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Briefing

Marine Renewable Energy: necessary for safeguarding the marine environment?

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Introduction & Context

It is necessary to rapidly deploy large quantities of marine renewable energy to reduce the carbon emissions from fossil fuel burning which are leading to ocean acidification, global warming and climatic changes. Done well and sensitively its deployment could be beneficial to marine wildlife compared to the alternative scenario of greater levels of climate change. This briefing outlines current evidence.

According to new research by the Met Office in the UK[i], global emissions of greenhouse gases (GHGs) need to peak in 2016, with annual declines of 3.5% every year afterwards, in order to provide even a 50:50 chance of avoiding a 2 degree rise in global average temperatures.

Yet despite major international meetings and agreements focused on reducing the output of GHGs, global emissions have continued to rise, indeed accelerate, over the last 10 years. Consequently, recent predictions of future global warming are now at the top end of models produced a decade ago or so and suggest that, without rapid action, temperatures may increase by 4 degrees or more above pre-industrial temperatures.

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Climate change is now a visible reality. Each of the last 11 years is in the top 12 warmest years on record, the only other year in this top 12 being in 1998, which was an exceptional global El Niño year and saw unprecedented bleaching of the world's coral reefs.

Notable warming of the seas around NW Europe has been recorded over the last 30 years, with extensive spatial changes to plankton and fish assemblages[ii,iii] that have subsequently impacted top predators such as cod and seabirds[iv,v]. 2012 has also seen the lowest ever cover of summer Arctic Sea ice.

Sea level rise is now measurable, due to both thermal expansion and ice melt, with a global average rise of 3.3 mm/year between 1993-2009[vi]. This rate is accelerating: a 1m sea level rise by the end of the century in some areas is an increasing possibility, with major consequences for the integrity of low-lying coastal and wetland ecosystems.

Finally, ocean acidification is becoming measurable[vii], heading us on the predicted locked-in path to lower pH seas with severe consequences for organisms using $CaCO_3$ in their biology, such as reefs, molluscs and some key planktonic producers. It is thought that the current rate of acidification is 10-100 times faster than any time in the past 50 million years. Today's change may be unlike any previous ocean pH change in Earth's history[viii].

It is therefore clear that the marine environment is already being damaged by the increasingly apparent impacts of climate change; however it is not too late to make a difference to avoid more extreme impacts (including, obviously more extreme impacts on global societies and economies).

To do so requires a major decarbonisation in the UK and other countries. The Committee on Climate Change has recommended that the UK decarbonise electricity to 50g/KWhr of CO_2 by 2030. This will require at least a ten-fold expansion of Marine Renewable Energy (MRE) even if carbon capture and storage technology or nuclear power is deployed (both of which seem unlikely at significant scale by 2030).

It is a truth that to prevent extremely negative impacts on marine biodiversity – and society - it will be necessary to intrude into the marine environment by building large amounts of MRE. Done well – in consultation with marine ecologists and conservation groups, within the spirit and letter of the Habitats Directive - MRE could hold benefits for the marine environment.

This paper will summarise[2] the key main issues in terms of environmental impact of MRE devices and farms and the likely concerns. It assesses the biological impacts of offshore wind, tidal turbines and wave energy converters[1]; it will not cover barrages as such constructions have a very different range, and scale, of issues. Four main categories of potential impact are considered: collision and displacement; noise; electro-magnetic fields; introducing physical structure to the environment. The paper builds on four key reviews[ix,x,xi,xii], plus further evidence. As a summary document can only relay key examples, detail will be provided in five subsequent more detailed papers.

[2] This summary paper will be complemented by 5 further details reports presenting a fuller analysis of environmental impact. These are on: fish and benthos; marine mammals; physical impacts (oceanography); fisheries; birds

It is important at the outset to differentiate between *response* and *impact* on marine organisms from the construction and deployment of MRE. Organisms may respond to MRE - e.g. relocate for a period during construction, avoid tidal turbines. This may, or may not, have any negative impact on the species population. The *impact* of displacement on population size is poorly understood and is likely to be species and location specific. For example, do the responses result in energetic loss that affects survival and reproduction? Does the whole population move elsewhere, and is there anywhere for it to move to (and what of the species already in that habitat)? Is any mortality significant relevant to other factors and thus reduces overall population numbers? It is the *impact on species populations* that is of primary concern for future maintenance of biodiversity.

Collision and displacement

The potential of organisms to collide with MRE devices, in particular wind turbines, probably has the highest profile with the public and media of all the environmental issues associated with MRE, beyond aesthetics. Certainly birds and bats are killed by onshore turbines where evidence is most detailed, and can include important conservation species such as raptors. The American Bird Conservatory estimates up to 40,000 birds are killed each year in the US by wind turbines, although it is important to put this mortality in context. Erickson et al[xiii] analysed unnatural bird mortality in the US, reporting that 4.5 million birds are killed by flying into communication towers, 100 million by domestic cats and approximately 500 million from flying into buildings. Nevertheless, poor location of a wind turbine can have an impact on the population of *certain species*, particularly large birds of prey of conservation value such as eagles and vultures, which is why choosing the correct locations is important.

Offshore there is less evidence of significant levels of bird collisions, although collecting data is more difficult. Many species fly low over the water and so would not encounter blades of large turbines; whilst certain species such as large gulls may be more vulnerable, but data are lacking. There is some evidence that some species avoid wind turbines, or even whole wind farms, but also that some species may be attracted. For example, Marsden et al.[xiv] demonstrated that 200,000 migrating eider ducks changed course to avoid the Nysted wind farm between Denmark and Sweden, adding a “trivial” 500 m to a 1400 km migration. However, such avoidance appears to be species specific, with some species showing no change in abundance following wind farm construction, whilst others such as swans and some geese are displaced[xv]. Lindeboom et al[xvi] found similar varied results in a Dutch wind farm, with bird numbers decreasing (e.g. pelagic seabirds), static or increasing (e.g. gulls and terns) within the farm depending on species.

Overall, in general the main issue associated with birds and offshore wind farms appears to be one of displacement rather than collision impacts at a scale that significantly affects populations, although evidence for this is sparse and a poorly-located wind farm near colonies of species with low populations and slow breeding rates could potentially have negative impacts at a population scale. The consequences of displacement is as yet poorly understood and needs further research, although over 10 years of monitoring from some European wind farms has not evidenced any major impact.

In addition, whilst wind farms remain comparatively small, they do not seem to act as a barrier causing major energetic cost to migrating species, but extensive farms in sensitive areas may well cause major impacts. Location, spacing and the provision of corridors in large developments may mitigate this and should be considered as ways of preventing detrimental displacement.

Wave energy converters, as currently designed, present a minimal collision risk to birds unless designs develop that significantly rise above the water surface [xvii]. However, underwater tidal current turbines pose a similar potential collision risk as wind turbines, particularly for marine mammals, fish and some diving species of bird depending on location, design and depth of the device[xviii]. Clearly locating devices next to diving bird colonies or key foraging areas should be avoided.

There is much more concern about collision between marine mammals and turbines, but currently there is little evidence this occurs as to date there are relatively few areas where turbines exist, although monitoring is necessary as devices are deployed. In Strangford Lough, NI, a tidal turbine has been operating for years near a grey seal colony and has been extensively monitored. Three years into the monitoring Queen's University's Graham Savidge stated "the half million movements recorded so far suggest turbines and seals avoid one another"[xix]. Cetaceans therefore may be able to avoid the devices but only if they are able to detect the objects, realise they are a threat and be able to take appropriate action i.e. swim around, evade, swerve etc. This can be aided by the sensitive design of turbines; large, slower moving turbines should also cause less of a problem. Turbines may, if poorly sited, impact on migrating fish populations.

As for the expansion of offshore wind, however, potential problems may arise from large increases in the scale of tidal turbine deployment, with possible displacement effects at a scale that could have negative population impacts. For certain species of cetacean with a large foraging range this may not be a problem, but design and deployment needs to prevent forming long barriers to movement. Large-scale tidal turbine developments underway in other parts of the world, such as South Korea, may provide useful data.

Noise

The effect that noise has on an organism is dependent not just on the noise level, but on frequency as animals have a wide range of levels of frequency detection, often much different from humans. There is little doubt that pile driving during the construction of a wind farm produces a level and frequency of noise that organisms, particularly marine mammals, notice, as potentially can extensive use of sonar mapping methods from survey ships. Hearing loss may occur within 1.8 km for porpoise and 400 m in seals[xx]. Such organisms therefore have been shown to leave an area when constructing a wind farm. During the construction of Horns Rev and Nysted wind farms in Denmark[xxi], for example, harbour porpoise avoidance behaviour was reported (including 10 km away at the control) with temporary displacement of porpoise and seals from the site. Bottlenose dolphins have also be observed to have behavioural responses up to 40 km during the construction of the offshore wind farm during pile driving. At Nysted, porpoise densities decreased significantly during construction with the porpoises leaving the construction area, indicating noise can also cause displacement. After two years of operation, the population did partially recover; however it is unclear if the same animals retuned, or if they were new animals moving into the area. Mueller-Blenkle et al[xxii] also found responses to distant pile driving noise in cod and sole. Construction of the Scroby Sands wind farm caused marked reductions in clupeid fish, the prime food item for a local tern colony resulting in egg abandonment and lack of chick hatching[xxiii]. Pile driving (for not just wind farms of course) can therefore cause displacement of local populations.

The operational noise created by MRE devices appears to have a much lower impact on marine organisms than construction, primarily because the highest levels of noise are produced at low frequencies at the edge of hearing for many species. At Horns Rev, 100 m from the turbine, peak sounds were at 150 and 180 Hz with no sound above 800 Hz[xxiv]. This is at the limit of hearing for porpoises and seal, but is within the main hearing range of baleen whales[xxv]. This sound is likely audible for a porpoise at 100m, a seal at 1km and fish at 4km[xxvi xxvii]. No significant impact on behaviour or populations has been recorded, with Lindeboom et al[xxviii] actually recording more porpoise clicks within a Dutch wind farm than outside it, perhaps exploiting the higher fish densities found. It has been suggested that some organisms may actually use the noise from turbines as a cue to prevent collision, although this is unlikely to be universal[xxix].

New technologies for offshore wind may significantly mitigate the levels of noise from construction and operation. A move towards floating wind turbine technology, for example, would remove the need for major pile driving (although moorings need fixing) and there are designs for offshore, vertical axis wind turbines much more suitable for marine conditions and floating platforms (Figure 1). These newer technologies should be encouraged as they are likely to be a better ecological option, reducing the unequivocally most damaging aspect of MRE developments, which is pile-driving during construction.

Electromagnetic Fields (EMFs)

EMFs are produced by sub-surface cables transferring electricity to (and from) the shore, as well as, potentially, by wave generating devices that utilise magnets in their design. A range of marine organisms can detect EMFs, such as some bony fish and marine mammals, but in particular species of elasmobranch (rays and sharks) are sensitive to EMFs and can use them, for example, to detect prey or navigate during migration. The strength of EMFs from offshore cables depends on design, magnitude of current and how deep the cable is buried[xxx]. Potentially, sensitive species may have their behaviour changed by the presence of these fields, or their feeding disrupted, for example. Although studies have shown magnetic fields could affect fish, as yet there is little evidence that underwater cables are having any major effect[xxxi]beyond an inconsistent range of small-scale behavioural response such as a change in swimming direction[xxxii]; it is unsure whether this would represent a biological effect.

Whilst some have raised concerns about the potential for impacts when MRE has a greater network of cables, there is limited evidence of any wider impact of the current offshore power cables that have been in the sea for a considerable time[xxxiii]. The greater potential for cables to have an impact is not the EMF but the routing of the cables from sea to shore. The routing should be carried out sensitively and avoid biologically diverse rich areas.

Addition of Physical Structure

The majority of wind farms are situated in areas of soft substratum, primarily due to the need to fix monopiles into the seabed; however, this would not necessarily be the case for wave, tidal stream and floating wind devices as often optimum high-energy conditions may be on rocky or mixed ground. Whilst the latter three structures will have moorings and some belowwater structure, the current design of offshore wind turbines result in the greatest change of habitat, replacing soft sediment with a hard substratum. Wilson[xxxiv] estimated that each turbine results in approximately 452 m^2 of sedimentary seabed habitat (including scour protection) and 102 m^3 of water column habitat lost. For the Thanet wind farm, for example, this would give a total loss of 45,000 m^2; however, this only represents 0.13% of the total wind farm area across the same habitat. Wilson & Elliott[xxxv] state, however, that the amount of area created by wind turbine monopole is 2.5 times the area lost through the placement.

Such constructions therefore result in loss of organisms within the existing habitat - as does infrastructure development on land - but what also needs to be considered is that much of the subtidal soft sediment habitat around the UK, particularly in the south and east, is already significantly damaged. Olsen[xxxvi] published a piscatorial atlas of the North Sea in 1883 that included a map of the distribution of seabed types. This included a huge 20,000 km^2 area across the southern North Sea that was a vast oyster bed, plus a range of rocky/stony reefs along the south UK coast and up the east coast. Much of this habitat has been lost due to over 100 years of intensive trawling and dredging (the oyster bed was last harvested in 1936 and had completely gone by 1970[xxxvii]), together with an important ecological filtration function that the huge areas of bivalve molluscs and other filter feeders provided. Therefore, a large part of the current soft sediment within UK waters is not the original habitat. We have lost vast areas of biogenic and stony reef, but this shouldn't be taken to imply that all soft sediment areas are fair game; soft sediment areas of conservation importance should be avoided.

Also it has to be recognised that benefits may accrue from adding physical structure to the environment in some locations, as it provides a new, albeit artificial, reef habitat for organisms to settle on (such as filter feeders). Such structure tends to attract and concentrate fish. Monitoring of the Horns Rev wind farm demonstrated a 60-fold increase in available food biomass for fish[xxxviii], whilst Reubens et al.[xxxix] found large aggregations of pouting and cod within a Belgian wind farm, a result confirmed by Lindeboom et al.[xl] in Dutch waters, who also recorded higher numbers of porpoise clicks within the wind farm and the varied responses of bird species. Higher benthic biomasses were recorded on turbines off Sweden, but with lower diversity compared with control reef structures[xli], explained by the lack of complexity on the monopiles. Fish abundance was greater in the vicinity of the turbines than surrounding areas, however, with similar diversity levels[xlii]. Langhamer and Wilhelmsson[xliii] demonstrated that populations of edible crab could be boosted within foundations for wave energy devices by enhanced engineering adding holes to the design. Provision of physical structure therefore results in increased benthic and fish biomass, though whether this is a concentration effect of fish or is a true boost to local populations is as yet unsure, in parallel with other artificial reef structures.

Another impact of introducing extensive new hard structures across parts of the seabed is to reduce the level of current destructive fishing activity within the area[xliv], particularly restricting the use of towed fishing gear. Although this may have socio-economic impacts, particularly if coupled with displacement of fishermen from Marine Protected Areas, this may be offset through the use of static gear and increases in populations of commercial fish and shellfish. In addition, there is also much scope for looking at co-locating aquaculture, algal biomass production, etc. within a wind farm to maximise use of the marine space.

MRE areas could function as *de facto* Marine Protected Areas, as long as they were additional to, not instead of, MPAs designated specifically to preserve biodiversity. As Wilson and Elliott[xlv] state, such potential to protect or enhance biodiversity raises important issues for marine nature conservation managers and, if marine spatial planning is done carefully, the environment can benefit from offshore renewable energy developments[xlvi].

Summary and conclusions

Due to the great threats climate change poses to marine biodiversity – and terrestrial biodiversity, people, food production and economies – it is, paradoxically, critical that MRE is rapidly deployed at scale around the UK.

This overview suggests that it may be possible to do so in a way that does not have a significant negative overall impact on marine biodiversity. However monitoring is needed during and after deployment, particularly regarding the species that may be at greater risk than others. Subsequent papers will provide further detail on particular species.

It is likely that the deployment of MRE could be beneficial to some species, especially in association with Marine Protected Areas, and could be beneficial for commercial fisheries.

However, although rapid deployment of MRE at scale is necessary, this is not a reason to avoid deploying MRE sensitively and with care. Developers and regulators should work closely with marine ecologists and conservation groups at an early stage to identify suitable locations for the MRE and associated cabling. The Habitats Directive should be clearly complied with, in both spirit and letter. Developers should strive to enhance marine biodiversity and productivity.

The Government should also fund further research at a strategic-scale as well as site-specific, where environmental impact assessments are not always designed for wider interpretation or are deemed commercially sensitive. It is important to monitor the cumulative impact of MRE on the marine environment over time. Lessons learnt from this monitoring could not only help mitigate any negative impacts from MRE, it could help ensure lessons on enhancing benefits are learnt and spread.

The UK is current the world leader in deployment of offshore wind. It could, and should, be a world leader in other MRE technologies. This brings significant employment and economic opportunities within an industry worth £ billions. But with this leadership comes a responsibility to demonstrate to the World how deployment can be carried out whilst protecting our precious biodiversity.

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