Marine Renewable Energy Developments: benefits versus concerns.

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Abstract

There is concern about the negative consequences of the deployment of renewable energy devices in the marine environment, although some have suggested that they may also have ecological benefits. Many references to these devices highlight the general benefits of renewable energy sources (irrespective of whether they are in the sea or on land) and some stress the special opportunities that the marine environment provides for energy generation.

Here we list the range of issues involved in making a full cost-benefit evaluation of the deployment of marine renewable energy devices and make an initial assessment of the state of the knowledge available relating to each. We conclude that there is inadequate knowledge about many relevant issues, making a full objective assessment difficult. In addition, the degree of importance afforded to the various consequences of marine renewable devices may be highly subjective.

Key Words: marine renewable energy, climate change, cetaceans, noise pollution

Introduction

Climate change driven by the greenhouse effect is a fundamental threat to cetaceans (Simmonds and Elliot, 2009), as it is to other life. Hence, efforts aimed at reducing our dependence on the combustion of fossil fuels for energy should be welcomed. However, wind turbines on land have proven to be unpopular in some places, related to concerns about aesthetics, noise and other impacts. Turbines out at sea may be argued to have less aesthetic impact and the marine environment also offers other opportunities for energy generation from the movements of waves, tides and currents. However, the deployment of marine renewable energy devices (MREDs) may also have local impacts or even potentially impact marine wildlife at the population level. Even if they are out of sight and mind for most people, their ecological impacts may not be insignificant (e.g. Simmonds and Dolman, 2008; Snyder and Kaiser, 2009).

Several publications have recently highlighted potential concerns related to the deployment of MREDs (see for example Simmonds and Dolman, 2008 and Dolman and Simmonds, 2010). Conversely, others have indicated that they may create local marine conservation benefits under certain conditions (e.g. Inger *et al*., 2009). Many references to these devices highlight the general benefits of renewable energy sources (irrespective of whether they are in the sea or on land) and some stress the special opportunities that the marine environment provides for energy development.

At the Scientific Committee meeting of the International Whaling Commission in 2009, concerns were expressed about the potential impacts of MREDs on cetaceans and the Committee recommended that further research should be conducted into their impacts (IWC, 2009a). However, it was also suggested that careful consideration should be given to the societal and other benefits that would come from marine renewable developments (IWC, 2009b). In response to this suggestion, here we attempt to list the range of issues involved in such an evaluation and make an initial assessment of the state of knowledge available relating to each.

Comparing the benefits and costs of offshore energy

Here we draw on the available literature to make an initial assessment of the issues that need to be parameterised to allow a cost-benefit analysis to be attempted. Table 1 provides a preliminary list of issues, noting whether or not these are exclusive to the renewable energy industry in the marine environment, and comments on the state of knowledge on these matters. This latter element is highly subjective and based on our own current understanding.

1. Energy-related benefits

The following benefits have been proposed in general for renewable energy sources (e.g. GUFW, 2010):

- Renewable energy causes far less pollution than the burning of fossil fuels;
- Renewable energy is a far more sustainable option;
- Renewable energy can be produced locally and therefore can benefit local communities and business as well as stimulating local economies;
- The renewable energy industry creates jobs;
- Experts suggest that using renewable energy will result in more stable energy prices;
- Using renewable energy can be a selling point for a business;
- Grant subsidies may be available for setting up a small-scale renewable energy generator; and
- Renewable energy may be sold on to other energy distributors.

Snyder and Kaiser (2009) have published a cost benefit analysis of the offshore wind energy industry in the context of the United States. On the positive side of their evaluation, they note that this industry should mitigate climate change, decrease water use, improve air quality, reduce foreign fuel dependence, create jobs, create

electrical price stability, utilise the higher levels of wind available offshore and also 'reduces user conflict' (presumably because people are less opposed to turbines out at sea than next to their homes). However, they also raise a number of concerns and on balance offer the comment that the 'higher economic costs of offshore wind power relative to onshore wind power could be justified if the ecological or social costs of onshore wind were significantly different from onshore wind power, but this seems not to be the case'. They go on to explain that both onshore and offshore wind power face local opposition and user conflicts, although the ecological impacts affect different ecosystems and so, they believe, are not comparable.

2. Ecological benefits

Inger *et al*. (2009) suggest that, if appropriately managed and designed, MREDs may increase local biodiversity and potentially benefit the wider marine environment. Installations, they suggest, have the capacity to act as both artificial reefs and fish aggregation devices. Reefs and aggregation devices have been used previously to facilitate restoration of damaged ecosystems, and to form *de facto* marine-protected areas, which have proven successful in enhancing both biodiversity and fisheries. However, the extent to which marine renewable sites may cause fisheries to be excluded (or encouraged) or, more generally, the levels of protection for species that they may create, remain unclear.

3. Ecological Concerns and Consequences

Other papers have already reviewed a range of potential concerns related to MREDs (see for example Simmonds and Dolman 2008, Wright *et al.,* 2009 and Dolman and Simmonds, 2010). These include collision (for example with underwater turbines); entanglement (for example with mooring or electricity cables); displacement resulting from noise; harm caused by high-levels of noise from pile-driving and so forth. In most cases we know very little about the precise nature of the negative consequences because so little research has been conducted to date. There have been some studies on the reactions of harbour porpoises to wind farm developments. However, there is an almost complete lack of information about how cetaceans and other biota may interact with underwater turbines and other novel devices deployed in the field for the first time.

Some of the potential categories of harm for wildlife can be identified as follows (Wright *et al*., 2009):

- *Underwater and surface noise:* Noise will be generated during construction, installation, maintenance operations and decommissioning. Installation is a particular concern as pile driving may be used for many installations (notably many wind farms) and this has the potential to cause physical harm. Explosive decommissioning of sites is another major concern. Noise and other disturbance from MRED-associated drilling, dredging, cable laying and vessel activity could have a negative impact.

The noise transmission from an operational array of wind farms or other converters may combine synergistically to have an enhanced biological effect. However, noise and vibrations during the operational phase are generally thought likely to be less intrusive than construction noise, but significantly more research is needed to determine chronic, long term effects. Particular attention should be paid to identifying the range of frequencies utilized by marine mammals and minimising the production noise within this frequency range (Inger *et al*, 2009).

Humans continue to introduce sound into the marine environment, both purposefully and as a by-product of human activities, with an extremely limited understanding of its effects on cetaceans. Discovering how cetaceans perceive and respond to anthropogenic noise sources is increasingly important for their conservation (Nowacek *et al*., 2007).

- *Contamination of the local environment:* this could occur via leaks or spills of hydraulic fluid, the use of biocides to control growth of fouling organisms on submerged structures, and also the dumping of wastes from structures.

- *Entrapment, entanglement or collision:* the devices themselves and certain features in particular (such as rotating blades) may present risks of entrapment, entanglement and harmful, perhaps even lethal collisions. The greatest hazards for some animals may be cables. Types and amounts of cable vary according to the device type, but include mooring cables, guy-lines and power cables. They may be slack, taut, vibrating, horizontal, diagonal, vertical, crossed, current-carrying and so forth, and with the potential to be hazards for cetaceans and other wildlife. Floating devices could present a collision hazard along with their supporting structures.

- *Navigational lights on MREDs* may attract a variety of marine organisms (e.g. cephalopods a primary prey source for some cetaceans). This may increase risks of negative impacts with renewable energy devices.

- *Electrical and electromagnetic disturbance*: the extensive underwater electrical cables associated with MREDs may affect wildlife. This has been highlighted as a threat to elasmobranchs but other wildlife, including cetaceans, might also be affected.

- *Siting of devices*: devices may be placed in sensitive areas, such as those used for breeding, feeding or migration. Tidal barrages have a significant negative impact on estuarine ecology such as wading birds and migrating fish.

- *Other habitat degradation:* this might include damage to the sea bed, changes in vertical mixing and increased turbidity (particularly during installation and construction). Local benthic flora and fauna may be disturbed, though the effects may be short-term. Disturbance of pelagic or demersal organisms, including fish, may have negative implications for their predators.

- *Displacement*: It is possible that a combination of disturbing/habitat-degrading activities, potentially including increased vessel movements for maintenance

purposes, could cause displacement of cetaceans from the area where MREDs are deployed. (Boat disturbance has been shown to affect behaviour and displace dolphins). The severity of these impacts will differ at each site based on a number of variables, the type of converter, location (devices can be sited at the shoreline, near-shore, offshore, deep water channels, in rivers, estuaries, on the sea bed, surface etc.), scale (single devices will have a different impact to that of an array) and so forth.

Other factors potentially affecting impacts could include:

- The type of seabed support used. For example, wind turbines with concrete foundations emit higher noise levels below 50Hz and lower levels between 50Hz and 500Hz, than those with monopole foundations; and

- The topography of the seabed and the nature of the seabed substrate.

The likely ecological consequences of a marine renewable energy development are going to be strongly affected by its location. For example, if it is being established in an otherwise pristine environment, or one which is regularly used by vulnerable or important wildlife populations, its impacts may be greater than at other locations. (This consideration, combined with the variety of devices now being developed, points to the need for a detailed case-by-case environmental impact assessment.)

Many potential impacts would be site-specific. Baseline data are required to understand the abundance and distribution of species and local habitat use, so that wave and tidal converters or wind farms are not located in sensitive areas such as breeding and feeding grounds, or on migratory routes. For example, many shallow waters in northern Europe are important calving and nursing areas for harbour porpoises (*Phocoena phocoena*). Planning should consider the entire life of the MRED developments from exploration, construction and operation to maintenance and decommissioning, during all seasons of the year.

The acute and chronic effects of noise pollution and disturbance on cetaceans are considered further in Simmonds *et al*. (2004), Jasny (2005) and Weilgart (2007). Issues relating to marine wind farms are discussed more fully in Evans (2008) and the authors note that there are concerns that relate to the potential impacts of marine wind farms on seabirds, mainly relating to collisions with moving turbine blades. However, Inger *et al.* (2009) comment that despite some ten years of studies, the impacts of terrestrial wind farms on avian populations remain unclear. A number of studies suggest that wind farms may have detrimental impacts on birds but evidence remains poor, largely because of methodological weakness and the short time scales of previous studies.

Discussion and Conclusions

What we have presented here is very much a work in progress (and we welcome comments and corrections). As can be seen from Table 1, there are many data gaps and a wide variety of issues that still need to be more fully evaluated before the implications of MRED deployment can be properly judged.

Snyder and Kaiser (2009) concluded that the 'higher economic costs of offshore wind power relative to onshore wind power could be justified if the ecological or social costs of offshore wind were significantly different from onshore wind power, but this seems not to be the case'. They go on to explain that both onshore and offshore wind power face local opposition and user conflicts, although the ecological impacts affect different ecosystems and so, they suggest, are not comparable. They calculate the cost of energy generated by offshore wind as $100/MW h stating that this is not currently cost competitive with either onshore wind or 'conventional electricity'.

Undoubtedly the expansion of MREDs over the coming years will profoundly alter the seascape. Given the demand for renewable energy, related engineering and policy decisions made in the near future will have a significant impact on the state of the marine environment. The industry is still in its infancy in many ways and so the evidence-base for its impacts is currently poor. This paper highlights the urgent need for all stakeholders to engage in wide ranging ecologically-orientated research to help more fully understand and mitigate the impacts of MREDs and aid good decision making.

Acknowledgements and Disclaimer

Our thanks to Sarah Dolman for helpful discussions on this matter. We would also like to make it clear that neither we as individuals, nor the Whale and Dolphin Conservation Society, oppose renewable energy development *per se*. However, we are concerned that its potential impacts in the marine environment have not been adequately considered and that this is particularly important for an industry that is dramatically expanding in some sea areas. We are also responding here, as stated earlier, to a request made during last year's IWC Scientific Committee to take a broader look at this issue.

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Table 1: A preliminary list of issues relating to the renewable energy industry in the marine environment (expanded from Inger *et al*. (2009), Snyder & Kaiser (2009) and Nowacek (2007)).

Points in favour	State of knowledge	Notes	Only applies to offshore
Provides 'renewable energy' with all the associated benefits (see main text), including mitigation of climate change	Good	Cost of unit energy needs to outweigh production and maintenance costs etc.	No
Potential for no-take zones around some marine renewable plants - *less fishing* - *less bycatch*	Mainly theoretical	It is currently unclear if fishing activities might be excluded or limited from marine wind farms or other renewable developments.	Yes
Potential for renewable areas to act as Marine Conservation Zone	Suggested but not yet tested	This would be a 'Conservation Zone' where activities other than renewable energy generation which would include construction and servicing activities would be allowed. Other activities would be regulated.	Yes
Reef effect	Medium	Hard structures in the water column will support fouling organisms (if not coated with anti-fouling treatments). Fouling communities can reasonably be expected to attract other wildlife, including feeding fish.	Yes
Creates jobs	Good		No
Decreases water use	Good		No
Improves air quality	Good		No
Reduces foreign fuel dependence	Good		No
Creates electrical price stability	Good		No
Aesthetics - out of sight in the sea	Subjective		Yes

Points against	State of knowledge	Notes	Only applies to offshore
Kills birds	Medium	Most studies have been conducted on terrestrial sites where wind farms take a toll on birds and bats	No
Wave, current and tidal energy generation limited geographically	Good	Suitable locations, for example for high energy sites may coincide with high marine wildlife densities.	Yes
Disrupts/ harms fisheries	Unclear	For example, spacing between renewable energy structures may limit fishing boat movements and safety issues may arise; fishing activities may be displaced.	Yes
Unpredictable power *- intermittency of power from offshore wind farms*	Good	More predictable sources offshore?	No
Entanglement *- in cables used including mooring cables, guy-lines and power cables*	Poor*	New technology.	Yes
Increased collision risk of cetaceans with renewable energy devices	Poor	Being large and fixed, wind farms are unlikely to be as significant a risk as wave and tidal energy collectors which may pose greater hazards. The most advanced designs of these are still in the pilot stages but several proposed devices have rotating turbines which have the potential to seriously injure or kill. (Inger *et al.*, 2009).	Yes
Increased collisions with vessels *- due to the increased vessel activities during exploration, construction, maintenance and decommissioning; and potentially collisions with devices*	Unknown	Unclear if ordinary vessel traffic will be allowed within marine renewable zones	Yes

Increased vessel traffic - *including burning of fossil fuels by boats*	Poor	Renewable devices will require servicing and maintenance in addition to installation and decommissioning	Yes
Displacement - *prey displacement* - *avoidance of traditional feeding/ breeding/ nursing/ calving grounds*	Poor		Yes
Reef effect - *change of habitat* - *ruins special/historic seascape* - *species composition of artificial reefs may not be the same as natural reefs and species composition may influence the biodiversity of surrounding areas* - *artificial reefs may influence spread of non-native species and harmful algal blooms*	Poor	Little information available on the impact of marine renewables on the marine environment. No long term surveys have been conducted on the impacts of marine renewables on cetaceans. Most considerations of environmental effects have been predictive studies and environmental assessments that have not been verified.	Yes
Habitat degradation - *change of currents, waves, circulation patterns, water quality* - *change of flora and fauna in vicinity of altered substrates*	Poor	Little information available on the impact of marine renewables on the marine environment. No long term surveys have been conducted on the impacts of marine renewables on cetaceans. Most considerations of environmental effects have been predictive studies and environmental assessments that have not been verified. Different renewable devices will affect the seabed in different ways and to varying degrees – i.e. some will float and be anchored and others will be fixed on the seabed e.g. by piles.	Yes

Contamination/ pollution - *leaks or spills of hydraulic fluid* - *use of biocides (e.g. antifouling treatments) to control growth of fouling organisms on submerged structures* - *disturbance of seabed may cause release of contaminants in sediments*	Poor	Toxicity of biocides or leaked fluids should be known; quantities that may be released are however, unclear. No long term surveys have been conducted on the impacts of marine renewables on cetaceans. Most considerations of environmental effects have been predictive studies and environmental assessments that have not been verified.	Yes
Electrical and electromagnetic field disturbance from underwater cable	Poor	Impacts mainly anticipated for elasmobranchs but cetaceans may be sensitive to effects too.	Yes
Noise/Disturbance - *pile driving is primary concern* - *construction noise* - *decommissioning - especially the potential use of explosives* - *noise generated whilst in operation* - *increased vessel traffic noise* - *noise generated from maintenance of the devices*	Medium	Little information available on the impact of marine renewables on the marine environment, some studies on the reactions of harbour porpoise to wind farm development, but no long term surveys have been conducted on the impacts of marine renewables on cetaceans. Operational noise is generally anticipated to be less significant than construction noise (particularly from pile-driving) or explosive decommissioning. Most considerations of environmental effects have been predictive studies and environmental assessments that have not been verified.	Yes
Navigational lights on renewable energy devices	Unknown	Lights may serve to produce artificial concentrations of prey animals which in turn may attract predators increasing the risk of negative impacts with renewable energy devices.	No

Cost and risk *- increased equipment and time costs as well as insurance costs due to increased risks offshore* *- cost of transport and installation of devices into the marine environment (amount of fossil fuel burnt)* *- cost of maintenance of devices in the marine environment (amount of fossil fuel burnt)*	Presumably good	No plans/information available on how to decommission them once they have reached their 'sell-by date'. No information on how long marine devices will last in the salt water environment, how much maintenance they will need, etc.	Yes

*although it is clear that cetaceans become entangled in nets and lines, including potting lines