated UK cases may also have been induced by acoustic exposure (acoustic exposure is unknown in the UK cases) (Jepson *et al* 2005).

b Responsiveness: Is the indicator able to act as an early warning signal?

Cetacean MSEs and the detection of DCS-like pathologies in stranded cetaceans can act as an early warning sign for potential impacts from high-intensity acoustic activities in a particular area or cetacean species.

c Spatial applicability: Is the indicator measurable over a large proportion of the geographical range to which the indicator metric is to apply to, e.g. if the indicator is used at a UK level, is it possible to measure the required parameter(s) across this entire range or is it localised to one small scale area?

Cetacean MSEs and the detection of DCS-like pathologies in stranded cetaceans can show geographical variation in exposure. For example, DCS cases have been recorded in a range of cetacean species stranded in western England, Scotland and Wales (Jepson, 2005).

d Management link: Is the indicator tightly linked to an activity which can be managed to reduce its negative effects on the indicator, i.e. are the quantitative trends in cause and effect of change well known?

Once potential impacts of acoustic exposure have been detected (e.g. DCS) in cetaceans within in area, a wide array of mitigation measures (e.g. soft-starts, etc.) are available to reduce the risk of negative impacts. The ASCOBANS Conservation and Management Plan requires the Parties to work towards the prevention of significant disturbance, "especially of an acoustic nature".

e Validity: Is the indicator based on an existing body or time series of data (either continuous or interrupted) to allow a realistic setting of objectives?

Data on MSEs in UK-stranded cetaceans have been collected by the Natural History Museum since 1913 (see Jepson, 2005; Jepson and Deaville, 2009) and most European countries hold good datasets on cetacean strandings (including MSEs). Data on DCS in UK-stranded cetaceans are derived from time-series data collected from 1990-present using established diagnostic criteria (see Jepson, 2005; Fernandez *et al* 2005; Jepson *et al* 2005). The methods used for DCS determination are based on European standardised necropsy methodologies (e.g. Jepson *et al* 2005) so are readily applicable to other countries/regions.

f Relatively easy to understand by non-scientists and those who will decide on their use?

There is considerable public and NGO understanding/awareness of the risk of high-intensity acoustic exposure in marine mammals.

Economic evaluation of DCS/MSEs indicator:

Platform requirements

Necropsies for investigating both MSEs and detecting DCS can be conducted on stranded animals using standardised methodologies.

Equipment requirements for sample collection

Collection of samples from stranded animals can be conducted using limited necropsy equipment and techniques.

Amount of staff time required to plan collection of a single sample

The time to actually plan a necropsy of a stranded cetacean is minimal since necropsies are usually done opportunistically with standard equipment.

Amount of staff time required to collect a single sample

The gross necropsy of stranded cetacean takes several hours using standardised techniques.

Amount of staff time required to process a single sample

A range of samples are taken from each gross necropsy. Depending on the condition of the carcass, and the level of detail of the investigation, the complete analysis of a range of tissue samples can take several days-weeks.

Amount of staff time required to analyse & interpret a single sample

Experienced cetacean pathologists, working under the aegis of the CSIP, interpret results gathered during post-mortem investigations, leading to a diagnosis of the most likely cause of death.

Amount of staff time required to QA / QC data from a single sample

Use of standardised post-mortem protocols and criteria for establishing cause of death categories usually allows swift QA/QC. Both strandings and post-mortem data collected under the CSIP are routinely stored and archived on a relational web-accessed database, allowing open and current access to data to all members of the CSIP consortium. Oversight of this dataset is managed by the CSIP contract managers.

5.1.8 Climate Change

The impact of climate change on cetaceans remains poorly understood. Direct impacts are likely to be observed in species tracking a specific range of temperatures in which they can survive (MacLeod, 2009), whilst 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 potentially confounding effects (e.g. natural climatic variation, human exploitation of the prey resource) and any changes observed may simply be the cetacean species responding to short-term regional variability in the prey resource rather than long-term anthropogenically mediated climate change. As a result, there has been a great deal of speculation and conjecture but little substantive evidence. Despite this, one possible indicator of climate change (both natural and anthropogenic) for consideration is the ratio of common dolphins to white-beaked dolphins in relation to surface seawater temperature (MacLeod *et al* 2005, 2008).

Common dolphins are widespread in warm temperate to tropical waters of the Atlantic and Pacific oceans. In the northeast Atlantic, distribution extends from northwest Africa to northern Britain, with occasional records up to 62°N. It is also one of the most abundant cetacean species in many offshore areas, such as the Bay of Biscay and southwest of Britain and Ireland. Common dolphins are also numerous in some shelf waters, particularly the Celtic Sea and Southwest Approaches to the Channel (Figure 2; Reid *et al* 2003). Available evidence indicates that, with the possible exception of animals off southern Portugal, short-beaked common dolphins in the northeast Atlantic belong to one wide-ranging population.

In 2005, the abundance for European continental shelf waters was estimated to be 63,400 (95% CI: 27,000-148,900) (SCANS II, 2008) and in 2007 the offshore waters the abundance was estimated to be 116,700 (95% CI: 61,400-221,850) (CODA, 2009). It should be noted that this species moves between the offshore and continental shelf environments, with numbers using the continental shelf varying considerably both within season and from year to year. For example, there is a 10 fold increase in numbers in the western English Channel during the winter months in some years, a change that is likely to be linked to food resources (Bereton *et al* 2005).

The white-beaked dolphin has a more limited range than common dolphins, being found only in cool temperate and subarctic waters of the North Atlantic (Figure 2). This species is found mostly in continental shelf waters less than 100m deep in UK waters (Northridge *et al* 1995). The population in the eastern Atlantic is thought to be larger than that in the west, with a range extending from northern Norway and Iceland to the British Isles and North Sea. There have been a few sightings in the Bay of Biscay and as far south as the Straits of Gibraltar.

UK waters may hold a significant proportion of the total population of the north east Atlantic, and indeed of the total global population. White-beaked dolphins are present throughout the year and abundant around west and north Scotland and in the northern North Sea. They are much less common in the southern North Sea, the English Channel and Irish Sea, and rarely recorded in deep waters offshore. SCANS II in 2005 estimated the European continental shelf abundance to be 22,700 (95% CI: 10,300-49,700) (SCANS II, 2008). The SCANS 1994 survey estimated the abundance to be 7,900 (95% CI: 4,000-13,000) for the North Sea (Hammond *et al* 2002). In 2005, SCANS II estimated the abundance in a similar area to be 10,600 (95% CI: 6,000-18,400). There is no evidence for a change in the overall abundance between the two SCANS surveys. However, more recently, concern has been raised regarding local changes in distribution. For example, the sightings of white-beaked dolphins have become much less common in the Minch, Scottish west coast, since the 1990s (MacLeod *et al* 2005; Weir *et al* 2007).

Investigating these changes further using sightings data, it has been shown that there is a marked shift in the occurrence of common and white-beaked dolphins at a surface seawater temperature of approximately 13^{o}C in summer months at both a local (MacLeod *et al* 2007) and regional (MacLeod *et al* 2008) scale on the continental shelf. As waters warm, common dolphins become more common and white-beaked dolphins less common. The change appears to be relatively rapid and can occur with a short distance and over a short time period.

a Indicator for Climate change: Ratio of Common Dolphin to White-beaked Dolphin Records on the Continental Shelf in Summer Months

This indicator is quantitative, but with a number of key ‘tipping' points. The key tipping points in this indicator are: 1. only white-beaked dolphins recorded (>99% white-beaked dolphin); 2. common dolphin recorded but rare (65-99% white-beaked dolphin); 3. common dolphin and white-beaked dolphin recorded in similar numbers (35-65% white-beaked dolphin); 4. white-beaked dolphin recorded but rarely (1-35% white-beaked dolphin); 5. only common dolphin recorded (>1% white-beaked dolphin). These key tipping points are tied to specific water temperatures. For summer only they are: <~8^{o}C; ~8-12^{o}C; ~12-14^{o}C; ~14-18^{o}C, >~18^{o}C (Figure 3).

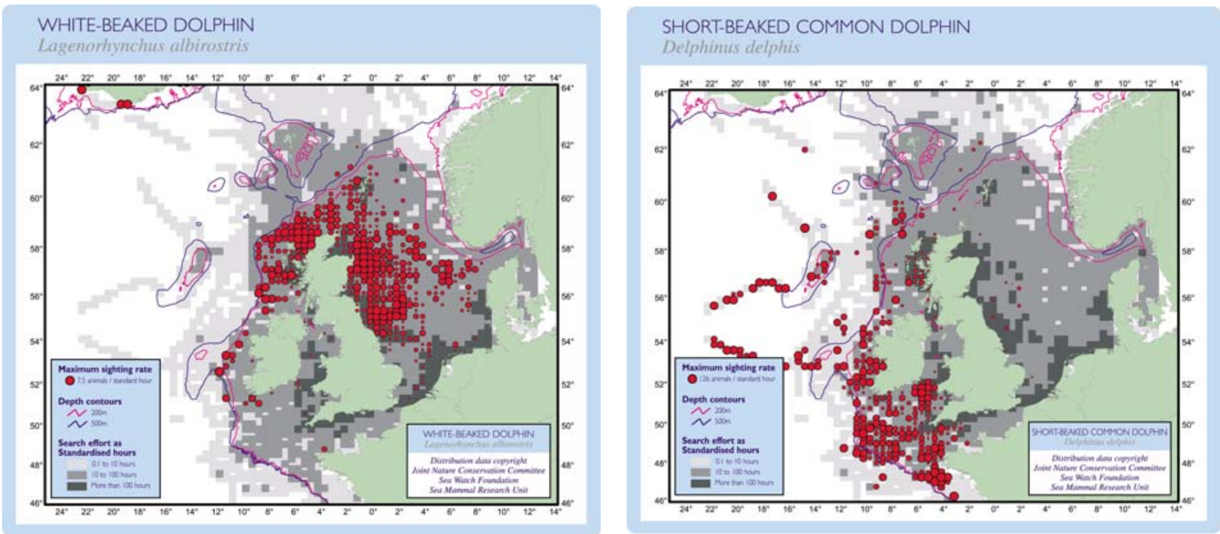

Figure 2. Known distribution of white-beaked and common dolphins prior to 1997 (from Reid *et al* 2003).

Currently this is a summer-only index as this is the main season for sightings data collection and, consequently, where most for the data exists. Although the data are more limited, the relationship also holds for winter months (Figure 4). The categories of relative occurrence between the two species are, however, shifted into cooler temperatures due seasonal changes in blubber thickness enabling both species to tolerate cooler temperatures.

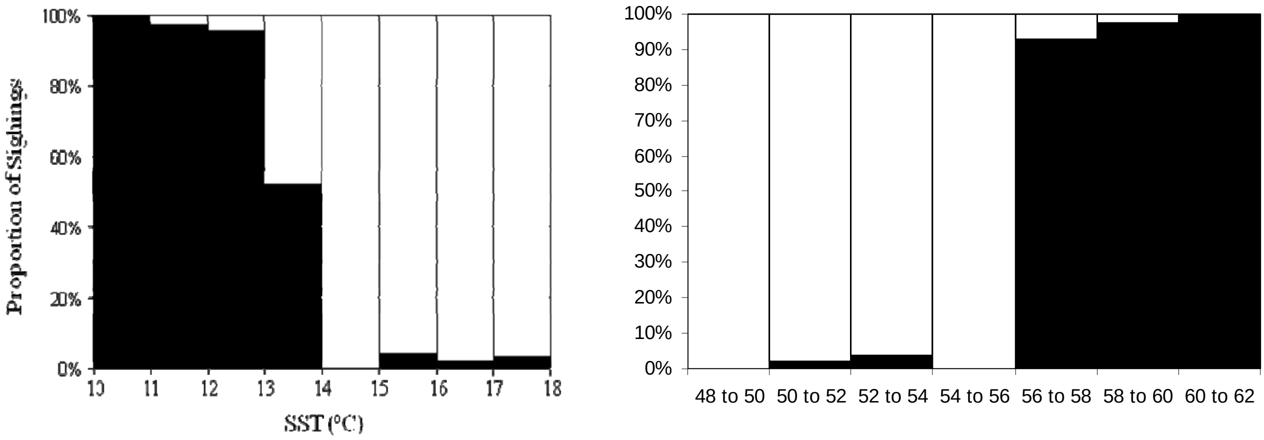

Figure 3. The ratio of white-beaked (black bar) to common dolphins (white bar) in relation to summer seawater surface temperature (from MacLeod *et al* 2008) and latitude (MacLeod pers. comm.).

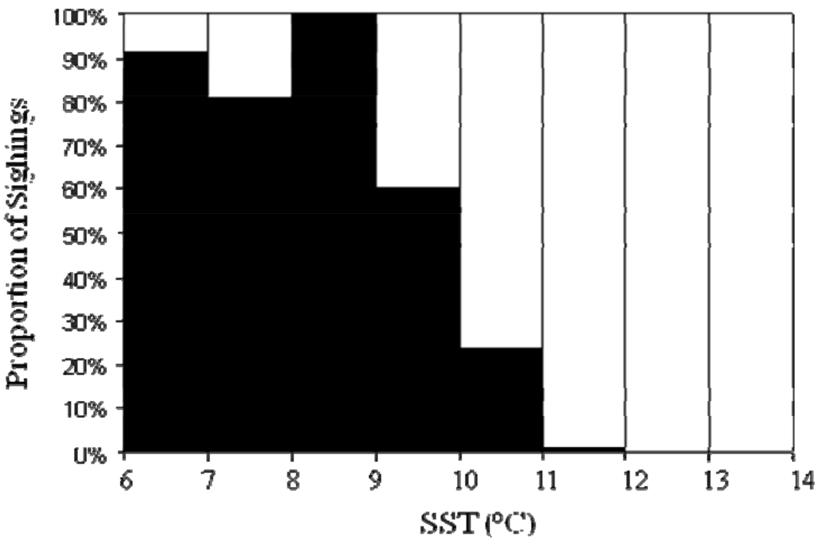

Figure 4. The ratio of white-beaked (black bar) to common dolphins (white bar) in relation to winter seawater surface temperature

Although more work is required, the ratio also appears to hold true for the strandings data (Figure 5). Currently, the observed changes in summer strandings data for the four regions suggest a consistent decline in white-beaked dolphin occurrence relative to common dolphin around the UK which is consistent with a contraction in this species range associated with warmer water temperatures caused by climate change. The strandings database goes back to 1913, so there is the possibility to look at this ratio historically.

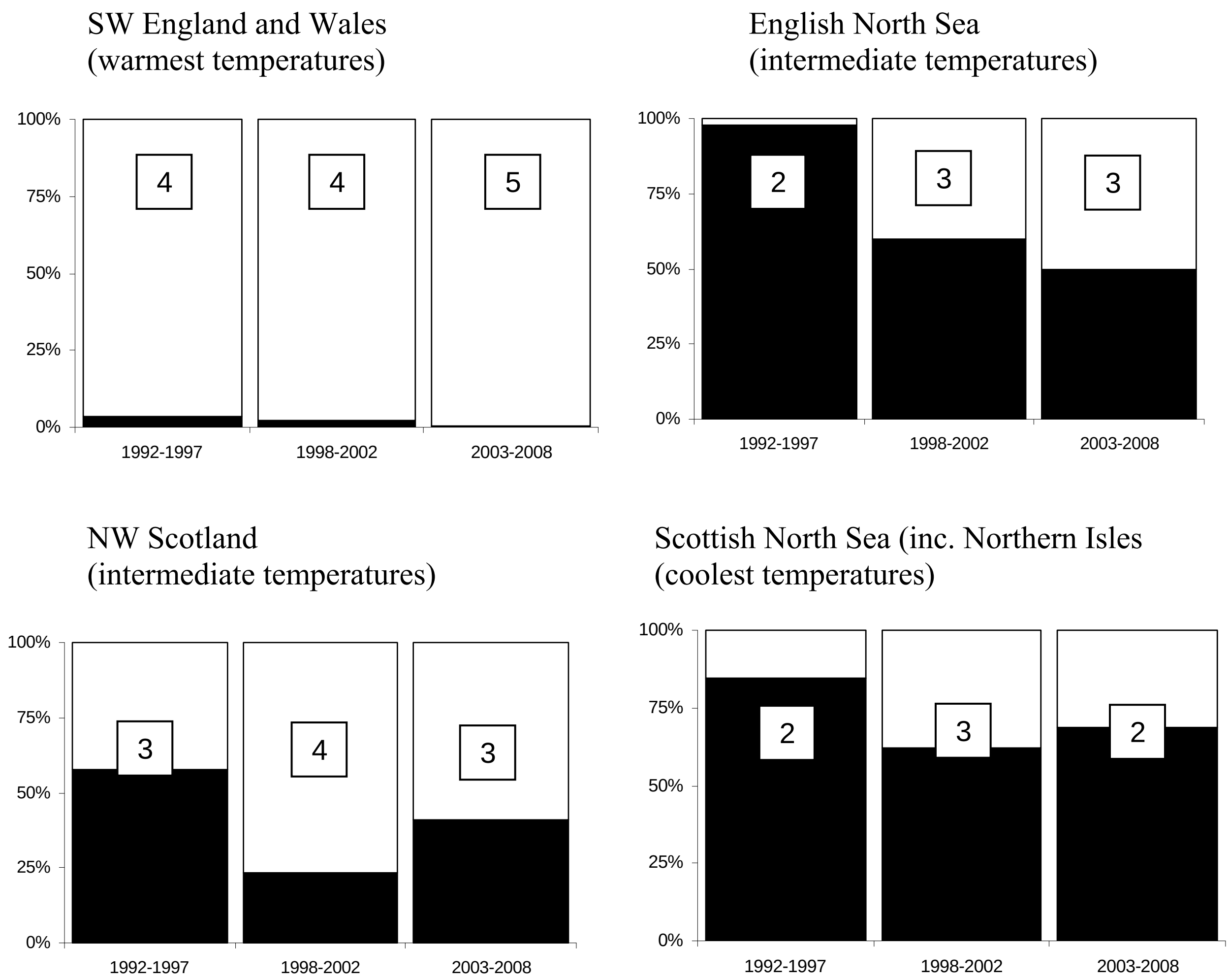

Figure 5. Change in Ratio of Strandings of White-beaked dolphins to Common Dolphin for various regions in UK waters since 1992 when systematic collection of records began. The numbers in boxes indicate the position on the semi-quantitative scale shown in Table 1.

The change appears to be relatively rapid and can occur with a short distance and over a short time period. This indicator is, therefore, best applied by looking for changes at a number of specific locations. In summary, this indicator represents a change between a cetacean community dominated by cool water species and one dominated by warm water species (MacLeod *et al* 2005, 2008), which, over the long term, is under the influence of climate change (both natural and anthropogenic). Table 1 outlines a proposed semi-quantitative scale for use of ratio of common dolphin to white-beaked dolphin (from strandings and/or sightings) as an indicator of the effect of climate change on cetacean species range in UK waters.

Table 1. A semi-quantitative scale for use of ratio of common dolphin to white-beaked dolphin as an indicator of the effect of climate change

Scale	Ratio of Common Dolphin To White-Beaked Dolphin	Summer Water Temperature Range
1	>99% White-beaked dolphin	<~10^{o}C
2	99-65% White-beaked dolphin	~10-12^{o}C
3	65-35% White-beaked dolphin	~12-14^{o}C
4	35-1% White-beaked dolphin	>~14^{o}C
5	<1% White-beaked Dolphin	>~18^{o}C

Scientific evaluation of species ratio indicator.

Sensitivity: Does the indicator allow detection of any type of change against background variation or noise:

The change in the ratio of common dolphins to white-beaked dolphins has been noted in both the strandings (all year) and sightings data (summer only). This is thought to be relatively insensitive to background variation. The link between the ratio of the two species and seawater temperature, however, varies with season. Consequently, this ratio needs to be considered for summer and winter separately.

Accuracy: Is the indicator measured with a low error rate?

While the quantitative values for this indicator may be difficult to measure accurately, the key tipping points outlined above are relatively robust and easy to measure with a low error rate.

Specificity: Does the indicator respond primarily to a particular human pressure, with low responsiveness to other causes of change?

The indicator responds specifically to changes in local surface seawater temperature. Based on what we currently know about the ecology of the two species, it is unlikely that the ratio will be affected by other causes of change. For example, although there is some variation in diet, both dolphin species are relatively catholic feeders, taking a wide range of overlapping fish species (Reid *et al* 2003; Weir *et al* 2007). Changes in the dominant prey item are therefore likely to effect both species in a similar manner.

One exception to this is possibly bycatch, which is a considerably more common cause of death in common dolphins than white-beaked dolphins particularly in the southwest. However, this would bias the ratio in a specific direction (towards white-beaked dolphins) whilst increasing seawater temperature would push the ratio in the opposite direction. Additionally, if there is a specific regional pattern to the ratios showing that the zone where you get a switch from white-beaked dolphin to common dolphin is shifting northwards, then this is likely consistent with a climate effect. However, if the ratio changed in the same way in all regions at once, then it is more likely to be the result of other factors.

Performance:

a Simplicity: Is the indicator easily measured?

This indicator is relatively easy to measure in that it can be based on sighting or strandings data that are already routinely collected as part of existing research programmes. As a simple ratio of raw count data, it is easy to calculate. It is also very clear to understand.

b Responsiveness: Is the indicator able to act as an early warning signal?

Given a change from one tipping point to another, this indicator can act as an early warning signal of further similar changes. For example, a change from point 1 to point 2 on the scale will occur before a change from point 2 to 3. Therefore, the occasional rare occurrence of common dolphin will precede an equal occurrence of common and white-beaked dolphin and so forth. This, therefore, acts as an early warning of further changes.

c Spatial applicability: Is the indicator measurable over a large proportion of the geographical to which the indicator metric it to apply to, e.g. if the indicator is used at a UK level, is it possible to measure the required parameter(s) across this entire range or is it localised to one small scale area?

While this indicator would have to be measured at a local level, e.g. along particular fixed sightings survey routes, by comparing it at a number of locations, a region-wide indicator could be constructed. For example, UK waters could be divided into an appropriate number of sectors, based on species ecology and oceanographic characteristics, and the level of the indicator in each sector compared. Any variation in any sector would then indicate a change was occurring.

d Management link: Is the indicator tightly linked to an activity which can be managed to reduce its negative effects on the indicator, i.e. are the quantitative trends in cause and effect of change well known?

The links between climate change and seawater temperature are reasonably well established. This indicator is an expression of changes in seawater temperature in summer months for sightings data. It should be noted, however, that some of the historical links between changes in sea surface water temperature and increased stranding were associated with the natural phenomenon of the North Atlantic Oscillation (NAO) (MacLeod *et al* 2005). It is, therefore, currently not possible to distinguish between natural and anthropogenic forcing of climate.

Additionally, management of the pressure and activities associated with anthropogenic climate change will be required at an international level and are not restricted to the UK Government or Devolved Administrations.

e Validity: Is the indicator based on an existing body or time series of data (either continuous or interrupted) to allow a realistic setting of objectives?

The justification for this indicator is based on analyses of sightings data (collected over the last 20-30 years in various forms) and strandings data (collected since 1948 in MacLeod *et al* 2005). It could also be calculated from strandings data, which have been collected since 1913, although only systematically since 1990.

f Relatively easy to understand by non-scientists and those who will decide on their use?

There is a general public concern, including substantial NGO work and media attention regarding the impact of climate change on these charismatic species. As a simple ratio, this is easy for people to understand: as water temperatures increase, common dolphins start appearing, become more common, and then become dominant as white-beaked dolphins disappear. It should be noted, however, that it is not possible to separate natural climatic variation from that driven by human activity.

Economic Evaluation of species ratio indicator:

Platform requirements:

Requirements depend on the approach taken. If based on strandings data or sightings data based on platforms of opportunity (such as the ferry survey network surveyed by ARC), then there are no requirements for vessel charter. If based on dedicated research vessels, then costs associated with the platform will be considerably higher.

Equipment requirements for sample collection:

All that is required are a pair of binoculars for sightings surveys.

Amount of staff time required to plan collection of a single sample:

Sightings surveys using commercial ferries as a platform of opportunity are generally planned on an annual basis to enable appropriate coverage and identification of volunteer surveyors. The annual planning takes approximately 5-7 days, which covers approximately 15 individual ferry routes per year. For each of these routes, a sightings survey is undertaken at least once a month in summer months.

Amount of staff time required to collect a single sample:

A single sample is considered to equate to all the data collected on a single ferry route for sightings data. For strandings data, a sample would equate to an entire year of carcass collection in a predefined sector.

Amount of staff time required to process a single sample:

Once the sightings data has been collected, calculation of the ratio of the two species is extremely rapid. Similarly for the strandings data.

Amount of staff time required to analyse & interpret a single sample:

Analysis and interpretation of a single sample can be done in seconds for an individual sightings route. To be effective, analysis and interpretation will need to be undertaken on a regional or national basis, which is also a fairly rapid process once the data has been collected. Similarly for the strandings data.

Amount of staff time required to QA / QC data from a single sample:

This is done during data entry, which is part of processing.

5.2 Review of indicators against ecosystem structure & function aspects and identification of gaps

As top predators, it is generally thought that abundance of cetaceans should indirectly represent good health status in the marine environment. Changes in population growth rates are the result of increased mortality due to incidental capture and disease, a decline in prey resource availability, or a decline in reproductive output due to anthropogenic toxins and disease. However, a rapid decline in abundance is likely to reflect a natural catastrophic event or deleterious anthropogenic influence, of which the former are usually easily and rapidly identified. Three potential indicators are identified to represent ecosystem structure and function:

- the abundance and usage of core areas by bottlenose dolphins (*Tursiops truncatus*),
- the abundance of harbour porpoise (*Phocoena phocoena*) and
- temporal changes in reproductive parameters using post-mortem data for common dolphin (*Delphius delphis*) and harbour porpoise.

5.2.1 Indicator for ecosystem structure and function: Abundance and usage of core areas by bottlenose dolphins (*Tursiops truncatus*)

Under Article 4 of the Habitats Directive there is a requirement, where certain conditions are met, to protect [common] bottlenose dolphins and harbour porpoises through the development of Special Areas of Conservation (SACs) as part of the Natura 2000 network. The sites are graded A (15-100% of national population) to D (non-significant presence). Where designated A to C, assessment of sites were required and undertaken in 2006. The UK has a number of sites graded D for both species (23 for harbour porpoises and 7 for [common] bottlenose dolphins), but only three sites graded C or above for [common] bottlenose dolphins: Moray Firth (northeast Scotland), Cardigan Bay (west Wales) and the Lleyn Peninsula and the Sarnau (west Wales). Monitoring of the favourable conservation status of these sites is required on a six yearly basis. Hereafter, the term Cardigan Bay is taken to cover the wider area of the bay incorporating both the SACs in west Wales.

Common Standards of Monitoring (CSM) were developed during 2005 for [common] bottlenose dolphins (JNCC, 2005). The criteria for assessment are based primarily on abundance within the SAC and use of the area. Population estimates for the Moray Firth are currently 111 individuals (95% CI: 92-160) and considered to be stable, although numbers in the SAC vary considerably from year to year with individuals ranging down the NE Scottish coast as far as the Firth of Forth (Thompson *et al* 2006). For Cardigan Bay, the abundance estimate is 248 (95% CI: 231-277) and considered to be stable or possibly increasing slightly although numbers also vary considerably from year to year (Ugarte & Evans, 2006; Peasante *et al* 2008a). These individuals are known to range widely, in both a southerly and northerly direction (Wood, 1998; Peasante *et al* 2008b).

Scientific evaluation of Tursiops truncatus abundance and usage indicator

Sensitivity: Does the indicator allow detection of any type of change against background variation or noise?

[Common] bottlenose dolphin abundance and distribution in the Moray Firth and/or Cardigan Bay is a measure of state rather than linked to a particular pressure directly. Numbers of individual dolphins using the SAC is deemed essential to assessing the condition of the feature. A site would be in favourable conservation status if numbers using the SAC stay within or above the normal level of variation. Short-term fluctuations may occur and also need to be allowed for – one estimate of numbers outside the normal level of variation should trigger further work to determine whether there was a temporary or permanent change in numbers.

Accuracy: Is the indicator measured with a low error rate?

The most effective way to assess the number of individual dolphins using the SAC and surrounding areas is to use mark-recapture methods applied to photo-identification data. Abundance from photo ID is measured with a low coefficient of variation (CV, usually less than 0.15). In addition it is also possible to use shore or boat-based visual surveys and passive acoustic surveys.

Specificity: Does the indicator respond primarily to a particular human pressure, with low responsiveness to other causes of change?

Bottlenose dolphin abundance and area usage in the Moray Firth and/or Cardigan Bay is a measure of state rather than linked to a particular pressure directly. Changes in population growth rates are the result of increased mortality due to incidental capture and disease, a decline in prey resource availability, or a decline in reproductive output due to anthropogenic toxins and disease. A rapid decline in abundance is likely to reflect a natural catastrophic event or deleterious anthropogenic influence, of which the former are usually easily and rapidly identified.

Performance:

a Simplicity: Is the indicator easily measured?

Abundance and usage is measured using standard techniques (Thompson *et al* 2004, 2006; JNCC, 2005; Bailey *et al* in press).

b Responsiveness: Is the indicator able to act as an early warning signal?

Bottlenose dolphins are long lived (up to 50 years), reach maturity late (around 10 years) and reproduce slowly (approx. 5% yr; Wilson *et al* 1999b). Natural fluctuations in the size of bottlenose dolphin populations, in the absence of significant emigration and immigration, are likely to occur slowly. Consequently, population dynamics are most sensitive to changes in adult survival rate and, to a lesser extent, sub-adult survival rate. These life history parameters can be studied using analysis of photo-identification data and used as input to a population model to predict the overall rate of population growth (Sanders-Reed *et al* 1999).

This indicator can act as an early warning for major changes, but due to the time lags involved, more subtle effects will take longer to detect.

c Spatial applicability: Is the indicator measurable over a large proportion of the geographical to which the indicator metric it to apply to, e.g. if the indicator is used at a UK level, is it possible to measure the required parameter(s) across this entire range or is it localised to one small scale area?

Monitoring is restricted to the core areas of the semi-resident inshore populations, rather than specifically to SAC boundaries, in Wales and NE Scotland. Such monitoring would contribute to the wider surveillance of cetaceans as required by the Habitats Directive.

d Management link: Is the indicator tightly linked to an activity which can be managed to reduce its negative effects on the indicator, i.e. are the quantitative trends in cause and effect of change well known?

Additional assessment studies would be needed to elucidate which of the likely activities or pressures is causing the observed rapid decline in abundance. The more obvious anthropogenic activities are bycatch, pollutants (both chemical and noise), and prey availability; all of which can be managed to reduce negative effects by UK Government and/or the Devolved Administrations as appropriate.

e Validity: Is the indicator based on an existing body or time series of data (either continuous or interrupted) to allow a realistic setting of objectives?

The University of Aberdeen have been studying the bottlenose dolphin population in the Moray Firth since 1989. In 2004, Scottish Natural Heritage signed a Memorandum of Agreement with the University of Aberdeen to monitoring the bottlenose dolphins within the Moray Firth SAC until 2012. Photo-ID has been used to estimate population size, follow the movements of individual dolphins and study their social behaviour and reproduction (e.g. Hammond & Macleod, 1991; Janik & Thompson, 1996; Sanders-Reed *et al* 1999; Hastie *et al* 2004; Wilson *et al* 2004; Stockin *et al* 2006). Monitoring of abundance and survival of animals using Photo-ID is ongoing (e.g. Thompson *et al* 2006). Acoustic static monitoring (T-Pods) is being used to determine the frequency with which dolphins use some parts of the SAC (Bailey *et al* in press). Current research also includes factors affecting the distribution of dolphins within the SAC and the effects of disturbance on dolphins.

In contrast, the dolphins of Cardigan Bay are less well studied; although work has been conducted on cause of mortality in stranded individuals (Kirkwood *et al* 1997), the uptake of organochlorine pollutants (Law *et al* 1995) and, more recently, distribution and habitat use (Baines *et al* 2002; Evans *et al* 2002). Up to the 2008 field season, CCW contracted the Sea Watch Foundation to monitor bottlenose dolphins, harbour porpoises and other marine mammals in the Cardigan Bay and Pen Llyn ar Sarnau SACs to provide information on abundance trends and site usage. They also studied the interactions between bottlenose dolphins and harbour porpoises, which have increased in recent years leading to porpoise mortalities.

f Relatively easy to understand by non-scientists and those who will decide on their use?

There is a general public concern, including substantial NGO work and media attention of these charismatic species. A decline in a particular population is easy to understand, although it may take time to elucidate the causes of that decline.

Economic evaluation of Tursiops truncatus abundance and usage indicator:

Platform requirements:

Requires use of small inshore vessel (e.g. RHIB) although some work can be done from the shore.

Equipment requirements for sample collection:

Binoculars and suitable photographic equipment are required.

Amount of staff time required to plan collection of a single sample:

The monitoring effort is planned on an annual basis to enable sufficient coverage the SAC and surrounding areas.

Amount of staff time required to collect a single sample:

A single sample is considered to equate to a field season, approximately 20-50 days for three people.

Amount of staff time required to process a single sample:

Analysis of the field season data takes several weeks, depending on the level of information required.

Amount of staff time required to analyse & interpret a single sample:

Analysis and interpretation is undertaken on an annual basis but is reasonably rapid once processing has been completed.

Amount of staff time required to QA / QC data from a single sample:

Undertaken during data entry which is part of processing.

5.2.2 Indicator for ecosystem structure and function: harbour porpoise abundance

The harbour porpoise is the most numerous and widespread cetacean in continental shelf waters of northwest Europe. Porpoises are found throughout UK shelf waters, but are most abundant in the north and west and rather uncommon in the English Channel. They are also present on Rockall Bank and are occasionally recorded in deeper waters beyond the shelf edge (Figure 6; Reid *et al* 2003; MacLeod *et al* 2007).

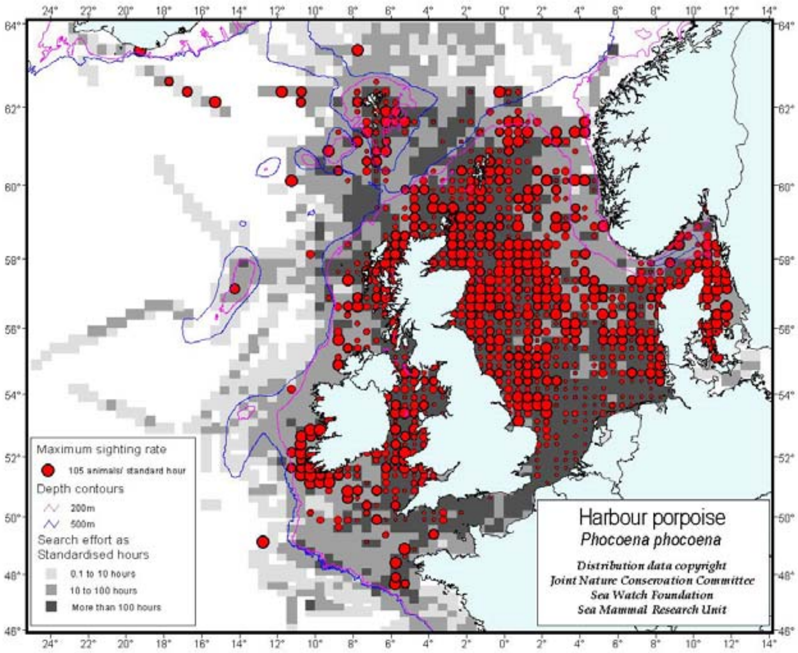

Figure 6. Distribution of harbour porpoise in north east Atlantic waters (From Reid *et al* 2003).

Abundance estimate for the European continental shelf is 385,600 (95% CI: 261,300-569,200) (SCANS II, 2008). SCANS 1994 survey estimated the abundance to be 341,400 (95% CI: 260,000-449,000) for the North Sea and adjacent waters (Hammond *et al* 2002). In 2005, SCANS II estimated the abundance in a similar area to be 315,000 (95% CI: 201,500-395,100) (SCANS II, 2008). There is no evidence for a change in the population over the last decade in UK waters. However, between the two SCANS surveys there has been a significant southerly shift in the species within both the North and Celtic Seas.

Historically, abundance/range is thought to have declined during the 20th century in some areas such as the central and southern North Sea and English Channel (e.g. Smeenk 1987; Evans, 1992). However, porpoise numbers in these areas have been increasing in the last few years. Results from the SCANS II survey show an increase in porpoise sightings in the southern North Sea and English Channel (Hammond and McLeod 2006). In addition, countries such as France, Belgium and the Netherlands have been reporting increased numbers of reported stranded harbour porpoises (Camphuysen 1994; Haelters & Jacques 2006; Hassani 2006; ASCOBANS 2006). Sightings records have also indicated an increase in harbour porpoise abundance in southern UK waters (Evans *et al* 2003). Although it is not possible to detect trends from only two surveys separated by a decade (SCANS and SCANS II), the fact that the numbers estimated from the two surveys are not statistically different suggests that population numbers have remained relatively stable in the last decade in UK waters but that there has been a shift with fewer individuals in the northern North Sea and more in the southern North Sea.

As the most numerous of the cetaceans in UK waters and as a top predator, abundance should represent good health status in the marine environment. Currently however, there are no systematic annual assessments of harbour porpoise abundance in place.

Scientific evaluation of harbour porpoise abundance indicator.

Sensitivity: Does the indicator allow detection of any type of change against background variation or noise?

Where surveys are undertaken using similar techniques (platforms etc) at the same time of year, then changes can be detected against background noise where there is sufficient effort.

Accuracy: Is the indicator measured with a low error rate?

A variety of techniques have been used to assess abundance including vessel-based or aerial visual surveys and passive acoustic surveys. With sufficient effort, error rates are low. For European data, power analysis was undertaken on the SCANS 2 data comparing dedicated cetacean observers with seabird observers, acoustic surveys using towed hydrophones and aerial surveys for abundance estimates of harbour porpoise. For the same survey effort, highest power was achieved by the cetacean and seabird observers with 77-78% power to detect a 5% annual decline over a 10 year period (equivalent to approximately 37% decline overall) with annual surveys. Almost twice as much effort was required in aerial surveys to achieve a similar level of power.

It should be born in mind that these are for large scale surveys being used to estimate absolute abundance. The requirements for an annual estimate of relative abundance would be less.

Specificity: Does the indicator respond primarily to a particular human pressure, with low responsiveness to other causes of change?

This indicator is one of ecosystem structure and function rather than being related to a particular pressure. Harbour porpoises are affected by a variety of human activities including bycatch, chemical pollution, offshore industries, noise disturbance and prey availability. In a particular locality one pressure maybe significant over others. However, at a European scale, bycatch can be considered the most significant pressure on this species.

Performance:

a Simplicity: Is the indicator easily measured?

Abundance is measured using standard techniques (e.g. SCANS II, 2008).

b Responsiveness: Is the indicator able to act as an early warning signal?

Harbour porpoises live for approximately 12 years, although animals up to 24 years old have been recorded, and they reach sexual maturity at about 3-5 years (Evans, 2008). In UK waters, calves are born at intervals of two or more years. Consequently, population dynamics are most sensitive to changes in adult survival rate and so can act as an early warning for changes, although more subtle effects will take longer to detect.

c Spatial applicability: Is the indicator measurable over a large proportion of the geographical to which the indicator metric it to apply to, e.g. if the indicator is used at a UK level, is it possible to measure the required parameter(s) across this entire range or is it localised to one small scale area?

Monitoring occurs on a European Atlantic shelf basis (e.g. SCANS I and II). Currently no systematic scheme of monitoring is in place, but surveillance of cetacean populations on a regular basis is required by the Habitats Directive and currently under development by JNCC.

d Management link: Is the indicator tightly linked to an activity which can be managed to reduce its negative effects on the indicator, i.e. are the quantitative trends in cause and effect of change well known?

Additional assessment studies would be needed to elucidate which of the likely activities or pressures is causing the observed rapid decline in abundance. The most obvious anthropogenic activity is bycatch which is closely linked to management. It should be noted, however, that except for fishing in the 0-6 nautical mile limit and for UK vessels operating in 6-12 nm, competency for fisheries management lies with Europe and the Common Fisheries Policy rather than the UK government or Devolved Administrations. Others anthropogenic pressures are pollutants (both chemical and noise), and prey availability; all of which can be managed to reduce negative effects by UK Government and/or the Devolved Administrations as appropriate.

e Validity: Is the indicator based on an existing body or time series of data (either continuous or interrupted) to allow a realistic setting of objectives?

Besides the large scale SCANS surveys which provide the best baseline for the indicator, there is also an existing body of sightings records collected by a variety of non-governmental organisations. These are predominantly collated by the Seawatch Foundation.

At a more local scale, in recent years, CCW contracted the Sea Watch Foundation to monitor harbour porpoises and other marine mammals in the Cardigan Bay and Pen Llyn ar Sarnau SACs to provide information on abundance trends and site usage. As part of this work, the interactions between bottlenose dolphins and harbour porpoises were also examined, which have increased in recent years leading to porpoise mortalities.

f Relatively easy to understand by non-scientists and those who will decide on their use?

There is a general public concern, including substantial NGO work and media attention on cetaceans. A decline in a particular population is easy to understand, although it may take time to elucidate the causes of that decline particularly if not associated with bycatch.

***Economic evaluation of harbour porpoise abundance indicator*:**

Platform requirements:

Dependant on the scale of monitoring undertaken, platform requirements vary from shore-based sightings surveys through small inshore vessels (e.g. RHIB) to larger vessels or planes.

Equipment requirements for sample collection:

Binoculars are required.

Amount of staff time required to plan collection of a single sample:

Currently no systematic monitoring scheme is in place for this species. However, it is expected that this will be planned on an annual basis, taking several days.

Amount of staff time required to collect a single sample:

A single sample is considered to equate to annual data collection. Depending on the platforms used, this will take several months.

Amount of staff time required to process a single sample:

Analysis of the annual data takes several weeks, depending on the level of information required.

Amount of staff time required to analyse & interpret a single sample:

Analysis and interpretation is undertaken on an annual basis but is reasonably rapid once processing has been completed.

Amount of staff time required to QA / QC data from a single sample:

Undertaken during data entry which is part of processing.

5.2.3 Indicator for ecosystem structure and function: Assessing temporal changes in reproductive parameters using post-mortem data

Estimates of reproductive parameters in marine mammals can be used to assess changes in dynamics of populations as a result of incidental bycatch and/or climate change. Further, they allow assessment of the long-term effects from anthropogenic toxins, such as PCBs and DDT, and infectious disease outbreaks on reproductive out at the individual and population level. Although evidence is extremely limited at this time, it is thought that anthropogenic noise may also affect reproductive rates (Wright *et al* 2007).

To date within UK waters, population/stock reproductive parameters have been determined for common dolphins and harbour porpoises using post mortem data (Learmonth, 2006; Murphy, 2008; Murphy *et al* 2009). These data have been used to determine the effects of incidental capture in pelagic trawl fisheries on the common dolphin population in the Northeast Atlantic as part of the EC NECESSITY project; the effects of anthropogenic toxins on reproductive output in both species as part of the EC BIOCET and ASCOBANS funded projects; and incorporated into the production of bycatch mortality limits for harbour porpoises and common dolphins as part of the EC-LIFE SCANS II and CODA projects, respectively. An assessment of available data for other species has not been undertaken.

As part of the UK Cetacean Stranding Investigation Program (CSIP), cause of death and nutritional condition of individuals are investigated. Teeth, ovaries and testes are collected for subsequent analysis assessing reproductive parameters such as maturity status and age. These data allow an assessment of temporal variations in: population pregnancy rates, proportion of mature individuals, proportion of females simultaneously pregnant and lactating, average age attained at sexual maturity, nutritional condition, length and timing of the oestrus period, and variations in reproductive parameters with age. Temporal variations in the above parameters can occur due to alterations in the availability of prey resources and population density. Cetacean populations are regulated through density-dependent changes in reproduction and survival, and it has been proposed that food resources are the main causative agent in the expression of density dependence, resulting in an increase in population growth rates (and reproductive output) at low densities (e.g. following large scale incidental mortality in fishing gear) and a decrease in growth rates (and reproductive output) at high densities.

Knowledge of extrinsic factors such as bycatch rates and contaminant loads are required to give context to cross-sectional life history information. Anthropogenic toxins and disease can alter reproductive rates by decreasing fertility, and causing abortions, premature parturition and neonatal mortality.

Although largely ignored as an important part of the monitoring requirements under the Habitats Directive, the monitoring of changes/trends in life history parameters can also be used as a measure of conservation status. The regular monitoring of reproductive rates in common dolphins and harbour porpoises would therefore contribute significantly to our assessments of favourable conservation status. Additionally, the UK as obligations under ASCOBANS to monitor conservation status, including assessment of population dynamics.

Scientific evaluation of reproductive parameters indicator

Sensitivity: Does the indicator allow detection of any type of change against background variation or noise?

Reproductive parameters can be used as an indicator of a change in population growth rates, either as a result of increased mortality due to incidental capture and disease, a decline in prey resource availability, or a decline in reproductive output due to anthropogenic toxins and disease. Due to the natural life history of cetaceans and the need for sufficient samples, the pregnancy rate is likely to be re-estimated every five years rather than annually.

Accuracy: Is the indicator measured with a low error rate?

Although the pregnancy rate is easily measured, power analysis suggested that extremely large variations in the common dolphin pregnancy rate of the Northeast Atlantic population would have to occur, in order to detect a statistically significant increase or decrease in the pregnancy rate (Murphy *et al* 2009). At a power of ≥80%, and an initial pregnancy rate of 25%, a sample size of >150 mature females would be required to detect an absolute decline of >13% in the pregnancy rate, whereas a sample size of >100 mature females would detect a decline >16%. A sample size of 50 mature females however, would only detect a decline of >20% (pregnancy rate at 0.05 or below) and at a lower power of 72%. In contrast, if an increase occurred in the pregnancy rate, a sample size of >150 mature females would be needed to detect a >16% increase in the pregnancy rate at a power of ≥80%. It should be noted that changes in pregnancy rate may become biologically significant before they can be detected statistically. Furthermore, it has been reported in other studies that adequate age and reproductive data from males and females (at least 50 individuals of each sex) are also vital for estimating the average age attained at sexual maturity.

Obtaining such a large sample size of sexually immature and mature individuals is difficult, and requires that European stranding and observer bycatch programmes continue sampling all available and suitable carcasses. One compromise would be to alter the criteria used for significance. Many managers remain unaware that the standard criteria usually used for significance (i.e. the risk of a type 1 error occurring; α=0.05) is not an objective scientific value but a policy choice based on the most commonly used level of statistical significance (Taylor & Gerrodette, 1993). Where the power of a monitoring scheme (e.g >80%, $\beta = 0.2$) to detect change is different from the level of significance (e.g. 0.05) there is an imbalance in the risks of under and over protection. Using a lower significance level of 0.2, a power of ≥80%, and an initial pregnancy rate of 25%, a sample size of only 50 mature females would be required to detect an absolute decline of >16% in the pregnancy rate, and an absolute increase of >20% in the pregnancy rate.

Specificity: Does the indicator respond primarily to a particular human pressure, with low responsiveness to other causes of change?

This indicator responds to three main factors that alter population densities: incidental capture (bycatch), prey availability and pollutants. However, in order to interoperate reproductive data correctly, population abundance estimates, trends in abundance and data on parameters that affect the dynamics of the population, such as annual mortality rates in fisheries, temporal variations in prey abundance and levels of anthropogenic toxins are required.

Performance:

a Simplicity: Is the indicator easily measured?

It requires an assessment of the cause of death, nutritional condition, and the status of reproduction tract and organs during post mortem examinations. Age determination using teeth samples and gross and histological examination of gonadal material are undertaken during subsequent analysis. Once data are available, estimating population pregnancy rates and other reproductive parameters is relative straight forward.

b Responsiveness: Is the indicator able to act as an early warning signal?

For both common dolphin and harbour porpoises, this depends on the sample size autopsied on an annual basis by the CSIP. Based on the CSIP sampling in 2008 of 41 common dolphins and 69 harbour porpoises (including both males and females), insufficient sampling prevents the assessment of the indicator for that year. Combining data from the CSIP with data from other European stranding projects, would allow an assessment of the reproductive parameter indicator on a five year basis.

Additionally, and due in part to the age at which sexual maturity is reached, it is unknown how quickly population changes would be detected if, for example, one third of the population was eliminated. In other parts of the world harbour porpoises can produce annually, but in UK waters approximately 40% of mature females tend to breed in any one year.

c Spatial applicability: Is the indicator measurable over a large proportion of the geographical to which the indicator metric it to apply to, e.g. if the indicator is used at a UK level, is it possible to measure the required parameter(s) across this entire range or is it localised to one small scale area?

For common dolphins and harbour porpoises, these indicators can be used at a UK level. Though for both species, their population/stock distributional range extends beyond UK waters.

d Management link: Is the indicator tightly linked to an activity which can be managed to reduce its negative effects on the indicator, i.e. are the quantitative trends in cause and effect of change well known?

Complete biological assessments studies would be needed to elucidate which of the likely activities or pressures is causing the observed change in pregnancy rate. This indicator is linked to levels of bycatch and anthropogenic toxins in the environment, as well as prey availability; all of which can be managed to reduce negative effects. However, management responsibilities may not lie within the UK government or Devolved Administrations. For example, with the exception of fishing in the 0-6 nautical mile limit and for UK vessels operating in 6-12 nm, competency for fisheries management lies with Europe and the Common Fisheries Policy.

e Validity: Is the indicator based on an existing body or time series of data (either continuous or interrupted) to allow a realistic setting of objectives?

As part of the UK cetacean stranding investigation programme, post mortem examinations have been undertaken on marine mammals since the early 1990s. Teeth have been processed for age determination, and gonadal material for assessing biological reproductive parameters, as part of numerous UK and EC funded projects. Currently, samples are collected and stored, but no analysis is ongoing.

f Relatively easy to understand by non-scientists and those who will decide on their use?

Change in population status and pregnancy rate is relatively easy to understand. As more food becomes available, then pregnancy rates increase. This can be altered by pollutants, disease etc. With the wealth of material in the media, human analogy to this indicator enables easy comprehension. It is the linkages between the potential causes of change that is more complex and difficult to grasp, particularly as a number of the factors could be having a synergistic effect.

Economic Evaluation of biological parameter indicator:

Platform requirements:

Post mortem examinations and sample collection are already undertaken by the UK cetacean stranding investigation programme. Subsequent laboratory analysis for assessing biological parameters, including age determination and gross and histological examination of gonadal material requires payment of researcher’s time and laboratory costs.

Equipment requirements for sample collection:

Sample collection is already undertaken as part of the UK cetacean stranding investigation programme.

Amount of staff time required to plan collection of a single sample:

Sample collection is already undertaken as part of the UK cetacean stranding investigation programme.

Amount of staff time required to collect a single sample:

A single sample is considered to equate to one stranded or bycaught animal.

Amount of staff time required to process a single sample:

Analysing of biological samples (including processing teeth and gonadal samples for histopathology) from one individual is undertaken over a period of days, to a maximum of two weeks.

Amount of staff time required to analyse & interpret a single sample:

Gross assessment of ovaries (counting corpora scars – of ovulation and pregnancy) and examination of histological slides of teeth (age determination) and gonadal (testes and ovaries) samples from a single individual can be undertaken within a period of hours to days.

Amount of staff time required to QA / QC data from a single sample:

This is undertaken during laboratory analysis and data entry, which is part of processing.

5.3 Review of indicators against policy obligations and identification of gaps

The key policy obligations for cetaceans come from the Habitats Directive, EU Regulation 812/2004 and, more recently, MFSD. The UK also has additional obligations as a contracting party to ASCOBANS. Section 3.4 gives further detail on the specific obligations for cetaceans, but in summary they require the development of a monitoring and surveillance scheme, assessment of causes of incidental killing and capture and, more specifically, assessment of bycatch, and the recording of strandings. Much of this work is already provided through various government schemes, for example, the UK Cetacean Strandings Investigation Programme and the UK Bycatch Monitoring Scheme.

The UK is unique among European countries in the degree and sophistication of our volunteer contribution to surveillance. This includes a long history of biological recording that has generated a number of specialist groups, including a significant number dedicated to cetaceans. Currently, these organisations provide substantial quantities of data through volunteer work. However in 2005, the European Court of Justice (ECJ) started legal proceedings against a number of Member States in relation to failures to implement cetacean monitoring programmes as required under the Habitats Directive. In summary, cetacean surveillance programmes operated by voluntary groups and/or reliance on the decadal SCANS surveys were not considered adequate under the monitoring requirements of the Habitats Directive. The ECJ concluded that monitoring must be undertaken systematically, on a permanent basis (i.e. have an element of public funding) and cover all species of cetacean.

Consequently, the most significant gap the UK has in implementing its policy obligations is a systematic surveillance and monitoring scheme. Such a strategy is currently under development by JNCC as part of the UK Marine Monitoring and Assessment Strategy (UKMMAS), through collaboration with the other Countryside Agencies and the Sea Mammal Research Unit (University of St Andrews). The strategy takes a 'natural' population approach and JNCC are therefore discussing how to take an internationally co-ordinated approach with other Member States through ICES and ASCOBANS. In addition, mechanisms are being developed that will enable as much of the cetacean surveillance undertaken in European waters by agencies, research bodies and the voluntary sector to be included and used in the conservation status assessments.

6 Conclusions and recommendations

6.1 Database report tables

See 'annex 1 CETACEANS pressures.xls' and 'annex 2 CETACEANS struc_func.xls' respectively for the database report tables associated with pressures and ecosystem structure and function respectively.

6.2 Identification of an effective indicator set

See 'annex 3 CETACEANS conclusions table.xls' for the effective indicator set identified for cetaceans. The most important indicator and, currently the only pressure related one in operation, is that associated with bycatch. A number were also developed for different chemical contaminants, ecosystem structure and function and also a single indicator for climate change. With many of these, a good understanding of natural variations in distribution and abundance, and a variety of other biological parameters would greatly improve their applicability. It should be noted that these potential indicators are speculative and would require validation prior to their implementation.

6.3 Recommendations for areas of development to address significant gaps

The monitoring and indicator requirements for cetaceans need to encompass:

- Accurate assessment of distribution and abundance. Currently there is no systematic evaluation in place, although volunteer work is ongoing (e.g. ARC commercial ferry surveys).
- Assessment of threats to cetaceans including significant causes of death (currently provided by CSIP but needs further development)
- Monitoring of bycatch (currently provided by UK Bycatch monitoring scheme)

With cetaceans it is often difficult to link cause and effect, and to distinguish natural from human impacts on the species. The implementation and refinement of a strategic monitoring and surveillance programme will be essential to meet the requirements of the EC Habitats Directive and the MSFD. This will need to advocate a coordinated transboundary approach due to the wide ranging and highly mobile nature of cetaceans. A better understanding of the abundance and distribution patterns of cetaceans, including any existing persistent seasonal variations, as well as basic life history parameters for most species (growth rates, age at sexual maturity, reproductive rates and mortality) would help determine the magnitude of any impacts to populations and also potentially aid industry in reducing the risk of impacts.

The UK has one of the best bycatch observer schemes in Europe (European Commission, 2009). However, the fisheries, where cetacean bycatch is greatest, do not require monitoring under EU Regulation 812/2004. Initial investigations of such fisheries have been undertaken in recent years. Continuation and expansion of such work will inform possible management measures, which will need to be implemented at a European rather than national level. Work will also need to continue on assessing the effectiveness of acoustic deterrent devices in fisheries.

Other anthropogenic activities that generate noise will need to be characterised. This includes work looking at noise transmission in different sea areas and environmental conditions (e.g. topography, salinity, wave patterns etc) and the potential impacts on cetaceans. The possible synergistic effects of chronic exposure of cetaceans to various environmental pollutants will also require further consideration.

It is considered unlikely that any single current pressure in itself could affect the long term viability of any particular cetacean species in UK waters, although some pressures may be more acute than others at a local scale. It is the cumulative impact of a variety of pressures that is of greater concern and which may affect the long term viability of some species.

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