EXECUTIVE SUMMARY OF THE IWC SCIENTIFIC COMMITTEE WORKSHOP ON INTERACTIONS BETWEEN MARINE RENEWABLE PROJECTS AND CETACEANS WORLDWIDE

This workshop met at the El Panama Hotel, Panama City, Panama June 8-10, 2012.

The Scientific Committee of the IWC has over the last few decades developed research programmes and workshops on environmental subjects. Recently it started to consider marine renewable energy developments noting that they are increasing rapidly worldwide and that baseline data on the impact of interactions with cetaceans are lacking. This workshop aimed to identify research needs and formulate recommendations for research, monitoring, conservation and management.

A variety of marine renewable energy devices (MREDs) are being deployed around the world, with the highest concentrations in the northern hemisphere, especially in northern Europe. The three main forms of MREDs are wind farms, tidal-stream driven devices and wave energy converters. Each of these, as well as the supporting infrastructure, have potential for interaction with cetaceans during the construction, operation and decommissioning phases. The possible interactions include the impact of noise, collisions and entanglements in tethering lines.

The workshop considered in particular the current state of development of marine renewable energy in waters off Germany, the United Kingdom, Belgium and the United States. For the identification of the effects of construction and operation of wind farms, tidal devices and wave energy, the workshop drew on/ used a background document based on the work of the International Council for the Exploration of the Seas (ICES) Working Group on Marine Mammal Ecology.

The main recommendations from the workshop are:

1. **Strategy to minimise risk**

   Risks from both lethal and sub-lethal effects can be minimised via a series of actions: the collection, collation and analysis of appropriate baseline cetacean data and appropriate industrial data will allow the identification and quantification of threats and their potential implications for conservation objectives. All stakeholders need to be involved from the outset such that impacts from all factors are considered, ensuring that appropriate mitigation measures and associated monitoring programmes are developed. Suitable scientific evaluation and compliance mechanisms are needed to ensure that mitigation and monitoring are adequate.

2. **Broad management**

   Governments, managers and other stakeholders need to co-operate in strategic planning for MREDs taking into account the trans-boundary nature of cetaceans. Uncertainties over the level of impacts require a staged approach to developments taking into account lessons learned from other developments and other human activities that affect cetaceans, in order to be adequately precautionary.

3. **"Fundamental" research**

   International collaboration will be required to determine population structure, status, distribution and procedures for assessing impacts. The Committee can assist with design and evaluation of population and impact assessments. While there are established methods for assessing lethal takes, data on the effects of (sub-lethal) stressors on cetaceans are also needed.

4. **Evaluation of threats**

   All lethal and non-lethal impacts of human activities should be considered in an integrated manner, e.g. using modelling approaches that take into account the cumulative impacts from all threats when evaluating whether conservation objectives are likely to be met. The Committee has considerable expertise in developing management frameworks and testing their performance against specified objectives.

5. **Monitoring**

   Monitoring should be designed carefully, to assess impacts against pre-determined conservation objectives and to measure the efficacy of any mitigation measures that are implemented.

6. **Data sharing and the future role of the IWC Scientific Committee in the consideration of MREDs**

   Improved information and data-sharing were identified as key, and the workshop encouraged the Committee to continue to act as a forum to review the development of MREDs and their implications for cetaceans, including promoting the sharing of data. Countries were encouraged to help in this by providing appropriate information.

IWC SCIENTIFIC COMMITTEE WORKSHOP ON INTERACTIONS BETWEEN MARINE RENEWABLE PROJECTS AND CETACEANS WORLDWIDE

This workshop met at the El Panama Hotel, Panama City, Panama, June 8-10, 2012. There were 28 participants representing 15 countries. A list of participants is given in Appendix 1.

1. Introductions and background to the workshop

1.1 Introductory comments

As convener and chair of the workshop, Mark Simmonds welcomed all the participants, especially those that had travelled long distances to attend the meeting. He thanked the Secretariat for helping to find the funds that had allowed the workshop to take place, and Julie, Mark, Greg and Simon for their excellent logistical support. He described the recent history of the Committee with respect to environmental issues, noting that it was in 1973 that the first regular environmental agenda item – "Effect of pollution on whale stocks, including small cetaceans" – was placed on its agenda. Environmental work by the Committee has also been underpinned by a number of relevant Commission resolutions and responses, one of which (IWC, 1997a) established the Standing Working Group on Environmental Concerns. In 1997, the Committee developed two long-term, collaborative, multi-disciplinary, multinational research programmes. The first, on contaminants in whales, became the POLLUTION 2000+ project. The second focused on how climate change effects on temporal and spatial variability in the physical and biological Antarctic environment influence the distribution, abundance and migration of whales. In 1998, the Committee identified two further priority areas for research: (i) effects of habitat degradation on cetaceans and (ii) effects of environmental change on Arctic cetaceans.

Simmonds added that the Committee has also held a series of environmentally-focused workshops, including one on climate change and cetaceans held in Hawaii, USA, in March 1996 and another in Siena, Italy, on habitat degradation in 2005. A second workshop on climate change met in Siena in 2009, followed by a third IWC workshop on the same theme, but focused exclusively on small cetaceans, which was held in Vienna, Austria, in 2010. This current workshop in Panama is thus the latest in a series of environmentally-themed workshops.

The topic of marine renewable energy developments (MREDs), which we define here as all renewable energy installations deployed in marine, estuarine and/or coastal environments, has been considered by the Committee for several years and the rapid increase in developments across the world has been highlighted, along with possible implications for cetaceans (Simmonds and Brown, 2010). The Committee had noted that wind farms have greatly increased in size and are moving further offshore with considerable associated infrastructural development, including ports, service vessels and cable laying. Last year, the Committee noted that interactions with cetaceans were inevitable but, in many respects, poorly characterised and that, typically, adequate baseline data have not been obtained prior to development (IWC, 2012). The Committee agreed to hold a pre-meeting workshop on this topic and an intersessional planning group elaborated its draft agenda and participants list. Simmonds noted that the pre-meeting workshop was intended to consider the potential effects of MREDs on cetaceans (e.g. injuries; masking; behavioural changes), available information (including modelling approaches) and mitigation measures and adaptive management to address this. The workshop sought to develop procedures to coordinate and collate standardised effect measurements of marine renewable developments on cetaceans, and it will identify research needs and formulate recommendations for research, monitoring, conservation and management.

1.2 Appointment of rapporteurs and other meeting arrangements.

Andrew Wright was appointed rapporteur, with assistance from Meike Scheidat and others, as required.

Further to the introductory presentations described below, the workshop worked via a series of small topic groups. These groups reviewed the papers and other submissions that had been made available to the meeting (Appendix 2) in relation to the following topics (topic group leaders in parentheses): the three main types of MREDs (wind (Gero Vella), wave (Klaus Lucke), and tidal/current-driven (Ben Wilson)); supporting infrastructure (including operational and decommissioning issues) (Naomi Rose); monitoring, mitigations and adaptive management (Chris Parsons); noise and disturbance (including aversive sounds) (Lindy Weilgart); cumulative concerns (Andrew Wright); modelling approaches (including the identification of important habitat areas) (Leslie New); and overarching recommendations (Greg Donovan). Russell Leaper led a further discussion on monitoring.

2. Introductory presentations

2.1 An introduction to MREDs and their distribution

Simmonds outlined the current distribution of MREDs around the world noting that the greatest concentrations (an estimated 97%) were currently in the northern hemisphere and especially in northern Europe, compared to a relatively small number of developments in the south. He noted that the scale of some proposed developments was now very large; for example, the Round 3 wind farms proposed for UK waters (Simmonds and Brown, 2010).

Ben Wilson and Simmonds then described the range of technologies currently being developed.

WIND POWER

Having had several decades of onshore refinement, the overall features of offshore wind turbines are generally similar to one another. Most commonly a wind turbine consists of three rotors on a horizontal axis hub and nacelle (gearbox and generator unit) mounted on top of a slender tower. The size of turbines offshore, however, differs from their terrestrial equivalents with 3.6 to 7 MW devices being used compared to 2.5 MW or less on land. With fewer spatial constraints offshore, the sizes of these turbines are likely to increase in the future. A few other turbine concepts for capturing wind energy are being developed but are likely to remain in the minority in the medium-term future.

A variety of foundation types have been developed and used. These include: *Monopiles* which are large steel pipes driven into the seabed and typically used in areas where water depths are a few tens of meters or shallower. These foundations typically use pile driving to punch these foundations into the seabed with the consequent production of marine noise. As larger turbines are developed and deployed, the diameter of the piles is also increasing along with the noise associated with installation; *Tripod, Triple* and *Jacket foundations* are generally used at greater depths with their individual feet anchored using smaller diameter piles than the monopile designs. Alternatives to piled structures are being progressed that do not require significant seabed piercing. These include *Gravity foundations* which consist of a large and heavy base constructed from either concrete or steel and *Floating structures* that are secured using anchors and chains. Floating structures have the notable feature of being less depth constrained and so can be placed in deeper water (50 m or more) and consequently greater distances from shore.

TIDAL-STREAM GENERATORS (or Tidal Energy Converters)

Unlike wind turbines, of which there are relatively few variations, a wide variety of tidal-stream energy device concepts are being developed in parallel (>70 at present). Designed to capture the kinetic energy of water flow associated with tides, these range from submarine versions of the common wind-turbine concept (three bladed, horizontal axis turbine) to vertical axis, twin bladed to many bladed, ducted, turnstile-type configurations as well as many other variants. Alternatives include designs such as the *'Sea Kite'*, which is tethered by wire to the seabed and sweeps back and forth in figure -eight shapes in the tidal stream.

Because of the greater density of water than air, submerged tidal turbines are much smaller than wind turbines and are likely to range in scale based on their intended deployment sites and resource characteristics. However, in relation to cetaceans, these remain relatively large structures with rotor diameters of leading designs ranging from 6 to 20 m in diameter (Figure 1). Blade rotation speeds are also lower than wind turbines and are frequently engineered so that tip-speeds approach 12.5 $m.s^{-1}$ (43 kph). Cavitation becomes a problem if the rotors exceed this.

There are a number of ways that tidal energy devices can be fixed to the seabed including using monopoles, tripods, gravity bases and anchored floating structures. Methods to secure these structures are similar to wind turbines and include piling, pin-piling, gravity bases and so on. However tidal-stream mooring options are limited by local substrates, which are typically hard bottoms and most commonly rock. Methods of deployment and servicing are also likely to differ because of the brief operating windows during weak tidal flow periods (i.e. slack water between tides). Furthermore, sites suitable for tidal energy extraction are generally more discrete than wind or wave opportunities, most commonly being in constrictions such as straits, bay entrances or off headlands. Leading devices are generally around one MW in capacity and as such require several to generate equivalent power to a single offshore wind turbine. However, the temporal predictability of the tidal-stream resource offers a significant market advantage to these technologies.

WAVE DEVICES

Wave energy devices are intended to extract kinetic energy from various aspects of wave motion - from the lateral surge in near-shore environments to the up and down motion in more open water to the height differences in neighbouring peaks and troughs along the length of a machine. As with tidal-stream converters, there is a wide variety of concepts being developed in parallel (>100). Many of these are in the prototype stage though several test machines are now operating at full scale and delivering power to shore. The majority of devices float on the surface though others are fully submerged and some span the entire water column. Attachments vary from monopoles or jackets to being more conventionally anchored using cables or chains. Again, to provide commercially relevant power, these devices need to be large particularly in comparison with marine fauna (Figure 1). Devices rated less than or up to one MW are most common and therefore require several devices to become equivalent to a single wind turbine.

Simmonds noted that a range of interactions between cetaceans and these devices are possible including collisions, entanglements in tethering lines and the impacts of noise associated with operation and construction. Particular attention has focused on the noise associated with establishing the foundations for wind turbines, but other devices, as noted, may use similar foundations. Simmonds also drew attention to the relationship between developments in areas that may be important foraging grounds, for example, narrow channels around islands may be favoured for current-driven devices. Also the relationship between protected areas and renewable locations deserves further consideration (Simmonds *et al*., 2012).

Figure 1. Examples of three leading tidal-stream turbines and one wave device. People in the pictures provide scale. Top left: OpenHydro (www.openhydro.com), top right: Atlantis AK-1000 (www.atlantisresourcescorporation.com), bottom left: MCT SeaGen (www.seageneration.co.uk), bottom right: Pelamis Wave Power (www.pelamiswave.com).

2.2 Development of marine renewable energy and its management in German waters

Thomas Merck presented an overview of the situation in German waters. The 'Energy Concept' of the German federal government aims by 2030 to have an installed capacity of offshore wind-generated energy of 25 GW. By the end of 2011, two wind farms (110 MW) were operational with another 115 projects planned, already approved or under construction – reaching a total capacity of more than 32 GW. Merck also provided Figure 2, which illustrates wind farms and other activities in the German part of the North Sea.

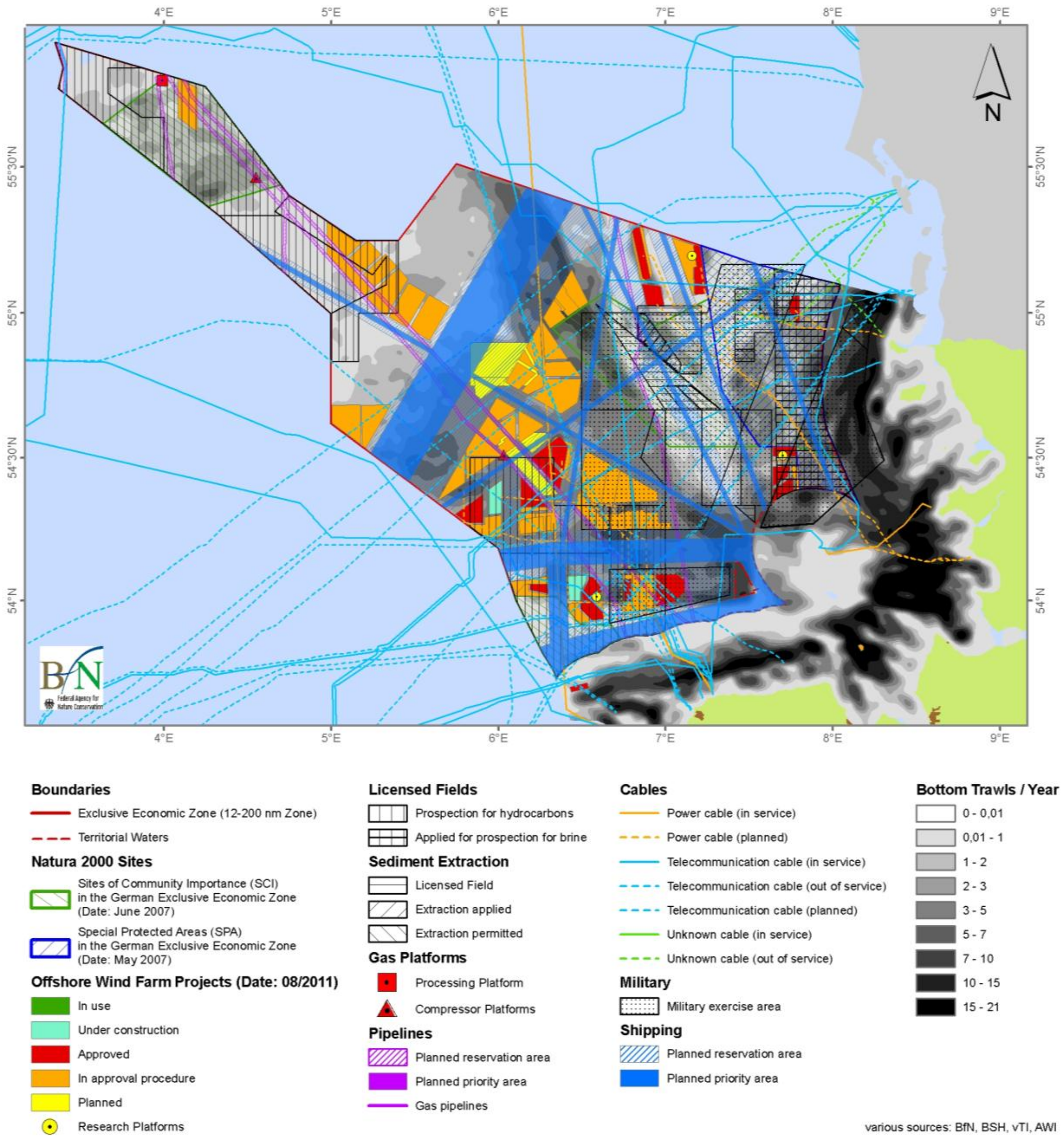

Figure 2: MREDs and other activities in German North Sea waters.

Ecological research programs are funded by the government to investigate potential impacts of wind farm construction. The development was intended to follow a step-wise approach in order to enable the consideration of the 'lessons learned' during this process. However, the current permitting procedure does not support this, although there is still some capacity for project-by-project evaluations and improvement.

According to the German legislation a permit for offshore installations, such as wind farms, has to be granted unless it is demonstrated to, among other things, pose a threat to the marine environment. In order to provide the necessary information the applicant must compile an environmental impact assessment (EIA) based on data gathered during a comprehensive two-year research program (see *http://www.bsh.de/en/Products/Books/Standard/7003eng.pdf*). Regulators must consider the provisions of the German Nature Conservation Act, including those implementing the European Habitats Directive (in addition to the Bird Directive) with respect to Natura 2000 sites. Changes to the legislation active since 2010 have extended the protection of habitats and species throughout all German EEZ waters.

Various pressures have been identified as causing potential impacts to the marine environment. Underwater noise emitted by pile driving activities during the construction or operation may disturb or even injure sensitive species, such as marine mammals. Turbines and towers may act as physical barriers to migrating species, such as birds, or lead to visual disturbance of sensitive sea bird species subsequently suffering habitat loss. Disturbance or destruction of benthic habitats and/or communities may arise from installing the foundations on the sea floor.

In recent times, pile driving and its impact on the harbour porpoise have been identified as a major issue of concern. Following the German Nature Conservation Act and in line with the Habitats Directive it is prohibited to injure or kill specimens of this species or to disturb them in a way that impairs the conservation status of the respective local populations. There is consensus among the competent German authorities that temporary threshold shift (TTS) is categorised as injury in the sense of the law. Consequently the developers are obliged to apply noise mitigation measures to reduce noise to a level below 160 dB (SEL) or 190 dB (SPL) at distances greater than 750 m to the piling site.

Monitoring of both the noise emission during various piling activities without mitigation measures, as well as the changes in distribution and behaviour of porpoises in the south-eastern part of the North Sea has revealed disturbances at distances of more than 20 km and at sound exposure levels of approximately 136 dB (SEL). At this level, disturbance of harbour porpoises would be expected within a radius of 10 km from the piling site, even if the 160 dB threshold mentioned above was met. From the nature conservation perspective, pile driving should be restricted or even prohibited in areas where the animals aggregate during times of the year with special importance for reproduction. How to finally assess ‘significant disturbance’ is still under discussion.

In the discussion that followed, the workshop **agreed** that there is an urgent need to develop or improve effective noise mitigation measures or quieter foundation installation methods. Further research is needed with respect to the impact of multiple sound exposures and cumulative effects of underwater noise from different sources.

2.3 The UK approach to offshore wind farm development

Vella gave a presentation on the UK experience with regard to the deployments of the offshore wind industry and cetaceans. The presentation outlined that research commissioned in the UK and Europe over the past decade has demonstrated that installation of turbine foundations by some methods, such as pile driving, can generate very high sound pressure levels. Construction monitoring has demonstrated a short-term behavioural (displacement) effect in small cetaceans (namely harbour porpoise). However, longer-term and population level effects remain unknown. Whilst early projects in the UK and Europe have been relatively small with a ‘limited’ risk to cetaceans, current plans in the UK in particular necessitate a need to better mitigate underwater noise emissions and their consequence to cetaceans. Risks are recognised at the European level through ‘Deliberate Disturbance’ legislation protecting European Protected Species and ‘Good Environmental Status’ of the European Union (EU) Marine Strategy Framework Directive recognising underwater noise emissions as a pollutant and requiring control of emissions. To meet these challenges, UK and Europe are working to better understand the issues through ‘cross party’ (industry/government regulator/advisors/NGOs) liaisons and looking to innovate novel mitigation solutions. This process will build on existing models, such as the Collaborative Offshore Wind Research into the Environment (COWRIE) charity, which facilitated much of the required research underpinning the first and second offshore wind licensing rounds in the UK (see *http://www.offshorewindfarms.co.uk*)

2.4 Wind farm development in Belgium

Fabian Ritter provided an overview of MREDs in Belgium waters based on three reports by the Management Unit of the North Sea Mathematical Models (MUMM) of the Royal Belgian Institute of Natural Sciences (RBINS) (see *http://www.mumm.ac.be/EN/Management/Sea-based/windmills_docs.php?proj=monitoring*). Three projects have been granted a domain concession and an environmental permit to build an offshore wind farm with a total of 236 turbines. Two areas within a dedicated “Belgian windmill zone” are under construction and operating today; both are situated offshore in the vast sand bank area off the Belgian coast. The first phase of the monitoring program started in 2005, the year before the (anticipated) construction of the first wind turbines.

Each project includes a mandatory monitoring program to (1) ensure the ability to mitigate or even halt the activities in case of extreme damage to the marine ecosystem and (2) ensure an understanding of the environmental impact of offshore wind farms to support policy, management and design of future offshore wind farms.

C-Power is located in depths of 18 and 24 m. 56 Gravity Based Foundations (GBF) turbines will be installed. 6 were built in 2008 and have been fully operational since early 2009. C-Power will possibly use another type of foundation for the construction of its phase II. The Belwind project is situated about 40 km off the coast in depths between 15 and 40 m and will operate 110 turbines while using monopiles. Fifty-six monopile windmills were built from 2008 until 2010.

For harbour porpoises monitoring, a Before-After Control-Impact comparison (BACI) study design is being pursued with dedicated control areas in place. Methods used include aerial surveys applying line transect sampling, passive acoustic monitoring (PAM) using C-Pods as well as strandings data analysis using information from a general database managed by the Royal Belgian Institute of Natural Sciences. Additionally, direct noise level recordings were conducted before and during construction, as well as during operation.

The results of aerial surveys in 2010 confirmed previous observations about the seasonal presence of harbour porpoises in Belgian waters and revealed a clear seasonal pattern, with porpoises being typically abundant (and showing the highest densities) in late winter and early spring, while in late spring to autumn lower numbers tend to stay in more offshore and northerly waters. Harbour porpoises were observed in, or in the vicinity of the wind farm areas during all aerial surveys. Combined data from aerial surveys, porpoise detector (C-Pod) recordings and strandings revealed that up to 1.6 % of the total North Sea population of harbour porpoises can at least occasionally be found in Belgian North Sea waters.

Direct recordings were made before and during construction, as well as during operation. The construction phase was documented for the six gravity-based founded (GBF) windmills and during piling activities. Maximum peak sound pressure levels (SPL) of 196 dB re 1µPa were recorded at 520 m from the place of piling. The Sound Pressure Level at the apparent source was estimated at 270.7 dB re 1µPa. This level is a concern for marine mammals in an area of at least tens of kilometres around the piling site. Underwater noise levels measured during operation were 5 to 25 dB higher than the background noise levels measured before construction began, showing that operation of concrete GBF windmills is likely to be less noisy than steel foundation windmills.

Recommendations for future research included that aerial surveys should be more regularly conducted throughout the year and should be performed immediately prior to, during and after pile driving activities. Also, every effort should be made to increase the number of C-Pods deployed in or near wind farm areas and at reference areas.

An exhaustive and thorough evaluation of possible impacts of marine wind farms in the Belgium part of the North Sea, where ultimately cumulative and synergistic effects over time and with other human activities are taken into account, will only be possible after the first six years of monitoring (2005-2012).

2.5 MREDs in the United States

Sue Moore and Debra Palka gave a presentation on the current situation regarding renewables in the United States. In the U.S. NOAA's National Marine Fisheries Service (NMFS) is responsible for the stewardship of the nation's living marine resources and their habitat. NMFS has consultation responsibilities under several statutes, including the Endangered Species Act and the Marine Mammal Protection Act. There are currently no marine renewable energy projects operating in U.S. waters, though there are sites in the US Atlantic waters that are being considered for near future commercial leasing. As part of its consultation responsibilities, NMFS has provided information through the Bureau of Ocean Energy Management (BOEM), "Smart from the Start" State Task Forces (http://www.boem.gov/Renewable-Energy-Program/Smart-from-the-Start/Index.aspx), to assist BOEM in avoiding and minimizing conflicts early in the process of siting of offshore renewable energy facilities. 'Smart from the Start' is a wind energy initiative for the Atlantic Outer Continental Shelf to facilitate siting, leasing and construction of new projects, spurring the rapid and responsible development of this abundant renewable resource. As offshore marine energy projects start to come online in the U.S., NMFS will continue to work with applicants and BOEM to address their potential impacts on cetaceans and other marine life.

Some scientific activities associated with possible US future renewable energy projects include collecting and modelling baseline data, developing public websites with data and tools to assist managers and developers, and improving technologies to survey/monitor cetaceans. Some specifics are detailed below.

There are a variety of studies that are or have already collected and modelled baseline spatial-temporal distribution and densities of cetaceans, pinnipeds, sea turtles and seabirds both on small scales around potential future sites and on the larger scale (out to the 200 nmi EEZ border). Data collection techniques included shipboard and aerial surveys, passive acoustics, radar and acoustic tracking of birds during the day and night, tagging, and photo-identification. Analytical approaches include using existing data, providing estimates of certainty, integrating ecosystem-level dynamics, and filling spatial gaps in survey data. These studies are being funded by federal, state, military, and industry sources. Examples of Atlantic small scale projects include the Biogeographic Assessment of Seabirds, Deep Sea Corals and Ocean Habitats of the New York Bight (*http://ccma.nos.noaa.gov/ecosystems/coastalocean/ny_spatialplanning.aspx*), and the ocean/wind power ecological baseline studies of waters off New Jersey (*http://www.nj.gov/dep/dsr/ocean-wind/report.htm*). An example of an Atlantic larger scale project is AMAPPS (*http://www.nefsc.noaa.gov/read/protspp/mainpage/AMAPPS/index.html*). A meeting sponsored by the U.S. Department of Energy is planned for July 2012, where principal investigators of the various Atlantic Ocean projects will discuss data collection protocols, analysis, modelling and possibilities for future collaborations.

There are some modelling exercises to create spatially – temporally explicit density maps of cetaceans and seabirds that incorporate habitat factors within the US EEZ, for example the Marine Animal Model (SERDP SDSS *http://seamap.env.duke.edu/serdp/serdp_map.php*), plus several on-going projects. In addition, the Cetacean and Sound Mapping Project (*http://cetsound.noaa.gov/index.html*) is creating both cetacean density and distribution maps and underwater sound field maps to better evaluate the impacts of anthropogenic noise in U.S. EEZ waters.

There is also work to create public website portals for data, information, and tools to support people engaged in planning for the future of the ocean, our coasts, and the Great Lakes. The goal is to be a one-stop hub to support planners and to provide useful information to the public (*http://www.data.gov/communities/ocean*). The EcoSpatial Information Database (ESID) has been developed, which is a database that permits compiling ecological information resources and associated data into a searchable database with a mapping interface (*http://www.ebmtools.org/demonstration-ecospatial-information-database-keld-madsen-and-daniel-hearn-amec.html*).

In addition, there is on-going research to develop new technologies that could help monitoring and surveying cetaceans, seabirds, and sea turtles, for example high-definition cameras to be used in airplanes.

There is also a National Oceanographic Partnership Program (NOPP) project enabling a team of University of Rhode Island researchers to develop data collection processes and standards which would be used along with existing and newly developed tools to evaluate the impacts of potential projects on the ocean environment. Ultimately, this could provide a comprehensive, yet flexible means of assessing the impacts of a broad range of offshore renewable energy resources projects on marine ecosystems and human activities (*http://www.seagrant.gso.uri.edu/coast/nopp.html*).

2.5 An introduction to the ICES Working Group on Marine Mammal Ecology Report

Lucke gave an introduction to the synthesis provided to the workshop of the recent work by ICES on MREDs (Murphy *et al*., 2012). This synthesis has not been approved by an ICES process, but is given here under the names of the authors.

In past meetings, the ICES Working Group on Marine Mammal Ecology (WGMME) looked at the effects of construction and operation of wind farms (ICES WGMME 2010), tidal devices (ICES WGMME 2011) and wave energy converters (ICES WGMME 2012) on marine mammals. This included an overview of some of the features of renewable energy devices and the distribution and scale of developments in the ICES Area. Further information on these can be found in the respective reports. In addition, in 2010 the WGMME presented an overview of each country's guidelines on monitoring and mitigation of the effects of the offshore wind renewable energy sector. Preliminary guidelines for the wet renewable energy sectors were reviewed in 2011 and 2012. As wet renewable devices are at a relatively early stage of development, so are their guidelines. Knowledge of the potential interactions with marine mammals is limited, based purely on first interactions and inferences derived from comparisons with other industries such as offshore wind, fisheries, and oil and gas developments.

The current synthesis summarizes the known and proposed effects of construction, operation and decommissioning of renewable energy devices on marine mammals, highlights information data gaps and presents the main recommendations of the ICES WGMME. The full reports can be found at *http://www.ices.dk/workinggroups/ViewWorkingGroup.aspx?ID=32*.

Simmonds thanked Sinead Murphy for preparing this important and helpful synthesis for the workshop and Lucke for introducing it.

2.6 Discussion

In discussion following these introductory presentations the workshop acknowledged that MREDs may well play a major role in the mitigation of climate change, which may profoundly affect cetacean populations (International Whaling Commission, 2007 and 2010). Discussion of their impacts has to date been mainly undertaken on project, national or regional levels. The IWC may be able to help lead a more biologically-appropriate population-focused approach and disseminate information related to best practice around the word. Many countries are currently considering putting MREDs into place; for example, South Korea.

A number of cross-boundary issues were noted:

1. National regulations are sometimes different between countries and might not "match"; e.g. in the Netherlands only one wind farm at a time can be constructed, but this does not take into account if construction is happening in a neighbouring country;
2. To be effective, EIAs need to consider biologically appropriate populations regardless of borders and not just "national populations," although there may be practical limitations;
3. To accomplish this would require increased information exchange regarding temporal and spatial distribution of animals, construction, planned wind farms, etc., and also at administrative levels (e.g., legislative and regulatory);
4. Coordination of temporal-spatial exclusions; and
5. Concentrations of construction along national boundaries to maximise space usage.

In Europe, it was noted that the Habitats Directive and the Marine Strategy Framework Directive (MSFD) may help address these cross-boundary issues which are also likely to arise in other parts of the world. The development of indicators for Good Environmental Status with respect to noise under the EU MSFD is expected to include national databases of all activities generating high intensity underwater noise. This may contribute to the assessment of multiple and cumulative impacts.

The extent and implications of reported avoidance of pile driving by cetaceans (as demonstrated in some studies for harbour porpoises) was then discussed (see for example, Thompson *et al*., In Press). It was noted that it is unclear if animals 'returning' after a construction phase are repopulating or if they are new animals moving into the area.

The relationship between MREDs and fishing activities was also discussed. In some national jurisdictions fishing activities may be prohibited from MRED sites (e.g. wind farms) and in others not. The potential for operating MREDs to act to some extent as refugia for wildlife and fish stock, if fishing does not occur, was noted but is not well characterised. It was also noted in discussion that such prohibition may displace fisheries to other locations, with due consequences.

3. Potential effects on cetaceans: available information (including modelling approaches).

3.1 Offshore and onshore wind farms

3.1.1 Statement of Current Knowledge

The ICES synthesis was considered to provide a comprehensive 'status of our current knowledge' and no further information was considered necessary.

3.1.2 Potential Threats to Cetaceans

Two of the key potential threats to cetaceans associated with underwater noise generated by wind farm construction were identified;

- Disturbance which may lead to displacement and other behavioural changes; and
- Physiological impacts, such as impairment of auditory senses.

Masking and stress responses were also identified as other potential concerns.

Auditory impairment can be mitigated, to some level, through the use of protocols to reduce the opportunity for cetaceans to be in close proximity to noisy activities. However, it was recognised that there is a need for scientific studies to determine the effectiveness of mitigation strategies such as noise threshold limitations (e.g. 160dB criterion in Germany) and/or the use of 'soft-starts'. In contrast, the 'behavioural disturbance' issue remains open with little, if any real consideration of the long-term behavioural impact and possible population consequences of offshore wind deployment. Accordingly, the issue of behavioural impacts influenced our consideration of knowledge gaps and recommendations.

3.1.3 Knowledge Gaps and Specific Recommendations

The Workshop identified the following knowledge gaps and **recommends** the following:

1. Need to continue to look at how to reduce noise creation (e.g. through consideration of differing options for device foundations), as well as to reduce noise propagation, e.g. through noise-reduction measures such as bubble curtains/piling sleeves. However, it was also recognised that economic aspects will need to be considered throughout the process;

2. Internationally accepted standards are of key importance, since a major problem is in the comparability of studies. These standards would be for underwater noise data collection, application and interpretation, and their publication would be helpful in addressing this problem; and
3. Developments in Northern Europe, where the industry is more advanced, could help inform other countries seeking to develop wind energy.

Foundation types that are not pile driven can offer a tangible noise mitigation opportunity, although their use may have economic consequences. Nevertheless, this does not preclude other noise mitigation techniques and strategies. The working group noted the current lack of understanding of impacts on species other than harbour porpoises. Because of uncertainty in the data it was noted that precautionary thresholds might be appropriate.

3.2 Tidal-stream energy devices

3.2.1 Statement of Current Knowledge

During construction there are commonalities of threat to other forms of marine renewable energy installation. However potential threats during operation are fundamentally different compared with other forms of energy extraction. This is because the moving parts of the turbine are entirely submerged and moving at speed (commonly up to 12 $m.s^{-1}$, or 43 kph; Wilson *et al*., 2007) relative to the streaming water mass.

3.2.2 Potential Threats to Cetaceans

Physical contact between cetaceans and turbines present a risk of damage to both animals and devices. Due to the early stage of development of this technology, rates of collision are currently unclear, although modelling of encounter risk suggests that rates of spatial overlap between marine mammals and turbine blades warrant further investigation (Wilson *et al.,* 2007). The spatial responses of animals to turbines are currently unclear and will have a large impact on the magnitude of this problem. Lab experimentation or extrapolation from other proxies has limited value so most of our understanding of interactions will come from the actual deployment of full-scale turbines. Accordingly this will require appropriate monitoring for evasion, avoidance, actual impacts and injury. Measuring these variables is likely to present a significant challenge and new methods and tools are required.

Deployments of turbines (as well as other MREDs) need to be appropriately monitored in order to learn about collision rates and whether or not mitigation is required. The expansion of the industry should be in step with the understanding of the ecological consequences.

In addition to the potential for injurious and lethal collisions with turbines, there are a number of potential sub-lethal effects. These include the presence of structures with moving parts producing noise and a downstream wake, which have the potential to alter the movements of animals in their vicinity. If there is spatial avoidance, there is a likelihood of barrier effects for animals passing through the area of device deployment. This may result in exclusion from important habitats either up/downstream or at the site itself. Conversely these installations may attract animals with implications for the collision risk described above.

The workshop recommended that, to more fully understand the habitat alteration impacts of these devices, more research should be undertaken on the ecology and behaviour of cetaceans in tidal-stream sites. Furthermore, distinction should be made between animals simply using the site in transit and those that inhabit it for longer periods (e.g. actively foraging).

Operating turbines are likely to produce noise both from the devices' machinery and from the passage of water through the structure. The importance of the noise arising from submerged turbines is presently unclear. However, this noise is currently considered unlikely to be sufficiently loud to produce hearing damage (TTS/PTS). It was noted that the sound emitted by a device is likely to be key in helping animals to detect devices and this is important with regards to collision-avoidance, though this also alters the marine acoustic habitat.

The workshop recommended that the acoustic properties of tidal turbines along with the ambient sound of tidal-stream sites be considered when evaluating the acoustic footprint of developments with respect to collision issues and habitat displacement.

A significant problem in understanding the interactions between cetaceans and tidal-turbines will be the number of device concepts being progressed in parallel, the number, configuration, diversity, unit type and complexity of deployment sites, as well as the potential number of cetacean species at risk. Studying each development presents a significant resource issue. On the other hand, pooling research resources to study particular devices may underrepresent the diversity of interactions that are likely.

3.2.3 Knowledge Gaps and Specific Recommendations

Understanding the relationships between tidal turbines and cetaceans is at a very early stage. The workshop **recommends** research be undertaken to address the following fundamental knowledge gaps:

1. the likelihood and rate of cetacean-turbine collisions
2. the consequences of a collision for the cetacean and the device
3. the extent of spatial responses of animals to turbines
4. the most appropriate configurations of arrays to minimize collision and habitat alteration
5. the capacity of cetaceans to detect turbines
6. methods to survey in tidal areas without bias, including during darkness and in foul weather
7. whether acoustic alarms are necessary and what responses they might elicit
8. how responses of cetaceans to turbines differ between device concepts and cetacean species.

Likewise, the prospect of installing grates across turbine duct entrances was considered. It was noted that these are likely to decrease inflow through collection of marine debris, with the associated economic consequences for the industry. These are consequently a highly unpopular topic with the industry.

3.3 Wave energy devices

3.3.1 Statement of Current Knowledge

Wave Energy Converters are under construction or in the planning stage in several countries around the world. Most of these efforts are centred in northern Europe at the moment, but initiatives exist also in North America, Oceania and East Asia. The ICES document (Murphy *et al*., 2012) provides a good basis for the report on Wave Energy Converters.

3.3.2 Potential Threats to Cetaceans

Like other MREDs, wave energy converters represent a collision risk to cetaceans, a source of contaminants through hydraulic fluid leaks and anti-fouling treatments, and a potential source of noise. However, the workshop expressed **particular concern** over the risk of entanglement presented by large numbers of floating devices.

3.3.3 Knowledge Gaps and Specific Recommendations

Like tidal-stream devices, wave energy converters are at a very early stage of development and there are many unknowns related to their potential impacts on cetaceans. Specifically, the workshop **recommends** research be undertaken to address the following fundamental knowledge gaps:

1. The workshop noted that it would be helpful to understand better how cetaceans navigate around devices, especially in stormy weather when collision risks might increase. By contrast, the entanglement risk is better understood and recommendations could be made based on the types of cables, etc. being used. Further research on this topic to help identify and minimise the risk of entanglement should be conducted;

2. The potential for wave energy converters to produce infrasound was noted, although their capacity to do this and the extent of the resulting potential impacts were unknown. Research into the impacts of infrasound (as with all other emitted operational sound) from wave energy converters should be conducted; and

3. Many parameters of the technical design are highly variable between different devices. For example, many devices cannot be readily moved if adverse effects are identified. Pilot studies on this are needed in order to determine whether or not to proceed with the development of a particular device.

3.4 Other developments (tidal barrages, OTEC, mass algal cultivation)

A variety of other types of marine-based sources of energy are being explored globally. It was noted that these might also impact cetaceans in the near future. These include Ocean Thermal Energy Conversion (OTEC), osmotic power, and micro- and macro-algae culture. These technologies were not explored in detail during the workshop though it was noted that macro-algal culture for biomass production will require relatively large areas of sea to deliver a significant source of power. China currently grows around 9 million tons of seaweed a year using these methods, with single farms covering very large areas (Liua *et al*., 2009). In terms of cetaceans, large seaweed farms have the potential to change coastal areas by adding structure to pelagic habitats. This structure will include growing ropes and moorings as well as the algae itself. Such developments might represent an entanglement risk and habitat alteration as well as potential artificial reef type effects for prey species. It must be noted that these properties are likely to be seasonally discontinuous due to annual harvests.

Similarly, tidal-barrages were not discussed in detail during the workshop, although it was **agreed** that they may be of significance to coastal cetaceans. These installations are walls that dam an enclosed bay or estuary. Typically, the rising tide is allowed to freely pass the wall to flood the area behind and then is blocked as the tide peaks. As the water level falls on the ocean side, water is allowed to flow out through a turbine. We noted that for cetaceans there is potential loss of habitat as well changes to local trophic productivity and tidal regimes over a wider area.

3.5 Common issues and recommendations

The workshop determined that a number of issues were common to all (or the majority of) MRED developments, although the precise extent to which they are a problem for any category of devices, or even specific designs, may vary substantially. Many of these relate to the knowledge required to determine their impacts, to ascertain the best site installations around sensitive species, and to conduct effective and biologically appropriate EIAs. Others relate to management decisions surrounding these technologies, while a third major category relates to actual impacts that were thought to be common across MREDs at a reasonably consistent level.

Recommendations that are common to all MREDs that were proposed by the workshop were as follows:

A. Knowledge needs and information transfer:

1. Noting that studies to date have mainly focused on harbour porpoises, more species-specific data are required for MREDs, especially given the paucity of results from robust impact monitoring programmes;
2. Data collection and impact assessment should be undertaken at two scales; the local/regional scale by a MRED developer and the much wider national/international scale by the Government/State. This is particularly important given that population/biogeographic data often extend beyond national borders. Cross boundary impacts and management need to be considered and, where appropriate, databases from different countries might be combined;
3. Research needs to have a more integrative and international approach than it has so far. An international database collating of relevant information (e.g., research, data and regulatory information) should be created; and
4. More information should be sought about the abundance, distribution and behaviour of cetaceans in locations and habitats suitable for MRED development, such as tidal habitats for tidal-stream devices.

B. Management procedures:

1. Ideally the best way to avoid any conflict is to choose a site with no overlap with cetacean habitat;
2. Careful site selection is important for all MRED technologies to allow for adequate function while minimising ecological impact;
3. Conservation objectives and measurable metrics need to be defined early on;
4. EIAs should include consideration of the impacts of the associated coastal and terrestrial infrastructure that may be require to support the construction, operation and decommissioning of these installations. This includes actual onshore (or near-coast) construction phases for wind farms and wave energy devices, prior to full installation;
5. It was noted that there is a definite benefit to educating the developers of emerging technologies on potential impacts early in the process, so they can better account for them in the design-phases;
6. Deployment of an offshore wind farm leasing programme should be underpinned by a strategic assessment (e.g. the EU Strategic Environmental Assessment) undertaken by the relevant Government/State to determine whether the environment has the carrying capacity to accept the programme. This strategic assessment should consider cumulative and in-combination impacts with other anthropogenic activities and the potential for trans-boundary impacts, i.e. the bio-geographic scale is particularly important when considering the health of populations;
7. Impacts can be gradual, despite the focus on absolute thresholds. Managers should give more consideration to disturbances and other impacts that may be more subtle and incremental;
8. More robust impact monitoring programmes are required that consider both short-term and longer-term effects;

9. Communication (both national and international) should be emphasised to find means to share information on cetacean seasonal habitat use, as well as plans for offshore energy development. An interactive website, such as envisioned by the IWC Cetacean Emerging and Resurging Disease (CERD) working group might serve as an example.
10. Installations should have the smallest ecological footprint possible, informed by temporal and spatial cetacean habitat use; e.g., avoid placing devices in migratory routes; and
11. International standards for EIAs should be developed (ideally via the establishment of an international expert body).

In addition to these recommendations, there was considerable discussion during the workshop about both the need to deal with uncertainty and how to do this. The workshop **agreed** that clear guidelines need to be developed and applied for dealing with uncertainty and how to apply the precautionary principle, considering also the underlying effects of climate change. Additional points were raised regarding the balance of uncertainty and precaution with development of the technology. Likewise, the question was raised about what exactly is the appropriate monitoring unit: e.g. a take, a mortality, or otherwise. Finally, it was pointed out that conservation objectives need to be carefully paired with measurable goals to make assessments of the efficacy of conservation actions possible. Where an appropriate metric has been developed to regulate deleterious population level effects, an associated monitoring scheme should be required to determine if that metric is exceeded. The working group also discussed the need for society to take a view on what an acceptable impact is in terms of balancing the probability of diminishing or losing some cetacean populations as a consequence of MRED-related impacts in the face of the costs of climate change (including to cetaceans).

Common impacts:

1. Some common operational issues may include pollution from leakage of hydraulic fluids (although this risk was considered only to be slight given quantity and rate of water passage through sites) and the use of anti-fouling applications. It was **agreed** by the workshop that toxic antifouling compounds (such as, e.g. TBT) should be avoided. (So far it is unclear what antifouling treatments will be used and also what regulations are in place);
2. It is likely that the addition of structures to tidal-stream habitats may alter the distribution and abundance of prey species. This could be through avoidance, injury from interactions with turbines, electromagnetic fields or the reef/FAD effects of mid-water column structures. As predators, cetaceans may respond to these changes by further avoiding or being attracted to the vicinity of devices; and
3. The workshop **agreed** that monitoring should not only take place prior to and during construction but should continue long after operation for better understanding of population effects.

The UK's Joint Cetacean Protocol (JCP) was suggested as a potentially useful model for data management (see *http://jncc.defra.gov.uk/page-5657*). The JCP is a framework between various government agencies and academic institutions, with some support from developers, which defines analytical approaches. Although potentially useful, certain concerns were noted in the wider discussions, which focused on the extrapolation to other areas due to the current limitation of the JCP to recent visual data from UK waters only.

There was also discussion about how to address the significant uncertainty in the data, including how to apply the precautionary principle given in particular the underlying effects of climate change on cetaceans. Finally, the pooling of financial resources by the industry was suggested as a useful option, e.g., for shared dedicated test sites for all devices.

3.6 Infrastructure

<u>3.6.1 Current Knowledge and Potential Threats to Cetaceans</u>

Regarding infrastructure impacts, two categories were considered: construction impacts (installation and decommissioning infrastructure) and operation impacts (maintenance infrastructure). A general concern was preventing fouling of devices and their parts, which was seen as a maintenance issue. For all arrays (wind, wave, and tidal), whether permanent land-based infrastructure is required to maintain or service the arrays and how often the arrays need to be maintained or repaired will determine the impact of the infrastructure associated with arrays.

For wind energy, installation infrastructure includes boats to take out and bring in materials, equipment, supplies, and personnel during construction and decommissioning. Cable laying must also be supported. If the substrate is rocky, blasting for pile driving may need to be accommodated. All of these may have impacts on cetaceans. Maintenance infrastructure will include boats and materials periodically going out to the wind turbines during their lifetime.

For wave energy, installation infrastructure will include boats, anchors for the array, and cable laying. Compared to the time to install wind turbines, the time for installing wave energy arrays is much shorter, as the array is assembled near-shore (in a sheltered area) and then towed out to the location and anchored relatively expeditiously (depending on the anchor type). The assembly area may be affected by some activities. Wave energy is probably the most maintenance-intensive technology and the most likely to need repair on an on-going basis. The risk of entangling cetaceans in a wave energy converter array is relatively high and monitoring for this, from an industry perspective, is a maintenance issue. Marine debris – such as lost fishing nets – may also become entangled in arrays and this may also have an effect on cetaceans and other wildlife.

Tidal energy is likely to have the smallest operational infrastructure, as installation is likely to be rapid during slack tides. Any boat traffic will be a matter of location – whether the location of the array is nearshore or offshore will determine the infrastructure impacts. This also means tidal energy will have the lowest repair needs – with many tidal devices being designed to be installed and left to operate with little maintenance and essentially no repair for 5 to 10 years and then removed.

During discussion, it was noted that because of the challenges of holding station in tidal streams a new generation of vessels need to be developed to work in tidal sites As noted above, many wave devices will require a sheltered area in which to be assembled and maintained and this assembly site may therefore be affected.

It was also noted that in the United Kingdom, some stranded animals – seals and dolphins – are stranding dead with characteristic spiral injuries (Thompson *et a*l., 2010), which have also been observed in the Netherlands. More research is needed to determine the cause and whether or not it is associated with renewables or some other marine industry. Cowled propellers have been suggested as a possible cause.

A workshop participant mentioned that the German Navy has required some wind turbines in Germany to be equipped with active transponders emitting an 8 kHz sound at 200 dB re: 1 µPa at 1 m. The workshop expressed **concern** at this[1].,

3.6.2 Knowledge Gaps and Specific Recommendations

The workshop **recommends** that

1. Infrastructure impacts should be taken into account early in the environmental assessment process – e.g., boat traffic (ship strikes, noise), material loss overboard (debris), etc.,; and
2. Research should be conducted on remote sensing modalities that would detect the presence of animals (or other problems, such as accumulation of marine debris or fouling) – this would help with maintenance and repair issues.

4. Working Group Summaries

4.1 Noise

The various noise signatures of the different renewable technologies are covered in the ICES synthesis (Murphy *et al*., 2012) and they are not repeated here. For the purposes of this discussion, we note that the output from single wave devices are assumed to be around 140 dB at 350 Hz re: 1 µPa at 1 m, while noise from tidal energy turbines may vary greatly and is largely unknown.

The use of noise for alerting cetaceans to the presence of tidal turbines (and other structures) was discussed. While operational noise might be useful in terms of warning animals to avoid them, many felt that there should be no additional acoustic deterrence devices attached to the turbines, at least at first. This will avoid the possible creation of a larger acoustic barrier than necessary for the animals to avoid the turbines and to avoid adding yet more noise to the environment. Acoustic alarms might have to be considered later, if it is shown that cetaceans cannot avoid turbines any other way.

[1] Post-workshop inquiries have revealed that these transponders would only emit sounds if and when a submarine approached too closely, lessening the risk of an effect considerably [Note added by MS during proofing of text]

Recommendations:

1. Given that the effects of noise on cetacean populations are very difficult to assess and very complex, and it may take too long to establish solid proof of effect, the workshop **agreed** to the following overarching principles:

   a) The precautionary principle often needs to be invoked. It is a challenge to determine the exact amount of noise disturbance that will not unnecessarily restrict industry, while affording sufficient protection for the environment. Management should err on the side of the environment, given the lack of knowledge (likely continuing for some time) of impacts;

   b) Spatial and temporal restrictions are among the most effective mitigation tools; and

   c) Source level reduction and the minimization of noise, using the quietest possible techniques and technologies, are additional very effective mitigation tools.

2. Discrete noise limits offer a relatively static framework that regulators and industry can work within. Noise limit goals are being worked toward. They can be established by regulators based on biological studies, as a useful first step by two criteria which are directed at two different spatial scales: (i) for smaller spatial scales, an absolute threshold for single events that cannot be exceeded and (ii) for larger scales, an overall noise budget for a specified time scale that cannot be exceeded. For example, for (i) using measures of habitat displacement of a number of individuals together with significant change in vocalizations, represents a useful management approach since these measures likely represent a meaningful impact. For (ii), one way to define these noise limits is to consider the normal variation of noise in the area, including how often and how long the loudest normal, natural ambient noises occur. This could indicate the natural tolerances of species to noise, as a starting point. The noise limit could then be set according to this value, perhaps by adding one to two standard deviations above the mean natural ambient levels.

3. However, one drawback is that the values (either for 2.i or 2.ii) chosen may prove to be too high and will be hard to make more restrictive once established (while moving the restriction in the other direction would be easier). Consequently, in addition to this noise limit, there should be incentives for noise producers to lower their noise footprint further.

   a) This could be done through a system similar to carbon credits, where for one area/region and time period, overall anthropogenic noise cannot exceed a certain value of x dB over ambient integrated over some time scale;

   b) An overall noise tolerance for each region and time should be determined that can't be exceeded. These noise limits should be adaptive, updated based on the best available cetacean science;

   c) Sensitive areas, including MPAs, and sensitive times should be allocated lower limits than other areas. Such sensitive areas will also need to have buffer zones to prevent cross-boundary noise impacts; and

   d) Incentives can be financial or via increased opportunities, e.g. the ability to obtain authorisation to build closer to sensitive areas.

Short-term behavioural responses of single individuals to noise are problematic measures of disturbance and impact. They do not convey less overt impacts, such as stress responses or masking sufficiently, and it is often the case that some of the most impacted animals respond the least in terms of overt avoidance and behavioural changes. Short-term individual behavioural responses are thus not necessarily reliable indicators of meaningful population impacts. It is, however, worthwhile to translate disturbance in the appropriate context into population impacts, such as is attempted by the Office of Naval Research's Population Consequences of Disturbance (PCoD) approach or the Okeanos Foundation's effort to model cumulative impacts of all stressors on Southern and Northern right whales and Western gray whales. However, these approaches are very difficult tasks that will take some time to complete. Thus, these "noise credits" could be a solution in the meantime, and could be implemented in parallel to continuing efforts to define population impacts through modelling efforts. This represents a more holistic, ecosystem-based management, which fits well into a wider marine spatial planning framework.

In the wider discussion, it was noted that there is some support for this sort of system under the EU MSFD. It was, however, also noted that carbon credits have not been a total success and that noise credits would need to be carefully implemented.

4.2 Mitigation

The potential level of impacts on cetaceans during construction and operation differ for the various types of renewable developments but for all developments impacts can be reduced by site selection. Selecting sites that have a low density of vulnerable species is likely to be the most effective measure to mitigate impacts from both operation and construction. Site selection taking cetaceans into account requires data on spatial distribution patterns. Approaches include:

1. Systematic surveys of a nation's seas, e.g. German approach; or
2. Identification of areas within a nation's seas within which developments of a certain type will be allowed, followed by surveys of those areas to inform identification of the most suitable locations for development within that area, e.g. UK approach to designate zones for wind farm development.

Protected areas may also play an important role in reducing impacts to cetaceans through site selection that avoids areas of particular importance. (For a discussion about the potential contribution of small protected areas see Simmonds *et al*., 2012.).

Impacts during construction can be reduced if there are key periods or seasons with relatively low densities of vulnerable species. Establishing temporal patterns of abundance requires monitoring over suitable time periods taking into account inter-annual variability.

Further construction mitigation options were noted as:

- Noise reduction at source through the choice of foundation type e.g. gravity base
- Noise reduction at source through installation techniques that do not require pile driving or reduce the amount of pile driving required
- Reduction of noise propagation through noise dampening/shielding techniques e.g. bubble curtains, pile sleeves.

Ramping up is a necessary technical requirement in pile driving activities to ensure, for example, that a foundation is correctly set into the substratum. Additional ramp-up duration has been considered a mitigation measure as it reduces the initial received noise levels to cetaceans in close proximity, which is assumed to allow them to move away from the construction area before being exposed to noise levels that may cause injury. However, it was also noted that these procedures increase the overall noise energy introduced into the marine environment, in addition to little evidence of its effectiveness to cause a displacement response. Therefore, the use of ramping up of piling energy as a mitigation measure should be carefully evaluated.

Other potential mitigation measures, such as the use of 'shut-down' procedures rely on detecting cetaceans within a designated risk zone. Shut-down procedures, including specific details regarding who has the authority to declare a shut-down should be made explicitly clear in advance. Methods to detect cetaceans will only ever detect a proportion of animals and therefore, this should be evaluated for each specific projects and species to allow the effectiveness to be quantified.

Acoustic alarms were also noted as a potential mitigation measure to (i) reduce the potential for injury during construction and (ii) to alert animals to the presence of tidal turbines and potentially other devices with submerged moving parts during operation. In both cases the aim of these acoustic alarms is to cause displacement of cetaceans. In the first case, the aim is to displace animals sufficiently to avoid injury for the duration of the piling activity. In the second case, the aim is to displace animals to the minimum extent to avoid colliding with the turbines over the lifetime of the project.

It is currently not clear whether acoustic alarms are effective. Moreover, they may also increase displacement from important habitat, increase the "barrier effect" of installations, increase overall anthropogenic noise in an area, and/or increase stress levels in animals.

4.3 Modelling

There are key areas of modelling that need to be considered when accounting for the potential impacts of marine renewables on marine mammal species. These are habitat, density/population and impact modelling. Habitat modelling can be used to identify key areas, and can highlight gaps in our knowledge of marine mammal spatial use. However, in terms of the construction of renewable facilities, it may be just as important to be able to identify areas not used by cetaceans. When considering habitat modelling, we need to identify the data required for these models, and recognise that some components informing these models are a result of models themselves (e.g., prey fields), increasing uncertainty. Another important factor to take into account is whether the interest is in single-species, multi-species or ecosystem approaches, since habitat importance may shift along these lines. In all of this, spatial and temporal scale is important, especially if the goal is to identify trends or shifts in habitat over time.

With density/ population modelling, the measures that are more useful for management, mitigation or conservation need to be identified,for example, relative versus absolute abundances, or whether counts or presence/absence may be enough for particularly rare or unusual species. Given the importance of baseline data, and its scarcity, it could also be helpful to identify potential historical data sets that may inform changes from historical patterns. Whaling data could be particularly important in this case, given the difficulty in collecting information on many of these species.

Impact modelling incorporates risk assessment, and can include using simulations to make predictions that could be tested against data collections. Both behavioural and physiological responses need to be accounted for when estimating the effects of disturbance, particularly when considering vital rates. When undertaking modelling, it should also be identified whether some individuals, or components of the population, are more sensitive or important than others. This can be both in a biological context and in a spatial and temporal context. Cumulative impacts must also be considered, no matter how difficult this may be. Experimental data from captive animals could also inform this area. However, the appropriateness of extrapolating to wild animals may be in question.

Before modelling, or even data collection (if possible) starts, the purpose of the modelling should be identified. Different approaches are taken to detect trends, estimate the probability of extinction and predict potential biological removals. Other potential important modelling outputs are habitat use, or shift in use, changes in vital rates and shifts in population structure. Many models, and their requirements, will also be location and species specific. It is important to consider whether the type of data that can be collected can be used to obtain the desired modelling outputs. Another important aspect to account for is who will do the modelling. Will statisticians be hired? Is a plug-and-play approach desired, or should it be approachable to the statistically inclined, even if they aren't fully trained statisticians? We need to define who the users are for these models.

Recommendations include the possibility of holding a workshop in which the feasibility and success of the different modelling approaches currently underway are discussed. A document that helped to outline the different relevant modelling approaches, their advantages, disadvantages, assumptions and their comparability would be useful. A conversation between modellers, managers, biologists and industry could be helpful to discuss what is needed from the modelling, and whether data collection standards need to be re-evaluated. Modelling should be incorporated into the planning process, rather than being applied only to address weakness in the data collection or assuming any data can be used to answer the questions key to the study.

In the wider discussion, one participant asked if small, land-based studies were useful. Although the answer is 'yes', it is necessary to think carefully about what data can be collected and what the questions are. Relative change, as opposed to absolute abundance, could potentially be obtained, or there may be higher levels of uncertainty. The level of acceptable disturbance should be considered. It is also always better to have something, than nothing at all.

Similarly, a point was raised about the importance of appropriate consideration of the users. There are currently only a small number of people that can do the modelling, so the approaches aren't often accessible. Thus, it is even more important that the results are.

Not only do we need to model, among other aspects, abundances and habitat, but we also need to model the effectiveness of the mitigation measures, and perhaps predict their effectiveness as well.

The difference between practical and statistical significance is important. It is necessary to differentiate between the two, both in cases of data scarcity and data abundance.

4.4 Monitoring

Monitoring addresses a number of different questions and can be divided into three categories within a development process:

1. Before development. Monitoring spatial and temporal distribution and abundance of species that may potentially be impacted is required for site selection. Regulators also require specific site related data on which to base decisions about consents;
2. Impacts during construction phase; and
3. Impacts during operation.

For all types of monitoring of distribution and abundance there is a need to consider the appropriate temporal and spatial scales. The uncertainty associated with any estimates should be explicit, including appropriate power analyses for the ability of any monitoring programme to detect a response.

The aim of the following tables is to identify areas where there is a need to develop further monitoring methodologies. For some aspects of monitoring such as distribution and abundance, well established techniques exist and merely need to be applied. For other monitoring needs in relation to renewable energy developments there is a need for further development of field and analytical methods.

4.4.1 Monitoring for Site Selection

What is needed?	*What tools are available?*	*What is missing, i.e. needs development?*
Surveys to identify most suitable areas, taking into account development needs and environmental impacts	Visual and acoustic survey techniques are well developed	Survey techniques for fast flowing currents, considering different detection probabilities related to tidal flow and issues related to surveying a body of moving water Quantifying absolute detection probability of land based observations, similar to dual platform vessel surveys Estimates of parameters to allow absolute abundance estimates (e.g. g(0)); measures of uncertainty associated with all estimates Modelling techniques to identify low density areas as well as hot spots Automated methods for detecting cetaceans (presence and preferably species), as aerial photographic surveys are becoming more common

4.4.2 Monitoring impacts during construction

What is needed?	*What tools are available?*	*What is missing i.e. needs development?*
Measures of displacement	Surveys or static acoustic recorders	Not discussed at the workshop
Measures of noise exposure	Surveys plus measures of received levels	The establishment of sound exposure thresholds related to single and multiple exposures to sound and impacts such as temporary or permanent hearing injury for all species of concern
Measures of behavioural impacts and stress	Interpreting behaviours can be difficult but some work has been done in relation to vessel disturbance Stress hormones related to noise have been measured in faeces	Further work to interpret behavioural responses and measure stress

4.4.3 Monitoring impacts during operation

This table currently focuses on tidal energy devices since these were considered to have high risks for cetaceans

What is needed?	*What tools are available?*	*What is missing i.e. needs development?*
Assess barrier impacts on animal movement from offshore arrays	Visual tracking of animal movements Acoustic tracking using multiple hydrophones Tagging	Better quantitative interpretation of observations in order to measure potential barrier effects
Collision risk for tidal turbines	Examination of stranded carcasses Characteristic damage to turbine blades (e.g. skin left during impact) Underwater video monitoring Arrays of hydrophones to investigate use of the water column High resolution sonar	Modelling to estimate where animals found stranded were killed and the probability that animals killed in collisions will be recovered Automatic processing of video and sonar data to detect large objects such as cetaceans Further development of acoustic tracking from multiple hydrophones to investigate vertical use of the water column
Effects on prey and feeding	Photo-identification may establish the number of individuals using a tidal site for feeding	Not discussed at the workshop

In the discussion, it was noted that there are also important legal aspects to the problem of monitoring. For example, a nation might be legislatively bound to collect one type of data, even when it proves only minimally useful in terms of the questions to be answered.

Monitoring studies during the construction phase of wind farms have generally focussed on displacement. However, a lack of avoidance may lead to other impacts, such as exposure to high noise levels that cannot be measured through monitoring distribution. These impacts may include changes to demographic parameters such as survival or reproductive rates. Detecting changes in demographics is difficult and attributing them to specific causes is particularly challenging.

The difficulties of assessing population trends were also discussed and it was noted that this issue has also been the subject of considerable work within the Committee.

4.4.4 Monitoring and Adaptive Management

The following issues were raised in discussions:

1. The provision of clarity on which bodies, government agencies, NGOs and scientific expertise should be involved in agreeing to site specific monitoring requirements;
2. The implementation of a back to basics approach for what monitoring is required, i.e. not data for data’s or interest's sake, but what do we really need to know to mitigate and reduce impacts and achieve legal compliance;

3. The choosing of appropriate monitoring methods for the question asked while considering the specific challenges of the location (e.g. the problems of monitoring offshore locations with adverse weather conditions and fast tidal currents), and the limitations of the data gathered in terms of guaranteeing negligible impacts (e.g. visual surveys cannot assess cetacean distribution at night or in poor sea conditions);
4. The insurance that personnel has the needed expertise to conduct effective monitoring (e.g. a potential marine mammal observer taking a simple short course is not sufficient produce an effective surveyor) and that there should be investment in long-term training for a large pool of visual and acoustic monitoring expertise;
5. Effective linkages pre-, during and post monitoring (as this is often conducted in a disjointed way) and addressing site-specific issues identified during the initial assessment process. Baseline and on-going monitoring should be conducted at a timescale and frequency sufficient to pick up tidal, diurnal and seasonal changes in behaviour;
6. Regulators should take a strategic view in terms of monitoring – e.g. reduce redundancy and repetition, improve data sharing, looking at cumulative impacts and issues on a regional basis, and allow better coverage on a specific issue (e.g. wide-scale impacts on harbour porpoises);
7. Periodic review of scientific research on monitoring effectiveness and best practice worldwide to build on lessons learnt, and feed this back into monitoring programs as needed;
8. Setting up a system where monitoring is reviewed regularly to determine whether the effort needs to be adapted, to ensure the most effective monitoring regime;
9. A look at ways that monitoring data can be standardized and combined with other monitoring and scientific programs to increase data gathering (e.g. seismic survey monitoring, data gathered from whalewatching platforms of opportunity, scientific surveys); and
10. Setting up an independent research fund that developers and/or government can contribute to, when appropriate, to fund scientific research specifically to address the questions that need to be answered related to renewable energy impacts (e.g. to increase coverage of surveys, to conduct specific experimental studies, to develop urgent models).

4.5 Cumulative impacts

Cumulative impacts are defined here as the combination of the various impacts arising from the different elements of one or more MREDs projects of the same kind, as well as in combination with impacts from other human activities (the latter cross-industry other human impacts are also known as in-combination impacts).

Impacts that should be considered in a Cumulative Impact Assessment (CIA) involving MREDs can be split into two major categories: construction impacts and operational impacts. Construction impacts include (but are not limited too) noise from pile driving, while operational impacts are more wide-ranging and include (but are not limited to): the presence of gear (current disruption, prey distributions, habitat loss); collisions (especially tidal); prey aggregation through effective artificial reefs (a positive effect); entanglement (wave especially); noise (albeit unquantified at this time); interruption of migration corridors and contaminants from anti-fouling treatments, etc. Construction and operational impacts must be handled by CIAs in very different ways given their respective temporary or near-permanent nature. For example, construction could be conducted outside a breeding period, but operational concerns will persist, making breeding sites a poor choice for a location.

In addition to these impact categories, there are also management concerns related to cumulative impacts. Most notably are concerns over authorisation thresholds (i.e., minimum size for permit requirement, full EIA, etc.). This leads to under-assessed impacts on a project-by-project basis and thus ultimately also unchecked cumulative impacts. However, cumulative impacts can also be influenced through management choices, including decisions on locating multiple and/or competing human uses of the marine environment.

Ideally, CIAs should be considered at a strategic level as early as possible in the planning process and prior to any deployments of a new industry. If possible, a quantitative CIA should be undertaken and used to guide mitigation. However, many uncertainties exist regarding impacts of MREDs (and other human activities) upon cetaceans, especially for many of the emerging designs for tidal and wave devices. These may make quantitative analyses unfeasible and a more qualitative CIA more appropriate.

Very little is known about many of the above-mentioned (or other) impacts, especially with regards to non-wind MREDs. Nevertheless, it is possible that emergent impacts on fitness (reproduction and survival) can occur given the cumulative/synergistic nature of combining multiple impacts through interactions of the nervous, immune and endocrine systems (such as via stress responses). Similarly, it is also possible that emergent impacts will arise from interactions between industries. For example, if MREDs functionally (or legislatively) exclude fisheries, this industry (and the associated bycatch) may be displaced to the benefit of marine mammals. On the other hand, MREDs may act as fish aggregation devices and, without such exclusions, may attract both predators, including cetaceans, and the interest of fisheries, to the detriment of cetaceans. Despite a lack of data about these cumulative impacts, management options are available for addressing them (e.g., Wright and Kyhn, 2012). Accordingly, the Workshop put forward the following **recommendations**:

1. Management thresholds for triggering permitting procedures and/or increased analysis requirements should be reduced and/or eliminated. Each project in a given region should consider the cumulative impacts of its development in combination with any other previous or foreseeable project within that region;
2. Multi-stakeholder efforts should be made at international levels to reach agreement over the appropriate scale (both spatial and temporal) of CIAs;
3. Marine spatial planning and ocean zoning offer mechanisms for improved consideration of co-location issues, which would formalise a process that currently depends upon national regulations and between-industry compatibility that varies greatly;
4. Specifically, given the potential interaction between MREDs and fisheries (through action as fisheries exclusion zones and/or fish aggregation devices), regulatory agencies should engage with biologists, the MRED industry and the fishing industry to explore the possible consequences thoroughly;
5. Permit cycles make certain management options available and these should be exploited to their maximum extent, especially in countries new to MREDs;
6. If species or populations are declining, no additional impact can be considered sustainable and new industries should be located away from these populations and other impacts need to be appropriately reduced;
7. In the case of populations with unknown trends (especially given afore-mentioned statistical limitations), the precautionary approach suggests that we should also treat these populations as declining (per (6)). Monitoring could then be employed to resolve this and possibly relieve protections. However, it was noted that this may be unrealistic given the inability of managers to exclude much more direct and defined impacts, such as bycatch. One alternative to this would be very careful planning and zoning (per (3)), with careful monitoring for impacts and/or declines to make sure the combination of activities is sustainable;
8. Managers should provide as much information to emerging industries as possible regarding their potential impacts to allow the designers and engineers to consider such things early in the research and development process. This should minimise cost and aggravation to industry while minimising the ultimate impact of the technologies on marine mammal populations;
9. Population demographic parameters, such as recruitment, are an important additional consideration with regards to determining impacts beyond those simply related to abundance. Consequently, these should be monitored in addition to population size where possible; and
10. Much additional monitoring is required in many areas, such as noted above (9). However, it is equally important that current monitoring requirements under the existing domestic and international regulations and agreements (e.g., under the EU Habitats Directive) should be fully implemented and enforced.

5. Overarching themes and recommendations

5.1 Introduction

Marine renewable energy sources can play an important role in overall energy strategies to reduce dependence on non-renewable resources and to reduce the impact of climate change ((IWC, 1997;2010). However, they also have the potential to be detrimental to the marine environment (including cetaceans), and it is important that their development is carefully considered, particularly as there will be increasing demand around the world in the coming years. The work of the ICES WGMME (Murphy *et al.*, 2012), with a focus on the European Atlantic area where most of the development has taken place thus far, provided an extremely valuable resource for the present workshop, both in terms of providing a comprehensive summary of what is known and in developing recommendations for the future. The present Workshop **acknowledges** this work and the WGMME recommendations. In its recommendations here, the Workshop seeks to build upon the work of the ICES group by focussing on the contributions that can be made by the IWC and in particular on providing advice that can be beneficial to areas where the development of marine renewable energy sources is in its infancy.

5.2 General strategy and principles

As in the management of other anthropogenic activities, there are several general stages in developing strategies to minimise the risk to the environment posed by MREDs (while the focus of this workshop is cetaceans, these are generally applicable), although some will occur in parallel and incorporate feedback (Figure 3). The Workshop **recommends** the following broad approach and principles, recognising that this represents a general summary and that they may need to be adapted to specific circumstances. In some cases, the strategy and principles outlined below may exceed requirements made by existing national legislation in some countries.

1. Collection/collation/analysis of appropriate baseline cetacean data (e.g. stock structure, distribution, abundance and other relevant population parameters) at the necessary geographical and temporal scale on the cetacean populations that may be affected by proposed developments. These should be planned well ahead of the development. It is **not** sufficient for 'snapshot' surveys to be undertaken to determine geographical and temporal distribution. This stage will almost always require surveys over a number of years at broader scales than national waters and certainly greater than small areas around proposed individual developments;

2. Collection/collation of appropriate industrial data (i.e. data related to activities that may pose potential threats to cetaceans e.g. noise profiles, entanglements, shipping traffic, chemical pollution, habitat loss, prey reduction, etc.) for proposed developments at appropriate geographical and temporal scales – note that this applies to the design, construction, operational and decommissioning phases;

3. Integration of (1) and (2) to identify potential/actual threats to cetaceans (including cumulative and synergistic effects and to attempt to develop quantitative evaluation/prioritisation of these *at least at the cetacean population level* and in the light of *conservation objectives* that must be developed by decision-makers (e.g. related to abundance, distribution, local densities etc.);

4. Use the information from (3) to develop effective mitigation measures. Some of these may be technical, such as reducing noise energy. Others, which in some cases may be amongst the most effective, may relate to ensuring that the location of the development and/or the timing of the activities that are most disturbing to cetaceans are such that the exposure of cetaceans to threats is eliminated or minimised. Mitigation measures and what is deemed acceptable levels of mitigation will need to take into account what is known of the status of cetaceans, their temporal and geographical distribution and their 'critical' habitat;

5. Note that the quantification of threats and the evaluation of the efficacy of mitigation measures is complex and will inevitably reflect scientific uncertainty. Decision-makers will need to act in the face of uncertainty and must develop a suitably precautionary approach;

6. Examination of proposed developments in light of the above must also take into account other actual/potential threats (both from similar proposed developments or other existing/proposed human activities);

7. If developments are approved by decision-makers, then it is essential that targeted monitoring programmes (of both cetacean populations overall and the efficacy of specific agreed mitigation measures) are designed and implemented. These will need to: (a) be at appropriate geographical and temporal scales (including at the cetacean population level); (b) incorporate population characteristics appropriate to the potential threats; and (c) have been evaluated using appropriate statistical methods to ensure that they are able to detect changes in key parameters should they occur, taking into account the conservation objectives agreed by decision-makers;

8. Similarly, it is essential that compliance mechanisms are in place to ensure that agreed mitigation and monitoring measures are correctly implemented, data are analysed and results are made publicly available to assist with the design and evaluation of future developments; and

9. It is clear from the above that such a process involves collaboration of a wide range of stakeholders including: scientists of various disciplines; developers; local and national governments; international collaboration if the range of the cetacean populations involved crosses national boundaries; other marine users (e.g. fishing, shipping, tourism); local communities; and NGOs. It is essential that this is recognised as early in the process as possible and that mechanisms are developed to involve these stakeholders at all stages in the process.

While this is an involved process, the Workshop recognised that because this is a relatively new field, then the potential to establish good practice (and learn lessons from areas where development has already started) at the outset is high. Early collaboration between developers and cetacean scientists can be extremely beneficial both in terms of potential engineering approaches and ultimately sites to avoid from the perspective of risks to cetaceans. It is particularly apparent that there is a need for countries and regions to develop common strategic planning and evaluation strategies that include marine renewable energy developments as part of overall coastal and zonal planning, with an initial level of precaution that reflects scientific uncertainty and agreed conservation objectives.

5.3 The IWC contribution

The Workshop **recognises** the valuable work being carried out on this topic outside the IWC. It **stresses** the need for international collaboration and notes that the IWC can be an important facilitator and advisory body at an international level. The Committee's work (including the present workshop report) is made freely available on the IWC website and relevant future activities (including workshops and/or special sessions within annual meetings) will be open to attendance and contributions from scientists within and outside the Committee's normal membership. The valuable contribution made by the industry representative was noted. Further interactions with industry and other stakeholders will be an important component of improved conservation and management of MREDs development.

Within the context of the above overall recommendation on an overall strategy and principles, the Workshop makes the following more specific **recommendations**, with a focus on areas where the IWC can provide specific expertise. These have been broadly divided into those that are management-related and those that are primarily scientific and research oriented, recognising that these are not mutually exclusive and that there is an important linkage between them.

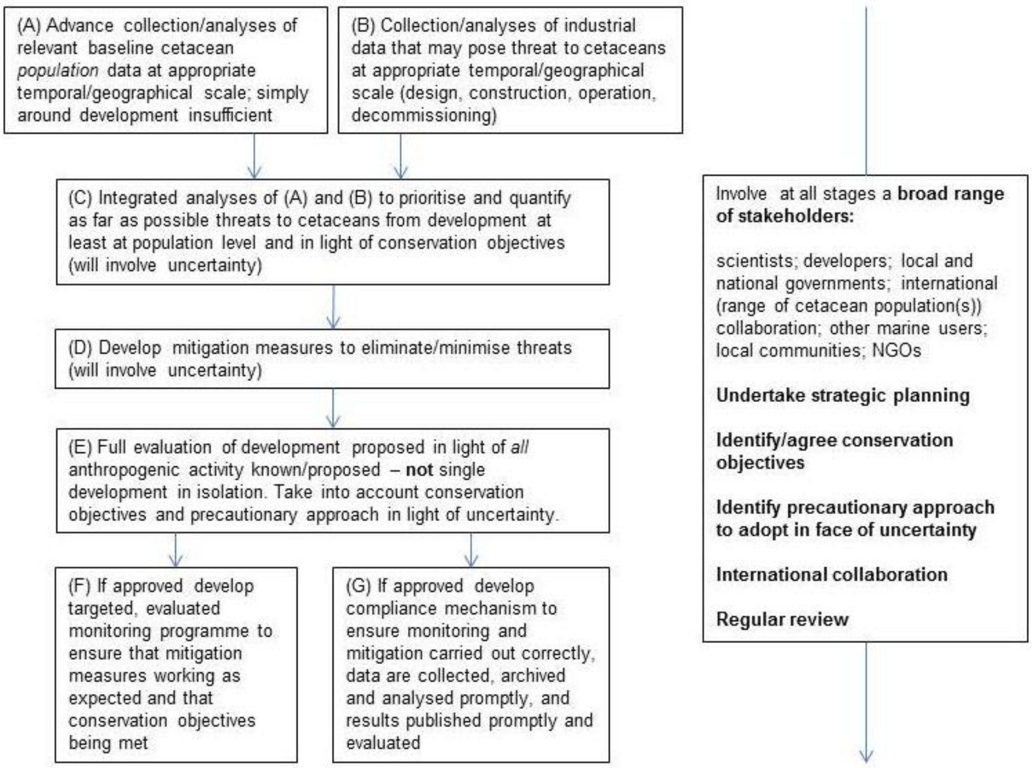

Figure 3. Simplified schematic summary of a general strategy and principles to minimise environmental threats posed by MREDs. Some stages will occur in parallel while others will involve feedback.

5.4 Broad management

There is a clear need for strategic planning that takes into account the trans-boundary nature of cetaceans. Governments and decision-makers need to co-operate with relevant stakeholders to develop such an approach and establish agreed conservation objectives and methods of evaluating proposed developments. Given inevitable scientific uncertainty, a precautionary, pragmatic approach must be developed as part of the strategic plan. The value of a staged approach, learning lessons from initial developments both in a specific region and elsewhere, should be considered. It is essential that proposed developments are not seen in isolation from other similar developments and other anthropogenic activities in the marine environment that affect cetaceans.

The Workshop **notes** that IWC member governments can assist in encouraging the development of international collaboration in this regard, and in particular, they can assist in emphasising the importance of incorporating consideration of cetaceans from an early stage and the value of following the broad strategy and principles outlined above.

5.5 Fundamental research

5.5.1 Baseline Population Information

There are many areas of the world for which the necessary information on cetacean population structure, status, temporal and geographical distribution (and natural variability) and other population parameters are poorly known. Obtaining such information is almost certainly beyond the financial and technical capability of developers alone and will require international collaboration in data collection and analyses. It should be noted that such information is required for the evaluation of many anthropogenic activities not just MREDS and there is the potential for considerable savings in terms of finances, logistics and value of results if such work is co-ordinated at a multi-national level.

The Committee has considerable expertise in these topics and could assist in the design of surveys (taking into account conservation objectives) and evaluation of new technologies. It is important that consistent methodology is adopted between and among surveys to facilitate the necessary collaboration and data sharing (and see 'monitoring' below). It also has considerable expertise in data analyses including the development and use of modelling approaches to identify areas of important habitat (see also 'evaluation of threats' and 'mitigation' below).

One area of particular relevance to certain MREDS that has not been as well studied is the question of surveys where fast moving water results in highly variable detection probability. The Committee can assist in the evaluation of approaches to address this issue, including the use of independent detection methods e.g. combined visual and acoustic.

5.5.2 Baseline Data on the Effect of Stressors on Cetaceans

Robust quantitative determination of the effects of stressors on cetaceans is difficult. For example, information on the effects of noise is generally poorly known except for a few species and circumstances. This is particularly true of cumulative effects, as well as at the behavioural level. As noted below, modelling approaches are being developed that can help to address the effects of stressors at the population level but these require baseline information.

The importance of directed targeted studies to obtain such information cannot be overemphasised and it is important that the collection of such data takes into account its likely use in modelling exercises. The Committee has expertise in the approach of linking fundamental research and modelling of effects (e.g. as part of its POLLUTION 2000+ programme) and can assist in the development of modelling approaches in this regard.

Information on the effects of stressors on cetaceans is also extremely valuable in helping to develop mitigation measures (see below).

5.5.3 Baseline Information on Stressors

To evaluate the effects of stressors, information on the stressors themselves is required. In many instances, once data have been collected (e.g. noise source levels of various equipment) then modelling exercises are required (e.g. of acoustic energy transmission) to quantify the stressors within the environment that will result from the various activities associated with particular proposed developments in their construction, operation and decommissioning phases.

Whilst the Committee does not necessarily have expertise in this specific field, its modelling expertise can be valuable in evaluating modelling exercises to ensure that the appropriate uncertainty is also modelled.

This information is essential in the evaluation of threats discussed below.

5.6 Evaluation of threats

5.6.1 Modelling Effects of Stressors and Undertaking Risk Assessments

As noted above, modelling is an extremely valuable tool in trying to evaluate population level effects of threats for which direct measurement is often difficult. The Committee has considerable expertise in this and can contribute to international efforts (e.g. PCAD) to address this important issue (which will provide essential input into any management procedure approach – see below).

Information on the effects of non-lethal stressors (noise, pollutants) as well as risk-assessment of potentially lethal threats (e.g. collisions with certain types of infrastructure) on cetaceans is also extremely valuable in helping to develop targeted mitigation measures. Non-lethal stressors may be more significant at the population level than lethal factors in some instances. Modelling approaches can be used to evaluate such threats and/or possible common mitigation guidelines (e.g. on noise exposure) in terms of the relative risks posed by such developments and any reduction expected to be achieved by specific mitigation measures. An integrated approach will allow the relative efficacy of various mitigation measures to be considered.

There has been considerable difficulty in developing appropriate analytical techniques to integrate the wide variety of disparate variables (e.g. behaviour, various characterisations of noise, prey information, etc.) when trying to determine whether specific activities have resulted in even short-term, let alone long-term effects on cetaceans (e.g. Gailey *et al*., 2007). This area of determining cause-effects is an area in which the Committee could assist international efforts. The Workshop **agreed** that the Committee may wish to consider the value of holding a targeted and well-prepared Workshop on this topic in the future. There was insufficient time during the present workshop to elaborate upon this idea further but the Workshop agreed that Donovan, Leaper and others should work together to develop a more detailed proposal for presentation at the sub-committee on environmental concerns.

5.6.2 Integrated Evaluation

The Committee has considerable expertise in using the management procedure approach to evaluate the threats to populations from directed hunts and bycatches, taking into account scientific uncertainty. This experience will be valuable in developing a similar approach to evaluating all lethal and non-lethal human activities in an integrated manner, recognising the need to consider cumulative and synergistic effects.

5.7 Monitoring

Effective and targeted monitoring is an essential component of any process involving new developments. Given the long lifespans of cetaceans and the operational lifetimes of developments that may be decades, this will inevitably involve long-term monitoring. It is essential that such monitoring is carefully designed in light of (1) agreed conservation objectives; and (2) the efficacy of implemented mitigation measures. Thus the objectives of monitoring must be carefully specified. From these objectives, monitoring schemes can be designed at the appropriate geographical and temporal scales (using power analyses to ensure that they will be able to detect changes at specified levels, should they occur).

The Committee again has considerable expertise in this regard to assist in international efforts. This is an issue that is broader than MREDs. The need for population level monitoring combined with smaller scale (e.g. relating to smaller 'core' areas or national waters) monitoring has been often referred to, especially by national decision-makers (e.g. SCANS II, 2008). This is relevant for the evaluation of many anthropogenic activities. The Workshop suggests that the Committee considers the value of holding a targeted and well-prepared Workshop on the topic of population level monitoring and the applicability of smaller scale monitoring in the future. Again, there was insufficient time during the present workshop to elaborate upon this idea further but the Workshop agreed that Donovan, Leaper, Palka and others should work together to develop a more detailed proposal for presentation to the Committee.

5.8 Data sharing

The need for data sharing (with requisite safeguards for data collectors/owners) in a prompt manner is extremely important at many stages of the broad process outlined above. This includes:

1. baseline population information and monitoring;
2. information on effects of particular activities on cetaceans (and the development of precautionary guidelines);
3. information on all anthropogenic activities in addition to those associated with any single development;
4. all information required for integrated evaluation of threats; and
5. results relevant to the development and evaluation of mitigation measures.

The IWC has faced some similar problems with its data availability guidelines. It could assist in the development of similar guidelines (in conjunction with relevant stakeholders) and could assist in other ways e.g. the hosting of metadatabases of available information/data sources with conditions of access and contact points on the IWC website. The guidelines will need to balance the industrial sensitivity of certain types of information with the need for a full evaluation of risks.

5.9 Further work by the Scientific Committee on MREDs

The workshop **recommended** that the Committee continues to monitor and review the developments of MREDs and their impacts on cetaceans, including encouraging the receipt of information on this topic.

The workshop also **encouraged** countries to provide information to the IWC about the development of MREDs, related research and relevant regulations in their waters.

6. Concluding comments

The workshop in closing noted that it looked forward to the comments of the SC on its report and a process was agreed to conclude the report in time for it to be reviewed by the Scientific Committee in the coming week (i.e. a revised text would be circulated shortly and participants would be able to comment until Wednesday noon – Panamanian time). Simmonds, Scheidat, Wright and Rose were entrusted with finalising the text.

Simmonds also thanked the rapporteurs Scheidat and Wright for their hard work and good humour and all the participants for engaging in such an excellent manner with the ambitious agenda of the meeting. He also thanked the organising committee for the workshop including his absent co-convener Alexander Liebschner and the Secretariat for their support. He in turn was thanked for his inspired chairmanship.

The attendance of participants in the workshop had been sponsored by various agencies and organisations in addition to the IWC. Particular thanks were noted in this regard to OceanCare, the Dutch Ministry of Environment, the Belgian Ministry of Environment Health and Food Chain Security, IMARES, Cetacean Society International and the Whale and Dolphin Conservation Society.

The workshop closed at 18.47 hrs on 10 June.

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