Marine
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Organisation

# The Marine Management Organisation (MMO) Response to an Independent Review of Environmental Data Collected at UK and European Offshore Wind Farms and 22 Recommendations for Future Post-Consent Monitoring

**Important Note:** This response is based on information presented in the full report that should be read alongside the recommendations made below, and considered in light of current Government policy (e.g. National Policy Statements, Marine Policy Statement etc.). The recommendations are based on a small dataset collected over a comparatively short timeframe (typically up to three years after wind farm construction) and must be treated with caution; where uncertainty remains and/or where new evidence comes to light monitoring may be required to minimise risks to environmental receptors.

*Link to Full Report used as basis for this review: https://www.gov.uk/government/publications/review-of-environmental-data-mmo-1031*

A number of policy leads, advisors and regulators were consulted on an earlier draft of this response and comments were received from the Major Infrastructure Environment Unit (Department for Environment, Food and Rural Affairs (Defra)), Planning Inspectorate, National Resources Wales, Marine Scotland, Natural England, Joint Nature Conservation Committee (JNCC) and the Centre for Environment, Fisheries & Aquaculture Science (Cefas). Whilst we have reviewed comments, the recommendations detailed below are those of the MMO only and do not necessarily represent the views of those consulted.

## Introduction

The UK has ambitious targets for the deployment of renewable energy installations and is legally committed to delivering 15% of its energy from renewable sources by 2020. Offshore wind is seen as playing a key role in meeting these targets and the offshore wind energy programme has gathered apace over the past decade such that the UK is now the world leader in offshore wind with over 3.6GW of operational installed capacity in early 2014, and a large number of projects in planning. The UK Government's Renewable Energy Roadmap highlights the potential for 18GW of offshore wind by 2020, if a reduction in costs required to make such energy financially viable is realised (DECC, 2012).

A number of potential negative environmental impacts attributable to offshore wind farms (OWFs) have been identified. These include those to coastal processes (e.g. mobilisation of seabed sediment during construction, operational impacts to wave and tidal processes); benthic ecology (e.g. loss of habitat and disturbance, introduction of artificial hard structures); birds (e.g. mortality due to collision with operational turbines, displacement, barrier effect); marine mammals (e.g. injury and displacement due to underwater noise); and fisheries resources (e.g. injury and displacement due to underwater noise, disruption of behaviour and migratory pathways due to electromagnetic fields [EMF] from power cables).

Activities that have been identified as having a significant adverse impact on environmental receptors are controlled through the conditions attached to an OWF marine licence. These conditions are the primary mechanism whereby the regulator can ensure compliance with mitigation measures identified in assessments, detect any unforeseen impacts and validate predictions made in the Environmental Impact Assessment (EIA) and/ or Habitats Regulations Assessment (HRA).

Despite over a decade of experience of constructing OWFs in the UK (the first two-turbine pilot project was commissioned in 2000 off Blyth) and growing evidence base there is still a paucity of robust data upon which to predict impacts to certain receptors including birds and the power to detect significant adverse impacts is difficult. Owing to the uncertainties regarding the prediction of adverse impacts, UK regulators have often taken a precautionary approach in line with European Directives (e.g. a proposal for an OWF in The Wash was unable to proceed given the prediction of adverse impacts from collisions with turbines to bird qualifying features of a European Marine Site).

Given the UK's better regulation agenda and the need to de-risk the regulatory landscape, there is a need for periodic review of the growing evidence base in order to review existing conditions applied to licences so as to streamline offshore renewable licensing and ensure that regulatory processes do not unnecessarily hinder the growth of this sector. The present study was commissioned following a UK Government review of the implementation of the Habitats and Wild Birds Directives and interrogated the evidence that has been gathered to date for OWFs.

The review examined outcomes and conclusions from monitoring regimes undertaken as a result of statutory requirements imposed on developers through consent conditions. The terms of the consent conditions are translated into monitoring specifications, which are required to be undertaken for defined durations. The consent conditions require that the outcomes of these monitoring programmes are subsequently reported to the regulator. The review aimed to:

- Provide a review of the extent to which data collected through post-consent monitoring has enhanced the evidence base on direct and indirect impacts of OWFs both at the site, and generic level;
- Explore whether the rationale and objectives of the post-consent monitoring conditions are appropriate, proportionate and achievable, and whether monitoring strategies and licence conditions are presently fit for purpose or require amendment; and
- Produce a list of recommendations to improve monitoring in the future and ensure that data collection is targeted at areas where the largest risks and uncertainties remain.

A key focus of this post-consent monitoring (PCM) review of OWFs was to seek ways of reducing burdens on business while maintaining the integrity of the purpose of the Directives. This can be used to develop a strategic approach to PCM that is better designed and targeted to inform future development proposals, mitigation measures and conditions of licence.

Across all topics monitoring should be receptor driven using EIA and HRA impact statements as a hypothesis for investigation. Monitoring should be used where there is uncertainty in the significance of an impact which could lead to a potentially significant impact on a sensitive receptor. Surveys should be designed so that data collected can reduce uncertainty in impact significance statements.

The MMO published the final report (MMO 2014) on the independent expert review of data collected to discharge licence conditions in April 2014. The MMO (2014) review made recommendations to help ensure consistency in data standards for PCM and also presented recommendations for the PCM of receptors including coastal processes, underwater noise, benthic ecology, fisheries, marine birds and mammals. This document is the MMO's response to the independent expert review and provides recommendations on how future PCM should be undertaken for the receptors included in the review. This response is based on the MMO (2014) review and the monitoring considered within; it is not an exhaustive list of all potential monitoring that may be required on future OWF developments.

## Methods and materials

### SYNTHESIS OF DATA

To ensure an impartial assessment, the review was undertaken by independent external experts. The review synthesised the outputs from monitoring studies collected from 18 OWFs constructed in the UK together with monitoring data from European OWFs in Belgium, Denmark, Germany and The Netherlands. Full details of the OWF data collated and analysed is provided in the full MMO (2014) report.

## Results and recommendations

It is important that the results of the review are taken in context. The review represents only a comparatively small dataset (18 UK OWFs) and the individual datasets from each OWF have been collected over a relatively short timeframe (typically including the establishment of a baseline pre construction, during construction and up to three years following OWF construction). This relatively short-term monitoring may be of such duration that changes might be masked by natural variability. Following the introduction of a revised UK marine licensing regime (Marine and Coastal Access Act 2009) that considers the whole lifetime of projects, future monitoring can, however, be programmed over longer periods and might provide more robust data post construction than has typically been collected under past licensing regimes. As our understanding grows, it should be possible to make more robust evidence-based decisions but future monitoring must also be proportionate and should be triggered where, for example, sensitive receptors are identified as being at risk to ensure mitigation is effective and data collected should inform adaptive management programmes.

The MMO has reviewed the recommendations made for individual receptors made by the external experts (MMO 2014) and a set of recommendations for each to inform PCM is presented below.

### GENERAL RECOMMENDATIONS

The recommendations below are to be considered for PCM monitoring on all receptors.

**Recommendation 1** - A regional PCM approach should be considered whereby PCM may be undertaken over a geographic area where a number of OWFs are developed (such as the Outer Thames or a Round 3 zone), as the pooling of data from several OWF sites can result in cost-effective monitoring (through reduction in the duplication of effort in collecting data for individual OWF sites) and provide robust evidence of any impacts at the regional scale.

**Recommendation 2 –** Statistical power analyses should be carried out in order to determine the minimum effort for sampling that is required in order to be able to detect changes in numbers.

COASTAL PROCESSES

In the UK, the focus of assessing any impacts from OWFs on coastal processes has been on monitoring of scour, suspended sediment concentrations (SSC) and changes to coastal morphology (e.g. beach profiles). The rationale for scour monitoring has not been triggered specifically by sensitive environmental receptors but has typically been undertaken to inform the structural and engineering integrity of structures including foundations and export cables. The licence requirements to monitor scour have, in part, been driven by engineering concerns, rather than impacts identified through the EIA process.

The review of post-consent scour monitoring data did not identify any significant adverse impacts on sensitive physical receptors. Scour monitoring may, however, be required where seabed erosion is identified as a potential stressor to sensitive receptors including the benthos.

SSC monitoring has been receptor driven (e.g. for the protection of oyster beds, fisheries resources) and has primarily been used to minimise uncertainty relating to modelling predictions. SSC monitoring should be tailored to record impacts on or linked to the monitoring of identified sensitive biological receptors. A separate, earlier review of PCM undertaken at OWFs also concluded that SSC monitoring would not routinely be required (Cefas 2010) but where deemed appropriate by the regulator, it should be applied to validate predictions and/or in adaptive management to provide a trigger for action on sensitive receptors as part of mitigation plans.

Coastal monitoring has generally been required to assess potential coastal erosion and has been undertaken at both near-shore OWFs located in relatively shallow waters, and for those sites located on near-shore sandbanks which might act as coastal protection features. In some cases, coastal monitoring was also required for OWFs located adjacent to designated features of conservation interest. Based on the present review, it is likely that any changes to coastal erosion and/or accretion directly attributable to the construction of OWFs would not be discernible against natural variability over the short-term (i.e. over the three year post-construction monitoring period that has previously been adopted for UK OWFs).

**Recommendation 3** - Coastal process monitoring should not routinely be required for OWF either in the construction or operation phase. Where site-specific conditions dictate otherwise or a sensitive receptor is present, however, PCM may be required to validate predictions and/or inform adaptive management.

UNDERWATER NOISE

The focus of underwater noise monitoring in the UK has been on the construction rather than the operational phase and predominately in relation to validating the efficacy of mitigation for marine mammals. The underwater noise data collected from operational OWFs was reported to be of a relatively low level and was broadly comparable to ambient noise at ranges of only a few hundred metres from the source.

PCM of underwater noise during construction has generally been adopted during the first few (typically four) monopile foundations installed. Monitoring of the ‘first few’ foundations may not capture the highest noise levels during construction as this depends on parameters such as hammer blow energy, pile locations and the worst case (i.e. the noisiest piling event) may not occur during the installation of the first few piles.

PCM showed that the underwater noise levels resulting from the pile-driving of monopile foundations are significant and assessing and validating these levels accurately is important. The monitoring should aim to demonstrate the validity of any marine mammal mitigation zone (JNCC 2010) and soft-start, i.e. that the noise levels (Sound Pressure Level and Sound Exposure Level) during the soft-start should not exceed the thresholds believed to cause auditory injury to marine mammals, both from instantaneous and cumulative exposures, at distances greater than the required mitigation zone. The monitoring of the soft-start is commonly specified and the requirement for a static measurement (i.e. fixed position), would enable empirical quantification of the variation in the sound output during the soft-start period, and help quantify the usefulness of this mitigation strategy and validate the predictions of the EIA regarding sound propagation and the required size of the mitigation zone.

There are currently no international standards for the measurement of underwater noise from the construction or operation of an OWF. The International Organization for Standardization (ISO) is currently drafting a measurement standard for the '*Measurement of radiated noise from pile driving'*, which should be available before 2016. There is also a lack in the consistency in reported parameters and use of standard metrics to support traceability and data comparability. Interim guidance on standards for measuring and reporting on underwater noise has recently been published in the UK (NPL 2014).

**Recommendation 4** - To ensure that representative noise profiles are obtained, PCM for construction noise should follow UK interim guidance (NPL 2014) and ISO standards once they are published and accepted.

**Recommendation 5** - PCM should focus on validating EIA model predictions and whilst it is important to monitor the first few foundations installed through piling, there should also be consideration to monitor during installation of the 'worst-case' piling events.

**Recommendation 6** - The PCM should aim to demonstrate the validity of any marine mammal mitigation zone and soft-start. Noise measurements should be conducted at fixed position monitoring stations 500m away from the piling (the standard mitigation zone) or farther if the noise risk assessment indicated that a larger mitigation zone was required. Consideration should be given to measuring sound levels at locations several kilometres away from the piling and relate these to animal responses to disturbance.

**Recommendation 7** - Provided that there are no major differences in turbine infrastructure or substrate conditions between those installed previously in the UK and those proposed for future sites, there is no requirement for noise monitoring in the operational phase.

## BENTHIC ECOLOGY

PCM of benthic ecological receptors has adopted various techniques reflecting the fauna targeted in the monitoring programme. Monitoring techniques have included benthic grabs, acoustic techniques and drop-down camera and video (e.g. for reef-forming *Sabellaria* sp.), 2m beam trawling of the epibenthos, intertidal surveys (primarily to assess impacts from cable installation) and turbine colonisation studies to detect the presence of non-indigenous and fouling species.

The benthic grab sampling reviewed during this study concluded that to date, OWFs have not had significant adverse impact on benthic habitats and associated faunal communities and where changes were evident they could be attributed to natural variability. There was, however, some evidence from the Thornton Bank OWF (Belgium) that localised scour pits developed and the species composition within the pits would be modified compared to existing seabed sediment and this may result in changes to infaunal community structure and composition, which in time may propagate across the wider wind farm site.

The PCM of the epibenthos showed that whilst some post-construction changes were evident, these were likely due to natural variability rather than changes attributable to OWFs. The inability to detect change was, however, primarily due to the limitations in survey design (e.g. through a lack of reference data and inappropriate location of ‘impact’ sites outside of OWF footprint).

The PCM undertaken at intertidal habitats showed that recovery following cable installation was related to habitat heterogeneity. For example, mobile sands and gravels impacted by cable installation are comparatively quick to recover from physical impacts with, in most cases, commensurate recovery of associated faunal communities. Where longer-lasting impacts due to cable laying have been identified these have been in relation to highly sensitive and specific biotopes, for example *Sabellaria* reef.

The PCM of colonising epifauna was sufficient to detect changes due to the introduction of hard substrata (turbine foundations). Whilst only a small number of turbine monopile colonisation surveys have been undertaken to date in the UK, non-indigenous species have not been detected (although non-native species have been found at other OWFs including the Horns Rev OWF in Denmark; Cefas 2010).

**Recommendation 8 -** Benthic ecological monitoring using grab sampling should be restructured so that it is focussed on areas or receptors predicted to be impacted.

**Recommendation 9 -** The temporal scale over which the benthic grab studies are employed should be modified. For example, where required, PCM should be undertaken over periods of >3 years which was typically applied under the previous UK licensing regime for offshore wind. Within the UK aggregates sector a useful model of cyclical 5-year substantive reviews has been adopted and a similar approach should be considered within OWF PCM.

**Recommendation 10 -** Where benthic ecological monitoring is required, scientifically robust strategies using cost-effective monitoring methods should be adopted (e.g. depending on issues to be investigated, drop-down video, or particle size analysis may be appropriate as a surrogate for macrofaunal taxonomic analyses).

**Recommendation 11 -** Where baseline surveys do not reveal the presence of species/habitat of conservation interest (e.g. Annex I habitat such as *Sabellaria* reef, Priority Marine Features (PMFs), Marine Protected Areas (MPAs), Biodiversity Action Plan (BAP) and OSPAR habitats; see JNCC 2014), and where modifications to the seabed through scour is not predicted then further PCM should not typically be required.

**Recommendation 12 -** The need for monitoring colonisation of foundations should be considered on a case by case basis and should be aligned with the Marine Strategy Framework Directive requirements for non-indigenous species.

FISH AND SHELLFISH

The PCM review highlighted the general lack of targeted approaches to the sampling of fish and shellfish populations in relation to the development of OWFs in the UK. Current PCM will likely detect major impacts on fish and shellfish populations but is often unable to distinguish between impacts and natural variation of fish and shellfish populations. As such, it has not been possible to draw meaningful conclusions from the PCM conducted to date.

Some species will migrate or travel long distances seasonally to access available resources including feeding, spawning, nursery and over wintering grounds. Such variability over spatial and temporal scales makes accurate monitoring of these populations difficult as the variability in the proportion of the population sampled due to movements between sites is unknown. This is further compounded by the environmental conditions (e.g. state of tide, sea temperature, time of day) varying considerably between sampling events. The typical area of predicted impact is also large and extends many tens of kilometres beyond the wind farm boundary in the case of piling noise. At such large scales and with such mobile species, impacts are most likely to be detected at a regional scale rather than individual sites.

Current PCM at UK OWFs is of too broad a scale to be able to distinguish between predicted impacts and natural variation in fish and shellfish populations. Greater emphasis needs to be placed upon gathering reliable baseline ecological data from a variety of spatial and temporal scales on sensitive receptors so as to better determine the natural variability of fish populations. Only impacts of moderate or greater significance have any chance of being identified using the PCM that has been adopted and the range of parameters requiring monitoring should be narrowed and should be dictated by the occurrence of sensitive receptors, and predictions and mitigation highlighted in assessments (e.g. EIA). Sampling gear, the number of replicates and subsampling techniques has also been inconsistent.

From the MMO (2014) review, there is no evidence to suggest that EMFs pose a significant adverse threat to elasmobranchs at the site or population level. EMFs emitted from standard industry OWF cables are unlikely to be repellent to elasmobranchs beyond a few metres from the cable if buried to sufficient depth. It is likely that the more subtle effects of EMF, including attraction of elasmobranchs and feeding response to low level EMFs may occur. EMF specific surveys including stomach analysis of elasmobranchs undertaken at an OWF in the Irish Sea (Burbo Bank) showed fish caught at the cable site (and hence subject to EMF exposure) were well fed. The MMO (2014) review was, however, unable to draw firm conclusions on the effects of EMFs upon migratory and diadromous species.

The MMO (2014) review of outputs to ascertain effects of EMF on migratory and diadromous fish could not conclude whether any significant adverse effects are evident. Such findings should, however, be considered alongside data collected at the Nysted OWF (Denmark) and existing UK policy. Industry standard power cables shield against the emissions of electric fields but they cannot completely shield the leakage of magnetic fields that can result in an induced electric field adjacent to the cable (Gill 2005; BERR 2008). The induced field has the potential to interfere with fish that use the earth's magnetic field for migration (e.g. Atlantic salmon *Salmo salar* and European eel *Anguilla anguilla*) and elasmobranchs that can be attracted to bioelectrical signals (Gill 2005; Gill & Kimber 2005; Gill et al. 2009). Mark-recapture studies of European eel at the Nysted OWF (Denmark) showed that fish did traverse the power cable and despite limitations to the experimental design (EMF were not measured directly) the study concluded that there was no reason to assume eel migration was influenced (Klaustrup 2006).

UK policy suggests that for OWF export cables buried to sufficient depth (>1.5m) the impact from EMF on fish is likely to be negligible and unlikely to be a barrier to fish movement (DECC 2011). It is likely that as more UK OWFs are located farther offshore, to reduce transmission losses, High Voltage Direct Current (HVDC) cables will be used to transport electricity to shore rather than the predominantly Alternating Current (AC) cables used to date in UK OWFs. Such HVDC cables can be laid in bundled configurations to transmit electricity through two cables and are designed to reduce EMF emissions. Both the electric and induced magnetic field from bundled 100MW capacity HVDC cables were predicted to be within natural background levels within a few metres of the buried cable (electric and magnetic fields were predicted to be within background levels within 1 and 5m, respectively; National Grid 2013).

**Recommendation 13 -** Cefas (2012) guidelines for fish monitoring should be adopted as they provide details on best practice data acquisition to support marine environmental assessments for offshore renewable energy projects. The Bundesamt für Seeschifffahrt und Hydrographie (BSH) (2007) guidance also provides standard fish monitoring methodologies and providing gear specifications for both active and passive fishing gears. The BSH (2007) guidance also recommends that measurements of depth, salinity, temperature and oxygen are taken at sites where fish monitoring occurs and such data should be collected to help to explain inter-annual variations in fish and shellfish populations. Because of the wide spatial scales at which mobile species might be present, PCM should be undertake on a regional scale (both inter and intra-zone cumulative monitoring is required).

**Recommendation 14 -** Unless site-specific conditions or biological receptors dictate otherwise, or the fields from power cables are predicted to increase significantly, EMF monitoring should not ordinarily be required for PCM at OWFs.

## BIRDS

The PCM to date has addressed displacement, barrier effect and collision risk of birds with OWFs. There were, however, limitations in the monitoring design and both the spatial and temporal coverage meant that the potential power to detect change may have been restricted.

In respect of the potential barrier effect of OWFs to birds, it has been shown from radar studies that pink-footed goose can adopt strong horizontal and vertical avoidance behaviour (Plonczkier and Simms 2012). Hence they were at limited collision risk, though conclusions as to whether the disruption of flight paths may have impacted energy expenditure and thus had fitness costs are not known (MMO 2014). Future developments should draw from experience in the Netherlands and Denmark, where radar has been intensively used to track the avoidance behaviour of birds approaching wind farms (macro-avoidance) and within OWFs (micro-avoidance), thereby informing both the evaluation of both collision risk and barrier effects.

PCM of actual collisions between birds and OWFs has not typically been carried out and the measure of risk was based on a calculation that uses the number of birds in the OWF site and the proportion of them that are at flight heights that could incur a risk of collision with rotor blades occurring (as indicated by boat survey data). The need to be able to monitor collisions offshore, to inform impacts and to help validate the avoidance rates used in collision risk models, has long been recognised. While progress in this regard is being made (field studies using radar, cameras are planned to collect evidence of bird behaviour and collision at OWF sites to help improve impact assessments; ORJIP 2014), limitations of technology restricted the feasibility of such studies in the monitoring programmes reviewed. PCM has thus been restricted to assessment of flight heights collected from boat surveys or for some OWFs detailed tracking of birds through radar and radio-tracking helped provide a better assessment of avoidance behaviour, if not actual monitoring of collisions.

Much of the PCM undertaken for birds has lacked rigorous statistically-robust monitoring design and/or assessment. The basic principle underlying survey design is that the study (impact) and reference site are surveyed before and after the OWF is constructed. There are, however, notable difficulties in identifying reference sites which are truly comparable in terms of their environmental conditions (e.g. oceanography) and in order for the Before After Control Impact (BACI) approach to be rigorously applied, numerous ‘controls’ have to be selected in order to be able to detect impacts of effects (the minimum number of ‘controls’ should be 5-6). Also, where the BACI approach has been adopted for OWFs, reference sites have been chosen immediately adjacent to the development which contravenes the assumed independence of the study and reference sites.

Consequently, a new approach to survey design has evolved known as Before-After-Gradient (BAG) and involves all areas within a given radius of the development being monitored before and after construction. ‘Gradient-style’ analyses are applied in which the pre-post differences at a site are taken as a function of the distance from the development. PCM analyses undertaken in conjunction with density-surface modelling approach aims to take into account environmental correlates (such as water depth) in order to better evaluate changes in bird densities that might be a result of either the construction or operation of an OWF. The density-surface modelling approach builds on that used at Danish OWFs and allows the significance of changes in densities across the survey grid to be evaluated and provide a better understanding of changes in bird distribution and such an approach can improve the power to detect change.

The PCM for birds undertaken to date has often lacked rigorous statistical interpretation. Power analysis is a technique that provides a measure of confidence that an adverse significant impact has arisen. Whilst power analysis should be routinely adopted for the PCM, it should, however, be considered alongside other data. For example, a recent power analysis of Belgian OWFs in the North Sea showed that to obtain sufficient power (90%) to detect a decrease in birds of 50-75% would require five to ten years of impact monitoring (Vanermen et al. 2013) and would require considerable cost and effort to undertake.

It should be noted that the relevant Statutory Nature Conservation Body(s) should be contacted before any field ornithological study or analysis of existing data is undertaken. The recommendations in this document should be taken alongside any advice they may give.

**Recommendation 15 -** Where barrier affects need monitoring, detailed tracking of birds should be undertaken using radar and/or other techniques (e.g. satellite tagging devices). Future developments should draw from experience in The Netherlands and Denmark and elsewhere, where radar has been intensively used to track the avoidance behaviour of birds approaching wind farms (macro-avoidance) and within OWFs (micro-avoidance), thereby informing both the evaluation of both collision risk and barrier effects.  Radar work should be conducted in conjunction with direct visual observations to supply species-specific resolution to the radar data.

**Recommendation 16 -** Monitoring should be undertaken at broadly the same time/season each year to allow comparison of results across the different phases of the development. Seasonal and temporal considerations should also be taken account of when designing monitoring to capture important sources of variation.

**Recommendation 17 -** The application of model-based approaches, such as density surface modelling techniques, can greatly improve the characterisation of development areas, thereby improving impact assessments and should be adopted for future OWF PCM. Distribution maps can provide a reliable foundation for PCM and thus improve the detection of seabird displacement arising from OWF developments and should also be included in future PCM. Although efforts should be made, wherever possible, to ensure that such model-based approaches are compatible for use alongside historic datasets allowing the latter to continue to add value.

**Recommendation 18** - There have been rapid developments in the survey methods used to detect impacts to birds around OWFs and modern digital techniques coupled with density surface models have been developed to allow changes resulting from environmental conditions to be appropriately attributed and differentiated from those due to construction and or operation of the OWF (Buckland et al. 2012). Such modelling techniques coupled with BAG survey design provide a robust means of understanding changes in bird distribution and should be considered for future PCM to identify causal relationships and such an approach can improve the power to detect change.

## MARINE MAMMALS

In the UK, conditions attached to licences to minimise adverse impacts to marine mammals has focussed on the mitigation measures required to reduce the risk of physical and auditory injury as a result of pile-driving noise, rather than any specific impact monitoring investigating the impact of the construction or operation of the wind farm on marine mammals. The construction phase can result in significant adverse impacts to marine mammals, mainly associated with pile-driving activity while the operational phase appears to have mostly no significant negative effect. Data from the noise measurements made during the operation of the wind farms reviewed suggest that operational noise levels are not of a magnitude to cause impacts to marine mammals and these findings reflects information reviewed from European OWFs.

OWF construction noise is not only capable of inducing physical damage to marine mammal hearing systems it can also result in behavioural changes and temporary habitat loss that can last for the whole construction period. The effects of pile-driving can reach distances beyond 20km from the OWF construction site. There are limited data on the relationship between piling duration and length of displacement. Behavioural changes are not necessarily caused by piling alone. They can also be induced by other construction activities such as increased boat traffic or by mitigation measures like pingers and seal scarers.

Monitoring the extent of auditory injury in marine mammals is extremely challenging and cannot be addressed on a site specific basis. However, predictions can be made based on noise modelling, which in turn can be validated by on-site noise measurements during construction. Behavioural displacement can to some extent be predicted and then validated during monitoring before, during and after construction if uncertainty remains about the potential for disturbance.

Given the large spatial scales over which marine mammal populations generally operate (including distant seal haul out sites) there are limits to what can be achieved through PCM on a site-specific basis. Marine mammal density and abundance is likely to be highly variable and the power to detect change and attribute it to activities associated with the OWF development may be low. The ability to link cause and effect to detect change using 'traditional' monthly visual methods (whether aerial or boat based) may be too low. It will be virtually impossible to determine population level changes as a result of activities on a particular site (even on large sites), or to determine cumulative effects of neighbouring sites. In those cases, a regional monitoring approach across a number of sites may be the only way to appropriately design a study to answer a site-specific uncertainty.

It should be noted that the relevant Statutory Nature Conservation Body(s) should be contacted before any marine mammal field study is undertaken. The recommendations in this document should be taken alongside any advice they may give.

**Recommendation 19 -** The recommendations proposed above (Recommendations 4-7) for underwater noise should be considered in the context of marine mammals (and fish); e.g. the use of standard measurements for noise parameters, model validation, gradient analysis.

**Recommendation 20** - The focus of the PCM should be to validate predictions in terms of the likely levels and duration of noise animals may be exposed to during construction, particularly validating noise exposure at the ranges predicted for injury and disturbance (often many tens of kilometres from the source).

**Recommendation 21** - PCM should also be coordinated with the development of a registry for impulsive underwater noise in order to identify potential cumulative effects. Each project should also submit information (e.g. a simple record of the day, time and location of any piling) for inclusion within the noise registry.

**Recommendation 22 -** Given the variability in marine mammal distribution and abundance, it is essential that impacts arising from OWFs are not confounded due to natural variables. The influence of environmental covariates on marine mammals (as recommended above for birds) should be considered along with careful spatial and temporal design of monitoring to account for natural variability. The monitoring programmes must also consider whether PCM has sufficient power to detect changes.

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