Marine Renewable Energy and Cetaceans

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ABSTRACT
There is an ongoing development of offshore renewable energy projects worldwide. Marine wind power technology is the most advanced and tidal and wave power projects are creating increasing interest. Marine renewable energy projects to date have been focused in northern Europe, yet developments are also planned and underway in other parts of the world. Whilst these offshore renewable energy developments are typically characterised as environmentally desirable, there are some associated adverse impacts that deserve careful consideration. However, the renewable energy industry is in some ways still in its infancy and, as such, not all of its impacts are clear or fully assessed. This paper outlines the global development of this sector, identifies species of particular concern, outlines some of the possible effects from renewable energy developments on cetaceans and identifies research and monitoring needs to address important knowledge gaps.

KEYWORDS: CONSERVATION, MANAGEMENT, RENEWABLE ENERGY, HABITAT

INTRODUCTION

There has been increasing interest in the development of offshore renewable energy projects in recent years. This paper provides an update to a previous paper submitted to the Scientific Committee of the International Whaling Commission concerning wind farms (Dolman *et al*., 2004) and also considers other marine renewable developments. Of the various energy generation options, wind power remains the most advanced, with many operating offshore windfarms in European waters, and further large scale projects in various stages of planning around the world. Tidal and wave power projects are now also progressing. Tidal energy utilises the predictable twice daily ebb and flow of the tidal cycle to generate power and barrages are already a familiar source of tidal power. More recently, tidal turbines (which resemble underwater wind turbines) have been designed to utilise tidal races. Progress is also being made with wave energy, which is generated from the surge of passing waves, and can be deployed in deeper offshore waters where waves are more powerful. The potential is greatest in temperate latitudes where the strongest winds exist (Figure 1). It has been suggested that utilising the predictable power of ocean currents may mean tidal power rivals wind in future if certain operational hurdles can be overcome (Bahaj and Myers, 2003).

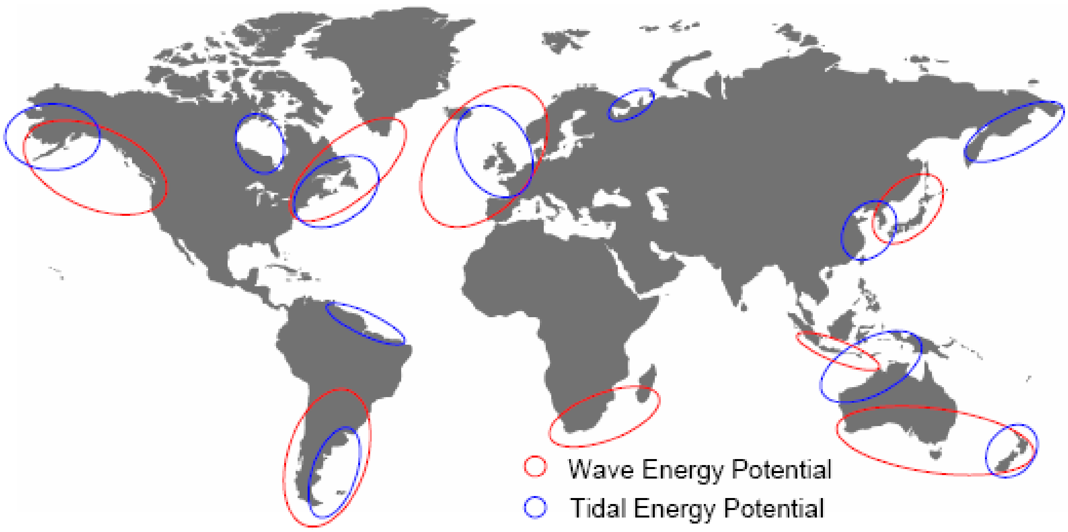

Figure 1. World tidal and wave energy potential (reproduced from Scottish Enterprise, 2005).

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The development of offshore renewable energy can be seen as environmentally desirable, especially for the amelioration of climate change, including meeting international carbon dioxide reduction targets. Whilst renewable energy sources are seen as clean and inexhaustible (see for example Demirbaş, 2006), there are nevertheless some adverse impacts from any marine energy development and these deserve further consideration. The renewable energy industry is in some ways still in its infancy and, as such, not all of its impacts are clear or fully assessed. It is important that all possible impacts are identified and resulting research and monitoring is carried out in a timely manner during the development of all marine renewable projects, including wind, wave and tidal power. In order for any marine renewable project to be seen as part of a move towards sustainable development it is important that any adverse impacts are considered, costs and benefits fully evaluated and adverse environmental impacts minimised through careful project design and implementation. Such investigation will help enable appropriate placement of renewable energy sites and careful monitoring will feed into adaptive management. A thoroughly precautionary approach is necessary in all developments.

This paper outlines the global development of the marine renewable energy industry and some of the possible effects on cetaceans from renewable energy developments. We also consider a number of research and monitoring needs to address important knowledge gaps.

GLOBAL DEVELOPMENT OF RENEWABLE ENERGY

There has been a considerable growth in world wind turbine capacity (Figure 2). Northern Europe has significant capacity for offshore wind, and testimony to this are the large scale investments in developments in Denmark, Germany, the Netherlands, Norway, Sweden and the UK (Pelc and Fujita, 2002). Plans are underway in Nantucket Sound, Massachusetts, US for one of the largest wind developments of its kind in the world, consisting of 130 generators over a 28 square mile area (Santora *et al.,* 2004). Such a development would produce an average of 170 mega watts (MW) per day, with a maximum of 420MW, sufficient energy to power three-quarters of the electrical power needs of Cape Cod (Kempton *et al.,* 2005). There are other developers investigating sites along the east coast of the US (Jarvis, 2005). The total installed wind generating capacity of the US is 11,603 MW (AWEA, 2007). The US has also developed a hybrid system that incorporates tide, wave and wind power (Pelc and Fujita, 2002). Innovative use of renewables includes a development of offshore wind and wave power to contribute towards self-sustainability of a French Island community (Babarit *et al.,* 2006).

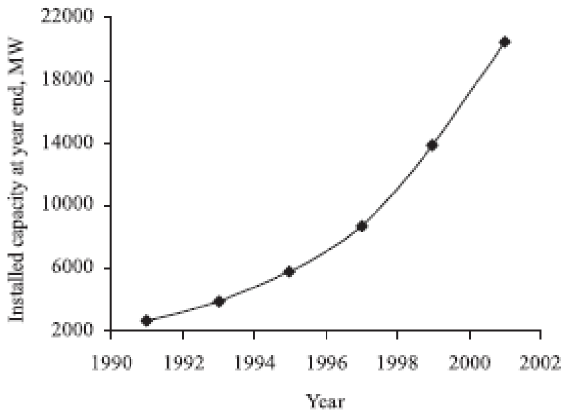

Figure 2. Global growth in world wind turbine capacity (reproduced from Demirbaş, 2006)

Europe accounts for almost half of the wave and tidal projects that have been proposed or installed around the world and over half of the potential projects that are proposed or planned for the future (Figures 3 and 4). Scotland in particular has set an ambitious goal for renewable energy generation, aiming for a target of 40% of all energy generation by 2020 (Scottish Executive, 2003). A marine renewable test facility located off the Orkney Islands in Scotland provides an experimental facility for developers of marine energy technologies investigating wave and tidal power (BWEA, 2007) and has the goal of becoming the leading international marine renewables centre (Winskel *et al.,* 2006). The first commercial wave plant in the UK was installed in 2000 and has since been providing power to the national grid via the island of Islay, Scotland (Pelc and Fujita, 2002).

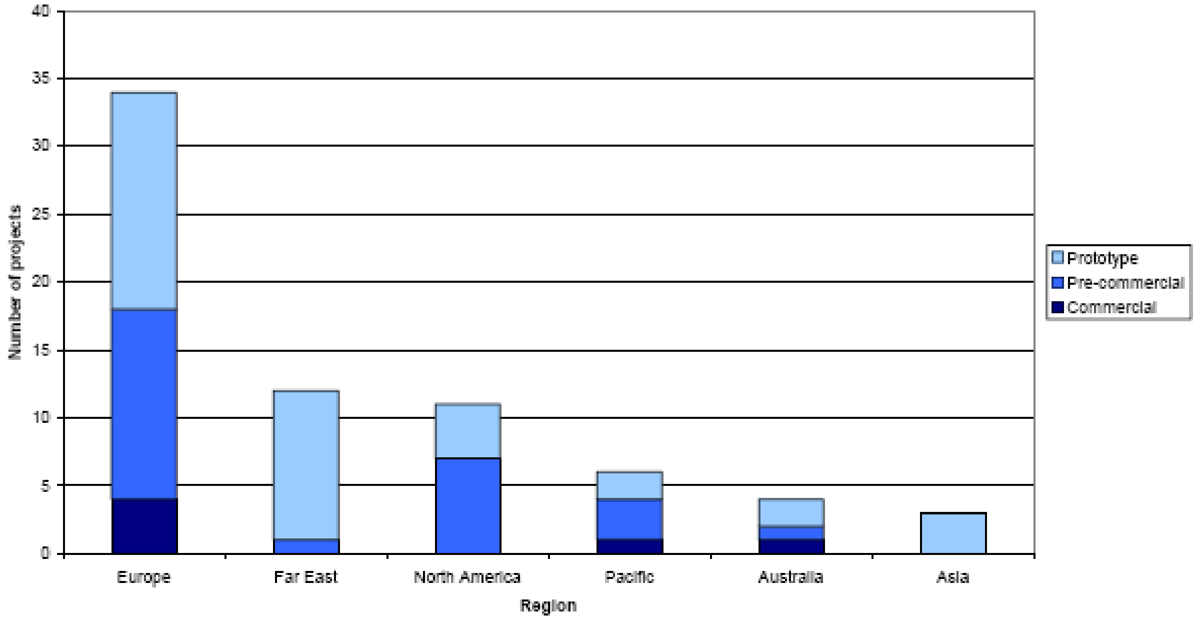

Figure 3. Global distribution of wave projects (reproduced from Scottish Enterprise, 2005)

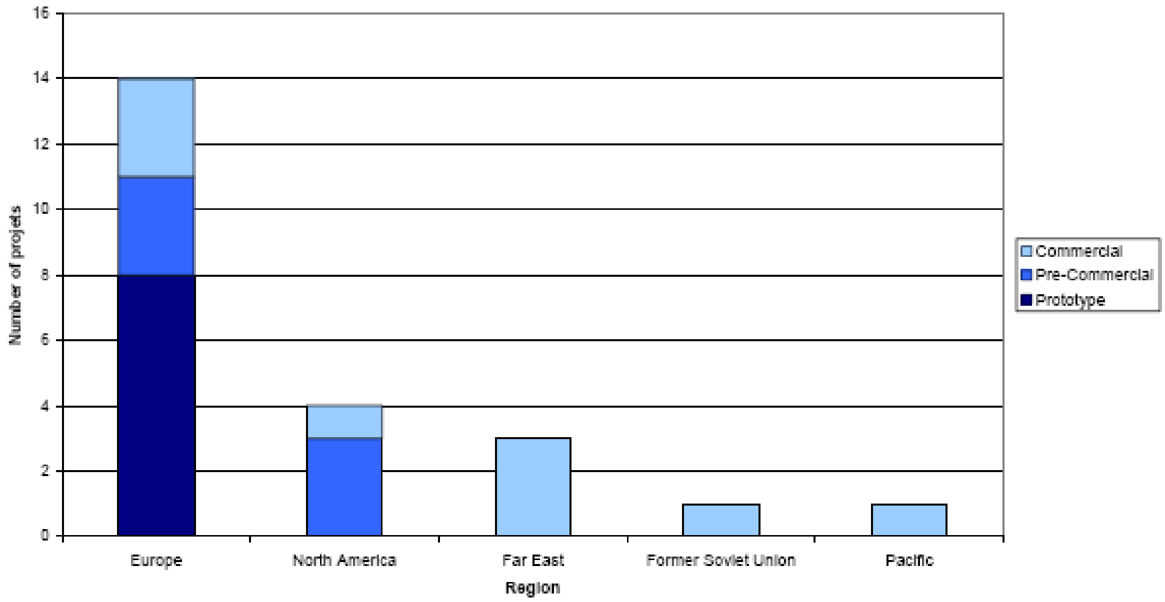

Figure 4. Global distribution of tidal projects (reproduced from Scottish Enterprise, 2005)

INTERNATIONAL CONSIDERATION OF MARINE RENEWABLE ENERGY CONCERNS TO DATE

The UK's Department for Environment, Food and Rural Affairs has produced guidance on offshore windfarm development (DEFRA, 2005). This guidance provides information on the implications of the EC *Wild Birds* and *Habitats and Species Directives* for developers and also includes consideration of impacts on marine mammals. The legal and regulatory issues surrounding the renewable energy industry in the US, which is in its infancy, are not straight-forward and this is demonstrated well by Santora, Hade and Odell (2004). We are not aware of any relevant guidance at a regional or national level for wave or tidal power and there are few existing developments to investigate or demonstrate possible impacts.

The potential significance of wind turbines to wildlife was recognised in Resolution 7.5 *Wind Turbines and Migratory Species,* adopted by the seventh meeting of the Conference of the Parties to the Convention on the Conservation of Migratory Species of Wild Animals (CMS, 2002). The Resolution invites intergovernmental organisations to co-operate with CMS in efforts to minimise possible negative impacts of marine wind turbines on migratory species. It also calls upon the Parties to:

- identify areas where migratory species are vulnerable to wind turbines;
- apply and strengthen comprehensive strategic environmental impact assessment to identify appropriate sites;
- evaluate possible negative ecological impacts prior to decision making;
- assess cumulative environmental impacts;
- take full account of the precautionary principle in development; and
- take account of impact and monitoring data as they emerge.

Potential impacts can also be expected for non-migratory species. This may be particularly true for a resident or semi-resident population where their home range coincides with a renewable energy development (Dolman *et al.,* 2004).

MARINE MAMMALS POTENTIALLY AFFECTED BY RENEWABLE ENERGY

Since renewable energy is currently restricted to shallow, coastal waters with maximum depths of 15-30 metres (Pelc and Fujita, 2002; Gaudiosi, 1999), potential impacts on coastal species warrant primary consideration. Mono-pile towers used to support wind turbines are currently restricted in their depth. As deeper-water mountings become available, the operational depth and therefore distance from shore will increase (Kempton *et al.,* 2005), with the potential for more marine species to be affected. To date, the impacts of wind turbines have been investigated for harbour porpoises (*Phocoena phocoena*) and harbour seals (*Phoca vitulina*) in European waters (Carstensen *et al.,* 2006; Teilman *et al.,* 2006). Recent construction of a small demonstrator wind farm project in the outer Moray Firth, a few kilometres from the Special Area of Conservation (SAC) established there for bottlenose dolphins (*Tursiops truncatus*) has prompted some consideration of potential impacts on the resident dolphins. Although the findings have yet to be published, the area was not considered part of the population's core range (Lusseau *et al*., 2005). We believe that if the demonstrator project is successful, a far larger wind farm will follow in the same area, potentially some 200 turbines and/or 1GW capacity (www.beatricewind.co.uk). Another wind farm development is being considered off Aberdeen in the northeast of Scotland, consisting of 23 turbines in an area of 2km x 4km (AMEC and AREG, 2006) with a total capacity of 115MW. This site is also used by bottlenose dolphins that are at least seasonally present around the harbour, and form part of the population that is better known in the Moray Firth, as well as harbour porpoises. Minke whales (*Balaenoptera acutorostrata*) are also known to frequent this site, at least seasonally along with white-beaked dolphins (*Lagenorhynchus albirostris*) (Weir *et al.*, 2006). The Aberdeenshire coast is clearly an important area for marine life.

White-beaked dolphins are a notably poorly studied species, with little known about their prey species distributions and preferred habitat needs in sheltered waters during the calving season, or any seasonal increase in energetic demand related to calving, lactation and/or seasonal migration (Weir *et al*, 2006). Baseline monitoring of marine mammals with reference to the proposed Aberdeen development commenced in early 2007.

The proposed Nantucket Sound wind farm will need to consider the potential impacts for a broad range of species for which we have no information with regard to potential impacts including right, (*Eubalaena glacialis*), humpback (*Megaptera novaeangliae*), and fin whales (*Balaenoptera physalus*) and Kemp's ridley (*Lepidochelys kempi*), leatherback (*Dermochelys coriacea*) and loggerhead turtles (*Caretta caretta*), as well as grey seals (*Halichoerus grypus*) (Santora *et al.,* 2004).

POSSIBLE IMPACTS

Several desk-top studies have been conducted to investigate the potential for impacts on cetaceans relating to the noise associated with various aspects of renewable energy developments (Thomsen, 2006; David, 2006; Madsen *et al.,* 2006). Results have included the potential for injury at short range due to pile-driving and behavioural impacts to considerable distances, including exclusion from habitat. Case-by-case differences are acknowledged, depending on substrate type and other environmental parameters. As far as the authors are aware, there have not been any field studies that have looked at the impacts of wind farms, or other sources of renewable energy, on any baleen species of cetacean, white-beaked dolphins or any odontocetes other than harbour porpoises to date.

The potential environmental impacts of marine renewable energy developments may be long, medium and short-term and each stage of a development has associated impacts. Generally speaking, the greatest concern has been raised about the operational phase because of its perceived potential for long term impacts (e.g. WWF & TWT, 2001). However, construction activities, such as pile-driving, also warrant considerable concern (Madsen *et al.,* 2006) and, in fact, each phase in the 'life-cycle' of the development requires thorough investigation. Activities associated with windfarm development that are of particular importance to cetaceans are listed (Table 1).

The results of some studies on impacts of wind developments are currently providing seemingly conflicting results which probably reflects the fact that we are still in the early stages of a 'new industry' (see for example, Carstensen *et al.,* 2006;

Koschinski *et al.,* 2003) and there is little information available about the potential impacts of tidal and wave power. In common with wind power, the infrastructure associated with generation of tidal power will involve major construction work and including pile driving in some cases. Consideration must be given to the proximity to tidal races, where productivity is likely to be increased (and these are thus likely to be feeding grounds), as well as the submerged nature of the structures which may bring moving parts into contact with wildlife. Studies of impacts from offshore industries including the oil and gas industry may provide useful guidance as a starting point.

The effects of renewable energy generation may combine with other stressors also affecting individuals and populations, such as other sources of chemical and noise pollution, and thereby produce an impact on marine life that may be greater than predicted for any one source or indeed the predicted sum of the impact of the stressors.

The fact that developments are typically only evaluated on their own without taking into account what else is affecting a region or population deserves to be challenged. Renewable energy should fully and transparently consider environmental implications, and commit to appropriate research programs. In European waters, this is in theory provided for by Strategic Environmental Assessments (SEA), as required by the SEA European Directive (2001/42/EC). In consideration of cumulative impacts, the positive potential impacts of a reduction in effort relating to traditional energy sources might be taken into account.

Table 1. Activities associated with windfarm development of particular importance to cetaceans

Activities likely to cause *longer term* impacts:

- The physical presence of structures (e.g. wind farm towers, tidal and wave generators and associated anchoring and artificial reef effects) and associated effects on habitat (ETSU, 2000);
- Continual operational noise and vibrations emanating from turbines (Simmonds *et al.,* 2003; Nedwell and Howell, 2004) and potentially other marine energy generators once in place;
- Electromagnetic impacts due to cabling that may impact navigation and affect food sources, particularly in the case of elasmobranchs (Gill and Taylor, 2001);
- Increased vessel traffic, for instance from maintenance operations; and,
- Collision with turbine blades on tidal generators.

Activities likely to cause at least *short* and *medium* term impacts:

- Seismic exploration;
- Intense noise during construction due to ramming/piling, drilling and dredging operations (Vella *et al.,* 2001; Nedwell and Howell, 2004);
- General construction noise and disturbance (Carstensen *et al.,* 2006);
- Increased vessel activities during exploration and construction;
- Increased turbidity due to construction and cable laying; and, later,
- Decommissioning (which may involve the use of explosives).

RESEARCH AND MONITORING NEEDS

General principles

Best practice should include avoidance or exclusion of developments from core home ranges. Such ranges would include areas used for breeding and feeding and transition zones (*e.g.* migratory corridors) between these areas. Avoiding locating windfarms on important feeding, spawning and nursery areas has been identified as the most effective mitigation of impacts (DEFRA, 2005). Such spatial management would clearly be applicable for all marine renewable developments.

The UK Marine Renewables Atlas has been designed for ‘strategic level’ and ‘first-order screening’ of sites and this is intended to be combined in each case with *in situ* validation (Cooper *et al.,* 2005). In our opinion, the Atlas provides a useful first step for early consideration of environmental variables and could be utilised in conjunction with Geographic Information Systems (GIS) to develop spatial modelling to augment cetacean distribution and abundance data to avoid high density areas and those which contain sensitive or vulnerable species.

Once the location for a development has been concluded, appropriate evaluation of impacts is essential and independent and high quality Environmental Impact Assessments (EIA) are required. EIA guidance provided by the UK’s Centre for Environment, Fisheries and Aquaculture Science (CEFAS) includes mention of marine mammals and contains useful advice on windfarm developments (CEFAS, 2004). Whilst no guidance currently exists for the development of wave and tidal power, the principles of identification and avoidance of key habitats remain broadly the same. Considerable effort should be focused on investigation of potential negative impacts.

Habitat Use

Knowledge of the abundance and distribution of cetaceans and how they utilise their habitats remains significantly limited for many populations globally. It is therefore very important to fill data gaps with information from detailed baseline studies before any development site is determined and construction commences.

Utilising energy generated in the underwater marine environment is going to be dependant on areas where water is swiftly flowing. These are often also highly productive areas and key cetacean habitats. Choice of site, and scale, are therefore key. The Bay of Fundy, a well known cetacean hotspot, has been identified, for example, as a suitable site for a tidal barrage (Pelc and Fujita, 2002), as have the productive waters around the British Channel Islands and the Sounds off the West coast of Scotland (Bahaj and Myers, 2003).

To identify whether or not changes in abundance or distribution are the result of adverse impacts from development, data are needed that allow identification of such trends. As annual variations in animal abundance and distribution are natural, ideally baseline data should be collected over many years. Studies therefore need to commence as soon as a project is instigated. Considerations should include direct effects on cetaceans as well as indirect effects on prey species.

Control sites are sometimes used to measure effects against development sites but as we know so little about how cetaceans interact with their environment it will be difficult to find control sites that reflect the conditions found at the development site.

Robust monitoring, both during construction and for some time afterwards during full operation is as important as robust baseline data. T-PODs (automated passive acoustic monitoring systems) promise to be useful and reliable tools for monitoring distributions and relative abundances of porpoises, providing information about habitat use (Cartensen *et al*., 2001; Skov *et al.,* 2002).

Information on how animals interact with structures can be used to predict impacts of new proposals in an adaptive management cycle. If changes are detected, further work may be required to understand the cause(s) of those changes. It may be necessary to develop novel methods of survey and detection for some sites and funding needs to be available to develop such methods.

Noise

Physiological impacts, such as hearing damage and increased stress, may occur as a result of noise pollution. Noise is also a potential source of significant disturbance to cetaceans and could lead to masking of important cues or displacement from an area and therefore loss of access to potentially important habitat (see Simmonds *et al*., 2004 for a review).

Noise is produced during the construction, operational and decommissioning phases of all offshore industries, including by vessels associated with each stage. At present, very little research has focused specifically on the impact that noise produced from individual turbines or entire marine energy developments might have on cetaceans. Furthermore, relevant data from existing operational wind farms is only very slowly becoming available, and none exists for other renewable energy developments. It is important to establish sound emission levels from all of the phases of energy developments and give consideration to their consequences and their mitigation.

Madsen *et al.* (2006) make some specific recommendations regarding assessment of noise impacts. Sources will include noise from construction and maintenance vessels and from possible use of explosives during decommissioning. Mitigation procedures during decommissioning should be revised in light of information as it becomes available and, in order to achieve transparency, provide mechanisms of reporting that allow assessment of the success of the measures put in place.

Collisions

The early demonstration projects of tidal stream generators should be monitored to assess if there is risk (for example by collision) to cetaceans, and other marine wildlife, such as seals and otters. It will be necessary to develop new techniques to do this. Video surveillance may be possible in clearer water, but more novel methods may need to be developed in more turbid waters.

Electromagnetic impacts

Research also needs to be carried out into the possible barrier and other disturbance effects of electromagnetic impacts from cabling. This should include direct effects on cetaceans as well as indirect effects on prey species.

Indirect Impacts

In addition, indirect impacts may result from adverse impacts to fish and shellfish stocks. Windfarm construction and development may impact fish spawning, overwintering, nursery and feeding grounds, and migratory pathways (CEFAS, 2004). Whilst this paper is focused on cetaceans, investigations should also consider basking sharks, fish and other marine life as well as potential aerial impacts on bats and seabirds.

CONCLUSION

As many new and, increasingly, large-scale renewable energy developments are planned all around the world it is imperative in each case that robust baseline data are available before any development site is determined and construction commences, to allow evaluation of conditions prior to monitoring possible effects post construction.

The development of guidelines for the protection of marine mammals is clearly appropriate, where choice of site, and scale, are key considerations. Independent and high quality Environmental Impact Assessments (EIAs) and Strategic Environmental Assessments (SEAs) should be undertaken. Results from any work should be made available as soon as possible to inform the design of further projects and allow adaptive management.

Should developments proceed in areas in which cetaceans are known to exist, mitigation measures that are put in place to reduce impacts below significant levels must be sufficiently researched and effective. Offshore renewable energy developments are but one of the many pressures on cetacean populations, and it is important that any adverse effects are identified and minimised as soon as possible. Research and monitoring needs should be built into national programmes for the development of offshore renewable industries. Lessons should be learned from other offshore industries. Whilst the renewable industry is in its infancy we are in a good position to lead in the development of best practise in the generation of renewable and environmental responsible energy.

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